ISSN 1794-6190
e-ISSN 2339-3459

Earth Sciences Research Journal

UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ

Volume 18, Special Issue - July 23-25, 2014

Proccedings

First Assembly of the Latin-American and Caribbean Seismological Commission - LACSC
Regional Commission of the International Association of Seismology and Physics of the Earth's Interior- IASPEI

Second Latin-American and Caribbean Symposium of Geophysics

Third Latin-American Congress of Seismology

Fourth Colombian Congress of Seismology

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Research Group in Geophysics

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Bogota, Colombia – July, 23 – 25, 2014

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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PRESENTACIÓN

La región de Latinoamérica y el Caribe, es un complejo mosaico tectónico donde convergen los esfuerzos producidos por la interacción entre varias placas litosféricas, y donde grandes sistemas de fallas con actividad, entre moderada y alta, afectan a una parte significativa de su población (más de 500 millones de habitantes). Dado el auge de la actividad minero-energética, en esta zona se despliegan grandes proyectos de exploración de recursos cuya recuperación futura generará importantes cambios en vastas zonas del continente americano. Bajo el actual entorno geodinámico y las expectativas extractivas orientadas al desarrollo socio-económico, afloran cuestionamientos sobre el impacto de la actividad antrópica y la inestabilización de los sistemas tectónicos de relevancia regional.

Muchos estudios geofísicos, tanto teóricos como aplicados, han sido realizados en diferentes regiones de Latinoamérica y el Caribe, principalmente desde la segunda mitad del siglo XX. Como en el resto del mundo, básicamente dos tendencias han marcado su desarrollo: la evaluación de amenazas naturales y la exploración de recursos. Los principales elementos orientados al avance de este conocimiento sismológico, y en general geofísico, han sido: (a) la estructura de la corteza y del manto superior, (b) entender la evolución tectónica regional, (c) estimar la amenaza sísmica regional y local, y (d) modelar la geometría de estructuras de trascendencia económica.

Por su parte, la región ha sido testigo de un crecimiento desmesurado en las grandes ciudades, evidenciado por el aumento progresivo de desigualdades sociales y económicas, y que generan a su vez un incremento en los niveles de vulnerabilidad; los cuales unidos a las particularidades de amenaza sísmica alta, configuran un contexto de riesgo sísmico alto.

En este Evento se abordarán los resultados más relevantes asociados al comportamiento sismotectónico en la región, las implicaciones del uso de métodos exploratorios activos sobre las condiciones tectónicas; la trascendencia socio-económica asociada a la exploración y explotación de recursos mediante aproximaciones no-convencionales y su impacto social, y que permitan contribuir al desarrollo sostenible.

Son bienvenidas contribuciones de todo el mundo.

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PRESENTATION

The Latin-American and Caribbean region is an area with a very complex tectonic setting, where stress and strain generated by the interaction of several lithospheric plates is being absorbed. Several regional fault systems, with moderate and high activity, represent a hazard for a significant part of the population (more than 500 million inhabitants). Given the recent developments in the mining and energy industries, a great deal of exploration has been focusing on this part of the world, and the potential extraction of mineral resources is going to generate important changes in vast areas of the American continent. Considering the geodynamic framework and the expectation of the extraction of economic resources, questions about the impact of human activities and the possible destabilizing of the relevant tectonic systems are raised.

Many theoretical and applied geophysical studies have been developed in different regions of Latin-America and the Caribbean, mainly since the second half of the 20th century. There have been basically two motivations to carry out these studies: The evaluation of natural hazards and the exploration of economic resources. Such studies have mainly focused on the knowledge of: (a) the structure of the crust and upper mantle, (b) the regional tectonic evolution, (c) the local and regional seismic hazards, and (d) the geometry of geologic structures of economic interest.

This part of the world has witnessed an excessive and disproportionate growth in the number of urban centers, evidenced by the increase in economic and social gaps. This situation puts a great portion of the population at a high level of vulnerability, which in addition to the natural hazard in the region, configures a scenario of high seismic risk.

In this academic event, the relevant results associated with the seismotectonic behavior of this part of the world will be addressed, as well as the implications of active exploration of the tectonic conditions, the socio-economic impacts of exploration and extraction of economic resources, and the implementation of non-conventional techniques for exploring and mining that can contribute to sustainable development.

We welcome contributions from around the world.

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TIME TABLE

	Wednesday July 23				Thursday July 24				Friday July 25			
Time	Room 1	Room 2	Room 3	Posters	Room 1	Room 2	Room 3	Posters	Room 1	Room 2	Room 3	Posters
9:00 - 9:20		Opening Ceremony										
9:20 - 9:40												ESGA-2
9:40 - 10:00		Inauguration Commercial Exhibition			TSHR-2	VMST-1	RMTS-1	SHLC-6	CTEM-1	VMST-3	SMIL-1	ANST-2
10:00 - 10:20		Plenary Lecture (Domenico Giardini)						SNOP-3				GSES-7
10:20 - 10:40												
10:40 - 11:00		Coffee break				Coffee break				Coffee break		
11:00 - 11:20												
11:20 - 11:40												AGTE-2
11:40 - 12:00	TSHR-1	ECGS-1	GSES-1	SHLC-5	SHLC-3	VMST-2	IDLM-1	TSHR-3	RTSG-1	ESGA-1	RMTS-2	RMTS-3
12:00 - 12:20				GSES-5				GSES-6				VMST-5
12:20 - 12:40												
12:40 - 14:00		Lunch				Lunch				Lunch		
14:00 - 14:20												
14:20 - 14:40												
14:40 - 15:00	SHLC-1	ECGS-2	SNOP-1	SPSP-2	SHLC-4	SZPR-1	GSES-2	VMST-4	AGTE-1	ANST-1	GSES-4	CTEM-2
15:00 - 15:20								IDLM-4				SMIL-2
15:20 - 15:40												
15:40 - 16:00		Coffee break				Coffee break				Coffee break		
16:00 - 16:20										Plenary Lecture (Göran Ekstrom)		
16:20 - 16:40												
16:40 - 17:00	SHLC-2	SPSP-1	SNOP-2	IDLM-3	IDLM-2	SZPR-2	GSES-3	SZPR-3		Closing Ceremony		
17:00 - 17:20				ECGS-3								
17:20 - 17:40												
18:00		LACSC Council Meeting			"Challenge Bowl" SEG	SZPR (subduction zone observatory)						

SCIENTIFIC SESSIONS

Code	Scientific Session	July 23	July 24	July 25
AGTE	Application of Geophysical Techniques on Exploration			O, P
ANST	Anthropogenic Seismicity			O, P
CTEM	Caribbean Tectonics, Earthquake Monitoring, Modeling and Early Warning			O, P
ECGS	Studying the Earthquake Cycle Using Geodesy and Seismology	O, P		
ESGA	Earth Structure - General Aspects			O, P
GSES	General Seismicity Studies	O, P	O, P	O, P
IDLM	Imaging and Dynamics of Lithosphere and Upper Mantle	P	O, P	
RMTS	Regional Moment Tensor Solutions: Advances and New Applications		O	O, P
RTSG	Real time seismology			O
SHLC	Seismic Hazard in Latin America and the Caribbean: Working Across Border	O, P	O, P	
SMIL	Seismic Methods for Illuminating the Lithosphere			O, P
SNOP	Current Practices and Recent Advancements in Seismic Network Operations	O	P	
SPSP	Statistics and Physics of Seismic Processes	O, P		
SZPR	Subduction Zone Processes (joint SSA/LACSC session)		O, P	
TSHR	Monitoring, Early Warning, and Evaluation of Tsunami Hazard and Risk	O	O, P	
VMST	Sharing Experiences on Volcano Monitoring Using Seismic Techniques in Latin America		O, P	O, P

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JULY 23 - ORAL

AUTHORS	AFFILIATION	COUNTRY	TITLE
TSHR-1			
Juan Gonzalez et al.	UCN/CIGIDEN	Chile	ANÁLISIS DE MODELOS INTERSÍSMICOS PARA ESTIMACIÓN DE INUNDACIÓN POR TSUNAMI
Franck Audemard et al.	FUNVICIS	Venezuela	LOCAL TSUNAMIGENIC EARTHQUAKES OFF NORTHEASTERN VENEZUELA, IN THE SOUTHERN CARIBBEAN REALM
Gustavo Lara et al.	Universidad de Antofagasta	Chile	MÉTODO NUMÉRICO PARA DESPLAZAMIENTOS DE LA SUPERFICIE TERRESTRE DEBIDO A FUENTES SISMOGÉNICAS
Christa von Hillebrandt-Andrade et al.	NOAA NWS Caribbean Tsunami Warning Program	Puerto Rico	CARIBBEAN AND ADJACENT REGIONS TSUNAMI WARNING SYSTEM: SEISMIC COMPONENT
Wilfried Strauch	Observatorio Sísmico del Occidente de Panamá (OSOP)	Panama	SISTEMAS DE ALERTA TEMPRANA (SAT) EN PANAMÁ
ECGS-1			
Marino Protti et al.	OVSICORI-Universidad Nacional	Costa Rica	TWO EARTHQUAKE CYCLE GEODYNAMIC CONTROL NETWORKS IN COSTA RICA: NICOYA AND OSA-BURICA PENINSULAS
Jean-Mathieu Nocquet et al.	Geoazur-IRD-CNRS-OCA-Univ. Nice	France	SYNCHRONOUS SLOW SLIP EVENTS AND SEISMIC SWARMS ALONG THE NORTHERN PERU-ECUADOR SUBDUCTION ZONE
Hector Mora-Paez et al.	Colombian Geological Survey	Colombia	GEODETIC CONSTRAINTS ON THE PRESENT-DAY KINEMATICS OF COLOMBIA, SOUTH AMERICA
Frederique Rolandone et al.	Sorbonne Universités	France	PRESENT-DAY DEFORMATION ALONG THE ANDEAN SUBDUCTION CONTROLLED BY CONTINENTAL SLIVERS MOTION
Rui Fernandes et al.	SEGAL (UBI/IDL)	Portugal	DETERMINATION OF EARTHQUAKE SOURCES USING GNSS SEISMOLOGY
GSES-1			
Marcelo Assumpcao et al.	University of Sao Paulo	Brasil	A TEST OF THE RSTT MODEL FOR SOUTH AMERICA WITH BRAZILIAN PGT EVENTS
Peter Sudaholc et al.	University of Trieste	Italia	STRONG MOTION RECORDED DURING THE EMILIA 2012 THRUST EARTHQUAKES (NORTHERN ITALY): A COMPREHENSIVE ANALYSIS
Stephen Myers et al.	Lawrence Livermore National Laboratory	United States	ALTERNATIVES FOR COMPUTING REGIONAL AND GLOBAL SEISMIC-PHASE TRAVEL TIMES USING A 3-DIMENSIONAL MODEL
Yanet Antayhua et al.	Universidad Nacional Autónoma de México	Mexico	INVERSIÓN DEL TENSOR DE ESFUERZO A PARTIR DE MECANISMOS FOCALES OBTENIDOS EN EL CAMPO VOLCÁNICO Y GEOTÉRMICO DE LAS TRES VÍRGENES, BAJA CALIFORNIA SUR (MÉXICO)
Marino Protti et al.	OVSICORI-Universidad Nacional	Costa Rica	THE SEPTEMBER 5TH, 2012 NICOYA, COSTA RICA EARTHQUAKE, A SUBDUCTION EARTHQUAKE CAPTURED IN THE NEAR FIELD
SHLC-1			
Marcelo Assumpcao et al.	Univ. de Sao Paulo	Brasil	INTRAPLATE SEISMICITY AND SEISMIC ZONING IN BRAZIL
Luz Maria Roodriguez Davila et al.	FUNVICIS	Venezuela	EL TERREMOTO DEL 18 DE MAYO DE 1875, EN LA REGIÓN FRONTERIZA COLOMBO-VENEZOLANA :INVENTARIO DE DAÑOS Y DE EFECTOS GEOLÓGICOS CO Y POSTSÍSMICOS
German Chicangana et al.	Corporación Universitaria del Meta	Colombia	LA SISMICIDAD EN EL PIEDEMONTE LLANERO Y LA AMENAZA SÍSMICA DE LA SABANA DE BOGOTÁ
Leonid Zimakov et al.	Trimble Navigation Ltd.	United States	HIGH-RESOLUTION, UITRA LOW POWER, INTERGRATED AFTERSHOCK AND MICROZONATION SYSTEM
Marco Guzman Speziale	Universidad Nacional Autónoma de México	Mexico	EL SISMO DE GUATEMALA DE 1816 (M 7.5). IMPLICACIONES PARA LA SISMICIDAD EN EL LÍMITE DE PLACAS NORTE AMÉRICA-CARIBE
ECGS-2			
Elkin de Jesus Salcedo Hurtado et al.	Universidad del Valle - OSSO	Colombia	CARACTERIZACIÓN SISMOTECTÓNICA DE LA REGIÓN DEL VALLE DEL CAUCA Y ZONAS ALEDAÑAS A PARTIR DE MECANISMOS FOCALES DE TERREMOTOS Y DATOS GEODÉSICOS
Robinson Quintana et al.	Universidad Nacional de Colombia	Colombia	DEFORMACIÓN BASADA EN DATOS DE GPS EN COLOMBIA
Hector Mora-Paez et al.	SGC	Colombia	EVALUACIÓN DE LA DEFORMACIÓN SISMOTECTÓNICA ASOCIADA AL SISMO DE MAYO 24, 2008 QUETAME, COLOMBIA
Hector Mora-Paez	SGC	Colombia	THE GNSS GEORED PROJECT: A TOOL FOR UNDERSTANDING THE STRAIN RATE FIELD AND THE SEISMIC CYCLE IN COLOMBIA, SOUTH AMERICA. CURRENT STATUS AND CHALLENGES

AUTHORS	AFFILIATION	COUNTRY	TITLE
SNOP-1			
Juan Manuel Solano Fino et al.	Universidad Nacional de Colombia	Colombia	PORTABLE, GPS SYNCHRONIZED, MOBILE PHONE NETWORK-BASED SEISMOLOGICAL STATION
Aderson Nascimento et al.	UFRN	Brasil	THE NORTHEASTERN BRAZIL SEISMIC NETWORK – RSISNE
Marcelo Bianchi et al.	University of Sao Paulo, Seismology Center (IAG/USP)	Brasil	THE NEW BRAZILIAN SEISMIC NETWORK: CURRENT STATUS AND DETECTABILITY TEST WITH THE RECENT PISAGUA EARTHQUAKE SEQUENCE, NORTHERN CHILE
Sergio Barrientos et al.	Universidad de Chile	Chile	THE CHILEAN SEISMOLOGICAL OBSERVATION SYSTEM
Dmitry Storchak et al.	International Seismological Centre (ISC)	United Kingdom	INTERNATIONAL SEISMOLOGICAL CENTRE (ISC): MISSION AND PRODUCTS
SHLC-2			
Julio Garcia et al.	GEM Foundation	Italia	MODELING SEISMIC HAZARD IN SOUTH AMERICA: CURRENT STATE OF THE STATE-OF-THE-ART BASED ON ACTIVITIES CARRIED OUT WITH THE SARA PROJECT
Stefan Drouet et al.	Observatório Nacional	Brasil	PRELIMINARY PROBABILISTIC SEISMIC HAZARD ANALYSIS FOR THE ANGRA DOS REIS NUCLEAR POWER PLANT SITE, STATE OF RIO DE JANEIRO, BRAZIL
Maria Cristina Dimate et al.	Universidad Nacional de Colombia, Geosciences Department	Colombia	MAGNITUDE AND LOCATION OF LARGE HISTORICAL EARTHQUAKES IN COLOMBIA FROM MACROSEISMIC INTENSITY DATA
Augusto Antonio Gomez Capera et al.	Istituto Nazionale di Geofisica e Vulcanologia, sezione di Milano, Italia	Italia	HACIA UN CATÁLOGO ACTUALIZADO DE TERREMOTOS DE SUR AMÉRICA : VENTANA TEMPORAL PRE-1930
Augusto Antonio Gomez Capera et al.	Istituto Nazionale di Geofisica e Vulcanologia, sezione di Milano, Italia	Italia	PARÁMETROS DEL TERREMOTO DE CÚCUTA DEL 1875 A PARTIR DE INTENSIDADES MACROSÍSMICAS
SPSP-1			
German Chicangana et al.	Corporación Universitaria del Meta	Colombia	¿QUE PRODUJO LOS SISMOS OCURRIDOS AL ORIENTE DE BOGOTÁ EL 10 DE OCTUBRE DE 1743 Y DEL 24 DE MAYO DE 2008?
Hugo Monsalve et al.	Uquindío	Colombia	MODELING SEISMIC SOURCES IN COLOMBIAN CENTRAL WEST USING INVERSION OF TELESISMIC BODY WAVEFORMS
Alexander Caneva et al.	Universidad Natonio Nariño	Colombia	MAGNITUD REPRESENTATIVA
Ganesh Rathod et al.	Council for Geoscience	South Africa	EARTHQUAKE CATALOGUE PROCESSING AND DECLUSTERING ISSUES
Wilfried Strauch et al.	Centro Nacional de Investigaciones Sísmicas (CENAIS), Santiago de Cuba	Cuba	DISTRIBUCIÓN ESPACIAL Y TEMPORAL DE LOS TERREMOTOS DESTRUCTIVOS Y SUS RÉPLICAS, DEL ABRIL DE 2014, CERCA DE MANAGUA, NICARAGUA
Vladimir Smirnov et al.	Institute of Physics of the Earth RAS	Russia	SEISMICITY RESPONSE TO THE ELECTROMAGNETIC PROBING OF THE LITHOSPHERE IN THE BISHKEK (KYRGYZSTAN) GEODYNAMIC TEST AREA
SNOP-2			
Martha Eugenia Tovar et al.	SGC	Colombia	MAPAS DE INTENSIDAD INSTRUMENTAL EN TIEMPO REAL PARA COLOMBIA
Aderson Nascimento et al.	UFRN	Brasil	THE SAINT PETER SAINT PAULO ISLAND ARCHIPELAGO SEISMIC STATION
Goran Ekstrom	Columbia University	United States	Activities of the FDSN: Current and Future
Richard Andres Mier	SGC	Colombia	OPTIMIZACIÓN DE REDES DE DATOS PARA EL MONITOREO VOLCÁNICO

JULY 23 - POSTERS

AUTHORS	AFFILIATION	COUNTRY	TITLE
SHLC-5			
Edna Maria Facincani et al.	UFMS	Brasil	SEISMIC ACTIVITY IN THE PANTANAL BASIN - BRAZIL
Estevao Vasconcello Campos Tadeu et al.	UFMS	Brasil	TELESEISMIC WAVES REGISTERED AT THE SEISMOGRAPHIC STATION OF AQUIDAUANA / MS /BRAZIL (AQDB), IN 2013.
Marlon Pirchiner	IAG-USP	Brasil	SMOOTHING TECHNIQUES APPLIED TO BRAZILIAN SEISMIC SOURCES CHARACTERIZATION
Nancy Trujillo Castrillon et al.	Universidad Nacional Autónoma de México	Mexico	CARACTERIZACIÓN DE LA FUENTE SÍSMICA ASOCIADA CON LA SISMICIDAD HB, LP Y DRUMBEATS REGISTRADA EN EL VOLCÁN NEVADO DEL HUILA – COLOMBIA , EN NOVIEMBRE DE 2008
John Jairo Mora Soto et al.	Universidad Nacional de Colombia	Colombia	CARACTERIZACIÓN DEL SUBSUELO DE LA ZONA LACUSTRE DE BOGOTÁ, USANDO TÉCNICAS DE ANÁLISIS DE MICROTREMORES./SUBSURFACE CHARACTERIZATION OF THE LACUSTRINE ZONE OF BOGOTA, USING MICROTREMOR ANALYSIS TECHNIQUES
Feng Wang Wang et al.	AIR Worldwide	United States	QUANTIFYING UNCERTAINTIES IN SITE AMPLIFICATION CAUSED BY USING LOW RESOLUTION SOIL MAPS FOR SITE CHARACTERIZATION
GSES-5			
Caio Ciardelli et al.	Institute of Astronomy, Geophysics and Atmospheric Sciences - University of Sao Paulo	Brasil	STUDY OF THE MONTES CLAROS SEISMOGENIC FAULT, IN THE SAO FRANCISCO CRATON, BRAZIL, WITH CORRELATIONS OF P- AND S-WAVE PHASES
Julio Cesar Cuenca Sanchez	Universidad Nacional Autónoma de México	Mexico	EFECTO DE SITIO NO LINEAL SOBRE BASALTO USANDO CINCO SISMOS M>6 DE GUATEMALA
Sebastian Gomez Alba et al.	Universidad Nacional de Colombia	Colombia	RUPTURE PROCESS ON FRACKING OPERATIONS APPLYING P- WAVE BACK PROJECTION IMAGES
Andres Rincon et al.	Universidad Nacional de Colombia	Colombia	DETERMINATION OF THE STRESS FIELD IN AN OIL PRODUCTION AREA BY MEAN ANALYSIS OF AMBIENT NOISE
Dante Sebastian Panella et al.	Universidad Tecnológica Nacional Facultad Regional Mendoza	Argentina	MAXIMOS PGA, PGV Y PGD EN EL PLANO HORIZONTAL
Juan Jose Tovar Angel	Universidad Nacional de Colombia	Colombia	INVERSIÓN SÍMICA POR MEDIO DE ALGORITMO GENÉTICO USANDO EL CONCEPTO DE MIGRACIÓN DE POBLACIONES
Elizabeth Mazo Lopera	SGC	Colombia	COMPLETITUD DEL CATALOGO SISMICO EN EL CENTRO OCCIDENTE DE COLOMBIA
Francisco Javier Munoz et al.	SGC	Colombia	RÉPLICAS DEL SISMO DEL 13 DE AGOSTO DE 2013 BAHÍA SOLANO -OCÉANO PACÍFICO COLOMBIANO
Francisco Javier Munoz Burbano	SGC	Colombia	SISMICIDAD EN EL PIEDEMONTE LLANERO: CARACTERIZACIÓN, RELOCALIZACIÓN Y TOMOGRAFÍA DE VELOCIDADES
SPSP-2			
Juan Salazar et al.	Universidad Nacional de Colombia	Colombia	DEPTH PROFILE OF THE FRACTAL DIMENSION AND THE SEISMOTECTONIC DEFORMATION RATES ASSOCIATED TO THE EARTHQUAKES DISTRIBUTION
Patricio Toledo et al.	Universidad de Chile and Universidad Adolfo Ibanez	Chile	EARTHQUAKE SOURCE PARAMETERS WHICH DISPLAY FIRST DIGIT PHENOMENON
Diego Fernando Gamboa Perdomo et al.	Universidad del Valle	Colombia	ANÁLISIS PROBABILÍSTICO DE LA SISMICIDAD DEL VALLE DE CAUCA Y ZONAS ALEDAÑAS, COLOMBIA
Nigyar Babazade et al.	Centre of Seismology and Earth's Physics	Azerbaijan	MUD VOLCANO SEISMO-GEODYNAMICS
IDLM-3			
Jose David Henao Casas et al.	Universidad Nacional de Colombia	Colombia	INFERENCES ABOUT THE LITHOSPHERIC SEISMIC STRUCTURE OF VALLE DE ABURRA BASED ON TRAVEL TIME RESIDUALS FROM STRONG MOTION NETWORKS
Marcelo Rocha et al.	University of Brasilia	Brasil	RELATIONSHIP BETWEEN INTRAPLATE SEISMICITY AND LOW VELOCITIES TOMOGRAPHY ANOMALIES IN THE TOCANTINS PROVINCE, BRAZIL
Ellen Syracuse et al.	Los Alamos National Laboratory	United States	JOINT INVERSION OF SEISMIC AND GRAVITY DATA FOR VELOCITY STRUCTURE AND HYPOCENTRAL LOCATIONS OF THE COLOMBIAN SUBDUCTION ZONE
Camilo Eduardo Munoz Lopez et al.	SGC	Colombia	MODELACIÓN FISICA Y SIMULACION NUMÉRICA EN PROCESOS DE ADELGAZAMIENTO LITOSFERICO PARA ZONAS CONVERGENTES
Sergio Alejandro Camargo Vargas	SGC	Colombia	ESTRUCTURA LITOSFÉRICA ASOCIADA A LA SIERRANEVADA DE SANTA MARTA A PARTIR DE DATOS DE GRAVIMETRIA , MAGNETOMETRIA Y SISMOLOGÍA
Faustino Blanco et al.	SGC	Colombia	LITHOSPHERIC AND UPPER MANTLE STRATIFICATION BENEATH COLOMBIA: USING RECEIVER FUNCTIONS FROM S-WAVES

AUTHORS	AFFILIATION	COUNTRY	TITLE
ECGS-3			
Gerald Galgana et al.	AIR Worldwide	United States	ASSESSING THE SEISMIC POTENTIAL OF SOUTH AMERICA WITH CRUSTAL DEFORMATION MODELS AND HISTORIC EARTHQUAKES
Paul Jarrin Tamayo et al.	Instituto Geofisico	Ecuador	RESULTS FROM THE NATIONAL CONTINUOUS GPS NETWORK IN ECUADOR
Carlos Reinoza et al.	FUNVICIS	Venezuela	HIGH RESOLUTION GEODETIC SURVEYS OF THE PRESENT DAY DEFORMATION ALONG THE SOUTH-CARIBBEAN MARGIN
Yerson Pardo Lopez	SGC	Colombia	UNA RED GRAVIMÉTRICA COMO HERRAMIENTA DE APOYO A LA SISMOLOGÍA

JULY 24 - ORAL

AUTHORS	AFFILIATION	COUNTRY	TITLE
TSHR-2			
Juan Gonzalez et al.	UCN/CIGIDEN	Chile	ASSESSMENT OF HETEROGENEOUS SLIP DISTRIBUTION IMPACT ON TSUNAMIGENIC HYDRODYNAMIC PROCESSES ALONG THE NORTHERN CHILEAN COAST
Wilfried Strauch et al.	Ministerio del Ambiente y Recursos Naturales (MARN), San Salvador, El Salvador	El Salvador	EXPERIENCIAS CON EL TERREMOTO LENTO Y TSUNAMI DEL 26 DE AGOSTO 2012 EN NICARAGUA Y EL SALVADOR
Luis Hernan Ochoa Gutierrez et al.	Universidad Nacional de Colombia	Colombia	FAST EPICENTRAL DISTANCE AND MAGNITUDE DETERMINATION USING A SINGLE THREE COMPONENT SEISMIC STATION WITH MACHINE LEARNING TECHNIQUES
Franck Audemard et al.	FUNVICIS	Venezuela	LOCAL TSUNAMIGENIC EARTHQUAKES OFF NORTHEASTERN VENEZUELA, IN THE SOUTHERN CARIBBEAN REALM
Wilfried Strauch et al.	Instituto Nicaragüense de Estudios Territoriales (INETER), Managua, Nicaragua	Nicaragua	EL DESARROLLO DEL SISTEMA DE ALERTA DE TSUNAMI EN NICARAGUA
VMST-1			
John Makario Londono et al.	SGC	Colombia	REDEFINICIÓN DE LAS FUENTES SISMOGÉNICAS VOLCANO-TECTÓNICAS EN EL VOLCÁN NEVADO DEL RUIZ A PARTIR DE LA ACTIVIDAD RECIENTE 2010-2014
Roberto Torres et al.	SGC	Colombia	SISMICIDAD FRONTERA COLOMBIA-ECUADOR EN LA REGIÓN VOLCANES CHILES Y CERRO NEGRO
Francisco Javier Nunez Cornu et al.	SisVOc-Universidad de Guadalajara	Mexico	ENJAMBRES SÍSMICOS EN EL VOLCÁN PICO DE TANCÍTARO , MICHOACÁN, MÉXICO. ¿INTRUSIÓN MAGMÁTICA O SISMICIDAD TECTÓNICA ?
John Makario Londono et al.	SGC	Colombia	TOMOGRAFÍA SÍSMICA DEL VOLCÁN PURACÉ
Carlos Eduardo Cardona Idarraga et al.	Universidad de Concepción - OVDAS SERNAGEOMIN	Chile	ENJAMBRES SÍSMICOS PERIÓDICOS RELACIONADOS CON LA TRANSFERENCIA ESTATICA DE ESFUERZOS ENTRE UNA DEFORMACION VOLCANICA DE GRAN ESCALA Y FALLAS STRIKE-SLIP CORTICALES: COMPLEJO VOLCANICO LAGUNA DEL MAULE (CHILE).
RMTS-1			
Hans Agurto Detzel et al.	IAG-USP	Brasil	THE 2012-2013 MONTES CLAROS EARTHQUAKE SEQUENCE IN THE SÃO FRANCISCO CRATON, BRAZIL: NEW EVIDENCE FOR NON-UNIFORM INTRAPLATE STRESSES IN THE SOUTH AMERICAN STABLE PLATFORM
Ronnie Quintero et al.	OVSICORI-UNA	Costa Rica	NEAR-REGIONAL CMT AND MULTIPLE-POINT SOURCE SOLUTION OF THE SEPTEMBER 5, 2012, NICOYA, COSTA RICA MW 7.6 EARTHQUAKE
Silvana Liz Spagnotto et al.	Conicet - Universidad Nacional de San Luis	Argentina	EL SISMO MW 6.2 DEL 27 DE FEBRERO DE 2010, SALTA ARGENTINA. MECANISMO FOCAL Y MODELOS DE DESLIZAMIENTOS USANDO INVERSIÓN DE FORMAS DE ONDAS SÍSMICAS E INTERFEROMETRÍA SAR.
Jiri Zahradnik et al.	Charles University in Prague	Czech Republic	NEW STRATEGY FOR WEAK EVENTS IN SPARSE NETWORKS: FIRST-MOTION POLARITY SOLUTIONS CONSTRAINED BY SINGLE-STATION WAVEFORMS
Juraci Carvalho et al.	University of Brasilia	Brasil	SEISMIC SOURCE PARAMETERS OF LOCAL MICRO-EARTHQUAKES IN GOIÁS STATE BRAZIL BY WAVEFORM INVERSION

JULY 24 - ORAL

AUTHORS	AFFILIATION	COUNTRY	TITLE
SHLC-3			
Eduardo Camacho et al.	Universidad de Panamá	Panama	MICROZONIFICACIÓN PARA DISEÑO POR SISMOS PARA LA CIUDAD DE PANAMÁ , PANAMÁ
Stefan Drouet et al.	Observatório Nacional	Brasil	SOUTH AMERICAN STRONG-MOTION DATABASE AND COMPARISON WITH GROUND-MOTION PREDICTION EQUATIONS: A GEM INITIATIVE
Gerald Galgana et al.	AIR Worldwide	United States	A STOCHASTIC RUPTURE PROBABILITY MODEL FOR EARTHQUAKES ON SUBDUCTION ZONES: A CASE STUDY FROM THE NAZCA SUBDUCTION ZONE
Carlo Meletti	Istituto Nazionale di Geofisica e Vulcanologia	Italia	PSHA AT A REGIONAL SCALE: EUROPEAN SHARE PROJECT VERSUS ITALIAN REFERENCE PSHA. AND THE WINNER IS...
Jay Pulliam et al.	Baylor University	United States	RESULTS FROM THE 2013 PAN-AMERICAN ADVANCED STUDIES INSTITUTE IN SANTO DOMINGO, DOMINICAN REPUBLIC: JOINT MODELING OF COMPLEMENTARY DATA FUNCTIONALS FOR SEISMIC SITE CHARACTERIZATION
VMST-2			
Lina Marcela Castano et al.	SGC	Colombia	ANÁLISIS DEL CAMPO DE ESFUERZO ACTUAL A PARTIR DE MECANISMOS FOCALES EN EL ÁREA DEL VOLCÁN NEVADO DEL RUIZ, COLOMBIA
Carlos Eduardo Cardona Idarraga et al.	Universidad de Concepción - OVDAS SERNAGEOMIN	Chile	ACTIVIDAD RECIENTE DEL COMPLEJO VOLCANICO LAGUNA DEL MAULE(CHILE): RELACION ENTRE SISMICIDAD Y DEFORMACION VOLCANICA DE GRAN ESCALA LIGADA A UN CAMPO VOLCANICO RIOLITICO.
Randall White et al.	US Geological Survey	United States	SEISMIC FORECASTING OF ERUPTIONS AT DORMANT STRATOVOLCANOES
Luis Enrique Franco Marin et al.	Universidad de Concepcion - OVDAS (RNVV-SERNAGEOMIN)	Chile	DESCRIPCIÓN DE LA ACTIVIDAD SÍSMICA RELACIONADA A ERUPCIONES ESTROMBOLIANAS VIOLENTAS: VN. LLAIMA, CHILE (2007 – 2010)
John Makario Londono et al.	SGC	Colombia	VARIACIONES EN LA ATENUACIÓN DE LAS ONDAS SÍSMICAS EN EL VOLCÁN NEVADO DEL RUIZ ASOCIADAS A LA RECIENTE REACTIVACIÓN 2010 2014
IDLM-1			
Anne Sheehan et al.	University of Colorado at Boulder	United States	THE MOANA EXPERIMENT: A BROADBAND OCEAN BOTTOM SEISMOLOGY INVESTIGATION OF A TRANSFORM PLATE BOUNDARY, NEW ZEALAND
Jordi Julia et al.	UFRN	Brasil	LOOKING FOR MANTLE PLUMES UNDER THE BRAZILIAN SHIELD: CASE STUDIES IN PARANÁ AND BORBOREMA.
Esteban Poveda et al.	Universidade Federal do Rio Grande do Norte	Brasil	CRUSTAL THICKNESS ESTIMATION BENEATH THE NORTHERN ANDES USING THE RECEIVER FUNCTION METHOD
Jefferson Yarce et al.	Jefferson Yarce	Colombia	TRAVEL TIME DELAYS AND RESIDUAL TOPOGRAPHY IN NORTHWESTERN SOUTH AMERICA PROVIDE CONSTRAINTS ON UPPER MANTLE TEMPERATURES AND SLAB GEOMETRY
Faustino Blanco et al.	SGC	Colombia	CRUSTAL MODELS 1D FOR COLOMBIA FROM SURFACE WAVES DISPERSION OBSERVATIONS AND RECEIVER FUNCTIONS
SHLC-4			
Hugo Yepes et al.	Instituto Geofisico	Ecuador	PROBABILISTIC SEISMIC HAZARD ASSESSMENT IN QUITO CITY, ESTIMATES AND UNCERTAINTIES
Tania Bustamante et al.	PUC-Rio	Brasil	SEISMIC HAZARD ASSESSMENT OF SITES OF LARGE STRUCTURES IN THE SOUTHEAST OF BRAZIL
Herbert Rendon et al.	FUNVICIS	Venezuela	TOWARDS THE CONSTRUCTION OF A SEISMIC CATALOGUE SUITABLE FOR PSHA STUDIES IN SOUTH AMERICA: INSTRUMENTAL CONTRIBUTION
Carlos Guzman	INETER	Nicaragua	RESPUESTA DINÁMICA DE SUELOS PARA MANAGUA /NICARAGUA
Jaime Eraso et al.	SGC	Colombia	AVERAGE SHEAR WAVE VELOCITY DOWN TO 30M (VS30) ZONING FOR THE CITY OF PASTO, COLOMBIA
SZPR-1			
Marino Protti et al.	OVSICORI-Universidad Nacional	Costa Rica	MAPPING PATCHINESS OF THE SUBDUCTION INTERFACE IN THE NEAR FIELD: THE CASE OF THE SOUTHERN TERMINUS OF THE MIDDLE AMERICAN TRENCH, COSTA RICA
Susan Beck et al.	University of Arizona	United States	SEISMOLOGICAL VIEW OF NAZCA-SOUTH AMERICAN CONVERGENT MARGIN BETWEEN 10° AND 20°S
Esteban Chaves et al.	University of California Santa Cruz	United States	SEISMIC VELOCITY REDUCTION FOLLOWING THE SEPTEMBER 5, 2012, MW=7.6 NICOYA COSTA RICA EARTHQUAKE FROM AMBIENT NOISE CORRELATIONS
Shoichi Yoshioka et al.	RCUSS, Kobe University	Japan	3D THERMAL MODELING ASSOCIATED WITH SUBDUCTION OF THE PHILIPPINE SEA PLATE IN SOUTHWEST JAPAN
Gabriel Gonzalez et al.	CIGIDEN, Universidad Católica del Norte	Chile	THE CAUSATIVE RELATIONSHIP BETWEEN THE MEGATHRUST AND UPPER PLATE FAULTS AT SUBDUCTION ZONES

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AUTHORS	AFFILIATION	COUNTRY	TITLE
GSES-2			
Goran Ekstrom et al.	Columbia University	United States	SEISMOLOGICAL DETECTION AND ANALYSIS OF CATASTROPHIC LANDSLIDES
Jose David Sanabria Gomez et al.	UNIVERSIDAD INDUSTRIAL DE SANTANDER	Colombia	PROPAGACION DE ONDAS DE RAYLEIGH EN EL VALLE DE MEXICO Y UNA POSIBLE EXPLICACION PARA LA LARGA DURACION DE LOS SISMOS.
Dmitry Storchak et al.	International Seismological Centre (ISC)	United Kingdom	ISC PRODUCTS FOR LARGE EARTHQUAKES IN THE LATIN AMERICA AND CARIBBEAN REGION
Fabio Dias et al.	IAG-USP	Brasil	STRESS FIELD IN BRAZIL WITH FOCAL MECHANISMS: EXAMPLES OF REGIONAL FORCES CONTROLLING THE STRESS FIELD.
Orlando Hernandez Rubio	SE SINAPRED, CEPREDENAC, BM	Nicaragua	ESTUDIO DEL EFECTO DE SITIO EN MANAGUA, NICARAGUA
IDLM-2			
Ryan Porter et al.	Northern Arizona University	United States	CRUSTAL AND UPPER-MANTLE STRUCTURE OF THE PAMPEAN FLAT-SLAB REGION FROM SURFACE-WAVE TOMOGRAPHY
Silvana Liz Spagnotto et al.	Conicet - Universidad Nacional de San Luis	Argentina	ASSOCIATION OF MW = 6.4, 2000/06/16 AND MW = 5.7, 2003/01/07 INTERMEDIATE-DEPTH EARTHQUAKES, IN SUBDUCTED NAZCA PLATE
Aaron Velasco et al.	University of Texas at El Paso	United States	CONSTRUCTING SHEAR WAVE MODELS USING MULTI-OBJECTIVE OPTIMIZATION FOR MULTIPLE GEOPHYSICAL DATA SETS
Anibal Sosa et al.	Universidad Icesi	Colombia	3–D STRUCTURE OF THE RIO GRANDE RIFT FROM 1–D CONSTRAINED JOINT INVERSION OF RECEIVER FUNCTIONS AND SURFACE WAVE DISPERSION
William Yeck et al.	University of Colorado - Boulder	United States	INVESTIGATION INTO THE KINEMATICS OF BASEMENT-CORED UPLIFTS THROUGH PASSIVE SOURCE IMAGING OF THE BIGHORN MOUNTAINS, UNITED STATES
Francisco Javier Nunez Cornu et al.	SisVOc-Universidad de Guadalajara	Mexico	ESTUDIO DE LA ESTRUCTURA DE LA CORTEZA EN LA ZONA DE CONVERGENCIA PLACA DE RIVERA – BLOQUE DE JALISCO (PROYECTO TSUJAL)
SZPR-2			
Hans Agurto Detzel et al.	IAG-USP	Brasil	SPATIO-TEMPORAL EVOLUTION OF THE 2014 PISAGUA, CHILE EARTHQUAKE SEQUENCE
Sarah Barrett et al.	Stanford University	United States	REVERSE POLARITY REPEATING EVENTS ARE ASSOCIATED WITH BOUDIN FORMATION AT INTERMEDIATE-DEPTHS IN THE BUCARAMANGA NEST
Gavin Hayes et al.	US Geological Survey	United States	MIND THE GAP – THE NORTHERN CHILE SUBDUCTION ZONE AND THE 2014 IQUIQUE EARTHQUAKE SEQUENCE
Hugo Yepes et al.	Instituto Geofisico	Ecuador	GRIJALVA RIDGE, A MAJOR PLAYER IN THE SUBDUCTION GAME UNDERNEATH ECUADOR
GSES-3			
Ganesh Rathod et al.	Council for Geoscience	South Africa	SEISMIC MICROZONATION OF URBAN AREAS
Orlando Hernandez Rubio et al.	SE SINAPRED, CEPREDENAC, BM	Nicaragua	ESTIMACIÓN DEL RIESGOS SÍSMICO EN MANAGUA, NICARAGUA, CON LA METODOLOGÍA CAPRA
Alejandro Duitama Leal et al.	Universidad Nacional de Colombia	Colombia	ATENUACIÓN Y DISPERSIÓN DE ONDAS ACÚSTICAS EN MEDIOS POROSOS SATURADOS CON FLUIDOS NO VISCOSOS INMISCIBLES
Luis Quintanar et al.	Instituto de Geofísica, UNAM	Mexico	CARACTERÍSTICAS ESPECTRALES DE LA SISMICIDAD ORIGINADA EN LA CUENCA DEL VALLE DE MÉXICO
John Gonzalez et al.	Universidad Nacional de Colombia	Colombia	APLICACIÓN DE ALGORITMO DE INVERSIÓN TOMOGRÁFICA APLICADA EN LA CUENCA DE URABÁ

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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JULY 24 - POSTERS

AUTHORS	AFFILIATION	COUNTRY	TITLE
SHLC-6			
Jaime Parada et al.	Universidad Central de Venezuela	Venezuela	SIMULACIÓN 3D DE LA PROPAGACIÓN DE ONDAS SÍSMICAS EN EL VALLE DE CARACAS USANDO DIFERENCIAS FINITAS
Claire Pontbriand et al.	AIR Worldwide	United States	CHALLENGES TO DEVELOPING A UNIFIED EARTHQUAKE CATALOG FOR SEISMIC HAZARD ASSESSMENT IN SOUTH AMERICA – ADDRESSING MAGNITUDE HOMOGENIZATION AND DEPTH UNCERTAINTIES
Brassnavy Manzunzu et al.	Council for Geoscience	South Africa	SEISMOTECTONIC AND SEISMIC HAZARD IMPLICATIONS FOR SOUTH AFRICA
Jorge Adrian Oviedo Reyes et al.	Universidad Nacional de Colombia	Colombia	TECTÓNICA ACTIVA EN EL COSTADO OCCIDENTAL DEL VALLE DEL RIO ZULIA – NORTE DE SANTANDER, COLOMBIA -APORTES DE LAS TÉCNICAS CUANTITATIVAS DE ANÁLISIS DE DRENAJE
Wilfried Strauch et al.	CEPREDENAC	Nicaragua	EVALUACIÓN PROBABILÍSTICA DE RIESGOS EN CENTROAMÉRICA CON LA METODOLOGÍA CAPRA
Ana Milena Sarabia et al.	SGC	Colombia	SISTEMA DE INFORMACIÓN DE SISMICIDAD HISTÓRICA DE COLOMBIA
SNOP-3			
Nicolas Oliveras Mercado	SGC	Colombia	TARJETA AMPLIFICADORA PARA LA ADAPATACIÓN DE LA DIGITALIZACIÓN DE LOS SISTEMAS SISMOLÓGICOS DE CORTO PERÍODO EN EL SGC
Andrés Antonio Nacif et al.	Instituto Geofísico Sismológico Volponi - Faculta de Ciencias Exactas Fisicas y Naturales - UNSJ	Argentina	ENSAMBLADO, CONFIGURACIÓN, INSTALACIÓN Y MONITOREO DE LAS ESTACIONES SISMOLÓGICAS EN LAS INSTALACIONES DEL OBSERVATORIO DE RAYOS CÓSMICOS DEL PROYECTO INTERNACIONAL PIERRE AUGER.
Lucio Quadros ett al.	University of Sao Paulo	Brasil	SUBDUCTION ZONE EVENTS IN BOLIVIA AS RECORDED BY THE BOLIVIAN AND BRAZILIAN NETWORKS: A TEST OF LOCATION ACCURACIES
Daniel Queiroz et al.	UFRN	Brasil	MICROSEISMIC NOISE IN THE SAINT PETER SAINT PAUL ARCHIPELAGO AND ITS RELATION WITH SOME ATMOSPHERIC AND OCEANOGRAPHIC VARIABLES
El-Madani Aissaoui et al.	Institut de Physique du Globe de Paris - IPGP	France	AEQC TOOLS FOR RETRIEVAL AND COMPLETION OF SEISMOLOGICAL WAVEFORM DATABASES FROM HETEROGENEOUS NETWORKS
Lina Paola Aguirre et al.	SGC	Colombia	ANÁLISIS DE RUIDO DE LAS ESTACIONES SISMOLÓGICAS DEL SERVICIO GEOLÓGICO COLOMBIANO A PARTIR DEL CÁLCULO DE DENSIDAD ESPECTRAL DE POTENCIA PROBABILÍSTICA
Jorge Andres De La Rosa Ramirez et al.	SGC	Colombia	COMPOSICION Y FUNCIONAMMIENTO DE LAS ESTACIONES SATELITALES DE LA RED SISMOLOGICA NACIONAL DE COLOMBIA
Carlos Lozano et al.	SGC	Colombia	EVOLUCIÓN DE LA RED NACIONAL DE ACELERÓGRAFOS DE COLOMBIA
Juan Carlos Bermudez Barrios et al.	SGC	Colombia	VELOCITY SPECTRAL ANALYSIS FOR TELESESISMIC EVENTS USING THE COLOMBIAN SEISMOLOGICAL NETWORK AS AN ARRAY
TSHR-3 (3)			
Wilfried Strauch et al.	INETER	Nicaragua	MAPAS DE AMENAZA DE TSUNAMI PARA EL GOLFO DE FONSECA (EL SALVADOR, HONDURAS Y NICARAGUA)
Sebastian Riquelme	Universidad de Chile	Chile	A RAPID ESTIMATION OF TSUNAMI RUN-UP BASED ON FINITE FAULT MODELS
VMST-4			
Maria Constanza Manassero et al.	Facultad de Ciencias Astronómicas y Geofísicas, Universidad de La Plata	Argentina	SEISMIC ATTENUATION AROUND PETEROA VOLCANO, ARGENTINA
John Makario Londono et al.	SGC	Colombia	ANÁLISIS ESPECTRAL DE FUENTES SISMOGÉNICAS DE SISMOS VOLCANO-TECTÓNICOS EN EL VOLCÁN NEVADO DEL HUILA, COLOMBIA
Luisa Fernanda Meza et al.	SGC	Colombia	ANOMALIAS DE GAS RADON ASOCIADAS A LA SISMICIDAD EN EL REGION VOLCÁNICA PURACÉ
Jose Augusto Casas et al.	Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata	Argentina	CHARACTERIZATION OF SEISMO-VOLCANIC ACTIVITY IN PETEROA VOLCANO, CENTRAL CHILE-ARGENTINA
Rosa Liliana Alpala et al.	SGC	Colombia	SISMICIDAD VOLCANO-TECTÓNICA EN EL NEVADO DEL HUILA
Carlos Alberto Ospina et al.	SGC	Colombia	SISMICIDAD VOLCANO TECTÓNICA EN EL VOLCÁN PURACÉ

AUTHORS	AFFILIATION	COUNTRY	TITLE
IDLM-4			
Alexandra Farrell et al.	University of South Florida	United States	STUDY OF SEISMIC ATTENUATION AND UNUSUAL PHASES AT UTURUNCU VOLCANO, BOLIVIA
Marcelo Rocha et al.	University of Brasilia	Brasil	AMBIENT NOISE TOMOGRAPHY: PRELIMINARY RESULTS AT SOUTHEAST OF SOUTH AMERICAN PLATFORM
Marcelo Assumpcao et al.	University of Sao Paulo	Brasil	DEEP LITHOSPHERIC FEATURES OF THE SÃO FRANCISCO CRATON
Carlos Alberto Chaves et al.	IAG-USP	Brasil	JOINT INVERSION OF GEOID ANOMALY DATA AND TELESEISMIC P-WAVE DELAY TIMES: MODELING DENSITY AND VELOCITY PERTURBATIONS UNDERNEATH THE PARANA MAGMATIC PROVINCE
Woohan Kim et al.	Gyeongsang National university	Korea	HYPOCENTRAL PARAMETER INVERSION FOR REGIONS WITH POORLY KNOWN VELOCITY STRUCTURES
Marianela Lupari et al.	Instituto Geofísico Sismológico F. Volponi - Facultad de Ciencias Exactas, Físicas y Naturales - Universidad Nacional de San Juan (UNSJ)	Argentina	SISMICIDAD LOCALIZADA EN LA REGIÓN DE MANTO LITOSFERICO DE PLACA SUDAMERICANA DEBAJO DE LA PROVINCIA GEOLÓGICA DE PAYENIA - SUR DE MENDOZA - ARGENTINA
SZPR-3			
Marily Trivino Abella et al.	Universidad Nacional de Colombia	Colombia	DISTRIBUTION ANALYSIS OF THE FREQUENCY–MAGNITUDE PARAMETERS ALONG THE SUBDUCTION SURFACE STRUCTURE IN SOUTH AMERICA

JULY 25 - ORAL

AUTHORS	AFFILIATION	COUNTRY	TITLE
CTEM-1			
Russ Welti et al.	IRIS Consortium	United States	THE NEW IRIS EARTHQUAKE BROWSER (NAVEGADOR DE TERREMOTOS)
Gabriel Dicelis et al.	University of Sao Paulo	Brasil	RELOCATION OF THE MAINSHOCK AND AFTERSHOCKS OF ML 5.7 QUETAME EARTHQUAKE, COLOMBIA.
Leonid Zimakov et al.	Trimble Navigation Ltd.	United States	COMBINATION OF HIGH RATE, REAL-TIME GNSS AND ACCELEROMETER OBSERVATIONS – TEST RESULTS USING A SHAKE TABLE AND HISTORIC EARTHQUAKE EVENTS.
Victor Huerfano et al.	Puerto Rico Seismic Network	United States	SEISMIC AND TSUNAMI MONITORING AND DATA SHARING IN THE CARIBBEAN
Jay Pulliman et al.	Baylor University	United States	SLAB TEARS AND INTERMEDIATE-DEPTH SEISMICITY IN THE NORTHEAST CARIBBEAN AND ELSEWHERE
VMST-3			
Daniel Arturo Basualto Alarcon	Servivo Nacional de Geología y Minería	Chile	CAMBIOS EN LA DISTRIBUCIÓN TEMPORAL DEL PARÁMETRO B RELACIONADOS CON INTRUSIONES DE MAGMA, HERRAMIENTA PARA PRONÓSTICO CASO ERUPCIÓN DEL COMPLEJO VOLCÁNICO CORDÓN CAULLE, JUNIO 04 2011
Oscar Ernesto Cadena Ibarra et al.	SGC	Colombia	APLICACIÓN DEL MÉTODO SOMPI EN LA EVALUACIÓN TEMPORAL DE LAS PROPIEDADES CARACTERÍSTICAS DE SISMOS TIPO TORNILLO EN EL VOLCÁN GALERAS
Roberto Torres et al.	SGC	Colombia	UN MODELO GEOFÍSICO DE LA ESTRUCTURA INTERNA DEL VOLCÁN GALERAS, COLOMBIA
John Makario Londono et al.	SGC	Colombia	VARIACIONES DE LA CONCENTRACIÓN DE GAS RADÓN Y SO2 ASOCIADAS A ACTIVIDAD SÍSMICA EN EL SECTOR DEL VOLCÁN GALERAS, COLOMBIA, 2005-2013
Jorge Armando Alpala et al.	SGC	Colombia	IMPLEMENTACIÓN Y RENOVACIÓN DE NUEVAS TECNICAS GEOFISICAS PARA MONITOREO DE VOLCANES ACTIVOS COLOMBIANOS
SMIL-1			
Diego Quiros et al.	Cornell University	Costa Rica	REFLECTION IMAGING OF DEEP MAGMA WITH NATURAL SOURCES: LESSONS FROM RECENT EXPERIMENTS ON AN INTERPLATE VOLCANO AND AN INTRAPLATE EARTHQUAKE
Kinya Nishigami	Kyoto University	Japan	CRUSTAL HETEROGENEITY AND EARTHQUAKE GENERATING PROPERTIES IN ACTIVE FAULT REGIONS IN JAPAN
Bruno Collaço et al.	IAG-USP	Brasil	CRUSTAL STRUCTURE OF THE PARANÁ BASIN FROM AMBIENT NOISE TOMOGRAPHY
Michael Schmitz et al.	FUNVICIS	Venezuela	GEOSCIENTIFIC RESEARCH FOR LITHOSPHERIC STRUCTURES OF THE MERIDA ANDES, VENEZUELA
Juan Carlos Bermudez Barrios et al.	SGC	Colombia	CRUST AND UPPER MANTLE SEISMIC TOMOGRAPHY IN NORTHWEST OF SOUTH AMERICA USING SURFACES WAVES
RTSG-1			
Danny Harvey	Boulder Real Time Technologies	United States	A STREAMING PROCESSING MODEL FOR EFFICIENT COMPUTATIONS OF LARGE CONTINUOUS DATA SETS
Leandro Perez et al.	Observatorio Sismico del Occidente de Panamá (OSOP)	Panama	COMPARISON OF MANUAL AND AUTOMATIC SYSTEM LOCATIONS FOR SEISMIC EVENTS IN PANAMA
Patricio Toledo et al.	Universidad de Chile and Universidad Adolfo Ibanez	Chile	USE OF THE FIRST DIGIT ANOMALY IN BACKGROUND SEISMICITY STUDIES UNDER CHILEAN TYPE OF SUBDUCTION ENVIRONMENT
William Barnhard et al.	U.S. Geological Survey	United States	NEAR REAL-TIME EARTHQUAKE SOURCE CHARACTERIZATION THROUGH JOINT GEODETIC AND SEISMIC APPROACHES AT THE US GEOLOGICAL SURVEY NATIONAL EARTHQUAKE INFORMATION CENTER
ESGA-1			
Vladimir Cermak	Institute of Geophysics	Czech Republic	BOREHOLE CLIMATOLOGY – PRINCIPLES, APPLICATIONS AND RESULTS
George Sand Franca et al.	University of Brasilia	Brasil	CRUSTAL STRUCTURE OF THE CRATON SAN FRANCSICO, BRAZIL DERIVED FROM RECEIVER FUNCTIONS
Javier Idarraga Garcia et al.	Universidad Nacional de Colombia	Colombia	NEW CONTRIBUTIONS TO THE KNOWLEDGE OF THE MAGDALENA SUBMARINE FAN (COLOMBIAN CARIBBEAN) FROM SEISMIC AND HIGH RESOLUTION BATHYMETRIC DATA
Jesus Avila et al.	FUNVISIS	Venezuela	FIRST INSIGHTS INTO THE CRUSTAL STRUCTURE OF THE MERIDA ANDES, VENEZUELA, ALONG THE SOUTHERN PROFILE
Luis Quintanar et al.	Instituto de Geofísica, UNAM	Mexico	RELACIÓN ENTRE ESTRUCTURA DEL SUBSUELO Y MOVIMIENTO SÍSMICO. EL CASO DE LA CIUDAD DE CONCEPCIÓN, CHILE

AUTHORS	AFFILIATION	COUNTRY	TITLE
RMTS-2			
Lucas Barros et al.	Universidade de Brasilia	Brasil	SOURCE SEISMIC PARAMETERS OF EARTHQUAKES CLOSE TO FUNIL RESERVOIR POWER PLANT IN THE SOUTH OF MINAS GERAIS STATE - BRAZIL
Esteban Poveda 2 et al.	esteban.poveda@gmail.com	Brasil	MOMENT-TENSOR CALCULATION FOR THE VEGA COLOMBIA MW 7.2 EARTHQUAKE
Fabio Dias et al.	IAG-USP	Brasil	MOMENT TENSOR SOLUTION OF MODERATE EVENTS AT LARGE DISTANCES: USING SURFACE WAVES DISPERSION TO BUILD VELOCITY MODELS FOR THE WAVEFORM INVERSION, EXAMPLES FROM BRAZIL.
Patricia Pedraza et al.	SGC	Colombia	MOMENT-TENSOR SOLUTION OF THE INTERMEDIATE-DEPTH 2013 GUAITARILLA (COLOMBIA) MW 6.9 EARTHQUAKE USING NEAR-REGIONAL WAVEFORM DATA
AGTE-1			
Jelime Aray et al.	Fundación Venezolana de Investigaciones Sismológicas (FUNVISIS)	Venezuela	ESTUDIOS DE AMENAZA GEOLÓGICA A PARTIR DE MEDICIONES CON GEORADAR: IDENTIFICACIÓN DE DEFORMACIONES POR FALLAS Y DESLIZAMIENTOS EN VENEZUELA
Leonid Zimakov et al.	Trimble Navigation Ltd.	United States	HIGH-RESOLUTION, LOW POWER, MOBILE INFRASOUND STATION
Caroline Whitehill et al.	Central Washington University	United States	GRAVITY AND MAGNETIC CONSTRAINTS ON THE STRUCTURAL FRAMEWORK OF THE NORTHERN VOLCANIC COMPLEX, CENTRAL CORDILLERA, COLOMBIA: APPLICATIONS FOR GEOTHERMAL RESOURCE PROSPECTING
Omar Mercado et al.	Universidad Nacional de Colombia	Colombia	INFIRIENDO LA ESTRUCTURA ESTRATIGRAFICA MEDIANTE INTERFEROMETRIA SISMICA A PARTIR DE DATOS MICROSÍSMICOS Y RUIDO AMBIENTAL
Diana Marcela Cortes Gomez et al.	Ecopetrol S.A. y Universidad Nacional de Colombia	Colombia	GEÓFONOS INDIVIDUALES VS ARREGLO DE GEÓFONOS: UN ESTUDIO DE CAMPO REALIZADO EN COLOMBIA
ANST-1			
William Yeck et al.	University of Colorado	United States	SEISMICITY INDUCED FROM NEARLY TWO DECADES OF DEEP BRINE INJECTION, PARADOX VALLEY, USA
Stanislaw Lasocki et al.	Institute of Geophysics PAS	Poland	STATISTICAL ANALYSIS OF SEISMIC ACTIVITY PRECEDING THE EMILIA-ROMAGNA (ITALY) EARTHQUAKE SEQUENCE FROM MAY/JUNE 2012
Beata Orlecka-Sikora et al.	Institute of Geophysics PAS	Poland	INTEGRATION PROGRAM FOR RESEARCH INFRASTRUCTURES FOR GEORESOURCES WITHIN EUROPEAN PLATE OBSERVING SYSTEM PROJECT
Beata Orlecka-Sikora et al.	Institute of Geophysics PAS	Poland	ASSESSING THE ROLE OF STATIC STRESS TRANSFER ON THE SPATIO-TEMPORAL DISTRIBUTION OF AFTERSHOCKS CAUSED BY A MW2.2 EARTHQUAKE IN MPONENG GOLD MINE, SOUTH AFRICA
Daniel Leon et al.	Corporación OSSO	Colombia	ESTIMACIÓN SIMULTANEA DEL MECANISMO FOCAL DE DOS MICROSISMOS CERCANOS
Luis Giron	Corporación OSSO	Colombia	PROPUESTA DE CALIBRACIÓN DE UNA ESCALA DE MAGNITUD PARA EVENTOS MICROSÍSMICOS QUE OCURREN EN CERCANÍAS A CAMPOS PETROLEROS
Beata Orlecka-Sikora et al.	Institute of Geophysics PAS	Poland	IS-EPOS – A PROTOTYPE OF EPOS THEMATIC CORE SERVICE FOR SEISMIC PROCESSES INDUCED BY HUMAN OPERATIONS
GSES-4			
Alexey Zavyalov et al.	Institute of Physics of the Earth RAS	Russia	APPLICATION OF MEE ALGORITHM FOR MEDIUM-TERM EARTHQUAKE FORECAST IN THE KOYNA-WARNA REGION
Alejandro Duitama Leal et al.	Universidad Nacional de Colombia	Colombia	MODELADO DE ATENUACIÓN Y DISPERSIÓN DE ONDAS ACÚSTICAS EN MEDIOS POROSOS SATURADOS CON FLUIDOS VISCOSOS INMISCIBLES
Tania Gonzalez et al.	Earth Consultants International, Inc.	United States	PALEOSEISMIC STUDY OF THE NORTH PANAMA DEFORMED BELT AND PROBABILISTIC SEISMIC HAZARD ASSESSMENT FOR A PROPOSED HARBOR FACILITY ON THE CARIBBEAN COAST OF COSTA RICA
Hans Diederix	SGC	Colombia	RESULTS OF RECENT PALEOSEISMOLOGIC STUDIES POINT TO THE PROBABLE SEISMOGENIC SOURCE OF THE 1875 EARTHQUAKE OF CUCUTA, IN THE BORDER AREA BETWEEN COLOMBIA AND VENEZUELA
Patricia Pedraza et al.	SGC	Colombia	STRUCTURAL DELINEATION OF THE SERVITA FAULT SYSTEM, COLOMBIAN EASTERN CORDILLERA, USING MICROSEISMICITY

JULY 25 - POSTERS

AUTHORS	AFFILIATION	COUNTRY	TITLE
ESGA-2			
Hernan Alvarado et al.	Universidad Nacional de Colombia	Colombia	CHARACTERIZATION AND IDENTIFICATION OF THE META FAULT (COLOMBIA) FROM THE DISTRIBUTION OF RESISTIVITIES
George Sand Franca et al.	University of Brasilia	Brasil	ABRUPT CHANGES IN MOHO DEPTH BENEATH THE CENTRAL ANDEAN PLATEAU INFERRED FROM APPARENT PN PHASE VELOCITIES
ANST-2			
Igor Oliveira et al.	University of Sao Paulo	Brasil	VARIATIONS OF PARAMETER B IN SE BRAZIL FROM LOCAL EARTHQUAKES
Jorge Mejia	Corporación OSSO	Colombia	LOS SONIDOS DE LAS ACTIVIDADES DE EXPLOTACIÓN DE HIDROCARBUROS
Oluwaseun Fadugba et al.	Boston College, MA	United States	DETECTION OF INDUCED SEISMICITY DUE TO OIL AND GAS EXTRACTION IN THE NORTHERN GULF OF MEXICO, USA
AGTE-2			
Carlos Lozano et al.	SGC	Colombia	DETERMINACIÓN DE MODELOS DE VELOCIDAD DE ONDAS DE CORTE EMPLEANDO EL MÉTODO DE AUTOCORRELACIÓN ESPACIAL (SPAC) EN LA CIUDAD DE ARMENIA, COLOMBIA
VMST-5			
Andres Hernando Narvaez Zuniga et al.	SGC	Colombia	SISMICIDAD VOLCANO-TECTONICA Y REGISTROS DE PERIODOS DE DEFORMACIÓN EN EL VOLCÁN SOTARÁ, "SEGMENTO CENTRAL DE COLOMBIA"
Nelson David Perez et al.	SGC	Colombia	CARACTERIZACIÓN DE FUENTES SÍSMICAS DE EVENTOS TIPO TORNILLO EN EL VOLCÁN PURACÉ MEDIANTE EL ANÁLISIS DE FRECUENCIAS COMPLEJAS
Dario Fernando Arcos et al.	SGC	Colombia	COMPORTAMIENTO DE LA ACTIVIDAD SÍSMICA Y REGISTRO DE PROCESOS DEFORMATIVOS EN LOS VOLCANES CHILES Y CERRO NEGRO, COLOMBIA (2013)
John Makario Londono et al.	SGC	Colombia	ACTIVIDAD SÍSMICA DE LOS VOLCANES DEL SEGMENTO NORTE DE COLOMBIA 1985-2014
John Makario Londono et al.	SGC	Colombia	ANÁLISIS DE LA SISMICIDAD TIPO DRUMBEAT Y SU RELACIÓN CON LA ERUPCIÓN DEL AÑO 2008 DEL VOLCÁN NEVADO DEL HUILA, COLOMBIA
Edwin Viracucha et al.	Instituto Geofísico	Ecuador	SISTEMA INFORMÁTICO PARA EL ANÁLISIS Y PROCESAMIENTO DE SEÑALES SÍSMICAS DE VOLCANES EN ECUADOR
CTEM-1			
Germán Chicangana et al.	Corporación Universitaria del Meta	Colombia	ASPECTOS GEOTECTÓNICOS, MORFOTECTÓNICOS Y GEODINÁMICOS DE LA AMENAZA SÍSMICA DE LA REGIÓN NORORIENTAL DE LA PLATAFORMA CARIBE COLOMBIANA
Alberto López et al.	Universidad de Puerto Rico - Mayagüez	Puerto Rico	THE MW6.4 NORTH OF PUERTO RICO EVENT: RESPONSE TIMELINE AND EVENT CHARACTERSTICS OF THE LARGEST EVENT EVER RECORDED AT THE PUERTO RICO SEISMIC NETWORK
Maria Cristina Araya et al.	Red Sismológica Nacional - RSN ICE UCR	Costa Rica	THE TABLÓN FAULT: SOURCE OF THE 2011–2012 TOBOSI EARTHQUAKE SWARM IN CENTRAL COSTA RICA
Lepolt Linkimer et al.	Universidad de Costa Rica	Costa Rica	RENOVATION OF THE NATIONAL SEISMOLOGICAL NETWORK OF COSTA RICA: IMPROVING STATION COVERAGE AND EARTHQUAKE MONITORING
Carlos Jose Ramirez Umana et al.	Red Sismológica Nacional (UCR-ICE)	Costa Rica	CREATING A DENSE SEISMIC NETWORK FOR COSTA RICA: A LOW-COST LATIN AMERICAN INSTRUMENT SOLUTION
Anglade Andre et al.	IPGP	France	SIGNIFICANT BREAKTHROUGHS IN MONITORING NETWORKS OF THE VOLCANOLOGICAL AND SEISMOLOGICAL FRENCH OBSERVATORIES IN THE WEST INDEES
Oscar H. Lucke	Universidad de Costa Rica	Costa Rica	STATIC STRESS STATE ON THE COSTA RICAN COCOS-CARIBBEAN PLATE INTERFACE AND ITS INFLUENCE ON THE ASPERITY DISTRIBUTION OF THE SESIMOGENIC ZONE
SMIL-2			
María Laura Rosa et al.	Facultad de Ciencias Astronómicas y Geofísicas - Univ. Nacional de La Plata	Argentina	SURFACE WAVE TOMOGRAPHY OF THE CHACO-PARANA BASIN
Gabriel Ignacio Urrego Montero et al.	Universidad Nacional de Colombia	Colombia	SEISMIC NOISE ENVIRONMENTAL CARACTERIZATION: APPLICATION TO A PILOT AREA IN BOGOTA FOR SEISMIC MICROZONATION PURPOSES

AUTHORS	AFFILIATION	COUNTRY	TITLE
GSES-5			
Cristobal Condori Quispe et al.	Instituto Geofisico del Peru	Peru	DETERMINACIÓN DE LA ESCALA DE MAGNITUD LOCAL (ML) A PARTIR DE REGISTROS DE BANDA ANCHA PARA EL PERU
Mónica Yanneth Acosta et al.	SGC	Colombia	DISEÑO E IMPLENTACIÓN DEL SISTEMA DE INFORMACIÓN DE LA RED SISMOLÓGICA NACIONAL DE COLOMBIA
Carlos Sanchez et al.	SGC	Colombia	EVOLUCIÓN TECNOLOGICA DE LA RED SISMOLÓGICA NACIONAL DE COLOMBIA –RSCN - Y LA RED NACIONAL DE ACELERÓGRAFOS DE COLOMBIA –RNAC- DEL SERVICIO GEOLÓGICO COLOMBIANO
Patricio Toledo et al.	Universidad de Chile and Universidad Adolfo Ibanez	Chile	PHYSISC AND STATISTICS OF THE SEISMIC SOURCE USING FIRST DIGIT ANOMALY
Ruth Emilse Bolanos Cifuentes et al.	SGC	Colombia	IMPLEMENTACIÓN DEL CÁLCULO DE LOS DE LOS PARÁMETROS DE LA FUENTE SÍSMICA MEDIANTE EL MÉTODO DE LA FASE W, EN EL SGC
RMTS-3			
María Celeste Bollini et al.	FCAGLP, UNLP	Argentina	MOMENT TENSOR SOLUTION FOR A M 4.2 EVENT IN TIERRA DEL FUEGO
Oscar Castro Artola et al.	Instituto de Geofísica, UNAM	Mexico	INVERSION OF A 2-POINT SOURCE MODEL OF THE M7.4 2012 MARCH 20TH GUERRERO, MEXICO
Raquel Judith Villegas Alvarez et al.	Instituto Geofisico Sismologico Volponi	Argentina	RESOLUCIÓN Y ANÁLISIS DE MECANISMOS FOCALES DE SISMOS CORTICALES EN CORDILLERA ENTRE 34.5°S Y 36°S
Fabio Luiz Dias et al.	IAG-USP	Brasil	FOCAL MECHANISM AND DEPTH DETERMINATION OF EARTHQUAKES IN BRAZIL USING TELESEISMIC P-WAVE WAVEFORM MODELING AND FIRST-MOTION POLARITIES
Vinicius Ferreira et al.	Observatorio sismológico da Universidade de Brasília	Brasil	SOURCE PARAMETERS BY WAVEFORM INVERSION OF 6.6MW EARTHQUAKE IN THE NICOYA PENINSULA ON OCTOBER 24, 2012 - AFTERSHOCK OF THE 7.6MW MAIN SHOCK ON SEPTEMBER 5, 2012
Alba Estella Ordonez et al.	SGC	Colombia	CÁLCULO DEL TENSOR DE MOMENTO SÍSMICO A PARTIR DE LA INVERSIÓN DE FORMAS DE ONDA USANDO EL SOFTWARE ISOLA: SISMO DE NUQUÍ COLOMBIA DEL 13-08-2013 (MW 6.5)
Lynette Vanessa Chavarria et al.	SGC	Colombia	MODELAMIENTO DE FUENTE SÍSMICA DEL SISMO DEL QUINDÍO (COLOMBIA) DEL 25 DE ENERO DE 1999 USANDO INVERSIÓN DE FORMA DE ONDA DE CUERPO TELESÍSMICA
Patricia Pedraza et al.	SGC	Colombia	SEISMIC MOMENT TENSOR SOLUTIONS OF M > 4.5 EARTHQUAKES IN COLOMBIA

TABLE OF CONTENTS

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ
FACULTAD DE CIENCIAS
DEPARTAMENTO DE GEOCIENCIAS
RESEARCH GROUP IN GEOPHYSICS

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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RESEARCH GROUP IN GEOPHYSICS

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Determinación de modelos de velocidad de ondas de corte empleando el método de autocorrelación espacial (SPAC) en la ciudad de Armenia, Colombia

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ABSTRACT

Se llevó a cabo un análisis de registros de microtemblores para la determinación de perfiles de velocidad de ondas de corte, con la ejecución de arreglos lineales de estaciones sismográficas y acelerográficas, con base en la aplicación del método de autocorrelación espacial modificado (SPAC por su abreviatura en inglés). Cinco arreglos dispuestos en forma lineal con tiempos de registro de 3 horas para cada distribución ejecutada se realizaron en los sitios Puerto Espejo y Hojas Anchas de la ciudad de Armenia. Mediante un proceso de inversión, se determinan los perfiles de velocidad de ondas de corte a partir de las curvas de dispersión de velocidad de fase. Para los arreglos realizados en lossitios Puerto Espejo y Hojas Anchas, se obtuvieron perfiles compuestos por tres capas con velocidades entre 110 m/s y 800 m/s.A partir de las relaciones espectrales H/V se determinaron frecuencias fundamentales de 2.5 Hz para Puerto Espejo y 2.1 Hz para Hojas Anchas, demostrando un buen ajuste con estudios de efectos de sitio realizados anteriormente en la ciudad de Armenia.

Palabras Clave: microtemblores, curvas de autocorrelación espacial, velocidad de ondas de corte, autocorrelación SPAC.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Gravity and magnetic constraints on the structural framework of the northern volcanic complex, Central Cordillera, Colombia: Applications for geothermal resource prospecting

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ABSTRACT

The structural framework of the Central Cordillera in the region of north-central Colombia is poorly constrained due to a lack of data on the fault geometries and connectivity at depth. This study presents an integrated approach using gravity and magnetic data from the SPAN dataset and new field research, in conjunction with previous studies and data on surface mapping of faults and geological relationships, seismic tomography and earthquake focal mechanisms to analyze and interpret a series of 12 transects that span 5.166666°N to 4.33333°N latitudes, and 76°W to 75°W longitudes across the northernmost volcanic complex of the Central Cordillera. These profiles are used as a reconnaissance tool for geothermal exploration around the Nevado del Ruiz volcanic system, provide the first presentation of transects of this scale and depth (up to 60 km depth) and, insight into the structures of Romeral (N-S), Palestina (NE-SW), and Nereidas (NW-SE) fault systems; depth to an elevated brittle-ductile transition zone; depth to Moho and potential geothermal conduits. This work complements current and ongoing field investigations in and around Nereidas Valley where the intersection of Romeral, Palestina and Nereidas fault systems control geothermal fluid flow.

Deep gravity and magnetic transects provide insight into the potential location of major undiscovered and untapped geothermal fields that are controlled by the tectonic framework of the region. This dataset allows the study of conductivity contrasts, heat transfer (fluids vs. solids) as well as magma and geothermal fluid movement, thereby, illuminating the location of potential geothermal reservoir bodies. For more refined constraints on the volumetric properties of geothermal reservoir bodies we integrate low frequency and broadband magnetolluric (MT) methods for geophysical imaging of subsurface geology and exploration of geothermal resources. Economically viable geothermal systems often include anomalous zones of low resistivity representing geothermally altered and impermeable cap rock with geothermal fluids underneath. MT is used to identify and isolate targets of low resistivity between depths of a few meters to many kilometers.

KeyWords: Nevado Del Ruiz, SPAN, Geophysics, Geology, Gravity, Magnetic.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Geófonos individuales Vs Arreglo de geófonos: Un estudio de campo realizado en Colombia

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ABSTRACT

Con el objetivo de evaluar el funcionamiento de geófonos individuales, se diseñó un test el cual consistió en grabar datos en un seudo 2D usando arreglos de seis elementos convencionales y un geófono individual de alta sensibilidad (solamente vertical). No se observaron diferencias relevantes cuando comparamos las trazas grabadas con elementos múltiples y las grabadas con un solo elemento en las estaciones. Esta afirmación está sustentada con los análisis en la relación Señal a Ruido realizados en ambos conjuntos de datos. Adicionalmente no se encontraron diferencias en la calidad de los datos cuando el espaciamiento entre los geófonos individuales fue puesto a intervalos de grupo (IG), de IG, 2IG/3 y IG/3 pero si mostraron baja calidad a intervalos de grupo de 2IG y 4IG/3. La distancia entre estaciones receptoras convencionales 6X1 (IG = 30 m) fue calculada para lograr el cubrimiento del subsuelo y el muestreo espacial necesarios para iluminar el objetivo deseado. Los resultados de este estudio soportan el uso del geófono individual para reducir los costos de la adquisición sin reducir la calidad de los datos sísmicos ni su intervalo de grupo, con la advertencia que este conjunto de datos de campo fue adquirido en una localización particular. Es necesario adquirir más de este tipo de estudios y publicar sus resultados con el fin de construir una base de datos de experiencias desde la cual se podrá crear conocimiento a partir de los hechos.

PalabrasClave:Geófonos individuales, arreglos de geófonos, relaciona señal ruido, imagen sísmica.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Estudios de amenaza geológica a partir de mediciones con georadar: identificación de deformaciones por fallas y deslizamientos en Venezuela

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ABSTRACT

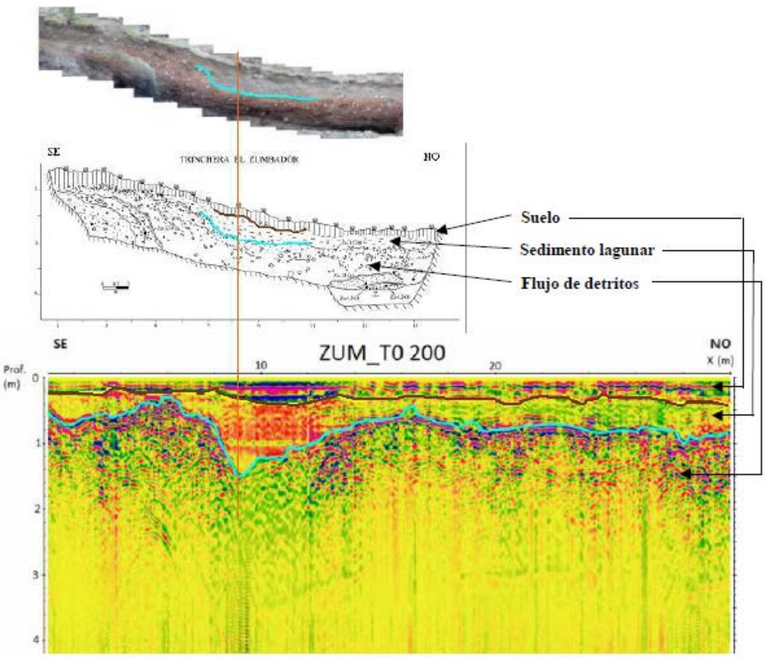
Este trabajo muestra algunos casos representativos de la respuesta obtenida con el georadar (GPR-Ground Penetrating Radar) en mediciones realizadas sobre zonas expuestas a amenaza geológica, particularmente, presencia de fallas activas cuaternarias y zonas de inestabilidad geológica por movimientos de remoción en masa (determinación del límite roca fresca-roca meteorizada). Para las mediciones se emplearon antenas de frecuencias de operación de 40, 80 y 200 MHz, resultando que las de 200 MHz generaron registros de mejor resolución, aunque con menor penetración en el subsuelo.

Se describen a continuación los resultados de dos de los casos que sirven como ejemplo de la utilidad del georadar en el estudio de geoamenazas:

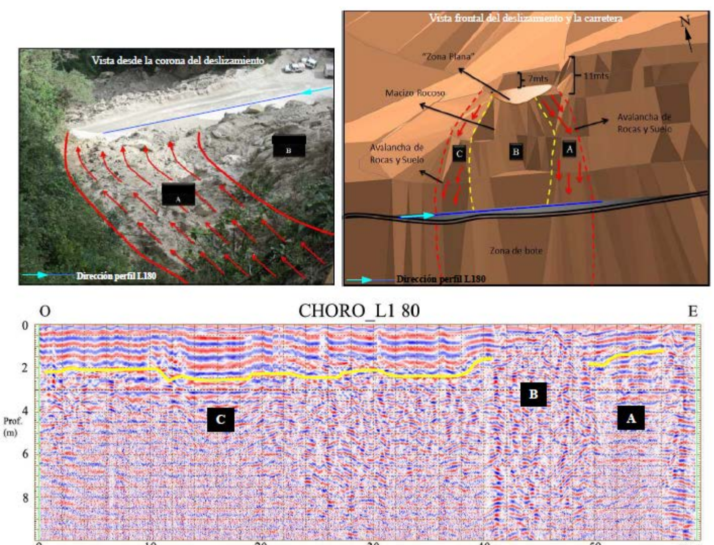
a) Identificación de deformación por fallas activas en el subsuelo, sector Páramo El Zumbador, estado Táchira (sitio previamente escogido para estudio paleosísmico): el radargrama obtenido con antenas de 200 MHz sobre el perfil T0 (ZUM_T0 200), muestra con claridad la deformación que ejerce la falla activa (Falla de Boconó) sobre los sedimentos cuaternarios. Se identificaron los límites entre distintas capas de sedimentos (flujo de detritos, sedimentos lagunares y suelo) que fueron corroborados posteriormente con el análisis de la trinchera paleosísmica (Imagen A).

b) Identificación del límite roca fresca- roca meteorizada en zona de deslizamiento, vía Maracay – Choroní, estado Aragua: en el radargrama obtenido con las antenas de 80 MHz sobre el perfil L1 (CHORO_L1 80) se identificó un horizonte entre 2 y 2,5 m de profundidad que describe un contraste de impedancia dado por el límite roca fresca-roca meteorizada (Imagen B). Hacia el extremo oeste (O) del perfil se observó el mayor espesor de material meteorizado en contraste con el extremo este (E) donde se determinó la presencia de roca fresca a profundidades someras (0,5 a 1 m).

Palabras Clave: Georadar, fallas activas cuaternarias, radargrama, amenaza geológica.



Radargrama obtenido con antenas de 200 MHz. Comparación de registro de georadar de 200 MHz, sobre el perfil T0, con perfiles geológicos en la población de El Zumbador (estado Táchira).



Radargrama obtenido con antenas de 80 MHz.. Interpretación del radargrama obtenido con antenas de 80 MHz sobre el perfil L1 ubicado en la vía Maracay-Choroní (estado Aragua) afectada por deslizamiento (A y C: zonas de deslizamiento de material, B: zona de macizo rocoso).

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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DEPARTAMENTO DE GEOCIENCIAS
RESEARCH GROUP IN GEOPHYSICS

High-resolution, low power, mobile infrasound station

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ABSTRACT

REF TEK a Division of Trimble. in collaboration with TRINAS Handels GmbH and Science Development Center "Geophysical Measurements" has developed the high resolution, low power, portable infrasound station for both permanent and portable deployment. The station provides high accuracy data with minimal expense associated with transportation, deployment and maintenance.

The infrasound stations combine three major components: a) high dynamic range differential microbarometer, b) high resolution broadband seismic recorder, and c) universal break-out box for easy connectivity and power supply to different system components. The station is housed in the small transportation case with external connectors for power and input signals.

The high dynamic range microbarometer combines rugged construction design with wide bandwidth and low noise to ensure accurate measurements in most applications. The microbarometer measures the infrasound signals in the frequency range from 0.02 to 4 Hz with the atmospheric pressure measurement range from 0.001 Pa to 100 Pa. The sensor does not require any altitude adjustments. The microbarometer is housed in a sealed compact case to prevent moisture damage.

The high resolution broadband recorder, model 130-01/6, is a self-contained state-of-the-art 24-bit resolution, low power, 6-channel recorder. The 130-01 recorder, designed to be an easy to use compact, lightweight, low power recorder, requires less maintenance than others available in the market. The 130-01 can hold up to two removable flash memory disks, which reside in a sealed compartment that is accessible by opening a lid located on the top of the 130 case, and provide data collection for extended time periods in the field. The 130-01 recorder also features built-in full duplex error correction protocol providing high reliability and data integrity of the system deployed in telemetry configuration.

The universal break-out box provides easy connection between different components of the station, minimizing the installation time in the field and avoiding trouble that often occurs when a technician is manually connecting multiple system components in the field. The rotary switch located on the top of the break-out box provides seamless connection of the different sensors to the 130-01 recorder. In addition, the break-out box distributes the DC power to the station's multiple components.

The REF TEK portable infrasound station offers a unique opportunity to end-users to obtain high resolution data in both stand alone and multiple-sensor-array configurations.

The detailed infrasound station specifications and performance are presented and discussed.

KeyWords: Mobile Infrasound station.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Infiriendo la estructura estratigráfica mediante interferometríasísmica a partir de datos microsísmicos y ruido ambiental

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ABSTRACT

Ha sido desplegado un arreglo sísmico lineal de 17 acelerómetros triaxiales separados aproximadamente cada 70 m, alineados con la boca de un pozo productor del Campo Chichimene, cuenca Llanos Orientales de Colombia. En este experimento se adquirió información por 80 horas continuas a una frecuencia de muestreo de 500 mps, que involucró el tiempo previo y posterior a una actividad de fracturamiento hidráulico realizada en Diciembre de 2012. Un preprocesamiento orientado a la eliminación de datos espurios, saltos por submuestreo electrónico y la respectiva filtración en bandas deseadas, permitió consolidar registros continuos para la aplicación sistemática de correlaciones cruzadas entre todas las estaciones y su respectivo apilado, obteniendo CDPs que permitieron ensamblar una imagen interferométrica. La aplicación de técnicas de migración con modelos de velocidad 1D del área permitió identificar reflectores consistentes con la estratigrafía local. Comparaciones entre las imágenes estimadas en este trabajo y otros adquiridas por la industria petrolera en la zona, permiten identificar contrastes acústicos de las unidades productoras.

PalabrasClave: Interferometría Sísmica, fracturamiento hidráulico, ruido sísmico ambiental, sísmica pasiva.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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ANST session – Anthropogenic Seismicity

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Integration program for research infrastructures for georesources within European Plate Observing System Project

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ABSTRACT

European Plate Observing System is a project, supported by the European Commission, aimed at building an integrated multidisciplinary solid Earth Sciences research infrastructure. EPOS is coordinating disciplinary (thematic) communities organized presently in ten working groups. Working Group 10 (WG10) of EPOS "Infrastructure for Georesources" deals with hazards evoked by exploitation of georesources, in particular with induced seismicity research infrastructure (IS RI). The group has brought together representatives from scientific community and industry from 15 European countries. WG10 focuses on priorities: 1) to facilitate a step-change in an anthropogenic seismicity research perspective from the present, technology-oriented approach, to one centered on physical problems of rockmass fracturing, without, however, losing touch with technological conditions of seismicity generation; 2) to intensify international scientific cooperation; 3) to improve research efficiency by facilitating instantaneous access to data, results and methodologies; and 4) to strengthen cooperation between industry and science. This will be achieved by creation of Induced Seismicity Thematic Core Service (IS TCS) within EPOS. The IS TCS will be open to broader community including research and industrial groups, educational centers, administrational bodies.

The IS RI to be integrated comprises three components: data, software and reports. The IS data consists of all data describing comprehensively separate anthropogenic seismicity cases, called IS episodes. The IS episode consists of time-correlated seismic and relevant production data, supplemented with other geo-data: geological, geomechanical, geodetic, etc. The second component of the IS RI are software tools for data handling and visualization, the standard and advanced software for research and newly proposed algorithms for tests and development. The third group of IS RI consists of both peer reviewed and unreviewed written materials. WG10 is working out strategic solutions for integration, a development of services to be provided by a future IS TCS, and an adequate science plan for IS TCS. Measurable benefits of the integration will be the intensification of studies on hazard and risk associated with anthropogenic seismicity.

KeyWords: EPOS, WG10, Research Infrastructure, induced seismicity.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Assessing the role of static stress transfer on the spatio-temporal distribution of aftershocks caused by a MW2.2 earthquake in Mponeng gold mine, South Africa

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ABSTRACT

The influence of the static stress changes caused by the Mw 2.2 Mponeng Gold Mine (South Africa) earthquake of 27 December 2007 on spatio-temporal distribution of aftershocks is investigated. We analyze the full recorded aftershock sequence, including events beyond 300 m from the network, to model the seismicity rate changes after the stress perturbation caused by the mainshock based on the rate- and state-dependent friction law. As a result we obtained seismicity rate distribution for six defined depth intervals. The model of seismicity rate distribution is evaluated for its capability in capturing underlying observations by using some metrics representing different categories of the goodness-of-fit evaluation. We chose measures representing three types of classes: information-based statistics, general distance statistics, and traditional statistics, namely the Bhattacharyya Metric, the psi statistic, standardized root mean square error and squared correlation coefficient. We have developed a testing method, which tests whether the observed aftershocks rate distribution does not differ significantly from the modeled seismicity rate distribution. To test such null hypothesis we generate number of control series using bootstrap method from the observed dataset of aftershocks taking into account aftershocks location error of 5m. Then for every control dataset and original dataset of aftershocks the goodness-of-fit statistics are calculated providing the empirical distribution of statistics under no seismicity rate difference condition. We compare the calculated values of statistics for the original and modeled dataset with these distributions. We also estimate the corresponding p-value which is the estimated probability of rejecting the null hypothesis. The results show that the estimated number of aftershocks is generally lower than the observed one. However, the ratio of the observed and estimated aftershocks differs between the depth intervals. The best correlation is for two upper intervals, however, the deepest level shows the lowest correlation. Testing procedure allows rejecting the null hypothesis of no significant difference between seismicity rates only for one depth interval containing the mainshock. Presented results show that the stress-based model well explains the main features of spatio-temporal distribution of the aftershocks of the small event in Mponeng gold mine. The mining-induced earthquakes can be followed by stress relaxation in a form of aftershocks located mostly on a rupture plane or in regions where Coulomb stress change is positive.

KeyWords: induced seismicity, Coulomb stress transfer, statistical inference, rate/state model.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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IS-EPOS – A prototype of epos thematic core service for seismic processes induced by human operations

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ABSTRACT

The community focused on seismic processes induced by human operations has been organized within EPOS Integration Program as Working Group 10 Infrastructure for Georesources. This group has brought together representatives from the scientific community and industry from 15 European countries. WG10 aims to integrate the research infrastructure (RI) in the area of seismicity induced (IS) by exploration and exploitation of georesources: tremors and rockbursts in underground and open-pit mines, seismicity associated with conventional and unconventional oil and gas production, induced by geothermal energy extraction and by underground reposition and storage of fluids (e.g. water disposal associated with energy extraction, CO2 sequestration, inter alia) and triggered by impoundment of surface water reservoirs, etc. WG10 priority is to create new research opportunities in the field, responding to global challenges connected with exploitation of georesources. WG10 has prepared the model of integration, which fulfills the scientific mission and raises the visibility of stakeholders. The end-state Induced Seismicity Thematic Core Service (IS TCS) has been designed together with key metrics for TCS benefits in four areas: scientific, societal, economic and capacity building. The IS-EPOS project, funded by National Centre for Research and Development, Poland within the program "Innovative Economy Operational Program Priority Axis 2 – R&D Infrastructure", aims at building a prototype of IS TCS. The prototype will implement fully the designed logic of IS TCS. Research infrastructure integrated within the prototype will comprise altogether seven comprehensive data cases of seismicity linked to deep underground mining, associating geothermal energy production and triggered by reservoir impoundment. The implemented thematic services will enable studies within the use-case "Clustering of induced earthquakes". The IS TCS prototype is expected to reach full functionality by the end of 2014.

KeyWords: EPOS, WG10, Research Infrastructure, induced seismicity.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Estimación simultanea del mecanismo focal de dos microsismos cercanos

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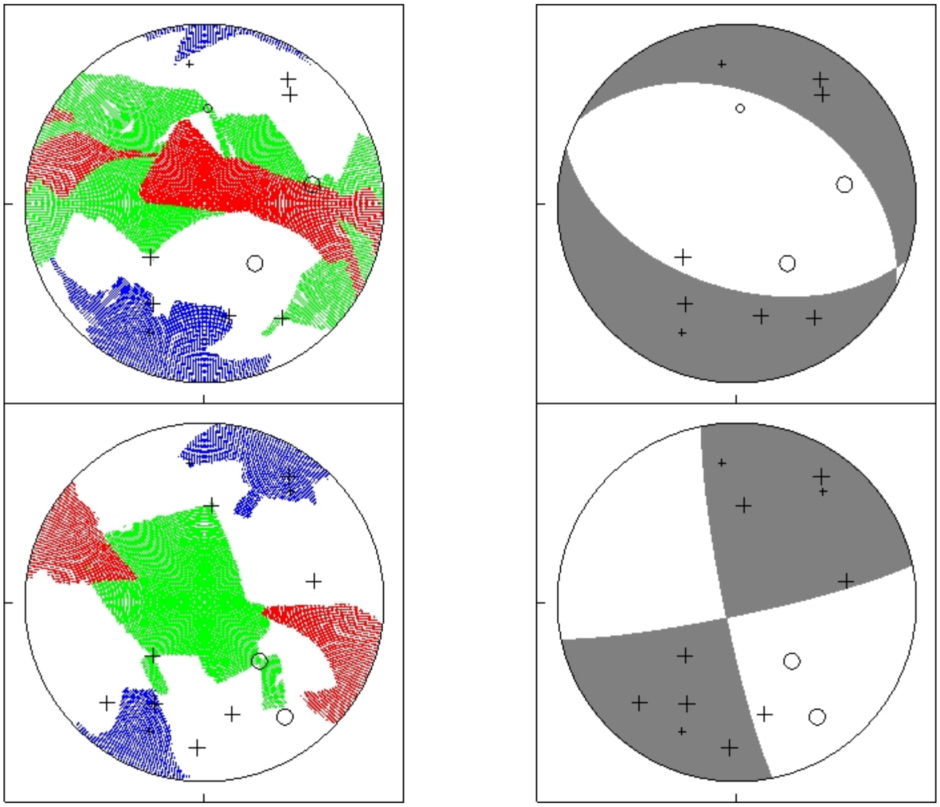
ABSTRACT

Los mecanismos focales son usados en el análisis de la sismicidad inducida en campos petroleros para conocer el estado y los cambios del régimen de esfuerzos en una región, y también la orientación y el tipo de fracturas activas sísmicamente. Para calcular los mecanismos focales se utiliza normalmente la información de las polaridades, de tal manera que se puedan separar las zonas de dilatación y de compresión en un mecanismo focal; y en algunos casos, esta información se complementa con las amplitudes de la P y la S; sin embargo se necesita que el evento tenga una magnitud tal que la señal no esté enmascarada por el ruido en las estaciones. Esta condición hace que sea un reto estimar la geometría de los microsismos más pequeños en un yacimiento.
Durante las actividades de producción de hidrocarburos, los cambios en la presión de yacimiento pueden favorecer el que se generen microsismos en pequeñas fracturas en muchas direcciones con mecanismos focales muy diferentes dentro de un volumen muy reducido. Sin embargo, para eventos localizados muy cercanos entre sí, tanto la estructura de la tierra como la respuesta del sensor pueden asumirse iguales para cada evento. En este caso, la relación de las amplitudes de la señal de dos eventos cercanos en una estación dependerá solamente del tipo de mecanismo focal y de la magnitud de cada evento. A partir de esta idea, se propone un método para estimar simultáneamente los mecanismos focales de dos eventos que ocurren dentro de un volumen reducido usando las polaridades y la relación de las amplitudes de la primera oscilación de la onda P en cada estación de una red superficial que registre los dos eventos.
La figura I muestra el caso de dos eventos localizados muy cercanos entre sí, de los cuales se muestran a la izquierda las polaridades y el conjunto de los ejes P (puntos rojos), T (puntos azules) y N (puntos verdes) de los posibles mecanismos focales permitiendo un desajuste de hasta una polaridad; y la solución final determinada a partir de la relación de amplitudes a la derecha.
Las soluciones estimadas a partir del método propuesto ajustan entre sí las diferencias de amplitudes en varias estaciones, haciendo que estas soluciones sean más acertadas que al tener en cuenta solamente las polaridades. Existen diferentes factores que pueden contribuir a un desajuste de algunas polaridades (trayectoria no conocida del rayo, no identificación de la fase correcta, ruido...), sin embargo las soluciones encontradas explican la relación de amplitudes en cada estación a causa de cada evento, lo cual hace a que estos mecanismos focales sean una mejor aproximación a la descripción real de la geometría de estos microsismos. Finalmente, la implementación de este método para estimar mecanismos focales integra distintos tipos de observación de los eventos de tal manera que se puedan estimar mecanismos focales de microsismos más pequeños a partir de una red superficial de estaciones.

PalabrasClave: microsismos, mecanismo focal, sismicidad inducida.



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Variations of parameter b in SE Brazil from local earthquakes

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ABSTRACT

The slope of the Gutenberg-Richter magnitude-frequency relation, known as parameter b, is widely used to characterize earthquake size distribution. Variations from the average b-value = 1 have been interpreted as indicating the degree of fracture density in the crustal volume, or the predominance of water-induced mechanisms (b-values higher than that of natural seismicity). One of the difficulties of comparing b-values between different earthquake sequences is the use of different local magnitude scales based on signal duration. Two intraplate earthquake sequences in SE Brazil (one case of natural seismicity and one case of water-induced earthquakes) were studied in search for differences in b-values by using the same magnitude scheme based on coda amplitudes. Empirical regressions were found for each local station relating coda amplitudes with regional magnitudes in the range mR= 2.5 to 4.0, which were then used to estimate local magnitudes for the smaller events.

In May 2012 a 4.0 mb event occurred in the Sao Francisco craton, near the town of Montes Claros. A local network was installed and recorded a set of about 30 events in the following six months, all occurring in the same rupture plane (inverse faulting mechanism on a NNW-SSE oriented fault plane). These events provided a ¬b¬-value of 0.5 +- 0.1. Although this value is unusually low, it is probably reliable because the G-R frequency-magnitude relation is quite linear above the completeness magnitude of 1.0.

In 2005, a large sequence of small earthquakes occurred near Bebedouro town, in the Parana intracratonic basin, induced by the drilling of several new wells, which added extra water into a confined fractured aquifer. Thousands of small events, with magnitudes up to 2.9 mR were recorded by a local network. Using events above the completeness magnitude of 1.0, a b-value = 0.84 +- 0.12 was obtained.

Although the b-value of the induced events in Bebedouro is "normal" (i.e., close to 1.0), it is nevertheless significantly higher than the b-value of the natural events in Montes Claros.

KeyWords: earthquake statistics, induced seismicity, b-value.

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Los sonidos de las actividades de explotación de hidrocarburos

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ABSTRACT

Con el nombre de sísmica pasiva se acostumbra denominar a la observación sismológica en áreas de explotación de hidrocarburos, ya que la intervención del subsuelo suele generar pequeños eventos microsísmicos que pueden ser observados con técnicas estándar de la sismología. Sin embargo, la sísmica es una rama de la geofísica que busca conocer detalles de la estructura y composición del subsuelo usando fuentes artificiales para tal fin. En este sentido, lo que más se aproxima a una verdadera sísmica pasiva es la técnica conocida como interferometría, que busca producir curvas de reflectividad a partir de registros de ruido; pese a que en sentido estricto no es la interferencia de ondas quien permite observar los valores de reflectividad. Pero "RUIDO" es otra de las palabras que no representa adecuadamente el fenómeno al que se refiere, pues es claro que si las señales que llamamos "RUIDO" contienen curvas de reflectividad entonces estas señales no deberían ser clasificado como ruido.

Con ejemplos concretos en una buena variedad de condiciones de campo, el autor interpreta las mal llamadas señales de ruido en campos petroleros a través de un conjunto de transformaciones y representaciones que nos ayuda a escuchar los hermosos sonidos que produce la actividad industrial en estos campos. Por ejemplo, si volvemos audible el rango del infrasonido, permitimos que el cerebro actúe y logramos aplicar con mínimo esfuerzo sofisticadas técnicas de reconocimiento que nos facilita la interpretación de ciertos tipos de señal presentes en el campo. De esta forma logramos transformar lo que comúnmente llamamos ruido en un conjunto de exóticas sinfonías que nos hablan de la industria y de sus prácticas. Cuando por el contrario transformamos las señales temporales en visualmente atractivos espectrogramas y representamos su información direccional por medio de las escalas del color, obtenemos un conjunto de representaciones sicodélicas, agradables a la vista, y en ciertos aspectos mucho más representativas que las series de tiempo que permitieron su generación. En estos paisajes es posible identificar el fugaz paso de un chorro de fluido por el subsuelo o el muy armónico silbido del taladro cuando en su función se encuentra, o el simple rompimiento de una roca durante las actividades de estimulación.

El reto ahora es conquistar a los operadores para que juntos logremos dar nombre a las sinfonías y producir un completo diccionario que nos permita traducir a sus letras, de manera que del ruido logremos extraer no solo alguna información estructural sino que logremos "ver" otro conjunto de fenómenos menos convencionales que el sísmico.

Palabras Clave: Microsismicidad, sísmica pasiva, ruido.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Propuesta de calibración de una escala de magnitud para eventos microsísmicos que ocurren en cercanías a campos petroleros

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ABSTRACT

Estimar con precisión la magnitud de los eventos microsísmicos observados durante el desarrollo de actividades de Exploración y Producción de hidrocarburos es de suma importancia para un operador a la luz de las nuevas reglamentaciones gubernamentales que se han venido desarrollando a nivel mundial. Colombia no ha sido la excepción en esta materia y ha reglamentado para yacimientos no convencionales, que las actividades de la operación de estimulación hidráulica deben suspenderse en caso de que se presente un evento sísmico de magnitud mayor o igual a cuatro en la escala de Richter, que tenga una localización hipocentral dentro de unos límites establecidos.Pero, ¿cómo podemos garantizar la conformidad con una norma a partir de una medida tan subjetiva como lo es la magnitud de un evento sismológico?
En este trabajo se estudiaron las diferentes opciones disponibles, concluyendo que es fundamental realizar un estudio de calibración de la escala de magnitud serio y detallado, y que los valores de referencia usados en estos estudios deben ser menos arbitrarios que aquellos propuestos por Richter en 1935. De lo contrario, ¿con qué criterios podría la ANLA o cualquier otra entidad refutar las estimaciones de magnitud realizadas por la institución designada por el operador del campo para verificar el cumplimiento de la norma?
La propuesta de este trabajo consiste en calcular el escalar del momento sísmico para un conjunto de eventos y aplicar la fórmula de Hanks y Kanamori (1979) para generar unas magnitudes de momento que sirvan de referencia para la construcción de una escala robusta. Sin embargo, durante la evaluación de la magnitud de momento (Mw) es frecuente hacer conjeturas acerca de algunos parámetros que no siempre están disponibles (valores de rigidez, atenuación, factores de calidad, etc.). De esta forma, la segunda parte de este trabajo se concentra en el efecto que cada uno de los parámetros tiene sobre el resultado de la evaluación final de magnitud, su posible variabilidad, y el máximo efecto esperable que tiene sobre el valor final de magnitud; culminando con la presentación de un margen de seguridad que debemos asumir los sismólogos, o un margen de tolerancia que debe contemplar el legislador al momento de confrontar la norma.

Palabras clave: Magnitud, eventos microsísmicos, momento sísmico, calibración.

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Detection of induced seismicity due to oil and gas extraction in the northern Gulf of Mexico, USA

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ABSTRACT

Drilling operations and extraction of oil and gas (O&G) may lead to subsurface slumping of sediments due to reduced vertical principal stress and may lead to small earthquakes. O&G extraction is common in the northern Gulf of Mexico (NGM) and only 35 earthquakes of magnitudes between 2.3 and 6.0 have been recorded in the area from 1974 to the present. Given the rate of oil extraction at the various oil fields in the region, the record of earthquake activity appears to underestimate the seismicity of the region. The purpose of this research is to detect more earthquakes using stacks of seismic data from the EarthScope Transportable USArray from 2011 to 2013, and determine the spatiotemporal relationship between the detected earthquakes and O&G extraction.
The EarthScope Transportable USArray seismic data around the NGM were retrieved from IRIS database and a bandpass filter of 2 – 10 Hz was applied to remove background noise. The detection algorithm was applied on the filtered seismic data at 4-minute interval with 2-minute overlap. Before stacking the data from each station, the arrival times were corrected in order to account for the change in arrival times due to different epicentral distances. The stack of the previous 4- minute data window was used as the background noise. A Hilbert transform was applied to generate an envelope function used in the stacking algorithm in order to avoid destructive stacking of the positive and negative amplitudes of the waveforms. An event is detected when the lambda, ratio of the standard deviation of the P- and S-waveforms to the standard deviation of the background noise, and the signal-to-noise ratio are greater than 3. The arrival times of detected events will be used in the grid-search algorithm to determine the best estimate of the hypocenter. Magnitude and spatial distribution of the earthquakes occurrence will be determined and will be correlated in time and space with the map of offshore drilling sites.
Understanding the relationship between small offshore earthquakes and O&G extraction will help reduce seismic hazards around local drill holes. The results of this study may be used to appraise the seismic hazard related to O&G extraction in other oil fields.

KeyWords: extraction, earthquakes, underestimates, EarthScope Transportable USArray and offshore drilling sites.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

Statistical analysis of seismic activity preceding the Emilia-Romagna (Italy) earthquake sequence from May/June 2012

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ABSTRACT

A series of earthquakes starting from M5.9 on May 20 visited Emilia province of Italy in May and the beginning of June 2012. Six earthquakes exceeded magnitude 5, and there was a multitude of smaller events, mostly aftershocks. The province is densely populated and highly industrialized as well as the location of many high value historical monuments therefore in addition to 26 lives taken, the series resulted in extreme material loss estimated to some 12.5 billion Euros. The report presents results of a statistical analysis of seismicity from seven years before the earthquake series. It is shown that this seismicity did not follow signatures of typical for background seismicity: the occurrence process was non-Poissonian, the Gutenberg-Richter b-values was time-varying. The event rate considerably increased in the last year before the mainshock from May 20th, 2012. The analysis of time-space clustering of events has indicated a strong connection between 22 events from before the earthquake series and seven major shocks of the series. The weaker event occurrences from one year before the May 20th mainshock turn out to be correlated with a rapid increase of parameters of oil and gas production from the reservoir in this area. The binomial test has indicated that the event rate after the beginning of this increasing trend was significantly higher than the event rate before when the production parameters were decreasing. Also this change of trends of production parameters correlated with the change of P and T directions of weaker seismic events that is with the change of stress field orientation. All this results does not allow for ruling out the possibility of triggering impact of the hydrocarbon production on the May 20th mainshock generation.

KeyWords: earthquake triggering, statistical analysis, Emilia-Romagna.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismicity induced from nearly two decades of deep brine injection, Paradox Valley, USA

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ABSTRACT

The Bureau of Reclamation (Reclamation) operates a deep injection well at Paradox Valley in western Colorado as part of the Paradox Valley Unit (PVU) of the Colorado River Basin Salinity Control Program. The objective of the PVU is to reduce the salt load of the Colorado River. The Dolores River, a tributary of the Colorado River, picks up nearly 185,000 metric tons of salt annually from natural brine groundwater inflow in the Paradox Valley. Paradox Valley overlies a salt anticline and therefore ground water in the valley can have 8 times the salinity of ocean water. PVU diverts up to 90 percent of the Paradox Valley brine inflow from entering the Dolores River. Subsurface brine flow is intercepted by the continuous pumping of shallow extraction wells located along the river. The extracted brine is then injected 4.8 km below the surface.

PVU has injected brine almost continuously for nearly 2 decades. Throughout PVUs lifetime, Reclamation has operated the Paradox Valley Oral Seismic Network (PVSN) to monitor seismicity induced by injection. Reclamation monitored seismicity 6 years prior to the initiation of injection and recorded only a single local event, 19 km from the injection well. Since injection began, over 6000 likely induced earthquakes have been recorded by the PVSN. We explore the spatiotemporal evolution of earthquake hypocenters and its relationship to both injection operations and local geology. Felt earthquakes are infrequent, but during its lifetime PVU has induced 3 ML 4.0-4.4 earthquakes. Of particular interest is the seismic hazard presented by these induced events. We investigate this topic through exploring the spatial evolution of seismicity with respect to population centers, changes in seismicity rate, estimated and observed maximum magnitude earthquakes, and observed ground motions.

Key Words: Induced Seismicity, Anthropogenic Seismicity, Deep Injection, Seismic Hazard.

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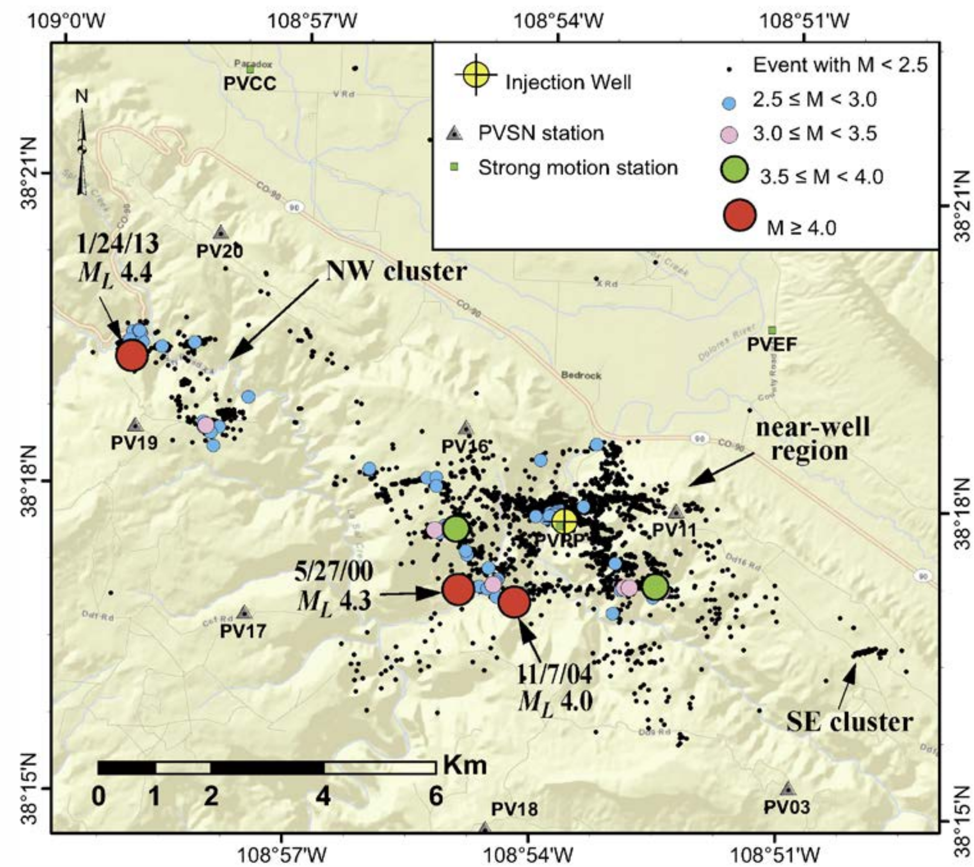

Figure 3 from: Block, Lisa V., Christopher K. Wood, William L. Yeck, and Vanessa M. King. "The 24 January 2013 ML 4.4 Earthquake near Paradox, Colorado, and Its Relation to Deep Well Injection." Seismological Research Letters 85, no. 3 (2014)

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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CTEM sesión – Caribbean Tectonics, Earthquake Monitoring, Modeling and Early Warning

Conveners:
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Jay Pulliam (Baylor Univ. - USA)
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The Mw6.4 North of Puerto Rico event: Response Timeline and Event Characteristics of the largest event ever recorded at the Puerto Rico Seismic Network

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ABSTRACT

Historically, the Puerto Rico – Virgin Islands (PRVI) region has been subjected to large and devastating earthquakes such as the Mw7.2 October 11, 1918, and the Mw7.8 July 28, 1943 event. Since its inception in the mid 70's, the Puerto Rico Seismic Network (PRSN) has been monitoring earthquakes in the PRVI region, and on the midnight of January 13, 2014, PRSN recorded for the first time the strongest event ever recorded instrumentally by the network. The Mwp 6.4 event occurred 70 km north of the Puerto Rico coastline. With a network of 20 broad-band seismographs, 10 continuous GPS sites and access to a dozen tide gauges and DART buoys, the PRSN is a multi-observational monitoring network in the northeastern Caribbean, and a leading observatory in the Caribbean. The January 13 event originated at 04:01:01 GMT and had a final manual review location at 19.138 N, and -66.823 E, with a depth of 36 km. With an aftershock distribution of more than 500 events, and a predominantly thrust mechanism, the earthquake must likely reflects contraction along a steep northward-dipping thrust fault. This poster presents two aspects of this event; first, we describe the response of the PRSN to the event (timeline, location, assessment of the threat based on the location and magnitude, and evaluation of the communications with emergency management agencies). Second is the scientific aspect (hypocenter in relation to the tectonic setting, aftershock distribution based on double-differencing relocations and its implications on the rupture zone, waveform inversion to obtain the moment tensor, ShakeMap and CIIM's, and cGPS time series). This event provides the first largest event recorded at PRSN and therefore provides a real-life test to auto-evaluate the outcome of the current earthquakes and tsunami protocols and work towards improvements in case a larger event strikes in the future.

KeyWords: Puerto Rico Seismic Network, Puerto Rico large earthquakes, Seismic Monitoring.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Significant breakthroughs in monitoring networks of the volcanological and seismological French observatories in the West Indies

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ABSTRACT

In the last few years, French West Indies observatories, in collaboration with the Seismic Research Center (University of West Indies-Trinidad), have modernized the Lesser Antilles Arc seismic and deformation monitoring network. 15 new permanent stations have been installed to strengthen and expand its detection capabilities. The global network of the IPGP-SRC consortium is now composed of 21 modernized stations, all equipped with broad- band seismometers, strong motion sensors, GNSS sensors and satellite communication for real-time data transfer to the observatories of Trinidad (SRC), Guadeloupe (OVSG), Martinique (OVSM). To improve the sensitivity and reduce ambient noise, special efforts were made to enhance the design of the seismic vault and the original Stuttgart shielding (D. Kurrle R. Widmer-Schnidrig, 2005) of the broadband seismometers (240 and 120 sec). Several months of tests have been performed in order to get the maximum performance level out of the seismometers with different types of shields. This renewed network feeds the Caribbean Tsunami Warning System supported by UNESCO and establishes a monitoring tool that produces high quality data for studying subduction and volcanism interactions in the Lesser Antilles arc. The project has been an opportunity to migrate the seismic data processing to SeisComP3 with new developed plu-gins to compute the duration magnitude and locate (modified HYPO71PC) ever small events such as volcanic ones. The new plugins are integrated in Seiscomp3 releases. Several tools for data management and treatment (EarthWorm and WebObs [Beauducel et al., 2004]) are also continuously improved. GPS data, real-time and validated seismic data (only broadband) are now available at the IPGP data center.

KeyWords: French West Indies observatories, Lesser Antilles Arc seismic and deformation monitoring.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Creating a dense seismic network for Costa Rica: A low-cost Latin American instrument solution

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ABSTRACT

During 1960's, Costa Rica started setting its first small seismic networks within the country in order to monitor volcanic activity in the Irazu volcano. This equipment was donated from International agencies, and even though maintenance was not complicated, getting spare parts was a significant issue. During the 1970's those seismometers were moved to the Central American School of Geology (ECG) at the University of Costa Rica (UCR), which was recently created at that time. In the following years, more instrumentation was donated to the ECG, but the lack of spare parts, specialized trained technicians, and the different kinds of instruments made the network worked very inefficiently. In 1982, the ECG joined with the seismic monitoring section of the Costa Rican Electric Institute (ICE), creating the National Seismological Network (RSN). The purpose of the seismic monitoring at ICE was mainly to look for energy production facilities near volcanoes and active faults. For this reason, the RSN had some budget for purchasing seismic instruments. However, prices of instrumentation were significant high and instruments were manufactured overseas, creating difficulties for establishing a dense network. Two decades later, with the digital technologies, the quality of the data increased as well as the price of the instruments, carrying seismologists to spend fortunes on seismometers. During the 2000s, the RSN initiated a great link with an enthusiastic equipment-developing group, which now is the Seismic Observatory of Western Panamá (OSOP). OSOP is now manufacturing the first series of seismic devices that fits the Latin American seismic network budgets, including the Sixaola-type seismometer. The Sixaola seismometers are all-in-one solution, with integrated six sensors (three seismic and three accelerometer components), the digitizer, the computer, and the GPS into a single box. Additionally, it comes with a web interface to allow for a rapid configuration, low power consumption, SeedLink or Earthworm export, and IP67 casing offering total protection in humid and aggressive environments like volcanic regions. The RSN just acquired a little more than 90 Sixaola seismometers. This means 15 times more stations for the price of a single broad band. These new instrumentation seems to solve a long history of issues that the RSN has faced in the past. In 2014, the RSN began a cooperation agreement with the Fire Fighter Department of Costa Rica in order to set up one instrument at each of their 75 Fire Stations. This will allow access to 24 hour personal on site, full time electricity, Internet, safety, and communications. This expansion of the seismic network at low cost will allow for a significant improvement in the station coverage and quality of earthquake locations for Costa Rica.

Key Words: RSN, OSOP, Costa Rica, ECG, ICE.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Relocation of the mainshock and aftershocks of Ml 5.7 Quetame earthquake, Colombia

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ABSTRACT

On May 24th, 2008, 19:20 UTC a 5.7 earthquake struck the center of Colombia. The Geological Survey of Colombia (SGC) put the earthquake epicenter in the SE of the capital Bogotá at a depth less than 30km. The earthquake affected 5 municipalities in the department of Cundinamarca: Quetame, Fosca, Guayabetal, Fómeque, Bogotá and El Calvario in Meta. The earthquake left a final balance of 6 deaths and 65 people injured. Approximately 9.000 persons resulted affected by the destruction of their houses. The SGC deployed a temporary 3-component broadband network. A total of 9 seismographic stations were installed to complement the Colombian National Seismological Network (RSNC), two days after the mainshock event due to difficult access to the area. During the period from May 2008 to February 2009 the mainshock was followed by a sequence of ~1,000 events.

In this work, we present the results of relocation of approximately 100 aftershocks with magnitude larger than 2.0, recorded by the local network as well as recorded by some stations of the national network. The phase data used in the relocation are mainly from 20 stations with epicentral distance less than 200km. As relative large horizontal and vertical shift were observed in the initial RSNC location, which may indicate an over simplification of the 1-D velocity model. We checked and re-picked many seismograms of this subset and estimated, a one-dimensional reference velocity model using the VELEST inversion process, which can simultaneously locate earthquakes and calculate the 1-D velocity model with station corrections. We used a combination of cross-correlation and arrival times to analyze the events, based on the similarity of their recorded seismograms. We combined P-wave and S-wave differential times derived from cross-correlation and used the HypoDD method to enhance the location precision, this method uses the traveltime differences to invert for relative hypocenter locations, thus eliminating the ray path effects to stations. The relocation results show that the aftershocks spread with an orientation trend NE-SW, which indicated a strike-slip fault consistent with the regional stress regime.

Key Words: earthquake, relocation, hypocenter, 1D velocity model, fault plane.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Aspectos geotectónicos, morfotectónicos y geodinámicos de la amenaza sísmica de la región nororiental de la plataforma Caribe Colombiana

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ABSTRACT

Para la región nororiental de la plataforma continental Caribe colombiana solo el sismo del 22 de mayo de 1834 es su único sismo histórico registrado en cerca de 500 años de historia colombiana. Este sismo de acuerdo a los historiadores afectó a la ciudad de Santa Marta destruyendo su arquitectura colonial de manera total. De acuerdo al estimativo macrosísmico este sismo tuvo una magnitud superior a 6.0 y es posible que su epicentro estuviera muy próximo a esta ciudad.

La parte oriental de la plataforma continental Caribe colombiana está constituida por la Sierra Nevada de Santa Marta (SNSM) al occidente, la Serranía de Perijá (SP) al oriente y la Península de La Guajira al norte. El basamento continental de esta región está constituido de rocas metamórficas que representan el basamento Proterozoico Andino que deriva de la orogenia Grenvilliana que se presentó a finales del Mesoproterozoico.Hacía el norte de esta plataforma continental se encuentra la corteza oceánica constituida por la placa Caribe. La colisión de la placa Caribe que resultó en el engrosamiento cortical del margen continental en el noroccidente de Suramérica abarcó en tiempo geológico el lapso Cretáceo Superior - Neógeno temprano, pero sin embargo el estilo orogénico que se observa hoy en esta región solo se desarrolló desde el Mioceno hasta el Presente.De acuerdo a la observación de campo y la evaluación morfotectónica, se demuestra que esta región es controlada en su estilo orogénico por la actividad tectónica y no por la actividad erosiva, tanto para el sector por donde discurre la falla Oca al norte de la SNSM y la SP, como por donde discurre la falla Perijá - El Tigre en la SP.

Por su configuración morfotectónica la falla Oca que separa la Península de la Guajira de la SNSM y la SP podría liberar un sismo de una magnitud equiparable a la del sismo de enero 12 de 2010 en Haití.

El otro sector de esta región que registra sismicidad se asocia a la falla Perijá – El Tigre, la cual define el límite orogénico entre la plataforma continental Caribe colombiana y la cuenca de Maracaibo. En este sector se presenta una sismicidad recurrente que se asocia a la actividad de esta falla, como el sismo que fue registrado por la RSNC con MW = 4.1, el 24 de febrero de 2014.

Este trabajo busca que se incentiven los estudios paleosismológicos y el monitoreo tanto geodésico como sismológico para estas dos fallas. La falla Oca incrementa la vulnerabilidad sísmica a ciudades como Maracaibo en Venezuela y, Riohacha y Santa Marta en Colombia. La falla Perijá – El Tigre, la incrementa por su lado a la ciudad colombiana de Valledupar y la zona densamente poblada del valle del Cesar ubicado entre la SNSM y la SP.

PalabrasClave: Amenaza Sísmica, Morfotectónica, Región Caribe, Colombia.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Slab tears and intermediate-depth seismicity in the Northeast Caribbean and elsewhere

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ABSTRACT

Active tectonic regions where plate boundaries transition from subduction to strike-slip can take several forms, such as triple junctions, acute and obtuse corners. Well-documented slab tears that are associated with high rates of intermediate-depth seismicity are discussed here: Gibraltar arc, the southern and northern ends of the Lesser Antilles arc, and the northern end of Tonga trench. Seismicity at each of these locations occurs, at times, in the form of swarms or clusters and various authors have proposed that each marks an active point of tear propagation.

The fore-arc region of the northeast Caribbean plate north of Puerto Rico and the Virgin Islands has been the site of numerous seismic swarms since at least 1976. Two six-month deployments of ocean bottom seismographs recorded several such tightly clustered swarms, along with additional events. Joint analyses of the ocean bottom seismographs and land-based seismic data reveal that the swarms are located at depths of 50–150 km.

Focal mechanism solutions, found by jointly fitting P wave first-motion polarities and S/P amplitude ratios, indicate that the broadly distributed events outside the swarm generally have strike- and dip-slip mechanisms at depths of 50–100 km, while events at depths of 100–150 km have oblique mechanisms. A stress inversion reveals two distinct stress regimes: The slab segment east of 65W longitude is dominated by trench-normal tensile stresses at shallower depths (50–100 km) and by trench-parallel tensile stresses at deeper depths (100–150 km), whereas the slab segment west of 65W longitude has tensile stresses that are consistently trench normal throughout the depth range at which events were observed (50–100 km). The simple stress pattern in the western segment implies relatively straightforward subduction of an unimpeded slab, while the stress pattern observed in the eastern segment, shallow trench-normal tension and deeper trench-normal compression, is consistent with flexure of the slab due to rollback. These results support the hypothesis that the subducting North American plate is tearing at or near these swarms. The 35 year record of seismic swarms at this location and the recent increase in seismicity suggest that the tear is still propagating.

KeyWords: slab tears, seismic swarms, intermediate-depth earthquakes, ocean bottom seismographs.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Combination of High Rate, Real-time GNSS and Accelerometer Observations – test results using a shake table and historic earthquake events

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ABSTRACT

One of the fundamental requirements of an Earthquake Early Warning (EEW) system (and other mission critical applications) is to quickly detect and process the information from the strong motion event, i.e. event detection and location, magnitude estimation, and the peak ground motion estimation at the defined targeted site, thus allowing the civil protection authorities to provide pre-programmed emergency response actions: Slow down or stop rapid transit trains and high-speed trains; shutoff of gas pipelines and chemical facilities; stop elevators at the nearest floor; send alarms to hospitals, schools and other civil institutions.

An important question associated with the EEW system is: can we measure displacements in real time with sufficient accuracy? Scientific GNSS networks are moving towards a model of real-time data acquisition, storage integrity, and real-time position and displacement calculations. This new paradigm allows the integration of real-time, high-rate GNSS displacement information with acceleration and velocity data to create very high-rate displacement records. The mating of these two instruments allows the creation of a new, very high-rate (200 Hz) displacement observable that has the full-scale displacement characteristics of GNSS and high-precision dynamic motions of seismic technologies. It is envisioned that these new observables can be used for earthquake early warning studies and other mission critical applications, such as volcano monitoring, building, bridge and dam monitoring systems.

REF TEK a Division of Trimble has developed the integrated GNSS/Accelerograph system, model 160-09SG, which consists of REF TEK's fourth generation electronics, a 147-01 high-resolution ANSS Class A accelerometer, and Trimble GNSS receiver and antenna capable of real time Precise Point Positioning (PPP) techniques using delivery of precise satellite corrections.

The test we conducted with the 160-09SG Recorder is focused on the characteristics of GNSS and seismic sensors in high dynamic environments, including historic earthquakes replicated on a shake table, over a range of displacements and frequencies. The main goals of the field tests are to explore the optimum integration of these sensors from a filtering perspective including simple harmonic impulses over varying frequencies and amplitudes and under the dynamic conditions of various earthquake scenarios.

KeyWords: Seismic, Geodetic, GNSS, Earthquake monitoring.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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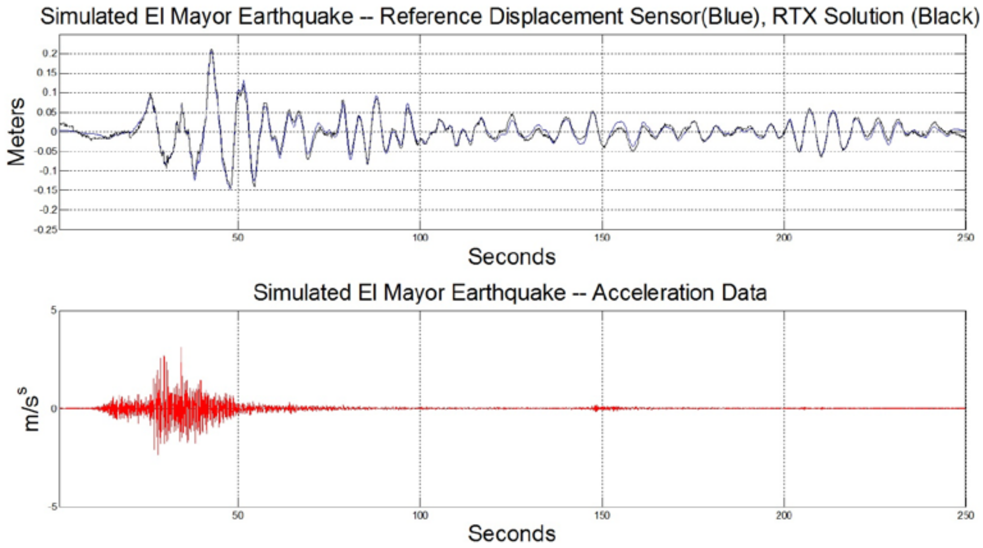
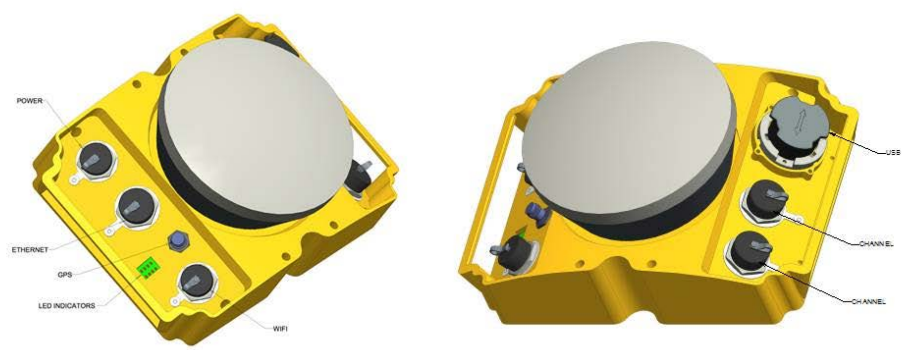


160-09SG-01	160-09SG-02	160-09SG-03	160-09SG-04
Integrated GNSS + Internal Accelerometer	Integrated GNSS + Ext Accelerometer	Integrated GNSS + Internal Accelerometer + 6 external channels	Integrated GNSS + Ext Accelerometer + Ext BB Seismometer



Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Renovation of the National Seismological Network of Costa Rica: improving station coverage and earthquake monitoring

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ABSTRACT

The National Seismological Network of Costa Rica (RSN) is a joint effort between the Seismology Laboratory of the School of Geology at the University of Costa Rica (UCR) and the Seismology Division of the main Costa Rican Electric Company (ICE). Since 1973, the RSN has continuously monitored the seismic and volcanic activity of Costa Rica. The goal of RSN is to develop scientific knowledge in Earth Sciences to transfer it to the Costa Rican society through teaching, research, and social work. In this presentation, we addressed some efforts performed by the RSN since 2012 for achieving this goal, separated in three groups: growing the station network, improving earthquake locations, and developing newer ways for disseminating the information generated to society. Since 2012, the network has expanded to a total of 60 permanent seismic stations transmitting to the University of Costa Rica Seismology Laboratory. In 2014, 90 new short-period seismometers have been acquired to provide a new coverage configuration with higher station density in the central part of the country where most of the population and economic activities are concentrated and where we intent to locate more and smaller earthquakes. Also, since 2012 earthquake locations have been improved by setting, automatizing, and integrating earthquake location routines from the SeisComp (GFZ), Earthworm (ISTI), and SeisAn (Univ. Bergen) software packages. We implemented the automatic earthquake triggering and location of SeisComP and Earthworm by acquiring data from a unique waveform buffer that both systems could read. We re-locate the initial locations using SeisAn and report the earthquake locations through an automatized web portal, which have resulted in reducing the time of earthquake notification of a revised location. We also have developed newer ways for disseminating the information generated to Society. The RSN is using Facebook and Twitter to report felt earthquakes and information on Seismology, geological processes, scientific talks, and RSN activities. Additionally, a new website was created in 2012 and an application for smartphones is been released in 2014. We see these new channels as opportunities to engage non-science audiences and encourage the population to participate in reporting seismic observations and thus providing intensity data for felt earthquakes. This approach to science education might transform the view of geological processes for Costa Ricans and might positively alter the current perception towards hazards. The renovation of the RSN is relevant as the knowledge developed could be applied in risk management plans, urban zonation, and emergency response in Costa Rica.

KeyWords: Costa Rica, Earthquake Location, Earthquake Monitoring, Station Coverage, Social Networks.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The Tablón Fault: source of the 2011–2012 Tobosi Earthquake Swarm in Central Costa Rica

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ABSTRACT

Central Costa Rica has a high seismicity rate. This region is part of the Central Costa Rica Deformed Belt (CCRDB), a 100-km broad boundary zone between the Caribbean Plate and the Panama Microplate that connects the Middle American Trench on the Pacific side to the North Panama Deformed Belt on the Caribbean. In this study, we analyzed a portion of the CCRDB, near the town of Tobosi, where an earthquake swarm took place between November of 2011 and February of 2012. We have re-located the best registered earthquakes by the National Seismological Network of Costa Rica (RSN) which is run by both the University of Costa Rica (UCR) and the main Costa Rican Electric Company (ICE). Additionally, we have computed first-motion focal mechanisms for the largest swarm earthquakes and have analyzed the Tectonic Geomorphology of the region by using remote sensing tools and by field trips. We have found that there is a transtension structure near the town of Tobosi composed by at least three faults: the Tobosi, Tablón, and Alumbre faults. This structure is located only 5 km south of the Aguacaliente fault, which caused the deadliest earthquake in Costa Rican history on May 4, 1910 (Ms 6.4). The earthquake locations analyzed are aligned with the Tablón Fault. The events varied in moment magnitude between 2.4 and 3.9 Mw and depths of 1 and 9 km. The largest events were felt mainly in the town of Tobosi and as far as San Jose, the capital city of Costa Rica. Based on earthquake locations, focal mechanisms, and geomorphology we have concluded that the Tablón Fault is a left-lateral strike-slip active fault with a normal component. The study of active faults in Central Costa Rica is significant as it may greatly improve seismic hazards assessment for this region where most of the population and the main economic activities occur.

Key Words: Active Fault, Earthquake Swarm, Costa Rica, Focal Mechanisms.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Static stress state on the Costa Rican Cocos-Caribbean Plate interface and its influence on the asperity distribution of the sesimogenic zone

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ABSTRACT

The fore-arc region along the Central American Subduction Zone shows a series of trench-parallel, positive gravity anomalies with corresponding gravity lows along the trench and toward the coast. These features extend from Guatemala to northern Nicaragua. However, the Costa Rican segment of the fore-arc does not follow this pattern due to the segmentation of the along-trench gravity low, the absence of the coastal low, and the presence of emerged continental mass along the fore-arc gravity high at the Nicoya Peninsula. Geodetic and seismological studies along the Costa Rican Subduction Zone have shown the presence of coupled areas beneath the Nicoya Peninsula prior to the 2012, magnitude 7.6 Mw earthquake. These areas had previously been associated with asperities. Previous publications on asperities have proposed a mechanical model for the generation of asperities based on the structure of the overriding plate above the seismogenic zone in which dense igneous bodies disturb the state of stress on the seismogenic zone and may influence seismogenic processes. Surface geology and gravity data indicate the presence of dense basalt/gabbro crust overlying the seismogenic zone where the asperities may be present. Bouguer anomaly values in this region reach up to 120x10-5 m/s2 which are the highest for the Costa Rican fore-arc. In this work, the state of stress on the Cocos-Caribbean plate interface is modeled from the geometry and mass distribution of a 3D density model of the subduction zone from satellite derived gravity. Results show a spatial correlation between the coupled areas at the Nicoya Peninsula and the presence of stress anomalies on the plate interface. The stress anomalies are calculated for the normal stress on the seismogenic zone and are interpreted as being generated by the dense material which makes up the fore-arc in the area. The dense material of the Nicoya Complex mafic rocks and the topographic load of the peninsula on the seismogenic zone may play a role in the distribution of coupled areas and the seismic behavior of the region.

Key Words: Asperities, Gravity, Subduction, Seismogenic Zone.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The new IRIS Earthquake Browser (Navegador de Terremotos)

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ABSTRACT

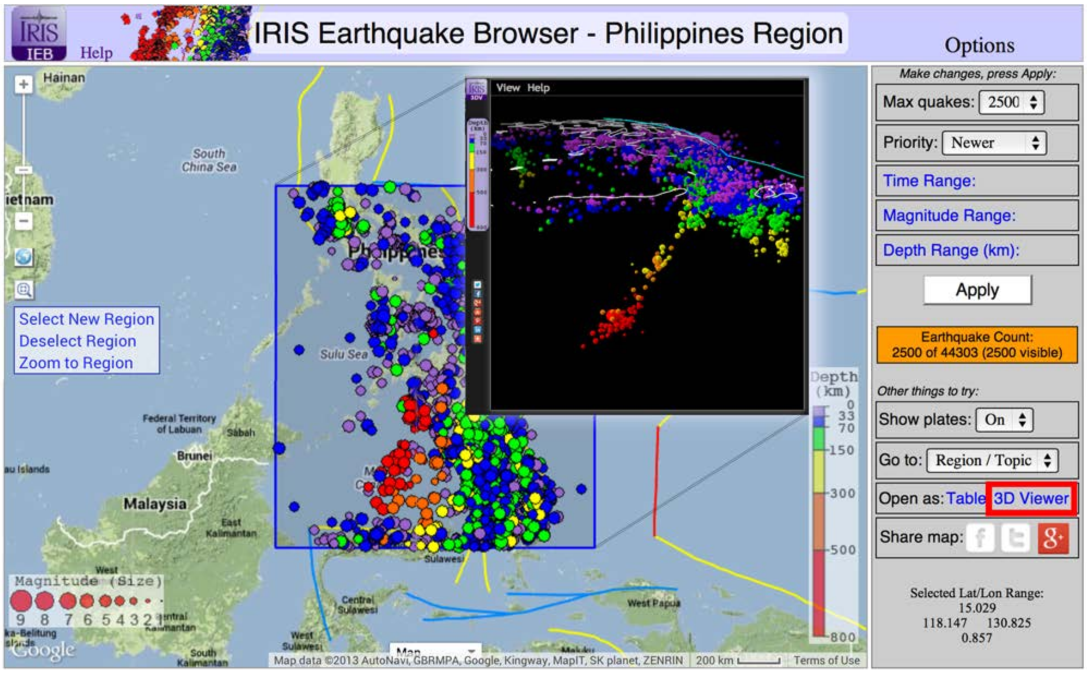
Visualizing thousands of earthquakes, in regions of interest such as the Caribbean, just got faster and easier, including 3D rotation. The IRIS Earthquake Browser (IEB) is a Google map application that maintains an optimized cache of 3.4 million events (from 1970 to 15 minutes ago) and allows up to 5,000 to be quickly selected, rotated and exported without the need for a stand-alone application. See www.iris.edu/ieb

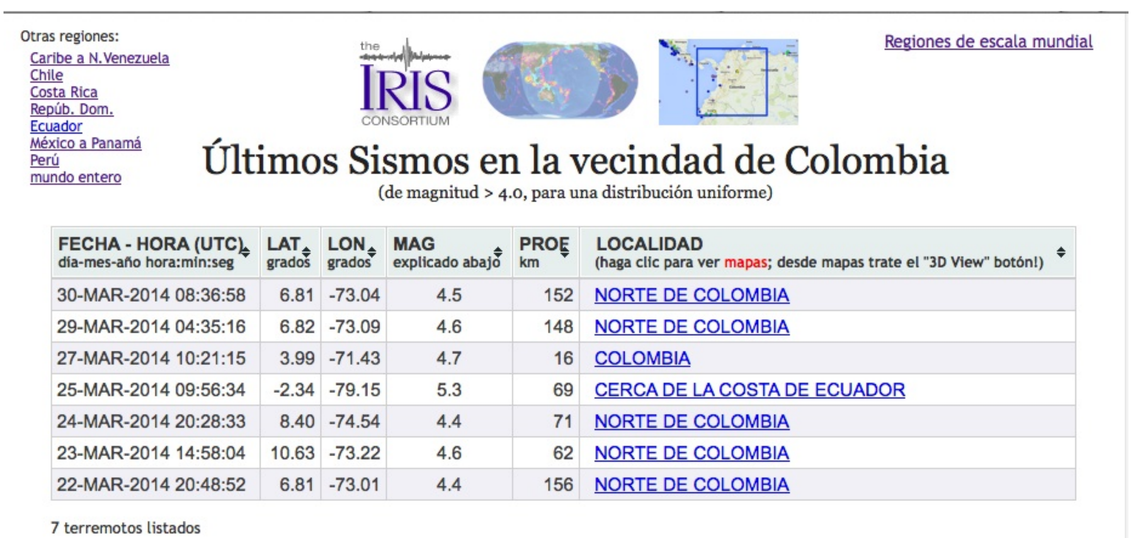
The newest feature is a pseudo-3D viewer, called 3DV, which is both easy-to-use and requires no Java or plugins. View large clusters of quakes in profile, freed from the flat world of the straight-down map. Plate boundaries come to life when viewed at various angles. Relationships and features normally hidden are revealed without the need to download software or import data. It is very responsive, having handled more than 10,000 unique visitors and 16,000 page hits on the day of a recent, large earthquake. IEB maps, including more than 6 parameters that can be set such as time, place, depth and magnitude ranges, can be named, bookmarked and shared via email and social networks. One can send a link to a specific event and its aftershocks complete with a title, just by dragging the IEB URL to an email. Streamlining, extensive help and popup tips make it easier to use than an earlier version.

While targeted at the general public, educators and scientists are also finding it a useful tool. The Help section includes a survey where we are soliciting suggestions for the next version. Spanish language support is being added throughout IEB, and several new, popular pages, in Spanish, direct traffic to IEB in "Spanish mode".

Hay varias formas de apoyo para gente de habla Española, incluso 10 paginas nuevas, muy populares y en español, que dirigen tráfico a IEB. (www.iris.edu/latin_am/)

Palabras clave: historical seismicity, visualization, 3D, web services, HTML5, Google maps.





Otras regiones:
Caribe a N.Venezuela
Chile
Costa Rica
Repúb. Dom.
Ecuador
México a Panamá
Perú
mundo entero

Regiones de escala mundial

the IRIS CONSORTIUM

Últimos Sismos en la vecindad de Colombia
(de magnitud > 4.0, para una distribución uniforme)

FECHA - HORA (UTC) día-mes-año hora:min:seg	LAT grados	LON grados	MAG explicado abajo	PROF km	LOCALIDAD (haga clic para ver mapas; desde mapas trate el "3D View" botón!)
30-MAR-2014 08:36:58	6.81	-73.04	4.5	152	NORTE DE COLOMBIA
29-MAR-2014 04:35:16	6.82	-73.09	4.6	148	NORTE DE COLOMBIA
27-MAR-2014 10:21:15	3.99	-71.43	4.7	16	COLOMBIA
25-MAR-2014 09:56:34	-2.34	-79.15	5.3	69	CERCA DE LA COSTA DE ECUADOR
24-MAR-2014 20:28:33	8.40	-74.54	4.4	71	NORTE DE COLOMBIA
23-MAR-2014 14:58:04	10.63	-73.22	4.6	62	NORTE DE COLOMBIA
22-MAR-2014 20:48:52	6.81	-73.01	4.4	156	NORTE DE COLOMBIA

7 terremotos listados

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic and tsunami monitoring and data sharing in the Caribbean

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ABSTRACT

The circum-Caribbean region has a documented history of large damaging earthquakes and tsunamis that have affected coastal areas, including the events of Jamaica in 1692, the Virgin Islands in 1867, Mona Passage in 1918, the Dominican Republic in 1946 and the most recent the M 7.0 Haiti event which killed more than 250,000 people. There is clear evidence that tsunamis have been triggered by large tsunamigenic earthquakes that deformed the ocean floor around the Caribbean Plate (CP) boundaries. The seismic water waves originating in the prominent fault system around the Puerto Rico Trench are considered to be a near-field hazard for Dominican Republic, Puerto Rico and the Virgin islands because they can reach coastal areas within a few minutes after the earthquake. Sources for regional and teleseismic tsunami-earthquakes have also been identified.

The Caribbean region is monitored jointly by national/regional/local seismic networks, and there are plans to establish a Caribbean Tsunami Warning Center as well as a GPS regionals data center. All Caribbean networks and monitoring institutions are participating in this initiative that consists in real time (RT) earthquake, geodetic and sea level data sharing and the improved warning and data collection center. Currently, more than 100 broad-band seismic, more than 20 sea levels channels and more than 20 GPS high rate stations are being received in the Puerto Rico Seismic Network (PRSN) in real time. These RT streams are used by the EarthWorm/EarlyBird/TideView/PR-DANIS packages to locate and determine the size of events in the Caribbean with magnitudes greater than 4.5 as well as the sea level evaluation, the solutions are provided in a timely framework. This program is also the base of a broader Caribbean Early Warning System (CEWS) with the added capability of estimating strong ground shaking and the tsunami potential in advance.

The CEWS is motivated both by research interests and geodetic, seismic and tsunami hazard monitoring and warning; it will allow to define the structure of the Caribbean region to a high detail, to study properties of the seismic source for intermediate and large events, and to apply this knowledge to procedures of civil protection. To reach its goals, the virtual network has been designed following the highest technical standards: BB sensors, 24 bits A/D converters with 140 dB dynamic range, real-time telemetry and good location. In addition countries are working together to improve the sea level and geodetic monitoring capabilities. All data generated by this virtual network are also shared with international geodetic, seismic and tsunami centers under the UNESCO ICG CARIBE EWS framework.

The need to establish a system of rapid notification for earthquake/tsunami alerting in the Caribbean region has been recognized by the emergency management and scientific community.

Key Words: Tsunami, earthquake, monitoring.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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ECGS session – Studying the Earthquake Cycle Using Geodesy and Seismology

Conveners:
Hector Mora-Paez (Colombian Geological Survey)
<hmora@sgc.gov.co>
Pete LaFemina (Pensilvania State Univ. - USA)
<pcl11@psu.edu>
Rui Manuel da Silva Fernandes (Univ. Beira Interior - Portugal)
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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High resolution geodetic surveys of the present day deformation along the South-Caribbean margin

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ABSTRACT

In early 2003, a joint effort by FUNVISIS and University of Savoie installed 36 new brass benchmarks covering eastern Venezuela in order to estimate the slip along the El Pilar Fault (EPF) system and of other minor active faults, as well as the eventual rotation of tectonic blocks. Most of these benchmarks were planted into stable natural rock outcrops, when possible. Sites were occupied in 2003, 2005 and 2013. More recently, we have targeted western Venezuela, where 19 new brass benchmarks were installed into rock outcrops in late 2011. Late in the same year and in early 2013, 30 sites (including new sites and already existing benchmarks) were measured in the western network. The sites have been measured with dual-frequency GPS and geodetic antennas for at least two 24h sessions with 30s sampling intervals. Data have been analyzed with Bernese 5.2 software using absolute antenna phase center offsets models, as well as IGS -final precise orbits and Earth rotation parameters- and data from nearby cGPS stations. Velocities have been estimated in the IGb08 reference frame and expressed in the SA reference frame using the rotation pole proposed by Altamimi et al. (2012).

Since the data from western Venezuela is still under processing, we shall only present our main results from the eastern array. Horizontal velocities on both sides of the EPF depict an important asymmetry of displacement gradients that suggest a change in elastic properties across the fault. We apply a heterogeneous asymmetric model associated with contrast of material properties on each side of a vertical fault simulating observed velocities with 20 mm/yr of creep at depth, as an alternative focus to homogeneous elastic half-space model (but also considered in this work). Our preferred model indicates a shallow locking depth at 3 km and 0.33K (asymmetric coefficient) indicating that the igneous-metamorphic northern side has rigidity ~2-times higher than the sedimentary southern side. Next, we evaluate a three-dimensional heterogeneous model considering a near-fault low-rigidity tabular zone. The results show a compliant zone in the upper 3 km and from 1-5 km in width with a 30% rigidity reduction with respect to the adjacent rocks. This model shows 12 mm/yr of slip in the upper western segment and 10 mm/yr of displacement in the upper eastern segment; both with lower creep portions (20 mm/yr) separated at 12 km in depth. We apply a third model evaluating a fault-slip distribution from interseismic displacement. Our results show a widespread partially-creeping pattern in the eastern-upper segment. As a last approach we upgrade the displacement simulation method with 2013 data, previously depicted in the Jouanne et al. 2011 work, using non vertical dislocations to simulate the deeper parts of the EPF. From comparisons using Fisher-Snedecor test of variances we select the near-fault low-rigidity as the probabilistic best model, nonetheless a significant slip associated with creeping or partially creeping fault segments is supported for all models. Moreover, the markers observed in the field in the years following the 1997 Mw=6.9 Cariaco earthquake (Audemard, 2006) support this idea. The post-seismic afterslip following the 1997 could help to explain the creep at the eastern segment (eastward of Cariaco Gulf). Furthermore, the localized aseismic displacement pattern along the fault could be related to a low historical seismicity. Our results also show the concentration along the El Pilar Fault of the whole Caribbean-South America relative displacement.

Key Words: El Pilar Fault, GPS, Creep, Compliant zone, Fault zone rheology.

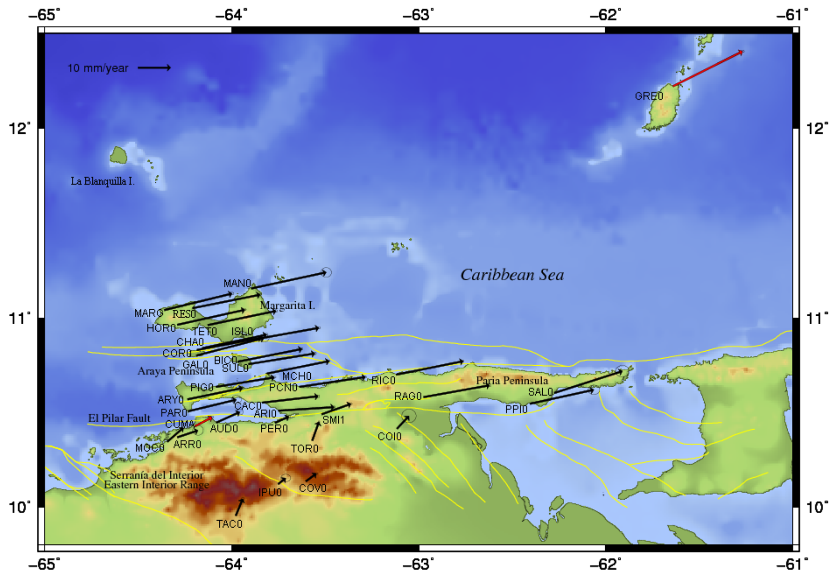

Figure 1. Observed velocities (black arrows) derived from comparison of 2003, 2005 and 2013 GNSS campaign measurements with error ellipses drawn for 66% confidence level and expressed in the SA plate reference frame using the rotation pole proposed by Altamimi et al. (2012). Red vectors correspond to cGPS station. The active faults in northeastern Venezuela are from Audemard et al. (2000). Topography and bathymetry data are from Lindquist et al. (2004).

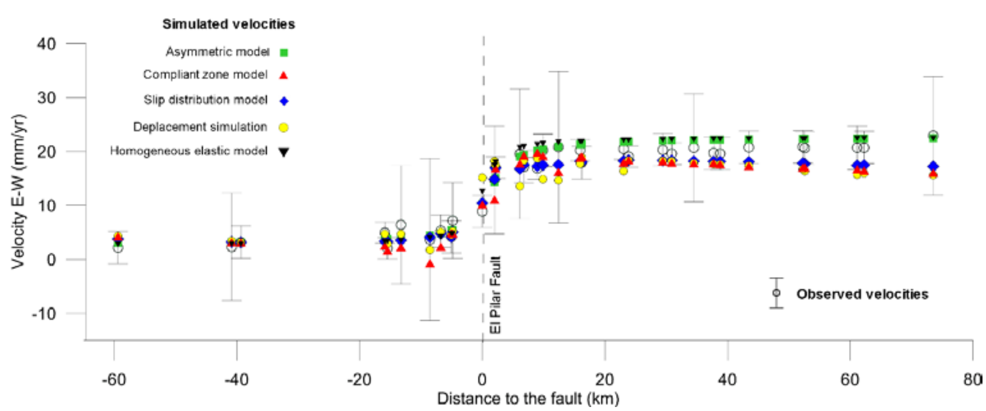

Figure 2. Velocities field in EPF for several models applied in this work. We show E-W observed velocities and simulated velocities from the asymmetric model with 20 mm/y far-field velocity. two segment compliant zone model, two segment slip distribution model, displacement simulation method and homogeneous elastic model.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Caracterización sismotectónica de la región del Valle del Cauca y zonas aledañas a partir de mecanismos focales de terremotos y datos geodésicos

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ABSTRACT

El presente trabajo analiza el mecanismo focal de 49 terremotos con magnitud Mw ≥ 4.8 en la región del Valle del Cauca y zonas aledañas, durante el periodo 1978 – 2010; las soluciones fueron tomadas de los catálogos del ISC y CMT. La profundidad de los eventos se distribuye entre superficiales e intermedios, hasta 215 kilómetros aproximadamente, asociados a la subducción de la placa Nazca, y unos pocos eventos superficiales que corresponden a la actividad de fuentes corticales en la placa continental suramericana. Concordante con el modelo de ambientes de regímenes de esfuerzos asociados con la deformación estática de la placa en subducción, se identifican cuatros ambientes sismotectónicos, que se distinguen por sus propias características sismológicas, tectónicas y régimen de esfuerzos. Para cada ambiente se establecen relaciones entre el escalar de momento sísmico (M0) y la magnitud Mw, y entre Mw con las magnitudes Ms y mb; además, se presenta la tasa de deformación sismotectónica (flujo sísmico de la masa rocosa) para cada uno de estos ambientes. El modelamiento del campo de esfuerzos de Coulomb, realizado usando la inversión de la orientación de los ejes principales de las soluciones del mecanismo focal de esfuerzos y la orientación del esfuerzo máximo de cizalla, muestra que el esfuerzo de cizalla crea una barrera que impide que el esfuerzo compresivo se proyecte al interior del continente en dirección SW-NE, interrumpiéndose en la zona en la fosa Colombo-Ecuatoriana; mientras que el esfuerzo de tensión, aunque también es interrumpido, si logra proyectarse al continente en dirección SE-NW, perpendicular al esfuerzo compresivo.

Palabras Clave: Terremotos, placas tectónicas, mecanismos focales, campo de esfuerzos.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Present-day deformation along the Andean subduction controlled by continental slivers motion

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ABSTRACT

Along the western margin of South America, previous studies from Chileto central Peru have evidenced high interseismic coupling along theplate interface and active backarc shortening in the subandean domain.New geodetic measurements from central Peru to southern Colombia(Nocquet et al., 2014) show a completely different pattern. A segmentof ~1000 km, from north of Lima to central Ecuador accommodates theplate convergence predominantly by creep, with little stressaccumulation along the plate interface, explaining the absence ofgreat earthquakes for the last five centuries. We further show thatcontinental deformation in the Andes from southern Peru to south ofthe Caribbean is controlled by the motion of two large (>1500 km long,300-500 km wide) continental domains wedged between the trench and thestable part of the South America continent, hereafter referred as"slivers": the North Andean Sliver encompassing Ecuador, Colombia andwestern Venezuela (Trenkamp et al. 2002, White et al. 2003) and a new sliver that encompasses Peru that we propose to name "Inca sliver". The sliver boundaries define strips of localized deformation accommodating rapid (4-10 mm/yr) motion where the major crustal earthquakes occur. These results, put in the contextof the whole Andean mountain range, show that motion of continental slivers are found all along the Andes. Indeed, previous studies haveidentified forearc sliver trench-parallel motion in southern Chile(the Chiloé sliver, Wang et al., 2008) and a Central Andes Sliver(Brooks and Bevis, 2003, Metois et al., 2013) with predominantlytrench-normal component. We further show that the sense of trenchparallel motion is controlled by the convergence obliquity, whichchanges with the strike of the trench. Our simple model furtherprovides explanation for prominent features of the Andean margin: theopening Gulf of Guayaquil is located at the convex bend of SouthAmerica where slivers show diverging motion, and crustal thickeningoccurs at the Bolivian Altiplano located at the concave bend of theSouth America.

Key Words: subduction, GPS, earthquake, continental deformation, earthquake cycle, northern Andes.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

Assessing the Seismic Potential of South America with Crustal Deformation Models and Historic Earthquakes

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ABSTRACT

We assess the seismic hazard potential of regions along the 7,500 km long South American (SA) Trench and the active Ecuador-Colombia-Venezuela Plate boundary Zone by examining active tectonic deformation, interplate coupling, crustal strain rates and historic seismicity patterns. The experiments use a continent-wide, two-decade old collection of (pre-Maule) GPS velocity field (1) observations as input to a suite of kinematic models that separately incorporate both fault-block and continuum approaches to quantify tectonic deformation. In parallel, we establish seismic activity rates for 40 seismic source zones all over SA by compiling a catalog of historic earthquakes. We quantify interplate coupling, fault slip-rates, and off-fault rates of strain for the deforming crust to provide geodetic constraints on the long-term patterns of active tectonic deformation. Specifically, we solve for slip and locking patterns along the South American subduction zone to reveal a series of highly coupled patches at offshore locations near the coasts of Ecuador, Colombia, Peru and Chile. These include locked patches that indicate high-friction producing "asperities" along the subduction interface responsible for the 2010 Mw 8.8 Maule and the April 1,2014 Mw 8.2 Iquique earthquakes. Predicted tectonic block motions and fault slip rates reveal that the northern part of South America deforms rapidly, consistent with that expected from a series of multiple tectonic blocks, with the northwestern region behaving as a continuously deforming region with concentrations of elevated strain rates. The fault slip rates and locking patterns predicted by our models reveal that the Oca Ancón-Pilar-Boconó fault system absorbs most of the complex convergence patterns in northeastern Colombia and Venezuela. The Guayaquil-Algeciras and its associated faults in eastern Colombia and Ecuador (e.g., the Romeral and El Tambor fault systems) absorb part of the crustal northeastward transpressional motion due to the Nazca plate convergence. To determine the seismicity rates and equivalent moment release in each seismic region, the spatio-temporal distribution of events were analyzed using information from historical earthquakes. In each source zone region, the moment deficit rates were determined by subtracting the seismic moment release (based on the historical earthquake catalogs) from the calculated tectonic moment accumulation rates. While most of the investigated regions have tectonic moment accumulations that are comparable with seismic moment releases detailed by historical catalogs, we identified zones that have unusually high discrepancies (e.g., the Bucaramanga and Medellín regions) presumably due to the sparse data coverage, inelastic deformation, and complex crust-mantle interactions. Eventually, we use the combined information from moment rates and fault coupling patterns to constrain stochastic seismic hazard models of the region that implement SA trench rupture scenarios. Compared to seismotectonic patterns from other active subduction zones of the world, convergence along the South American trench provides a classic case of a near-orthogonal subduction-orogen system dominated by a periodic, cyclical trench seismic release. In contrast, along the continent's active northern plate boundary zone, multi-directional plate convergence results in strain partitioning, with strain distributed along a broad triangular region, predominantly absorbed as slip distributed along fault systems.

Data is from the Global Strain Rate Model (Kreemer et al., in review) compiled mainly from Nocquet et al. 2014; Metois et al. 2012, 2013; Jouanne at al., 2011; Weber et al., 2001, among others.

KeyWords: Crustal Deformation, GPS, Kinematic Models, Subduction, Plate Boundary Zones, Seismic Hazards.

Geodetic constraints on the present-day kinematics of Colombia, South America

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ABSTRACT

The northwestern part of the South American continent has one of the most complex active tectonic settings in the world. The kinematics of this region are constrained by the relative motion between the stable South America plate and the Nazca, Cocos, and Caribbean plates, minor tectonic units (e.g., North Andes, Panama, and Altiplano blocks), and orogenic areas (e. g., Peru, Puna-Sierras Pampeanas). The relative motion between the major and minor units, have been producing recurrent destructive earthquakes and volcanic eruptions in the recent past.

Here, we discuss the present-day kinematics of this area through a new estimation of the velocity field derived from CORS (Continuously Operating Reference Stations) GNSS (Global Navigation Satellite Systems) observations. In particular, we compute the angular velocities of the major tectonic plates using data from a network of about 100 stations.

The estimated angular velocities are computed with respect to the latest global reference frame, ITRF2008. We compare our estimated angular velocity model with other estimations based on geodetic and geophysical/geological data to show the consistency of the predicted motions. Furthermore, we compare the uncertainty of the solutions by using different error models on the computation of the velocity field. We use the estimated angular velocity solutions to constrain the motions of stations of the Colombian GeoRED network in order to understand the tectonic complexity of this region of the South America continent.

Finally, we present an interpretation of the strain rate field estimated from the same GNSS network. The estimated maps are correlated with geological and geophysical data in order to identify the areas in Colombia with high rates of tectonic deformation.

KeyWords: GNSS, Present-Day Kinematics, Plate Tectonics.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Evaluación de la deformación sismotectónica asociada al sismo de mayo 24, 2008 Quetame, Colombia

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ABSTRACT

Los datos sismológicos y geodésicos suministran información relevante para entender la cinemática y tectónica activa, tanto a nivel interplaca como intraplaca. Entre las posibles alternativas de análisis existentes, las soluciones de los mecanismos focales permiten la determinación de las direcciones en que los esfuerzos tectónicos actúan cuando ocurre la ruptura a lo largo de una falla, mientras que las mediciones GNSS suministran información del campo de velocidad de corteza así como de las tasas de deformación actuales de períodos intersísmicos. De esta manera, la integración de datos sismológicos y de geodesia espacial GNSS se ha convertido en una excelente herramienta para el análisis sismotectónico en diversas regiones del mundo, permitiendo la generación de modelos de deformación. El 24 de Mayo de 2008, en la región de Quetame, Colombia, ocurrió un sismo de magnitud local en la escala de Richter de 5,7 y profundidad superficial de acuerdo con el registro en 21 estaciones de la Red Sismológica Nacional del Servicio Geológico Colombiano, anteriormente INGEOMINAS. El Grupo de Sismología de la Universidad de Harvard estableció para este sismo una magnitud Mw = 5,9. Tomando este sismo, se realizaron algunas aproximaciones relacionadas correspondientes a: 1) cálculo de la magnitud y la profundidad del sismo de Quetame a partir de datos macrosísmicos con el propósito de utilizarlos como test de validación para la determinación de los parámetros del terremoto histórico del 12 de julio de 1785, ocurrido en la misma región central del territorio colombiano; 2) estimación de la deformación sismotectónica producida en la región focal durante la ocurrencia del sismo; 3) análisis geodésico del sismo a partir de datos tomados antes, durante y después de la ocurrencia del sismo. Se presentan los resultados obtenidos y los análisis correspondientes efectuados.

Palabras claves: GNSS, sismo, deformación, sismotectónica.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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THE GNSS GeoRED Project: a tool for understanding the strain rate field and the seismic cycle in Colombia, South America - Current status and challenges

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ABSTRACT

Major advances in space geodetic techniques, as well as the rapid development of GNSS receivers and data transmission capabilities has launched a global revolution in the field of tectonic geodesy. Under this perspective, in order to investigate the current kinematics of northwestern South America, the Colombian Geological Survey initiated in 2007 a research and development project based on space geodesy technology. GeoRED, the acronym for "Geodesia: Red de Estudios de Deformación" was adopted for the project "Implementation of the National GPS/GNSS Network for Geodynamics", which takes a multifaceted approach to cataloging and defining the geodynamics of northwestern South America in order to reduce the risk associated hazards within a wide plate margin deformation zone. The deployment of a high quality GNSS infrastructure will be the fundamental geodetic framework for the study of crustal and atmospheric dynamics of the entire Colombian territory, and at the same time sharing data and research results with neighboring countries. The generation of GNSS time series, estimated using the Hector software provided by SEGAL/Portugal, will give fundamental information for both regional and local geodynamics studies, and will permit the compilation of surface velocity fields that register crustal dynamic behavior, a very important issue for geohazard investigations. It is intended to achieve a greater density of the National GNSS Network in an effort to address solid earth issues such as tectonic plate motion, plate boundary interaction and deformation, including the understanding of earthquake cycle processes, the registration of active fault slip rates, and surface subsidence. Currently, the GeoRED Network is managing 58 continuously operating GPS stations, including: 50 GeoRED GPS/GNSS continuously operating stations; 4 GNSS continuously operating stations provided by the COCONet Project; the Bogotá IGS GPS station (BOGT), installed under the agreement between JPL-NASA and the SGC; the San Andres Island station, installed under the MOU between UCAR and the SGC; the Medellin UNME station provided by the National University, and the CCAN station provided by Cenicaña, a Colombian Sugarcane Research Institute. In addition to the permanent installations, more than 270 GPS campaign sites have been constructed and are being occupied one time per year. Full implementation of 100 permanent installations and 350 campaign sites should be completed by 2016. The Authority of the Panama Canal and the Escuela Politécnica de Quito, Ecuador have also provided data of 4 and 5 GPS/GNSS stations, respectively. The GNSS stations are located on the three major plates that interact within the Wide Plate Margin Deformation Zone including existing GNSS permanent stations at Galapagos and Malpelo Islands on the Nazca Plate, and San Andres Island on the Caribbean plate. The GNSS data are processed using the GIPSY-OASIS II software. The velocity vectors confirm the oblique subduction of the Nazca plate and Carnegie aseismic ridge collision processes at the Colombia-Ecuador trench, which are assumed to be the mechanism for the transpressional deformation and the "escape" of the North Andes block. The northernmost vectors in Colombia are indicative of the ongoing collision of the Panama Arc with northwestern Colombia.

Key words: GNSS, earthquake cycle, velocity field.

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Synchronous Slow Slip Events and Seismic Swarms along the northern Peru-Ecuador subduction zone

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ABSTRACT

We report three Slow Slip Events (SSE) accompanied by intense seismicity that have recently occurred in northern Peru and central Ecuador. The first one took place in 2009 near Bayovar (latitude 6°S) in northern Peru in a context of very weak coupled subduction interface (Conquest et al., 2014). The Bayovar SSE lasted 7 months and involved a maximum trenchward displacement of 14 mm. Modeling of the cumulative surface displacement field shows that a shallow (<25 km depth) patch of the megathrust interface slipped up to 45 mm over a ~90 x 90-km square area, leading to an equivalent moment release of Mw=6.7. During this period an abrupt increment of the seismicity rate occurred in the same area, with four earthquakes of moment magnitude Mw ranging from 5.3 to 6.0. The cumulative seismic moment of these earthquakes accounts for about 30% of the total geodetic moment released. In details, the sequence alternated aseismic and seismic slips. The main events were followed by a sequence of localized aftershocks except an Mw 5.8 earthquakes that occurred in the shallowest part of the subduction interface and was followed by a large aseismic slip. In Ecuador, two SSE occurred at the downdip limit of a locally 50x50km shallow (<15km) locked patch located south of the rupture area of the great 1906 Mw 8.8 Ecuador-Colombia megathrust earthquake (Vallée et al., 2013, Nocquetet al., 2014, Chlieh et al., in press). The first one occurred in August 2010 and lasted a week and involved a 20mm trenchward and 10mm uplift. GPS data reveal that the SSE occurred at a depth of about 10 km, with an equivalent moment magnitude of 6.0–6.3. During the slow slip sequence, seismic data show a sharp increase of the local seismicity, with more than 650 earthquakes detected, among which 50 have a moment magnitude between 1.8 and 4.1. However, the cumulative moment released through earthquakes accounts, at most, for 0.2% of the total moment release estimated from GPS displacements. Moreover, the seismicity observed during the SSE consists in individual events and families of repeating earthquakes, which further evidences that the seismicity is driven by the stress fluctuations (Vallée et al., 2013). That area experienced another SSE, of similar duration but smaller size in January 2013, also synchronous to intense micro-seismicity (Segovia et al., 2013). Unlike most SSE documented in other subduction zones, the northern Peru/Ecuador indicate that both aseismic and seismic slip can co-exist along the plate subduction interfaces, at least at shallow depths. They favor a view of the anatomy of the plate interface consisting of patches with distinct frictional properties, interacting during stress release episodes.

Keywords:subduction, earthquake cycle, Slow Slip Event, Epru, Ecuador, GPS, seismology.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Two earthquake cycle geodynamic control networks in Costa Rica: Nicoya and Osa-Burica peninsulas

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ABSTRACT

The fast changing characteristics of the subducting Cocos plate along the Middle American Trench (MAT) creates a setting with a clear along-trench segmentation of the subduction zone and strong differences in behavior of the seismogenic zone. These differences include: a) frequency of background seismicity; b) occurrence or not of large earthquakes; c) recurrence time of large earthquakes, and d) the strength of coupling. A weak segment in central Costa Rica is bounded by two relatively strong segments capable of producing large earthquakes every 40 to 60 years. These two strong segments include peninsulas that sit right over the seismogenic zone allowing the recording of crustal deformation in the near field. This condition in addition to fast plate convergence and therefore short recurrence interval for large earthquakes makes these peninsulas excellent sites for the operation of earthquake cycle observatories, where seismic and geodetic instrumentation could document crustal deformation over an entire earthquake cycle and hopefully for several earthquakes cycles. One of these, the Nicoya peninsula in NW Costa Rica, was a focus site of the Seismogenic Zone Experiment initiative, of the US-NSF MARGINS program and a seismic and geodetic network successfully captured the preseismic, coseismic and postseismic deformation associated with the Nicoya 2012 Mw=7.6. The other site encompasses Osa and Burica peninsulas in SE Costa Rica, where an aseismic ridge subducts under the Panama microplate. This segment of the MAT had produced large earthquakes in 1856, 1904, 1941 and 1983. Osa and Burica peninsulas lie only 10 to 30 km from the trench, the angle of the plate interface is shallower than under Nicoya and therefore possesses the potential to obtained, though seismic and geodetic monitoring, a very detailed map of heterogeneities along the seismogenic zone and study the roll of upper plate deformation. With that purpose, OVSICORI-UNA is currently building up a dense geodynamic monitoring network on and around these peninsulas. We will describe the geometries, characteristics and results obtained from these networks.

Key Words: subduction, crustal deformation, earthquakes, monitoring.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Results from the National Continuous GPS Network in Ecuador

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ABSTRACT

We present an updated velocity field for Ecuador based on the network developed by the Instituto Geofisico de la Escuela Politecnica Nacional, Quito, Ecuador. The network now includes twenty years of measurements. The processing was made using the GAMIT/GLOBK software and uses a classical two-step approach for geodynamics: loosely daily solutions are first obtained. A 7-parameters transformation is then used to derive time series expressed with respect to the ITRF2008 reference frame. The velocity field confirms previous results coming from mixed campaigns and continuous measurements (Nocquet et al., 2014, Chlieh et al., in press): the overall velocity field is dominated by the northeastward motion of the North Andean Sliver at ~8-10mm/yr in central and northern Ecuador, while south of the Guayaquil Gulf and in the southern Ecuadorian Andes, 4-5 mm/yr southeastward motion is consistent with the Inca sliver motion further extending in Peru. Along the coast, high coupling is found in northern Ecuador, contrasting with weak to no coupling in southern Ecuador. Previous solutions (Nocquet et al., 2014 and Cisneros et al., in preparation) included campaign data spanning the 1994-2011 time window. Because the Ecuadorian coast experienced several transient episodes of aseismic slip (SSE) in the past years (Mothes et al., 2013, Vallée et al., 2013), we use our new solution to test the hypothesis of constant velocities by comparing 1994-2011 velocities to velocities from the 2010-2014 period. Discrepancy will be analyzed and discussed in terms of magnitude and frequency of possible past SSE. Secondly, we will discuss the ability to derive vertical rates and how their use might improve interseismic coupling along the subduction interface.

Key Words: GPS, velocity field.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Deformación basada en datos de GPS en Colombia

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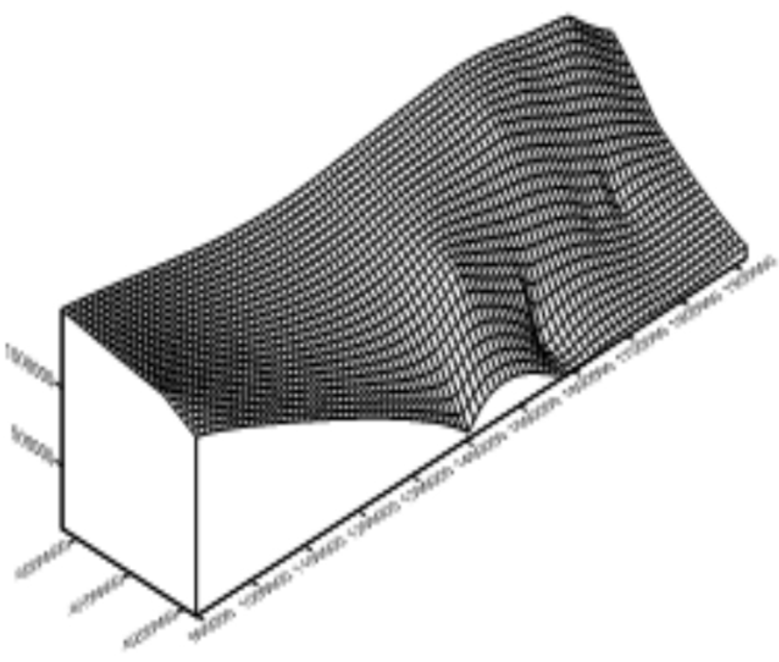
ABSTRACT

Tomando como base las coordenadas y velocidades de desplazamiento de las estaciones permanentes en Colombia de la red Sirgas- Magna eco, se calculó la deformación del área de estudio, para obtener este resultado se usaron los siguientes métodos: el método del vecino más cercano, el método de mínimos cuadrados y el método de la distancia ponderada, el resultado final del estudio genero mapas de máxima y mínima elongación, vectores de rotación que indican la dirección con respecto al norte de las deformaciones y la dilatación que presenta las deformaciones.

Palabras Clave: Esfuerzo, Deformación Tectónica, Vectores de Rotación



Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Determination of Earthquake Sources using GNSS Seismology

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ABSTRACT

The use of GNSS (Global Navigation Satellite Systems) observations, in particular GPS, to sense earthquakes displacements in real-time (to be applied into early warning systems) or post-processing (to be applied in the characterization of large earthquakes) has known significant developments in the last years. This approach, known as GNSS Seismology, is able to complement other geophysical sensors (namely seismometers), due to its high precision, sensitivity to the longest-period bands, and capability to measure absolute displacements.

The spatial pattern, magnitude, and timing of permanent displacement detected at GNSS stations can be inverted for earthquake sources in order to predict the 3D displacement field. In addition, the capabilities have been also demonstrated to integrate GNSS and seismic data to invert for earthquake sources.

In this paper, we discuss the current state-of-art to compute co-seismic displacements using GNSS observations, in particular using the Precise Point Positioning (PPP) technique, which can provide "absolute" co-seismic displacements with respect to a global reference frame using a single GNSS receiver. Such an approach requires the use of consistent satellite orbits and clocks, whose accurate estimation in real-time has greatly improved in recent years.

We present several cases that demonstrate the effectiveness of using GNSS solutions to estimate the surface displacements due to large earthquakes. The best example of the potentiality of the GNSS Seismology is the modeling of the 2011 March 11 Mw 9.0 Tohoku-Oki earthquake, Japan. The large number and distribution of GNSS stations in Japan permitted inversion of the estimated displacement field for fault slip distribution and moment magnitude. In addition, we also show computed displacements for recent earthquakes in South America, namely the 2014 April 1 Mw 8.2 Iquique, Chile and the 2013 February 9 Mw 6.9 Nariño, Colombia. (1) This last earthquake is also used to demonstrate the need for good network coverage in order to properly sense the displacements using GNSS.

KeyWords: GNSS Seismology.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Una red gravimétrica como herramienta de apoyo a la sismología

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ABSTRACT

Desde el año 2011 el Servicio Geológico Colombiano en el desarrollo del proyecto "Manual metodológico para la adquisición de datos gravimétricos terrestres" y con acompañamiento del proyecto GEORED, se inició la adquisición de lecturas de gravedad en algunas estaciones de la red pasiva (proceso aún en marcha). Esta información combinada con la base de datos gravimétricos terrestres de la institución y estaciones de la red gravimétrica oficial, proporcionan una fuente de información geocientífica que soporta y enriquece distintos estudios e investigaciones en las geociencias del país. Las mediciones del campo gravedad permiten conocer las anomalías gravitatorias, es decir, las diferencias entre los valores observados en superficie y lo teóricos, obtenidos a partir de un modelo de referencia. Considerando que las anomalías tienen una relación directa con la distribución de masas, un suficiente número de mediciones gravimétricas en un área determinada permite calcular la distribución de masas o densidades en dicha zona. En Sismología, los estudios tomográficos (de estructura de velocidad del subsuelo) a escala cortical se realizan con datos de estaciones sismológicas y son complementados con datos geofísicos, en donde la información de una red gravimétrica proporciona valores de densidad de alta calidad. Así, una red gravimétrica, adicional al cumplimiento de su función como un marco de referencia para la Geodesia, tiene múltiples aplicaciones en la Geofísica y demás ramas de la Geociencias.

En el caso de estudio del Volcán Azufral de Pasto el cual cuenta con una red de estaciones GNSS, Gravimétricas y sismológicas se muestra la aplicación de la geodesia en el campo de la sismología, utilizando la red gravimétrica como un insumo al estudio espacial de los eventos sísmicos.

Esta área de estudio es una analogía micro del cubrimiento trazado por GEORED para el territorio colombiano. En esta región piloto se realizó una relocalización de eventos sísmicos utilizando 5 estaciones de la red gravimétrica oficial (red local gravimétrica para el volcán), 307 estaciones gravimétricas de observación simple (proyecto Geotermia SGC) y más de 300 eventos sísmicos registrados desde 1993 (RSNC) y 10 sismos registrados por la red sismológica local.

Mejorar en la calidad de la localización de eventos sísmicos permite asociarlos a fenómenos espacio-temporales, de acuerdo a los comportamientos y dinámicas asociadas a los diferentes factores (fallas, intrusiones, volcanismo, esfuerzos, ciclos etc.) de su nueva localización y periodicidad.

Palabras clave: Geodesia, gravimetría, sismología, modelo de velocidad.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

ESGA –Earth Structure - General Aspects

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Crustal structure of the Craton San Francisco, Brazil derived from receiver functions

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ABSTRACT

Crustal thicknesses and Vp/Vs ratios were estimated beneath Craton San Francisco, Brazil, with receiver function analysis from broadband stations. Crustal thicknesses and Vp/Vs ratios were estimated with the whole seismogram stacking technique of Zhu & Kanamori (2000), as well as a newly developed slant stacking which identifies each of the converted Ps, Ppps and Ppss phases separately. Our preliminary results indicate crustal thicknesses from 36 to 44 km and Vp/Vs ratios about 1.70. The results showed the thinning crustal at the central of Sao Francisco.

KeyWords: Tectonophysics, Crustal Structure.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Abrupt changes in Moho depth beneath the Central Andean plateau inferred from apparent Pn phase velocities

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ABSTRACT

The Central Andean Plateau contains some of the thickest crust on Earth with an average elevation of 3:8 km and from west to east consists of the Western Cordillera, Altiplano and Eastern Cordillera. We are exploring the use of passive source seismic data from the CAUGHT seismic experiment to constrain crustal thickness and apparent Pn velocities in the Central Andean Plateau. We follow the method often used for wide-angle seismic data as outlined by Zelt and Smith [1992] for a 2D crustal thickness and Pn velocity using crustal earthquakes as sources. We obtained a 2D crustal model beneath the central Andean plateau using apparent Pn phase velocities recorded along an NE-SW transect with ~ 25 km station spacing and a length of ~ 500 km. The model is characterized by little variation in crustal thickness between 50 and 60 km from beneath the Western Cordillera and Altiplano and sharp bend Moho near the boundary of the Altiplano and Eastern Cordillera. Our results on crustal thickness match with crustal thicknesses determined from receiver function analysis along the same transect and from use P teleseismic delay time to perform tomographic inversion. The thinner crust under the Eastern Cordillera is consistent with the increase in average surface elevation suggesting that this region may not be isostatic compensation entirely in the crust.

KeyWords: Crust, structural, Pn apparent velocities.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Characterization and identification of the Meta fault (Colombia) from the distribution of resistivities

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ABSTRACT

We performed 34 Vertical electrical sounding (VES) between the Vichada and Casanare states, where to purchase Schlumberger arrangement was used with the maximum aperture AB of 600m and MN between 1m to 150m, height above sea level in the region averaged 75m; 11 Profiles were composed of three VES (on average) each, the separation between VES and the average distance between points was 417m and 6.25 km respectively; acquisition was carried out in late 2011 and early 2012; acquired resistivity values were in the range of 100 Ωm to 10.000 Ωm. The apparent resistivity data were processed using the software IPI2Win®, on the profiles that are made can be seen the possible layers that make up the field with a maximum depth of research was 200m. Was found in the north of the study area the presence of high resistivity values (5000Ωm - 10000Ωm) compared to those found south of the area.

KeyWords: Vertical electrical sounding, apparent resistivity, profiles, Meta fault.

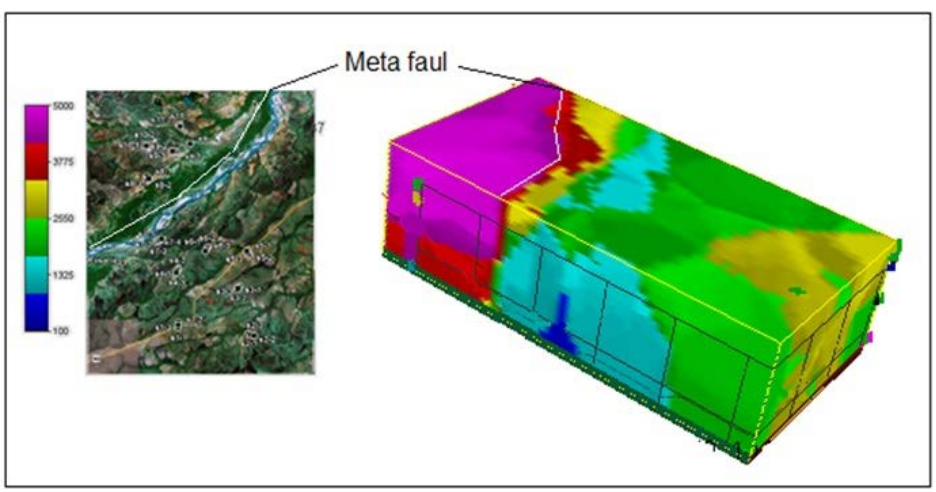

Figure 1. Map and Volume resistivity in the area of interest (Vichada-Casanare states), the abrupt change in resistivity is observed in the Meta fault (white line).

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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New contributions to the knowledge of the Magdalena Submarine Fan (Colombian Caribbean) from seismic and high resolution bathymetric data

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ABSTRACT

From the analysis of high resolution bathymetric, backscatter and seismic data recently acquired in the central sector of the Colombian Caribbean, we present new contributions to knowledge of the morphology and internal architecture of the Magdalena Submarine Fan (MSF). Previous studies have focused on describing the morphological and seismic characteristics of the upper and middle parts of the fan.

The results presented here include a detailed characterization of the upper, middle and lower parts of this active continental margin-related fan, highlighting their features and geomorphic processes of erosion/sedimentation. Also, we determined accurately the MSF outermost limit in the deep part of the Colombia Basin. Finally, information from several authors on the geomorphology and internal structure of other submarine fans around the world developed in both passive and active continental margins was collected in order to make a comparison with our findings and establish differences and similarities in the fan development.

Key Words: Magdalena submarine fan, Morphology, Internal architecture, Colombian Caribbean, Active continental margin.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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First insights into the crustal structure of the Merida Andes, Venezuela, along the southern profile

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ABSTRACT

The Merida Andes orogen is the topographic prolongation of the Eastern Coordillera of The Colombian Andes. Several works and interpretations have been done regarding crustal structure of Merida Andes due to the important role it has played for the development of hydrocarbon basins associated at both flanks. Most of the authors agree that the uplift of Merida Andes in the Miocene is contemporary with the one of Eastern Colombian Cordillera, and that both chains are subjected to strain partition process. Between February 18th and March 11th 2014, a deep seismic profiling campaign was carried out on three profiles perpendicular to the structure of Merida Andes in western Venezuela, in order to obtain information on crustal structure, as well as a better understanding of the dynamics in this complicated tectonic region. The seismic data was acquired along three principal deep seismic profiles called by their location as: North Andes, Central Andes and South Andes. This work is focused on the structures of South Andes profile which is about 450 km in length, the northern end is located west to Maracaibo Lake near Catatumbo River, crossing perpendicularly the Andes axis, and the southern end is located in Elorza town. The seismic data acquisition was made in two phases, in the first one; six shots of 170 - 1370 kg of explosives (proportion of Pentolite & Anfo) were recorded by 567 seismometers (TEXAN) along the profile with spacing of approximately 500 m between each one within chain, and 1 km spacing in the basins. In addition, 300 seismometers with 1 km spacing were installed along three profiles between 120 – 150 km length, running perpendicular to South Andes profile in order to obtain crustal information along the strike of the Andes. In the second phase, eight shots were done using 110 – 500 kg of explosives and recorded by 918 seismometers installed with a different geometry. In the chain a 100 – 200 m of spacing was used, while in the adjacent basins spacing was 1 km between seismometers. In the early stage of data conversion and data processing, a good level of recorded energy is observed.

Key words: crustal, structure, Merida Andes, Venezuela.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Relación entre estructura del subsuelo y movimiento sísmico. El caso de la ciudad de Concepción, chile

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ABSTRACT

Chile es un país con una alta sismicidad. En el sur de ese país ocurrió el sismo más grande que ha sido registrado en la historia (22 de mayo de 1960, Mw 9.5). Recientemente, en una zona ligeramente al norte de ese evento ocurrió nuevamente un gran terremoto el 27 de febrero de 2010 (Mw 8.8). El epicentro se localizó 150 km al noroeste de la ciudad de Concepción. El foco tuvo una profundidad de 30 km. Este evento causó daños significativos en gran parte del país, desde la región metropolitana hasta la Araucanía. En la ciudad de Concepción, la segunda ciudad más poblada de Chile, la intensidad de Mercalli alcanzó IX. Hubo numerosos daños en estructuras y se colapsó una torre habitacional. Es claro que la magnitud del evento y su cercanía a la ciudad fueron factores importantes en la destrucción observada en Concepción. Sin embargo, en la ciudad, la distribución de daños fue sumamente irregular y no parece estar relacionada de forma simple con la calidad de las construcciones. Por ello, es posible que una parte de los efectos observados se deban a la amplificación del movimiento sísmico por la estructura irregular del subsuelo en la zona; los efectos de sitio.

En este trabajo abordamos la relación entre la estructura geológica de Concepción y el movimiento sísmico. Lamentablemente, el evento de 2010 fue registrado únicamente por dos estaciones sismológicas en la zona urbana de Concepción. Por ello, recurrimos a información geológica y a mediciones geofísicas para caracterizar la estructura del valle y la amplificación local. Mediciones detalladas de gravimetría permiten estimar la profundidad del basamento rocoso en la zona central de la ciudad. Por otra parte, mediciones de ruido sísmico fueron utilizadas para estimar los efectos de sitio mediante cocientes H/V. Finalmente, algunas mediciones de ruido sísmico con arreglos de estaciones permiten estimar la velocidad de ondas de cortante en los sedimentos del valle y en el basamento rocoso. Los resultados muestran una excelente correlación entre forma de la cuenca y periodo dominante. Los valores de amplificación estimados muestran un buen acuerdo con la estimación del contraste de impedancia entre sedimentos y basamento. Esto sugiere que, en el caso de la ciudad de Concepción, los efectos de sitio están controlados por el contraste entre depósitos sedimentarios relativamente homogéneos y el basamento. La forma de la interfase en la base de los sedimentos puede influir considerablemente en la respuesta sísmica. Nuestros resultados son un primer paso hacia la construcción de un modelo 3D de la cuenca de Concepción.

PalabrasClave: Amplificación sísmica; Efectos de sitio; Estructura geológica.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Borehole Climatology – Principles, Applications and Results

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ABSTRACT

Shallow subsurface is a valuable source of information how to reconstruct recent climate history. By monitoring and analyzing temperature field down to several tens or hundreds meters we can trace what has happened on surface hundreds or thousands years ago. Long term climate changes accompanied by variations in the mean annual air temperature also govern the soil temperature, the time variations of which propagate downwards with attenuated amplitude and delayed phase. Characteristic examples of extracted climate recollections from various holes will be demonstrated as examples and discussed. Under favorable conditions climate "signature" of the major climate events, such as the Little Climate Optimum and the Little Ice Age can be recognized, nowadays "stored" some 400 700 m below the surface. Clear traces of recent global warming are generally common in many boreholes, evidencing a temperature rise of 1 2 K since the beginning of the 20th century. Certain geographical pattern of regions exists, where the recent warming rate has been more pronounced or where it has been relatively weaker, suggesting a potential impact of human activities. The inferred ground surface temperature histories were complemented with a detailed analysis of air temperature records from selected European meteorological stations, used also to test and calibrate the climate reconstruction method.

To better understand the mechanism of the downward penetration of the surface climate signal, we have been running a "geothermal observatory" by monitoring air, surface and soil temperatures within and below the near surface "active" layer, i.e. the zone where temperature field is affected by surface annual cycle (uppermost 40-50 m). Results of almost 20 year-long observation experiment were completed with additional experimental data confirming the significant role of the surface (vegetation) cover as well as the effect of meteorological phenomena such as rain fall, snow cover, winter freezing and thawing. Major outcome of these studies confirms a certain possibility to quantitatively describe the present (climate) warming and assess its magnitude.

KeyWords: climate change, recent warming, borehole logging, underground temperature, geothermal gradient.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Atenuación y dispersión de ondas acústicas en medios porosos saturados con fluidos no viscosos inmiscibles

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ABSTRACT

Este artículo reporta los resultados suministrados por la propagación de ondas elásticas en medios porosos, simulada mediante una generalización de las ecuaciones de Biot las cuales describen el comportamiento de las ondas acústicas y de corte. Estas ecuaciones fueron discretizadas mediante el método de diferencias finitas y los algoritmos codificados en C++/MPICH. Los algoritmos se aplicaron en modelos porosos homogéneos isotrópicos total o parcialmente saturados con dos fluidos no miscibles, como agua y gas, con el fin de observar cómo la porosidad y la saturación atenúan la amplitud y cambia la fase en las ondas acústicas. Para determinar independientemente los efectos de la porosidad y la saturación en la atenuación de la amplitud y el cambio de fase de las ondas acústicas, se realizaron dos clases de simulaciones separadas. En el primer caso, los modelos estaban saturados completamente cada uno con diferente porosidad mientras que en el segundo caso, los modelos tenían igual porosidad y distinta saturación. La onda que se propaga se observó en diferentes puntos en profundidad y las ondas registradas se analizaron espectralmente. La salida proporcionada por la simulación en los modelos completamente saturados, señaló una relación en la que la velocidad de la onda acústica disminuye no linealmente con la porosidad. Además, que la frecuencia asociada a la mayor amplitud del espectro se desplaza a frecuencias más bajas con la profundidad, y que la fase de la onda cambia linealmente con la frecuencia siendo esta tasa de cambio mayor con la profundidad. Se estableció una relación aproximadamente lineal entre la amplitud máxima y su frecuencia asociada y, finalmente, se observó que la atenuación se vuelve más fuerte cuando aumenta la porosidad y este comportamiento se refuerza cuando la frecuencia aumenta.

PalabrasClave: Teoría de Biot, atenuación, saturación, porosidad.

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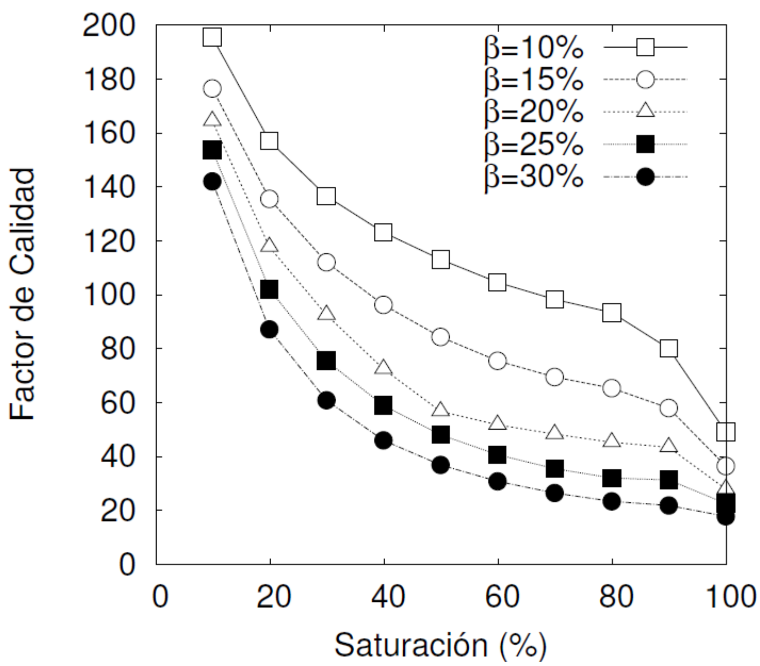

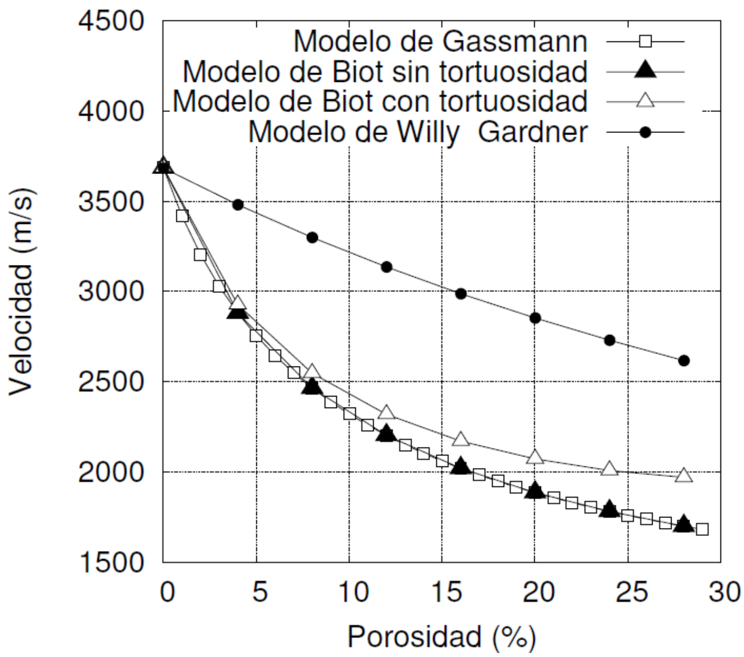

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Modelado de atenuación y dispersión de ondas acústicas en medios porosos saturados con fluidos viscosos inmiscibles

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ABSTRACT

Se realizó la simulación de la propagación de ondas elásticas en medios porosos, a partir de la generalización de las ecuaciones de Biot que permiten describir y modelar la propagación de las ondas compresionales y transversales. Se desacoplaron los dos campos de onda y se trabajaron las 9 ecuaciones diferenciales acopladas utilizando el método de diferencias finitas para desarrollar un algoritmo basado en el lenguaje c++ y Mpich para programación en paralelo. Se utilizó como modelo un medio con porosidad y saturación constante en todo su volumen, para observar cómo la viscosidad atenúa la amplitud y cambia la fase en las ondas acústicas. Para ello se colocaron puntos de registro a diferentes profundidades con el objetivo de registrar el campo de onda P y así poder hacer el respectivo análisis del espectro de amplitud y de fase de la señal. Los resultados permitieron determinar que la viscosidad no influye en la velocidad de la onda acústica, que la atenuación se hace menor al aumentar la viscosidad mientras que el ancho de banda sísmico se hace más estrecho cuando la viscosidad disminuye. El comportamiento de la atenuación resalta que su determinación permite discernir un fluido según su viscosidad y por ende permitiría diferenciar un reservorio saturado con agua de otro con hidrocarburo.

PalabrasClave: Factor de calidad, viscosidad, Teoría de Biot.

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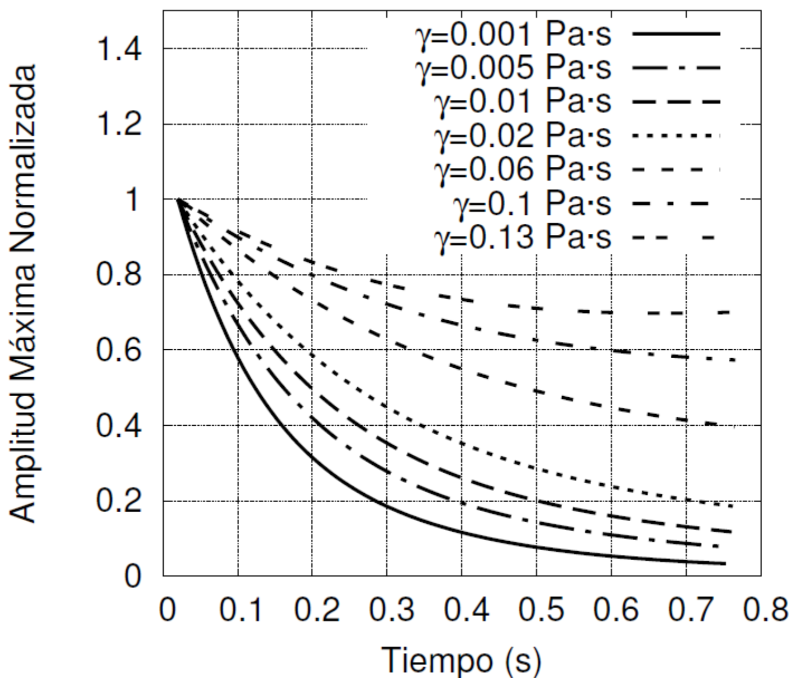

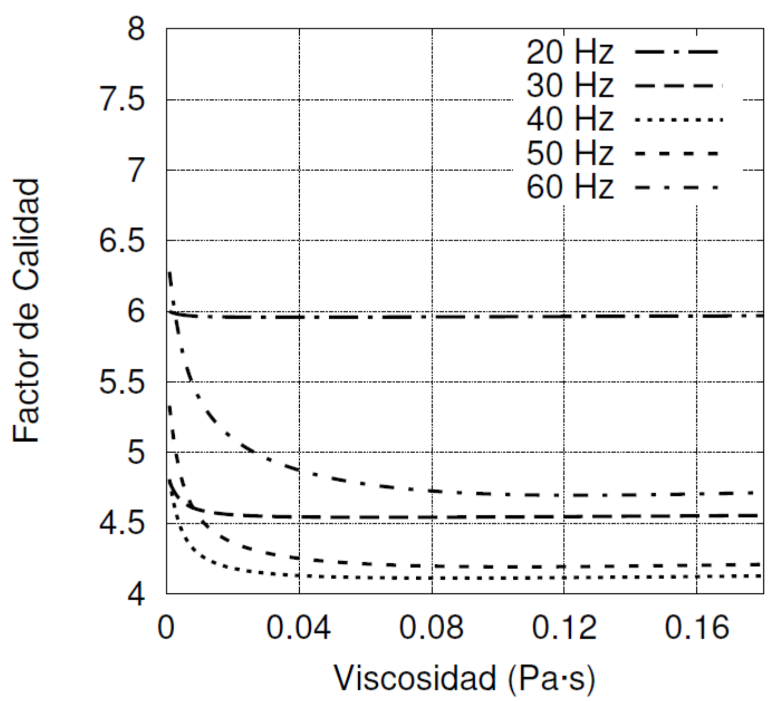

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Application of MEE algorithm for medium-term earthquake forecast in the Koyna-Warna region

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ABSTRACT

This report was the first to use the MEE (Map of Expected Earthquakes) medium-term earthquake prediction algorithm to develop maps of expected earthquakes in a classical area with a transient seismic regime, namely the Koyna-Warna reservoir site.

The local earthquake catalogue for this area, covering the period of time from 1996 to 2012 (approximately 17 years) and including 4,500 earthquakes with M_L=0-6.5 magnitudes that occurred in the depth range of H=0-20 km, was used. Linear dimensions of the seismic area are 40×60 km. Approximately half of all earthquakes included in the catalogue are the aftershocks of earthquakes with $M_L \geq 4$. They were not excluded from the catalogue when calculating time and space distributions of predictor parameters and expected earthquake map values. Magnitude M_c=2.1 selected as a representative magnitude. A standard set of seismic predictor parameters used for expected earthquake mapping of seismically active regions with pronounced tectonic activity was used for the Koyna-Warna area: *b*-value of the magnitude-frequency relationship, number of earthquakes in the form of relative seismic quiescences and in the form of seismicity activations, released seismic energy in the form of energy quiescences *and in the form of energy activations*, and density of seismogenic ruptures.

Earthquakes with $M_L \geq 4.0$ were selected as targets for prediction. In 1996-2012, 26 such earthquakes and their groups occurred in the area under study. Among these earthquakes, four groups of events that include earthquakes with $5.0 \leq M_L < 5.5$ were the largest. Seven groups include earthquakes with $4.5 \leq M_L < 5.0$. Unconditional probability of a major earthquake in the grid cell was estimated as $P(D_1)$=0.1698.

A series of 42 expected earthquake maps was developed for the Koyna-Warna area, from 1 July 2002 till 1 October 2012, with 3-month step and 2-year prediction periods for each map. The findings of using the MEE algorithm in a classical area with a transient seismic regime for the first time were very encouraging. They showed that its prediction reliability was quite high and equal to *J*MEE=2.76. Zones with conditional probability levels $P(D_1|K) \geq 90\%$ experienced 56.3% of all earthquakes with $M_L \geq 4.0$. The alarm area was 20.4±8.4% of the total area of observations.

The prediction can be verified in real time using the most recent expected earthquake map in the series for the period from 1 October 2012 to 30 September 2014.

Therefore, integral predictive reliability estimates obtained when the MEE algorithm was used for the Koyna-Warna reservoir site are close to the average values of these parameters for all previous seismically active regions. These findings may be considered proof of the flexibility of the proposed algorithm.

This work was supported by the project "Transitional geophysical processes in the areas of natural and technogenic influences: field observations and physical modeling" in the Integrated Long Term Program (ILTP) of cooperation in science, technology and innovation between the Government of the Russian Federation and the Government of the Republic of India.

Key Words: forecast, Koyna-Warna region.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Determination of the stress field in an oil production area by mean of analysis of ambient noise

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ABSTRACT

The fracking process in a well-hole in production of oil or/and gas, pursue the increment of its production and had been wide known in the hydrocarbon industry. There is a direct relation between the direction through the fracture is propagate and the distribution of stress field present in the area. Studies had been done under the use of VSP techniques in order to achieve this task. However this problem could be studied in the surface by mean the localization of micro-seisms which took place after the fracking and mapping them during the relaxing time and the accommodation of the stress. According to this, the problem had been focus on filtering the surface noise sources and how the waves are attenuated in the path to the surface. A velocities model had been taken as a starting point to be able to locate these events. The acquired data used come from 3 hours records of seismic ambient noise in 23 3-component stations, deployed in the field in a linear array over a well-hole during its fracking procedure. Collecting 204 CGF files (728 Megabytes of information). Due limitations in the record system and in order to be able to process the signals it had been necessary to make an edition work on them. Mainly related with removing of steps, over-scaled amplitudes and anomalous trends in the records.

After editing the signals it was possible to make an analysis of the site effect for each station. This by mean calculation of the spectral ratio which allows determinate the influence of superficial waves over the body waves for the records. Then a 1D inversion was done resulting in the characterization of the elastic parameters. Using this information it is possible to determinate if a transformation exist in these elastic parameters or the stress field after the fracking in the area.

Key Words: stress field, oil production area, ambient noise.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Study of the Montes Claros Seismogenic Fault, in the Sao Francisco craton, Brazil, with correlations of P- and S-wave phases

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ABSTRACT

The recent seismic activity in the small city of Montes Claros, located in Northern Minas Gerais state, started with a magnitude 4.0 earthquake in May 19, 2012. Since then, tens of events have been recorded by the recently installed local network, in cooperation between the universities of Brasilia and Sao Paulo.

Initially, the project focused in a small sequence of eight events occurred in December 19 and 20, 2012. These events were identified and picked using the SAC software (Tapley & Tull, 1992). A visual cross-correlation process was carried out in an attempt to reduce the relative pick errors both of the P and S phases. The absolute location of the hypocenters was performed using the Hypocenter program (Lienert & Havskov, 1995). Comparing the results between non-correlated and correlated data, a significant improvement was noticed in the second group because the hypocenters were more consistent with a plane.

Once this first analysis has been completed, a 3-component cross-correlation program was developed using Python language and the ObsPy (Beyreuther et al., 2010), Matplotlib (Hunter, 2007) e NumPy (Jones et al, 2001) packages. The algorithm can perform the cross-correlation using the standard technique, which consists in using a single event as reference to correct all the others. Nevertheless, it doesn't lead to good results every time because, seldom, all events have a similar waveform with the reference. Trying to minimize this problem, a new technique was created. This other algorithm starts searching for the most similar event to be correlated with the reference and, then, corrects it. The idea is that, once an event has already been corrected, it also can be used as a new reference to correct others. So, the next event to be correlated will be the most similar with initial reference or with any event already corrected. This process continues until all events have been correlated. This technique was called “branched correlation” and has already been applied with good results in the first study of the 2012-2013 Montes Claros sequence (Hans et al., 2014).

The double-difference location algorithm, implemented in the HypoDD code (Waldhauser et al., 2000), was used to relocate the events, improving their relative locations and better defining the seismogenic fault plane. The comparison between the results before and after the two kinds of cross-correlation is shown in figure 1. The events occur in a single fault plane with NNW strike and ENE dip. The aftershocks are distributed around a “gap” circular area with a diameter of about 1.5 km; the central aseismic area probably denotes the stress-released rupture of the mainshock with magnitude 4.0.

Lastly, the focal mechanism for two well recorded events was studied using FOCMEC (Snoke et al., 1984) and the results were very consistent with the plane determined using the swarm relocated with the “branch-correlated” method.

KeyWords: Sao Francisco craton, cross-correlation, hypocentral location.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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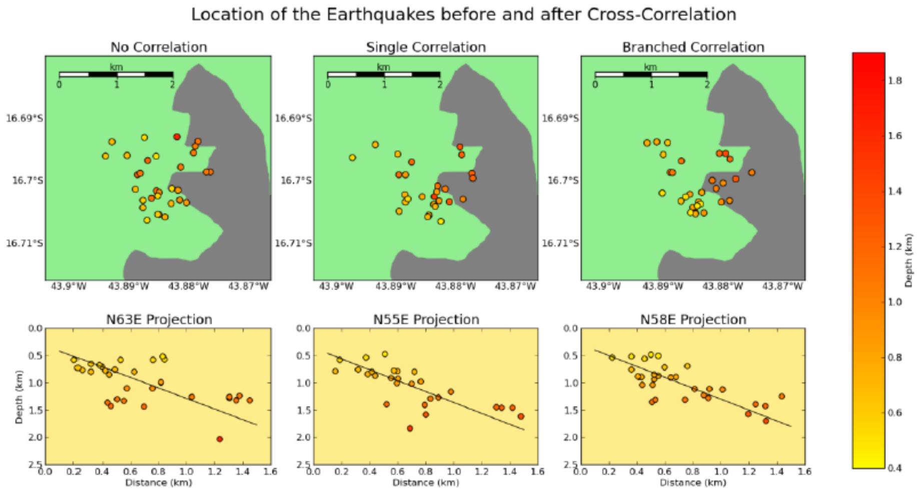

Figure 1: Left map shows the hypocenters located without any kind of cross-correlation. In the figure below, a lateral projection of the events was made in the direction of the dip. Central map shows the events located with the traditional cross-correlation process. In the right map, the correlation was performed using "branched correlation". Color scale denotes event depth.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Máximos PGA, PGV y PGD en el plano horizontal

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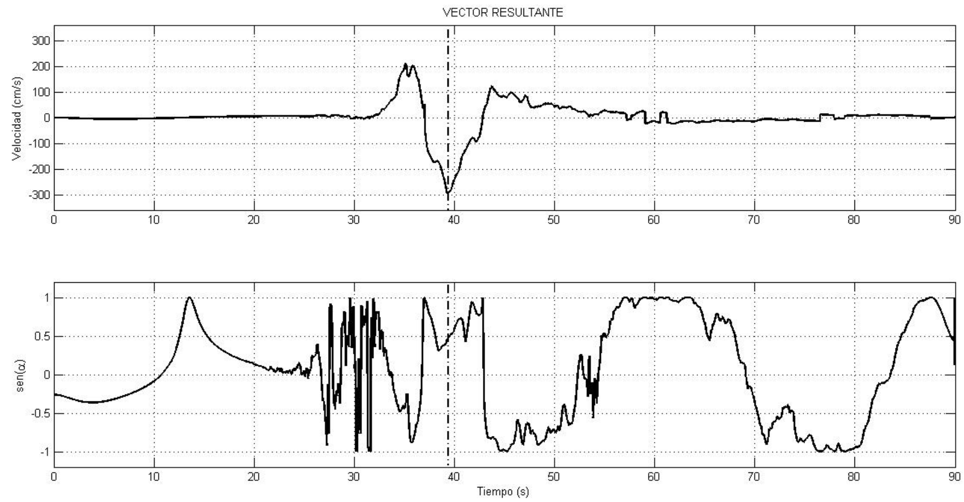
ABSTRACT

El conocimiento de las características del movimiento del suelo debido a terremotos que afectan las construcciones es de vital importancia para poder elaborar métodos confiables de diseño sísmico, La presencia de pulsos de aceleración, velocidad o desplazamiento en el movimiento del suelo constituye un factor importante en el daño de las estructuras. Distintos investigadores han desarrollado una gran variedad de parámetros para caracterizar el movimiento de suelo debido a sismos a partir de los registros de aceleración, de las historias de tiempo de velocidades o de desplazamientos; por ejemplo: Intensidad de Arias, Intensidad de Housner, Aceleración Efectiva, Potencial Destructivo entre otros. Pese a la gran variedad de estos parámetros el valor máximo de la aceleración, velocidad o desplazamiento conocidos como PGA, PGV y PGD (Peak Ground Acceleration, Velocity and Displacement) siguen siendo los más utilizados en los diversos ámbitos de la ingeniería. Por otro lado, se conoce que la orientación de los registradores no siempre captura la dirección predominante del movimiento en donde ocurren los picos máximos. Para salvar esta situación, en el análisis de registros de campo cercano se ha recurrido a rotar los registros a una dirección determinada, por ejemplo perpendicular a la traza de la fuente sismogénica. En este trabajo se presente un sencillo procedimiento para determinar el máximo PGA, PGV o PGD en el plano horizontal y la correspondiente orientación en la que ocurre. El método consiste en el cálculo del módulo del vector resultante instante a instante para dos componentes horizontales ortogonales de aceleración velocidad o desplazamiento del suelo; conjuntamente con el módulo del vector resultante se determina la orientación del mismo también para cada instante de tiempo. Luego, se determina el valor máximo para toda la historia de tiempo, el instante en que ocurre y la orientación que presenta. Por último se rotan las componentes originales del registro a esta nueva dirección con la certeza que en ella ocurre el verdadero pico máximo. Los resultados muestran que para ciertos casos los valores máximos hallados exceden en más del 35% a los correspondientes a la dirección de registración.

Palabras Clave: Registros Sísmicos - PGA PGV PGD Horizontal -Orientación de Registración.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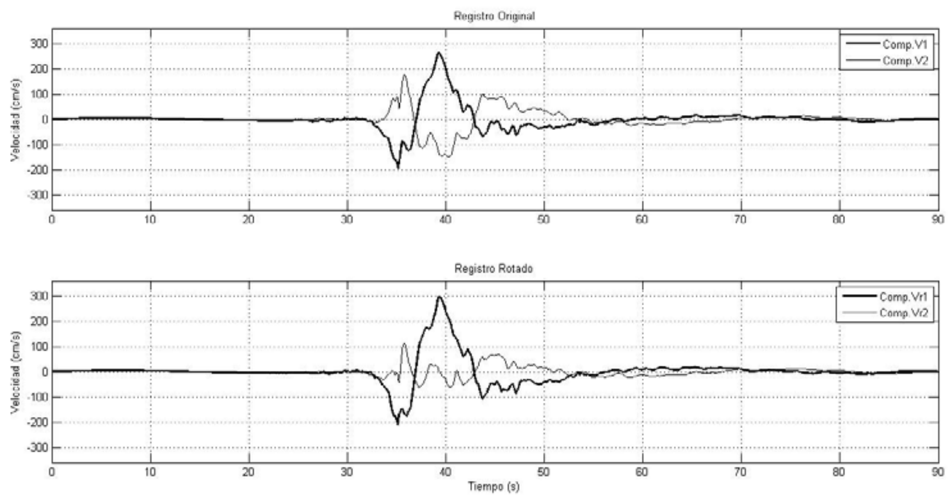
Registro Original
Comp.V1
Comp.V2
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Comp.Vr1
Comp.Vr2
Tiempo (s)

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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ISC products for large earthquakes in the Latin America and Caribbean Region

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ABSTRACT

The International Seismological Centre (ISC) is a non-governmental non-profit-making organization funded by 62 research and operational institutions including six in the Latin America and Caribbean (LAC) region. The main mission of the ISC is production of the ISC Bulletin, yet we also provide two special products related to large earthquakes: the ISC-GEM Catalogue and the ISC Event Bibliography.

The ISC-GEM Global Instrumental Earthquake Catalogue presents the most homogeneous record of some 19,000 moderate to large earthquakes instrumentally recorded during 1900-2009 period. Hypocentres of all events in the catalogue are re-determined using uniform and rigorous location and depth determination procedures. All magnitude values are expressed by either a direct value of Mw, or an Mw proxy estimate based on newly derived non-linear regressions between Ms-Mw and mb-Mw. The Catalogue is an invaluable source for seismic hazard studies on global and regional scales, including those currently performed in the LAC region.

The ISC Event Bibliography links seismic events in the ISC Bulletin with relevant scientific publications. It is an interactive map-based web-service that allows users to select an individual earthquake or earthquakes in a region of interest during a particular period of time and obtain a list of references to relevant scientific articles (including DOI) published by selected authors during selected period in selected journals. Currently the ISC Event Bibliography includes over 16,000 individual publications from about 500 titles related to events occurred in last 100+ years. Several thousands of those articles are devoted to ~800 earthquakes in the LAC region. The journals included in our database encompass a variety of fields in geosciences (e.g., engineering seismology, earthquake seismology, geodesy and remote sensing, tectonophysics, monitoring research, tsunami, geology, geochemistry, hydrogeology, atmospheric sciences, etc.), thus making this service useful in multidisciplinary studies.

KeyWords: earthquake, hazard, bibliography.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Completitud del catálogosísmico en el centro occidente de Colombia

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ABSTRACT

Se compiló un catálogo sísmico para la región centro occidental de Colombia, con información sismológica de las bases de datos del Observatorio sismológico de la Universidad del Quindío (OSUQ), y de la Red Sismológica Nacional de Colombia (RSNC), para el cuadrante de monitoreo del OSUQ que cubre las siguientes coordenadas geográficas: Latitud 4°N – 6°N y Longitud 78°W – 74.5°W, del cual forman parte los departamentos de Quindío, Caldas, Norte del Valle, Tolima y Risaralda, ubicados en una zona de amenaza sísmica alta según el reglamento colombiano de construcción sismo resistente NSR-10.

El catálogo presentado contiene información para el periodo comprendido entre los años 1999 – 2011 con magnitudes mínimas y máximas, además se constituye como un aporte importante para el conocimiento de la sismicidad de la región centro occidental de Colombia, así como para la determinación de la amenaza sísmica. Se organizó una base de datos que incluye 3737 eventos sísmicos registrados por el OSUQ y 5142 eventos de la base de datos de la RNSC. Mediante un proceso de unificación de los catálogos sísmicos y de su homogenización se procedió a la depuración, la cual consistió en la eliminación de registros repetidos y réplicas, obteniendo de forma definitiva 5583 eventos sísmicos.

Se clasificaron los eventos sísmicos según su profundidad para determinar la completitud del catálogo sísmico y los parámetros de “a” y “b”, mediante los métodos de regresión lineal y máxima verosimilitud (mmv). Se tuvo en cuenta los resultados obtenidos con el mmv por la confiabilidad en los resultados, en comparación con la regresión lineal. Para eventos sísmicos con profundidad superficial (0 - 30 km) se obtuvo una magnitud de completitud Mc de 2.2 y valores de a = 4.9 y b = 0.79. Se determinó una Mc de 2.2 y valores de a = 4.26 y b = 0.74 para eventos sísmicos con profundidad intermedia (30 – 70 km). Para eventos sísmicos con profundidad mayor que 70 km se calculó una Mc de 2.6 y valores de a = 5.05 y b = 0.88. El parámetro “b” indica que los niveles de esfuerzo, referente a toda la gama de profundidad estudiada, son predominantemente bajos.

Palabras Clave: Parámetros “a” y “b”, Análisis de completitud, Amenaza sísmica.

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Stress Field in Brazil with Focal Mechanisms: examples of regional forces controlling the stress field

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ABSTRACT

The determination of the stress field is fundamental not only to understand the driving forces and plate deformation but also to study intraplate seismicity. In Brazil the stress field has been determined using mainly focal mechanisms, and a few breakout and in-situ measurements. Previous compilations of focal mechanisms show reverse, strike-slip and normal faulting that indicate a variable stress field. However, the stress field still is poorly known in Brazil. We determined some additional focal mechanisms in Brazil using different waveform modelling techniques according to the available data.

For events with magnitudes ~5 mb, we stacked the records of several teleseismic stations (> 30°) with a good signal/noise ratio, according to distance and azimuth. The stacked teleseismic P-wave signal was modeled using the hudson96 program (Herrmann, 2013) and the consistency of the focal mechanism with the first-motion polarities was checked. For some smaller events (mb < 4) the regional moment tensor was determined with the ISOLA code (Sokos & Zahradnik, 2013).

With the focal mechanisms available in the literature and those obtained in this work, we were able to identify the following patterns (Fig. 1): central Brazil shows a purely compressional pattern (E-W SHmax), which is predicted by regional theoretical models (Richardson & Coblentz, 1996, and the TD0 model of Lithgow & Bertelloni, 2004). This compression is mainly due to the continental-scale plate-tectonic forces.

In the Amazon craton we find an indication of SHMax oriented in the SE-NW direction, probably caused by the Caribbean plate interaction (Meijer, 1995). Near the Amazon Fan, flexural stresses caused by sedimentary load seem to be important, which is in agreement with local theoretical models (Watts et al., 2009). In the northeastern coastal region, the compression rotates following the coastline, which indicates an important local component related to spreading effects at the continental/oceanic transition as well as flexural stresses.

We will show examples of stress perturbations induced by local effects (e.g. flexure and continental spreading). The results of this work should be useful for future numerical modeling of global/regional intraplate stress field.

KeyWords: Stress Field, Brazil, Focal Mechanism.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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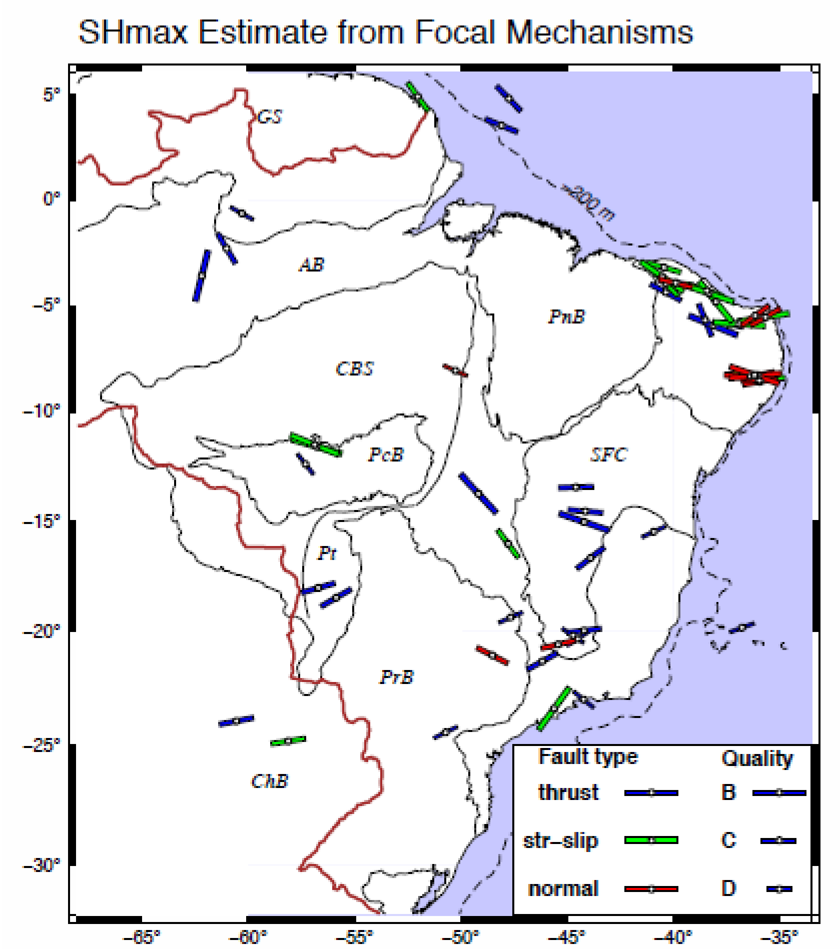

Fig1: SHmax direction in Brazil from focal mechanism. Blue, green and red bars indicate thrust strike-slip and normal mechanism respectively. Fault type and quality according to the World Stress Map criteria. Open bars are in-situ measurements.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sismicidad en el Piedemonte Llanero: caracterización, relocalización y tomografía de velocidades

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ABSTRACT

Se presenta una relocalización de sismos en el Piedemonte Llanero colombiano entre los 3° a 5°N y 73° a 75°W mediante los métodos de inversión sísmica simultánea y dobles diferencias teniendo en cuenta tiempos de llegada de ondas P y S; además se presenta la inversión de un modelo de velocidad Vp en 3D. Se tomaron en cuenta 483 sismos registrados por la Red Sismológica Nacional de Colombia (RSNC) entre 1993 y 2012 que proporcionan 4961 observaciones de tiempos de arribo de onda P y S. Con la relocalización se logró una reducción de los tiempos de error cuadrático medio (RMS) y la identificación evidente de "*clusters*" de sismos asociados a los sistemas de fallas de la cordillera oriental, principalmente en el sector suroeste del área de estudio entre los sistemas de fallas de Servitá-Santa María y Guayuriba. El modelo de 3D brinda información de anomalías de baja velocidad para el general de la cordillera oriental y estabilidad para la zona suroriental que corresponde al cratón suramericano, sin embargo las imágenes presentan zonas de anomalías positivas de Vp para el sector suroeste de la grilla que involucra los sistemas de fallas anteriormente citados. Finalmente el modelo presenta un buen desempeño hasta profundidades no superiores a los 40 km, debido a que el 95% los hipocentros de los eventos registrados no superan esa profundidad.

Palabras clave: tomografía de velocidades, relocalización de sismos, inversión sísmica simultánea, dobles diferencias, Piedemonte Llanero.

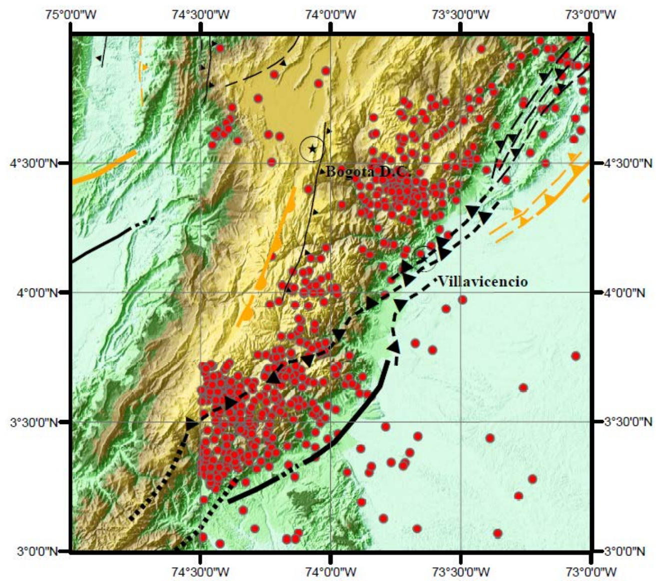

Figura 1. Localización de sismos registrados por la RSNC entre 1993 y 2012. Incluye mapa de fallas cuaternarias de Colombia. Modificado de Paris, G et al. (2000).

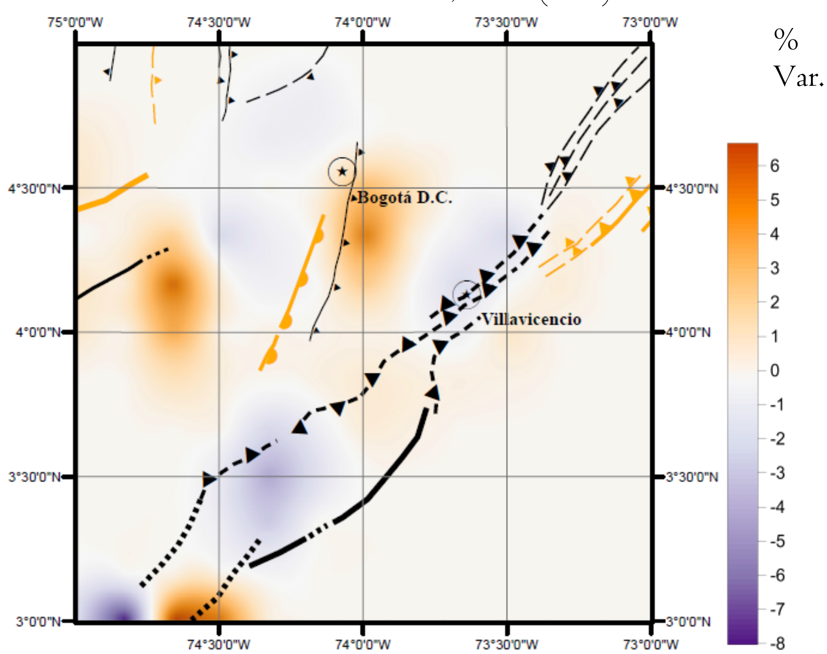

Figura 2. Cambio porcentual de velocidad de onda P con respect al modelo inicial 1D a 20 Km de profundidad.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Réplicas del sismo del 13 de agosto de 2013. Bahía Solano - Océano Pacífico Colombiano

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ABSTRACT

El 13 de agosto de 2013 a las 15:43:14 (U.T), ocurrió un evento sísmico superficial localizado en el Océano Pacífico Colombiano, en las coordenadas 5.757°N y 78.254°W, con una magnitud Mw 6.5. Dada la magnitud del evento principal y la ocurrencia de réplicas desencadenadas por el evento, se instaló la estación sismológica portátil NUQC en el municipio de Nuquí (Chocó), con el propósito recolectar datos para el mejoramiento de la calidad de localización y caracterización de las réplicas. El registro de información se llevó a cabo entre los días 17 de agosto y 6 de noviembre de 2013. Se presenta un análisis estadístico de las réplicas y una estimación del área de ruptura del sismo principal, teniendo como fuente de información los registros sísmicos de las estaciones permanentes de la RSNC y de la estación portátil NUQC.

Palabras clave: réplicas, área de ruptura, estación sismológica portátil.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic microzonation of urban areas

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ABSTRACT

The earthquakes are one of the most destructive natural disasters and it is difficult to predict them with accuracy. The assessment of risk associated with earthquakes (seismic risk) and its possible reduction are of great concern to the scientific community particularly in the field of seismology and civil engineering. The infrastructure development in the urban areas would have serious societal impact in terms of human life and structural damage, if due importance is not given to adequate preparations for possible seismic hazard.

Seismic microzonation has generally been recognized as the most accepted tool in seismic hazard assessment. Seismic microzonation helps in describing the ground motion levels to be expected in a given region in the future and it is defined as the subdivision of a seismic zone into smaller zones that have relatively similar exposures to various earthquake related effects and ground motion characteristics taking into account source and site conditions. In other words it is an effort to evaluate and to map the potential hazards found in an area, urban area in particular, that could be induced by strong ground shaking during an earthquake. These hazards include ground motion amplification, liquefaction and landsliding etc.

North India and particularly the Himalayan belt have experienced many strong to moderate earthquakes that pose a high seismic risk in the region. The present work focuses on the detailed study for seismic microzonation of National Capital Region of Delhi, India. The study area has a population of more than 28 million located on the banks of river Yamuna. Being the capital of India, the city is considered as highly important in regards to social and economical issues. It falls under seismic zone IV according to seismic zonation map of India. The region is located near the highly active Himalayan seismic belt. Regional geology, seismotectonics, subsurface information, geotechnical data, seismic attenuation relationships and earthquake data are considered for the present study. Earthquake catalogue processing, geophysical field testing (MASW and Refraction), local site response using ambient vibration measurement and effect of various uncertainties on the amplification of ground motions through subsurface are attempted. Based on the geotechnical data and considering the varied geology, liquefaction potential of the area is also assessed for various scenarios using different methods. Finally, results of all the studies carried out are combined together to propose the seismic microzonation model of the area.

KeyWords: Seismic microzonation, MASW, Refraction, Geology, Tectonics, Earthquake catalogue, Ambient noise, Site response, Liquefaction, NCR of Delhi.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismological detection and analysis of catastrophic landslides

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ABSTRACT

Catastrophic landslides involve the sudden acceleration and deceleration of millions of tons of rocks and debris in response to the forces of gravity and dissipation. Their unpredictability and frequent location in remote areas have made observations of large landslide dynamics very rare. In this work we show that routine monitoring of the global long-period seismic wavefield regularly detects and locates massive landslides with long-period surface-wave magnitudes around 5.0. Inverse modeling of the teleseismic data in terms of a time-varying force vector acting on the surface of the Earth leads to the determination of a landslide force history (LFH), which, by Newton's third law, provides a remote means of inferring the momentum change of the landslide mass. Augmented by geometric constraints obtained by satellite imagery, the seismically determined dynamic parameters of the landslide can be used to infer mean landslide mass and runout trajectory. Combined analysis of the LFH and short-period signals provides possibilities for inferring additional details of the landslide process, in particular details of landslide initiation and termination. We present results and interpretations for recent catastrophic landslides, including the two large landslides associated with the 2013 Kennecott Mine, Utah, pit collapse, and the 2014 Oso landslide in Washington State.

KeyWords: seismology, landslides.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Results of recent paleoseismologic studies point to the probable seismogenic source of the 1875 earthquake of Cucuta, in the border area between Colombia and Venezuela

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ABSTRACT

The well-known NE-SW oriented right lateral strike-slip Bocono Fault of the Merida Andes of Venezuela, on approaching the border area with Colombia in the vicinity of the city of Cucuta, ramifies into several branches that start to curve southward once in Colombian territory. The Northern branch, which is the focus of this study, is known as the Aguascalientes Fault. This in turn ramifies into three branches that present morphotectonic evidence of dextral strike-slip movement with a component of reverse faulting. The Northern one of these is the Cucuta Fault, the middle branch is the Aguascalientes Fault proper, and the Southern branch is known as the Lomito Fault. The Aguascalientes Fault, which has the most outspoken morphotectonic expression, is the most important of the three branches, and traverses the Venezuelan border town of Ureña, passes just to the South of the urban conurbation of Cucuta, where it crosses the Pamplonita River before turning South to continue as the N-S running Chitaga Fault. The name of the fault relates to the occurrence of thermal springs along its trace. The Lomito Fault, situated to the South of the Aguascalientes Fault, is characterized by a flexural scarp along a gravel terrace in an abandoned floodplain of the Tachira River that constitutes the frontier between the two countries. Both faults were subjected to paleoseismologic trench studies that have yielded evidence of Holocene tectonic activity. Along the Lomito Fault scarp the presence of a south verging blind fault is manifested at surface as a flexural scarp marked by the presence of an accumulation of gravelly colluvial wedges that interfinger with floodplain sediments of the Tachira River (Figure 1). C^{14} dates of samples taken in this sequence of colluvial wedges yielded ages between 16.260+/- 60 and 1.740+/- 30 years BP, confirming Holocene fault activity. Trenching on a fault controlled terrace scarp of the Aguascalientes Fault on the West bank of the Pamplonita River just South of the city of Cucuta, revealed a vertical offset of almost 6 m of Holocene terrace gravels overlying clayey shales of the Neogene León Formation (Figure 2). Only one reliable C^{14} date of a sample taken in the middle of the down faulted gravel bed produced an age of 3520 +/- 30 years BP. The horizontal component of displacement could not be established. This considerable vertical offset of the fault during the Late Holocene strongly suggests the Aguascalientes Fault to be the seismogenic source of the earthquake of the 18th of May 1875 that caused the almost total destruction of the towns of Cucuta and Villa del Rosario in Colombia and San Antonio in Venezuela. This interpretation has been corroborated in a recently undertaken study of historic seismicity of co- and post seismic effects related to that earthquake.

Key Words: Cucuta earthquake 1875, Bocono Fault, Aguascalientes Fault, paleoseismology.

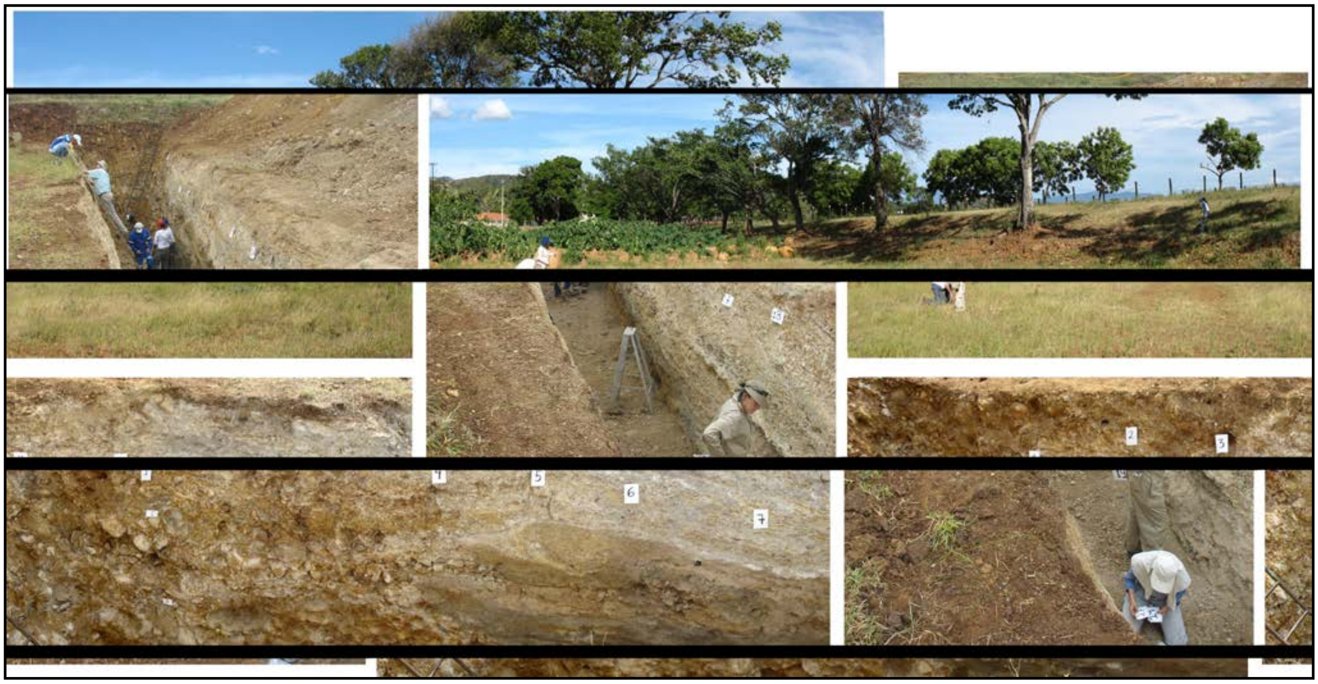

Figure 1. Flexural scarp of the Lomito Fault at Finca La Casona looking to the West; Trench in process of logging, looking to the North; Detail of trench exposure in scarp area where gravelly colluvial wedges interfinger with floodplain deposits of the Tachira River, looking to the East.

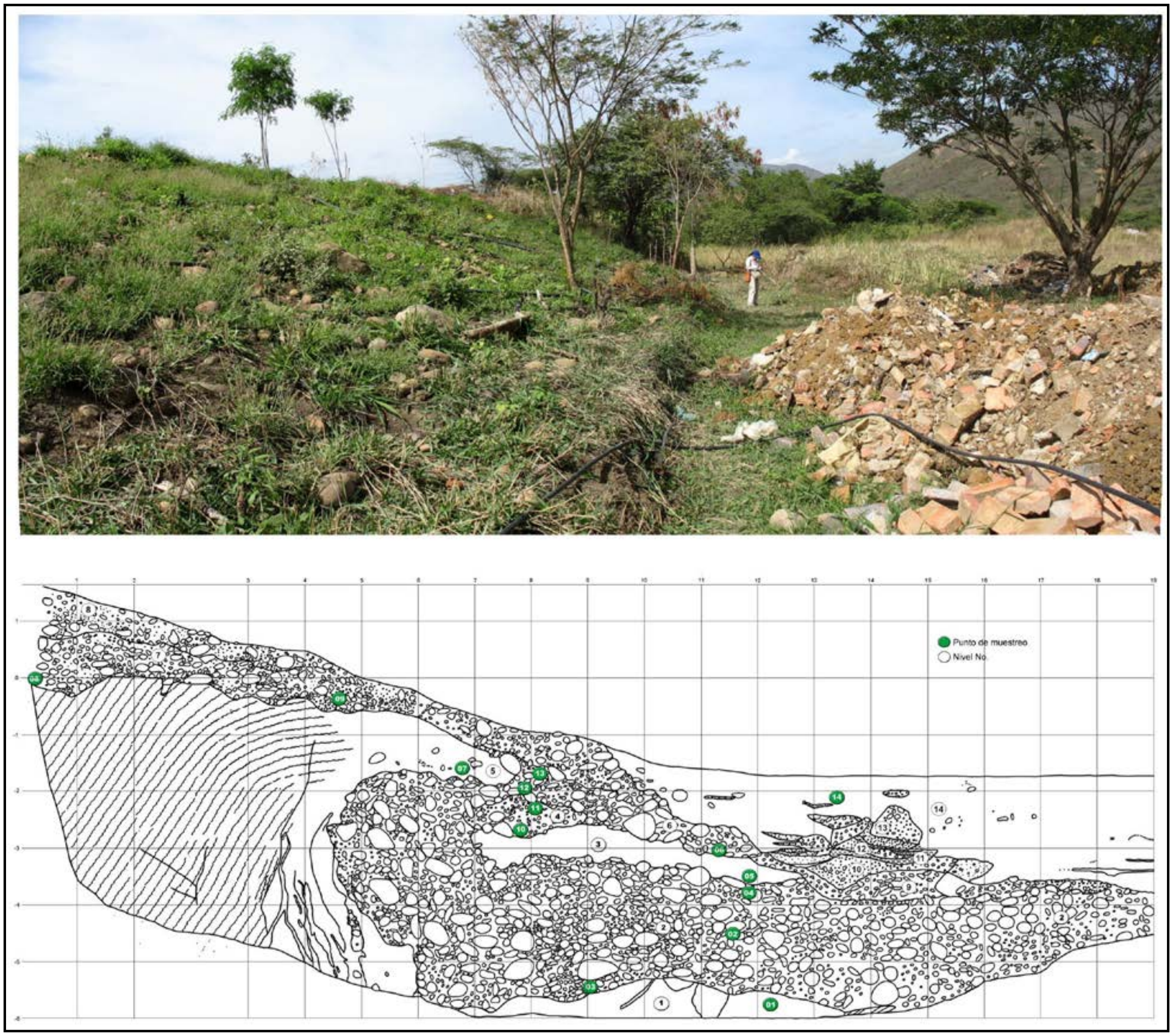

Figure 2. Fault scarp of the Aguascalientes Fault at the locality of El Resumen before trench excavation, view to the SW; Trench log showing 6 m of vertical displacement of Holocene terrace gravels overlying clayey shales of the Neogene León Formation. Effects of sliding along fault scarp.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

Inversión del tensor de esfuerzo a partir de mecanismos focales obtenidos en el campo volcánico y geotérmico de las Tres Vírgenes, Baja California Sur (México)

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ABSTRACT

La instalación de una red de estaciones sísmicas alrededor del Campo Volcánico y Geotérmico de Las Tres Vírgenes (CVGTV), B.C.S. (México), durante el periodo septiembre 2003-diciembre 2012, permitió localizar 423 sismos y obtener 90 mecanismos focales de tipo normal, strike slip y mínimamente inversos. Sin embargo, con el propósito de determinar los cuatro parámetros del tensor de esfuerzo ($\sigma1$, $\sigma2$, $\sigma3$ y R) y caracterizar el campo de esfuerzos del CVGTV, utilizando las metodologías descritas por Angelier y Mechler (1984) y Delvaux y Sperner (2003); en este estudio se seleccionaron, únicamente, 57 mecanismos que fueron agrupados en 4 zonas (A, B, C, D) considerando su ubicación geográfica y periodo de ocurrencia (enjambres de sismos), características tectónicas (locales, regionales) y su proximidad a los pozos productores e inyectores (Figura 1).
Los resultados de la inversión del tensor en cada una de las zonas del CVGTV (Figura 1) muestra que en la zona A se presentan dos tipos de régimen de esfuerzos: el extensivo (A1) orientado en dirección NW-SE, está asociado a la falla El Volcán; los eventos respectivos habrían ocurrido como respuesta al proceso de inyección de agua en el pozo LV6 en diciembre de 2009; mientras que el segundo, de tipo strike slip (A2), está asociada a la tectónica regional y local de las fallas Reforma y Los Azufres, similar a lo obtenido por Sumi et al. (2010). En las zonas B y D, el régimen extensivo está orientado en dirección NW-SE y NE-SW los que se correlacionan con las fallas normales Cimarrón (B) y el sistema de fallas NW-SE ubicadas entre Bonfil y Mezquital (D). Mientras tanto, a nivel regional, la inversión del tensor de esfuerzo realizado entre las zonas A-C y C-D presentan un régimen extensivo con orientación NW-SE acorde al fallamiento normal de La Virgen (A-C) y el régimen strike slip observado entre C-D, estaría correlacionada con la falla Mezquital.
En general el régimen de esfuerzo principal del CVGTV es de tipo extensivo y esta correlacionado con la actividad tectónica local, cuya actividad sísmica se presentó como enjambres; mientras que los de tipo strike slip están asociados a la tectónica regional del Golfo de Baja California.

PalabrasClave: Tensor de esfuerzo, strike slip, enjambre, campos geotérmicos.

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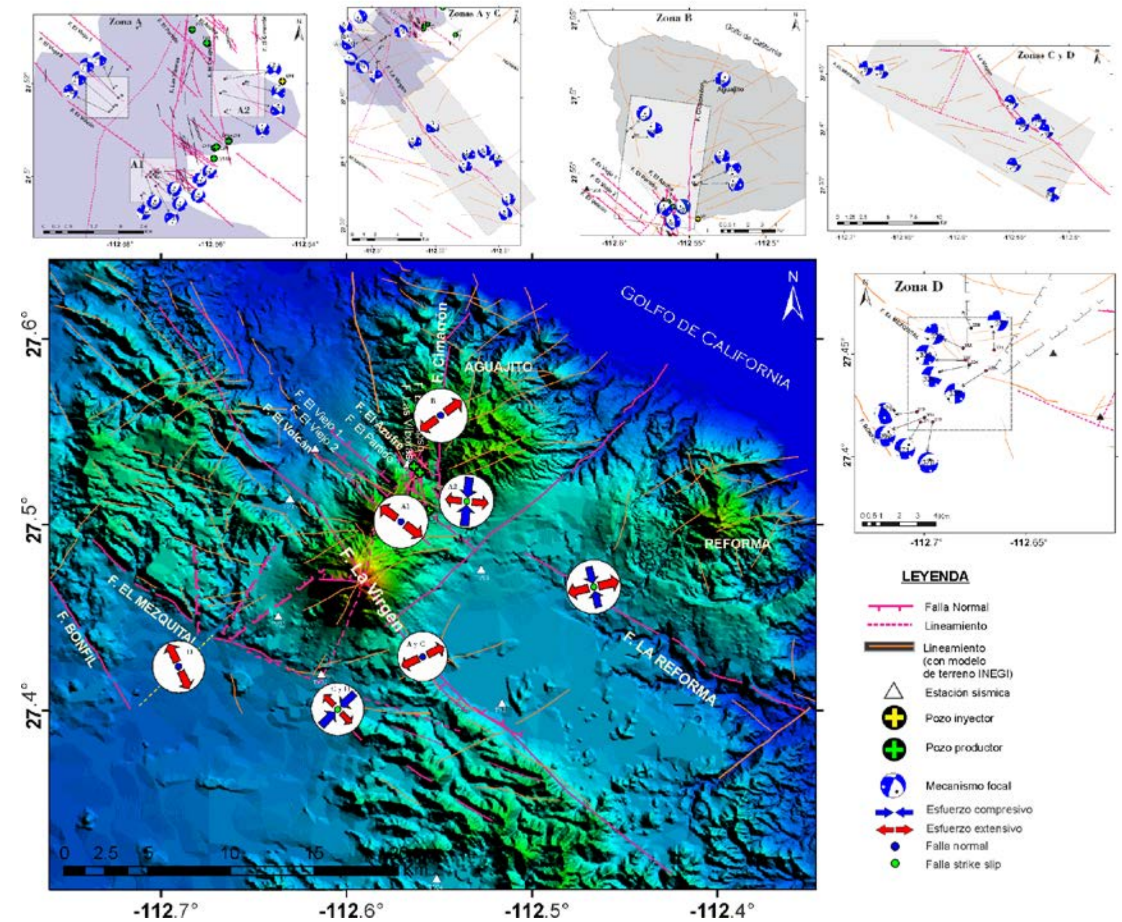

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Aplicación de algoritmo de inversión tomográfica aplicada en la Cuenca de Urabá

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La Cuenca de Urabá es de gran interés geológico, debido a su complejidad y posición, donde se tiene la confluencia de distintas placas convergentes, pero es una zona que ha sido poco entendida. Con este trabajo se obtuvo un modelo del subsuelo, utilizando información de sísmica pasiva. Fueron utilizados 54 eventos sísmicos, de los cuales se discriminaron más de 400 tiempos de llegada correspondientes a las ondas P y S. Esto permitió realizar una inversión simultánea de los hipocentros, tiempos de origen y la distribución de velocidad 3D. De esta manera se estableció un modelo de velocidad correspondiente con las características geológicas del área, ejemplo de ello es la geometría y el lineamento de la Falla de Murindó y el Sistema de Fallas satélites. Estas características y la expresión geomorfológica y litológica, pueden ser claramente asociadas con el modelo de velocidad superficial.

PalabrasClave: Tomografía, Inversión, Cuenca de Urabá, Diferencias finitas, Fronteras no reflectivas.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Propagacion de ondas de Rayleigh en el Valle de México y una posible explicacion para la larga duracion de los sismos

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ABSTRACT

Se presentan resultados de simulaciones de sismos en los regímenes elástico y viscoelástico en el Valle de México, considerando la topografía del terreno y un modelo de la estructura 3D de la cuenca sedimentaria sobre un lecho rocoso. El dominio de simulación es de 93 x 80 x 50 km^3, y posee capas superficiales de ~50 m de espesor con velocidad de onda S, Vs>= 100 m/s y factores de calidad Qs>=32. Se utilizaron 8 fuentes puntuales de tipo doble par, distribuidas en la región de simulación y a profundidades de 150m, para favorecer la generación de ondas superficiales. La solución del sistema hiperbólico de ecuaciones viscoelásticas en su formulación velocidad-esfuerzo para la simulación de ondas se llevó a cabo empleando el método de elementos finitos discontinuos (i.e. Galerkin Discontinuo), en una malla no estructurada de ~14 millones de elementos tetraédricos y con adaptabilidad hp (i.e. refinado de la malla y adaptación local del orden de interpolación polinomial en función de las propiedades del medio) [1,2]. Este método permite resolver el problema numérico satisfaciendo los criterios de precisión y estabilidad en función de las propiedades locales del medio de propagación. Con este conjunto de simulaciones se estudia la propagación de ondas de Rayleigh en el Valle de México, en particular, el papel que puede jugar la propagación de modos superiores para las ondas de Rayleigh en la duración del movimiento del suelo.

Palabras Clave: Soluciones numéricas, sismología computacional, propagación de ondas superficiales, cuencas sedimentarias.

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Efecto de sitio no lineal sobre basalto usando cinco sismos m>6 de Guatemala

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ABSTRACT

En la determinación de la amplificación sísmica y el comportamiento no lineal ha sido en depósitos de suelo blando, como las capas sedimentarias de edad cuaternaria, las poco consolidadas, lacustre, aluvial, los suelos blandos hablando geotécnicamente. Muchos autores han reportado en trabajos de microzonificación sísmica de ciudades usando microtremores y/o movimientos fuertes. Es propósito es asociar el daño asociado a la estructuras ingenieriles asentadas en dichos suelos donde tienen una gran influencia la geología superficial y la topografía. Aki (1993) menciona una linealidad en la ciudad de México durante el terremoto de Michoacán de 1985, sin embargo Singh et al. (1988) reportaron poca evidencia no linear sísmica en la Zona de Lago de la ciudad de México. La Ciudad Universitaria de la Universidad Nacional Autónoma de México (UNAM) se encuentra construida dentro de derrames basálticos de volcanes monogenéticos al sur de la ciudad. Estos depósitos de roca basáltica comprenden la Zona Firme o Dura según la zonificación geotécnica. Desde el 2006 funciona la estación UNM con sismómetro de banda ancha de la red "geoscope", de la cual solo los eventos más fuertes normalmente de subducción son analizados en este trabajo. Con estos eventos bastante alejados (S-P mayores a 1 minuto) parecería que es difícil calcular cocientes espectrales H/V debido a la distancia las ondas sísmicas cuando arriban aportan ondas superficiales que a veces se confunden dentro de las amplitudes del ruido de fondo. Se analiza cinco eventos del 2007 al 2012, con magnitudes de 6.3, 6.5, 6.6, 6.8 y 7.4, ellos tienen una trayectoria bastante similar a la estación UNM, calculando sus espectros, cocientes espectrales H/V y haciendo comparaciones entre sismo y ruido. Se encontrado que existe una amplificación de sito alrededor de 4 veces usando ventanas analizadas de cinco fuertes sismos localizados en Guatemala, con su frecuencia predominante es 0.2 Hz para los sismos y de 0.17 Hz para la señal de ruido seguidamente posterior al sismo. Para el caso de ruido, la amplificación es bastante menor que la encontrada con sismo. Esto implica que hay un comportamiento sísmico no lineal de sitio, debido a los depósitos superficiales de roca basáltica en Ciudad Universitaria UNAM.

PalabrasClave: Efecto de sitio no lineal, basalto, Ciudad de México.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Características espectrales de la sismicidad originada en la Cuenca del Valle de México

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ABSTRACT

Este trabajo presenta un análisis de las características focales de la sismicidad en el Valle de México, el cual ha sido posible gracias a los registros obtenidos de una red sísmica de banda ancha recientemente instalada en esta zona.

De los sismos ocurridos en el Valle de México durante el período 2008-2012, se escogieron los 15 eventos con la mejor relación señal-ruido. Se transformaron a registros de aceleración y mediante un análisis espectral, se encontraron los parámetros de fuente de sismos característicos de distintas zonas de concentración de eventos dentro de nuestra zona de estudio, determinando el momento sísmico (M0), la caída de esfuerzo ($\Delta\sigma$) y el factor de atenuación (t*). Se encontraron diferencias significativas en el factor de atenuación de cada región así como una caída de esfuerzo media $\Delta\sigma$=1.2 MPa. Con respecto al valor de t*, se encontró un promedio de t*=0.04 s para sismos en el Valle de México, lo que indica que esta zona exhibe atenuaciones altas comparado con regiones fuera de él. Este resultado es acorde con las determinaciones más recientes del factor de calidad Q0 de las ondas sísmicas dentro del Valle de México (Ortega and Quintanar, 2005, Singh et al. 2007), y refuerza la hipótesis de que, en general, el centro de México está caracterizado por un rápido decaimiento de la amplitud de las ondas con la distancia, similar al ocurrido en otras regiones tectónicamente activas.

Con este estudio se pretenden conocer las características focales de esta sismicidad que por sus características resulta vital, toda vez que el Valle de México es la región más importante de México desde un punto de vista económico y de concentración poblacional, además de aportar elementos para el conocimiento preciso del peligro sísmico en esta zona. En todo caso, enfatizamos que la importancia de los sismos locales se comprenderá a plenitud cuando entendamos las diferencias del movimiento del suelo debido a fuentes locales y regionales, lo cual pasa por el cabal conocimiento de la estructura bajo el Valle de México.

PalabrasClave: Valle de México; Análisis Espectral; Parámetros focales.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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A Test of the RSTT Model for South America with Brazilian pGT events

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ABSTRACT

Good 3D lithospheric velocity models are necessary for reliable epicentre determination, especially at regional distances. The RSTT (Regional Seismic Travel Time) project, an on-going effort coordinated by CTBTO and ISC, is improving the 3D model in South America by incorporating new GT5 data as well as a recent compilation of crustal thickenesses in the continent. To test the last versions of the RSTT model for South America, we used a set of 17 Brazilian reference events, with magnitudes 4.0 to 5.1, with well-determined epicenters. Only four were truly GT5 (Ground Truth) events with an accurate origin time. Most of the events had the epicenter assigned to the middle of the aftershock zone determined by local studies, with origin times calculated with IASP91 table using teleseismic stations; these events are called pGT (pseudo GT). The epicenters were calculated in two-steps: 1) an initial epicenter was determined with a 1D model derived for the Brazilian mid-plate region, and 2) corrections were applied to the observed travel times using the RSTT calculator, and the epicenters were relocated with the corrected times. The "hypocenter" code was used in the two steps, and only regional stations (200-1500 km distance) were employed. The relocated epicenters are closer to the true pGT location compared with the initial uncorrected locations, as well as compared with the teleseismic ISC locations.

KeyWords: 3D model, hypocenter location, Brazil.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The September 5th, 2012 Nicoya, Costa Rica earthquake, a subduction earthquake captured in the near field

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ABSTRACT

On September 5th, 2012 a large Mw=7.6 earthquake expectedly occurred at the southern terminus of the Middle American Trench (MAT) off NW Costa Rica. For over a decade before this earthquake, first as a target site of the NSF MARGINS Program's initiative SEIZE and then as an extension through the GeoPrisms Program, a dense geodynamic control network of seismic and geodetic instruments was installed over the seismogenic zone of the Nicoya segment of the MAT where the Cocos plate subducts at ~80mm/yr under the Caribbean plate. There we were taking advantage of the existence of the Nicoya peninsula that extends as close as 60 km from the trench and right over the seismogenic zone of large underthrust interplate earthquakes. Given the occurrence of large earthquakes in this segment of the subduction zone in 1853, 1900 and 1950, this network was designed to capture the next large earthquake. Campaign and continuous GPS data that expanded for almost two decades before the earthquake were crucial in delineating heterogeneities along the plate interface before the earthquake and anticipating the area where the next earthquake would potentially occur and what magnitude it could reach. Two locked patches were recognized, one that extends from 10 to 20 km in depth just offshore the Nicoya peninsula and another from 20 to 30 km deep. We will show how the Nicoya 2012 earthquake was successfully captured in the near field, including 5 Hz GPS seismograms, through this international collaborative project. This earthquake may be the best recorded subduction earthquakes in history. We will also show how this event represents a partial rupture of the plate interface with slip mainly on the deeper patch.

Key Words: earthquake, Costa Rica, Nicoya, monitoring.

Estimación del riesgos sísmico en Managua, Nicaragua, con la metodología CAPRA

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ABSTRACT

El proyecto "Iniciativa Centroamericana para la Reducción del Riesgo a Desastres y Adaptación al Cambio Climático" financiado por el Banco Mundial por medio del GFDRR (Aportación España al fondo/SFLAC), apoya la implementación de la Política Centroamericana de Gestión Integral de Riesgo de Desastres (PCGIR).

Uno de los componentes de este proyecto es la Modelación Probabilista de escenarios de riesgo sísmico en Managua, Capital de Nicaragua. Esta modelación se lleva a cabo empleando la metodología CAPRA. El Proyecto comenzó en el mes de noviembre de 2013 y culminará en julio del año en curso.

Se ha calculado la amenaza sísmica para Managua empleando el programa CRISIS (Ordaz y otros). Además se ha elaborado una capa de efecto de sitio, para incorporarla en el cálculo de la amenaza, para esto se han empleado los datos del trabajo de Hernández (2009), donde evaluó la respuesta de los suelos de Managua en más de 270 puntos de la ciudad.

También se han determinado las tipologías estructurales más comunes en la ciudad y se han propuesto sus respectivas funciones de vulnerabilidad. Por otro lado se ha recopilado y depurado las bases de datos de los portafolios: educación, salud y vivienda; los que se incluirán en el cálculo del riesgo.

Se ha seguido una metodología participativa e incluyente con todas las instituciones que pertenecen al Sistema Nacional para la Prevención, Mitigación y Atención de Desastres de Nicaragua. Para tal fin se han llevado a cabo varios talleres, en los cuales cada uno de los asistentes ha participado de forma activa.

Al concluir el proyecto en el mes de julio, se pretende calcular las pérdidas debidas a sismos para diferentes escenarios en la Ciudad de Managua.

PalabrasClave: CAPRA.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Structuraldelineationof the ServitaFaultSystem,ColombianEasternCordillera, usingmicroseismicity

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ABSTRACT

TheServitaFaultSystem(SFS)islocatedintheeasternfoothillsoftheColombianAndesEasternCordillera. At least one event in historical times has been associated to this fault (1917, Ms=6.9). To delineate theseismicallyactivesegments of this structure and to understand its relation with neighboring active structures we deployed a portable seismic network during the period 2011–2012 to record microseismicity. We use, then, microseismicityasastructuralmarkerthatilluminates activeelements in the Servita Fault region.
Theseismologicaldatafromthetemporarynetworkwere integratedwithgeologicalinformationforanalyzingthegeometry, kinematicsandseismogenicdepthofthemajorstructures. Adatasetof890earthquakeswithalocalmagnituderange between0.1and3.2anddepthsupto40kmwasanalyzed.
The network operated in two sectors, north and south, according to main tectonic features of the region, at different periods. Different1-Dmodelswereestablished foreach sector. The refined locations of the events show a general SW-NE trend that follows the trace of the SFS. Selected focal mechanisms show predominantly right-lateral strike slip motion. Inthenorthernsectorepicentersareseparatedintwolocations,one on the axial zone of the cordilleraandtheotheron the eastern flank. The former, were most of the epicenters are located, coincides with the rupture zone of Quetame earthquake (2008, Mw=5.9). Alignment of hypocenters of the eastern flank events andsomefocalmechanisms suggestafaultplanedippingtothewest, which is interpreted as the Servita Fault plane. Southwards of theRioNegro,seismicitydecreasesandlosescontinuity. This feature coincides with the trace of the WSW-ENE Rio Blanco Fault which possibly segments the Servita Fault. Seismicity at the southern sector is spread over a wider area and exhibits deeper hypocenters compared to the northern sector. Hypocenter distribution and focal mechanisms in this sector suggest two planes dipping to the west which we interpret as segments of the Algeciras Fault and another plane (northwards) steeply dipping to the southeast interpreted as the fault plane of the Altamira Fault.

Key Words: ServitaFaultSystem,ColombianEasternCordillera, microseismicity.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Strong motion recorded during the Emilia 2012 thrust earthquakes (Northern Italy): a comprehensive analysis

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ABSTRACT

A complex seismic sequence characterized by two thrust earthquakes of magnitudes ML 5.9 and ML 5.8 occurred on May 20 and 29, 2012, respectively, and activated the central portion of the Ferrara Arc structure beneath the Po Plain in northern Italy. The sequence, referred to as Emilia 2012, was recorded by the Italian Strong Motion Network, the Irpinia Network, the Friuli Venezia Giulia Network and 15 temporary stations installed by the Civil Protection Department. In this study, we compile and analyze a large dataset that contains 3,273 waveforms from 37 ML≥4.0 seismic events. The main aim of this paper is to characterize the ground motion induced by the Emilia 2012 seismic sequence and compare it with other data in the Italian strong motion database and to the recent Ground Motion Prediction Equations (GMPEs) developed for northern Italy, all of Italy and Europe. This is achieved by (1) the computation and analysis of the strong motion parameters of the entire Emilia Strong Motion Dataset (ESMD) and (2) a comprehensive investigation of the May 29 event recordings in terms of time–frequency analysis, the ground motion parameters and the response spectra. This detailed analysis was made possible by the temporary Civil Protection Department stations that were installed soon after the May 20 event at several municipalities in the epicentral area. Most of the recordings are characterized by low-frequency content and long durations, which is a result of the thick sedimentary cover that is typical of the Po Plain. The distributions of the observed horizontal peak ground accelerations and velocities (PGAs and PGVs) with distance are generally consistent with the GMPEs. This is particularly true for the data from ML ≥ 5.0 (MW ≥ 5.0) events, though the data are scattered at distances beyond approximately 60–70 km and show faster attenuation than the European GMPEs. The horizontal components for the May 29 event at two near-fault stations (Mirandola and San Felice sul Panaro) are overestimated by all of the analyzed GMPEs. In contrast, the vertical components, which played an important role in the shaking near the source, are underestimated. The May 29 event produced intense velocity pulses on the horizontal components and the highest peak ground acceleration ever recorded in Italy on the vertical component of the Mirandola near-fault station. The ground motion recordings contained in the ESMD significantly enrich the Italian strong motion database. They contribute new information about (1) the possibility of exceeding the largest recorded PGA in Italy, (2) the development of a spectral design that takes into account the role of the vertical component and the extreme variability of the near-fault ground shaking, and (3) the characterization of the ground motions in deep sedimentary basins.

KeyWords: Strong motion parameters, Strong motion network, Thrust fault, Emilia 2012 seismic sequence, Po plain, Northern Italy.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Rupture process on Fracking Operations Applying P- Wave Back Projection Images

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ABSTRACT

Hydraulic fracturing is an essential technology for most unconventional hydrocarbon resources and many conventional ones as well. The primary limitation on the improvement and optimization of the fracturing process is the minimal access to observe the behavior of the fracture in the subsurface. Without direct observational evidence, hypothetical mechanisms must be assumed and then tested for their validity with indirect information such as wellbore measurements, indirect production and pressure behavior.

One of the most important sources of information today is the relation made between micro seismic source mechanisms and fracture behavior. Hydraulic fractures induce some level of micro seismicity when the stress conditions in the Earth are altered by changes in stress during the operations. The result is the sudden movement between rock elements and the radiation of both compressional and shear energy in a seismic range that can be detected and recorded with sensitive receivers.

The objective of this work is to provide reasonable information when applying the Back Projection Method in order to predict the distribution of seismic radiation (energy) of microseisms while fracking operations.

The method consists in back project the seismograms recorded at an array or a seismic network to a grid of possible source locations. It provides rupture properties such as direction, speed and duration. The back projection method is used to estimate the rupture propagation of seismic record of a fracking operation in the Chichimene Oil field, located in the western area of the foreland Eastern Llanos Basin in Colombia. Data corresponds to a 17 triaxial accelerometers-linear array which are located close to the source coordinates. A grid of points is set to cover the area of study which includes all seismic stations and the source location. The entire volume is a cube where a homogeneous model velocity model is applied. Values for velocities were Vp= 5.94 km/s and Vs=3.45 km/s. To simplify the analysis, the value for the density was 4500 kg/m3 for the entire body. The analysis uses the vertical components from seismograms recorded. The simplifications of the model contribute to minimize the computation time.

The analysis clarify some ideas about what information can be gained from the micro seismic source data and according to the obtained results, what kind of comparisons and associations might be done to evaluate the fracking performance operation. Obtained results such as distance, velocity and orientation of the seismic energy radiation show accordance to the type of operation took place and were used to characterize the generated fracture.

Key Words: Fracking, Micro seismicity, Energy, Back Projection.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Alternatives for computing regional and global seismic-phase travel times using a 3-dimensional model

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ABSTRACT

We compare computational costs, travel time accuracy, and applicable phases for a global 3D model and ray tracer (LLNL-G3D) and a computationally efficient method for computing Region Seismic Travel Times (RSTTs). LLNL-G3D is a whole-earth 3D model of P- and S-wave seismic velocity. A 3D ray tracer (Earth3D) is used to compute LLNL-G3D travel times for a suite body phases that are commonly used for seismic location. LLNL-G3D phases include first-arriving P waves (e.g. P, Pn), surface reflections (e.g. pP), reflections off of velocity discontinuities (e.g. PmP, PcP), crustal phases (e.g. Pg and Lg) and core phases (e.g. PKP). Single-processor computational times depend on non-linearity of the ray-path as a function of deviation from radially symmetry for seismic velocity. Teleseismic travel times are commonly computed in less than 0.1 second. Regional phases generally require 0.25 seconds to compute, but travel times in particularly complex regions can take 1 second to compute. Median absolute deviation for first-arriving P-wave residuals is approximately 0.5 seconds at teleseismic distances and between 0.5 and 1.0 second at regional distances. RSTT is a model and method for computing travel times for regional phases Pn, Pg, Sn, and Lg. The RSTT model includes a 3-dimensional crust and laterally varying P- and S-wave velocity in the mantle. Mantle velocity is parameterized as a linear function of depth. This parameterization enables travel time computation in approximately 1 millisecond, which is 100 to 1000 times faster than 3-dimensional ray tracing. For event-station distances between 1° and 15°, Pn travel time prediction error is approximately 1.25 seconds. While RSTT error is slightly large than the error for the full 3D model, RSTT travel time prediction error is far lower than Pn prediction error for standard 1D global models (e.g. ak135), for which travel time prediction error is approximately 1.75 to 2.5 seconds. We conclude that travel time prediction accuracy for LLNL-G3D is superior for all phases used in seismic location. However, computation time for 3D ray tracing may limit LLNL-G3D applicability for use in both real-time monitoring systems and for application to very large data sets. RSTT is an excellent alternative for real-time regional monitoring systems and for relocation of large data sets when large, multi-core computers are not available. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-654775.

KeyWords: Seismic, Location, model, 3-dimensional.

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Paleoseismic Study of the North Panama Deformed Belt and Probabilistic Seismic Hazard Assessment for a Proposed Harbor Facility on the Caribbean Coast of Costa Rica

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ABSTRACT

As part of the feasibility and design studies for a new harbor facility on the Caribbean coast of Costa Rica, we were tasked with identifying and quantifying the seismic hazard posed to the site by faults within a 100-km radius as part of a Probabilistic Seismic Hazard Assessment (PSHA). The background review revealed that at least 17 Quaternary-active faults have been mapped within the study region, in addition to the Middle America Trench, which, although farther away, can generate events sufficiently large to be felt across the isthmus, on the Caribbean side. The North Panama Deformed Belt (NPDB) is the fault closest to the site, and the one posing the most severe seismic hazard. Rupture of a section of this fault caused the April 22, 1991 Ms 7.6 earthquake that generated extensive damage between Moín, Costa Rica and Bocas del Toro, Panamá, as well as up to 1.4 m of strike-slip surface rupture on the Río Blanco fault where the offshore NPDB steps inland as the Siquirres-Matina fault. The event generated coastal uplift of up to 1.85 m in the Limón-Moín region, about 0.5 m uplift near the Costa Rica-Panama border, and subsidence between Moín and Matina and in northwestern Panama. Several elevated coral platforms in the site area suggest that similar uplift-causing earthquakes have occurred before. Based on the historical record, the next higher platform was probably the result of an 1822 event, but the record is too short to ascribe older platforms to other, previous events. To evaluate the periodicity of these events and rate of uplift of the region, we surveyed the elevated coral platforms between Moín and Limón and collected coral and shell samples for dating. Twelve of the coral samples were dated using the U-Th method; this data set was supplemented with four radiocarbon-dated corals from published sources, and one newly radiocarbon-dated shell. Assuming that the corals died off when uplifted by earthquakes on the NPDB, we interpreted 12 such events in the past about 7,000 years, with an average recurrence of about 600 years. The data indicate, however, that earthquakes on this section of the NPDB are not periodic, and appear to cluster in time, with large events having a 1,400-year return period, and smaller events occurring every few hundreds of years. Our data confirmed the 1822 event, although uplift as a result of that earthquake appears to have been less than during the 1991 earthquake. Using the sea level curve for the Caribbean of Hubbard et al. (2005), we calculated the total amount of uplift for each dated sample, resulting in an average uplift rate for the last 7,000 years of 1.9 ± 0.2 mm/yr. The results of this study allowed us to develop realistic ground motion parameters for use by the project engineer to design the proposed facility.

Key Words: Paleoseismology, Costa Rica, North Panama Deformed Belt, Probabilistic Seismic Hazard Assessment, uplifted coral platform, coral dating.

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IDLM session – Imaging and Dynamics of Lithosphere and Upper Mantle

Conveners:
Anne Sheehan (Colorado Univ. - USA)
<afs@cires.colorado.edu>
Gaspar Monsalve (UNAL - Colombia)
<gmonsalvem@unal.edu.co>

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Constructing Shear Wave Models Using Multi-Objective Optimization for Multiple Geophysical Data Sets

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ABSTRACT

Understanding Earth's tectonic processes requires determining the Earth structure. We develop and apply a multiple objective optimization joint inversion scheme for multiple geophysical datasets to construct 3-D shear wave models. In particular, we expand on a constrained optimization approach for joint inversion to characterize a one-dimensional Earth's structure. We initially use seismic data from regional networks in New Mexico, Texas, and the USArray, a dense network of permanent and portable seismographs placed systematically across the continental United States. We collect and process seismic data (receiver function, surface wave, body wave travel times), with plans to expand to a fourth data set (gravity). By jointly inverting these three geophysical data sets, we can better handle the inherent non-uniqueness from inversion. The Multi-Objective Optimization (MOP) technique enables the capability to combine linear and non-linear problems, enabling the combination of inhomogeneous data sets and different statistical properties of error associated with each data set. We demonstrate through numerical and experimental testing that the MOP scheme matches all data sets, is more robust, and is more flexible than traditional inversion approaches. To develop quasi 3-D models, we interpolate the 1-D results using a kriging approach, only when we have excellent station coverage. Our quasi 3-D velocity models provide insight into the tectonic history and physical properties of the Earth structure of New Mexico and Texas, and we will compare crust and upper mantle structure to ancient in Texas and to active rift systems in New Mexico.

KeyWords: Joint inversion, shear-wave models, geophysical data sets, computational geosciences.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Study of Seismic Attenuation and Unusual Phases at Uturuncu Volcano, Bolivia

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ABSTRACT

Uturuncu Volcano, 22.27° S, 67.18° W, is located in the Central Volcanic Zone of the Andes, a volcanic arc resulting from the subduction of the Nazca Plate beneath the South American Plate. Despite having an active hydrothermal system, the last eruption of the volcano was circa 270,000 years ago. Recent InSAR studies of this area show an inflation rate of 1.5-2 cm/yr over an area that has a width of 70 km (Pritchard and Simons, 2002). This inflation has been modeled to a source depth of 15-17 km located to the southwest of Uturuncu's summit. Current studies have found a source area of decreased density with respect to the crust and with a Vp/Vs ratio of > 1.9, with a depth matching that derived from the deformation signature [Potro et al., 2013; M. E. West, H. McFarlin, D. Christensen written comm.]

Determining the size, geographic location, source depth, and source shape of deformation at Uturuncu Volcano is important because this can indicate either (or a combination of) injection of magma from depth into the system, melting of crustal rock from a previous injection, or the build-up of pressure in a hydrothermal system (Pritchard and Simons, 2002). To further our understanding of these important parameters, we have been analyzing the attenuation of teleseismic P-wave phases from 15 events from four different azimuthal ranges. Looking at the peak-to-peak p-wave amplitudes, we see that there is a distinct, elongated area of attenuation approximately 13.6 by 33.3 km in size to the southeast of the volcano for earthquakes from the southeast and northwest, and for events from the southwest and northeast, a larger but much more subtle decrease in amplitude wrapping around the south of the volcano and approximately 40 by 35 km. We go further by looking at 100 events showing unusual phase arrivals between the P and S waves – these may be either reflections off of, or phases converted by, the top of the attenuating feature. At this congress, we will show our preliminary results from this analysis in the framework of other studies carried out at this volcano.

KeyWords: amplitude, attenuation, teleseism, Uturuncu, volcano, Bolivia, phase.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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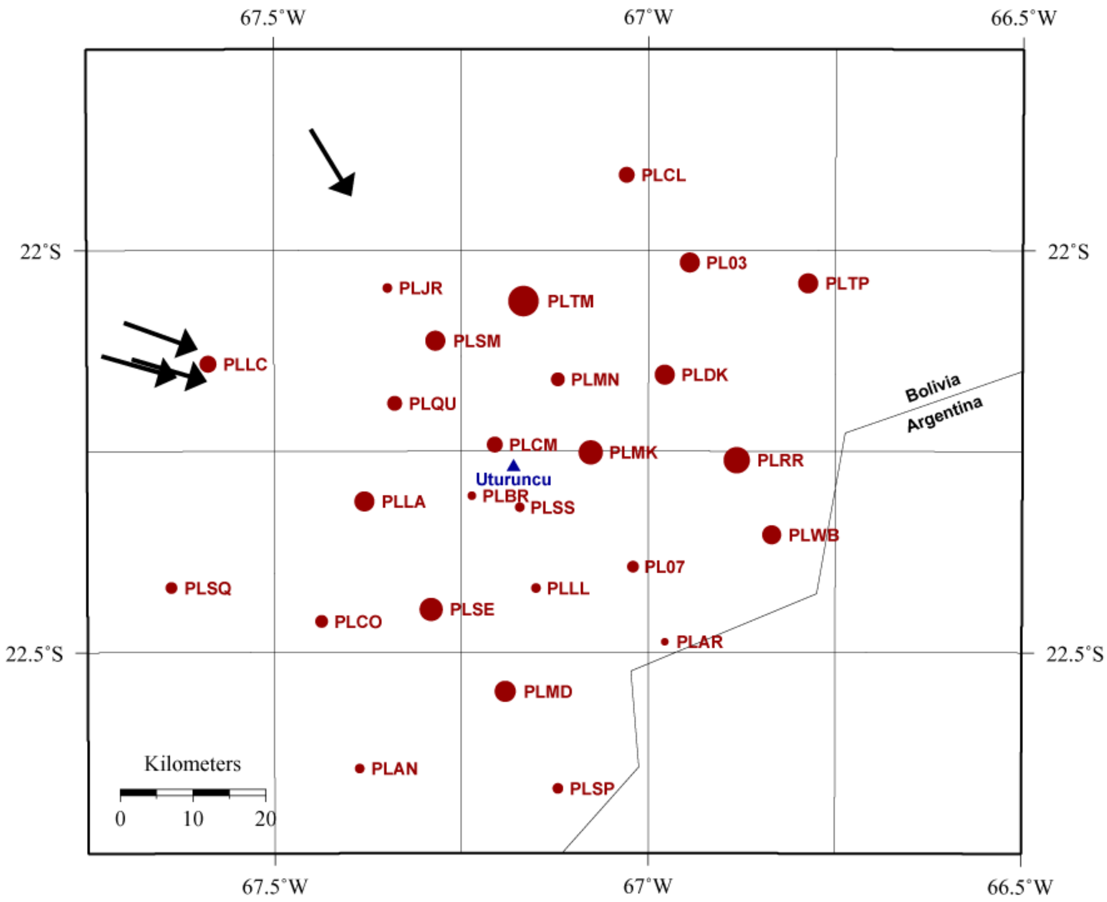
Mean Teleseismic Amplitudes for Events Coming From Northwest of Uturuncu Volcano



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Title: 3-D Structure of the Rio Grande Rift from 1–D Constrained Joint Inversion of Receiver Functions and Surface Wave Dispersion

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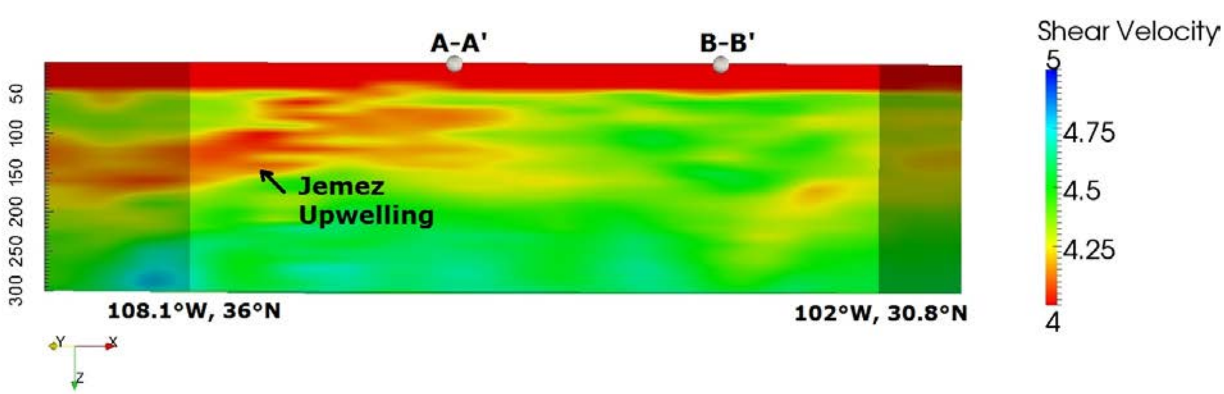
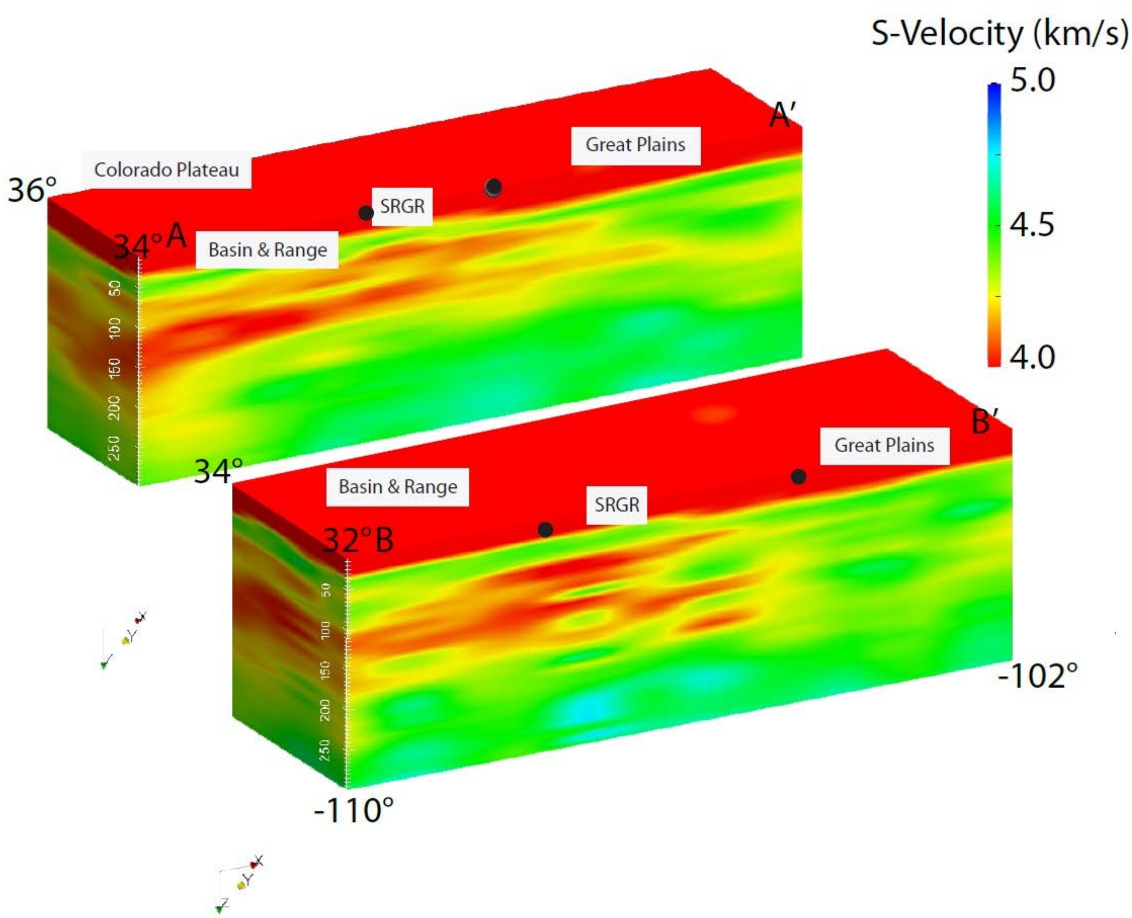
ABSTRACT

The southern terminus of the Rio Grande Rift region has been poorly defined in the geologic record, with few seismic studies that provides information on the deeper Rift structure. In consequence, important questions related to tectonic and lithospheric activity of the Rio Grande Rift remain unresolved. To address some of these geological questions, we collect and analyze seismic data from 147 EarthScope Transportable Array (USArray) and other seismic stations in the region, to develop a 3–D crust and upper mantle velocity model. We apply a constrained optimization approach for joint inversion of surface wave and receiver functions using seismic S wave velocities as a model parameter. In particular, we compute receiver functions stacks based on ray parameter, and invert them jointly with collected surface wave group velocity dispersion observations. The inversions estimate 1–D seismic S-wave velocity profiles to 300 km depth, which are then interpolated to a 3–D velocity model using a Bayesian kriging scheme. Our 3–D models show a thin lower velocity crust anomaly along the southern Rio Grande Rift, a persistent low velocity anomaly underneath the Colorado Plateau and Basin and Range province, and another one at depth beneath the Jemez lineament, and the southern RGR. We expect to implement our approach for building 3-D Earth subsurface structure models in south-western Colombia, that can be used to improve the current scenarios associated to major earthquakes.

KeyWords: Geophysical inversion, Rio Grande Rift, Jemez lineament, Interior-point methods.




S-Velocity (km/s)
5.0
4.5
4.0
Colorado Plateau
Great Plains
36°
A'
SRGR
34° A
Basin & Range
50
100
150
200
250
34°
Basin & Range
SRGR
Great Plains
B'
32° B
-102°
-110°

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The MOANA experiment: A broadband ocean bottom seismology investigation of a transform plate boundary, New Zealand

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ABSTRACT

The Marine Observations of Anisotropy Near Aotearoa (MOANA) experiment included a one-year deployment of 30 broadband ocean bottom seismometers (OBS) installed off both coasts of the South Island of New Zealand from January 2009 to February 2010. The use of ocean bottom seismometers greatly increases the array aperture available to investigate both the onshore and offshore portions of the New Zealand continental lithosphere, resulting in improved resolution for the land portion of the study area, and first results for offshore. The OBS array combined with the permanent GeoNet array onshore has an aperture of approximately 1000 km and includes the Challenger Plateau, the South Island of New Zealand, the Chatham Rise, and the Campbell Plateau. MOANA tested between two prominent models of transform plate boundaries, one where deformation is distributed throughout the lithosphere, and one where deformation occurs in a narrow zone in the lithosphere and broadly in the asthenosphere. Our results from teleseismic S-wave splitting show strong shear wave splitting near the Alpine Fault, aligned nearly parallel to the plate boundary and direction of relative plate motion. Anisotropy remains strong to the northwest of the Alpine fault, onto the Challenger Plateau, and tapers in amplitude while remaining roughly aligned with the plate boundary. The splitting pattern off the east coast is quite different, rotating to nearly perpendicular with the transform plate boundary. Combined with crust and upper mantle estimates of anisotropy from Pn, local S wave splitting, and surface waves, we find that the results near and to the west of the Alpine Fault are consistent with distributed deformation in the lithosphere. Anisotropy in the east may be due to fossil lithospheric anisotropy or to current absolute plate motion. Further lithospheric studies are underway with both ambient noise and earthquake surface wave dispersion. Receiver functions are difficult in oceanic studies due to a combination of microseismic noise, water layer reverberations, and seafloor sediment reverberations, and we have developed joint inversion methods to address some of these issues. Our joint inversion method combines seafloor compliance with receiver functions and surface wave dispersion, and can resolve seafloor sediment properties but is still problematic for resolving the Moho. Surface wave dispersion is measured using group and phase velocities from approximately 6 s – 80 s (ambient noise from 6-40 s, earthquake data from 30-80 s). The surface wave tomography reveals variations in crust and mantle shear velocity structure from 0-120 km. These methods resolve the thick crust of the Southern Alps and the transition from oceanic to continental lithosphere off the west coast. A fast high P-wave speed anomaly is observed in the upper mantle beneath the Southern Alps, and ongoing work seeks

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to determine the dip and depth extent of this anomaly.

KeyWords: lithosphere,anisotropy,shear wave splitting,transform fault, New Zealand,surface wave dispersion.

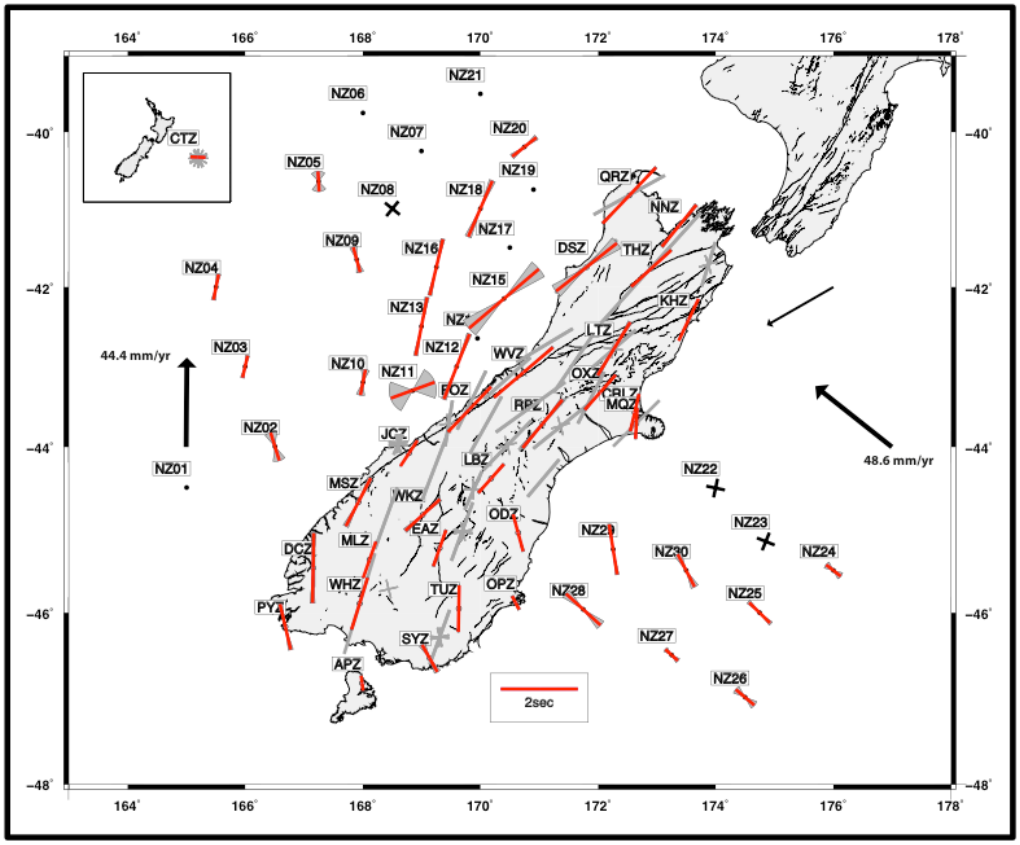

Figure 1. Summary of MOANA SKS splitting measurements [Zietlow et al., 2014]. Red bars indicate orientations of the polarizations of the faster quasi-shear wave, and black crosses indicate null measurements. Thick black arrows show current absolute plate motion, thin black arrow shows plate motion relative to the Australian plate. SKS splitting measurements from prior studies plotted in light grey.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Modelación fisica y simulacion numérica en procesos de adelgazamiento litosférico para zonas convergentes

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ABSTRACT

En este trabajo se presenta una simulación de la evolución temporal asociada al comportamiento que pudo tener la raíz litosférica de la Sierra Nevada de Santa Marta. Para esto se usó la ecuación de Navier Stokes y la segunda ley de la termodinámica con la intención de modelar las fuerzas que rigen el movimiento del sistema manto litosfera y su interacción. Con base en lo anterior, se hizo un programa en Matlab utilizando el método de diferencias finitas que reproduce el comportamiento dúctil del sistema en tiempos superiores al millón de años. Por otro lado se hizo un estudio con el fin de comprobar la no existencia de la raíz litosférica en la Sierra Nevada de Santa Marta, para esto se utilizaron telesismos registrados por la Red Sismológica Nacional desde el 2013 hasta la actualidad y se hallaron las funciones receptoras asociadas a cada sismo registrado en estaciones cercanas a la zona de interés.

Se hicieron varias simulaciones basadas en modelos ya propuestos de adelgazamiento litosférico como lo son la remoción convectiva y la delaminación, obteniendo flujos convectivos generados por diferencias de temperaturas y flujos inerciales creados por gradientes de densidades y viscosidades, mostrando resultados acordes con los de las funciones receptoras en donde no se encontró evidencia de un moho profundo asociado a una raíz litosférica.

Palabras clave: Raíz litosférica, Simulación, Funciones receptoras, Adelgazamiento litosférico

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Joint inversion of geoid anomaly data and teleseismic P-wave delay times: Modeling density and velocity perturbations underneath the Parana Magmatic Province

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ABSTRACT

The Parana Magmatic Province (PMP) is one of the largest continental igneous provinces (LIP) on Earth. It is well dated at 133 Ma preceding the opening of the South Atlantic Ocean, but the causative geodynamic processes are still poorly understood. Although a low-velocity anomaly has been imaged by seismic tomography in the northeast region of the PMP and interpreted as a fossil conduct of a mantle plume that is related to the flood basalt eruptions, geochemical data indicate that such magmatism is caused by the melting of a heterogeneous and enriched lithospheric mantle with no deep plume participation.

Models of density perturbations in the upper mantle estimated from joint inversion of geoid anomalies and P-wave delay times will offer important constraints on the dynamics.

A new generation of accurate global geopotential models derived from satellite-missions (e.g. GRACE, GOCE) allows us to estimate density distribution within the Earth from geoid inversion. In order to obtain the residual geoid anomaly related to the density structure of the mantle, we use the EGM2008 model removing estimated geoid perturbations owing to variations in crustal structure (i.e., topographical masses, Moho depth, thickness of sediments and basalts).

Using a spherical-Earth approximation, the density model space is represented by a set of tesseroids and the velocity model is parameterized in nodes of a spherical grid where cubic B-splines are utilized as an interpolation function. To constrain the density inversion, we add more than 10,000 manually picked teleseismic P-wave delay times. During the inversion procedure, density and P-wave velocity are linked through a relationship provided by mineral physics [Karki and Karato, 2001].

We will present the results of this joint inversion scheme and hypothesize on the geodynamic processes responsible for the flood basalt eruptions.

KeyWords: Geoid anomalies, P-wave delay times, Parana Magmatic Province, density, joint inversion.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Joint inversion of seismic and gravity data for velocity structure and hypocentral locations of the Colombian subduction zone

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ABSTRACT

Joint inversions of geophysical data recover models that simultaneously fit multiple types of constraints while playing upon the various sensitivities of each data type. Here, we combine body wave arrival times with surface wave dispersion measurements and gravity observations to develop a combined 3D P- and S-wave velocity model for the crust and upper mantle of Colombia. P- and S-wave arrival times were obtained for local earthquakes from instruments in the Colombian National Seismic Network. Rayleigh wave dispersion curves were inverted for using a subset of network stations and larger local earthquakes. Gravity observations were extracted from the global satellite-based 200-m-resolution model GGMplus.

Preliminary results using only body waves show reduced velocities beneath the volcanic arc in the upper 25 km of the crust. Crustal velocities are also reduced from the 1D starting model beneath the Cordillera Oriental in the northern half of the country. Relocations of intermediate-depth seismicity clearly indicate a discontinuity in the slab centered 5° N latitude, where the southern portion of the slab is ~200 km trenchward of the northern portion, coincident with the termination of arc volcanism. Seismicity below 100 km depth in the southern portion of the subduction zone¬¬¬ is surrounded by a ~100-km-thick region of elevated velocities, associated with the subduction of the Nazca Plate, and embedded within a broader region of reduced velocities. The northern portion of the subduction zone at 100 km depth and below is characterized by a broad region of elevated velocities, which may be consistent with a slab of an old, thickened Caribbean Plate origin. This overlapping of the edges of two slabs may contribute to the seismicity of the Bucaramanga nest.

KeyWords: subduction, tomography, Latin America.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Crustal thickness estimation beneath the Northern Andes using the receiver function method

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ABSTRACT

We calculated receiver functions under the Northwestern Andes and adjacent areas, to deduce crustal thickness. For this purpose, we use data from the broadband network of Colombia, which has been working since 2008; presently the network consists of 29 stations, 10 of which have been installed between 2012 and 2014, and are operated by the Colombian Geological Survey. Recent stations were installed to improve the epicentral locations in the SGC where there was a high azimuthal gap. With the receiver function calculation, we were able to map crustal thickness and Vp/Vs ratio in regions of the Northwestern Andean system where there were no previous estimations. We also collected information of Moho depth from previous studies and neighboring regions to present a new map of interpolated crustal thickness of the Northern Andes. Our results included a wide range of crustal thicknesses, with values of around 14 km beneath the Malpelo Island on the Pacific ocean, 20 to 30 km at the coastal Pacific and Caribbean plains of Colombia, 25 to 35 km beneath the eastern plains and foothills, 34 to 40 km beneath the Western Cordillera, 40 to 45 km at the Magdalena River intermountain valley, 53 to 58 km in the northern Central Cordillera, and reaching almost 60 km beneath some of the volcanoes of the southern cordilleran system of Colombia and the Plateau of the Eastern Cordillera. The Vp/Vs ratio was obtained using a combination of Wadati diagrams and an H-k (crustal thickness – Vp/Vs) stacking technique, which gave a bulk value for most of the crust under each station. In general, high values of Vp/Vs are associated to regions of high crustal thickness, and volcanic and high temperature gradient areas. The low Vp/Vs values are located in the intermountain valleys, regions of relatively low crustal thickness and areas where oceanic material has been accreted to the continent. The continuation of this work will consist of the collection of Love and Rayleigh surface wave dispersion observations, in order to combine the surface wave data and receiver functions to perform a joint inversion to obtain a more precise crust-mantle velocity structure.

KeyWords: Crustal thickness, receiver functions, H-k stacking and joint inversion.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Crustal models ID for Colombia from surface waves dispersion observations and receiver functions

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ABSTRACT

Colombia is located in a complex system of geological faults, geological accidents and three of the major tectonics plates are colliding. The seismicity is one of the main geological hazards in Colombia; the National Seismological Network of Colombia -RSNC (for its acronym in Spanish) has recently developed important improvements of the quality and the amount of seismological equipment, which has allowed the use of new and more accuracy techniques to model the velocity structure in the crust and the upper most mantle. Some of these techniques are dispersion observations, receiver functions and joints. The receiver functions are sensitivity to changes in medium impedance and dispersion curves are used to estimate shear velocity variations. The simultaneous inversion allows velocity models estimation for crust and upper most mantle, which are used to perform a body wave inversion using VELEST (Kissling, 1988) to improve the velocity models.
Velocity models are primary to improve earthquake's parameters location, and are used in different techniques to calculate others as the seismic tensor moment. In this work records of 482 earthquakes at distances between 29° and 90° are analyzed to calculate receiver functions and regional dispersion curves, follow is used the "Computer programs in seismology" (R. B. Herrmann, C. J. Ammon 2002) package to perform a joint inversion. Velocity models outcome together with RSNC's seismicity catalogue were used to calculate body wave joint inversion using VELEST. Four velocities models for different regions in Colombia were calculated and tested.

Key Words: Velocities models, Receiver functions, dispersion curves, simultaneous inversion.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ
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Lithospheric and upper mantle stratification beneath Colombia: Using Receiver Functions from S-waves

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ABSTRACT

The knowledge of the structure of the lithosphere is an important issue to understand the evolution of the Earth and plate tectonics behavior. Seismic recordings at the National Seismological Network of Colombia –RSNC (for its acronym in Spanish) and the Incorporated Research for Seismology -IRIS stations are processed with S-wave receiver function (SRF) technique to determinate this structure. The technique uses distant seismic events, 65° to 85° from the station, to detect the S-wave and its Sp wave conversion at broadband-three component stations. To isolate the recorded phase was necessary to apply a rotation process to the components; this process takes the ZNE into the ZRT components through the back azimuth of the event, and then is necessary an extra rotation through the incident angle to obtain the LQT components. The L-component is almost free of transverse energy from the S-wave and it is de-convolved from Q-component to obtain the SRF.
To outcome the LAB (Lithosphere Asthenosphere Boundary) currently have been processed five broad-band stations, mostly at the central region in Colombia, and ten events per station. According to the distribution of the seismological stations and estimations obtained in this work, we suggest that the lithosphere structure in the study area is highly inhomogeneous. The results are analyzed and compared with previous works using receiver function from P- waves.

Key Words: Receiver functions, Lithosphere structure, Colombia.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Estudio de la Estructura de la Corteza en la zona de Convergencia Placa de Rivera – Bloque de Jalisco (Proyecto TsuJal)

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ABSTRACT

Con el objetivo de estudiar el Riesgo Sísmico y Tsunamigénico en las costas de Jalisco y Nayarit, en el Pacífico mexicano, asociado con la estructura cortical del contacto Placa de Rivera – Bloque de Jalisco, se ha llevado a cabo el Proyecto TsuJal (Caracterización del Peligro sísmico y tsunamigénico asociado con la estructura cortical del contacto Placa Rivera-Bloque de Jalisco) como resultado de una colaboración entre instituciones de México y España. Este experimento forma parte de una amplia investigación mar-tierra para la que se han movilizado grandes instalaciones marinas y terrestres. En la primera fase del proyecto, llevada a cabo en febrero y marzo de 2014, se han realizado 5,200 km de sísmica multicanal y se han tomado datos de campos potenciales (gravedad y magnetismo) y sonda multihaz. Se fondearon 16 OBS en 32 posiciones de registro en la zona marítima de Jalisco y Nayarit y en la zona continental de esos estados. En tierra, se desplegó una red portátil de 100 estaciones sísmicas de corto período, en 240 posiciones de registro, a lo largo de 5 líneas sísmicas de 200-300 km de longitud que funcionaron en combinación con la Red Sismológica del estado de Jalisco (SisVoc). Adicionalmente, se instalaron 9 estaciones sísmicas en las Islas Marías y en la Isla Isabel. Esos equipos registraron, en modo continuo, los disparos de aire comprimido generados desde el mar por un grupo de cañones de 5,800 c.i. a razón de un disparo cada 120 s. El buque inglés RRS James Cook, que participó en este proyecto en régimen de intercambio entre buques españoles y británicos, se encargó de la realización de los perfiles de sísmica multicanal (MCS) y del fondeo de 16 OBS. Para ello, se usó un streamer de 6 km de longitud y un sistema de cañones de aire comprimido de gran capacidad. Además de la mencionada infraestructura, participó el Buque de la Armada Mexicana ARM Holzinger y el buque de investigación mexicano EL Puma de la UNAM.
Los nuevos datos adquiridos proporcionan un muestreo denso de las placas estudiadas y aportan imágenes nuevas, nunca vitas antes, sobre la deformación cortical a lo largo y a través de la zona de subducción, las dimensiones del prisma de acreción, sobre la zona de contacto entre la placa de Rivera y la Placa de Norteamérica y sobre la transición entre la corteza oceánica y la corteza continental. En total se han realizado más de 750,000 disparos para la sísmica de reflexión, lo que supone unos 90 millones de muestras de la corteza en la Placa de Rivera y en el Bloque de Jalisco. Para la sísmica de refracción, se realizaron 80,000 disparos.

PalabrasClave: Placa de Rivera, Bloque de Jalisco, Subducción.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Travel time delays and residual topography in Northwestern South America provide constraints on upper mantle temperatures and slab geometry

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ABSTRACT

The cause of tectonic deformation of northwestern South America and their link to upper mantle structure are still actively debated. We measure seismic P-wave travel time residuals for Colombia and use them jointly with receiver function measurements to make inferences regarding the geometries and interactions of the subducting Caribbean and Nazca slabs. We used a combination of seismic data that indicates the presence of two subduction segments in the NW of South America and contrasting crustal thicknesses. Negative travel time differential residuals for stations in northern Colombia, including the Caribbean coastal plains and the Santa Marta Massif, suggests cold crust and cold upper mantle, or a thin crust, or combinations thereof. The opposite occurs for the Andean region and the Pacific coast where seismic stations yield positive travel time differential residuals. Incorporating estimates of crustal thickness from receiver functions, we corrected these relative time residuals to isolate differences in upper mantle structure between stations. In the region near the Caribbean coast, the negative delays are mainly due to thin crust (crustal thicknesses can be below ~25 km), but in the region of the Bucaramanga Nest and the San Lucas range, to the SW of the Caribbean coast line, the corrected delays are all negative. In the Andean region, there is a tendency of the data towards positive delays; near the Pacific coastline the positive differential time residuals dominate.

One way to interpret these path-integrated, mantle and lithospheric velocity anomalies that are implied by our relative travel time anomalies is in light of their possible dynamic effect, by means of the associated density anomalies and/or the induced mantle flow. Such sub-crustal anomalies will be reflected on the surface in terms of depressing or elevating topography beyond the level that would be expected from isostasy. We explore how the non-isostatic residual topography, inferred from the shallow layer structure, compares with our inferred delay time patterns. We find that most negative delay times in central Colombia are associated with anomalously low topography, perhaps depressed by a cold lithospheric anomaly, or a slab-associated downwelling. In contrast, there is a pronounced positive residual just off the east of Bucaramanga, where we also have some indication of strongly positive delay times. This anomaly may be related with a steeply subducting Caribbean slab beneath this area.

We interpret that Caribbean subduction is initially flat under northern Colombia and steepens beneath the Eastern Cordillera, which seems to be associated with the Bucaramanga nest. On the other hand, Nazca subduction seems to be associated with an asthenospheric mantle wedge, where volcanism is currently active, and thermal structure and heat flows indicate a warmer upper mantle than in the Caribbean region.

KeyWords: Colombian Andes, Caribbean Slab, Nazca Slab, teleseismic travel time residuals.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Looking for mantle plumes under the Brazilian shield: Case studies in Paraná and Borborema

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ABSTRACT

The origin of intraplate volcanism has often been explained through the presence of mantle plumes originating deep in the mantle. Mantle plumes have been successful in explaining features such as the age progression of some volcanic island chains and the formation of large igneous provinces worldwide, but cases of diffuse intraplate volcanism have proven more challenging. An excellent example is the Cenozoic volcanism of the Borborema Province of NE Brazil. The Borborema Province is regarded as part of a larger Neoproterozoic mobile belt that structured during the Brasiliano/Pan-African orogeny, which was marked by episodes of intraplate volcanism and uplift during the Cenozoic. The volcanism consists of small volumes of alkaline rocks arranged along an approximately NS trending line known as the Macau-Queimadas Alignment (MQA) and the uplifted area forms an elliptically shaped dome known as the Borborema Plateau. The stress pattern of the Cenozoic deformation, along with the time overlap with the MQA volcanism, were initially invoked to propose doming from thermal activation due to a deep mantle plume as a possible mechanism. More recently, however, small-scale convection at the edge of the continent combined with isostatic uplift by mafic underplating of the crust, and lateral flow along lithospheric thin spots from a distant, deep-seated plume in the Paraná basin of SE Brazil were suggested as plausible alternatives. Here, we investigate the presence of mantle plumes under the Brazilian shield by mapping the thickness of the upper mantle transition zone with P-to-S conversions observed in receiver functions. We focus on the Borborema and Paraná provinces, as recent broadband deployments in the regions allow for detailed mapping of transition zone topography. The transition zone is bounded by two discontinuities, nominally at 410 and 660 km depth, that originate from phase transformation in the olivine-normative component of the mantle. The depth of the transformation varies with temperature, so that variations in the thickness of the transition zone can be used as diagnostic for thermal anomalies as generated, for instance, by the passage of a mantle plume. Our results show that transition zone thickness is not anomalous in any of the two regions, demonstrating that a mantle plume origin for Cenozoic volcanism in the Borborema Province - from either local or distant upwellings - is not justified.

Key Words: Brazilian shield, upper mantle transition zone, mantle plumes, receiver functions.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Inferences about the lithospheric seismic structure of Valle de Aburra based on travel time residuals from strong motion networks

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ABSTRACT

The aim of this work is to make inferences about the seismic structure of the Valle de Aburra's Lithosphere. For this purpose P and S travel time residuals were analyzed.

P and S waves travel times were obtained taking seismic events with origin times and hypocenters reported by the Colombian Geological Survey. We took wave arrival times recorded at 17 stations from Medellin and Valle de Aburra strong motion networks. Such arrivals were recorded from 2008 through 2013, as arrivals at this interval are clear and reliable. A total of 276 travel times from 52 earthquakes were obtained. Theoretical travel times were calculated with the TauP Toolkit which is based on the $\tau(p)$ function. At this stage, three velocity models were tested in order to find the one which yielded the smallest residuals and thus represents the best fit. Those models were IASP 91 (Kenett and Engdahl, 1991), and those constrained for Colombia by Ojeda & Havskov (2000) and Vargas et al. (2003).

The models from Vargas et al. and IASP 91 are the ones that best represent the lithospheric seismic structure at Valle de Aburra. Total residuals indicate a general delay of the P-waves with respect to those calculated, except for Santa Helena Station, to the east of the valley. S waves show a shorter than predicted travel time at Santa Helena and Sabaneta (to the south of the Valley) stations. When a regional mean residual is extracted to residuals at each station, Santa Helena, Sabaneta and Ayura stations (located to south of the valley) show negative values indicating faster structure for both P and S waves.

KeyWords: Valle de Aburra, Travel time residuals, Strong motion network, lithospheric seismic structure.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Deep lithospheric features of the São Francisco craton

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ABSTRACT

Studying the thick lithosphere of cratons is important to help understand their formation and the mechanisms for their preservation. We present a synthesis of the information available for the deep structure in Eastern Brazil, from seismological and gravity data, to characterize the São Francisco Craton (SFC) and help better define its lateral boundaries at depth. Early results from deep seismic refraction lines worldwide (Durheim & Mooney, 1991) suggested that Archean cratons tended to have thinner crust and slightly more felsic average composition, compared with Proterozoic provinces, which would be accompanied by lower density, depleted upper mantle (Durheim & Mooney, 1994; Hawkesworth et al., 1990). However, more recent compilations seem to indicate a large variability in crustal properties of Archean provinces (Artemieva & Meissner, 2012), with apparently no significant difference from Proterozoic crust. Here we present the characteristic crustal and lithospheric features of the SFC.

Only one deep seismic refraction line was shot, near the central part of the SFC (Soares et al., 2006). Crustal thicknesses of the SFC are known mainly from receiver function studies and range between 38 and 42 km, except for a localized thickening (up to 44km) in the northern part, and crustal thinnning towards the Atlantic continental margin in Bahia state. Overall, the crust is slightly thicker near the geologically-defined surface boundaries (40-42 km) and slightly thinner in the center (38-40 km), which is consistent with generaly low Bouguer anomalies and high topography to the East and to the West of the craton probably defining the suture zones during the Gondwana amalgamation. A relatively thin crust (38km) occurs near the SW boundary and the Brasilia foldbelt.

Surface-wave continental-scale tomography (Feng et al., 2007) suggested the thickest lithosphere, around 200 km, to be in the Archean southern part of the SFC. This is consistent with P- and S-wave tomography in SE and Central Brazil (Rocha et al., 2011). Both the surface-wave and the body-wave tomographies show high upper mantle velocities beneath the Brasilia foldbelt, to the west of the SFC's surface limits, which is interpreted as a continuation at depth of the craton's lithosphere, beneath the low-grade external metamorphic domain of the Brasilia foldbelt.

KeyWords: tomography, receiver functions, cratonic crust, gravity anomalies.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Ambient Noise Tomography: Preliminary results at Southeast of South American Platform

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ABSTRACT

The Ambient Noise Tomography technique was employed to study the crust and the shallow mantle under the southeast portion of the South American Platform. This method was chosen due to the poor spatial distribution of ray paths which would be obtained for earthquake surface wave tomography at periods which range from 5s to 20s. In this work, we focus on Rayleigh waves which are extracted from empirical Green's functions which we obtain from the phase cross-correlations (PCC) of vertical component ambient noise recordings. PCC is based on the instantaneous phase coherence of the analytic signals and was chosen since it is amplitude unbiased. The obtained cross-correlations were then stacked using the time-frequency domain Phase Wave Stacking (tf-PWS). These methods are expected to detect and to enhance weak, but coherent signals concealed in other larger amplitude signals and to improve the signal-to-noise ratio of the final results. Here, we will present group velocity maps for periods of 8s and 15s which represent the average structure down to depth of about 15 km. Our results were discussed in terms of the geological settings and provide mapping of structures such as sedimentary basins and cratonic regions.

KeyWords: Ambient noise tomography, South American Platform, Phase Cross Correlation.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Relationship between intraplate seismicity and low velocities tomography anomalies in the Tocantins Province, Brazil

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ABSTRACT

Intraplate seismicity regions, such as Brazil, are very common, although earthquakes of larger magnitudes are rarer. The study of the intraplate seismicity is very important to help the understanding of the neotectonic processes. We present a discussion of the possible causes of intraplate seismicity in the region of Tocantins Province in Brazil from recent P- and S-wave seismic tomography results.

In the South American continent, the regional stress field is dominated by compressions in east-west direction (Zoback, 1992). The origin of this system of tensions is mainly related to the formation of the South American plate from the mid-Atlantic ridge, and resistive forces exerted by the Caribbean plate to the north and the Nazca plate forces in the west (Mendiguren & Richter, 1978; Coblentz & Richardson, 1996).

Assumpção et al. (2004) proposed a model to explain intraplate seismicity, especially in southeastern Brazil. According to this work, the high seismicity is due to the weakness of the lithosphere with his thinning. This hypothesis is based on the fact that the concentration of events coincides with tomographic low-velocity anomalies, which indicate regions of lithospheric thinning. According to the model of Assumpção et al. (2004), stresses would be concentrated uniformly in depth along the lithosphere. In intraplate regions with thicker lithosphere, the intensity of the focused stress would be smaller than the thinner regions. Thus, the crust in regions of thinner lithosphere, concentrate more intense stresses promoting a higher seismicity.

In our results, we observed for the Tocantins Province the same pattern observed in the work of Assumpção et al. (2004). The region of low velocity in the Tocantins Province center is usually accompanied by a high concentration of seismic events following the direction of the Transbrasiliano Lineament. Thus, this lineament could be reactivated by stresses accumulated in the crust due to thin lithosphere.

Assumpção & Sacek (2013) proposed that flexural stresses from uncompensated lithospheric loads are high enough to explain the seismic zone, which continues for the northern part of the Tocantins Province. The improvement of the tomography results suggest that lithospheric thinning is still important to explain intraplate seismicity in the Central Brazil.

Key Words: Seismic tomography, Intraplate seismicity, lithospheric thinning, flexural stresses.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sismicidad localizada en la región de manto litosferico de Placa Sudamericana debajo de la provincia geológica de Payenia - Sur de Mendoza - Argentina

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ABSTRACT

Las formas de onda registradas por el experimento temporal denominado Bloque San Rafael (BSR) fueron utilizadas en este trabajo para localizar y cuantificar la actividad sísmica de la región. Dicho experimento consta de 12 estaciones sismológicas desplegadas en la región enmarcada por las latitudes 34.5° y 36° Sur y las longitudes 67.5° y 70° Oeste (Figura 1).
A estas latitudes, la Placa de Nazca subduce con una inclinación de aproximadamente 27° (Anderson et al. 2007) y a un ritmo de 6.3 cm /año (Kendrick et al. 2003).
Con el fin de aportar, desde el punto de vista sismológico, al conocimiento general de la zona, se localizaron 340 eventos sísmicos ocurridos en un periodo de 7 meses (Dic./2011 y May. a Oct./2012) (Ver Figura 2). De la sismicidad analizada en la región, 71 sismos poseen profundidades entre 50 y 100 km, lo que indica que se ubican por encima de la placa de Nazca subducida, y por debajo de la corteza continental, justo debajo de la provincia geológica de Payenia. Ésta, ubicada en el retroarco andino, está caracterizada por sus extensos campos volcánicos. Payenia está integrada por más de 800 conos basálticos y unos pocos conos poligenéticos como el volcán Chachahuén, El Nevado y el Payún Matru (Llambías et al. 2010). La intensa actividad volcánica de retroarco tuvo su desarrollo a en el Mioceno, con un pico en el Plioceno – Cuaternario. Numerosos autores han estudiado esta provincia geológica con el fin de analizar y comprender su historia, evolución y comportamiento geodinámico. En este trabajo se presenta sismicidad en la región de manto litosférico de placa Sudamericana entre 50 y 100 km de profundidad, no reportada con anterioridad. La misma abre nuevos interrogantes relacionados a la geodinámica de la región.
Burd et al. (2013), utilizando datos de magnetotelúrica propone la presencia de una pluma de manto, la cual estaría correlacionada con la sismicidad estudiada. La aplicación de diferentes técnicas sismológicas (ej. resolución de mecanismos focales) a este conjunto de datos aportará en el entendimiento en la mecánica de generación de esta sismicidad.

PalabrasClave: Payenia, Sismos de profundidad intermedia, Manto Litosférico.

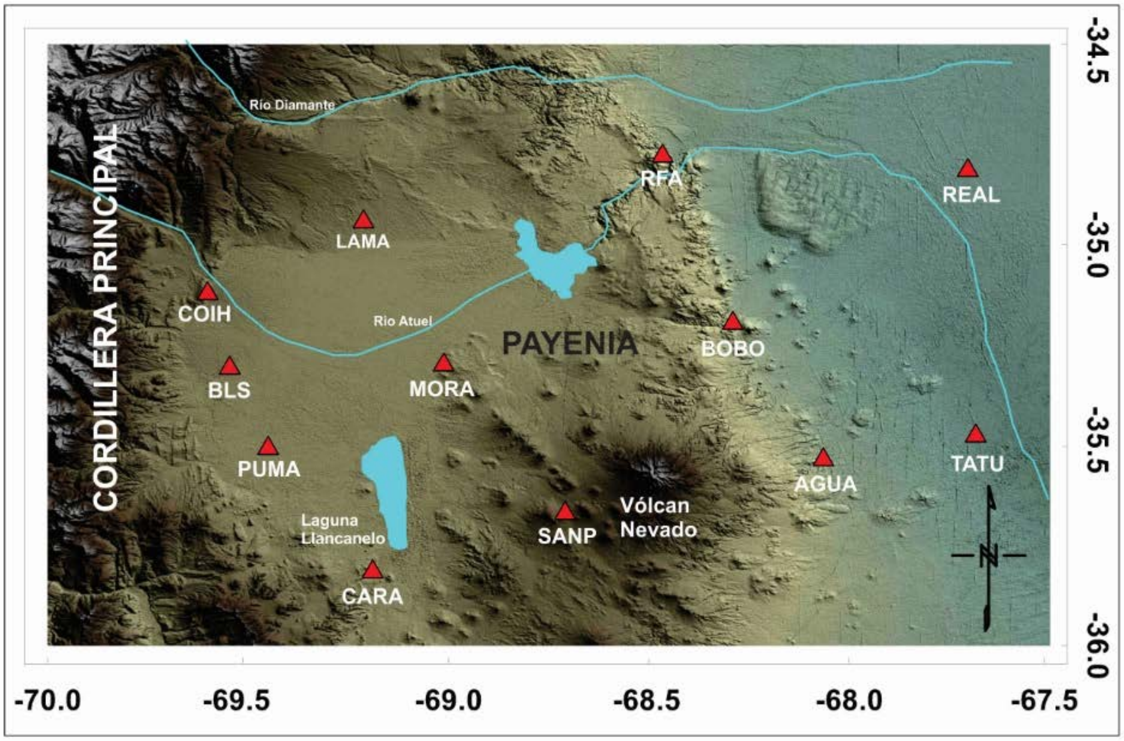

Figura 1 - Región de estudio. Estaciones sismilógicas del experimento Bloque San Rafael “BSR” (Triángulos Rojos).

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

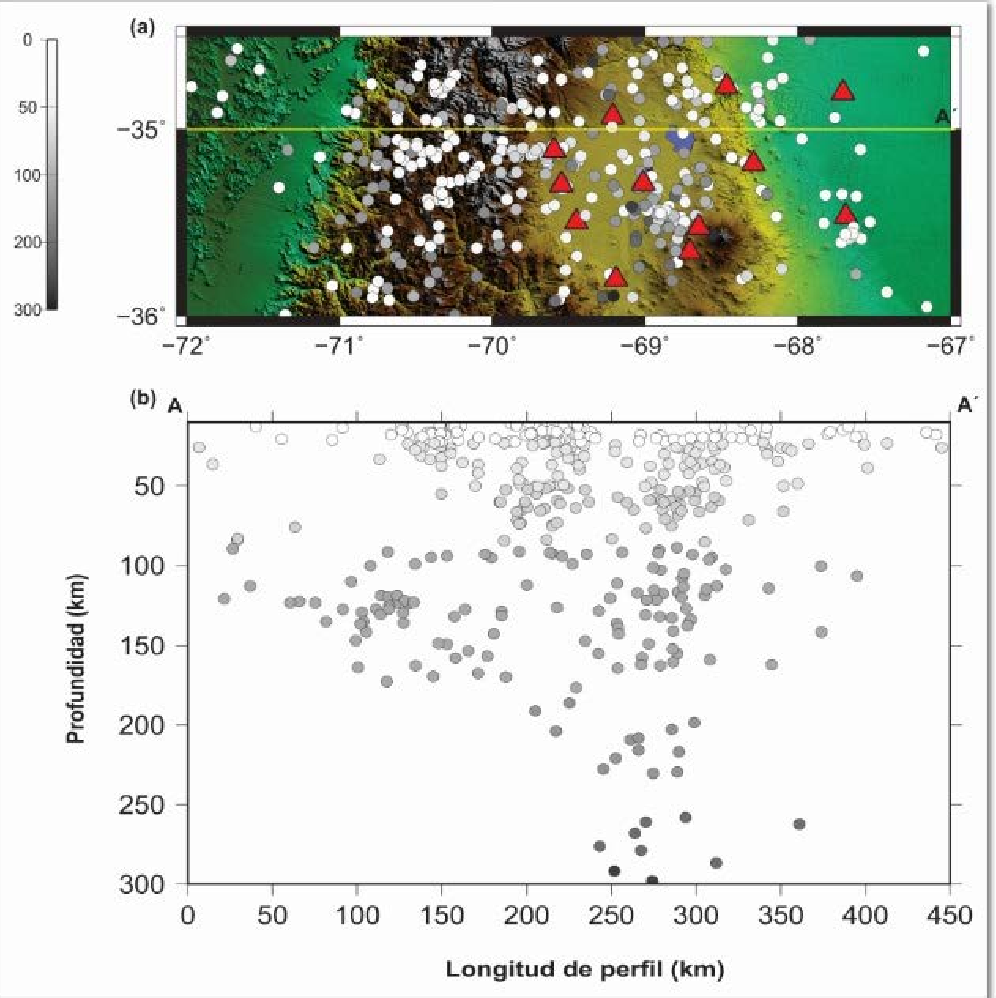

Figura 2 - (a) Mapa de sismicidad localizada en la región del experimento Bloque San Rafael (BSR), Estaciones sismológicas (triángulos rojos) . (b) Perfil AA´ donde se muestra la sismicidad localizada entre 50 y 100 km de profundidad.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Crustal and Upper-Mantle Structure of the Pampean Flat-Slab Region from Surface-Wave Tomography

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ABSTRACT

The geology of South America has been greatly influenced by subduction along its western margin. The Pampean region, located in west-central Argentina and Chile between ~28° and ~34° S, exemplifies this. This region is composed of numerous terranes accreted onto the Rio de la Plata Craton during previous episodes of subduction. Modern subduction within the region is characterized by the slab subducting to ~100 km depth before assuming a sub-horizontal geometry for over 300 km at which point it resumes a more typical angle of subduction. This unusual slab geometry, referred to as flat-slab subduction, is associated with a cessation of arc volcanism and the migration of deformation inboard from the Andean fold and thrust belt into the foreland, forming the basement-involved Sierras Pampeanas. In order to better understand the continental lithospheric structure and subduction dynamics of the region, we use broadband seismic data collected during 3 temporary deployments to produce a regional 3-dimensional shear-velocity model from ambient noise and earthquake-generated surface-wave measurements. Results show significant variations in shear-velocity within both the down-going slab and over-riding plate. Within the subducting Nazca plate, these variations are interpreted in the context of slab hydration. Shear velocities increase from west to east within the slab and decrease from west to east in the overriding mantle. We believe this represents slab dehydration as hydrous minerals within the slab become unstable and release water into the overriding mantle and that this hydration and subsequent dehydration may impact the buoyancy of the downgoing plate. Variable lithospheric structures are also within the region. Crustal thickness estimates, based on shear velocities, show thick crust beneath the high Cordillera that thins to the east. Beneath the Sierras de Cordoba, located in the far eastern portion of the study area, we observe a high-velocity body immediately beneath the crust, and interpret it as lithospheric mantle. This feature thins to the west beneath the central Sierras Pampeanas. The presence of this high-velocity feature suggests that the Rio de la Plata Craton lithosphere is largely intact while its westward thinning is consistent with little mantle lithosphere existing beneath the accreted terranes. Similar patterns in mantle-lithospheric thicknesses are observed in the southern part of the study area at 34.5° S where a more typical subduction geometry is observed, suggesting that the thin mantle lithosphere is not unique to the flat-slab region and that either a) thin mantle lithosphere has existed since terrane accretion or b) that mantle lithosphere has been removed in both regions. Overall, our results highlight the complicated interactions between the overriding plate and down-going slab and suggest that modern structure of the region is influenced both by slab dynamics and preexisting structures within the lithosphere.

KeyWords: Tomography; Subudction; Lithosphere-Asthenosphere Boundary.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Estructura litosférica asociada a la Sierra Nevada de Santa Marta a partir de datos de gravimetría, magnetometría y sismología

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ABSTRACT

La zona en la que se encuentra la Sierra Nevada de Santa Marta (SNSM) presenta una composición atípica basándose en trabajos desarrollados en geología por Tschanz (1974) y Cedielet al. (2003). Su desarrollo presenta características estructurales, geológicas y geofísicas que difieren de lo que se esperaría para esta estructura. De igual forma en la mayoría de los Andes se presenta una correlación inversa entre las longitudes de onda de la topografía y la anomalía de Bouguer (Ussami, Shitaiwa, & Landim Dominguez, 1999)), efecto que no es apreciable de igual modo en la SNSM, donde la relación es directa evidenciando así la no compensación isostática. El estudio muestra a partir de los datos gravimétricos, magnéticos y de valores de hipocentros todos estos re muestreados (kriging) desde el uso de la geoestadística, un análisis de condiciones tectónicas, donde implementa la teoría base de los modelos flexurales, la cual se desarrolla a partir de la teoría elástica de compensación isostática, donde las variables más significativas son el espesor elástico efectivo, la rigidez flexural y la magnitud de la carga, mostrando valores de deflexión no superiores a los 25 km dependiendo esto de los factores usados como variables significativas. Este resultado se corrobora desde el uso de metodologías para la determinación del espesor cortical, donde se encuentran rangos que oscilan entre 25 y 30 km, así mismo el uso de la metodología de la correlación espectral Hernandez (2006) donde se puede evidenciar altas entre la gravimetría y la magneotmetría sobre la zona de interés así como bajas en sectores aledaños, proceso que evidencia fuentes provenientes de lugares comunes. Esto se aplica en este caso para realizar un análisis de la respuesta isostática de la litosfera en la zona Caribe de Colombia, teniendo como objeto principal la SNSM y plantear una hipótesis inicial sobre las condiciones tectónicas asociadas a la SNSM, combinado para esto las diferentes fuentes y metodologías de análisis geoestadístico, gravimétrico, magnético, y sismológico.

Palabras Clave: Estructura litosférica, Sierra Nevada de Santa Marta, gravimetría, magnetometría, sismología.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Association of Mw = 6.4, 2000/06/16 and Mw = 5.7, 2003/01/07 intermediate-depth earthquakes, in subducted Nazca plate

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ABSTRACT

The Nazca plate is subducted beneath the South American plate characterized by along-strike variations in slab dip angle. The angle of subduction is ~ 27° in the studied earthquakes area (Figure 1). The intermediate earthquakes in a subduction environment have been related to pull slab forces and dehydration processes of the slab.

The Mw=6.4, 16/6/2000 and Mw=5.7 7/1/2003 intermediate depth (~ 120 km) earthquakes were analyzed. These earthquakes are closely related to each other, with the first one, which breaks the oceanic subducted crust, increasing the Coulomb static stress around ~ 1 bar in the area where the rupture of the second one began (Figure 2). The rupture of the second event was developed in the mantle and penetrated into it to about 40 km in depth.

The mechanisms were obtained by waveform inversion (Kikuchi and Kanamori, 1982, 1991, Kikuchi et al. 1993) and slip distribution using direct modeling with the same software. Coulomb static stress changes were calculated using Coulomb 3.2 software (Toda et al, 2005, Lin and Stein, 2004).

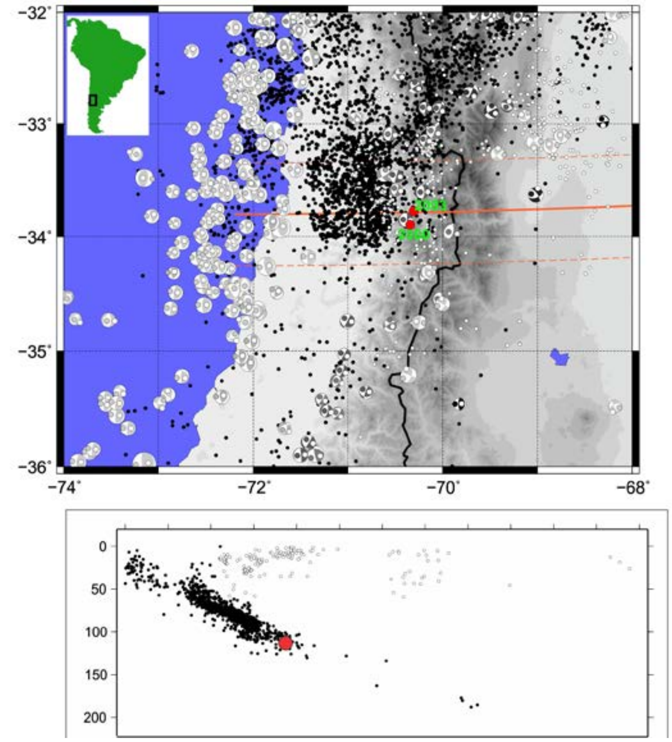
For the 2003 earthquake, the fault plane is defined by aftershocks which were determined by Marot et al (2012); while for the 2000 earthquake, we define the fault plane by association with the 2003 earthquake.

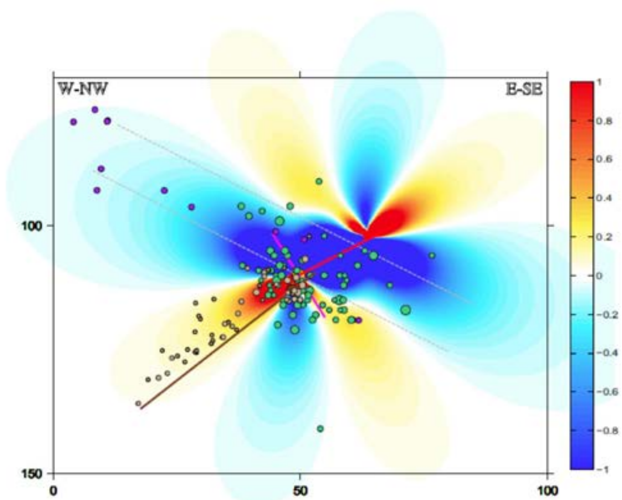
We propose that both earthquakes are related, indicating the subducted crust rupture of 2000 earthquake which promotes the rupture of 2003 earthquake on the mantle around 18 months later. The 2000 and 2003 rupture planes strike parallel to the outer rise, suggest that the crustal fault is originated in this tectonic environment.

ACKNOWLEDGMENTS

We would like to express our thanks IRIS Data Management Center (USA) for the waveforms obtained. Our research was founded by PICTO N°254 Riesgo Sísmico, 2011-2014, PICT-2011-1079 and UNSJ-CICITCA Proyect. Res.022/13-CS.

Key Words: Coulomb static stress, outer rise fault, subducted Nazca plate.


-32°
-33°
-34°
-35°
-36°
-74°
-72°
-70°
-68°
0
50
100
150
200


W-NW
E-SE
100
150
0
50
100
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

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Investigation into the Kinematics of Basement-Cored Uplifts through Passive Source Imaging of the Bighorn Mountains, United States

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ABSTRACT

Basement-cored uplifts are observed globally and remain an enigmatic feature of plate tectonics, as many of these uplifts occur distant from plate boundaries. Prominent ranges composed largely of basement-cored foreland arches include: the Sierras Pampeanas, South America; the Tian Shan, Central Asia; and the Rocky Mountains, North America. To investigate these structures, we focus on the Bighorn Range of the Rocky Mountains, United States. The Bighorn Mountains are an archetypal Laramide basement-involved foreland arch and therefore serve as an excellent setting to investigate these structures. First order questions about Laramide foreland arches include: (1) how was shortening accommodated at depth? and (2) why did arches nucleate at large distances from plate boundaries? We investigate these questions using a combination of passive source seismic methods including high-resolution receiver function imaging and ambient noise tomography.

Previous studies proposed diverse arch formation models, each of which predict a unique crustal geometry. We test these models using seismic Ps receiver functions, which isolate the signals of P-to-S conversions from subsurface interfaces, such as the Moho. We utilize a combination of two-layer receiver function thickness-Vp/Vs (H-κ) stacking and Common Conversion Point (CCP) stacking. Our results illuminate a Moho geometry discordant from Laramide structure of the Bighorn Arch. We do not see a crustal root or Moho-cutting faults. These observations do not eliminate the possibility of a mid-crustal detachment, which would decouple the upper and lower crust. The mismatch between our observed Moho geometry and the shallow Laramide arch geometry suggests a new hypothesis, a pre-Laramide origin of at least a part of the Moho geometry. The observed heterogeneity of Moho structure in a cratonic environment leads us to further explore how pre-existing heterogeneities may have influenced the Bighorn Arch nucleation. We use ambient noise tomography to constrain the azimuthally anisotropic phase and group velocity and isotropic shear velocity of the crust and upper mantle. We target specific lithospheric heterogeneities that may affect shortening including: a discontinuous high velocity (7.x layer) lower crust, the presence of large batholiths, and the boundaries between distinct cratonic environments.

KeyWords: Basement Cored Arches, Laramide, Receiver Functions, Ambeint Noise.

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Hypocentral parameter inversion for regions with poorly known velocity structures

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ABSTRACT

The determination of accurate hypocentral parameters is crucial in seismic monitoring, and is highly dependent on the accuracy of the implemented velocity model in conventional methods. A method to determine accurate hypocentral parameters based on an approximate velocity model is desirable. We introduce an iterative velocity updating scheme that can be readily combined with conventional hypocentral inversion methods. The algorithm searches for an optimum velocity model in a prescribed velocity range that minimizes the traveltime residuals. The hypocentral parameters are determined using the optimum velocity model. The proposed scheme reduces the dependence on a given velocity model in hypocentral inversion, providing reasonable hypocentral parameters based on an approximate velocity model. The feasibility and accuracy of the algorithm are tested with synthetic and field data. The scheme yields hypocentral parameters that are as accurate as those from full inversion methods but with approximately 70 times lower cost in terms of computational time. The proposed scheme can be readily implemented in any conventional method that is based on a fixed velocity model.

KeyWords: hypocentral parameters, optimum velocity model.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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RMTS session – Regional Moment Tensor Solutions: Advances and New Applications

Conveners:
Jiří Zahradník (Charles Univ. in Prague - Czech Rep.)
<jz@karel.troja.mff.cuni.cz>
Efthimios Sokos (Univ. Patras - Greece)
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Cálculo del tensor de momento sísmico a partir de la inversión de formas de onda usando el software ISOLA: Sismo de Nuquí Colombia del 13-08-2013 (Mw 6.5)

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ABSTRACT

El 13 de agosto de 2013 se registró un evento sísmico de magnitud Mw 6.5 superficial asociado a la subducción de la placa Nazca bajo la placa sudamericana en el océano pacífico colombiano. El reciente despliegue de nuevas y mejores estaciones sismológicas en el territorio colombiano, así como la adquisición en tiempo real de estaciones compartidas de otras redes, ha contribuido a incorporar nuevas técnicas para el estudio de los sismos que ocurren en Colombia. Uno de los parámetros que se estudian es el proceso de ruptura, para su cálculo se pueden utilizar varios métodos entre los cuales se encuentra el de inversión de formas de onda. ISOLA (Sokos, E. N., Zahradnik, 2008) es un paquete de software basado en el método de Kikuchi and Kanamori (1991), utilizando fuentes múltiples y que realiza una deconvolución iterativa para encontrar el tensor momento que mejor se ajuste por medio de una aproximación por mínimos cuadrados. ISOLA se encuentra desarrollado bajo MATLAB lo cual lo hace muy amigable con el usuario, posee herramientas para el preprocesamiento de los datos, preparación de las funciones de Green, inversión de forma de onda, visualización de resultados, también están presentes ayudas para inspeccionar la calidad de los datos mediante filtros, integrar las formas de onda, etc.

El evento sísmico fue registrado ampliamente, seleccionando 15 estaciones por distancia para realizar la inversión, 13 de ellas de banda ancha y 2 acelerógrafos, la calidad de estos datos fue la adecuada excepto por una de banda ancha que fue descartada a posterior. Se obtuvo un mecanismo focal de tipo de rumbo, con una magnitud de momento de 6.5 y una profundidad de 14 kilómetros. En el presente trabajo se reportan los resultados obtenidos al realizar la inversión con ISOLA, comparados con los dados por el Global Centroid-Moment-Tensor (GCMT) y el calculado con las polaridades con el software de SEISAN. También se muestran los espectros calculados de cada una de las estaciones que registraron el evento, así como la calidad de ajuste de los resultados.

Palabras Clave: ISOLA, inversión de momento sísmico, sismo, Colombia, mecanismo focal.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Moment Tensor Solution of moderate events at large distances: using Surface Waves Dispersion to build Velocity Models for the Waveform Inversion, examples from Brazil

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ABSTRACT

In intraplate regions, where there are few earthquakes, the moment tensor determination can be difficult. Sometimes, it happens because the event had low magnitude and it may not have been well recorded by enough stations. Brazil has a low seismicity compared with other regions: since 1990, around 18 earthquakes with magnitude greater or equal than 5.0 mb occurred and the maximum magnitude was 6.2 mb referring to an event in central region in 1955.

We show an example of a 4.8 mb event in Pantanal Basin in 2009 and the closest broadband station (BEB4B) was ~800 km from the earthquake. We measure the Rayleigh and Love surface waves dispersion in BEB4B to build a velocity model to perform the tensor inversion. The Moho depth and Vp/Vs was fixed from receiver function crust models (Assumpção et al., 2012). The dispersion curve adjust was made with Herrmann code (Herrmann, 2013) and the result is shown in figure 1.

We did the waveform inversion with ISOLA code (Sokos & Zahradnik, 2008; Sokos & Zahradnik, 2013) using velocity model obtained from surface waves dispersion. The epicenter was fixed and we chose Deviatoric MT inversion for the three components of BEB4B station at frequency range 0.04,0.06 - 0.1,0.12 Hz.

The result was shown in figure 2. We obtained a good fitting between real and synthetic seismograms and the P and S-waves arrival was marked in the seismograms showing that the adjusted waves were the surface waves. Since the back-azimuth between the station and epicenter is 280°, the vertical and east-west components show Rayleigh wave and north-south shows mostly Love wave. The mechanism from waveform fitting is similar to the mechanism from first-motion polarities and magnitude 4.4 Mw agrees with 4.8 mb.

The inversion of a moderate earthquake at large distance using a single station is very challenging. We showed a way to obtain a reasonable velocity model that helps to perform the inversion that may be useful in low seismicity regions.

Figure 1: Surface waves dispersion fitting (top) in BEB4B station and Vs profiles initial (left-bottom) and final (right-bottom). The colors are misfit: purple is the worst and red is the best. Black line is the weighted mean model using 10 models.

Figure 2: Event surface waves modeling using ISOLA program. In order, we have Z, NS and EW components in displacement (m) from BEB4B station (~ 800 km distance) with origin time (O), P and S-waves arrival marked. Real data is the black line and synthetic is gray. The resultant focal mechanism is shown in the top left with the depth, magnitude Mw and the frequency band used. In top right, we have the mechanism form first-motion polarities.

KeyWords: moment tensor, full waveform inversion, surface waves.

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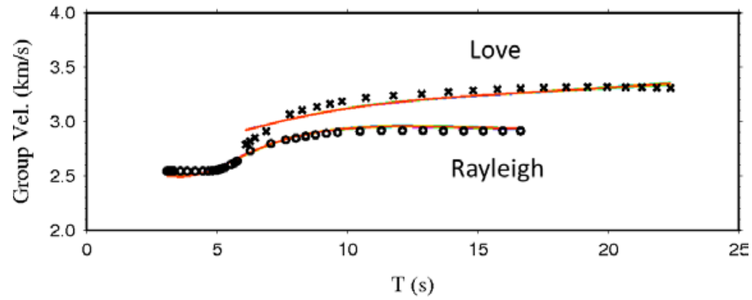

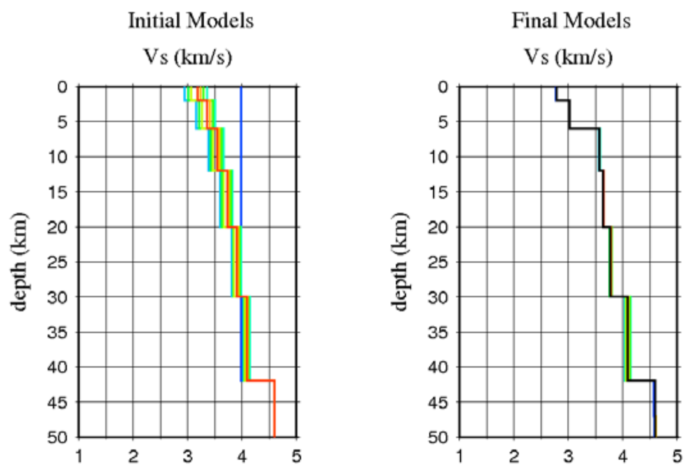

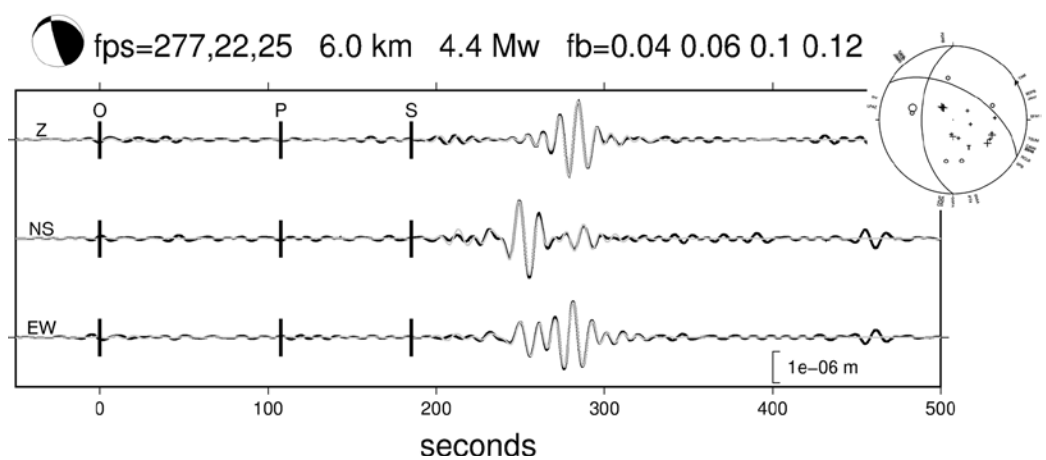

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Focal Mechanism and depth determination of earthquakes in Brazil using Teleseismic P-wave Waveform Modeling and First-Motion Polarities

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ABSTRACT

We determined depths of shallow (< 25 km) recent earthquakes with moderate magnitude (range of 3 to 5 mb) in Brazil using teleseismic P-waves modeling of P, pP and sP phases. The stations ($\Delta > 25$) were grouped according to distance and azimuth and every record was visually inspected and those with a good signal/noise ratio (SNR) are stacked and the first-motion polarities read. We usually consider groups with at least two stations, but sometimes, a good record of single station with different azimuth was also used to improve the focal depth.

We used the hudson96 program of Herrmann seismology package (Herrmann, 2013) based on Hudson (1969) to perform the modeling. One advantage of the program is the possibility of using different velocity models for the source, the path and the receiver allowing use water layers for events occurred in the ocean. The modeling is especially useful for the shallowest events (less than ~ 1 km) where the P, pP, sP phases are so close that is not possible to separate them. We used the grid-search method to do a more general search of strike, dip, rake and depth. Then we use Genetic Algoritm of Matlab to find a better solution around the grid-search output.

We are able to constrain this methodology using the focal mechanism solution of two different from literature: São Francisco craton event (4.9 mb) studied by Chimpliganond et al. (2010) and São Vicente earthquake in continental shelf studied by Assumpção et al. (2011). In the craton event, using only waveforms it was possible to recover the mechanism but in the São Vincent event we had to use the P-wave polarities to recover the depth and the focal mechanism.

For three earthquakes in the Amazon Fan: 5.3 mb in 1998, 4.8 mb in 2006 and 5.1 mb in 2007, we identified the depth phase pP by stacking teleseismic records grouped by distance and azimuth. Using refraction seismic models in the region (Watts et al., 2009) we determined a depth of 14 km for the 2007 event and 26 km for 1998 event. In the event of 2006, closer to the coast, it was not possible see the pP phase, indicating that it was a shallow earthquake. Synthetic seismograms were calculated to constrain 2 km depth.

For the event in the Pantanal basin (4.8 mb) the pP-P time difference indicates a 5.7 km depth, while teleseismic P-wave modeling gives a 6.0 km depth. This shows that the earthquake occurred in basement beneath the sedimentary basin. By modeling the teleseismic P waves we determined focal depths and compared with some previous determination available. It was shown that this technique is capable of recovering focal depth from shallow events when P, pP, sP are difficult to identify. Also, it is a useful technique to retrieve focal depth when local stations are not available, as in most cases studied in Brazil.

Key Words: Focal mechanisms, telessismic waveform.

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New strategy for weak events in sparse networks: first-motion polarity solutions constrained by single-station waveforms

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ABSTRACT

Determinations of focal mechanisms of small earthquakes (Mw 2-3) are challenging. As a rule, their signal-to-noise ratio is good only at frequencies above the microseismic noise peak (~ 0.2 Hz) and, at the same time, waveforms can be modeled only up to ~1-2 Hz at relatively near stations (up to a few kilometers). More distant stations might provide enough first-motion polarities, but the polarity solution is often highly non-unique. To overcome these problems we suggest a simple approach called ‘cyclic scanning of the polarity solutions’ (CSPS). Input data are represented by a suite of the first-motion polarity solutions from FOCMEC software. These solutions (the strike/dip/rake angle triplets) are used, one by one, and the near-station waveform is repeatedly inverted in ISOLA software for the scalar moment (by the least-squared method), source depth and time (by grid search). Each member of the FOCMEC solution suite is thus quantified by the waveform fit, and a subset of well fitting solutions is defined, which considerably reduces the uncertainty of the polarity solution. The CSPS method strongly differs from the standard single-station waveform inversions (in which the strike/dip/rake angles belong to the inverted parameters). The standard single-station waveform inversion might occasionally produce correct mechanisms, but sometimes not; as a generally ill-posed approach, it cannot be recommended as a safe tool. On the contrary, the CSPS method has a great application potential in sparse networks where weak events are recorded in many stations, thus providing polarities, but only few of the stations are situated near epicenter to allow full waveform modeling. The method has been validated on a previously studied event in the Corinth Gulf, Greece.

KeyWords: Focal mechanism, small earthquakes, first-motion polarities, single-station waveforms, ISOLA, FOCMEC, CSPS method.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic source parameters of local micro-earthquakes in Goiás State Brazil by waveform inversion

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ABSTRACT

Only few earthquake focal mechanism studies have been done in Brazil due to low seismicity associated with low density of seismograph stations. Thus a little is known about intraplate tectonic stress distribution in Brazil and active faults, which is the fundamental information for understanding seismicity and making seismic hazard studies possible. To overcome the lack of such information, in addition to the traditional technique to obtain focal mechanism solutions by using the first P-phase polarities recorded in many stations, we demonstrate how to take advantage of full waveform inversion, from few stations. More specifically, in this contribution we perform the inversion of data from weak events, such as aftershocks, recorded by local stations (epicentral distance less than 8 km). The unique feature of this work is that thanks to the short epicentral distances we are able to model the complete wavefield up to the relatively high frequencies of 2.0 Hz.

We investigate the focal mechanisms using the ISOLA package developed by Sokos and Zahradnik (2008, 2013) for local and regional events, based on the least-squares calculation of the moment tensor and grid search of the centroid position and time. The Green function calculation is based on the discrete-wavenumber method developed by Countant (1990) and Bouchon (1981, 2003). The events are aftershocks of a 5.0 mb earthquake (MMI VI) which occurred on 2010/10/08 in Mara Rosa, Goiás State, Brazil. Eleven events recorded by at least four and up to seven stations from a temporary local seismographic network, using broad band (30 s to 100 Hz) and short period (1s to 100Hz) seismometers were used. The magnitudes range from 1.2 to 2.0 mD and distances vary from 1.0 km to 8.0 km. In a previous study, Barros et al. (2012) showed a fault striking to NW-SE and dipping to NW. A local crustal model developed by Barros et al. (2012) was used in this study.

To assess the results reliability, we used several quality-control parameters, such as VR (variance reduction), CN (condition number), DC% (double-couple percentage), SNR (signal-to-noise ratio), the first-motion polarity agreement, the focal-mechanism uncertainty described by the Kagan-angle dispersion (Zahradnik and Custodio, 2012), etc. Prior to the inversion a thorough data inspection of the waveforms was done to remove data with instrumental disturbances (the so-called 'mice'; Zahradnik and Plesinger, 2005 and 2010), electronic noise, excessive cultural noise and/or any kind of equipment malfunction which could bias the inversion results.

The inversion frequency band was determined according to the SNR (the minimum usable frequency, f-low = 1.5 Hz) and according the corner frequency and velocity model resolution (f-high = 2.0 Hz). The grid-searched centroid positions (trial sources) were situated below the fixed epicenter in a depth range of about 3.8 km and in a time window of about ±3.0 sec around the origin time to allow optimization of the deviatoric moment tensor.

Good results were obtained for eight of the eleven studied events with most of the quality-control parameters meeting optimum values established in previous studies. The results are in general agreement with Barros et al. (2012), but, importantly, they also demonstrate the focal-mechanism variability among the aftershocks. The variability of the mechanisms opens door for possible stress inversions.

KeyWords: source parameters, focal mechanism, waveform inversion, double-couple percentage, deviatoric moment tensor.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Source seismic parameters of earthquakes close to FUNIL reservoir power plant in the south of Minas Gerais State – Brazil

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ABSTRACT

FUNIL reservoir is located in the south of Minas Gerais State in the southeastern of Brazil in the middle of São Francisco Craton. Close to the reservoir there are three potential sources of triggered seismicity: the lake itself, mining and water table variation due to water pumping. On August 14th, 2011, a local seismic station installed near o the reservoir, detected an earthquake of 3.2 magnitude on the Richter Scale. This event was felt more strongly in the town of Ijaci, located on the left margin of the FUNIL reservoir. On October 5th, November 13th and November 23th, 2011, Ijaci residences were again shaken by new seismic occurrences. As a result, in December of 2011, the Seismological Observatory of the University of Brasilia, in a partnership with the FUNIL Consortium, deployed a local six stations seismograph network, four broad-band and two short-period to better study this seismicity. The instruments operate in the band of 30s to 100Hz and 1 Hz to 100 Hz, respectively, and data were sampled at a rate of 100 sps.
The network operated until May 23th, 2012, and during these five months it were detected more than 1000 seismic events (natural and artificial), which 500 were located, but only about 70 with reasonable accuracy. The events were located very close to the lake and in the quarries of the region. In these areas no previous seismicity had been detected before.
The quarries make systematic detonations, most of the time, without scheduling information and when this is accomplished, it is done inaccurately. This hampers the discrimination of tectonic events from artificial events, considering the similarity between the waveforms of certain bursts with those generated by natural events in the same area. So, it is difficult to analyze the data because some explosion records are much like the records of natural earthquakes and therefore discrimination is very difficult and time consuming.
In order to get focal mechanism solution it was made a selection, according to the hypocentral location accuracy, just ten events set on magnitudes ranging from 0.3 to 1.6, and from this set it were used 5 events with magnitudes from 1.2 to 1.6 to made waveform inversion using ISOLA package.
So, the goal of this work is to present the results of source seismic parameters of the best events of the FUNIL reservoir seismic sequence using two methods, composite focal mechanism and waveform inversion, and see if their results are in agreement, as well as the to discuss how to discriminate tectonic events from artificial events.

KeyWords: waveform inversion, focal mechanism, seismic source parameters, triggered seismicity.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Modelamiento de fuente sísmica del sismo del Quindío (Colombia) del 25 de enero de 1999 usando inversión de forma de onda de cuerpo telesísmica

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ABSTRACT

El sismo de Armenia – Quindío, Colombia (M_w = 6.2) del 25 de enero de 1999, es el sismo superficial más grande registrado instrumentalmente en el Eje Cafetero Colombiano. Se localizó en las inmediaciones del municipio de Córdoba (Quindío), a 17 kilómetros de la ciudad de Armenia. Se obtuvo mediante inversión de forma de onda el área y proceso de ruptura, con registros de desplazamiento de banda ancha con ondas en el rango de 5 a 0.01 Hz. En dicho proceso de inversión se obtuvo un área de ruptura de 125 km^2, una magnitud M_w = 6.0 y una falla normal de desplazamiento lateral izquierdo de tipo unidireccional debido a que la presencia de réplicas indican que la ruptura de la falla creció con el tiempo hacia el noreste, sugiriendo una falla de este tipo; el mecanismo focal total predominante es de rumbo con componente normal, con buzamiento δ = 48.9°, azimut ϕ = 111.5° y ángulo de deslizamiento λ = -166.7° producto de dos subeventos distribuidos a lo largo del área de ruptura, el primero de ellos se presenta en τ =8 s y l=0 km y el segundo localizado en τ =26 s y l=5 km. Se obtuvo una profundidad del hipocentro de h = 20 km, un momento sísmico de 1.26 x 1025 dina*cm y una dislocación Δ_u = 0.324 m.

Se realizó la validación de los registros acelerográficos de la Red Sismológica Nacional de Colombia (RSNC) en dos estaciones, la primera de campo lejano (a una distancia de 141 km del sismo) y la segunda de campo cercano (a una distancia de 42 km del sismo) con registros sintéticos de movimiento del suelo, obteniendo un ajuste aceptable.

Palabras Clave: Sismo de Armenia – Quindío, Inversión de ondas de cuerpo telesísmica, mecanismo focal, validación.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Moment Tensor solution for a M 4.2 event in Tierra del Fuego

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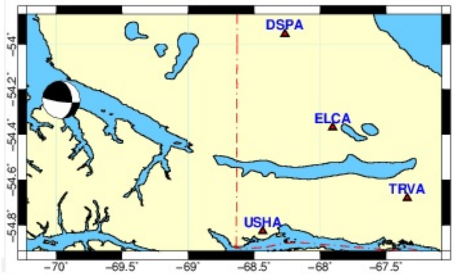
ABSTRACT

Tierra del Fuego island is divided into two continental blocks due to the Magallanes-Fagnano fault system (MFS) which represents the transform tectonic boundary between Scotia and South America plates. The main fault is a strike-slip fault with sinistral displacement.
An important low-medium seismicity related to the MFS is recorded by a local network whereas only few events and their associated moment tensor are calculated by global international networks in that area.
This work obtains the moment tensor for a moderate event (mb 4.2) using a regional crustal model and two different hypocentral parameters corresponding to ISC location and using SEISAN with local network data. The latter location was calculated for this purpose using the same crustal model as for the moment tensor and it was obtained with an rms < 0.3.
Waveforms from 4 broadband stations at near-regional distances (115-180 km) were inverted using the two different hypocenter determinations, at frequency ranges below 0.15 Hz and using the ISOLA-GUI software package. Source position was searched below the epicenter to optimize the solution.
Preliminary results show that focal mechanism obtained with the location from the local network is consistent with the regional tectonics and in general the polarity check is agree with the solution.

Key Words: Moment tensor, waveform inversion, seismicity, local network, Tierra del Fuego.


2009-11-06 local network location
2009-11-06 ISC location
Image Landsat
Data LDEO-Columbia, NSF, NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth


DSPA
ELCA
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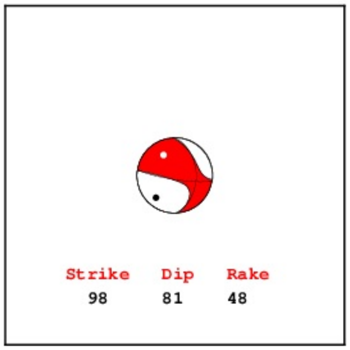
-69°
-68.5°
-68°
-67.5°


Strike Dip Rake
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Inversion of a 2-point source model of the M7.4 2012 March 20th Guerrero, Mexico

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ABSTRACT

On March 20th 2012 a M7.4 earthquake occurred in the coast of Guerrero, Mexico. Its magnitude, depth, location and focal mechanism show that this is a typical subduction earthquake. UNAM Seismology Group (2013) used strong motion records to invert the displacements on the fault. It showed a complex slip distribution with two main patches. The first and biggest patch occurred downdip of the hypocenter, this patch reaches an amplitude around 4m, while the second patch is smaller in space and amplitude. The patches ruptured at different times. These observations motivated us to try to obtain a 2-point source model similarly to Zahradník and Sokos (2014). We worked with ISOLA (Sokos & Zahradník, 2008 and 2013) in order to find a 2-point source inversion that could be congruent with the tectonic environment and with other observations. We used regional data (from ~130km up to 500 km) obtained from the National Seismological Service (SSN, for its acronym in Spanish) in Mexico. All data come from seismometers belonging to the Broad Band Network of the SSN. We found almost the same focal mechanism and centroid as those obtained from GCMT and USGS. The 2-point source spatial distribution claims for a more detailed study and the incorporation of more data. The moment magnitude value that we found is 7.4 which is congruent with other agencies.

KeyWords: ISOLA, 2-point source.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Moment-tensor solution of the intermediate-depth 2013 Guaitarilla (Colombia) Mw 6.9 earthquake using near-regional waveform data

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ABSTRACT

The Guaitarilla (Colombia) earthquake, Mw = 6.9, occurred on February 9, 2013 at the intermediate depth ~ 160km in the Wadati-Benioff zone of the Nazca Subduction in southwestern of Colombia. This event was located down-dip of the rupture zones of the 1906 Colombia (M~8.7) and the 1979 Colombia (M~8.2) thrust earthquakes in a seismic gap zone of intermediate depth. This earthquake was felt strongly in the center and southwest of the country and affected 66 municipalities in the departments of Nariño and Cauca, with a final balance of 402 houses destroyed, 3560 houses damaged and 67 schools damaged.

The source parameters are calculated with near and regional broadband and strong motions data from the national seismological and strong motion networks of Colombia. By means of inverting waveforms recorded at distances 30 km to 800 km, in the frequencies range 0.01-0.05 Hz with ISOLA code. Initially, the depth and the horizontal centroid position are obtained by grid-searching around the starting parameters using different 1D crustal models, then a possible source complexity is studied by multiple point source model. One of the possible indications of the source multiplicity is the low DC percentage (~55%). The focal mechanism is strike-slip, possibly due to the presence of an asperity. The hypocenter-centroid (H-C) method based on mutual relative position of centroid and hypocenter and the location of aftershocks are used for determining the fault plane. The reliability of the solution is established by mean of the joint assessment of the signal-to-noise ratios, variance reduction, conditional number and the space-time variability of the solution with the innovative tools of the last version of ISOLA code.

Key Words: Moment tensor inversion, intermediate depth, Colombian subduction.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismicmomenttensorsolutionsof M > 4.5 earthquakesinColombia

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ABSTRACT

TheColombianterritoryiscurrentlycoveredby42broad bandseismicstationsand30strongmotionstationsthattransmitdatainrealtimetonationalseismologicalnetwork ofColombiaoperatedbyColombianGeologicalSurvey. Thishighdensitydataallowus to retrievalearthquakesourceparametersandruptureprocess.Weestimatedthemomenttensorofearthquakeswith Mw>4.5thatoccurredbetween2012and2014inColombiaandoffshoreareas.Momenttensorinversionswerecalculatedwiththeinversionofcompletewaveformsinthe rangeof0.01 – 0.1HzusingtheISOLAcode. Theepicenters,depthsandmagnitudesestimatedbynational networkwereusedasinput,and thenthecentroidpositionanddepthwererefinedbygrid-searchingaroundthestartingparameters.Theimplementationofautomaticsolutionswasevaluatedconsideringthequalityandreliabilityofdataandthestabilityofthesolutions. The joint assessment of the signal-to-noise ratios, variance reduction, conditional number and the space-time variability of the solution allowed us to establishing the reliability of the results.

Key Words: Moment tensor inversion, ISOLA, Colombia.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Resolución y análisis de mecanismos focales de sismos corticales en cordillera entre 34.5°s y 36°s

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ABSTRACT

Se estudió la sismicidad cortical de la placa sobremontada ubicada en Cordillera Principal, Frontal entre 34.5°-36°S. Se usaron los datos del Experimento Temporal CHARGE (Chile-Argentina-Geophysical-Experiment) para lo cual las formas de ondas fueron facilitadas por IRIS*. Se localizaron 24 sismos usando el software HYPOCENTER (Liener and Havskov 1995) con el modelo de velocidad de Nacif 2012.

Se utilizó la polaridad de los primeros movimientos de la onda P e inversión de forma de onda para determinar los mecanismos focales. Solo 4 de los sismos (M>4) fueron procesados con técnicas de inversión de forma de onda mediante ISOLA (Sokos y Zahradnik 2008). El modelo de velocidad utilizado en la inversión fue el obtenido por Spagnotto 2013. Para los sismos de magnitud menor a 4 se utilizó el programa FOCMEC (Snoke et al. 1984) en una primera etapa y HASH (Hardebeck y Shearer 2002) en una segunda.

Los mecanismos focales resueltos presentan soluciones normales con componente de rumbo e inversas con componente de rumbo a profundidades que van desde ~ 10Km hasta 36Km (incertidumbre en parámetros de localización < 8Km). Los distintos métodos utilizados para obtener los mecanismos focales evidencian la necesidad de un conocimiento más exacto de la estructura de velocidades en la zona para poder aplicar metodologías de inversión de forma de onda a sismos de magnitud menor a 4.

*The facilities of the IRIS Data Management System, and specifically the IRIS Data Management Center, were used for access to waveform, metadata or products required in this study. The IRIS DMS is funded through the National Science Foundation and specifically the GEO Directorate through the Instrumentation and Facilities Program of the National Science Foundation under Cooperative Agreement EAR-0552316. Some activities of are supported by the National Science Foundation EarthScope Program under Cooperative Agreement EAR-0733069.

Palabras Clave: Mecanismos focales, ISOLA, Inversión del Tensor Momento.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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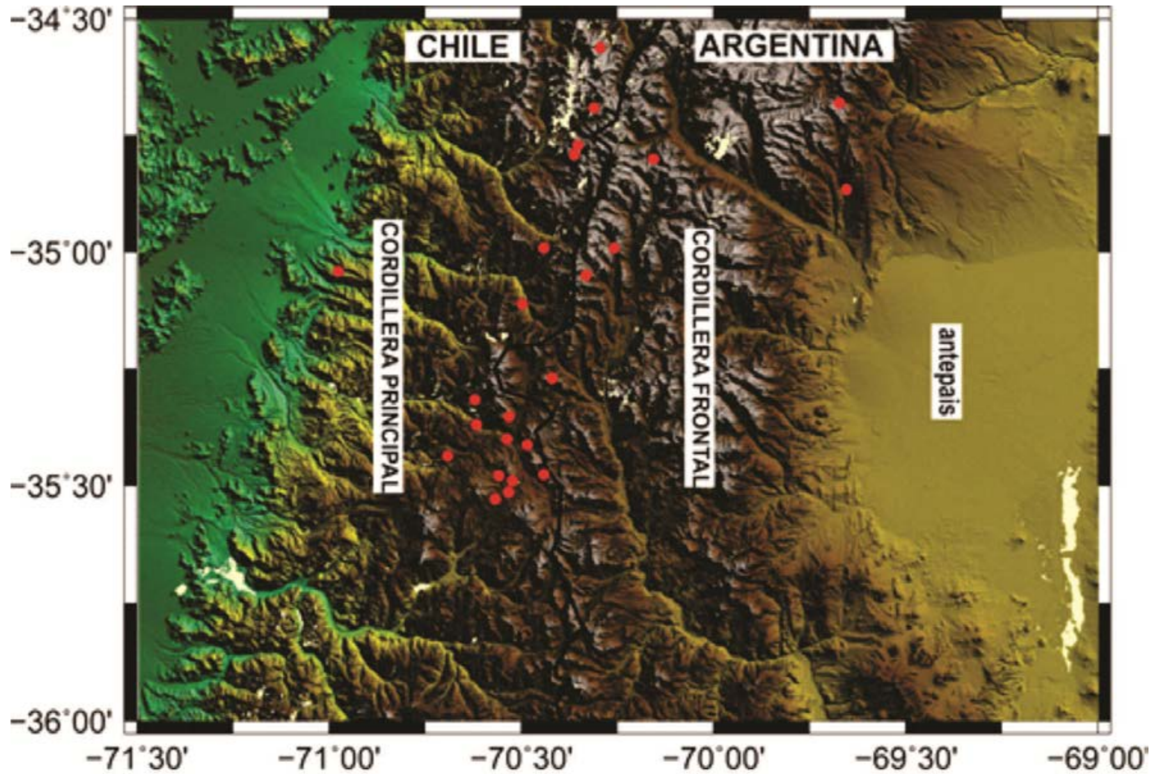

Figura 1 - Ubicación de la sismicidad utilizada en este trabajo

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Near-regional CMT and multiple-point source solution of the September 5, 2012, Nicoya, Costa Rica Mw 7.6 earthquake

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ABSTRACT

We use acceleration data from the Observatorio Vulcanológico y Sismológico, Universidad Nacional de Costa Rica (OVSICORI-UNA) and Laboratorio de Ingeniería Sísmica, Universidad de Costa Rica (LIS-UCR) seismic network for the relocation and moment-tensor solution of the September 5, 2012, 14:42:03.35 UTC, Nicoya, Costa Rica earthquake (Mw 7.6 GCMT). Using different relocation methods we found a stable earthquake hypocenter, near the original OVSICORI-UNA location in the Nicoya Peninsula, NW Costa Rica at Lat 9.6943°N, Lon 85.5689°W, depth 15.3 km (Figure 1), associated with the subduction of the Cocos plate under Caribbean plate. Acceleration records at OVSICORI-UNA (Figure 2) and LIS-UCR stations (94-171 km), at $0.03 < f < 0.06$ Hz were used in the waveform inversion for a single-point centroid moment tensor (CMT). Using spatial grid search the centroid position was found at the depth of 30 km, situated at Lat 10.0559°N, Lon 85.4778°W, i.e. of about 41 km NNE from the epicenter. The centroid time is 14:42:18.89 UTC, i.e. 15.54 sec later relative to the location-based origin time. The nodal plane (strike 318°, dip 27° and rake 115°) is the fault plane that agrees with the geometry of the subducted slab at Nicoya, NNW Costa Rica. Increasing the maximum studied frequency from 0.06 to 0.15 Hz, the multiple point source inversion model leads to two subevents. The first one was located near the centroid and the second subevent was situated 20 km along strike and 10 km down dip from the first subevent and 6 sec later. The uncertainty of the source model was carefully examined using complementary inversion methods, viz the iterative deconvolution and non-negative least squares.

KeyWords: near, free, field, acceleration, records, CMT.

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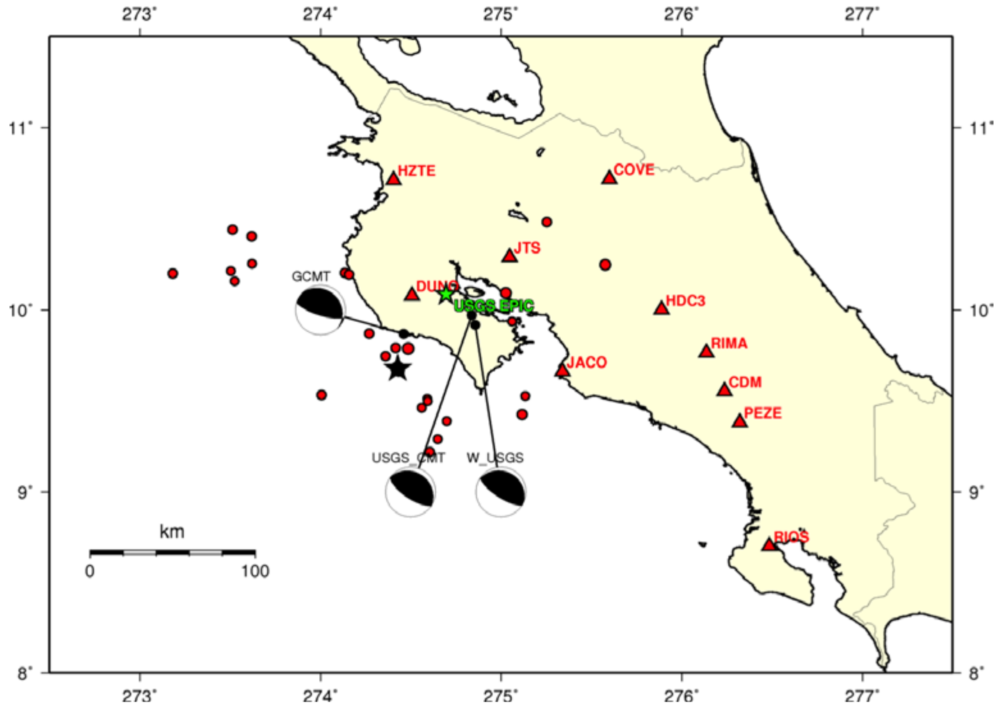

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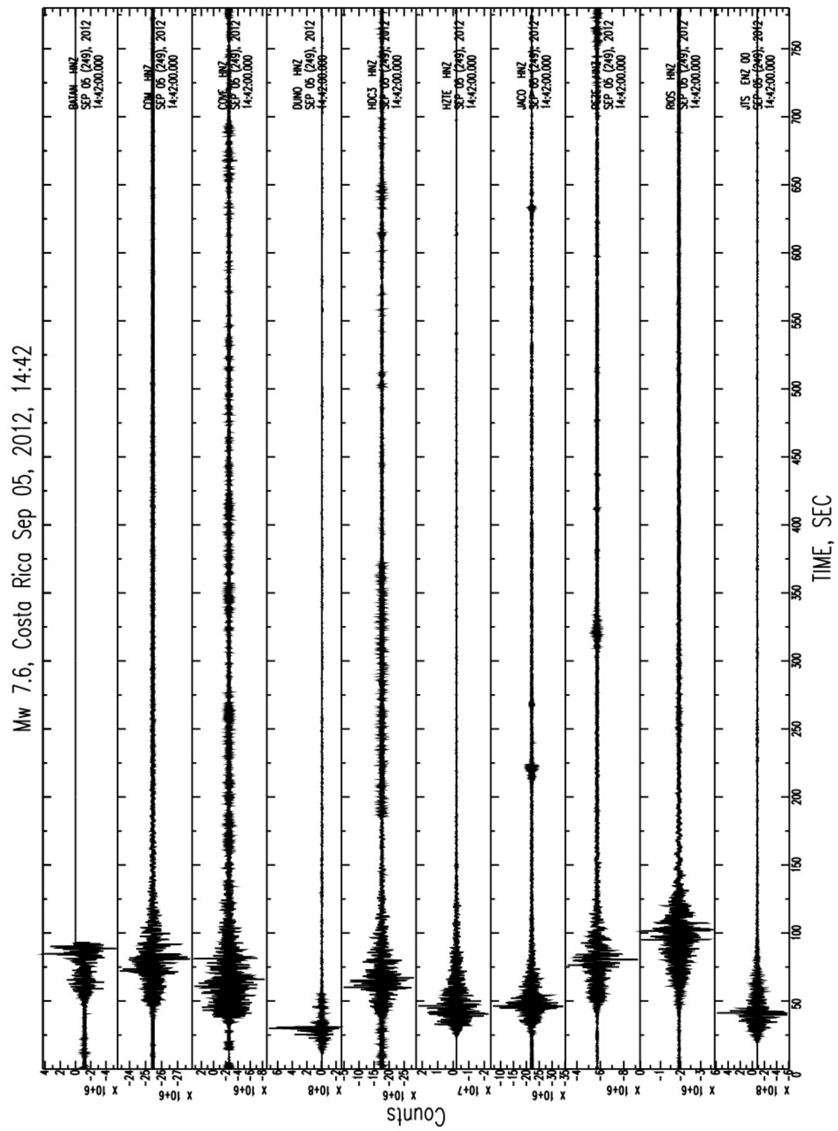

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El sismo Mw 6.2 del 27 de Febrero de 2010, Salta Argentina. Mecanismo focal y modelos de deslizamientos usando inversión de formas de ondas sísmicas e Interferometría SAR

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ABSTRACT

La sismicidad de intraplaca en la región según el catálogo de INPRES, indica que el valle de Lerma es una zona tectónicamente activa. Los sismos históricos que afectaron a la ciudad de Salta (1692, 1844, 1908, 1948 y 1973) tuvieron su epicentro dentro del Sistema de Santa Bárbara, al este del valle de Lerma. Estos eventos probablemente se encuentren relacionados con la inversión tectónica del rift del Grupo Salta (Monaldi et al., 1996; Mon et al., 2005).

El sismo de Salta del 27 de Febrero de 2010 fue el primer evento de intraplaca de magnitud mayor a 6 registrado en el valle de Lerma. Las mayores intensidades fueron reportadas en las poblaciones de Campo Quijano, La Silleta, Rosario de Lerma, Cerrillos y La Merced y dos personas perdieron la vida como consecuencia de derrumbes durante el terremoto. La proximidad temporal de este sismo con el Mw 8,8 de Maule hace suponer que podría haber sido disparado remotamente (Scott et al., 2014).

En el presente estudio se determinó el mecanismo focal, a partir de formas de onda utilizando telesismos y sismos regionales usando datos de IRIS. Para el estudio de los telesismos se utilizó Kikuchi y Kanamori software (2003) y para los sismos regionales ISOLA software (Sokos y Zahradnik, 2008). Se obtuvieron resultados similares en el mecanismo, la magnitud, y profundidad hipocentral. Se obtuvo una solución compresiva con una pequeña componente destral. Utilizando las réplicas localizadas por Sánchez (2012) y la configuración tectónica regional (García et al., 2011) se determinó que el plano de falla responsable del movimiento posee una orientación 180/32/111.

Se obtuvo además la distribución de deslizamientos utilizando inversión de ondas sísmicas e interferometría SAR (synthetic aperture radar).

Por la geometría de la solución y la localización del centroide, se propone que la fuente sismogenética se habría localizado sobre un corrimiento ciego buzante al oeste responsable del levantamiento de los cordones montañosos del Malcante, Obispo, y San Miguel, y que se conectaría con el nivel de despegue regional ubicado a 20-25 km de profundidad por debajo del cordón del Nevado de Cachi. La tip line de este corrimiento se ubicaría por debajo del valle de Lerma y estaría relacionado con las estructuras neotectónicas descriptas recientemente por García et al. (2013a y b).

PalabrasClave: sismo Mw 6.2 del 27 de Febrero de 2010, Salta; mecanismo focal; distribución de deslizamientos; INSAR e inversion de forma de onda.

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Source parameters by waveform inversion of 6.6Mw earthquake in the Nicoya Peninsula on October 24, 2012 - aftershock of the 7.6Mw main shock on September 5, 2012

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ABSTRACT

Large earthquakes with magnitudes greater than 7.5 occur with recurrence of 50 years in Nicoya Peninsula, located in NW of Costa Rica. The seismic potential of this region can be associated with stress concentration inferred by the observation of slower subduction velocity of the Cocos plate under the Caribbean plate relative to that one observed in Mid-Oceanic ridge (Reference). The first earthquake (magnitude-7.5) reported for this area took place in 1853; the second of magnitude 7.8 occurred on October 5, 1950. Recently, on September 5, 2012, another large earthquake (magnitude-7.6) shook this region with maximum intensity of VIII (MM). The epicenter was located 20km northwest of Sámara at a depth of 35km. This earthquake was widely recorded by global stations and some seismographic stations of the Volcanological and Seismological Costa Rica Observatory - National University (OVISCORI-UNA), saturated their signal. Ten broadband accelerometers and 19 seismographic stations (Trillium 120s to 100 Hz) of OVISCORI network monitored the aftershock activity. The largest observed aftershock, 6.6 Mw, occurred on October 24, 2012 at 00:45:00 UTC at a depth of 13km and its epicenter was located in southeast of Nicoya Peninsula. The time domain waveform inversion, by ISOLA software (Sokos & Zahradnik, 2008) to obtain the moment tensor used the 6.6Mw aftershock recorded in ten stations of the OVISCORI network. The waveforms in the others stations were disregarded due to saturation of signals and among these two another stations were not used for not display clear first P-wave polarities. The ISOLA methodology consists in the inversion (time domain) of complete waveform recorded by local stations for determine the seismic moment tensor (Sokos & Zahradnik, 2008). The position, time and depth for centroid were determined by successive queries in spatial and temporal domain. The results demonstrate a source with 87.3% of double-couple and 0.59 of variance reduction. It was noted that the source parameters results presented by ISOLA has close values for the same source parameters found by NEIC-USGS.

KeyWords: ISOLA, Peninsula de Nicoya, waveform inversion, moment tensor.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Alessia Maggi (Univ. Strasbourg - France)
<alessia@unistra.fr>
Victor Huerfano (Univ. Puerto Rico)
<victor@prsn.uprm.edu>
Zacharie Duputel (Univ. Strasbourg - France)
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Diseño e implentación del sistema de información de la Red Sismológica Nacional de Colombia

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ABSTRACT

La Red Sismológica Nacional de Colombia (RSNC) adquiere, procesa y administra la información concerniente a la sismicidad del País. Dicha información era almacenada en dispositivos falibles, además de requerirse procesos complejos y demorados para su consulta. Actualmente se cuenta con un sistema de almacenamiento de información más confiable y ágil, que permite la centralización de los datos y la automatización de los distintos procesos.

El desarrollo e implementación del Sistema de Información de la RSNC, incluye al grupo de la Red Nacional de Acelerógrafos de Colombia (RNAC) y al Grupo de Tectónica Cuaternaria. La RNAC hoy cuenta con un banco de datos propio, que contiene los registros de aceleración de sismos internacionales y de sismos originados en el territorio Colombiano hasta el año 2008. Esto ha permitido centralizar la información de la RNAC, agilizar la respuesta a las peticiones de los usuarios y hacer de fácil acceso la información al público en general.

El grupo de Tectónica Cuaternaria cuenta recientemente con un sistema de Información Geográfica que permite almacenar, visualizar, analizar y difundir la información tectónica cuaternaria, como fallas geológicas y pliegues. Dicha información desplegada sobre los distintos depósitos cuaternarios, complementa la evaluación de la amenaza sísmica en Colombia. Adicionalmente, este desarrollo permite la recopilación de toda la información dispersa, su centralización y puesta a disposición del público interesado en su consulta, además de permitir una posterior retroalimentación.

A la fecha la RSNC cuenta con un banco de datos que contiene los registros sísmicos desde el año 1993 hasta hoy. Además de tener la información sísmica almacenada de manera confiable y de contar con un sistema de información propio, que permite la administración de toda la información interna tal como: el estado y funcionamiento de estaciones y sus dispositivos periféricos, toda esta información puede ser consultada y descargada a través de internet.

Este trabajo tiene como objetivo presentar los productos diseñados e implementados por el grupo de Tecnologías de la Información del SGC en los últimos años y difundir los beneficios de dichos productos, para facilitar así el acceso a la comunidad científica, estudiantil y público en general a la información disponible.

Palabras Claves: Sistema de Información, banco de datos, automatización.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Determinación de la escala de magnitud local (ml) a partir de registros de banda ancha para el Perú

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ABSTRACT

Se ha generado una relación de escala de magnitud ML para el Perú basado sobre el análisis de regresión de registros simulados a Wood-Anderson, empleando 742 registros de amplitud medidos en la componente vertical. Para la solución se ha considerado 186 eventos de foco superficiales (0-60 Km de profundidad) registrados por 13 estaciones sísmicas de banda ancha de la Red Sísmica Nacional (RSN), periodo 2011-2013. El rango de distancia comprende entre 50 a 1400 km. La corrección por distancia ha sido evaluada en términos del coeficiente de expansión geométrica (a), y coeficiente de atenuación inelástica (b) siendo de 1.5489 y 0.0009, respectivamente. La nueva escala de magnitud ML propuesta para el Perú está definida por ML=Log10AWA+1.5489Log10(R)+0.0009(R)-0.1878, donde, AWA es la amplitud (mm) medido sobre un registro de desplazamiento simulado a Wood-Anderson y R es la distancia hipocentral en (km). Los resultados estimados para la magnitud ML presentan buena correlación con los datos proveídos por el NEIC. Asimismo, el valor de atenuación inelástica es similar al de California para distancias menores a 500 km y comparable con los obtenidos para otras regiones altamente sísmicas.

PalabrasClave: Escala de magnitud local, Wood-Anderson, Corrección de distancia.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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A streaming processing model for efficient computations of large continuous data sets

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ABSTRACT

Many traditional software processing models are not well suited to the large continuous, real time data streams from observatories and data centers around the world that are readily available today. Traditional software processing has tended to treat data as discrete sets that were processed in a batch mode. This has been especially true with active source exploration processing software and passive seismic event oriented processing software. The treatment of data in these traditional batch oriented software modules is not well suited to processing continuous data nor does it support the minimum latency requirements for early warning systems. This has led to a certain segregation in processing software development; continuous real-time processing vs. discrete batch processing. We present a software design methodology that provides researchers with a substrate that can be used to effect both continuous real time and discrete batch processing using the same software source coding. The software substrate consists of a set of interoperable dynamically linked modules, each running in its own thread and communicating with the other modules through specialized real time packet pipes. We provide a standardized set of import and export software modules that regularize the inner computational modules so that they can process both real time continuous and discrete data sets without the need for separate code versions. This software design methodology provides inherent threading, transparent to the application programmer, to provide maximum leverage of modern multiprocessor computer systems, as well as an architecture that can provide solutions as quickly as possible for support of early warning systems. We show real examples of this methodology, including seismic array processing, data resampling, real time spectra estimation and a particle motion based real-time detector that can identify P and S arrivals.
Autores:

Key Words: Streaming, data processing, real time.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Moment-tensor calculation for the Vega Colombia Mw 7.2 earthquake

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ABSTRACT

On September 30, 2012, an earthquake of magnitude Mw 7.2 occurred at the depth of ~170 km in the southeast of Colombia. This seismic event is associated to the Nazca plate subduction converging eastward relative the South America plate. The seismicity distribution recorded by the National Seismological Network of Colombia (RSNC) since 1993 shows a segmented subduction zone with varying dip angles. The earthquake occurred in a seismic gap zone of intermediate depth. We estimated the moment tensor, the centroid position, and the source time function. The parameters were obtained by inverting waveforms recorded by RSNC at distances 100 km to 800 km, and modeled at 0.015-0.035 Hz, using two 1D crustal models, taking advantage of the ISOLA code (Zahradnik and Sokos, 2008 and 2013). The DC-percentage of the earthquake is very high (~95%). The focal mechanism is mostly normal, hence the determination of the fault plane is challenging. An attempt to determine the fault plane was made based on mutual relative position of the centroid and hypocenter (H-C method). Studies in progress are devoted to searching possible complexity of the fault rupture process, quantified by multiple-point source models. We evaluated two sources in the frequency range 0.01-0.09 Hz.

Key Words: Moment tensor, crustal models, centroid, multiple-point source.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Comparison of manual and automatic system locations for seismic events in Panama

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ABSTRACT

The Seismic Network of Panama uses manual and automatic processing routines to determine basic location and magnitude of the local seismicity. Reliable and timely reports are delivered to risk management agencies and the community in general.
This study aims to compare the epicentral locations determined by the manual and automatic system from August to November 2013. The software used for manual processing is Seisan, from Bergen University, Norway. The automatic processing was done, using real-time data with SeisComP, developed by GFZ/Potsdam and Gempa GmBH, Germany. The results show the reliability of the automatic locations by comparing them to solutions from Seisan. We discuss the possible factors that can influence variation in locations. These results will help to improve earthquake monitoring and provide better estimates of the impact strong of earthquakes on populated areas of Panama.

Palabras Clave: manual system, automatic system, Earthworm, Seisan, SeisComP, seismic events, detections and univariate statistical analysis.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Physisc and statistics of the seismic source using first digit anomaly

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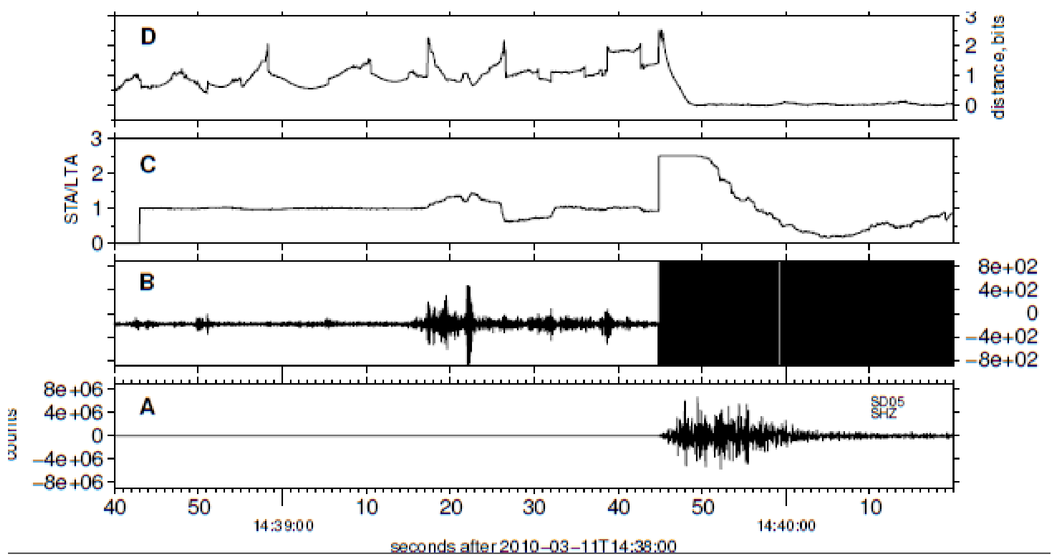
ABSTRACT

Using first digit anomaly for ground base seismicity studies under Chilean subduction environment, we face the problem of identification of a seismic signal, under a superpositionof events environment, through the development of an algorithm of detectionbased on a statistical pattern, linked to Shannon's entropy, obtained from firstdigit anomaly present in seismograms. This detection method, exploits aninformation invariant contained in the seismic signal, which is independent ofthe size of events, at least in the range accessible to our observations. Using nearfield data belonging to the 11/3 2010 Pichilemu aftershock, we compared theperformance of the proposed trigger versus a generic STA/LTA algorithm. Ourfindings show that both algorithms are complementary, and its simultaneous useincreases the efficiency of detection. We propose this strategy of recognition,well adapted to the processing and analysis needs imposed by today's massseismic recording capacities, might also be important for early warningsystems.

Key Words: first digit anomaly, early warning.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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Use of the first digit anomaly in background seismicity studies under Chilean type of subduction environment

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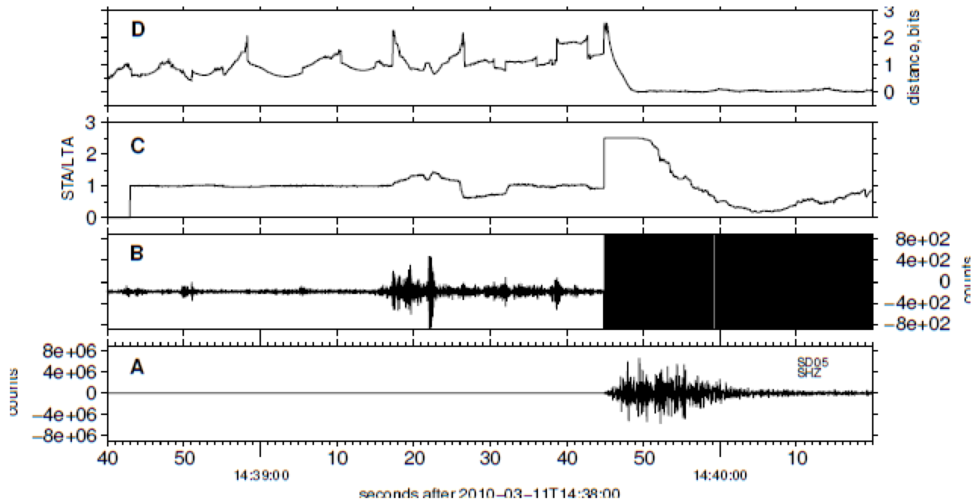
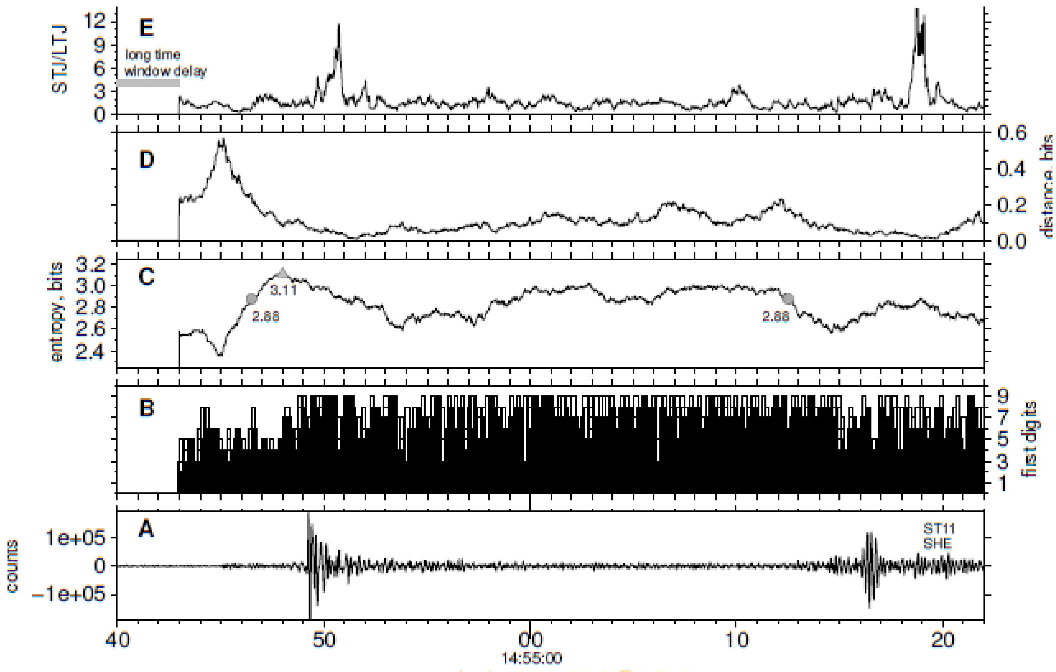
ABSTRACT

Using first digit anomaly for ground base seismicity studies under Chilean subduction environments we face the problem of identification of a seismic signal, under a superposition of events environment, through the development of an algorithm of detection based on a statistical pattern, linked to Shannon's entropy, obtained from first digit anomaly present in seismograms. This detection method, exploits an information invariant contained in theseismic signal, which is independent of the size of events, at least in therange accessible to our observations. Using near field data belonging to the11/3 2010 Pichilemu aftershock, we compared the performance of the proposedtrigger versus a generic STA/LTA algorithm. Our findings show that bothalgorithms are complementary, and its simultaneous use increases the efficiencyof detection. We propose this strategy of recognition, well adapted to theprocessing and analysis needs imposed by today's mass seismic recordingcapacities, might also be important for early warning systems.

Key Words: first digit anomaly, triggers.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Implementación del cálculo de los de los parámetros de la fuente sísmica mediante el método de la Fase W, en el SGC

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ABSTRACT

La necesidad de conocer rápidamente los parámetros de la fuente sísmica para dar información oportuna que permita a las entidades del Sistema Nacional de Gestión del Riesgo de Desastres tener herramientas para declarar una alerta por tsunami, llevó al SGC a implementar el software de la fase W (Rivera, Kanamori, 2009).

La fase W es un algoritmo de inversión de la fuente sísmica el cual usa la fase W de eventos distantes, esta fase es de periodos muy largos principalmente entre 100 y 1000 segundos, que se registra en la estación al mismo tiempo que la onda P. Debido a estos periodos largos y a que es registrada entre la onda P y las ondas superficiales, la fase W puede dar una rápida y confiable información sobre los parámetros de la fuente para grandes eventos.

El sistema de procesamiento automático de eventos sísmicos desarrollado por el "West Coast Alaska Tsunami Warning Center (WC/ATWC)" llamado EARLYBIRD, ha sido implementado en el SGC para obtener localizaciones automáticas de eventos sísmicos locales y regionales. Para sismos con Magnitud de momento de onda P (Mwp) $\geq$ 6, se ha creado una rutina que hace la extracción automática de las formas de onda, envía la localización automática al programa de la fase W para el cálculo de los parámetros de la fuente sísmica, este hace la inversión y envía la solución a una lista de correos electrónicos.

Mediante el método de la fase W se han calculado los parámetros con estaciones del SGC e internacionales para los sismos del 5 de enero de 2014, Mw 5.5; el 17 de febrero de 2014, Mw 5.4 y el 9 de marzo de 2014, Mw 5.6; los cuales son similares a los reportados por el CMT (Global Centroid-Moment-Tensor).

Mediante este método se han identificado estaciones que no se pueden usar para el cálculo de la fase W, estaciones con ruido, archivos de respuesta que se deben mejorar y la forma de adquisición de las señales. Estos datos son útiles para diagnosticar el estado de las estaciones y poder de esta forma implementar correctivos para su mejoramiento.

Palabras Claves: Fase W, tsunami, EARLYBIRD.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Evolución tecnologica de la Red Sismológica Nacional de Colombia - RSNC - y la Red Nacional de Acelerógrafos de Colombia - RNAC- del Servicio Geológico Colombiano

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ABSTRACT

La Red Sismológica Nacional de Colombia -RSNC- y la Red Nacional de Acelerógrafos de Colombia – RNAC- adquieren, procesan y almacenan la información sismológica del país desde sus inicios en 1993. La tecnología para llevar a cabo estos procesos, ha ido evolucionando, permitiendo suplir los requerimientos por parte de las diferentes áreas temáticas y logrando una mejor calidad de los datos sísmicos para el procesamiento y apoyo a los procesos de investigación. Actualmente se cuenta con software y hardware que permite estar a la vanguardia con tecnología de punta y poder suplir las necesidades de gestión y administración ofreciendo una alta disponibilidad en la difusión y entrega de los datos.

Este trabajo tiene como objetivo presentar y dar a conocer cómo se obtienen los datos sísmicos en la RSNC y RNAC, los sistemas de adquisición, procesamiento y almacenamientos de los datos y la evolución de TI en los últimos años. Este tipo de tecnología nos permite dar a conocer a la comunidad científica y estudiantil datos de calidad entregados por el Servicio Geológico Colombiano a través de la RSNC y la RNAC.

Palabras Clave: Adquisición, Procesamiento, Tecnologías de la Información TI.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Near real-time earthquake source characterization through joint geodetic and seismic approaches at the US Geological Survey National Earthquake Information Center

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ABSTRACT

The United States Geological Survey (USGS) National Earthquake Information Center (NEIC) provides real-time earthquake locations and magnitudes for global events >Mw4.5 and generates impact assessment and scientific information for large and potentially damaging earthquakes. These products include ShakeMap, PAGER, finite fault models, moment tensors, and regional geologic background information. Currently, impact assessment products depend on models generated from regional and teleseismic waveform observations to provide information on the earthquake slip distributions. In many cases, geodetic observations of ground deformation from global positioning systems (GPS), Interferometric Synthetic Aperture Radar (InSAR), and optical imagery pixel tracking place additional constraints on the spatial properties of an earthquake, including location, source dimensions, and depth. These constraints help to both reduce uncertainties in teleseismic waveform inversions and provide a benchmark for calibrating seismic locations. In this presentation, we review current efforts to incorporate geodetic observations into global, real-time earthquake monitoring and assessment, and highlight recent successes from the 2014 Mw8.2 Iquique and 2013 Mw7.7 Pakistan earthquakes. These two examples demonstrate the capabilities of geodetic observations to better inform models of perceived shaking and damage for offshore and complex geometry ruptures. We also address the current major setbacks to near real-time geodetic monitoring – specifically time latency in real-time operations, data coverage, and inversion methods. Forthcoming InSAR missions will provide a vital data line for many tectonically active locations in South and Middle America, but temporal resolution will be a significant limiting factor in the applicability of these observations to earthquake monitoring. For these reasons, the continued development of continuous, high-rate GPS networks, like COCONet, with open data access to the earthquake response community will play a vital role for future event response.

KeyWords: Real-time earthquake response, geodesy.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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SHLC session – Seismic Hazard in Latin America and the Caribbean: Working Across Border

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Hacia un catálogo actualizado de terremotos de Sur América: ventana temporal pre-1930

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ABSTRACT

En el marco del proyecto "SARA" (The Seismic Risk in South America), el tópico 4 está compilando un catálogo de terremotos para América del Sur, incorporando los datos disponibles del CERESIS (1985) que se realizó bajo el proyecto SISRA (Mitigación de los terremotos en la Región Andina), los más recientes estudios nacionales e internacionales y los análisis realizados en el transcurso del proyecto. En particular serán considerados las últimas versiones del catálogo del CERESIS-91 elaborado para el Instituto Panamericano de Geografía e Historia (IPGH), el cual posteriormente fue empleado por el mismo CERESIS en su vinculación al Programa Mundial de Evaluación de Riesgo Sísmico (GSHAP); determinación de parámetros por estudios recientes, incluyendo aquellos propuestos por el catálogo ISC-GEM, y cuando esté disponible, los catálogos nacionales que cumplen con los criterios de transparencia exigidos por el proyecto. Las actividades se han iniciado a partir de la ventana temporal pre-1930.

Siguiendo la metodología descrita en el programa de investigación y discutido durante la reunión inicial del proyecto (Bogotá, 20-22 de noviembre del 2013), el primer objetivo ha sido la elaboración de un inventario crítico de todos los estudios públicos relativos a los eventos de Sur América. Los estudios relativos al mismo evento han sido asociados entre ellos por medio de un procedimiento semi-manual a partir de la comparación del tiempo de origen, de las coordenadas del epicentro y del tamaño del terremoto. Para cada evento ha sido seleccionado, de manera preliminar, un conjunto de parámetros considerados confiables.

El problema principal del catálogo consiste en la necesidad de expresar los valores de magnitud en términos de Mw. Actualmente, pocos estudios relativos a pocos terremotos proveen dicho valor (Choy et al., 2010; Beauval et al., 2013). Para muchos eventos están disponibles valores en términos de Ms o mb, a pesar de que para la mayoría de los casos, en la ventana temporal considerada, estos valores de magnitud son calculados a partir de datos macrosísmicos. Para estos terremotos se está investigando la utilización de relaciones de conversión (Mw/Ms y Mw/mb) más comunes a nivel internacional (Scordilis, 2006; Storchak et al.,

2012), y posiblemente alguna relación determinada localmente.
Asimismo están los eventos para los cuales existe un valor de Imax o Io. Para estos eventos, a partir de la experiencia que se ha logrado en Europa (Stucchi et al, 2012; Grünthal et al., 2009), se está buscando determinar relaciones Mw/Io de carácter regional, utilizando los datos más confiables y recientes en términos de Mw e Io. En una segunda fase, para algunos eventos que tienen un número suficiente de datos macrosísmicos, se está tratando de determinar los parámetros de terremotos utilizando el método de Bakun y Wentworth (1997) calibrado regionalmente, sobre la base de lo que ya se ha llevado a cabo por Beauval et al (2010), Palme et al. (2005) y otros.

PalabrasClave: terremotos, catálogo, Sur América.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Parámetros del terremoto de Cúcuta del 1875 a partir de intensidades macrosísmicas

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ABSTRACT

San José de Cúcuta capital de la entonces provincia de Santander (Colombia) fue muy destruida por el terremoto del 18 de mayo de 1875. El sismo ocasionó fuertes daños en la zona limítrofe Colombo-Venezolana que corresponde a hoy al departamento del Norte de Santander en Colombia y el estado del Táchira en Venezuela. El evento del 1875 ha sido objeto de muchos estudios en literatura. Uno de los más recientes estudios de tipo histórico y macrosísmico es propuesto por el Servicio Geológico Colombiano y Universidad Nacional de Colombia (2012) el cual asigna 41 puntos de intensidad en escalas EMS98 y MM. La intensidad máxima es clasificada con valor 10 en las localidades de Villa del Rosario, San José de Cúcuta y San Antonio del Táchira. A partir de dicho estudio, el presente trabajo modela la localización y la magnitud del sismo del 1875 aplicando el método de Bakun and Wentworth (1997) y la relación de atenuación de intensidad macrosísmica calibrada en magnitud momento Mw propuesta por Palme et al. (2005) para los andes de Mérida. De manera preliminar, la magnitud obtenida es Mwi=7.1±0.2 con centro de intensidades entre Villa del Rosario y San Antonio del Táchira. Modelación de bootstrap están siendo realizada para analizar la confianza de la localización y grandeza del evento.

Palabras Claves: terremoto histórico, intensidad macrosísmica, parámetros del terremoto.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismotectonic and seismic hazard implications for South Africa

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ABSTRACT

Though South Africa is considered to lie in a stable continental region, earthquakes are recorded and located daily. Earthquakes have been recorded that caused severe damage to infrastructure in nearby towns, farms, underground mines and even deaths in some circumstances. These events have serious hazard implications especially to cities within South Africa were building and infrastructure are built with little emphasis on seismic hazards. The 1969 Ceres earthquake of magnitude 6.2, resulted in the deaths of 12 children as well as damage worth $20 million in the Ceres/Tulbagh area near Cape Town in South Africa. Therefore, it is necessary that we consider the effects of these events in the design of our infrastructure. The seismotectonic map for South Africa will assist in delineating seismic hot spots in order to carry out a proper seismic hazard assessment. The map will enable us to conduct reliable seismic hazard and risk studies for our region using state of the art methodologies. In preparing the map, fault plane solutions were obtained from publications, reports and international organizations such as the ISC, USGS etc. Though few such data are available for southern Africa, all collected information is vital in the effort to understand the tectonics of the region and was used in the modeling of stress orientations of the region. Through these efforts, a draft of the seismotectonic map of South Africa has now been prepared. Investigations are also being carried out to study the possible impact of the collected information on the seismic hazard of southern Africa. Previous regional efforts such as GSHAP used large area source zones without considering the influence of active faults in the assessments. Thus the information in the seismotectonic map will contribute to the preparation of more accurate hazard assessments. Included in this presentation are results of preliminary hazard assessments for southern Africa that show the impact of including faults in the source model.

We continue to collect and improve collection methods of historical and instrumental seismicity data, as well as geological information to improve the seismotectonic model for our region.

KeyWords: Seismotectonic, Seismic hazard, South Africa.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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PSHA at a regional scale: European SHARE project versus Italian reference PSHA. And the winner is…

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ABSTRACT

Seismic hazard does not know political border, because faults and earthquakes do not need passport for crossing customs. For this reason, when evaluating seismic hazard at national scale it's necessary to extend the investigation to a wider area, for taking into account possible seismic sources abroad that could contribute to the hazard.

The European SHARE project (http://www.share-eu.org) had the aim of release a homogenized seismic hazard model, where homogenized mainly means a uniform level of knowledge and accuracy across the whole investigated area, by involving researchers from all countries.

Many researchers were involved also at national scale for assessing seismic hazard that is adopted by building code (Swiss and Italy among others).

The question that arises is about the comparison between the two models: are the European and the Italian models consistent each other for the overlapping areas? Are the differences in the models within the aleatory uncertainty or not? It is necessary to update of seismic code in Italy after the release of the SHARE model?

Looking only at PGA with 10% of probability of exceedance (considered the standard), SHARE model shows increased expected values with respect to the Italian reference model (Stucchi et al., 2011), up to 70% more than what adopted in national building code. Looking in detail at all parameters of both the models, it is possible to observe a different behaviour for other spectral accelerations and for several probability of exceedance. For spectral periods greater than 0.3 seconds the existing PSHA for Italy proposes values higher than the SHARE model for many and large areas. The observation of a non-generalized increase of expected values suggests that this behavior is not linked to a different definition of seismic sources and relevant seismicity rates, but this is the result of the adoption of recent GMPEs that propose higher values for PGA and spectral periods less than 0.3 seconds and lower values for periods greater than 0.3 seconds.

Many tests have been performed and they seem to confirm the large impact of the new generation ground motion predictive equations on the seismic hazard we obtain today.

The result of this analysis appears to be consistent with the observation by Bommer and Abrahamson (2006).

Even if the SHARE model was not released for replacing the existing national hazard maps, the impact of the new seismic hazard model if adopted in the Italian building codes will be also discussed.

KeyWords: Seismic Hazard, Building code, Europe.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Respuesta dinámica de suelos para Managua/Nicaragua

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ABSTRACT

En dos distritos de Managua, Capital de Nicaragua, se realizaron 1045 puntos de medición de la amplificación del suelo basados en el método de Nakamura, Las mediciones del ruido cultural para cada punto de medición se efectuaron utilizando un acelerógrafo de tres componentes de la marca ETNA/Kinemetrics. Se realizó el proceso de análisis de los datos y se obtuvieron resultados en forma de mapas zonificados.

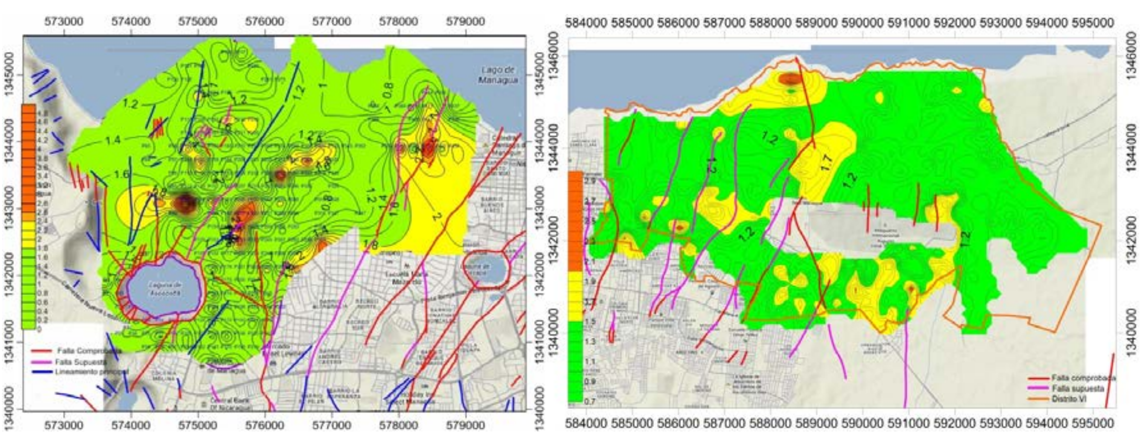
El resultado final son mapas de iso-amplificaciones del suelo. Para ambas zonas estudiadas se muestran mapas en la figura.

Las amplificaciones se muestran en los mapas con zonas en colores verde, amarillo y color naranja. Las zonas con color verde amplifican hasta el factor 1.5, las amarillas entre 1.5 y 2 y las zonas en color naranja mayor que 2.

Estos resultados pueden ser utilizados para actualizar el código de construcción de las zonas específicas.

El trabajo fue llevado a cabo, en 2013, con el auspicio del proyecto DIPECHO VIII y Cruz Roja.

Palabras Clave: Respuesta dinámica, Suelo, Managua, Nicaragua



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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Challenges to developing a unified earthquake catalog for seismic hazard assessment in South America – Addressing magnitude homogenization and depth uncertainties

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ABSTRACT

Constructing a unified earthquake catalog is an important step in developing regional seismic hazard models in South America with a broad seismotectonic environment that includes very active subduction zones and fault systems as well as stable regions. Several earthquake catalogs (international: GEM, USGS NEIC, GCMT, ISC, etc.; and regional: CERESIS, IGEPN, RSNC) provide records of seismicity, characterized by different magnitude types and uncertainties. We evaluate the completeness and quality of each catalog for the purpose of merging multiple data sources into a high-quality comprehensive historical catalog. Challenges include homogenizing magnitudes to a common magnitude scale and addressing uncertainties in hypocenter location and common default values reported for focal depth. Here, we present the sensitivities of magnitude-rate distributions (i.e. recurrence periods) - at the level of seismic source zones - to these procedures and their underlying assumptions.

One challenge in developing a comprehensive catalog is the homogenization of magnitudes to a single magnitude scale, in this case, the moment magnitude scale, Mw. Reporting agencies provide magnitude data on many different scales (Mw, mb, MS, ML, MD, etc.). Many authors have published global relations connecting magnitude scales (e.g., Scordilis et al., 2006, GEM Homogenization equations). However, scaling equations are varied and many employ simple linear regressions, which have a potential to induce systematic errors in magnitude conversion, introducing apparent catalog incompleteness and bias to magnitude-frequency distributions. We use the ISC Bulletin, which provides a compilation of magnitudes from different reporting agencies for each earthquake, to develop general orthogonal regressions (GOR) for scaling to Mw. We compare GOR models for South America data for each catalog (reporting agency) at seismic source zone levels to global equations, applying both to assess the impact of these approaches on magnitude-rate distributions.

In building a unified catalog, attention must be given to uncertainties in the focal depth in order generate a realistic view of potential ground motions. Catalogs often provide default depth solutions when hypocenter depth cannot be well-determined. In order to constrain the realistic depth distribution of seismicity in a source zone, we present a magnitude- and location- dependent bootstrap methodology for resampling default depths using available, well-determined depth data. We show the impact of this procedure on recurrence rates for shallow and deep seismicity.

KeyWords: magnitude homogenization, unified catalog, recurrence.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic Activity in the Pantanal Basin - BRAZIL

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ABSTRACT

The Pantanal is a sedimentary basin of Quaternary age, tectonically active, positioned in the Hidrografhic Basin of AltoParaguai, Center-West Region of Brazil. The basin of the Pantanal is a region sismogenic intraplate environment. The two largest earthquakes recorded were the Miranda 1964 and Cushion 2009, with magnitudes 5.4 and 4.8 respectively and depth around 5Km, both results transpressive / compressive stress. Despite being a region of subsidence, the neotectonic stresses in the upper crust are compression. The Federal University of Mato Grosso do Sul (UFMS), through Aquidauna Campus (CPAq), is participating in the Integrated Brazil Seismograph Network (BRASIS) at the University of São Paulo (USP) and the Project " Lineament Transbrasilian: origin, evolution and influence on Phanerozoic sedimentation basins " at the University of Brasilia (UNB), aiming to understand the seismic activities in the Pantanal region and relate the structure of the lithosphere with the record of earthquakes. Currently the state of Mato Grosso do Sul, has three seismographic stations: Aquidauna (AQDB), Plain of the South (C2SB) and Sonora (PP1B).
Aiming at monitoring sites originated in the Center-West region of Brazil telessismos mainly the Andean mountain range, and regional earthquakes, in addition to training and qualifying skilled labor in geodynamics and seismicity of the lithosphere. It is expected that more detailed studies of seismicity in the Pantanal with more stations, as AQDB, PP1B and C2SB, allow delineating the regime of active efforts in the basin and its surroundings. Seismic / subsurface geologic informationon the basin of the Pantanal are far from satisfactory. Many questions still remain on its origin and evolution, highlighting their structural framework, neotectonics and the role of Lineament Transbrasilian since the epicenters of earthquakes in the Pantanal are aligned with the epicenters of the region Goiás, suggesting a relationship with Lineament Transbrasilian (Zone shear) of NE-SW direction.

Key Words: Pantanal Basin, Seismic Activity, Brazil.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Microzonificación para diseño por sismos para la ciudad de Panamá, Panamá

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ABSTRACT

Empleando sismógrafos de banda ancha se hicieron mediciones de ruido en 239 sitios de la ciudad de Panamá por espacio de al menos 30 minutos cada una. Para seleccionar las zonas de medición se empleó información geotécnica y registros de aceleración realizados en estudios de respuesta de sitio anteriores. Fundamentados en el mapa geotécnico desarrollado por Palma (2007), se desarrolló un nuevo mapa geotécnico para la ciudad de Panamá que toma en cuenta las zonas de relleno artificial, Del análisis de los datos también se desarrolló un mapa de periodos dominantes con rangos de la amplificación relativa para la Ciudad de Panamá, el cual valida las zonas con mayor peligrosidad sísmica, ya que nos muestra espacialmente el efecto de sitio de los 239 puntos analizados.
A partir de los espectros obtenidos se crearon familias espectrales proponiéndose la clasificación los suelos de la Ciudad de Panamá en cuatro zonas que son las siguientes:
Zona Firme, o zona estable para cualquier tipo de infraestructura. Corresponde a la zona de colinas y lomas bajas donde las FTE carecen de amplificación relativa.
Zona Alta, zona inestable para viviendas entre 1 a 3 pisos y con curvas de isoperiodos entre 0.1 a 0.2 segundos.
Zona Transición, zona inestable para viviendas entre 3 a 4 pisos y con curvas de isoperiodos entre 0.2 a 0.3 segundos.
Zona Baja, zona inestable para viviendas entre 4 a 6 pisos y con curvas de isoperiodos entre 0.4 a 0.5 segundos.
Utilizando el nuevo mapa geotécnico de la Ciudad de Panamá y las microzonas, se presenta la primera propuesta de microzonificación para diseño por sismos para la ciudad de Panamá.

PalabrasClave: amplificación del suelo, microzonación sísmica, respuesta de sitio, mapa geotécnico, isoperiodos.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Teleseismic waves registered at the seismographic station of Aquidauana / MS /BRAZIL (AQDB), in 2013.

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ABSTRACT

This project aims to monitorate seismic waves generated from more than 1500km, meaning that those were teleseisms and to achieve this, were gathered data from the seismographic station of Aquidauana, Mato Grosso do Sul State, Brazil (AQDB). There were gathered and analyzed data information from January 1st to December 31st 2013, from which the seismic activity was generated in the Central and South Americas. In South America, the Andean region can be considered as the main source of teleseisms, mainly originated from Chile. The identification, interpretation and analysis of the events registered by AQBD station were made using the software SEISGRAM, SAC, TAUP and ORIGIN. Into the SEISGRAM were gathered and read daily data, that allowed the identification of the shock waves, used in post calculations inside SAC Software. The arrival times of the P and S waves were calculated into the TAUP software. The completion of these steps resulted in the determination of the P and S waves. These magnitudes were correlated within the results shown into the NEIC catalog using the ORIGIN software.
The obtained results will support the Pantanal and the BRASIS projects, whereas the Federal University of Mato Grosso do Sul (UFMS), through its Geosciences department is participating in the Integrated Seismographic Network of Brazil (BRASIS project). The combining efforts with the Astronomy, Geophysics and Atmospherical Sciences Institute from São Paulo University (USP) are made with the purpose to comprehend better the relation between the seismicity activities inside Pantanal region (border of Parana Sedimentary Basin) and the lithosphere structuration using the seismic data registration acquired with the AQDB station.

Key Words: Seismicity, Seismographic station and Pantanal.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Quantifying uncertainties in site amplification caused by using low resolution soil maps for site characterization

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ABSTRACT

It is well established that shallow soil conditions play important role in shaping earthquake ground motions. Many large scale regional hazard and risk analysis use surface geology maps to characterize shallow soil conditions to infer Vs30 average shear wave velocity for site amplification analysis. The quality of spatial distribution of V30 data and thus the hazard maps depends upon the resolution of the soil maps used for site characterization.

Using high or low resolution soil maps could impact large scale regional hazard and loss analysis. It is the objectives of this study to examine the impact of using low resolution soil maps for site characterization on regional hazard and risk analysis and quantify the corresponding site amplification uncertainty.

We use cities of Santiago, Chile and Bogota, Colombia as testing regions for this purpose. First, we systematically processed the low and high resolution geological and microzonation vector maps to obtain comprehensive soil maps with 1:1,000,000 and 1:100,000 resolutions for Santiago and 1:500,000 and 1:40,000 resolutions for Bogota. With those low and high resolution maps of two regions, we then conduct a comparison on regional ground motions at grid level due to different characterizations of the site amplification, and we quantify the uncertainties in ground motion predictions due to uncertainties in soil maps by computing mean and standard deviation of site amplification from high-resolution soil maps. Finally, we use our regional seismicity model to quantify the uncertainties in hazard curves at specific grid locations covered by those soil maps, and develop a model to obtain the hazard estimates for high-resolution soil maps by approximately modifying the hazard estimates for low-resolution soil maps following the idea introduce by Bazzurro and Cornell (2004).

KeyWords: Site amplification.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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A Stochastic Rupture Probability Model for Earthquakes on Subduction Zones: A Case study from the Nazca subduction zone

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ABSTRACT

Most subduction zones rupture in complex patterns that create earthquakes of different magnitudes with overlapping rupture areas. This makes it difficult to identify a single characteristic earthquake for time dependent rupture probability analysis (TDRPA). For many subduction zones, limited historic earthquake data on large magnitude earthquakes do not provide sufficient information to estimate reliable mean recurrence intervals and rupture probabilities for such earthquakes. To improve the situation there is a need to complement the TDRPA with auxiliary data. Physical models based on geodetic data have been successfully used to obtain information on the state of coupling and slip deficit rates for subduction zones. Coupling information provides valuable insight into the complexity of subduction zone rupture processes, as demonstrated by the excellent correlation between the coseismic slip distribution from the 2010 M 8.8 Maule, Chile earthquake and the corresponding results from a GPS-based physical model published before the earthquake (Moreno et al., 2010).

In this study we present a TDRPA model that is formulated based on slip deficit rate distribution over subduction zones. In this model, a subduction zone is represented by an integrated network of cells. Each cell ruptures multiple times from numerous earthquakes that have overlapping rupture areas. The rate of rupture for each cell is calculated using a moment balancing concept that uses information from historic data and slip deficit rates. The model enables us to estimate the expected mean recurrence intervals for all cells forming the subduction zone. This information in conjunction with past earthquake rupture data is used to estimate time dependent rupture probabilities for cells. Rupture probabilities for earthquakes are formulated by integrating different combinations of cells that form rupture areas of different magnitude earthquakes at different locations on the subduction zone. The resulting rupture probability estimates are fully consistent with the state of coupling of the subduction zone and the regional and local earthquake history as the model takes into account the impact of all large (M>7.5) earthquakes on the subduction zone on TDRPA. The granular rupture model as formulated in this study allows estimating rupture probabilities for large earthquakes other than just a single characteristic magnitude earthquake. This provides a general framework for formulating physically-based rupture probability models for large earthquakes on subduction zones that is consistent with their true locking state and earthquake history. We will present the formulation of the proposed TDRPA model, its application to the entire Nazca plate subduction zone and the model sensitivity to some common initial assumptions critical to TDRPA.

KeyWords: Seismic Hazards, Earthquake Rupture, Stochastic Models, Subduction Zones, Interplate Coupling, Kinematic Models.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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La sismicidad en el Piedemonte Llanero y la amenaza sísmica de la Sabana de Bogotá

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ABSTRACT

El Piedemonte Llanero colombiano está configurado geomorfológicamente por el Sistema de Fallas de la Falla Frontal de la Cordillera Oriental (SFFFCO). El SFFFCO es el límite entre el bloque Andino y la placa Suramericana, y este límite es una zona de alta movilidad tectónica debido al empuje que la placa de Nazca al subducir bajo Suramérica produce en este sector del continente. La actividad tectónica del SFFFCO ha producido sismos con MW $\geq$ 7.0 como el del 9 de febrero de 1967. Por la cercanía a la Sabana de Bogotá, un sismo con M $>$ 7.0 daría lugar a una muy fuerte aceleración de sus suelos debido a que estos se originaron a partir de un lago interandino. Los depósitos lagunares de la Sabana de Bogotá se constituyen de sedimentos finos con alta saturación de agua. Las grandes aceleraciones en estos suelos afectarían por esta razón a aquellas construcciones y estructuras que no cumplan con los parámetros exigidos por el código colombiano de construcción sismorresistente (NSR -10). En este trabajo a partir de una revisión de los sismos históricos de 1743, 1785, 1845, 1917, 1967, 1995 y 2008, los cuales han sido asignados a las fallas del SFFFCO, se muestra como este sistema de fallas contribuye a que la amenaza sísmica de la Sabana de Bogotá sea categorizada como alta y cómo igualmente un sismo con profundidad focal menor a 30 km y M $>$ 7.0, generado en este sistema de fallas y que se encuentre a una distancia inferior a 250 km, producirá un escenario de desastre para el área metropolitana de Bogotá.

PalabrasClave: Fallas del Piedemonte Llanero, Sabana de Bogotá, Amenaza Sísmica.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Towards the construction of a Seismic Catalogue suitable for PSHA studies in South America: Instrumental contribution

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ABSTRACT

A comprehensive raw Seismic Catalogue, the database where it is kept the record of earthquake occurrence in terms of its location, origin time and magnitude, for a given study area and time span, is the product of the effort of various generations of specialists, including seismologists, geologists, historians and analysts. The associated ample set of strategies, criteria and methods to capture the data values for the whole set of events, necessarily imprints to the raw Seismic Catalogue an inhomogeneous characteristic. On the other hand, an adequate homogeneous Seismic Catalogue constitutes a need and a key factor to accomplish a robust assessment of the Seismic Hazard associated to the given region.

Despite the great every day work at regional and national levels, and the high valuable CERESIS's work at continental scale, a South American catalogue with reliable Mw magnitude values does not exist as an open dataset available to seismic hazard studies. Although, three known exceptions need to be mentioned. One is the Global CMT catalogue witch is an open and reliable dataset but covering 1976-present time period just for high values of magnitudes. Another is the recent ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009), which represents a huge earthquake parameter recalculation. The last one should be the Global Earthquake History catalogue, which worked hard on global literature compilation of historic (1000-1903) earthquakes parameters and macro-seismic datasets.

In the recent past, the GEM Foundation in association with the ISC, and working with available global data sets, established an impressive standard with the construction of a homogeneous instrumental seismic catalogue, adequate to be applied to consistent, transparent and verifiable Probabilistic Seismic Hazard Assessment (PSHA) studies; in particular, within this effort, it was reached a complete catalogue down to MW=5.5 for the time period 1960-2009 for the SA region. More recently, it is taking place a regional effort, also supported by GEM, that aims to achieve a harmonized Seismic Catalogue that will attempt to achieve completeness down to magnitude values equal to MW=4.5, within a time period to be established, and with the integration of existing national instrumental seismic catalogues.

For this work, we plan to bring to the surface possible differences, if any, between the Global catalogues and the national seismic catalogues provided by the SGC of Colombia, the FUNVISIS from Venezuela, the IGEPN of Ecuador, the USP of Brazil. We plan to present an overall comparison, for the most recent period where national seismic networks have proven to be determinant in solving earthquakes parameters for seismic events within the countries and in the boundary areas, between the parametric solutions offered by the various catalogues. An attempt will be given to account for significant differences that may show up between the solutions, and an effort will be made to reconcile

Key Words: Seismic Catalogue, Seismic Hazard, South America.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Probabilistic seismic hazard assessment in Quito city, estimates and uncertainties

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ABSTRACT

This study estimates the probabilistic seismic hazard for Quito, a large city built up on a piggy-back basin, on the hanging wall of a five segments, active reverse fault system. Five centuries historical records show that the city experienced intensities in the range VII to VIII, with damages reported in churches and houses. In an attempt to extend the observation time window, Hibsch et al. (1997) analyzed earthquake-induced deformation phenomena in lacustrine sediments in northern Quito basin; one major (Intensity X) event was identified between the 10th-16th centuries, when the entire fault length could have ruptured with magnitudes 6.5-7.0. More recently, GPS measurements at sites with 10-15 years of recordings, revealed east-west horizontal shortening with rates in the range 4.3-5.3mm/yr across this blind thrust.

Probabilistic seismic hazard estimates at 475 years return period were calculated for Quito using the available crustal and subduction seismic source zones with results showing that hazard levels in Quito almost entirely proceed from the contribution of the crustal host zone. Therefore, emphasis is put on identifying the uncertainties characterizing the host zone, i.e. uncertainties on the recurrence of earthquakes expected in the zone and uncertainties on the ground motions that these earthquakes may produce. Globally accepted GMPEs are used. Rather than sampling a complex logic tree, several plausible models are considered and associated to corresponding uniform hazard spectra.

Significant variability in the estimated acceleration at 475 years resulted from this exercise. When frequency-magnitude distributions obtained from the country catalog were used, both uncertainties on the GMPE choice and on the seismicity model were responsible for PGA's variability from 0.28-0.55g. When GPS inferred slip rates were used assuming that most of the deformation occurs seismically, PGA was between 0.43-0.73g. If only 50% of the deformation were to be released by earthquakes, the PGA range is from 0.32-0.58g. If we restricted the occurrence of magnitudes 6-7 to the Quito fault (a simplified geometry), and applying GMPEs including a hanging-wall coefficient (Abrahamson and Silva 2008, Chiou and Youngs 2008), the hazard increases up to 40% at sites located above the fault plane.

Based on the results we conclude that 0.3g should be considered as a strict minimum bound for PGA at 475 years return period for Quito for rock sites. If modeling the recurrence based on the earthquake catalog, as in most probabilistic seismic hazard studies in the world, the mean value obtained is around 0.4g, which we propose should be considered as the reference value in Quito for rock in that return period. Further considerations should be done for site amplification. We underlie the large uncertainty on the obtained hazard values and stress that the seismic hazard in Quito must be considered of the utmost importance for the future of the city.

KeyWords: PGA, uncertainties, hanging wall, Quito.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Average shear wave velocity down to 30m (vs30) zoning for the city of Pasto, Colombia

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ABSTRACT

Evaluation of the seismic site effects constitutes a key piece of information fundamental for local seismic hazard assessment, for structural design and for urban planning. One of the most used parameters for soil classification and the analysis of site effects is the average shear wave velocity in the upper 30m (Vs30). Nevertheless, most techniques oriented to its estimation have high costs, requiring long periods of time and logistical and practical conditions that restrict their application.

In this work, the refraction of microtremors (ReMi) technique (Louie, 2001) is implemented (which combine an acceptable level of accuracy and confidence with low costs of acquisition and easy implementation) developing a Vs30 zonation (scale 1:10.000) for the city of Pasto (located at southern Colombia). 157 measurements of microtremors were performed within the urban perimeter of the city. Estimation of shear wave velocity profiles, sedimentary deposits thickness and seismic amplification factors also have been carried out classifying most of the city as soils with high amplification potential.

Within the framework of this project, strong motion stations were installed in different zones of the city which recorded an earthquake occurred on February 9 of 2013 (Guaitarilla earthquake), Mw=7.0 at 162.0 km depth located at 33 km from Pasto where it was widely felt. This information was analyzed using methods such as Spectral Standard Ratio which combined with studies of historical seismicity it was possible to observe that actual amplifications matches with the high potential amplification zones predicted in this work showing a coherence and validity of the obtained results.

Key Words: Shear wave velocity, Vs30, ground motion amplification, seismic hazard assessment.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Simulación 3D de la Propagación de Ondas Sísmicas en el Valle de Caracas usando Diferencias Finitas

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ABSTRACT

En este trabajo, se presentan resultados preliminares de simulaciones 3D de la propagación de ondas elásticas en el valle de Caracas utilizando un método de diferencias finitas escalonadas de cuarto orden en espacio y segundo orden en tiempo. El valle de Caracas es modelado por un cubo con dimensiones de 50 por 50 kms^2 con 12.5 kms de profundidad, con dos capas sedimentarias sobre el lecho rocoso. Para este modelo de velocidades de onda, se emplea un tamaño de paso de 25 metros el cual permite modelar una respuesta sísmica suficientemente precisa de hasta 4Hz. El sismo de La Guaira del año 2009 de Mw 4.3 grados es utilizado como sismo escenario de validación para estas simulaciones donde la técnica de los cocientes espectrales estándar permite la comparación de los registros reales con los sintéticos.

PalabrasClave: simulación 3d, propagación de ondas, valle de caracas.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Results from the 2013 Pan-American Advanced Studies Institute in Santo Domingo, Dominican Republic: Joint Modeling of Complementary Data Functionals for Seismic Site Characterization

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ABSTRACT

In July 2013 the U.S. National Science Foundation funded a "Pan-American Advanced Studies Institute" (PASI) in Santo Domingo, Dominican Republic, entitled "New Frontiers in Geophysical Research: Bringing New Tools and Techniques to Bear on Earthquake Hazard Analysis and Mitigation." The goals of the workshop were to explore new approaches to "seismic site characterization" that suggest it may be possible to determine shallow Earth structure through low-cost, non-invasive seismic surveys that make use of ambient noise and to teach these methods to early career scientists and engineers from around the Americas. The PASI included data collection and analysis as a proof-of-concept survey in a highly built-up urban environment.

In this talk we will present a strategy for determining seismic "site characterization" through joint modeling of horizontal to vertical spectral ratios (HVSR) and surface wave dispersion, determined via spatial autocorrelation (SPAC), refraction microtremor (ReMi), and/or multi-channel analysis of surface waves (MASW). Fitting of data functionals by synthetics is driven by global optimization and the models are assessed quantitatively. The products of this approach are shear wave velocity profiles for the shallow subsurface, accompanied by posterior probability distributions and parameter correlation matrices. Optimization strategies for solving nonlinear problems in geophysics have several advantages over linearized inversions. Jointly fitting dispersion curves and HVSR functionals via global optimization allows us to characterize the space of possible models, assess model reliability, identify parts of the "best-fit" model that are poorly constrained, and guide us toward new data that might improve constraints on the model. Tools such as the posterior probability distribution and the parameter correlation matrix allow us to assess the relative contribution of both types of data to model constraints and how to choose the optimal weights between data types. The joint modeling technique is applied to data acquired in the 2013 Santo Domingo PASI.

KeyWords: Seismic Site Characterization, H/V Spectral Ratios, surface wave dispersion, global optimization, uncertainty assessment.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Caracterización del subsuelo de la zona lacustre de Bogotá, usando técnicas de análisis de microtremores

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ABSTRACT

Seismic hazard in Bogotá is strongly associated with the response of the soil on which it is built. Ambient noise techniques have been used to characterize the subsoil as a first step for the estimation of the response to strong seismic excitations. This work uses these techniques for the characterization of the structure of the subsoil in a lacustrine zone of Bogotá. The “single instrument" technique known as H/V, the spectral ratio between the horizontal component and the vertical component of the ambient noise, is used to obtain the approximate subsoil transfer function. We use also the spatial autocorrelation technique (SPAC), an "instrumental array" technique, to obtain the shear-wave velocity profile at the site. This study evaluates the contribution of these techniques to obtain the subsoil velocity profile by comparing the results with information from a nearby geotechnical wellbore. The data collection was conducted on the campus of the Universidad Nacional de Colombia at Bogota using broadband seismometers.

PalabrasClave: Seismic hazard, ambient noise, H/V, SPAC.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Tectónica activa en el costado occidental del Valle del Rio Zulia – Norte de Santander, Colombia -Aportes de las técnicas cuantitativas de análisis de drenaje

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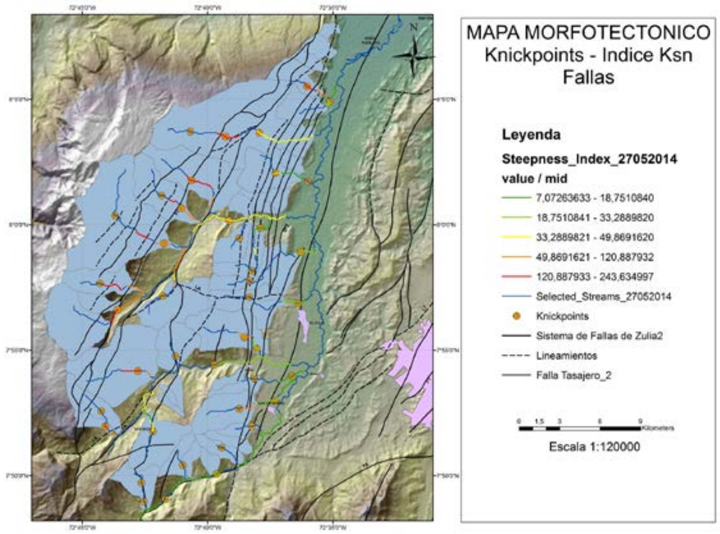
ABSTRACT

El valle del rio Zulia (Norte de Santander, Colombia) se encuentra controlado estructuralmente por un sinclinal conformado por una secuencia de rocas sedimentarias principalmente del Terciario. En el flanco occidental en su parte proximal se encuentra delimitado por el Sistema de fallas del Zulia que hacia el norte del valle se une con la falla de Aguardiente de tipo inverso conformando un conjunto deformativo con vergencia hacia el oeste. En el valle del rio Zulia se observa un cinturón de deformación del Cuaternario producto de los esfuerzos asociados a la colisión del Bloque Choco-Panamá sobre el conjunto del bloque triangular de Maracaibo (Figura 1). Esta deformación del Cuaternario evidencia actividad neotectónica no relacionada con la Falla de Bocono. En este trabajo se estudia la deformación reciente del relieve del costado occidental del valle del río Zulia mediante el análisis de las tasas de levantamiento cuantificadas a través de los índices de verticalidad de los drenajes, bajo el principio de que en configuraciones tectónicas que contienen una discontinuidad en las tasas de levantamiento, se espera que canales con altos índices de verticalidad (Ksn) estén asociados a zonas de levantamiento alto, mientras que índices de verticalidad bajos indican zonas de bajo levantamiento (Wobus et al., 2006). Usando el programa TecDem (Shahzad & Gloaguen, 2011) se visualizan los perfiles de corriente de 28 drenajes tributarios que drenan en dirección W-E desde la Serranía de Aguardiente hacia el rio Zulia (Figura 1), se construyen curvas pendiente vs. área para cada drenaje con el fin de determinar los puntos de quiebre (knickpoints) y se calculan los índices de verticalidad Ksn (steepness index) para un índice de concavidad θref = 0.45, según la relación S=Ks 〖nA〗 ^(-θref), donde S es la pendiente de la corriente y A es el área involucrada del drenaje. A partir del análisis de las curvas de pendiente se clasifica el tipo de quiebre de la pendiente (slope-break knickpoint) para determinar el tipo de morfologías asociadas a un proceso tectónico, resistencia de la roca o cambios transitorios fluviales (Figura 2).Índices de verticalidad Ksn con valores mayores a 120 se concentraron principalmente sobre el trazo de las fallas de Aguardiente e Icuperena y sugieren una tasa mayor de levantamiento tectónico en el área en comparación con la deformación sobre el cuaternario del Valle del rio Zulia para los cuales se obtienen valores menores a 120. En conclusión, la deformación actual sobre depósitos cuaternarios sobre el Valle del Rio Zulia que consiste en terrazas basculadas y levantadas se debe probablemente a tasas de levantamiento altas, evidenciadas según el análisis de los perfiles de corriente en drenajes que cruzan las fallas de Aguardiente e Icuperena, de tipo inverso que caracterizan un régimen compresivo W-E que no está relacionado directamente con la Falla de Boconó.

PalabrasClave: Geomorfología tectónica, TecDem, perfiles de corriente, índice de verticalidad, quiebre de pendiente, tasas de levantamiento.


MAPA MORFOTECTONICO
Knickpoints - Indice Ksn
Fallas
Leyenda
Steepness_Index_27052014
value / mid
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18,7510841 - 33,2889820
33,2889821 - 49,8691620
49,8691621 - 120,887932
120,887933 - 243,634997
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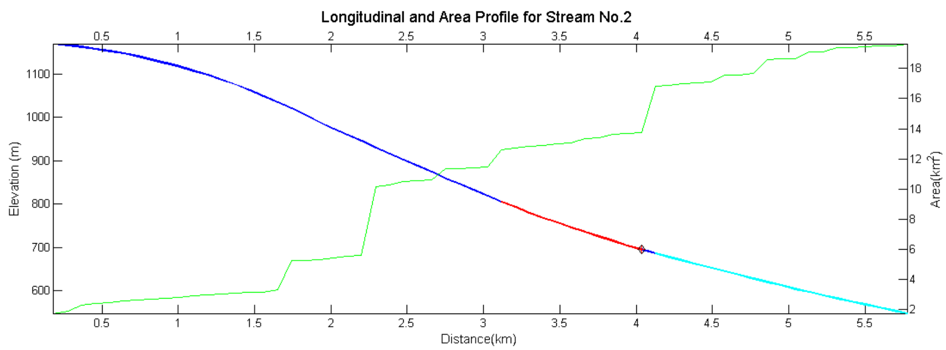
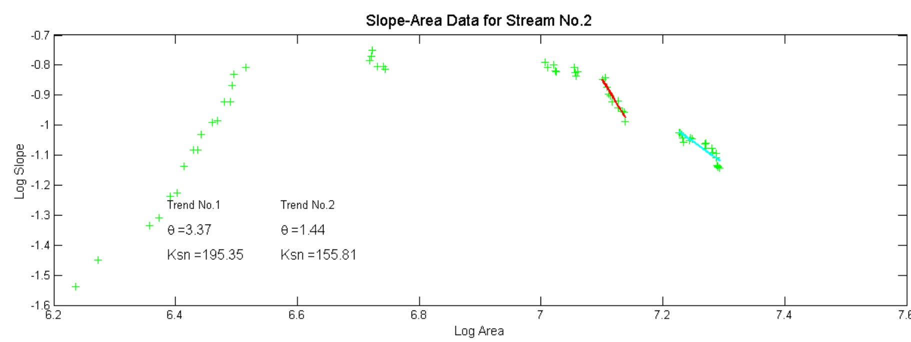
Knickpoints
Sistema de Fallas de Zulia2
Lineamientos
Falla Tasajero_2
Escala 1:120000


Longitudinal and Area Profile for Stream No.2
Elevation (m)
Area(km²)
Distance(km)


Slope-Area Data for Stream No.2
Log Slope
Log Area
Trend No.1
θ =3.37
Ksn =195.35
Trend No.2
θ =1.44
Ksn =155.81

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Modeling Seismic Hazard in South America: current state of the state-of-the-art based on activities carried out with the SARA project

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ABSTRACT

SARA (South America Seismic Risk Assessment) is a GEM coordinated collaborative project sponsored by the Swiss-Re Foundation, which aims at completing an integrated assessment of seismic risk in South America though a strong involvement of the local scientific community. The creation of a new harmonized seismic hazard model and the computation of the probabilistic seismic hazard (PSHA) for the whole region are the two key milestones for the hazard component of this project.
An initial step in the construction of a new seismic hazard model is an appraisal of existing seismic hazard models that have been produced for the study region. An international team is collecting information (i.e. publications, reports, electronic files) about the available PSHA input models currently adopted in different countries of the region for the objective of creating an homogeneous – open – library of PSHA input models (in the OpenQuake-engine format) suitable to be used by the scientific South American community. Previous experiences in neighboring regions (Arcila et al., 2012, 2013) already proved the utility of this approach in building regional, community-based and more homogenous models.
In the present communication, we describe the available PSHA models in terms of their consistency, transparency and reproducibility, the problems faced in the implementation process, the likely ways to harmonize them in view of their possible use as a backbone for the new SARA hazard regional model.

Key Words: seismic hazard assessment; SARA project, South America.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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High-resolution, uiltra low power, intergrated aftershock and microzonation system

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ABSTRACT

Rapid Aftershock Mobilization plays an essential role in the understanding of both focal mechanism and rupture propagation caused by strong earthquakes. A quick assessment of the data provides a unique opportunity to study the dynamics of the entire earthquake process in-situ. Aftershock study also provides practical information for local authorities regarding the post earthquake activity, which is very important in order to conduct the necessary actions for public safety in the area affected by the strong earthquake.

REF TEK a Division of Trimble has developed a self-contained, fully integrated Aftershock System, model 160-03, providing the customer simple and quick deployment during aftershock emergency mobilization and microzonation studies. The 160-03 has no external cables or peripheral equipment for command/control and operation in the field. The 160-03 contains three major components integrated in one case: a) 24-bit resolution state-of-the art low power ADC with CPU and Lid interconnect boards; b) power source; and c) three component 2 Hz sensors (two horizontals and one vertical), and built-in ±4g accelerometer. Optionally, the 1 Hz sensors can be built-in the 160-03 system at the customer's request.

The self-contained rechargeable battery pack provides power autonomy up to 7 days during data acquisition at 200 sps on continuous three weak motion and triggered three strong motion recording channels. For longer power autonomy, the 160-03 Aftershock System battery pack can be charged from an external source (solar power system). The data in the field is recorded to a built-in swappable USB flash drive. The 160-03 configuration is fixed based on a configuration file stored on the system, so no external command/control interface is required for parameter setup in the field. For visual control of the system performance in the field, the 160-03 has a built-in LED display which indicates the systems recording status as well as a hot swappable USB drive and battery status.

The detailed specifications and field performance are presented and discussed.

KeyWords: Seismology, Aftershock studies, Microzonation, Hazard Mitigation.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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El terremoto del 18 de mayo de 1875, en la región fronteriza colombo-venezolana :inventario de daños y de efectos geológicos co y postsísmicos

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ABSTRACT

En la mañana del martes 18 de mayo de 1875, a las 11:15 am ocurrió un terremoto en la zona fronteriza entre el estado Táchira, Venezuela y el Departamento Norte de Santander, Colombia. Algunos caseríos y poblaciones fueron destruidos casi en su totalidad, mientras que en otras se reportaron daños menores. A más de un siglo de la ocurrencia de este evento sísmico, muchas interrogantes aún quedan por resolver, y tras la búsqueda de evidencias, empleando la Sismología Histórica se ha indagado en la documentación primaria y secundaria, buscado datos que permitan reconstruir el escenario de los hechos, y para ello se ha elaborado una base de datos.

Entre las incertidumbres por resolver se encuentran: 1) La destrucción de asentamientos poblacionales y su relación con los efectos de sitio (ubicación de los mismos, principalmente en planicies de inundación de ríos, abanicos aluviales, terrazas y en laderas con pendientes pronunciadas); 2) Tipología constructiva usada a finales del siglo XIX, mediados del siglo XX (paredes de bahareque o tapia con techos de teja o paja) y su relación con la capacidad de soporte ante un sismo de considerable magnitud y 3) Posible falla geológica activa responsable del evento sísmico en una región con importantes accidentes tectónicos activos y su relación con la presencia de reflujos momentáneos de los ríos Táchira y Pamplonita al momento de la ocurrencia del evento, como es descrito en la crónicas.

Para el entendimiento y comprensión de estas interrogantes en esta primera fase y como resultado de este trabajo se elaboró una base de datos que ha sido alimentada por la información extraída de los archivos históricos públicos (Academia Nacional de la Historia, gobernaciones, y alcaldías) archivos eclesiásticos y parroquiales (libro de defunciones, libro de gobierno); además se contó con la revisión de documentos secundarios: libros, periódicos de la época, transcripciones de cartas enviadas al gobierno, informes técnicos y tesis, información que se encuentra digitalizada y clasificada en carpetas, guardadas de forma electrónica.

La base de datos está compuesta por un inventario de mapas y tablas que presentan las evidencias para la reconstrucción de los hechos. A manera de ejemplo se presenta un modelo de la información contentiva en tablas.

Esta investigación se ha desarrollado con el apoyo del proyecto Estudio Geodinámico de los Andes de Mérida (GIAME) por FUNVISIS, Venezuela y con el apoyo del proyecto Implementación Red Nacional de estaciones geodésicas satelitales GPS/GNSS para estudios e investigaciones geodinámicas en el

territorio colombiano – GEORED del Servicio Geológico Colombiano S.G.C.

PalabrasClave: Terremoto de 1875, sismología histórica, frontera entre Venezuela y Colombia, destrucción de poblaciones.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

Intraplate seismicity and seismic zoning in Brazil

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ABSTRACT

We discuss the seismicity in Brazil and neighboring intraplate areas, which among the least seismically active stable continental regions in the world: the maximum magnitude was 6.2 mb; magnitudes 5 occur every four years. Overall, the exposed cratonic regions tend to have half as many earthquakes compared to the average mid-plate South America. Earthquakes tend to occur in Neoproterozoic foldbelts especially in areas of thin lithosphere, or near craton edges around cratonic keels. Areas with positive isostatic anomalies tend to have more earthquakes, indicating that flexural stresses are important in explaining the intraplate seismicity. The Brazilian passive margin is also a region of higher than average activity. Although clear differences are found between different areas along the margin overall the Brazilian margins have 70% more earthquakes than the average stable continent. Distribution of epicenters and stress patterns suggest the main seismic zones are: (1) southern Guyana shield and middle Amazon Basin, the largest magnitude being a 5.5 mb in 1983; (2) a N-S trending zone along the eastern border of the Amazon craton; (3) Northern part of the Borborema Province, in NE Brazil around the Potiguar marginal basin, with the largest event in 1980 with 5.2 mb; (4) The Porto dos Gauchos seismic zone with activity known since the 6.2 mb event of 1955; (5) a NE-SW zone in the Tocantins province possibly continuing towards the Pantanal Basin; (6) southern Minas Gerais zone, in and around the southern tip of the São Francisco craton; and (7) the SE offshore zone with activity along the continental slope in areas of extended crust.

Key Words: Seismic hazard, Intraplate stresses, Lithosphere

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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El sismo de Guatemala de 1816 (M 7.5). Implicaciones para la sismicidad en el límite de placas norte América-Caribe

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ABSTRACT

La falla Polochic, junto con la Motagua, marcan el límite entre las placas Norte América y Caribe en Guatemala. La falla Polochic comprende los segmentos reconocidos como Cuilco, Chixoy y Polochic, que corren a lo largo de los cauces de los ríos del mismo nombre.

El 22 de julio de 1816 ocurrió un sismo de magnitud 7.5 en Guatemala. Las intensidades de este sismo reportadas para varias poblaciones en el centro y norte de Guatemala, graficadas en mapa, muestran que el evento rompió los segmentos Chixoy y Polochic, pero no el Cuilco, que es el más occidental. En cambio, las más altas intensidades (VIII-IX) se registraron a unos 50-100 kilómetros al noreste de la falla Cuilco, a lo largo de los ríos Selegua y Nentón. Estos ríos tienen un curso arqueado, cóncavo hacia el noreste y al parecer también están controlados por falla. Los ríos desembocan en México, en el río Grijalva. El curso del río Grijalva en la Depresión Central de Chiapas, es controlado por las fallas Concordia y Angostura, a lo largo de unos 150-200 km y con rumbo NW-SE. Alguna de estas fallas fue activada durante el macrosismo de 1902 (M≈7.6), evento somero y aparentemente de desplazamiento lateral.

La distribución de intensidades máximas reportadas para el sismo de 1816 sugiere entonces que la ruptura ocurrió a lo largo de las fallas Polochic, Chixoy y Selegua, mas no a lo largo de la falla Cuilco. El hecho que el sismo haya sido reportado como sentido con intensidad VII en San Cristóbal de las Casas sugiere incluso que la ruptura pudo haber progresado aún a lo largo de la falla Angostura, en territorio mexicano.

Los resultados aquí presentados sugieren que durante el sismo de 1816, la deformación asociada al límite placas Norte América Caribe ocurrió a lo largo de una línea de falla que va de la parte central de Guatemala y corre a lo largo de un arco cóncavo hacia el norte-noreste, formado por las fallas Polochic, Chixoy, Selegua (y/o Nentón) y Angostura, conectando así zonas de deformación en Guatemala y el sureste de México. Asimismo sugieren que estas fallas tienen un gran potencial sísmico al que no se le ha puesto la debida atención.

PalabrasClave: Falla Polochic, Sismicidad, Placa Caribe, Placa Norte América.

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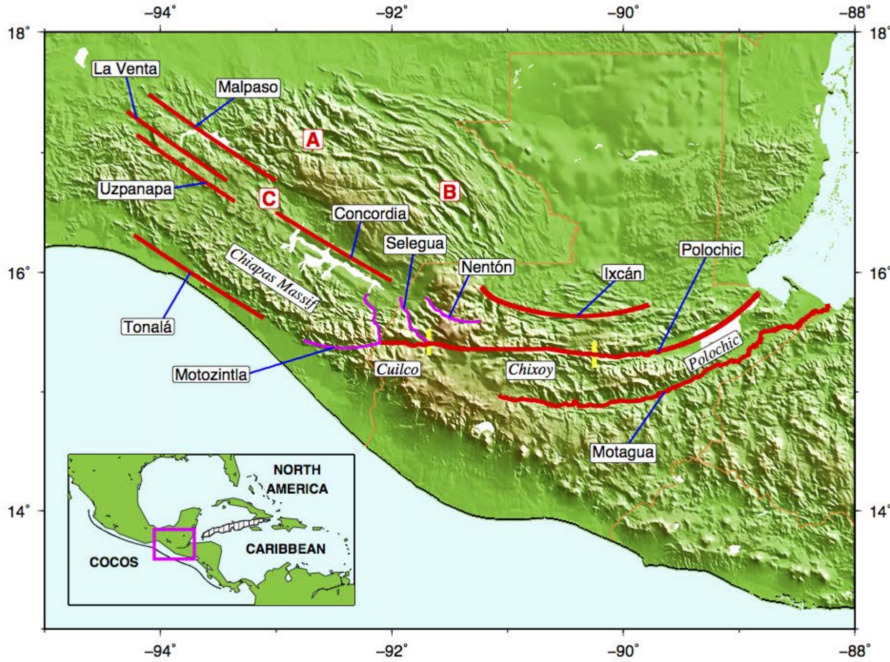

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Magnitude and location of large historical earthquakes in Colombia from macroseismic intensity data

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ABSTRACT

Macroseismic intensities of about twenty modern, instrumentally recorded, earthquakes are used to develop intensity attenuation equations for the three main seismotectonic environments in Colombia: crustal, interface and in-slab deformation. With the aim of obtaining better predictions and of reducing heteroscedasticity problems with the data, various types of models are explored, from a simple linear model to a log-type dummy variable model. The final models are selected after a detailed process of earthquake data selection, independent variables significance analysis, cross-validation and test-event validation. Thereafter, attenuation equations are rearranged in terms of magnitude. To locate and estimate the size of historical events with enough number of intensity evaluations, we follow Bakun's (1997) strategy of gridding the space of probable locations, then assume each grid node as a possible location of the event, calculate the corresponding magnitude and select as the preferred location that one with the smallest rms. Following this procedure we have located and estimated the size of many of the most significant earthquakes in Colombian seismic history.

Key Words: historic seismicity, macroseismicity, earthquake intensity.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Smoothing techniques applied to Brazilian seismic sources characterization

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ABSTRACT

Seismic sources characterization plays a key role in PSHA calculations. Standard hazard modeling approaches, in general, uses all available tectonic information and historic events catalogue to, based on experts judgments, identify distinct zones (and faults) which will be characterized by an magnitude-frequency distribution, minimum and maximum magnitude.

Smoothing techniques (also known as zone-less or zone-free approach) are a catalogue-based group of general methodologies which makes possible the seismic sources characterization without definition of seismic zones geometry. The interest sources region are gridded and for each grid cell, the seismic rate (and in some cases even the Gutenberg-Richter b-value) are calculated by a kernel density estimator (KDE) of all non-negligent influences of kernel-functions centered on each earthquake on the catalogue. The main distinguish between methods is the way to choose the bandwidth of kernel functions. After this each cell will represent one 'point' seismic source in the further PSHA calculation.

The main proposal of this work is explore three distinct approaches applied on the Brazilian context, where the lack amount of seismicity and data makes hard the seismic sources zone definition, and discuss the results.

First explored technique was the smoothing seismicity developed by Frankel (1995) available in Hazard Modeling Toolkit (HMTK) from Global Earthquake Model (GEM) scientific group. Frankel proposes a fixed-width KDE.

Woo, in 1996, proposed the second smoothing technique used on this work. In this technique the kernel bandwidths are proposed to be exponentially proportional to the earthquake magnitude nearest-average-distance distribution in each magnitude bin.

In the same direction, but with another perspective, Helmstetter (2012) proposed an optimized locally adaptive KDE to estimate the background seismicity to long-term earthquake forecasts in the Southern California. The idea of this work was check the method behavior in a low seismicity context and discuss the results.

Additionally, as each method output is one gridded set of seismic point sources, a simple GEM's OpenQuake classical PSHA calculation was ran to allow comparisons on the hazard domain.

KeyWords: smoothing, zoneless, seismic sources characterization.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Caracterización de la fuente sísmica asociada con la sismicidad HB, LP y drumbeats registrada en el Volcán Nevado del Huila – Colombia, en noviembre de 2008

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ABSTRACT

En el periodo comprendido entre el 2 y el 21 de noviembre de 2008, se registraron alrededor de 11200 eventos sísmicos asociados a la dinámica de fluidos. Estos eventos que se clasificaron como Híbridos (HB), Largo Periodo (LP), y drumbeats, precedieron la erupción freática ocurrida el 21 de noviembre y se caracterizaron por ser eventos altamente repetitivos, con formas de onda y anchos de banda de características similares. Hecho que hizo suponer la posibilidad de que toda esta sismicidad compartiera la misma fuente sísmica. Por tal razón, Cardona et al. (2009), hicieron un análisis de dicha sismicidad y establecieron la existencia de dos posibles familias sísmicas, una para los eventos HB y LP registrados entre el 9 y el 21 de noviembre, y la otra para los eventos tipo drumbeat que ocurrieron entre el 20 y el 21. Por tanto, para la realización de este proyecto de investigación, se retomó el trabajo realizado por Cardona et al. (2009) y se aplicaron las siguientes técnicas de procesamiento digital de señales: Transformada de Hilbert para la caracterización inicial de las señales sísmicas, correlación cruzada para establecer el grado de similitud entre eventos y así poder identificar posibles familias, y el Stack o apilamiento de señales para reducir los niveles de ruido y a la vez resaltar las características principales de las señales sísmicas analizadas. De los resultados obtenidos a partir del procesamiento digital de la información se destacan: ~ 8000 eventos con coeficientes de correlación > 0.9 y la posible existencia de 5 familias sísmicas, las cuales fueron localizadas en el sector SE del edificio volcánico. Un análisis detallado de la señales sísmicas obtenidas a través del stack, permitió concluir la existencia de tres familias, la primera de ellas para la sismicidad registrada entre el 4 y el 18 de noviembre, la segunda para la sismicidad registrada entre el 14 y el 21 y la tercera para la sismicidad tipo drumbeat. Cada una de estas familias se presume está asociada a una fuente sísmica diferente, de tal forma que: las dos primeras familias se asocian a fuentes con mecanismos de origen, posiblemente asociados al fracturamiento frágil que puede ocurrir en zonas de debilidad que interceptan grietas o conductos, en los que se produce el fenómeno de resonancia acústica, y la tercera familia asociada a la sismicidad tipo drumbeat puedo ser producida exclusivamente por el fenómeno de resonancia acústica dentro de los conductos volcánicos.

PalabrasClave: HB, LP, drumbeat, familia sísmica, mecanismo de origen, fuente sísmica.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sistema de información de sismicidad histórica de Colombia

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ABSTRACT

El estudio de los sismos históricos involucra conocer los efectos ocurridos en el territorio, teniendo en cuenta la percepción de las personas, daños en las construcciones y fenómenos en el medio ambiente. A partir de estas descripciones y mediante el uso de una escala de intensidad se evalúan las intensidades, las cuales a través de procesamientos matemáticos y estadísticos, permiten estimar parámetros como magnitud, profundidad y localización, que se utilizan para complementar el catálogo sismológico del país.
Teniendo en cuenta lo anterior, varios autores han trabajado en la recopilación y análisis de información histórica de los sismos, en la evaluación de intensidades y en el análisis sismológico de los mismos, publicando sus investigaciones en informes, artículos, libros, bases de datos, entre otros.
Debido a que la documentación publicada en esta temática para Colombia se encontraba dispersa, había difícil acceso a los documentos primarios utilizados y que la evaluación de intensidades estaba en varias escalas, se vio la necesidad de estructurar una base de datos en la que se almacenara toda la información relacionada con los sismos históricos destructivos que han ocurrido en el país. Es por esto, que en el año 2010 el Servicio Geológico Colombiano (SGC) y la Universidad Nacional de Colombia (UN), emprendieron las actividades necesarias para diseñar, implementar y poner en funcionamiento un sistema de información con acceso público a través de la página Web del SGC, en el que tanto usuarios expertos como la comunidad en general, pudieran consultar los eventos ocurridos en el país desde el Siglo XVI.
La implementación se desarrolló en varias etapas, y se incluyó en el sistema de información institucional "SIGER", cuyo objetivo es facilitar la captura, almacenamiento, gestión, despliegue e intercambio de información Geocientífica. La arquitectura del sistema institucional bajo el cual opera el sistema de sismicidad histórica es: Motor de base de datos Oracle 10g, Arcgis Server 9.3.1, ArcSDE 9.1, y jboss como servidor web. La consulta al sistema se realiza en línea, mediante el siguiente enlace:
http://agata.ingeominas.gov.co:9090/SismicidadHistorica/
El sistema fue publicado oficialmente en diciembre de 2012 y permite elaborar consultas tabulares, gráficas y espaciales, por medio de criterios de búsqueda como: fecha o rango de fechas, sitio (municipio), coordenadas (cuadrángulo), consulta avanzada (incluye búsqueda simultánea de fecha, intensidad y coordenadas), y una consulta de sismos falsos o dudosos. También se pueden realizar búsquedas en el calendario "Un día como hoy", en el que se encuentran resaltados los días en los que ocurrió algún sismo histórico, entre otras funcionalidades.

Palabras Clave: sismicidad histórica, intensidad, sistema de información, SIGER.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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South American strong-motion database and comparison with Ground-Motion Prediction Equations: a GEM initiative

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ABSTRACT

This study takes place in the context of the Global Earthquake Model project (http://www.globalquakemodel.org/), and more specifically in its South American component GEM-SARA (http://www.globalquakemodel.org/what/regions/south-america/). The global aim of the project is to build a seismic hazard model at the global scale.

Our team, involving researchers from Brazil, Colombia, Chile, Ecuador, and Venezuela focus on the particular aspect of strong ground-motion recorded data and the comparison with Ground-Motion Prediction Equations (GMPEs) at the South American scale.

Within the next one year and a half, we will gather all recorded strong-motion data for the various tectonic contexts one finds in South America: shallow crustal seismicity, subduction areas involving interface and in-slab events, and stable continental regions. After processing these data using a homogeneous scheme, we will compare them with appropriate GMPEs, those pre-selected for the GEM project (Douglas et al., 2013), as well as with local models, to assess the suitability of them or state the need to develop regional ones.

The database building process will include record processing, event characterization, and site term estimation for each station that recorded significant events. Record processing will be performed following state of the art methodologies for both broadband and accelerometric data. One of the main difficulties is to gather homogeneous metadata. Site characterization will be approach by multiple means, where available shear wave velocity profile will be used to compute Vs30 (as required by many GMPEs), otherwise assessed based on H/V ratios, geology or other available information. Event information will be gathered from regional and international agencies, and updated using the results of the GEM-SARA Topic 4 project (earthquake catalogue for South America).

The aim of this study is to build a ground-motion logic-tree for PSHA at the South American scale, including the weights for each selected GMPEs, based on expert judgment and statistical properties of the residual distributions (observed vs. predicted ground-motions).

KeyWords: Strong-motion data, GMPEs, GEM, PSHA.

EARTH SCIENCES
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Seismic Hazard Assessment of Sites of Large Structures in the Southeast of Brazil

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ABSTRACT

This paper presents a seismic hazard analysis of the Southeast region of Brazil, involving the states of Minas Gerais and the onshore and offshore regions of Rio de Janeiro and Espirito Santo. Although Brazilian seismicity is low (magnitude < 5) when compared to the Andean coast of South America, where strong earthquakes occur more frequently, a seismic hazard analysis must be considered as a natural consequence of a good engineering design, under the economic, environmental and safety viewpoints, especially when the structures are located in densely populated areas. According to Berrocal et al. (1993) the seismicity in the Southeast region of Brazil presents a diffuse distribution, not allowing the association of faults and other tectonic features with active seismogenic sources. In this work, two polygonal areas are used as diffuse seismogenic sources encompassing events with magnitude between 3 to 5, according to the Brazilian earthquake database at the University of Sao Paulo (IAG/USP). In the first area, located onshore, the main objective is to establish the acceleration spectra in order to investigate the dynamic behavior of several large dams while, in the second area, located offshore, the main purpose is to study the dynamic behavior of a pier installation currently being constructed on the seaside of the Rio de Janeiro state. Because of the seismotectonic characteristics of both areas, the attenuation laws used in this study are those developed for similar areas in Central and Eastern North America and herein incorporated through a logic tree process. The design spectra are obtained through probabilistic methods, considering maximum horizontal acceleration in the bedrock determined with recurrence periods of 72, 475, 975 and 2475 years. Artificial earthquakes can be later generated from these design spectra in order to investigate the dynamic behavior of dams and pier installations through finite element analyses.

KeyWords: seismic hazard, Southeast region of Brazil, design spectra.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Evaluación probabilística de riesgos en Centroamérica con la Metodología CAPRA

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ABSTRACT

CAPRA (http://www.ecapra.org/) es una plataforma de software de código abierto desarrollado con apoyo del Banco Mundial para la evaluación de riesgos; el paquete aplica técnicas probabilistas al análisis de las amenazas y pérdidas causadas por desastres naturales. Los programas fueron diseñados desde un principio para ser modular y extensible. La información sobre amenazas se combina con la referente a la exposición y vulnerabilidad física, que le permite al usuario determinar el riesgo conjunto o en cadena en función de múltiples riesgos relacionados entre sí.

Desde hace algunos años, los países de Centroamérica han realizado esfuerzos con apoyo del BID y BM para aplicar la herramienta CAPRA. Para los años 2013-14, con apoyo de Banco Mundial, CEPREDENAC contribuirá a reforzar el trabajo en los países de la región en seguimiento a la implementación de la Política Centroamericana de Gestión de Riesgos (PCGIR). Se ejecutan los siguientes proyectos:

Bajo coordinación de CEPREDENAC se realizan: 4 proyectos en Guatemala, El Salvador, Nicaragua, Panamá para la evaluación del riesgo sísmico en sectores de educación, salud, viviendas, edificaciones públicas importantes. Las áreas de trabajo son las capitales de los países, con excepción de Guatemala donde se trabaja en el sector de San Marcos, afectado por el terremoto del 7 de noviembre de 2012.

Bajo coordinación del Banco Mundial se realizan: los proyectos de la evaluación del riesgo sísmico para sistemas de distribución de agua potable en Tegucigalpa y Managua.; un proyecto de evaluación del riesgo sísmico en San José y un proyecto piloto sobre riesgo de inundaciones en Boquete, Chiriquí en Panamá.

La Secretaría Ejecutiva de CEPREDENAC trabaja en estrecha cooperación con el equipo del Banco Mundial asignado al proyecto CAPRA, con los coordinadores nacionales (instancias rectoras nacionales de protección civil), las instituciones científicas nacionales y con los equipos específicos de los proyectos. Se coordinan las actividades con el Banco Mundial (reuniones periódicas, visitas conjuntas a los países) y se realiza un monitoreo de los avances, bajo la coordinación de la Secretaria Ejecutiva de CEPREDENAC. Se orienta para que entre los proyectos de los países se desarrolle intercambio, comunicación y cooperación. Antes de tomar la decisión final sobre la realización de los proyectos, se visitó Guatemala, El Salvador, Nicaragua y Panamá para verificar si todas las condiciones están dadas para la ejecución de los proyectos propuestos, específicamente la existencia de datos necesarios y la capacidad de las instituciones encargadas para garantizar la sostenibilidad e institucionalidad para la aplicación de CAPRA.

Los trabajos sobre riesgo sísmico incluyen (re)evaluaciones de la amenaza sísmica, estimaciones de la amplificación del suelo, estimaciones de la vulnerabilidad sísmica para el portfolio de las casas y edificios en la zona de trabajo.

Palabras Clave: Riesgo sísmico, Centroamérica, CAPRA.

SMIL session – Seismic Methods for Illuminating the Lithosphere

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Crustal structure of the Paraná Basin from ambient noise tomography

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ABSTRACT

Conventional seismic tomography is known to have poor resolution in regions of low seismicity, therefore, studies carried out in South America did not mapped clearly smaller areas of the continent, for example the region of the Paraná basin. Most paths used by Feng et al. (2007) in this region are roughly parallel, which prevents good spatial resolution in tomographic inversions.

This work is part of a major project that will increase knowledge of crustal structure in Southern Brazil and Eastern Argentina and is being carried out by IAG-USP (Brazil) in collaboration with UNLP and INPRES (Argentina).

To improve resolution for the Paraná Basin we used inter-station dispersion curves derived from correlation of ambient noise for new stations deployed with the implementation of the Brazilian Seismic Network (Pirchiner et al. 2011). This technique, known as ambient noise tomography (ANT), was first applied by Shapiro et al. (2005) and is now expanding rapidly, especially in areas with high density of seismic stations (e.g. Bensen et al. 2007, Lin et al. 2008, Moschetti et al. 2010). ANT is a well-established method to estimate short period (< 20s) and intermediate periods (20 - 50s) surface wave speeds both in regional or continental scales (Lin et al. 2008).

ANT data processing in this work was similar to the one described by Bensen et al. 2007, in four major steps with addition of a data inversion step. Group velocities between pairs of stations were derived from correlation of two years of ambient noise in the period range 5 to 60 s.

The dispersion curves measurements were made using a modified version of PGSWMFA (PGplot Surface Wave Multiple Filter Analysis) code, designed by Chuck Ammon (St. Louis University) and successfully applied by Pasyanos et al. (2001). Our modified version is no more event based and is working now with station pairs.

For the tomographic group velocities maps, we used the conjugate gradient method with 2nd derivative smoothing applied by Pasyanos et al. 2001. The group velocities maps were generated with one degree grid. For the tomographic inversion, we also add data derived from traditional dispersion measurements for earthquakes in SA.

The velocity maps obtained for periods of 10 to 100s correspond generally well with data from previous studies (Feng et al, 2007), validating the use of ANT and contributing to increase resolution of tomography data in SA.

The inversion maps obtained with 2nd derivative smoothing are more unstable at boundary zones for the inversion of sediments and crustal thickness. It can be explained by the smoothness factor, which is not reduced at expected discontinuities such as ocean/continent boundaries.

As the steps of data processing are well defined and independent, as new stations are deployed with the progress of the Brasis Project (Pirchiner et al. 2011) new paths will be added to the initial database, increasing the resolution and reliability of the results.

Key Words: Seismology, Tomography, Computational Seismology.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Reflection imaging of deep magma with natural sources: lessons from recent experiments on an interplate volcano and an intraplate earthquake

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ABSTRACT

Although deep reflection profiling in many parts of the world have produced detailed images of what is interpreted as molten material at varying crustal depths, most regions of active volcanism are problematic for high resolution reflection seismology partly because of difficult terrain. Here we report on the lessons of two recent experiments that indicate how the new generation of large N seismic arrays coupled with seismic interferometry may offer a fresh approach to imaging the roots of active volcanic systems.

In 2007 the SEA-CALIPSO onshore-offshore seismic experiment sought to explore the potential of 4D reflection monitoring of an active andesitic volcano in the Caribbean island of Montserrat. SEA-CALIPSO consisted of a deployment of seismographs on land and on the ocean bottom to record air gun shots on a series of circular and radial lines around the island. Conventional reflection processing of the airgun sources resulted in little useful images beneath the volcanic system. Reflection imaging using microearthquakes from the volcanic edifice revealed the presence of deep reflectivity, but signal enhancement proved difficult because of the few sources. Neither dataset probed directly beneath the volcanic edifice due to limitations with terrain and bathymetry. However, by treating the 72 hours of continuous recordings with seismic interferometry it was possible to extract surface and body waves from the seismic noise. Analysis of subsets of the data suggest the virtual body waves originated from the airgun sources, while the surface waves were generated by coastal wave action. Moreover, seismic interferometry allows us to generate virtual shot geometries that do probe directly beneath the volcano. The recording interval was too short to allow us to obtain a more coherent reflection image, but these results indicate that longer periods of recording (i.e. weeks or months) could well provide 3D images of unprecedented detail of the deeper magmatic system.

A complementary approach to using the natural volcanic seismicity for deep reflection imaging in 3D is suggested by a recent pilot study in Virginia, U.S. of the aftershock sequence of the 2011 Mw 5.8 Mineral Virginia earthquake. In this experiment (AIDA or Aftershock Imaging with Dense Arrays) a dense (i.e. $\Delta x \sim 200$ m) array of highly portable seismographs was used to record hundreds of aftershock waveforms. These recordings provide a basis for imaging using reverse Vertical Seismic Profiling (VSP) techniques, resulting in a 3D reflection image analogous to those obtained by conventional common reflection point analysis of recordings from controlled surface sources.

Both the SEA-CALIPSO and AIDA-VA experiments clearly demonstrated that continuous recording of seismicity in active volcanic regions with super dense surface arrays can be used to produce high resolution reflection images in 3D, perhaps even 4D, of complex structure at depth in general, and magmatic systems in particular.

KeyWords: Seismic interferometry, VSP, afteshocks.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic Noise environmental caracterization: Application to a pilot area in Bogota for seismic microzonation purposes

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ABSTRACT

This work shows the results of environmental seismic noise analysis associated to the implementation of temporal arrays in Bogota city, in order to characterize the recent stratigraphic units. Two triaxial high dynamic range accelerometers arrays were installed, each one acquired continued information for approximately one month with asymmetric array (distance between stations oscillate since 2.5 km and 8.7 km) and one week with a circular symmetric array (radial distances of 5 to 20 m).The analyses suggest an inverse dependence between the autocorrelation coefficients with the distance and the anthropic noise levels. Based on the elastomechanical structure of the studied units, were found contrasting results that suggest the lateral variations of the geotechnical units.

Key Words: environmental seismic noise.

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RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Crust and upper mantle seismic tomography in northwest of South America using surfaces waves

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ABSTRACT

The aim of this study is to generate a tomographic image for the crust and the upper mantle of Northwestern South America based on the study of surface-waves group velocity dispersion. We have selected 562 shallow earthquakes with magnitudes larger than 6.0 and epicenters located in the area bounded by coordinates 60ºN, 140ºW, 0ºE and 60ºS; 438 of these events were recorded by broadband stations of the Colombian National Seismic Network (RSNC) while 122 were compiled by the IRIS Consortium. The vertical component of the records was used to extract Rayleigh waves and rotated horizontal components to extract Love waves. We processed more than three thousand paths associated to Rayleigh waves and about the same number of paths associated to Love waves, to obtain in total about eighty thousand dispersion measurements. The dispersion curve for each event-station path is obtained by multiple narrow-band filtering of the displacement records in a period range between 10s and 160s.

We used the conjugated gradient method of Pasyanos et al. (2001) to invert dispersion measurements for spatially varying group velocity. We found significant lateral velocity anomalies in the shallow structure which we interpret as due to velocity contrasts between sedimentary basins and the surrounding relief. Deeper velocity anomalies clearly identified are associated to known structures as the Carnegie Ridge and the subducted oceanic crust.

Key Words: Surface Waves, dispersion, dispersion curves, group velocity tomography.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Crustal heterogeneity and earthquake generating properties in active fault regions in Japan

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ABSTRACT

It is essential to estimate detailed heterogeneous structures in and around the earthquake source region, in order to understand the generating process of earthquakes. For this purpose, we can invert coda envelopes from local earthquakes to estimate a 3-D distribution of relative scattering coefficients in the lithosphere. We discuss the detailed image of crustal heterogeneity in two active fault regions in southwest Japan, from a viewpoint of elucidating its correlation with the earthquake occurrence in space and time. The first example is the Yamasaki fault zone, a typical strike-slip active fault with a total length of ~80 km. We deployed dense seismic observation network, composed of 32 stations with average spacing of 5-10 km, around the fault zone. We have been estimating detailed structure such as fault dip and shape, segmentation, and possible location of asperities and rupture initiation point, as well as generating properties of earthquakes in and around the fault zone, through analyses of accurate hypocenter distribution, 3-D velocity tomography, and coda wave inversion. We also deployed a linear seismic array across the fault in order to delineate the fault-zone structure in more detail using fault-zone trapped waves. In the scattering analysis of coda waves, we analyzed 3,033 waveforms recorded at 60 stations from 136 earthquakes in 2008-2010 and 2002-2003. The result shows high micro-seismicity and stronger scattering along the entire fault zone from surface to ~15 km depth. Strong scattered distribution suggests almost vertical fault plane for some segment faults of the Yamasaki fault zone. Scattering seems to be stronger at segment boundaries. We will construct a fault structure model, with adding more data, and discuss its relation to earthquake generating properties in the fault zone. The second example is the high micro-seismicity area in central part of the Kinki district. We analyzed 1,799 seismograms recorded at 50 stations from 121 earthquakes in 2002 and 2003. The result shows the existence of remarkable scattering zone at depths from 20 to 30 km, just below the high micro-seismicity area. The 3-D velocity structure shows the strong scattering zone has relatively lower velocity and higher Vp/Vs. Low-frequency earthquakes occur at depth of 30-40 km just below this strong scattering zone. We suppose the existence of fluids, dehydrated form the subducting Philippines Sea plate, around the strong scattering zone. We consider this scattering zone should have some influence on active microearthquakes just above it, in such a way supplying fluids to the seismogenic zone in the upper crust. We have a data base of earthquakes in recent 30 years in this region. We will discuss the correlation between the temporal variation in seismicity and that in scattering images, especially for an earthquake with M 5.4 in 2001, aiming at detecting some evidence of crustal fluids affecting the earthquake occurrence.

KeyWords: seismic scattering, crustal heterogeneity, tomography, deep structure of active faults.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Surface wave tomography of the Chaco-Parana basin

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ABSTRACT

We present the results of a study of surface-wave group velocity tomography, using earthquake data and ambient seismic noise correlation, for the region of the Chaco-Parana basin, a Neopaleozoic intracratonic basin, formed by a complex history of different processes of subsidence.
Previous surface waves analysis (e.g., Feng et al., 2004, 2007; Snokes and James, 1997) estimated Moho depth in the central Chaco basin and a low-velocity anomaly in the lithospheric mantle. However the seismic structure of the crust and upper mantle remains little characterized across the region due to the rather poor resolution, especially for the south region.
The aim of this work is to improve the resolution and reliability of crustal images obtained from traditional earthquake-based measurements. Thus, we increased the number of group velocity curves using data from regional earthquakes recorded at LPA station (Argentina), Brazilian Seismic Network stations (BRASIS), permanent (GSN) and portable (BLSP) stations. We also added inter-station dispersion curves derived from correlation of ambient noise, for a dataset of seismic noise recordings from BRASIS, INPRES stations, LPA, CPUP and TRQA stations. The ambient noise tomography (ANT) is an innovative method to estimate surface wave velocities in the period range 5 to 60 s. The resulting path coverage is denser and displays a more uniform azimuthal distribution producing better tomographic images.
Dispersion curves were obtained by a multiple filter technique (Dziewonski et al, 1969) using a phase-matched filter. A 2D group velocity tomographic inversion was performed, applying a conjugate-gradient method (Paige and Saunders, 1982). The group velocity maps for 10 to 100 seconds correspond very well to tectonic structures throughout the studied area. The resolution was improved in northern Argentina and southern Brazil by the better seismic ray coverage, showing low-velocity anomalies in the upper mantle beneath the Chaco basin, compatible with other dispersion results. The new group velocity maps were inverted for S velocity structures, using a linearization method.
Estimates of the crustal thickness for the Chaco basin agrees with the ~34 km found for CPUP station (by receiver function) and the observed thin crust (less than 35 km), suggested by Assumpção et al., 2013. The Paraná basin has deeper crust compared with the Chaco basin in Paraguay and the eastern part of Argentina.

Key Words: surface waves, ambient noise, tomography, Chaco-Parana Basin.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Geoscientific research for lithospheric structures of the Merida Andes, Venezuela

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ABSTRACT

The lithospheric structure of the Merida Andes (MA), one of the most important orogenic belts in Venezuela, is objective of the multidisciplinary research group GIAME (Geociencia Integral de los Andes de Merida), coordinated by FUNVISIS, in close cooperation with UCV, ULA and PDVSA. Although there is a wealth of near surface data which has been used during past decades to explain the structure, and led to different genetic models, there are no seismic studies at lithospheric scale which cross MA. Therefore, as the backbone of the integrated research, in early 2014, three deep seismic profiles crossing the MA perpendicularly, as well as one parallel profile within the Falcón Basin, have been measured with 40 shot points recorded on up to 1000 recording instruments. We expect detailed information on the lithospheric structure across the MA, which will help to address the inner structure and its relation with the orogen's gravimetric root. Widely distributed gravity measurements in whole Western Venezuela, as well more dense arrangements along the seismic profiles were done during the first year of the project. The wide angle seismics will be complemented with the re-processing and re-interpretation of existing reflection seismic data, which will allow establishing a relationship between MA and its associated flexural basins (Maracaibo and Barinas-Apure basins). Several principal tasks, consisting in MA Quaternary deformation studies, using some research methods like neotectonics and paleoseismology, georadar, numerical modeling, kinematic GPS, thermocronology, detailed studies on regional geology, flexural modeling, gravity modeling, among others, are ongoing. We expect that this project will help to solve many of the doubts regarding the origin, evolution and structural configuration of the MA, as well as the relation to the seismicity of the principal fault systems, as the Boconó fault. Further members of the GIAME working group are: J. Choy, M. Cerrada, M. Rengifo, R. Aranguren, P. Vizcarret, A. Pérez, S. Mata (ULA), M. Bermúdez, J. González, M. Arnaíz-Rodríguez, A. Ughi, L. Piñero-Feliciangeli, R. Jiménez, F. Quintero, H. Socorro, M. Flores, S. Arcía, C. Viana (UCV), F. Urbani, A. Singer, H. Rendón, L. Rodríguez, J. Aray, J. Moncada, A. Leal (FUNVISIS), M. Bolívar, H. Cerquone, M. Forgione, R. Ramírez, P. Camacho, J. Requena, J. Lara, Y. Molero (PDVSA), M. Barquero, F. Araujo (PDVSA-INTEVEP), C. Padrón, O. Guzmán (USB), S. Yépez (CPDI), C. Reinoza, I. Angel, L. Pousse (FUNVISIS-ISTerre).

Key Words: Lithosphere, orogenic evolution, basin development, Mérida Andes, Venezuela.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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SNOP session – Current Practices and Recent Advancements in Seismic Network Operations

Conveners:
Dmitry Storchak (ISC - UK)
<dmitry@isc.ac.uk>
Marcelo Assumpção (USP - Brazil)
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The Northeastern Brazil Seismic Network – RSISNE

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ABSTRACT

The Brazilian Seismic Network (RSBR) is today composed of 73 permanent broadband stations covering different regions of the country. The duties regarding installation and operation of this seismic network are on four Brazilian institutions: University of São Paulo (operating 23 stations), University of Brasília (operating 18 stations), National Observatory and the Federal University of Rio Grande do Norte (each operating 16). The deployment of the NE (Brazil) Seismic Network (RSISNE) is of particular interest because NE Brazil is the main seismic area of the country. Since the deployment of RSISNE many previously unreported intraplate seismic activity has been recorded. Here we show all the stages of deployment, data quality control and event report for this seismic network. We also report the recent intraplate seismicity since RSISNE deployment. The new RSISNE will certainly increase detectability of the Brazilian seismicity, improve regional crust models in South America and, in particular, in NE Brazil.

KeyWords: seismic network.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The Saint Peter Saint Paulo Island Archipelago seismic station

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ABSTRACT

The Saint Peter Saint Paul Archipelago (SPSPA) is located in the equatorial region of the Atlantic Ocean about 1,100 km distant from the Brazilian northeastern coast. The SPSPA is composed by a set of several small rocky formations with a total area of approximately 17,000 m². Since 2011 we operate a seismic station (composed of a broad band sensor and a strong motion sensor). Despite the severe environmental conditions and the logistics we have (quasi) continuous monitoring of the seismicity. Due to its remote distance from the continent and the lack of cultural noise, the SPSPA location is unique for investigating microseismic noise and its relation with ocean-atmospheric variables, and the South Mid-Atlantic Ridge geodynamics. Here, we present results related to the installation and maintenance of the SPSPA station and also present some scientific results regarding microseismic noise and earthquake monitoring with this station.

KeyWords: seismic station, microseismic noise.

Image1: Figura1.jpg
IMG:image1:
IMG:image2:

Ensamblado, configuración, instalación y monitoreo de las estaciones sismológicas en las instalaciones del Observatorio de rayos cósmicos del proyecto internacional Pierre Auger

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ABSTRACT

Se desplegaron 12 estaciones sismológicas en la región ubicada entre las latitudes 34.5°-36°S y longitudes 67.5°-70°O (Figura 1.), con el fin de posibilitar una evaluación del riesgo sísmico en las poblaciones cercanas y asociar la sismicidad localizada a las fallas activas. Dicho experimento denominado Bloque San Rafael (BSR) activo desde Diciembre 2009 está enmarcado dentro del proyecto PICTO N°254 Riesgo Sísmico.

De las 12 estaciones instaladas 5 de ellas (COIH-LAMA-BLS-MORA-PUMA) están ubicadas en las estaciones de fluorescencia del Observatorio Pierre Auger (Malargüe). La estación COIH está compuesta por un sensor Guralp EDU-V y una PC configurada con el S.O. Linux (Ubuntu), corriendo el programa de adquisición en tiempo real y monitoreo Scream 4.5. Los sistemas de adquisición de datos de las 4 estaciones restantes (sensores periodo corto S13) fueron ensamblados en el Instituto Geofísico Sismológico F. Volponi (IGSV), compuestos por placas SARA SADC20I y PC con el S.O. Debian5. Se instaló y configuro el programa de adquisición en tiempo real y monitoreo EARTWORM 7.4. Se configuro el protocolo NTP (Network Time Protocol) utilizado para la sincronización de relojes de sistemas computacionales a través de la red, haciendo uso de intercambio de paquetes y latencia variable para el uso del GPS. Estas estaciones se encuentran transmitiendo en tiempo real y son monitorizadas tanto en el IGSV como en Instituto Nacional de Prevención Sísmica (INPRES). Earthworm permite monitorizar las estaciones en tiempo real y ver los eventos en el momento que suceden almacenando el registro continuo en una base de datos que son exportadas y subidas a un servidor FTP (instalado en el IGSV).

Se localizó la sismicidad de corteza y de placa de Nazca subducida (Lupari., 2014) en un periodo de 7 meses con el programa Hypocenter 3.2 (Lienert B., 1994) usando el modelo de velocidad obtenido por Lupari., 2014. (Figura 2.).

KeyWords: sismicidad, transmisión tiempo real.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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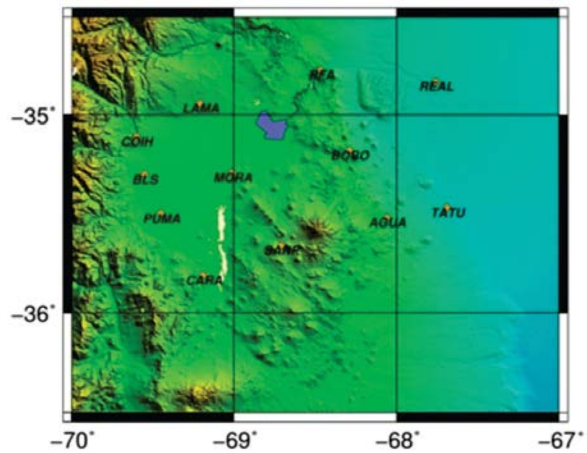

Figura 1: Red de estaciones sismológicas del Experimento BSR. Instituciones Integrantes: IGSV, INPRES, Observatorio Pierre Auger y Universidad de la Plata.

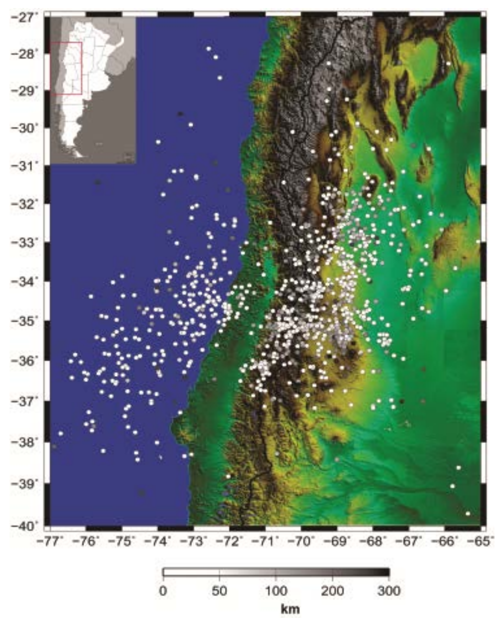

Figura 2. Sismicidad registrada y localizada en 7 meses. La escala inferior muestra la variación de la sismicidad en profundidad.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Velocity spectral analysis for telesesismic events using the Colombian Seismological Network as an array

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ABSTRACT

In the present work is presented a velocity spectral analysis (VESPA) for teleseismic events, recorded for the Colombian seismological Network (RSNC, for its acronym in Spanish) broad band and short period stations. To reach this aim we selected earthquakes with magnitude bigger than 7.0 and located at epicentral distance between 20º and 150º. This analisys was done to increase coherent signal ratio over no coherent noise and thus, to improve the SNR, which it was useful to identify phases from slowness variation getting the vespagrams, beside we used beamformig analysis to compare with the VESPA.

Key Words: Array seismology, vespagram, beamforming.

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Evolución de la Red Nacional de Acelerógrafos de Colombia

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ABSTRACT

Después del sismo de Popayán del 31 de Marzo de 1983, Mb=5.5 surgió entre los ingenieros civiles la preocupación de los daños que podrían ocurrir en otras ciudades similares. Esto condujo a que el Gobierno Nacional generara un estudio detallado que recomendaba el desarrollo de un Código Colombiano de Construcciones Sismo Resistente y la implementación de una red sismológica y acelerográfica nacional, así como la instrumentación local.

El año de 1993 inició su operación la Red Nacional de Acelerógrafos de Colombia (RNAC) bajo el auspicio del Fondo Nacional de Calamidades, a través del Programa de las Naciones Unidas para el Desarrollo (PNUD) y el Gobierno Nacional mediante el Servicio Geológico Colombiano (antiguo INGEOMINAS). El propósito fundamental de instalar una red acelerográfica en el territorio colombiano, es obtener registros de los sismos intensos (con ML $\geq$ 5.0) que ocurren a lo largo del país, y llevar a cabo su procesamiento para ofrecer esta información básicamente a la actualización del Reglamento Colombiano de Construcciones Sismo Resistente mediante el Estudio de Amenaza Sísmica Nacional y generación de Leyes de Atenuación Sísmica. De igual forma, contribuir a la evaluación de la respuesta sísmica de ciudades a través de estudios de Microzonificación.

La red está compuesta de 102 estaciones de acelerógrafos: 30 estaciones transmiten la información en tiempo real a una central de datos en Bogotá mediante telemetría satelital e internet y en las 72 estaciones restantes, la información se recolecta en las visitas de mantenimiento. La red está dotada con moderna instrumentación que permite obtener información confiable y cuenta con el personal capacitado para el procesamiento y análisis de la misma.

Durante estos 20 años se ha generado un gran banco de datos de 7900 acelerogramas producto de 3600 sismos. Hoy contamos con una base de datos disponible en línea para consulta de esta información desde el año 1993 hasta 2013. Igualmente, esta información se ha divulgado en 16 boletines anuales de movimiento fuerte.

La RNAC ha suministrado información procesada para los estudios de Microzonificación Sísmica de las ciudades de Bucaramanga, Villavicencio y Cali. Ha prestado apoyado en el proceso de instalación de redes locales de acelerógrafos de las ciudades de Popayán (5 estaciones), Bogotá (30 estaciones), Manizales (5 estaciones) y Cali (12 estaciones). Ha desplegado su red portátil para el estudio de réplicas de los sismos intensos como los de Tauramena (1995), Armenia (1999), Pizarro (2004), Gorgona (2007) y Quetame (2008). Recientemente, aportó información en la actualización del Mapa Nacional de Amenaza Sísmica a través de la comparación de leyes de atenuación mundiales con los registros obtenidos en las estaciones de la RNAC.

A corto plazo, se prevé complementar la instrumentación sismológica sobre el Océano Pacífico Colombiano, mediante la instalación de acelerógrafos que permitan localizar sismos generadores de tsunamis, a fin de suministrar en forma veraz y rápida esta información a las entidades encargadas de alertar sobre este fenómeno y apoyar a la comunidad en caso de un desastre.

Palabras Clave: Acelerógrafo, movimiento fuerte, leyes de atenuación.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Microseismic noise in the Saint Peter Saint Paul Archipelago and its relation with some atmospheric and oceanographic variables

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ABSTRACT

Microseisms are continuous vibrations pervasively recorded in the mili Hertz to 1 Hz frequency range. These vibrations are dominated by Rayleigh waves and are strongest in the 0.04 to 1 Hz frequency band. Their precise source mechanisms arean ongoing debate but it is agreed that they are related to atmospheric perturbations and ocean gravity waves. The Saint Peter Saint Paul Archipelago (SPSPA) is located in the equatorial region of the Atlantic Ocean about 1,100 km distant from the Brazilian northeastern coast. The SPSPA is composed by a set of several islets with a total area of approximately 17,000 m². Due to this sui generis geographic location the SPSPA is a unique natural observatory for measuring microseismic noise and to investigate its relation with climate and oceanographic variables. In the SPSPA we have recorded both primary microseisms (PM) at 0.04 – 0.12 Hz and the secondary microseisms (SM) at 0.12 – 0.4 Hz during 10 months in 2012 and 2013. Our analysis indicates a good correlation between the microseismic noise in the region and a seasonal dependency—in particular with the winter in the northern hemisphere. We also show that most of the PM is generated in the SPSPA itself. On the other hand, the SM source location depends to the seasonal climatic and oceanographic variables in the northern hemisphere.

KeyWords: microseismic noise, seismic station.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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International Seismological Centre (ISC): mission and products

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ABSTRACT

The International Seismological Centre (ISC) is a non-governmental non-profit-making organization funded by 62 research and operational institutions including six in the Latin America and Caribbean (LAC) region. The ISC is charged with the production of the ISC Bulletin – the definitive summary of the global seismicity based on reports from over 130 seismic networks worldwide, including 14 in the LAC region. We also distribute the EHB bulletin – a groomed subset of the ISC Bulletin widely used in studies of inner structure of the Earth. Jointly with NEIC, the ISC runs the International Seismic Station Registry (IR). The ISC station codes and event hypocenters are used by IRIS DMC in serving seismic waveform data to its users. The ISC provides a number of additional products including the IASPEI Reference Event list (GT). The ISC-GEM Catalogue is another dataset that was designed to be used for global and regional studies of seismic hazard and risk. The ISC Event Bibliography is an interactive facility to search for scientific articles devoted to both natural and anthropogenic seismic events that occurred within a region and time period of interest. The multitude of ISC data are freely distributed and widely used in different fields of geophysical research.

KeyWords: earthquake, bulletin, GT, ISC-GEM, bibliography.

AEQC tools for retrieval and completion of seismological waveform databases from heterogeneous networks

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ABSTRACT

Seismological and volcanological observatories are responsible for monitoring the earth activity through seismic networks, and for providing good quality dataset for scientific studies. To ensure a reliable monitoring systems it's required to build resilient networks whatever the data transmission the observatories use: VSAT, WIFI, ADSL and others. Unfortunately datastreams may be interrupted for few seconds or several days for many reasons: network failures, server maintenances, lightnings, field equipment failures, strong earthquakes... All these factors can have an impact on the continuity of collected data. Retrieving data from field stations for database completion is a tedious work and is very expensive in manpower.

The AEQC tools were developed with the aim of retrieving missing data to improve the quality of continuous archives (and to guarantee the most complete miniseed database available). It provides as output a miniseed archive with a SeisComP DataStructure (SDS) with a quality control on gaps, overlaps, sampling frequency and compression integrity. This tool working in background as a daily process is based on bash and python scripts, it uses the Passcal software libraries, IRIS DMC tools and runs on linux systems.

Data completeness analysis are made daily for all the configured networks and stations, emails reports are sent and data timelines are generated to provide a quick view of data continuity. AEQC retrieves only gaps thus data retrieving is optimized for limited bandwidth connections. The corrections and completions are done locally and overlaps are also corrected.It can work inside a heterogeneous seismic network and supports various data sources:

-Arclink server -Kinematrics digitizers: Q330, Baler14, Baler44
-Nanometrics Libra1 and Libra2 systems with Naqs
-Nanometrics digitizers (Taurus and Centaur)
-SDS archives accessible through ftp or http

It has a modular structure and it is easy to add a new data source. At this time AEQC scripts have been installed and are successfully used in the following seismological networks:

-PF network at OVPF, Reunion island in the Indian Ocean (Observatoire Volcanologique du Piton de la Fournaise / IPGP)
-GL and WI networks at OVSG, Guadeloupe island in the Lesser Antilles (Observatoire Volcanologique et Sismologique de Guadeloupe / IPGP)
-MQ and WI networks at OVSM, Martinique island in the Lesser Antilles (Observatoire Volcanologique et Sismologique de Martinique / IPGP)
-CX network in the North of Chile

KeyWords: data completion correction continuity timelines reports, gaps overlaps database retrieving observatories control quality seismic earthquakes heterogeneous networks source Kinemetrics nanometrics digitizers.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Activities of the FDSN: Current and Future

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ABSTRACT

The International Federation of Digital Seismograph Networks (FDSN) provides an international forum for fostering and supporting international cooperation in seismology. The organization currently represents 91 institutions in 67 countries. Through its five working groups (1. Station Siting and Instrumentation; 2. Data Exchange; 3. Coordination of Products, Tools and Services; 4. CTBT Issues; 5. Portable Instrumentation), the FDSN strives to facilitate the development and operation of seismological networks around the world. Important FDSN activities include the development of standards for instrumentation, data, and data exchange, the coordination of station siting, and the pursuit of free and open access to data. Emerging topics of importance for the FDSN are data quality and ensuring the long-term preservation of and access to seismological data. In my talk, I will describe current FDSN functions, and invite participation in a discussion of future goals and activities.

KeyWords: seismology networks.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Composición y funcionamiento de las estaciones satelitales de la Red Sismologica Nacional de Colombia

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ABSTRACT

En el presente trabajo se realiza una descripción en detalle de la composición y el funcionamiento de la Red Sismológica Nacional De Colombia -RSNC-. Para ello se describe el funcionamiento de los tres subsistemas que componen las estaciones sismológicas que pertenecen a la RSNC la cual está conformada actualmente por cincuenta y tres (53) estaciones sismológicas que están distribuidas en todo el territorio Colombiano. Los tres subsistemas que son de interés de este trabajo son el subsistema de energía y protecciones eléctricas, el subsistema de comunicaciones y el subsistema de instrumentación; de los que se hará una síntesis de los diferentes equipos que actualmente están en uso y que permiten el buen funcionamiento de cada estación sismológica; y por ende el buen funcionamiento de la Red Sismológica Nacional De Colombia.

Palabras Clave: Estaciones sismológicas, subsistemas, energía y protecciones eléctricas, comunicaciones, instrumentación.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Portable, GPS synchronized, mobile phone network-based seismological station

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ABSTRACT

A station for acquisition, storage and real time transmission of seismic data has been developed. The station's software scalability, taking into consideration that the data logger includes a small laptop, makes the station versatile and easy to update. It synchronizes by GPS, stores data on mSEED format, and sends real time data by using a modem. The station has a real time event identifier based on the long and short time average algorithm. It has seven differential channels divided on three DB9 ports: two for triaxial sensors and one for an additional low sampled signal (temperature, barometers, inclinometers, radiometers, etc.). The application is designed and implemented on LabVIEW, devices are USB plugged and sensors are connected through DB9 ports. The station is composed of a ten inches netbook, a USB HUB, a GPS, a data acquisition device, a DC-DC converter, a reboot circuit and the sensors. All the elements, except the sensors, are protected in a high-resistant case. Station is capable to acquire data up to 3000 SPS with 24 bit resolution and store up to 3 years of data with 3 channels at 200 SPS.

In order to get time synchronization, data acquisition and real time transmission, a Windows environment application was designed. It was programed over National Instruments' LabVIEW software, which allows the user to program on G (Graphic) language. The 5 sections –subsystems- of this app count with queue communication. Queues are useful because they prevent data loses since they are able to save data from one stage to another. For example, data acquired remains on a queue if there is some issue with the storage, once this issue is solved data will be stored. Additional features include e-mail alerts for storage space, battery level and major seismological events detected via STA/LTA algorithm.

It should be noted that real time transmission requires a data plan with a cellphone provider. Currently, there are five stations registering for the Red Sismológica de la Sabana de Bogotá. These stations are working standalone since 2012 with maintenance every 6 - 12 months.

Key Words: Seismological station, portable, mobile phone network, GPS, stand-alone.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Análisis de ruido de las estaciones sismológicas del Servicio Geológico Colombiano a partir del cálculo de densidad espectral de potencia probabilística

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ABSTRACT

Este trabajo muestra el proceso y resultados de la caracterización de ruido de 5 estaciones de banda ancha de la Red Sismológica Nacional de Colombina - RSNC- a partir del cálculo de la densidad espectral de potencia probabilística (PPSD por sus siglas en inglés). La configuración de estaciones de la RSNC al día de hoy permite un buen cubrimiento de la actividad sísmica nacional, por ello uno de los retos de la red es mejorar la calidad de la información adquirida.

Se realizó un análisis preliminar de las formas de onda de todas las estaciones en intervalos de tiempo así: 05:00 - 08:00, 13:00 -16:00 y 22:00-01:00 (UT). En consecuencia se identificaron 4 estaciones con niveles críticos de ruido y adicionalmente se escogió una estación de referencia con un desempeño aceptable para llevar a cabo la comparación entre los diferentes niveles de ruido.

La utilización del software SEISAN permitió obtener los espectros de potencia de las formas de onda para realizar el análisis preliminar. Adicionalmente, se utilizó el módulo PPSD del ecosistema ObsPy, para analizar las trazas sísmicas de las estaciones seleccionadas. Para ello se tomaron intervalos de tiempo desde horas hasta meses. Como resultado se obtuvieron las gráficas de distribución probabilística (PDF) y energía espectral (PSD) combinada para cada componente de las 5 estaciones seleccionadas. A partir del análisis de estas gráficas se identificaron las posibles fuentes de ruido sísmico y antrópico de cada estación y se evaluó su desempeño.

Palabras Clave: Densidad Espectral de Potencia probabilística (PPSD), ruido sísmico, curvas de Peterson.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Subduction zone events in Bolivia as recorded by the Bolivian and Brazilian Networks: a Test of location accuracies

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ABSTRACT

The Brazilian Seismic Network (RSBR) is being installed since 2010 and has recorded hundreds of small events (magnitudes down to 3.5 mb) in the Andean subduction zone, especially intermediate events beneath northern Argentina, Bolivia, and southern Peru. The RSBR also uses some Andean stations, such as LPAZ (Bolivia) and LVC (Chile) in the detection/location system. We present a comparison of the RSBR hypocenters, obtained automatically with a SeisComp3 system and the "LocSat" code, with the hypocenters of the Bolivian Network (OSC, Observatorio San Calixto, using the "hypocenter" code) as well as with the NEIC/USGE locations.

In the magnitude range 4.0 to 4.6, the RSBR epicenters determined since early 2013 are mostly within 10 to 25 km of the NEIC epicenters, and the OSC locations are mostly within 10 to 20 km of the NEIC solutions. The differences between the RSBR and OSC epicenters are mainly less than 50 km. Differences in depth are usually less than about 20 km. We also tested the automatic LocSat location with an offline location using the "hypocenetr" code: the epicentral differences are mostly within 20-30 km. We conclude that, in general, the RSBR automatic locations of intermediate-depth events using Brazilian stations (together with LPAZ, LVC and CPUP) are comparable to the NEIC teleseismic epicenters.

We will show the results of the re-locations of the events by combining the RSBR and OSC datasets, as well as the improvements by using the RSTT travel time corrections to account for 3D structural variations.

RSBR is being installed with support from the Petrobras Geotectonic Research Program by a joint effort of four institutions: Sao Paulo University (USP), Brasilia University (UnB), National Observatory (ON) and Federal University of Rio Grande do Norte (UFRN).

KeyWords: Hypocenter determination, Subduction zone.

EARTH SCIENCES
RESEARCH JOURNAL

262

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

The New Brazilian Seismic Network: current status and detectability test with the recent Pisagua Earthquake Sequence, Northern Chile

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ABSTRACT

Efforts from four different institutions are establishing the new permanent Brazilian Seismic Network (RSBR) that today is composed of 73 broadband stations operating across different regions in Brazil: University of São Paulo (USP) operates 23 stations, University of Brasília (UnB) 18, National Observatory (ON) and Rio Grande do Norte Federal University (UFRN) 16 each. USP and UnB stations form a sub-network called BRASIS (BL and BR network codes respectively), ON stations form the RSIS sub-network (ON) and UFRN the RSISNE sub-network (NB). Most stations transmit in real-time via satellite or cell-phone links. The data/services distribution topology is based in technology and concepts adopted by the EIDA network in Europe. Each institution maintains a local data center with a SeedLink/ArcLink server that can be used to obtain real-time and archived waveform data when allowed by each participant. All nodes use the SeisComP3 system as a levering back-end.

While the main RSBR purpose is to monitor the seismicity in Brazil, its geometry and position in relation to the majority of the South America seismogenic sources will enhance the data availability in the distance range 5° to 35°, filling a gap in the previous station distribution in South America. The recent Pisagua earthquake sequence in northern Chile, which started on March 16th and reached 8.1 Mw, was used to test the RSBR detectability. We compared our hypocenters with the Chilean National Seismological Center (CSN) catalog, which is more complete and accurate. A global well known USGS/NEIC/PDE catalog comparison was also performed as reference.

During the Pisagua sequence our system automatically located 265 earthquakes from 21°S to 18°S, and from 72°W to 69°W. Besides the RSBR stations, our system used two Andean stations (LVC and LPAZ) near the epicentral area. All events were revised and associated with CSN hypocenters using a maximum time and distance offsets of 30s and 130km, respectively, parameters that maximized the association ratio. Comparison shows that RSBR is presenting an automatic completeness magnitude of 5.5 mb for the sequence with a lower threshold of 3.5. Equivalent comparison of the NEIC catalog with the reference CSN catalog shows a magnitude completeness of 4.8 with a lower threshold of 3.1. The mislocations (median difference in epicentral/hypocentral distances) while constrained by the association parameters show a median value of 20 km (RSBR/CSN) versus 8 km (PDE/CSN) and a median depth error of 15 km (RSBR/CSN) versus 20km (PDE/CSN).

Our magnitude estimates are consistent with the CSN catalog, while the NEIC catalog tends to have higher values (up to 0.5) compared to CSN. We also found that the depths vary greatly, most probably due to the different procedures used by each institution rather than the location methods. The new RSBR will certainly increase detectability of Andean earthquakes and help improve location accuracies in South America.

KeyWords: Brazil; Pisagua; Earthquake Detectability; Catalog Comparison.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Tarjeta amplificadora para la adapatación de la digitalización de los sistemas sismológicos de corto período en el SGC

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ABSTRACT

En los centros de monitoreo sismológico y vulcanológico del Servicio Geológico Colombiano (SGC) ha nacido una implementación conocida desde hace aproximadamente 10 años pero con algunas deficiencias tanto técnicas como de interpretación por la parte del grupo científico. Esta es la digitalización de sensores sísmicos de corto período pasivos con digitalizadores diseñados y usados para sistemas de banda ancha. Actualmente las pocas implementaciones realizadas evidenciaban la falta de un documento de referencia para la calibración de este nuevo sistema, así como su baja sensibilidad ha generado desplazamientos en líneas bases de interpretación al no comprenderse bien la ubicación del nuevo sistema en la curvas de PETERSON. El avance tecnológico, la obsolescencia de la tecnología telemétrica analógica, la alta confiabilidad de los sensores de corto período pasivo en sitios de difícil acceso, ha hecho que se usen estos últimos con todas las nuevas herramientas de comunicación Ethernet, sistemas de calibración remota y la tecnología digital de adquisición y procesamiento. Esto plantea un reto a nivel tecnológico: ¿Son los digitalizadores de banda ancha adecuados para digitalizar las señales de los sensores sísmicos de corto periodo pasivo en cuanto a ruido de fondo, amplificación y adaptación de impedancia? Para ello se ha resuelto este problema con el diseño del sistema T-AMP-3D-48 el cual es un sistema interfaz para el sensor corto período pasivo a digitalizador que permite amplificar la señal de este sensor sísmico con bajo ruido y adaptar el sistema para conservar las características en frecuencia y de calibración instrumental de los clásicos sistemas analógicos convencionales.
Con este equipo se ha podido así mismo ampliar el ancho de banda, un poco más, mediante el uso de damping tipo capacitivos y conservar las funcionalidades de verificación con señales de prueba como los actuales sistemas de banda ancha. En la actualidad el sistema T-AMP-3D-48 es usado en casi todas las estaciones sismológicas de corto período del Observatorio Vulcanológico y Sismológico (OVSPOP) del SGC. Desde el 2011 se ha obtenido una calidad de señal equiparable a las estaciones sismológicas de banda ancha y con mayor rango dinámico que las estaciones tradicionales con telemetría analógica, a excepción por la frecuencia de detección intrínseca de los sensores usados. De esta forma el sismólogo puede interpretar los datos de este nuevo sistema como si fuera el clásico analógico de una forma transparente.
Actualmente se realiza el proceso para el registro patente de modelo de utilidad para proteger la novedad tecnológica y garantizar que el desarrollo intelectual del amplificador, realizado en el OVSPOP del SGC, este registrado para una eventual fabricación a nivel industrial.

Key Words: Ruido Sísmico, Amplificador, Corto Periodo, Densidad Espectral de ruido.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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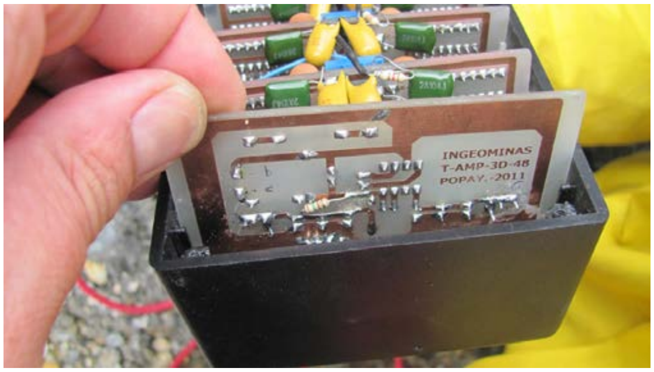

Figura 1. Primer amplificador elaborado en el OVSPOP para adaptar las señales de los sensores sísmico de corto periodo a los digitalizadores GURALP DM24. Estación Agua Blanca volcán Puracé Colombia Noviembre 2011.

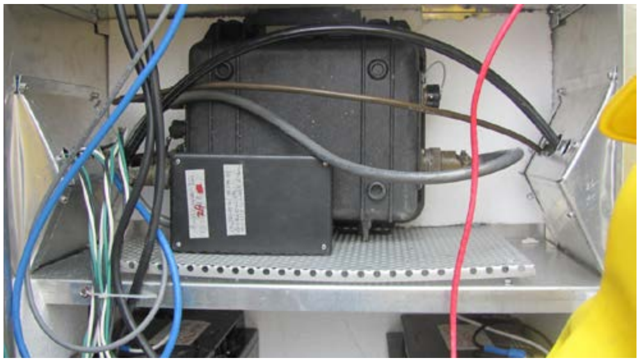

Figura 2. Instalación típica del amplificador T-AMP-3D-48 en una caja de un sistema multiparamétrico, donde puede apreciarse el digitalizador GURALP DM24, al fondo, conectado con el amplificador ubicado al frente. Estación Agua Blanca volcán Puracé Colombia Noviembre 2011.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Optimización de redes de datos para el monitoreo volcánico

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ABSTRACT

La red de comunicación inalámbrica en el Observatorio Pasto, año tras año presenta cambios y mejoras en capacidad y robustez, así como también ha evolucionado desde sistemas analógicos hasta sistemas que transportan información digital, hoy en día la mayor parte de la red opera bajo el protocolo TCP/IP; derivado de este proceso, se requiere cada vez más el control y gestión de la misma, para esta labor es necesario un re-diseño del sistema e incorporar equipos con funcionalidades y prestaciones adicionales que permitan calidad de servicio, soporte a fallos, balanceo de carga, control de tráfico, redundancia y escalabilidad.

La pérdida de conectividad con los sensores instalados en campo, ya sea por fallos propios de los equipos de red, condiciones climáticas adversas o eventos volcánicos considerables, ocasiona una pérdida de datos valiosa e irrecuperable disminuyendo la capacidad de procesamiento y afinamiento de información. Durante este año, el porcentaje de funcionamiento de la red de monitoreo volcanes monitoreados por el Observatorio Pasto en promedio es del 96 %.

La participación de la red pública de internet a la red de monitoreo volcánico ya sea por proveedores (ISP) o a través de operadores de sistemas celulares, puede considerarse positiva en relación al uso de infraestructura y servicios que pueden aportar a diseños de sistemas redundantes. Tecnologías que usan bandas libres del espectro electromagnético como las de 900 MHz, 2.4 GHz y 5.1 GHz, sumado a tipos de radiación como Direccionales, Sectoriales y Omnidireccionales, aportan a diseños tolerantes a fallos.

Los equipos instalados actualmente hacen parte de una red conmutada (Bridge – Capa 2 modelo OSI) su tarea es la comunicación y transporte de datos, la inclusión de dispositivos de tipo UTM (Unified Threat Management) multipropósito, permiten la gestión de tráfico en las capas superiores (3-IP y 4-Transporte del modelo OSI) brindando herramientas a los administradores de la red para una completa gestión, control y mejoramiento.

Considerando lo anterior se diseñó un sistema de red que hace uso principalmente de la red existente y se consideran cuatro áreas principales como son: BackBone (Núcleo), Transporte, Distribución y acceso, enmarcados en los conceptos de seguridad y calidad de servicio.

El sistema propuesto, aumenta el porcentaje de disponibilidad de la red de monitoreo, disminuyendo así la probabilidad de pérdida de datos. El concepto de seguridad se asocia a la disponibilidad, confidencialidad e integridad de los datos, la gestión es transversal a todo el proceso y la calidad del servicio ofrece garantías en condiciones adversas a zonas o estaciones principales para el envío de datos.

Palabras Clave: Monitoreo volcánico, Red de datos, Conectividad, Gestión de tráfico, Gestión de redes, Monitorización, Interoperatividad, Red pública de Internet

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The Chilean Seismological Observation System

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ABSTRACT

Several high-impact earthquakes have taken place in Chile during the last few years. These events have prompted local authorities to improve the seismic monitoring capabilities in the country. Along these lines, the University of Chile created the National Seismological Center, an agency that is the continuation of the Seismological Service. The Seismological Center at the University of Chile has been charged with the installation and robust operation of a network which includes three types of observations: acceleration, velocity and displacement.
The complete observational system is based on the University´s backbone of more than 60 BB and strong motion instruments which include international collaborations with GeoForschungsZentrum (GFZ, Germany), Institut de Physique du Globe de Paris (IPGP, France) and Incorporated Research Institutions for Seismology (IRIS, US). To this, 65 broadband, 65 strong-motion and 130 real-time dual-frequency GPS devices are being installed to complement the observational system. Additionally, 297 accelerometers distributed throughout the country will be connected to the main acquisition, processing and distribution system, which is also being upgraded by incorporating hardware virtualization capabilities. It is expected that most of the installation of the remote sensors is completed by 2015.
A description of the observational system, as well as the degree of progress will be presented, together with the performance of the system during the Mw=8.2 April 1, 2014, earthquake.

KeyWords: Seismic Networks, Chile earthquakes.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Mapas de intensidad instrumental en tiempo real para Colombia

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ABSTRACT

Los sismos son uno de los eventos naturales con mayores niveles de afectación social y económica. En Colombia, algunos de ellos han dejado considerables pérdidas humanas y materiales, muestra de ello los sismos de Popayán en 1983, Tauramena en 1995 y Armenia en 1999. Una de las lecciones aprendidas es que las mayores aceleraciones y por tanto los mayores daños, no solo se concentran en el área epicentral, sino que diferentes factores o condiciones (geología, topografía, tipo de suelo, etc.), pueden alterar su comportamiento.

Al estar Colombia en un contexto sismotectónico activo, y donde un alto porcentaje de la población habita en zonas de amenaza sísmica alta e intermedia (de acuerdo con la Norma Técnica de Construcción Sismo Resistente NSR-10), es necesario desarrollar e implementar, entre otros, sistemas que permitan la estimación teórica de las aceleraciones del suelo generadas por un sismo, así como la definición de los escenarios probables con el fin de ofrecer información oportuna a los organismos de emergencia y entes tomadores de decisiones acerca de qué áreas pudieron sufrir daños (relacionados con la intensidad). La distribución de la intensidad o de la severidad de la sacudida es la que provee información útil para dichos organismos.

A partir del 2011, el Servicio Geológico Colombiano ha venido implementando y desarrollando una de estas herramientas, los mapas de intensidad instrumental (basados en la metodología del Servicio Geológico de los Estados Unidos (USGS)) los cuales muestran el movimiento del terreno expresado en niveles de intensidad sísmica (MMI, etc.) para sismos registrados por la red sismológica y red acelerográfica. Dichos mapas combinan información sísmica en tiempo real, relaciones de atenuación, información sobre condiciones locales sísmicas, factores de amplificación, etc. La información sísmica (localización, magnitud y parámetros de movimiento fuerte del suelo), es generada por el sistema *EarthWorm*, el cual adquiere y procesa en tiempo real la información de los registros instrumentales; para la atenuación sísmica se consideran las ecuaciones empleadas en la actualización del mapa Nacional de Amenaza Sísmica de Colombia; las condiciones sísmicas locales se obtienen mediante la estimación regional de velocidades de onda de corte a 30 m de profundidad (Vs30) y, los factores de amplificación son los adoptados en la NSR-10 de acuerdo al tipo de suelo.

La importancia de la implementación de estos mapas está no solo en suministrar información oportuna a las entidades del Sistema Nacional para la Gestión del Riesgo de Desastres, sino por su utilidad para validar relaciones de atenuación, ajuste de modelos de velocidad y de amplificación, y relaciones aceleración-intensidad que aportan directamente al estudio de la amenaza sísmica del país además de ser un mecanismo de información para la comunidad científica, medios de comunicación y público en general.

Palabras Clave: Amenaza Sísmica, aceleración, Intensidad.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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SPSP session – Statistics and Physics of Seismic Processes

Conveners:
Vladimir Smirnov (Moscow State Univ. - Russia)
<vs60@phys.msu.ru>
Alexander Caneva (UAN - Colombia)
<alexander.caneva@uan.edu.co>

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Magnitude of Completeness for the seismic data catalogue of the National Seismological Network of Colombia (RSNC), 1993-2014

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ABSTRACT

The results of the estimation of the Magnitude of Completeness Mc for the seismic data catalogue provided by the National Seismological Network of Colombia (RSNC), correspondingto the period 1993-2014 are presented.

Mc corresponds to the minimum value of the magnitude of seismic events, which are registered without interruption, in certain region, during an interval of time.

The variations of the values of Mcin time and with depth are analyzed. These results show that in time Mc decreases from 2.8 in 1993 and reaches its minmum Mc ~ |1.9 during 2010. After that we observe how Mc increases up to 2.3 inthe final part of the study period.

The variations of Mc with the depth show a local maximum for depth ~ 40 km. This feature maybe associated to the fact that there is not enough seismic data corresponding to those depths, since in Colombia the seismic activityprincipallyhas its manifestation in shallow seismicity ($H \leq 30$ km) and deep seismicity ($H \geq 80$ km), so, the seismicity in intermediate depths is not so relevant. Anyway, in the end of the time of observation, the Mc values,according to the depth,are lower in comparison with these values in the beginning of the time of observation.

Key Words: seismic data catalogue, RSNC, completeness, Colombia.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Análisis probabilístico de la sismicidad del Valle de Cauca y zonas aledañas, Colombia

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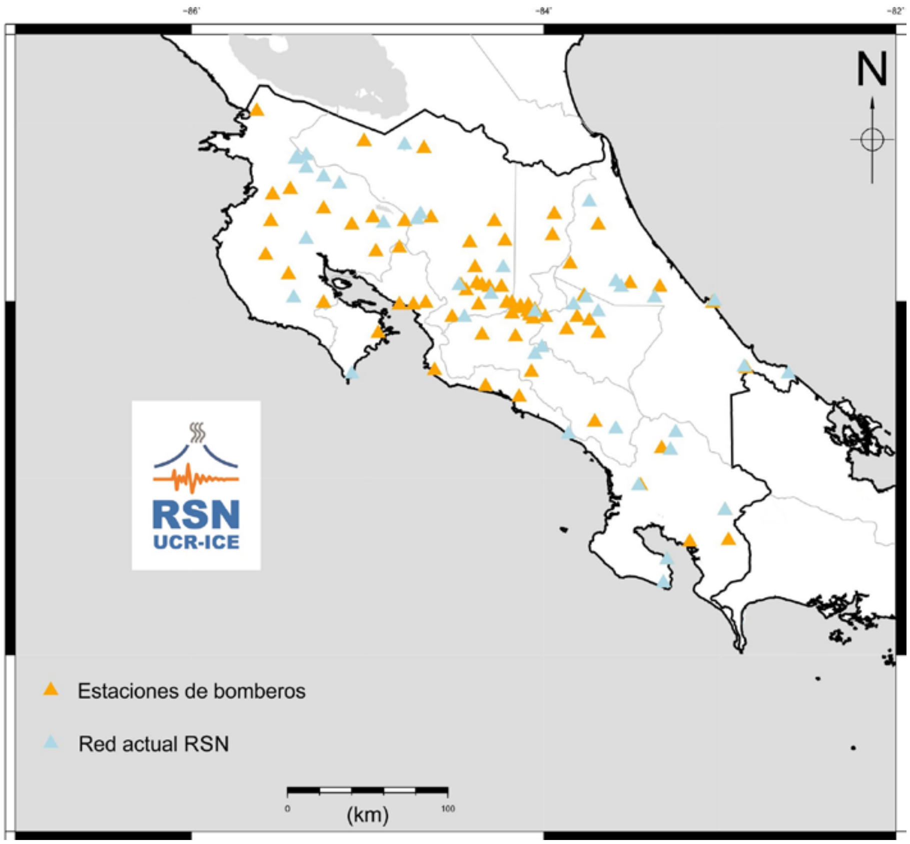
ABSTRACT

En el presente trabajo se estudia la sismicidad del departamento del Valle del Cauca y zonas aledañas tomando como base el catálogo sísmico de la Red Sismológica Nacional de Colombia (RSNC) para el periodo entre 1993 y 2013; se considera solo la sismicidad registrada en el continente debido al mejor control de la solución epicentral por la escasez de estaciones sismológicas en la zona oceánica. Se presenta un análisis univariado de los sismicidad en la zona, determinándose la magnitud mínima representativa por medio del método de Magnitud de Rango Entero, siendo ésta de 2,3 Ml; para verificar la completitud del catálogo se utilizó el método de Stepp que se basa en la distribución Poisson. Se analiza el comportamiento espacial de los sismos usando la técnica de patrones puntuales, donde se verifica que los sismos no siguen un proceso de Poisson homogéneo; para realizar el análisis probabilístico la sismicidad se discrimina en superficial e intermedia, por medio de gráficos probabilísticos se identifica que la distribución que mejor modela los sismos ocurridos es la exponencial, llegando a la conclusión que la ventana de tiempo es un poco corta y el espacio geográfico o cuadrante es demasiado grande para realizar un análisis sísmico más certero respecto a la recurrencia y ocurrencia de los pequeños y grandes sismos, esta conclusión se presenta debido a que el catálogo sísmico presenta problemas de completitud y homogeneidad para magnitudes mayores o iguales a 5,9 Ml. Para el caso de los sismos superficiales se detalla que la probabilidad de que se presente un sismo de cualquier magnitud es aproximadamente del 100% dentro de 7 años, para el caso de los sismos intermedios la probabilidad de que suceda un sismo de cualquier magnitud es aproximadamente del 100% dentro de 5 años. A pesar de que la región del Valle del Cauca está catalogada como una zona de amenaza sísmica alta, se muestra que no se presentan muchos sismos fuertes o destructivos. Por último, se realizó el cálculo de los parámetros a y b de la ley de Gutenberg y Richter obteniéndose que para el caso de la sismicidad intermedia estos parámetros disminuyen simultáneamente en el tiempo y para la sismicidad superficial su variación no sigue un patrón determinado.

PalabrasClave: Sismicidad, Método Stepp, Proceso Poisson, Distribución Exponencial, Método de Magnitud de Rango Entero, Patrones puntuales.



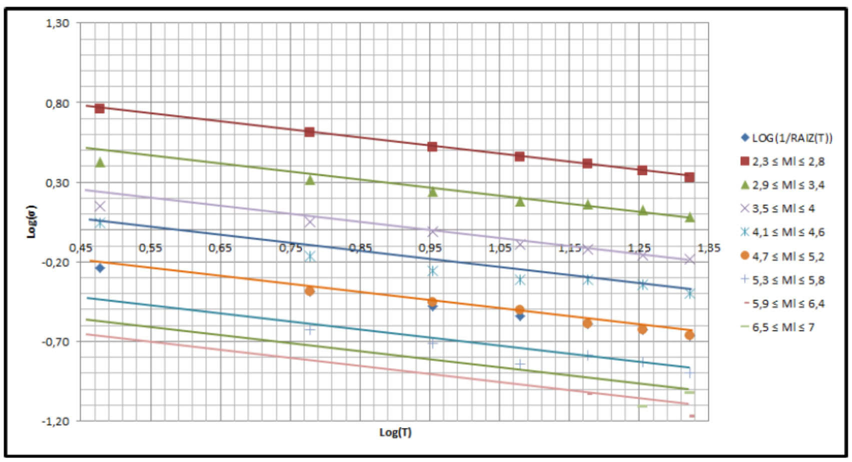


Figura 5-6: Análisis del catálogo sísmico instrumental (1993-2013). $2,3 \leq Ml \leq 7$

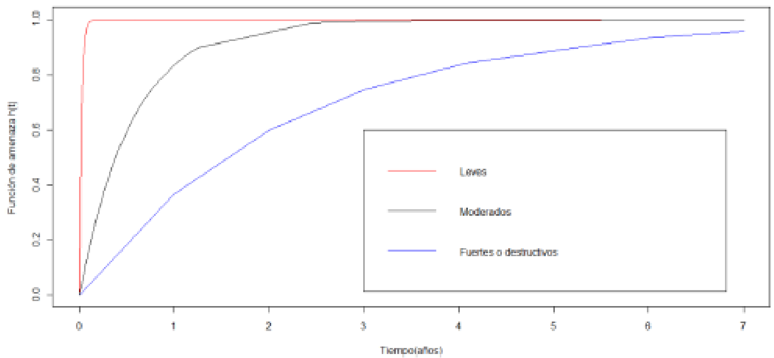


Figura 5-17: Función de amenaza asociado a los sismos superficiales

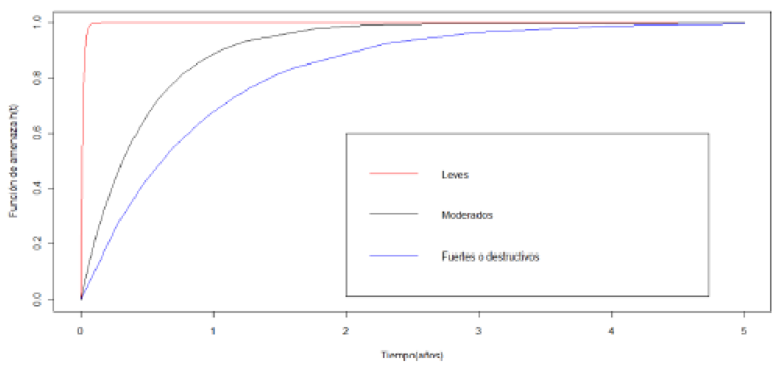


Figura 5-18: Función de amenaza asociado a los sismos intermedios

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earthquake catalogue processing and declustering issues

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ABSTRACT

The compilation of a complete database of earthquake events is useful in understanding the recurrent behavior of major earthquakes and helps to visualize the future events and their outcome. Earthquake catalogues are one of the most important products of seismology. They provide a comprehensive database useful for numerous studies related to seismotectonics, seismicity, earthquake physics, and hazard analysis. A critical issue to be addressed before any scientific analysis is to assess the quality, consistency and homogeneity of the data. A complete catalogue processed for foreshocks and aftershocks which is free from errors, plays a crucial role in assessing the recurrence relationship of the region. A complete and consistent catalogue of earthquakes can provide good data for studying the distribution of earthquakes in a region as a function of space, time and magnitude. A catalogue of events following the Poissonian distribution provides strength to seismic hazard analysis. However, most catalogues do not report the magnitude of earthquakes consistently over time, in addition to varying uncertainties in hypocenter locations. This may pose as an obstacle for delineating seismicity patterns or for assessing seismic hazards. It is important to convert the original magnitudes based on various scales in different time periods to a common magnitude scale throughout the whole period.

Declustering attempts to separate the time-independent part of seismicity (background) from the time-dependent or clustered parts (aftershocks, foreshocks, and swarm type activity). For most hazard related studies, it is required that the seismicity behaves in a time independent fashion. It can be investigated whether or not the temporal distribution of events within the raw catalogue is stationary Poissonian, which would argue that declustering may not be necessary. There are many declustering algorithms available which were developed for specific seismotectonic regions. A decision on declustering algorithm to be used plays a crucial role in declustering the data. Magnitude range for the catalogue is of same importance. The completeness period and b value are also important and helps in assessing the quality of compiled data. There are many issues related to the processing of earthquake catalogue. Here an attempt has been made to discuss some of those issues with the help of procedures carried out on an earthquake database from north India.

Key Words: Earthquake catalogue, declustering, magnitude, completeness period, Poissonian process.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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¿Qué produjo los sismos ocurridos al oriente de Bogotá el 10 de octubre de 1743 y el 24 de mayo de 2008?

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ABSTRACT

El 24 de mayo de 2008 se presentó al oriente de Bogotá un sismo con ML = 5.5 y profundidad focal de 4 km de acuerdo a la Red Sismológica Nacional de Colombia (RSNC) y MW = 5.9 y profundidad focal de 35 km conforme la red mundial (NEIC). La solución del mecanismo focal indicado por el proyecto Global - CMT de la Universidad de Harvard fue lateral derecha con componente normal, presentando el plano principal un azimut de 196°, buzamiento de 82° y estría de falla con -179°, y el plano secundario un azimut de 106°, buzamiento de 89° y la estría de falla – 8°. Las dos redes coinciden con un margen de error de solo 7 km en el epicentro, el cual fue en el Páramo de Chingaza, sin embargo para el foco, la diferencia fue de más de 30 km en la vertical y +/- 10 km en la horizontal entre la RSNC y la red mundial. Para esta última se estima un error en la horizontal de +/- 4,9 km fijando el foco en profundidad por su programa de localización.

Por las diferencias iniciales dadas con la localización hipocentral y por su mecanismo focal, en este trabajó se buscó revisar y caracterizar el esquema tectónico que se presenta en este sector de la cordillera Oriental de Colombia tanto en superficie como en profundidad.

En esta región la corteza superior (con un espesor máximo de 10 km) se constituye de rocas metamórficas de bajo grado y rocas sedimentarias que abarcan en edad geológica el lapso Neoproterozoico - Presente. Estas rocas están afectadas por plegamientos, fallas de cabalgamiento y fallas normales que derivan de un régimen extensional producido por un efecto gravitacional principalmente.

Debajo de esta, se presenta una corteza frágil (con un espesor promedio de 20 km) que se compone principalmente de un basamento Mesoproterozoico relacionado con la orogenia Grenviliana que está constituido por rocas plutónicas y metamórficas de alto grado en el que predominan fallas normales y fallas de cabalgamiento con dimensión cortical.

La activación de estas fallas durante el Neógeno Superior dio origen a la conformación orogénica de este flanco de la cordillera. En la divisoria de aguas, las elevaciones llegan a alturas de cerca de 4000 m. Estas últimas configuran el denominado "Domo de Chingaza" y hacía el SE estos escarpes disminuyen en altura hasta 1000 m definiendo el Piedemonte Llanero.

Con la ayuda de imágenes satelitales, mapas topográficos, verificación de campo y tomografía sísmica, se ha encontrado indicios de la presencia una gran falla profunda la cual presenta un rumbo ENE, que define un prisma cortical que controla las máximas alturas de esta región hacía el oriente de Bogotá y que delimita el Domo de Chingaza.

La movilidad y el constante ajuste de la acomodación de este prisma cortical frente al campo de esfuerzos presente en esta región han originado en esta, los sismos de 1743, 1923, 1966, 1988 y 2008.

PalabrasClave: Sismo de Quetame, Falla Servitá, Piedemonte Llanero, Geotectónica, Sismotectónica.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Modeling seismic sources in Colombian Central West using inversion of telesismic body waveforms

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ABSTRACT

Source parameters for four earthquakes that originated within the Benioff zone of Nazca plate subducting the South American Plate near Colombia were determined. The first earthquake took place on 2nd February 1995, Mw=6.3, H=75.5 km, Mo=3.6*1025 dyne-cm, strike=137.3°, dip=38°, and it generated an aproximate rupture plane size of 20x15 km2; the second earthquake on 19th August 1995, Mw=6.4, H=115.0 km, Mo=5.06*1025 dyne-cm, strike=67.9°, dip=72.7°, rake=-73.5°, and it generated an aproximate rupture plane size of 25x20 km2; the third earthquake on 2nd September 1997, Mw=6.7, H=215.5 km, Mo=8.04*1025 dyne-cm and it generated an aproximate rupture plane size of 30x25 km2; and the fourth earthquake on 11th December 1997, Mw=6.3, H=189.5 km, Mo=2.42*1025 dyne-cm, and it generated an aproximate rupture plane size of 15x10 km2. The first two earthquakes originated in the intermediate Benioff zone, while the other two originated in the deep Benioff zone.

The source parameters were obtained by deconvolving multiple events through teleseismic analysis of body waves recorded in long period station. Simultaneous inversion of P and SH waves is performed. Rupture is modeled as a line source propagating in two directions at velocities of 3km/s. The time function of these events showed different stages which could be interpreted in the inversion as either three or two subevents; the aspect ratio W/L varied within 0.73 and 0.83.

Key Words: Source parameters, waveform inversion, teleseismic waves, subduction zone.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Depth profile of the fractal dimension and the seismotectonic deformation rates associated to the earthquakes distribution

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ABSTRACT

We have analyzed a seismological catalog of approximated 161035 seismic events and 2300 focal mechanisms in depths ranging between 0 and 200 km. This catalog was compiled by the International Seismological Centre, and includes aprox. 580 stations in the period 1977-2014. Dataallowed calculate the spatial variations (dependence with depth) of the seismic regime (fractal dimension of the earthquakes distribution D) and the seismotectonic deformation rates in a tectonically complexarea located in the SW Caribbean. Variations of the fractal properties of seismicity and the seismotectonic deformation rates were observed along depth, suggesting a stratified rheology and/or a differentialbehavior of the lithospheric system.

Key Words: Fractal dimension, Seismotectonic deformation rates, Seismic regime.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Earthquake source parameters which display first digit phenomenon

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ABSTRACT

We study main parameters of earthquakes from the perspective of the first digit phenomenon: the non-uniform probability of the lower first digit different from zero compared to the higher ones. We found that source parameters like cosesimic slip distributions at the fault and coseismic inland displacements show first digit anomaly. We also found the tsunami run-ups measured after the earthquake to display the phenomenon. Other parameters found to obey first digit anomaly are related to the aftershocks: we show that seismic moment liberation and seismic waiting times also display an anomaly. We explain this finding by invoking a self-organized criticality frame. We show that critically organized automata show the first digit signature and we interpret this as a possible explanation of the behavior of the studied parameters of the Tohoku earthquake.

Key Words: seismic source, first digit phenomenon.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismicity response to the electromagnetic probing of the lithosphere in the Bishkek (Kyrgyzstan) geodynamic test area

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ABSTRACT

Earthquake catalogue of the Bishkek (Kyrgyzstan) geodynamic test area for 1967-2008 was analyzed with aim to study the properties of seismicity response to the power electromagnetic probing of the lithosphere in 1983-1990 and 2000-2005. Time variations of statistical parameters usually used for investigation of background and transient modes of seismicity were analyzed in the 150-km vicinity of the probing dipole. Analysis is carried out on the two levels of time scales: first years – before, during and after probing series, and first days – during 10 days after each acts of probing. Main results obtained on the scale of first days are as follows: directly during probing GR b-value is significantly higher than in background mode; gradual decreasing of b-value follows after probing finishing has duration about one and half day; seismic activity slightly increases during probing; after probing, when b-value decreases, activity is minimal. Analysis on the scale of first years reveals time variations of seismicity parameters, but there is no evidence to relate these variations with probing series. Revealed variations are typical signatures of preparation and after-action of tectonic earthquakes occurring in the studied area.

Key Words: Seismicity response, b-value, electromagnetic probing, Kyrgyzstan.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Distribución espacial y temporal de los terremotos destructivos y sus réplicas, del abril de 2014, cerca de Managua, Nicaragua

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ABSTRACT

El Jueves, 10 de abril de 2014, a las 17:23 horas, INETER registró un terremoto de magnitud 6.2 en el Lago de Managua, con epicentro cerca de la Isla Momotombito, a unos 30 km de Managua. El evento fue sentido en todo el país, muy fuerte en los departamentos Managua y León. La afectación fue amplia con intensidades MMI máximas de V a VII. Hubo muchos daños – grietas, caída del techo, inclusive casas colapsadas - en casas de mala construcción (adobe, taquezal) en las ciudades y poblados en o cerca de las riberas occidentales de Lago como Nagarote, Mateare, La Paz Centro Puerto Momotombo. La magnitud 6.3 (INETER) o 6.1 (USGS) es casi idéntica a la del terremoto que destruyó Managua en 1972 (USGS - 6.2). El evento figura entre los más fuertes en la historia en Nicaragua, sin contar los terremotos extremos en el Océano Pacífico. Solo la ubicación del epicentro en el Lago de Managua evitó un gran desastre. Afortunadamente, no hubo víctimas humanas directamente por el terremoto.

El número total de sismos de esta actividad, en abril de 2014, fue superior a 64,000; de estos, 642 pudieron ser localizados. Las primeras réplicas se concentraron cerca del terremoto principal pero pronto ocurrieron en el Volcán Momotombo, a unos 40 km de Managua. Después de pocas horas se dieron sismos en el Volcán Apoyeque, a solo 8 km de Managua. La migración de la actividad sísmica es un fenómeno anteriormente observado en Nicaragua. El presidente de Nicaragua declaró, a medianoche del 10 de abril, “Alerta Roja” para toda Nicaragua. Las autoridades advirtieron que Managua podría ser afectada por mayores sismos. La sismicidad podría ser premonitora de un terremoto destructivo en Managua. Se recomendó a las familias que durmieran afuera si sus casas eran de mala construcción. El 13 de abril, ocurrió un terremoto de magnitud 5.7 en el Volcán Apoyeque. Muchas casas en Managua, en Ciudad Sandino y Los Brasiles sufrieron daños.

Desde el inicio de la actividad, las autoridades revisaron casas afectadas, escuelas, colegios, edificios públicos, en cuanto a su estado después del impacto de los terremotos y a la vulnerabilidad relacionada a un posible terremoto en Managua. Con gran velocidad, se realizaron reparaciones y mejoras de infraestructura, también se eliminaron 49 ruinas - remanentes del terremoto de 1972 - que todavía fueron habitadas por familias pobres a las cuales se asignaron otras viviendas. Además, se mejoró la capacidad del INETER para procesar automáticamente los sismos fuertes en la zona de Managua.

El temor de un fuerte terremoto en Managua en el futuro próximo es presente, las medidas impulsadas por la última actividad sísmica ayudaron a estar mejor preparado para esta eventualidad.

Palabras Clave: terremoto, réplicas, Managua, Nicaragua.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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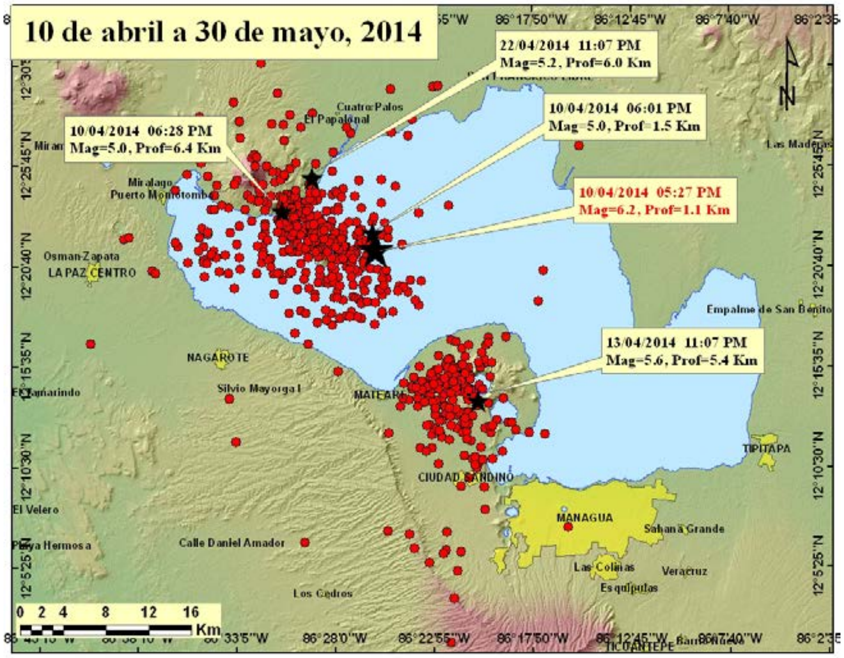

Figura 1. Terremoto del 10 de abril, 2010 y sus réplicas, localizaciones del INETER. Tiempo en hora local (ut-6).

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Mud volcano seismo-geodynamics

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ABSTRACT

According to author's results, the mud volcanism is sensitive enough to changes of the stressed state of the Earth's crust. Seismicity and mud volcanism are in the definite spatial-time (chronologically) ratio. Moreover the mud volcanoes eruption and their connections with earthquakes located within or near areas of the mud volcanoes localization are divided into accompanying seismic events forestalling them and events occurring after the earthquake. Due to our investigations it has been determined that the strong seismic events can influence on the stress area condition at the considerable distance. The conclusion is important for earthquakes prediction on the practicability of the vast geophysical control and usage of the mud volcanic to forecast the dynamic processes in the focus zones of strong preparing earthquakes. Different scale migration manifestations of mud volcanic activity dynamics in processes of main earthquake preparation with magnitude 5.0 – 9.0 were invented. Some remarkable migration of mud volcanic eruptions prior to the main earthquakes are described based on the systematic analysis of the National Catalogue of the active mud volcanoes in the period of 1810-2004 in and around the South Caspian depression including the region of east Central Iran. The discovery of pattern of migration of the mud volcanic activity before the main earthquake can be considered as new precursory phenomena. There was used a methodology of finding of two types of migrations of mud volcanic eruptions by reconstruction of the earthquake preparing pattern. There are provided the detailed results of revealing the ordered migration of the mud volcanic eruption by reconstructions of the preparatory phase of earthquakes of November 25, 2000 (M=5.8; 6.3) and December 6, 2000 (M=7.3), having respectively, arisen in a few kilometers to the south-west and north-west of Baku in Caspian Sea and to the west Turkmenistan. These Absheron mud volcanic eruptions were triggered by M 9.0 great earthquake preparation patterns that occurred on December 26, 2004 of the west coast of northern Sumatra, Indonesia. The relationship between Caspian Sea level oscillations and the seismic dynamics the largest magnitude 6.0 to 8.0 and greater, earthquakes worldwide in the Sumatra-Andaman main event. These phenomena are explained and substantiated by the proposed conception of the upper crustal sedimentary-stage degree of the seismogeodynamic manifestation. They are an integral part of the modern evolution of fluid-magmatic systems of the volcanoes.

KeyWords: Absheron, volcanoes.

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SZPR – Subduction Zone Processes (joint SSA/LACSC session)

Conveners:
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic velocity reduction following the September 5, 2012, Mw=7.6 Nicoya Costa Rica Earthquake from ambient noise correlations

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ABSTRACT

The unique location of the Nicoya Peninsula, directly over the interface where the Cocos plate is subducting beneath the Caribbean plate, resulted in excellent broadband seismic and cGPS coverage of the 2012 Nicoya earthquake rupture area, making it one of the best recorded megathrust earthquakes ever. This comprehensive instrument coverage makes it possible to use high-resolution data (seismic and cGPS) to study the pre-seismic, co-seismic and post-seismic processes related to this large earthquake. In the present work we apply the cross-correlation of ambient seismic noise technique to reconstruct dispersive Rayleigh waves (empirical Green's Functions) between station pairs distributed along the Nicoya Peninsula, Costa Rica, to characterize any changes in the velocity structure associated with the September 5, 2012, Mw=7.6 Nicoya Peninsula Earthquake. Our results show a clear velocity reduction of 0.4% immediately following the earthquake with a gradual post seismic recovery. These earthquake related velocity variations are most clearly visible in the period range of 1-10s with no appreciable change at longer periods. Because the cross-correlation function is primarily composed of surface waves, the depth sensitivity of the velocity change is a function of signal period. In the period range of 1-10s the surface waves are sensitive to the upper most crust (hundreds of meters to 10 km). Our results average velocity variations between all station pairs and we are presently investigating both regional variations and the frequency dependence of the coseismic velocity reduction. These preliminary observations of temporal variations in Rayleigh wave velocities are likely due to a combination of: (a) coseismic damage in the shallow layers due to non-linear site effects; (b) co-seismic stress changes; and (c) post-seismic stress relaxation or healing processes.

KeyWords: Seismic ambient noise, velocity structure.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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The causative relationship between the megathrust and upper plate faults at subduction zones

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ABSTRACT

The last three great subduction earthquakes on Earth have demonstrated that slip activity at subduction zones seems to be related in two ways with the upper plate fault activity. The 2010 Mw 8.8 Maule Earthquake and the 2011 Mw 9.1 Tohoku-Oki Earthquake generated aftershocks in the upper plate compatible with the reactivation of normal faults. On the other hand the recently 2014 Mw 8.2 Pisagua Earthquake was preceded by several foreshocks; the first of which we suspect was located in a trench-orthogonal reverse fault of the upper-plate. In this contribution we show several argumentations (relocation, moment tensor orientation and stress change analysis) to postulate that the Pisagua Earthquake was effectively initiated in an upper plate event and then seismic instability was propagated to the interplate contact triggering the Mw 8.2 Pisagua Earthquake. Although upper plate earthquakes caused by subduction earthquakes are well identified, the process in the other direction has not been previously described.

Key Words: Subduction zone, upper plate earthquakes, megathrust, foreshocks, aftershocks.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Mind the Gap – the northern Chile Subduction Zone and the 2014 Iquique Earthquake Sequence

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ABSTRACT

The seismic gap theory, which identifies regions of elevated hazard based on a lack of recent seismicity in comparison to adjacent sections of a fault, is useful for qualitatively describing where future large earthquakes might occur. The hypothesis has successfully explained past events including the M 8.8 Maule, Chile earthquake in 2010. An earthquake of a similar size had been expected in the subduction zone adjacent to northern Chile, which until recently had not ruptured in a megathrust earthquake since a M~8.8 event in 1877. On April 1 2014, a M 8.2 earthquake occurred within this seismic gap, offshore of the city of Iquique; the size and spatial extent of the rupture indicate it was not the earthquake that had been anticipated.

Here, we present a rapid assessment of the seismotectonics of the March-April 2014 seismic sequence offshore northern Chile, including analyses of earthquake relocations, moment tensors, finite fault models, moment deficit calculations, and cumulative Coulomb stress transfer calculations over the duration of the sequence. This ensemble of information allows us to place the current sequence within the context of historic seismicity in the region, and to assess areas of remaining and/or elevated hazard. Our results indicate that while accumulated strain has been released for a portion of the northern Chile seismic gap, large amounts of seismic moment are still stored along this portion of the subduction zone. In particular, a significant section of the seismic gap immediately to the south of the March-April 2014 sequence remains unruptured since 1877, and could host an event as large as M ~ 8.7. Earthquakes to date have increased the stresses in the northernmost portion of this remaining gap, elevating the short-term hazard of earthquakes in the subduction zone immediately south of Iquique, which could rupture as far as ~200 km south toward Antofagasta.

KeyWords: Iquique, Subduction Zones, Seismic Gap, Finite Fault Modeling, Moment Tensor Inversion, Earthquake Relocations, Stress Modeling.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Spatio-temporal evolution of the 2014 Pisagua, Chile earthquake sequence

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ABSTRACT

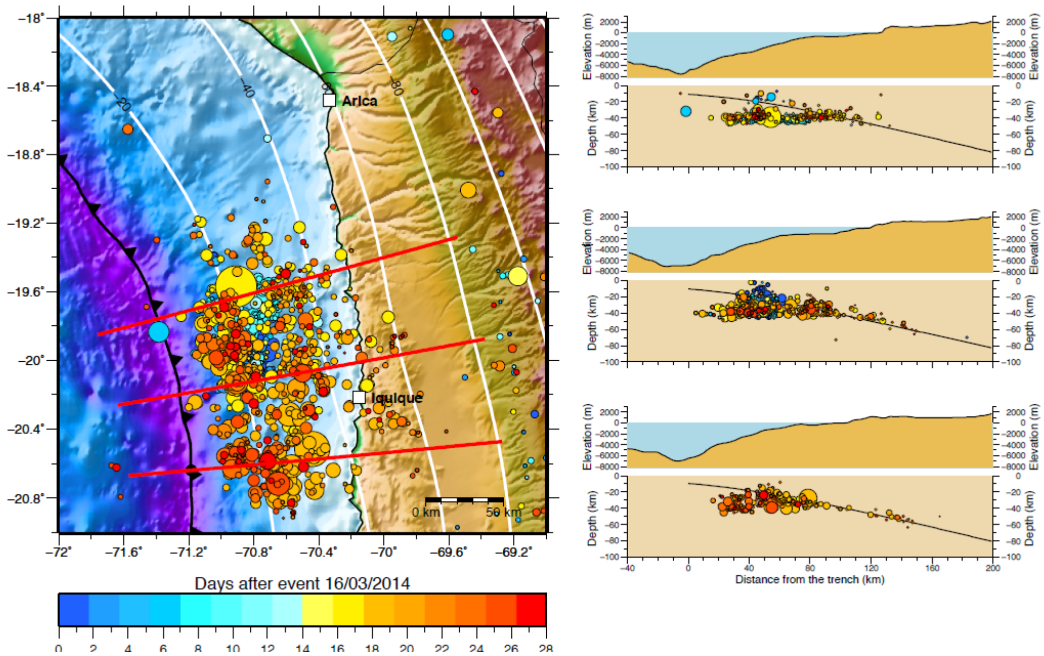
On the evening of the 1st of April 2014, a Mw=8.2 tsunamigenic megathrust earthquake struck the coast of North Chile, causing 6 fatalities, vast material damages, and prompting the preventive evacuation of around one million people along the coastal urban areas of North and Central Chile. This earthquake, known afterwards as the 2014 Pisagua earthquake, was preceded by a sequence of foreshocks that lasted about 2 weeks and nucleated at the center of a well-known seismic gap existent since 1877, when an M~8.5 earthquake shook northern Chile, producing a large tsunami across the Pacific.

In this work, we benefit from the hypocentral locations provided by the Chilean National Seismological Center (CSN) and the well-known NEIC-PDE catalog to characterize the spatio-temporal evolution of this seismic sequence. Additionally, we analyze the catalogs completeness magnitude (Mc) and b-value variations in the area, comprising the background and foreshock activity previous to the earthquake and approximately 1.5 months of its aftershocks.

Early precursors started in late 2013/early 2014. The main sequence begun in mid-March 2014 with an Mw=6.7 foreshock about 60 km NW of the city of Iquique. The seismicity then slowly migrated northwards surrounding the future epicentral region where the 1st of April earthquake nucleated. Hundreds of aftershocks followed the mainshock defining a rupture area mainly southwards and deeper into the seismogenic interface. The extension on this rupture area only partially covers the total extension of the pre-existent seismic gap. The largest aftershock was an Mw=7.7 event with epicenter around 50 km SW of Iquique, after which the seismicity started to decrease. We found that the Mc of the CSN catalog decreased from 3.5 before 2010 to around 2.5 the year before the Pisagua earthquake, mostly as a consequence of the densification of the local seismic network in northern Chile. For the aftershock period, Mc rises to 3.2 likely due to the increase of seismicity and short time-span considered. The NEIC-PDE catalog presents a quite stable Mc around 4.3 for the 10 years period before the mainshock, rising to 4.7 during the aftershocks. Given the stability of Mc for both catalogues and the relative large amount of events with magnitude larger than Mc, we studied temporal variations of the frequency-magnitude relationship observing a notable decrease (from 0.6 to 0.4) of b-value since mid-2013 (suggesting pre-seismic stressing of the megathrust as observed for others large earthquakes) and large fluctuations accompanying the foreshock sequence (perhaps related to rapid changes in pore fluid pressure).

Our study of the foreshock and aftershock periods shed some light on the current state of the North Chile seismic gap and the potential predictability of great megathrust earthquakes such as the 2014 Pisagua earthquake.

Key Words: Seismic gap, Pisagua, Chile, Subduction zones, megathrust earthquakes, b-value, aftershocks.


Arica
Iquique
0 km
50 km
Days after event 16/03/2014
Elevation (m)
Depth (km)
Distance from the trench (km)

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Grijalva Ridge, a major player in the subduction game underneath Ecuador

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ABSTRACT

There has been a long debate on the role Carnegie ridge's arrival and subduction has in Ecuador's geodynamics. Some authors favor the idea that the buoyancy of the subducted part of Carnegie would explain a torn in the undergoing plate and would be responsible for a very gentle dipping of Nazca plate underneath Ecuador (Gutscher 1999). Other authors (e.g. Guiller et al 2001, Michaud et al. 2009) have contradicted the flat slab hypothesis and have explained intermediate depth seismicity distribution or coupling based on the presence of Carnegie ridge. This ongoing debate has distracted attention from another prominent geomorphic feature located immediately south of Carnegie ridge: Grijalva ridge.

Grijalva Ridge is the morphological evidence of a paleo-rift that separates the old (>12 Myr old) Farallon subducted plate to the south from the new (7 Myr old) Nazca plate to the north (Lonsdale 2005). Grijalva ridge inland prolongation –GRIP- explains several observations made in the course of preparing the seismotectonic sources for seismic hazard assessment in Ecuador. High energy intermediate depth seismicity (IDS) is located almost exclusively south of GRIP and is related to the tearing of Farallon along its lines-of growth fabric. At least six M≥7 earthquakes have been localized along a SSE trending, 300 km long, narrow zone south of GRIP in the last 80 years. Rotation of fault plane strikes obtained from IDS normal faulting focal mechanisms south of GRIP strongly suggests a contortion in the plate. At ~150 km depth it plunges abruptly in a northeasterly direction. The conspicuous IDS seismic cluster - known as El Puyo cluster- results from stress concentration in the maximum contorted zone. To the north of GRIP no M>6 IDS has been reported and locally recorded microseismicity is restricted to maximum depths of around 120km located below Ecuador's foreland. The Ecuadorian volcanic arc on top of the Andean chain attests to the presence of a hot slab further east of the seismic evidence, but also favors the idea of an along strike continuity of the dipping slab to the south as stated by Michaud et al (2009). On the surface, directly above the El Puyo cluster, the Pastaza megafan is occupying the continental foredeep resulting from the viscoelastic adjustment of the lithosphere above the plunging tip of Farallon slab. More relations between seismicity, coupling and active faulting with GRIP and the related plates will have to be confirmed and may reveal the major role that the two plate's differences may play in the geodynamics of this part of South America.

KeyWords: Grijalva rige, Carnegie rige, Farrallon plate, Nazca plate, El Puyo cluster.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Distribution analysis of the frequency–magnitude parameters along the subduction surface structure in South America

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ABSTRACT

A catalogue of approach 22,470 seismic events registered in Central and South America between 1900 and 2014 and obtained from the U.S. Geological Survey was analyzed in terms of Frequency-Magnitude Distribution parameters. Accepting the assumptions of the Gutenberg – Richter Law, and taking into account the minimum magnitude of homogenous catalog, we estimated the b-value parameter of the subduction structure along a regular grid (0.5° x 0.5°) and for profiles defined previously, which allow to know a distribution of recurrence time and annual probability of earthquakes.

We have correlated this spatial mapping with other subduction parameters (angle, dominant source parameters, geophysical response of several variables, etc.) in order to evaluate the critical conditions of the fracture regime. Contrast values of these parameters suggest a large lateral variation of the subduction structure in South America and Centro America.

We hypothesize that this contrasting conditions are response of the complex regime of convergence and may support an alternative regionalization of the seismic hazard at west of the region.

Key Words: Subduction, Seismic Hazard, geophysical variables, seismic events.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Mapping patchiness of the subduction interface in the near field: the case of the southern terminus of the Middle American Trench, Costa Rica

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ABSTRACT

Mapping heterogeneities along plate interfaces in subduction zones is becoming possible as more densely-spaced seismic and GPS arrays are being installed worldwide. Large patches of nearly 100% coupling, or the simultaneous failure of several smaller strong patches, generate great earthquakes. These great earthquakes are uncommon (every hundreds of years), but the failure of medium-size, strongly coupled patches is very common (every tens of years) worldwide. Mapping and tracking the loading and failure evolution of these medium-size patches could lead to more precise assessments of size, location and timing of future earthquakes. In Costa Rica, thanks to the existence of three peninsulas, Nicoya, Osa and Burica, which extend close to the trench and over the seismogenic zone of large and frequent thrust interplate earthquakes, it has been possible to initiate an international effort to map heterogeneities on the subduction interface. We will be presenting results from the mapping of a) patch that failed with the 1990 Mw=7.0 earthquake at the entrance of the Nicoya gulf; b) a successful experiment in the Nicoya peninsula with the record in the near field of a Mw=7.6 earthquake, and c) we will share the design of a geodynamic control network that are being installed on and around Osa and Burica peninsulas, to capture and map the rupture area, also in the near field, of a Mw=7.2-7.4 earthquake that will likely occur in the next 10 to 15 years.

Key Words: subduction, Costa Rica, Middle American Trench.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Reverse polarity repeating events are associated with boudin formation at intermediate-depths in the Bucaramanga nest

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ABSTRACT

The Bucaramanga nest seismicity is associated with slablet subduction at intermediate depths. This region in northern Colombia produces the densest concentration of seismicity in the world. We detect ~18 events per day in this nest using a regional network in Colombia. Of these events we observe two populations of waveforms: each with highly correlating waveforms (repeating events) and with reverse polarity to the other group. We define these reverse polarity repeating earthquakes using a divisive clustering algorithm, which divides the repeating waveforms into two groups. These events are relocated first using hypoDD and then using the associated errors to apply feature extraction algorithm. This secondary relocation step searches for possible locations within the realm of uncertainty, favoring an outcome of simple structures. This result illuminates two distinct, roughly linear features – one associated with each repeating group. We interpret these features to be related to boudin formation (boudinage) associated with the extension of the slab at depth. We also examine the recurrence interval of these events and observe a clustering of the two groups in time and space. This cascading failure pattern provides further evidence for a thermal-shear failure mechanism.

KeyWords: Repeating earthquakes, intermediate-depth, Bucaramanga, thermal shear failure, cluster analysis.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)
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3D thermal modeling associated with subduction of the Philippine Sea plate in Southwest Japan

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ABSTRACT

Constructing a parallelepiped three-dimensional thermal convection model, we investigated temperature, mantle flow and heat flow distributions associated with subduction of the Philippine Sea (PHS) plate in southwest Japan. We proposed a new, realistic, and high-resolution temperature field on the plate interface, and attempted to clarify its relationships with the occurrences of megathrust earthquakes, long-term slow slip events (L-SSEs), and low-frequency earthquakes (LFEs). For this purpose, we newly developed a numerical model to deal with subduction of an oceanic plate with 3D arbitrary geometry. We modeled subduction of the PHS plate by using the up-to-date three-dimensional slab geometry, referring to high resolution P-wave seismic tomography and seismic reflection studies. We also used large number of heat flow data such as BSRs, borehole, heat probe, and Hi-net to constrain calculated temperature field, and took account of complicated subduction history in southwest Japan. The results showed that temperature change due to erosion and sedimentation affected surface heat flow with short wavelength. We also found that the obtained interplate temperature in the Nankai seismogenic zone was wider than that in the Tonankai seismogenic zone. The existence of large temperature gradients from the surface to the inside of the PHS plate was considered to be related to the occurrence of L-SSEs beneath the Bungo Channel. Temperature where LFEs occurred near the plate interface beneath Shikoku was found to be lower by approximately 100°C than that beneath the Kii Peninsula.

KeyWords: temperature, heat flow, 3D thermal modeling, southwest Japan.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismological view of Nazca-South American Convergent Margin between 10° and 20°S

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[2]University of North Carolina, US.
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ABSTRACT

The central Andean convergent margin in South America is characterized by along-strike variations in magmatism, crustal thickness, and slab geometry that make it an ideal region to study the relationship between the subducting slab, the mantle wedge, and the overriding plate. The north central Andes between 10° and 20°S is characterized by a change in the geometry of the subducting slab from normal (~30° dip) subduction in the south to near horizontal subduction in the north. We deployed ~85 broadband seismometers in this region (CAUGHT and PULSE seismic deployments) to image the Earth beneath the array to study the lithospheric scale structures of high plateaus, mechanisms of surface uplift, and slab geometry.

On the eastern margin of the Central Andean Plateau (CAP) both receiver functions and Ambient Noise Tomography (ANT) studies reveal crust ~40 km thick at the eastern edge of the active fold and thrust belt. The crustal thickness beneath the Eastern Cordillera is variable and ranges from ~55 km east of La Paz to ~70 km further south near Potosi, Bolivia. The thinner crust under the Eastern Cordillera corresponds to a region of high rates of exhumation and may be due, in part, to erosion-driven exhumation. The crust thickens to ~60-70 km thick crust below the Altiplano and Western Cordillera. The average seismic velocity of the crust beneath the relatively flat-lying Altiplano is remarkably low, consistent with a bulk crustal composition on the felsic-end of the compositional spectrum. Even within this relatively slow-velocity crust, the ANT shows an extensive mid-crustal (~15-20 km) low shear-wave body along the western margin of the CAP that we interpret as a zone of Neogene to modern plutons. The emplacement of such a large volume of plutons in the past ~10-20 Ma may play a role in the uplift of the western margin of the CAP.

We used finite-frequency teleseismic P-wave tomography to image velocity anomalies in the mantle from 60 - 700 km. SKS-splitting measurements are used to map mantle anisotropy and infer mantle deformation and flow patterns. Seismic images of the lithospheric scale structure of the Altiplano suggest a very heterogeneous upper mantle.

KeyWords: convergent margin, lithospheric structure.

TSHR session – Monitoring, Early Warning, and Evaluation of Tsunami Hazard and Risk

convener:
Wilfried Strauch (CEPREDENAC)
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Caribbean and Adjacent Regions Tsunami Warning System: Seismic Component

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Jean Marie Saurel, IPGP Observatoire Volcanologique et Sismologique de Martinique.
Dan McNamara, USGS Geologic Hazards Science Center.
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Working Group 1 UNESCO IOC Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS).
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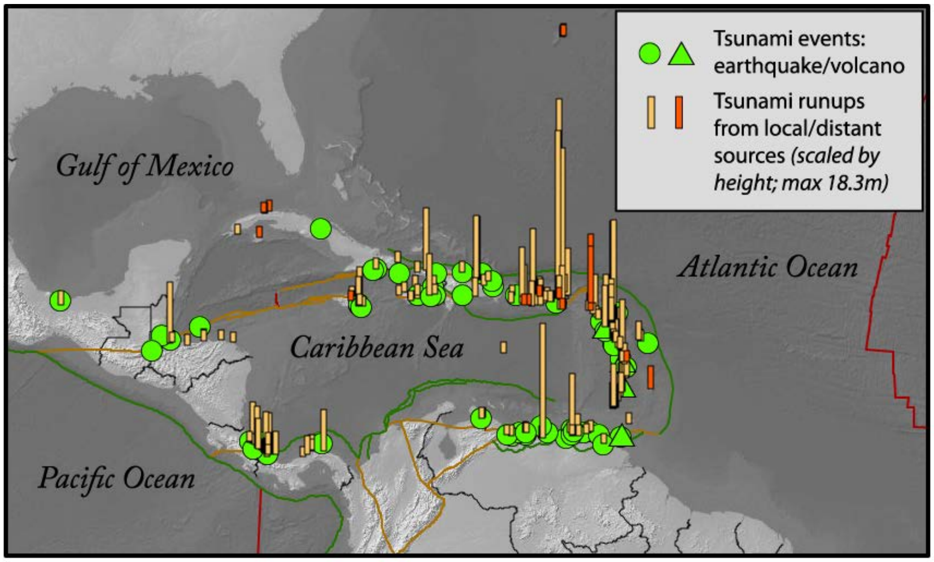
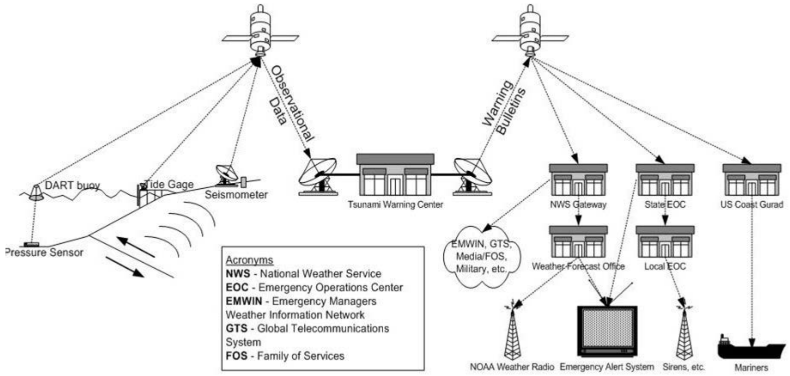
ABSTRACT

Over 75 tsunamis have been documented in the Caribbean and Adjacent Regions during the past 500 years. Since 1500, at least 4484 people are reported to have perished in these killer waves. Hundreds of thousands are currently threatened along the Caribbean coastlines. In 2005 the Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) was established. It recommended the following minimum seismic performance standards for the detection and analysis of earthquakes: 1) Earthquake detection within 1 minute, 2) Minimum magnitude threshold = M4.5, and 3) Initial hypocenter error of M4.0) can be detected within 1 minute throughout much of the Caribbean. The remaining exceptions to this standard for detection are portions of northern South America and Mexico. Another performance criterion is 90% data availability. Currently 60-70% of the stations meet this standard. These data permit the Pacific Tsunami Warning Center and the US National Tsunami Warning Center (Alaska), responsible for providing tsunami services to the Caribbean, to rapidly notify the Tsunami Warning Focal Points in the 48 Countries and Territories that make up the CARIBE EWS. These seismic data are also provided too many local, national and subregional centers, to monitor earthquakes for their area of responsibility. The UNESCO IOC Intergovernmental Coordination Group also encourages all the networks to submit their data to IRIS to potentiate research of tsunami sources. These seismic data are also complemented by dozens of GPS and Sea Level data. The presentation will further report on the status of the CARIBE EWS capability for the timely and accurate detection and analysis of earthquakes for tsunami warning purposes for the Caribbean and Adjacent Regions.

KeyWords: Tsunamis, Seismic Monitoring, Caribbean.



Tsunami events: earthquake/volcano
Tsunami runups from local/distant sources (scaled by height; max 18.3m)
Gulf of Mexico
Atlantic Ocean
Caribbean Sea
Pacific Ocean



Observational Data
Warning Bulletins
DART buoy
Tide Gage
Seismometer
Pressure Sensor
Tsunami Warning Center
NWS Gateway
State EOC
US Coast Gurad
EMWIN, GTS, Media/FOS, Military, etc.
Weather Forecast Office
Local EOC
NOAA Weather Radio
Emergency Alert System
Sirens, etc.
Mariners
Acronyms
NWS - National Weather Service
EOC - Emergency Operations Center
EMWIN - Emergency Managers Weather Information Network
GTS - Global Telecommunications System
FOS - Family of Services

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Local tsunamigenic earthquakes off northeastern Venezuela, in the southern Caribbean realm

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ABSTRACT

The 1983 National Inventory of Geologic Hazards and the 1999 Catalog of felt/destructive Venezuelan Earthquakes (1530-1998) report reliably the occurrence of tsunami waves on the Caribbean eastern Venezuelan coasts, or phenomena that might be interpreted as substantial sea level modifications in the region, during 5 local earthquakes only. We have confirmed this through the search and evaluation of the accounts by primary sources (eye witnesses) of the tsunami inundation during the 5 events. Such tsunamigenic events are the 1-IX-1530, 15-VII-1853, 29-X-1900, 17-I-1929 and 9-VII-1997 earthquakes. All but the 1900 shock affected the Cumaná city, and the offshore right-lateral strike-slip El Pilar fault has been accounted for. The 1900 AD tsunami waves were reported along most of the Ensenada de Barcelona coast (W of Cumaná) and Los Roques Archipelago, being this quake attributed to the San Sebastián fault segment running offshore Cabo Codera. The 1530 and 1853 quakes were produced by the Cariaco trough segment of the El Pilar fault, within a restricted over-1000-m-deep marine pull-apart basin on the San Sebastián-El Pilar releasing step-over, whereas the 1929 and 1997 events occurred on the Cariaco gulf segment. Several authors have interpreted all four events as the result of major submarine sliding inside the steep-walled trough. First-hand accounts by locals about the abnormal waves during the Cariaco 1997 event, as well as the identification of coastal sliding at the Manzanares river mouth at Cumaná, support this thesis at least for the two latest events, because of the small size of the tsunami-affected area. In addition, recent monitoring (CARIACO Project) has observed turbidite currents in the Cariaco trough and the Manzanares canyon during the Cariaco Mw 6.9 quake and the smaller Mw. 5.2 August 2008 event. However, the 1900 tsunami, and the 1530 and 1853 tsunamis by extension, appears to result from right-lateral tectonic slip along the Cariaco through walls.

Key Words: Tsunami, Local earthquakes, Historical seismicity, Caribbean.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Método numérico para desplazamientos de la superficie terrestre debido a fuentes sismogénicas

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ABSTRACT

En la evaluación de riesgos de tsunamis de fuente cercana, es necesaria una estimación del movimiento del suelo marino producido por el sismo, constituyéndose en la información de entrada para la simulación de la propagación y llegada de la perturbación a las costas. La mayoría de los software de simulación utilizan el levantamiento del fondo marino a partir de formulaciones teóricas válidas para una superficie plana, sin embargo, en algunas regiones la topografía del fondo marino se desvía de esta idealización, en una magnitud suficientemente grandes como para reexaminar el método de cálculo del desplazamiento de este fondo marino.

En este trabajo se muestra un procedimiento y cálculos numéricos basados en el método de elementos de frontera (BEM) aplicado a un medio homogéneo e isotrópico, donde la superficie de frontera sigue la topografía del fondo marino. La comparación entre la formulación válida para superficie plana y los resultados numéricos para una topografía real correspondiente a l norte de Chile muestra que las diferencias son suficientemente importantes como para considerarlas en la condición inicial de una simulación de tsunami en la región.

PalabrasClave: tsunamis simulación numérica.

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Análisis de modelos intersísmicos para estimación de inundación por tsunami

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ABSTRACT

Los mapas de inundación por tsunami no sólo facilitan la confeccionar de planes de evacuación de la población, sino también ayudan a la planificación territorial y estimación de daños en estructuras. Sin embargo, la precisión en la estimación de la inundación por tsunami depende en gran medida de la condición inicial del tsunami, la que a su vez se obtiene a partir parámetros sísmicos de la zona de ruptura. Una práctica común es usar simplemente modelos de ruptura homogéneos basados en eventos históricos y la formulación de Okada. Sin embargo, el evento tsunamigénico de Maule de 2010 demostró que la distribución de los desplazamientos es heterogénea, distribuida en parches, con un alto grado de correlación con el déficit de desplazamiento intersísmico propuesto para la brecha. El presente trabajo tiene como objetivo principal estudiar la factibilidad de usar modelos intersísmicos no homogéneos para definir la condición inicial del tsunami y así estimar posibles daños por eventos futuros. Para ello se analizó el tsunami de 2010 y su comportamiento en Talcahuano al interior de la Bahía de Concepción. Un escenario sísmico predictivo se definió a partir del modelo propuesto por Moreno et al., 2011, realizado a partir de mediciones geodésicas de la tasa de acoplamiento intersísmico, que es capaz de entregar una visión bastante fina del déficit de desplazamiento para la brecha sísmica, además fueron analizados escenarios cosísmicos realizado a partir de diversos tipos de mediciones, tales como ondas telesísmicas (Sladen y Hayes), inversión de ondas de tsunami (Lorito), datos geodésicos para la deformación postsísmica (Vigny y Moreno). Adicionalmente se utilizó un modelo sísmico homogéneo definido a partir de la magnitud del evento sísmico. Para las modelaciones numéricas se utilizó el Modelo NEOWAVE con 4 mallas anidadas de 120, 30, 6 y 1" de arco de resolución. Las condiciones iniciales del tsunami se definieron a partir modelos de fallas finitias y superposición mediante la formulación de Okada. Se simularon 6 horas y se definieron mareógrafos virtuales en Talcahuano y Penco para analizar las series de tiempo. Los resultados muestran que todos los modelos sísmicos generan tsunamis con tiempos de arribo y periodos de ondas similares, sin embargo, las amplitudes máximas presentan diferencias. Los modelos cosísmicos de Lorito y USGS son los que mejor se ajustan a los registros instrumentales y visuales. Además, el modelo homogéneo sobreestima la primera onda, mientras que la segunda onda es subestimada. Adicionalmente, se observó que el modelo Intersísmico analizado concuerda bien con los datos observados, tanto en tiempos de arribo como en amplitudes máximas, al igual que los modelos cosísmicos antes mencionados. Por lo tanto, es posible concluir que la condición inicial de un tsunami generado a partir de un modelo intersísmico basado en déficit de desplazamiento puede ser usado para realizar estudios de inundación por tsunami.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

PalabrasClave: tsunami, numerical model, interseismic coupling model.

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Assessment of heterogeneous slip distribution impact on tsunamigenic hydrodynamic processes along the northern Chilean coast

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ABSTRACT

The Chilean continental margin lies in the western margin of the South American plate. The interaction between the Nazca and South America plates has a high tsunamigenic potential. Historically, Chilean coastal cities has been affected by the strongest earthquakes and tsunamis recorded in the world. The location of the mega-thrust close to the land has raised the need to improve early warning systems. Typically fast tsunami threat assessment in early warning systems is based on homogeneous slip distribution models related with the historical earthquake scenarios. Actually, one of the main aspects in numerical tsunami modeling is the use of finite fault rupture models where slip distribution is provided with more realistic and precise seismic representations. However, in recent years it has been tested that slip distribution has an essential contribution to tsunamigenic hydrodynamic processes such as wave period propagation, arrival times, inundation and run-up pattern along the coast. In this work we have a twofold aim, on one side to test the implications of slip distribution on the tsunamigenic hydrodynamic processes along the Arica, Iquique and Patache coastal zones resulted from the 2014 Pisagua earthquake, and on the other side compare the use of tsunami numerical codes based on linear, and non-linear/non-hydrostatic hydrodynamic equations to assess the above mentioned datasets. The analysis has been possible due of the availability of high resolved finite fault model for the 2014 Pisagua earthquake (Hayes, 2014), the recorded tsunami wave in Arica, Iquique and Patache tsunamigrams and the high resolution coastal bathymetry in the study region in northern Chile. The results provide a better insight of the inference of physical characteristics of the source, the morphological characteristics of seafloor and coastline geometry on the wave period and frequency as well as on the run-up distribution and coastal resonance effects.

Key Words: tsunami, resonance, numerical model.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Fast epicentral distance and magnitude determination using a single three component seismic station with Machine Learning Techniques

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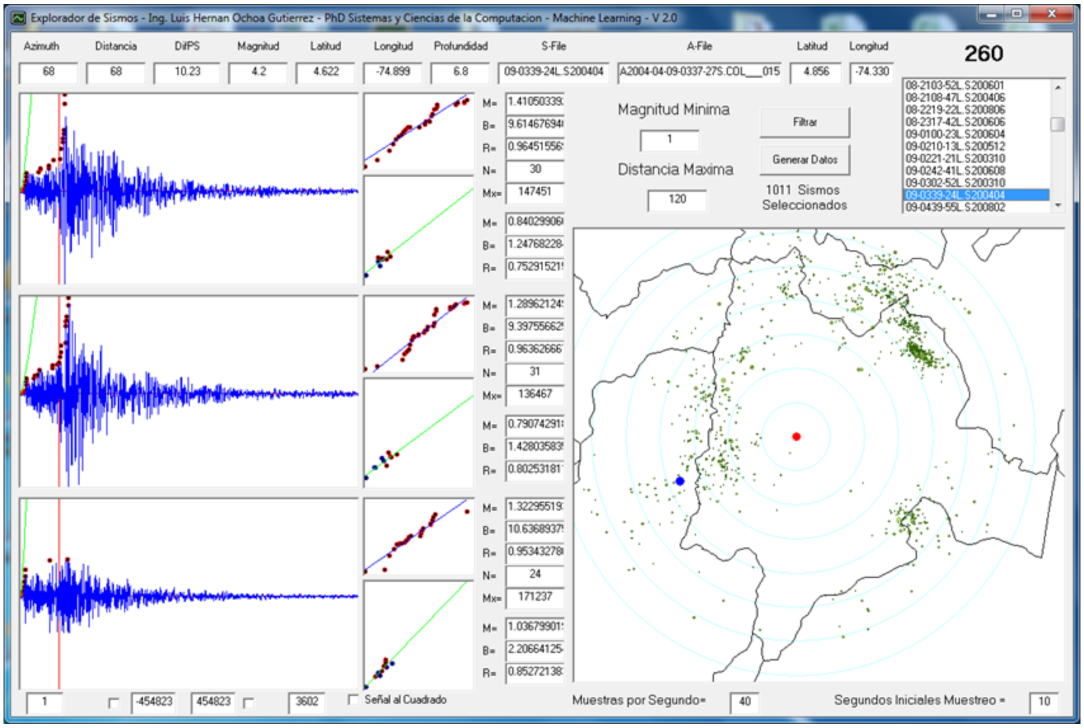
ABSTRACT

To minimize adverse effects originated by high magnitude earthquakes, early warning has become a powerful tool to anticipate a seismic wave arrival to an specific location and lets to bring people and government agencies opportune information to initiate a fast response. To do this, a very fast and accurate characterization of the event must be done but this process is often made using seismograms recorded in at least 4 stations where processing time is usually greater than the wave travel time to the interest area, mainly in coarse networks. A faster process can be done if only one three component seismic station is used that is the closest unsaturated station respect to the epicenter. Here we present a Support Vector Regression algorithm which calculates Magnitude and Epicentral Distance using only 5 seconds of signal since P wave onset. This algorithm was trained with 36 records of historical earthquakes where the input were regression parameters of an exponential function estimated by least squares, corresponding to the waveform envelope and the maximum value of the observed waveform for each component in one single station. A 10 fold Cross Validation was applied for a Normalized Polynomial Kernel obtaining the mean absolute error for different exponents and complexity parameters. Magnitude could be estimated with 0.16 of mean absolute error and the distance with an error of 7.5 km for distances within 60 to 120 km. This kind of algorithm is easy to implement in hardware and can be used directly in the field station to make possible the broadcast of estimations of this values to generate fast decisions at seismological control centers, increasing the possibility to have an effective reaction.

Key Words: Early Warning, Support Vector Regression, Earthquake, Rapid Response.


Explorador de Sismos - Ing. Luis Hernan Ochoa Gutierrez - PhD Sistemas y Ciencias de la Computacion - Machine Learning - V 2.0
Azimuth
Distancia
DifPS
Magnitud
Latitud
Longitud
Profundidad
S-File
A-File
260
Magnitud Minima
Distancia Maxima
Filtrar
Generar Datos
1011 Sismos Seleccionados
Señal al Cuadrado
Muestras por Segundo=
Segundos Iniciales Muestreo =

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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A rapid estimation of tsunami run-up based on finite fault models

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ABSTRACT

Many efforts have been made to estimate the maximum run-up height of tsunamis associated with large earthquakes. This is a difficult task, because of the time it takes to construct a tsunami model using real time data from the source. Usually, it is possible to construct a database of potential seismic sources and their corresponding tsunami a priori. However, such models are generally based on uniform slip distributions and thus oversimplify our knowledge of the earthquake source. Instead, we can use finite fault models of earthquakes to give a more accurate prediction of the tsunami run-up.

Here we show how to accurately predict tsunami run-up from any seismic source model using an analytic solution found by Fuentes et al, 2013 that was especially calculated for zones with a very well defined strike, i.e., Chile, Japan, Alaska, etc. The main idea of this work is to produce a tool for emergency response, trading off accuracy for quickness. Our solutions for three large earthquakes are promising. Here we compute models of the run-up for the 2010 Mw 8.8 Maule Earthquake, the 2011 Mw 9.0 Tohoku Earthquake, and the recent 2014 Mw 8.2 Iquique Earthquake. Our maximum run-up predictions are consistent with measurements made inland after each event, with a peak of 15 to 20 m for Maule, 40 m for Tohoku, and 2,1 m for the Iquique earthquake. Considering recent advances made in the analysis of real time GPS data and the ability to rapidly resolve the finiteness of a large earthquake close to existing GPS networks, it will be possible in the near future to perform these calculations within the first five minutes after the occurrence of any such event. Such calculations will thus provide more accurate run-up information than is otherwise available from existing uniform-slip seismic source databases.

Key Words: Tsunami, Earthquake, Run-up, Finite Fault.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Mapas de Amenaza de Tsunami para el Golfo de Fonseca (El Salvador, Honduras y Nicaragua)

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ABSTRACT

Las costas del Golfo de Fonseca, una extensa bahía del Océano Pacífico compartida por ElSalvador, Honduras y Nicaragua, se encuentran bajo amenaza de tsunamis originados porterremotos en el Océano Pacífico, por erupciones volcánicas en los volcanes Cosigüina,Conchagua y otros centros volcánicos locales y por deslizamientos y colapsos laterales de los volcanes. Para el Golfo existen registros históricos e instrumentales de afectación por tsunami.

En 2010, se realizaron mapas de amenaza de tsunami, para 12 sitios particulares, 4 islas enteras, 3 zonas nacionales, y para todo el Golfo. En el proceso de la elaboración de los mapas participaron especialistas de las instituciones científicas, comisiones de emergencias, de las autoridades locales de El Salvador, Honduras y Nicaragua. Los mapas se discutieron también con pobladores locales en los diferentes sitios. Durante este trabajo se observó que la gran mayoría de la población en las ciudades y poblados en la costa del Golfo de Fonseca no tiene conciencia que se encuentran bajo riesgo de tsunami. Por eso, durante el proceso se dieron múltiples entrevistas a los medios locales de comunicación masiva (TV, radio, prensa). De esta forma se logró informar a una parte considerable de la población sobre la amenaza de tsunami existente para el Golfo de Fonseca y sobre las posibles medias de prevención de desastres por este fenómeno. Para facilitar el entendimiento del fenómeno de tsunami y su posible efecto en el Golfo de Fonseca se elaboraron simulaciones numéricas de generación y propagación de olas de tsunami en el Golfo de Fonseca y de la afectación en las playas. El presente trabajo se entiende como inicio de un desarrollo dirigido a la reducción del riesgo por tsunami en el Golfo de Fonseca. Para la continuación de este proceso se requiere de medidas adicionales como 1) Información, capacitación y educación a la población incluyendo prácticas de evacuación; 2) Desarrollo de un sistema local de alerta de tsunami (tri-nacional); 3) Investigación científica del posible impacto de tsunami; 4) Elaboración de mapas de tsunami a mayor precisión; 4) Medidas físicas de protección para aquellas zonas donde la evacuación en caso de posible afectación por tsunami es muy difícil.

El trabajo tuvo el apoyo del proyecto sobre Geo-Riesgos en Centroamérica, BGR/Alemania.

Palabras Claves: Tsunami, Amenaza, Mapas, Golfo de Fonseca, Nicaragua, Honduras, El Salvador.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sistemas de Alerta Temprana (SAT) en Panamá

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ABSTRACT

En la prevención y mitigación de riesgos naturales, Panamá como país tiene dificultades por atraso metodológico y falta de potencial en los sistemas de alerta temprana (SAT). El Observatorio Sísmico del Occidente de Panamá (OSOP, http://www.osop.com.pa) se creó para ofrecer servicios, equipos, métodos y conocimientos científicos. Con financiamiento de la Secretaría Nacional de Ciencia y Tecnología (SENACYT) se desarrolla, desde noviembre de 2011, un proyecto de 3 años que ayuda en diseñar y crear SAT a establecerse en las instituciones nacionales responsables (o apoyar a SAT ya existentes) para monitoreo y alerta temprana de los fenómenos naturales peligrosos. Etapa I del proyecto consistió en gran medida en trabajos analíticos basándose en publicaciones, reportes y visitas a instituciones de alerta tempana en Panamá, en la región centroamericana y a nivel internacional. Para conocer la realidad en Panamá, se realizaron reuniones con el Sistema Nacional de Protección Civil (SINAPROC), Universidad de Panamá (UPA), Autoridad del Canal de Panamá (ACP) y otras instituciones.

La segunda etapa, recientemente terminada, se concentró en elaborar, juntos con las instituciones responsables, propuestas detalladas y en el comienzo de su implementación de los siguientes SAT:

Sistema nacional de monitoreo sísmico

Sistema local de alerta de tsunami para el Golfo de Chiriquí

(Incluye la elaboración de un mapa de amenaza de tsunami para Puerto Armuelles)

Sistema de alerta de correntadas, inundaciones y actividad sismo-volcánica en el Volcán Barú

Sistema piloto de alerta sísmica para la ciudad de David

De gran importancia es la elaboración de un conjunto de protocolos que definen exactamente las responsabilidades de las diferentes instituciones y personas que participan en los SAT. Además el desarrollo de un sistema de mensajes que se enviarán de forma rutinaria o en las emergencias a SINAPROC, otras instituciones relevantes y al público en general. La formulación de los mensajes debe ser clara, fácilmente entendible, concreta y adaptada al grupo de destinatarios. En el envío de los mensajes se prevén métodos automáticos, y mensajes enviados convencionalmente por correo electrónico y SMS. Además se entrega información gráfica y alertas acústicas directamente en pantallas de información. Debe existir un sistema de supervisión que verifica continuamente si el SAT funciona, si existe un registro los mensajes enviados, elabora estadísticas de mensajes de alertas acertadas y falsas para su posterior análisis. Se aplican las experiencias que se hicieron recientemente en Panamá con la instalación de nuevos sistemas de monitoreo sísmico automático.

Una tercera etapa del proyecto se dedicará, a partir de 2014, en la puesta en función de los sistemas, la realización de pruebas y ejercicios con las instituciones y la población.

Este trabajo es apoyado por SENACYT Contrato por Mérito no. -4-CAP11-001-

Palabras Claves: Alerta Temprana, Amenazas, Sismos, Tsunamis, Inundaciones, Volcanes, Mapas.

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Experiencias con el terremoto lento y tsunami del 26 de agosto 2012 en Nicaragua y El Salvador

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ABSTRACT

El 26 de agosto de 2012, a las 10:37 PM (hora local), las redes sísmicas de Nicaragua y El Salvador detectaron un sismo de baja profundidad con magnitud de 5.7 en el Océano Pacífico frente a sus costas. El sismo fue sentido leve en ambos países. No obstante, a las 22:51 PM entró un mensaje de información del PTWC señalando una magnitud de 7.4 para el evento, posteriormente PTWC recomendó alerta de tsunami para Centroamérica. La magnitud 7.4, sobrepasó por mucho el umbral a partir del cual los sistemas nacionales de alerta de tsunami debían declarar la alerta. Un tsunami impactaría en las costas dentro de unos 40 minutos después del sismo.

No obstante, por el efecto macrosísmico leve del evento y con magnitudes significativamente más bajas determinadas por los sismólogos nacionales las instituciones de protección civil vacilaron en declarar la alerta. A nivel nacional no se pudo explicar la diferencia entre las magnitudes locales y las de las agencias internacionales o se demoró mucho en hacerlo.

En El Salvador, la posibilidad de un tsunami fue negada en el momento por las autoridades de Protección Civil. Eso también porque la estación mareográfica en Acajutla, El Salvador, a unos 100 km del epicentro, indicaba una ola insignificante de pocos centímetros. En Nicaragua, se declaró una "alerta interna", es decir se alertó a estructuras de protección civil y autoridades locales en la costa pero no se emitió un llamado público a la población de tomar medidas de protección.

Posteriormente, se determinó que el terremoto, del 26 de agosto 2012, era un "terremoto lento". Este tipo de terremoto ya ha causado, en 1992, un destructivo tsunami en Nicaragua con olas de hasta 10 m de altura y 170 víctimas humanas.

Días después del evento, surgieron noticias en ambos países sobre el impacto de tsunami confirmadas poco después por visitas del campo de expertos de COI e ITIC juntos con especialistas nacionales. Se supo que decenas de personas fueron afectadas por olas con una altura máxima de 5 metros, por inundaciones y correntadas. La baja densidad de población en las zonas afectadas evitó un mayor desastre.

A raíz del tsunami, del 26 de agosto, 2012, los sistemas nacionales de alerta de tsunami en Nicaragua y El Salvador revisaron sus procedimientos y sistemas técnicos para la alerta de tsunami y las mejoraron significativamente. El personal de las instituciones sismológicas y de protección civil debe conocer las características de los terremotos lentos. Las redes sísmicas de los sistemas nacionales de alerta de tsunami deben disponer de métodos confiables para determinar correctamente la magnitud de terremotos lentos.

Palabras Clave: terremoto lento, tsunami, Nicaragua, El Salvador.

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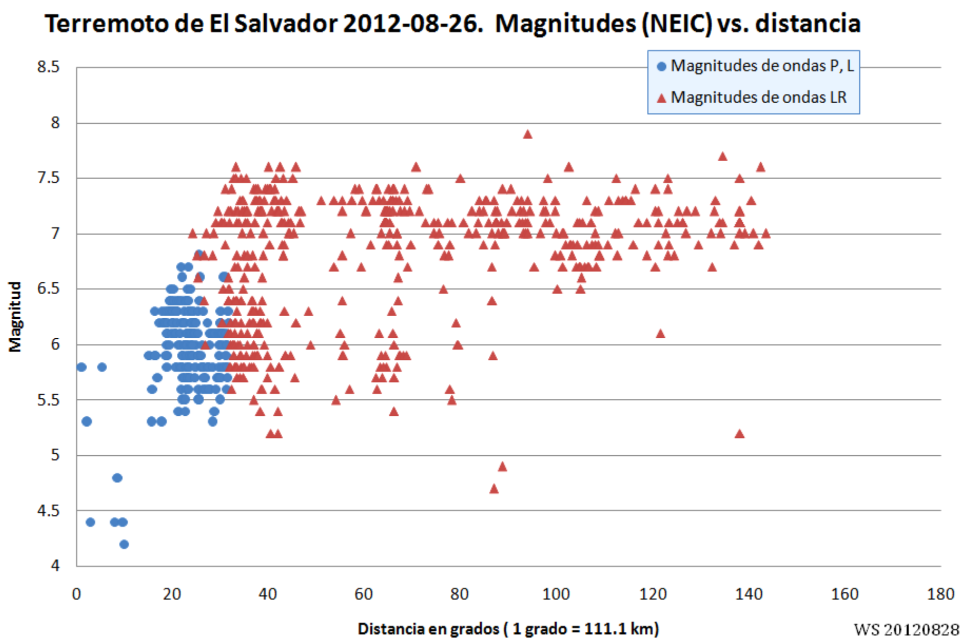

Figura 1. Se observan las magnitudes reportadas por NEIC para el terremoto del 28 de agosto de 2012. La magnitudes de ondas P, L usadas típicamente por agencias locales son mucho menores que las magnitudes obtenidas a largas distancias usando ondas LR de bajas frecuencias

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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El Desarrollo del Sistema de Alerta de Tsunami en Nicaragua

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ABSTRACT

En 1992, un tsunami afectó la costa del Pacífico de Nicaragua con olas de hasta 10 metros de altura, devastó las playas y cobró la vida de más de 170 personas. El país no contaba con un sistema de alerta, no existía una red sísmica, tampoco hubo conciencia sobre el peligro de tsunami en población, gobierno e instituciones científicas. Este evento creó una gran conciencia sobre la temática de tsunami e impulsó un desarrollo de largo plazo en que se formó el Sistema de Alerta de Tsunami de Nicaragua.

El INETER se concentró en establecer la red sísmica y el centro de monitoreo y alerta. Hoy, el sistema de monitoreo sísmico es uno de los más desarrolladas en Centroamérica con unas 60 estaciones digitales. Además, se reciben por Internet los datos de unas 200 estaciones de Centroamérica y de todo el mundo para la información rápida sobre cualquier sismo tsunami generador en el Océano Pacifico y en el Caribe. El procesamiento automático con los paquetes SeisComp3 (GFZ/Potsdam) y Earthworm es supervisado por sismólogos del turno 24x7. Hipocentros y magnitudes de sismos mayores en Nicaragua y Centroamérica se obtienen en menos de un minuto, soluciones de eventos fuera de la región pueden tardar algunos minutos más. Resultados se envían automáticamente por medio de correo electrónico y SMS a las autoridades del gobierno y SINAPRED y se publican en el sitio Web. El Centro de Operaciones de Emergencias (CODE, 24x7) de SINAPRED y DEFENSA CIVIL dispone de clientes de SeisComP3 que visualizan en tiempo real el procesamiento y los resultados de INETER. Así, el CODE siempre está al tanto de la situación y obtiene el resultado del procesamiento o de relocalizaciones, inmediatamente.

Terremotos de magnitud 7 o mayor en Nicaragua o Centroamérica se consideran potencialmente tsunami génicos y se propone inmediatamente la alerta de tsunami. Con el visto bueno de la presidencia de Nicaragua, el CODE activa las sirenas para las playas bajo peligro de tsunami. Nicaragua dispone de 100 sirenas automáticas instaladas en la costa del Pacífico y del Caribe. Inmediatamente, se inician las operaciones previamente establecidas del sistema de prevención de desastres en las zonas posiblemente afectadas para apoyar a la población.

INETER ha participado en estudios sobre la amenaza de tsunami e Centroamérica, y ha elaborado mapas de amenaza de tsunami para toda la costa del Pacífico que detallan las zonas bajo riesgo, vías de evacuación, zonas seguras. SINAPRED y defensa Civil han realizado el trabajo de concientización, capacitación y entrenamiento para población, organizaciones populares, instituciones del estado, policía, Cruz Roja, y otros. Se elaboraron protocolos que regulan la cooperación de las instituciones del país. En múltiples simulacros - a nivel local, nacional o internacional - población e instituciones fueron informadas y capacitadas de actuar correctamente en caso de tsunami.

Palabras Claves: Sistema de Alerta, Tsunami, Nicaragua.

VMST – Sharing Experiences on Volcano Monitoring Using Seismic Techniques in Latin America

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Implementación y renovación de nuevas tecnicas geofísicas para monitoreo de volcanes activos colombianos

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ABSTRACT

Durante la última década, las redes de monitoreo volcánico en Colombia han crecido exponencialmente debido a la incursión de nuevas técnicas, cuya finalidad en conjunto con la sismología es, dar un diagnóstico integral del estado de actividad de un volcán y generar procesos de investigación que conlleven a conocer y comprender mejor los diferentes sucesos que ocurren en un volcán activo antes, durante y después de un proceso eruptivo. Las redes de monitoreo se han visto reforzadas con equipos de última tecnología y de amplio uso a nivel mundial, entre estas se puede mencionar los siguientes: Estaciones GNSS permanentes e imágenes InSAR (para monitoreo de la deformación volcánica); cámaras web y procesamiento digital de imágenes de sensores remotos (para seguimiento de la actividad superficial y emisiones de gases); sensores acústicos (para el monitoreo de explosiones volcánicas y/o salida de gases); equipos de mediciones móviles y permanentes de gases difusos en suelo y fumarolas (SO2, CO2, 222Rn) y equipos de seguimiento de temperaturas en campos fumarólicos y fuentes termales (para el monitoreo de parámetros fisicoquímicos); sensores magnetotelúricos como potenciales eléctricos y magnetómetros (para el monitoreo de campos magnéticos y gravitacionales); sensores sismológicos tipo banda ancha (para reforzar el monitoreo sismológico tradicional de corto periodo y capturar la sismicidad de baja frecuencia); sensores de flujos de lodo (para monitoreo de lahares); sensores meteorológicos (para control de cambios en el comportamiento volcánico debido a agentes externos), entre otros.

El hecho de la implementación de nuevas metodologías y con ello la instalación de nuevas estaciones, ha hecho que también se generen nuevas arquitecturas y metodologías en la adquisición, transmisión, recolección y procesamiento de las señales; de estas se puede destacar la migración a la transmisión telemétrica digital y creación de redes telemétricas redundantes.

Los Observatorios Vulcanológicos y Sismológicos del Servicio Geológico Colombiano, con la implementación de métodos de monitoreo volcánico de última tecnología, se encuentran a la vanguardia con los Observatorios del cinturón de fuego del pacifico, lo cual a futuro permitirá mayor investigación e implementación de nuevos métodos para el análisis del fenómeno volcánico, así como el diagnóstico integral y acertado de nuevos procesos eruptivos.

Palabras Clave: volcán, monitoreo, técnica, geofísica.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sismicidad volcano-tectónica en el Nevado del Huila

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ABSTRACT

El volcán Nevado del Huila (VNH) es un complejo volcánico activo de tipo estrato volcán, conformado por varios domos. El Observatorio Vulcanológico y Sismológico de Popayán, tiene a su cargo la vigilancia y monitoreo permanente de este volcán desde 1994. Tiempo en el cual se ha podido establecer que es fundamental determinar cambios importantes en la actividad sísmica asociada al fracturamiento de roca (volcano-tectónica o VT) para el análisis y pronóstico de los procesos eruptivos del VNH.

En los inicios de la vigilancia, el VNH presentaba bajos niveles de actividad sísmica, con un promedio de tres sismos diarios. Sin embargo el 18 de abril de 2007 el VNH inició su proceso de reactivación, con el registro de eventos tipo VT, localizados en la parte alta del edificio volcánico; seguidamente el sistema entró en un proceso de excitación continua, con la generación de eventos VT acompañados de eventos asociados al tránsito de fluidos y gases. El 19 de febrero de 2007, en menos de 24 horas del primer incremento sísmico, se presentó una erupción freática, a la cual se le asociaron la formación de una fisura de 2 km de largo en la parte alta del edificio volcánico, entre los picos Central y la Cresta en dirección NS y la generación de un lahar. Durante los dos meses siguientes, el VNH presentó un periodo de relajación parcial del sistema. No obstante, la noche del 17 de abril, se presentó un nuevo enjambre sísmico, mostrando un comportamiento similar a la primera erupción. 10 horas después del inicio del enjambre, se presentó la segunda erupción freática, la cual generó una nueva fisura de 2.3 km de largo que atravesó los costados SW y NE del Pico Central, pérdida de una porción de masa del glaciar El Oso y la formación de un nuevo lahar de mayor volumen al anterior.

Posteriormente, el VNH experimentó períodos de alternancia entre fases de relajación y etapas de mayor excitación. La última erupción del VNH registrada se presentó en el 2008, tiempo durante el cual se presentaron episodios de emisiones de ceniza, intensa actividad relacionada con la dinámica de fluidos y enjambres sísmicos de tipo VT. Finalmente, el 20 de noviembre de 2008, se presentó una erupción freatomagmática, que generó la formación de un lahar y extrusión de un nuevo domo lávico en el costado suroccidental del Pico Central, sobre el cual se generó una nueva intrusión de material magmático en el segundo semestre de 2009, este proceso de emplazamiento se mantuvo hasta septiembre de 2010, fecha en la cual el VNH retornó a su proceso de relajación, destacándose únicamente el incremento de la actividad de tipo VT presentada entre el 9 y 12 de enero de 2014, sismicidad que se localizó hacia el costado NE del volcán, y mantuvo magnitudes importantes, dentro de las cuales se destacan dos eventos con magnitudes de 4.5 y 5.0 en la escala de Richter. Actualmente, el VNH se encuentra en nivel Amarillo (III), mostrando un comportamiento estable en su actividad.

Palabras Clave: volcán, Huila, volcano-tectónica, erupción.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Enjambres sísmicos periódicos relacionados con la transferencia estática de esfuerzos entre una deformación volcánica de gran escala y fallas strike-slip corticales: Complejo Volcánico Laguna del Maule (Chile)

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ABSTRACT

El Complejo Volcánico Laguna del Maule (CVLM, 36.06°S-70.50°W) está localizado 200 km al E del epicentro del terremoto Mw=8.8 del Maule 2010 sobre la cordillera de Los Andes chilena. Esta, es una excepcional zona volcánica caracterizada por un extensivo volcanismo silícico postglacial, con más de 130 centros de emisión y aproximadamente 350 km3 de productos eruptados, sugiriendo un particular vulcanismo riolítico distribuido, y una de las más altas tasa de deformación vertical (alzamientos de aprox. 30 cm/año según InSAR) registrados en el planeta. A partir del año 2011 debido a los síntomas de actividad reportados, el Observatorio Volcanológico de los Andes del Sur (OVDAS-Sernageomin) implementó una red de vigilancia, compuesta por 17 estaciones sísmicas de banda ancha (12 permanentes y 5 portátiles), y 5 estaciones GNSS. Los datos obtenidos mostraron que el CVLM es uno de los sistemas volcánicos de los Andes Chilenos con mayor actividad reciente, siendo registrado una serie de enjambres sísmicos, con una periodicidad de aproximadamente dos meses, relacionados con rompimientos de roca (Tipo VT), localizados al SW de la cuenca volcánica a profundidades superficiales (< 4 km). Según se aprecia en la figura 1, el área epicentral de los enjambres coincide con el límite SW de la zona fuente de la deformación modelada por los estudios de InSAR, el trazo de la Falla Troncoso de carácter regional, y la ubicación de uno de los centros de emisión holocénicos riolíticos reconocidos. De igual modo, los datos recolectados por las estaciones de GSNN continuas, confirman las tasas de deformación reportadas previamente, mostrando un comportamiento incremental con el tiempo, con tasas de alzamiento calculadas que van desde los 20 – 30 cm/año. Con el fin de indagar sobre la relación existente entre la fuente de deformación y la sismicidad periódica de los enjambres, se determinó los esfuerzos tipo Coulomb, asumiendo como estructura fuente un dique de ~5 km de ancho y ~12 km de largo, localizado a ~5 km de profundidad en el centro del sistema volcánico y una tasa de apertura de 0.9 m/año (según estudios de InSAR publicados) y como estructura receptora una falla tipo strike-slip de componente dextral que atraviesa el complejo (Falla Troncoso). Los resultados sugieren que existe una transferencia efectiva de esfuerzos estáticos desde la fuente productora de la deformación hacia la zona de fallamiento, lo cual correlaciona temporal y espacialmente con la zona epicentral de los enjambres sísmicos registrados, dando nuevos indicios sobre los procesos que lideran el comportamiento y dinámica de complejos volcánicos riolíticos distribuidos.

PalabrasClave: Enjambres sísmicos, Deformación volcánica de gran escala, Trasferencia de esfuerzos, volcanismo riolítico.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Actividad reciente del Complejo Volcánico Laguna del Maule (Chile): relación entre sismicidad y deformación volcánica de gran escala ligada a un campo volcánico riolítico

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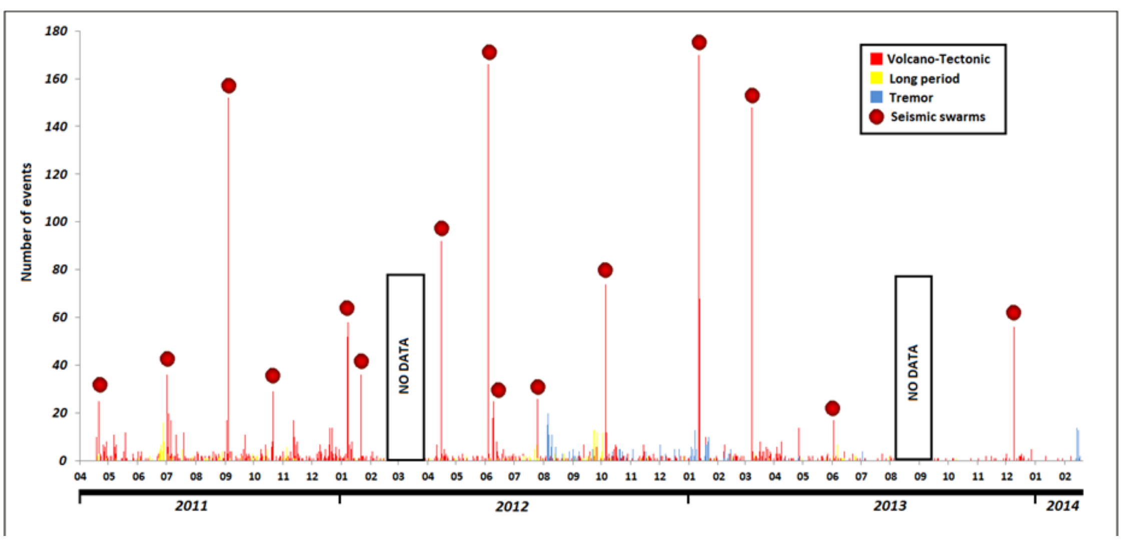
ABSTRACT

El Complejo Volcánico Laguna del Maule (CVLM, 36.06°S-70.50°W) es un campo volcánico con un extensivo volcanismo silícico postglacial, localizado en el límite oriental del arco volcánico moderno y a 200 km del epicentro del sismo Mw=8.8 del Maule. Los primeros síntomas de actividad en el CVLM fueron detectados a través de estudios INSAR, cuyo modelamiento conllevo a sugerir una zona inflacionaria localizada a ~5 km de profundidad en el centro del complejo, con una tasa de desplazamiento vertical de ~30 cm/año, siendo catalogada como una de las deformaciones volcánicas más grandes a nivel mundial durante las últimas décadas. Por este motivo en abril de 2011, el Observatorio Volcanológico de los Andes del Sur desplegó una red de vigilancia volcánica, compuesta por estaciones sísmicas de banda ancha y estaciones GNSS continuas, con el propósito de monitorear en tiempo real ésta actividad. Los registros obtenidos muestran sismicidad de carácter superficial.

PalabrasClave: Enjambres sísmicos, Deformación volcánica, Cambios de Atenuación.



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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Comportamiento de la actividad sísmica y registro de procesos deformativos en los volcanes Chiles y Cerro Negro, Colombia (2013)

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ABSTRACT

Los volcanes Chiles y Cerro Negro se encuentran ubicados al suroeste de Colombia, en el departamento de Nariño, en la frontera entre Colombia y Ecuador, con una altura de 4748 msnm y 4470 msnm respectivamente y separados entre sí unos 3.5 km. A finales del 2013, y debido a los reportes de sismos sentidos por la comunidad del Resguardo Indígena de Chiles, localizada a 10 km al oriente del edificio volcánico de Chiles, en noviembre de 2013, se inició el monitoreo permanente de la actividad sísmica y de deformación de estos volcanes, con dos estaciones sobre la superficie de Chiles y una sobre Cerro Negro (Sismómetros de Banda Ancha, Inclinómetros APLLIED GEOMECHANICS).

Hasta el 22 de mayo de 2014, se han registrado alrededor de 81.000 sismos asociados a fracturamiento de roca, llegando hasta 2.000 sismos por día, algunos de los cuales han sido reportados como sentidos; se cuenta con cerca de 60 eventos con magnitud mayor o igual a 3 en la escala de Richter, con un valor máximo de 4.8. La mayoría de los sismos se ubican hacia el sector sur suroccidente de Chiles, en inmediaciones de los dos volcanes, sin hasta el momento definir en particular de cual volcán es esta actividad.

Desde la instalación de los Inclinómetros, se han observado cambios en sus componentes, siendo las mayores las que registra el inclinómetro instalado en el volcán Cerro Negro (Figura 1). Los dos inclinómetros instalados en el volcán Chiles con menores variaciones, muestras tendencias que se asocian al comportamiento diario sísmico.

Asumiendo que la deformación observada obedece a una posible intrusión magmática se realizaron varios modelamientos, usando fuente esférica, esferoide y dique. Debido a que la inclinación observada en las estaciones no muestra una simetría radial que permita trabajar una fuente esférica, se enfatizó en el modelo de fuente de dique, obteniendo como resultado un dique ubicado entre Chiles y Cerro Negro, de aproximadamente 8.4 km de longitud a una profundidad a 1.6 km (Figura 2).

Palabras Clave: volcán, Chiles-Cerro Negro, sismicidad, inclinómetro, deformación, modelamiento.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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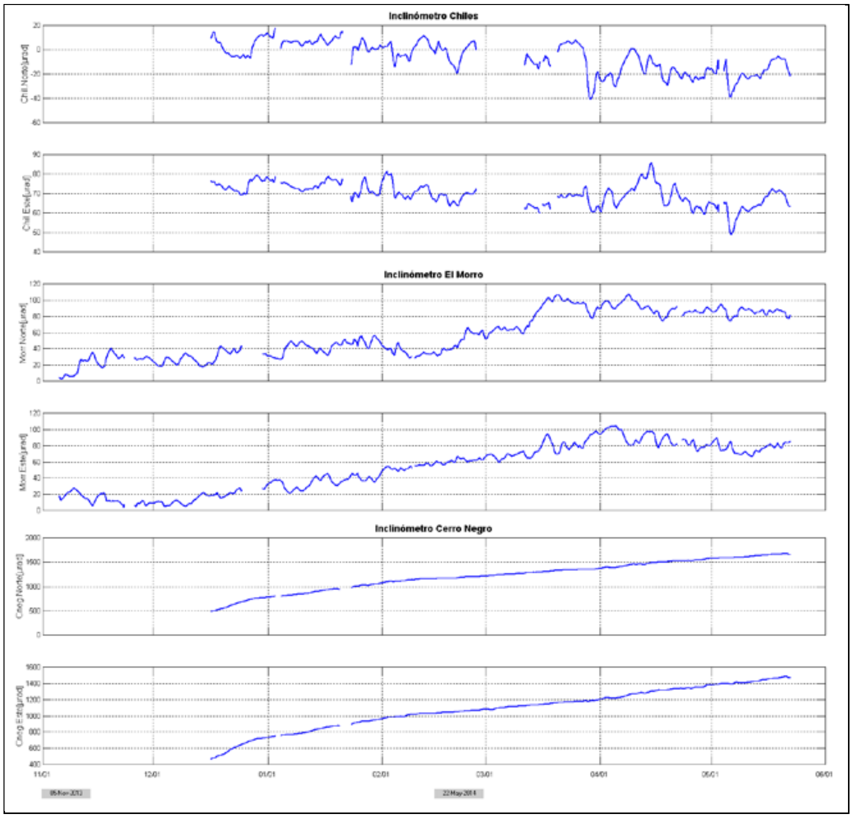

Figura 1. Componentes de inclinación Norte y Este (µrad) de los Inclinómetros instalados en Chiles-Cerro Negro, para el periodo comprendido entre noviembre de 2013 y mayo de 2014.

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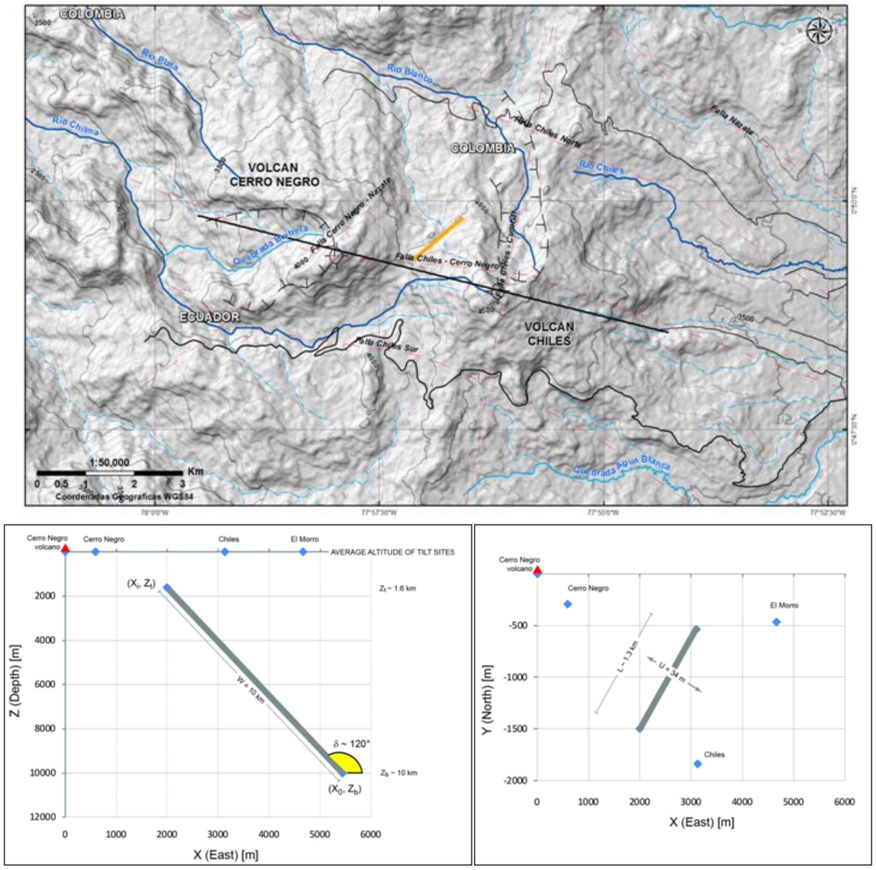

Figura 2. Localización epicentral (imagen superior, en color naranja el dique), en profundidad y planta (imagen inferior), de la solución obtenida del modelo de fuente Dique para los volcanes Chiles y Cerro Negro, usando la información de los inclinómetro electrónicos.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Cambios en la distribución temporal del parámetro b relacionados con intrusiones de magma, herramienta para pronóstico caso erupción del Complejo Volcánico Cordón Caulle, junio 04 2011

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ABSTRACT

Variaciones del b-value han sido atribuidas por diversos autores a cambios en el estrés regional, variaciones del estrés diferencial en fallas activas asociadas a zonas volcánicas o incrementos en la presión de fluidos relacionados con sistemas hidrotermales, vinculando dichas variaciones con incrementos en la actividad volcánica. El 02 de junio de 2011 y debido al aumento de la actividad sísmica, se elevó el nivel de alerta técnico-volcánica del Complejo Volcánico Cordón Caulle (CVCC) a Naranja. Un día más tarde y producto del ascenso en la actividad sísmica, la alerta volcánica fue cambiada a Nivel Rojo. El día 04 de junio, el CVCC inició una fase explosiva con un IEV 4, lográndose pronosticar exitosamente la erupción con 24 horas de anticipación. Aunque fue fundamental la clasificación de la actividad sísmica (Figura1); la evolución espacio-temporal de los hipocentros y la "distribución temporal de la frecuencia de magnitudes" (FMD) fueron las metodologías utilizadas para determinar los diferentes estados de alerta técnico-volcánica, ya que esta última fue capaz de cuantificar la generación sísmica en términos de sus magnitudes, tanto espacial como temporalmente. Para calcula el b-value finalmente se utilizó el ciclo eruptivo completo, seleccionando 1700 sismos registrados durante enero a diciembre de 2011. Para construir la variación temporal de dicho parámetro, se trabajó con el método de la máxima probabilidad, escogiendo ventanas de 125 eventos con un overlap del 75% y una magnitud de completitud (MC) que actuó de forma fija 1,6 (Figura2). Con relación a los resultados obtenidos de las variaciones temporales del b-value, se pudo observar que 3 días antes de la erupción, el valor de b mostró un abrupto descenso, característica que predominó independiente de las ventanas sísmicas o de los overlap utilizados, sugiriendo que dicho cambio estuvo relacionado con la inestabilidad generada por un ascenso de magma previo a la erupción. El análisis de los espectrogramas para cada uno de estos sismos precursores mostraron una predominancia en bajas frecuencias.

PalabrasClave: distribución temporal del parámetro b, herramienta para pronóstico, actividad volcánica.

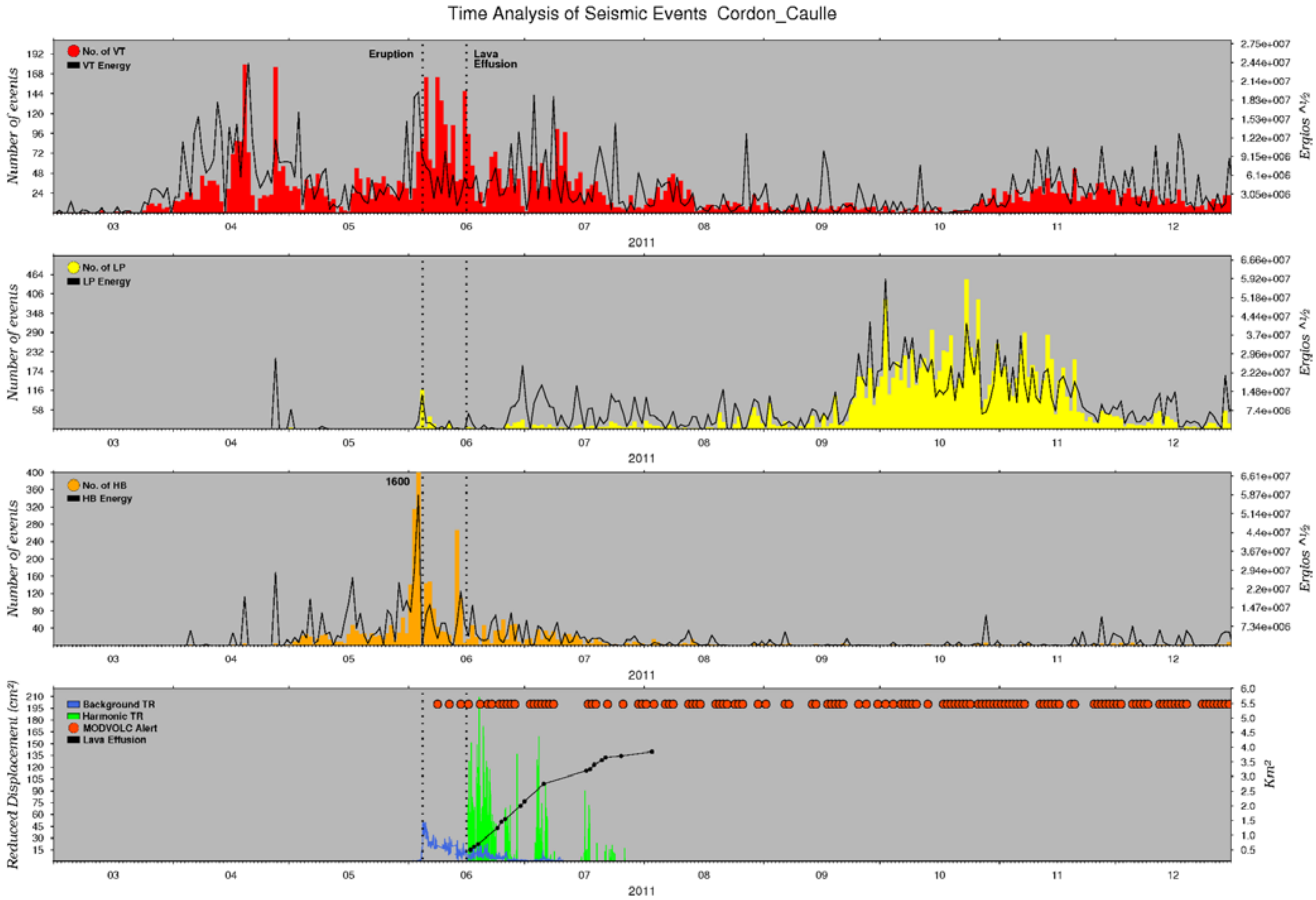

Figura 1. Las imágenes 1 a la 3 muestran la evolución de la sismicidad registrada por la Red Nacional de Vigilancia Volcánica RNVV durante el año 2011. La cuarta imagen representa el desplazamiento reducido calculado por hora (DR cm^2) tanto para el tremor espasmódico (azul) asociado a la columna eruptiva (12 km de altura máxima), como al tremor armónico (verde) generado por el ascenso y extrusión de lavas ocurrido desde junio 16 hasta agosto de 2011. La línea negra simboliza la superficie de lava medida en km^2. Finalmente, los puntos de color rojo muestran las alertas de incandescencia publicadas por MOLVOLC (http://modis.higp.hawaii.edu/cgi-bin/modis/modisnew.cgi).

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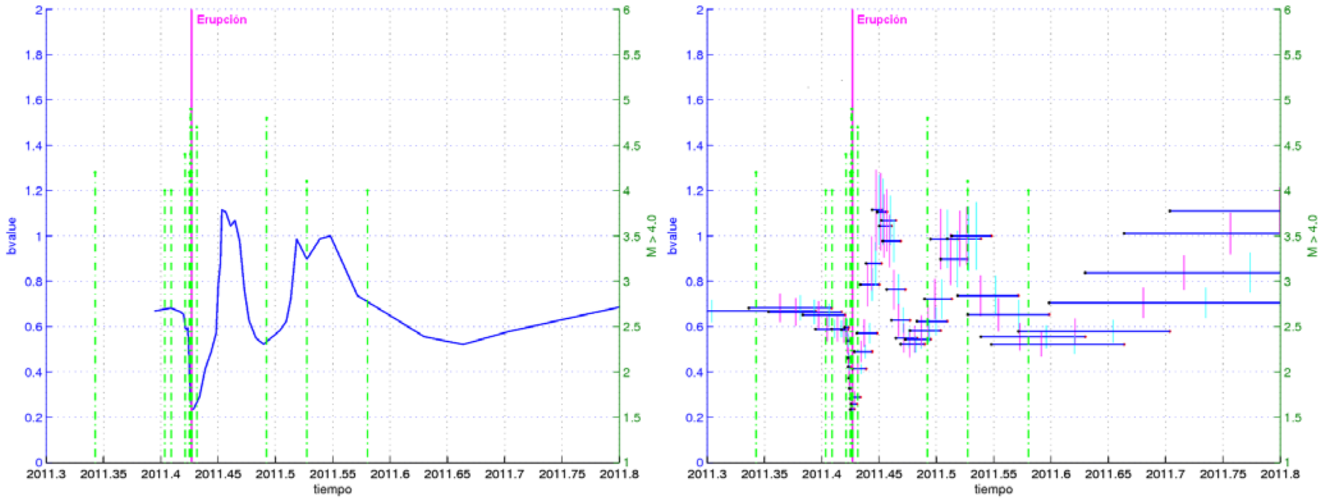

Figura 2. Izquierda, *valor de b-value* temporal para la serie de tiempo de 1700 sismos localizados durante el año 2011, cuya M_C fue de 1,6. Derecha; *valor de b* indicando además la extensión de cada una de las ventanas temporales correspondientes a 125 sismos (líneas horizontales azules). De igual forma, se destacan los errores determinados para cada una de las ventanas calculadas por diferentes métodos (Aki 1965 barras celestes; Shia & Bolt 1982 barras purpuras). Las líneas segmentadas de color verde señalan los sismos mayores a 4 M_L. ¶

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Sistema informático para el análisis y procesamiento de señales sísmicas de volcanes en Ecuador

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ABSTRACT

El sistema informático de análisis y procesamiento de señales sísmicas (SIPASS),actualmente constituye una herramienta de apoyo a los científicos y técnicos del Instituto Geofísico de la Escuela Politécnica nacional, en el análisis y procesamiento de las señales sísmicas de los volcanes. Esta nueva herramienta informática, trabaja con archivos sísmicos en formato SAC (Código de Análisis Sísmico). Permite la selección de estaciones sísmicas, donde el programa lee la información de los archivos y los guarda en variables temporales; con estas variables genera el directorio principal con la información de las estaciones seleccionadas.

Se selecciona un archivo del directorio principal para realizar el procesamiento de la señal sísmica. El sistema carga la información y el usuario visualiza la señal en pantalla de la estación o las estaciones que se hayan seleccionado, se debe activar el modo de señalamiento de tiempos de arribo, para que el programa le permita seleccionar dos o tres segmentos de la señal.

Dependiendo del número de segmentos seleccionados, se obtendrá de manera automática: fecha y hora, estación, s-p, coda, amplitud, periodo, frecuencia máxima, rms. El tipo de evento es determinado con el programa SIPASS, el cual utiliza la FFT (Transformada Rápida de Fourier), este algoritmo utiliza la información que genera la clase SAC (Código de Análisis Sísmico), el programa verifica que el número de puntos almacenados en el arreglo, sea potencia de base 2 y si no lo es, el programa completa con ceros; finalmente el sistema realiza los respectivos cálculos y presenta en pantalla el espectro de la señal.

SIPASS, permite quitar el ruido de fondo de la señal sísmica. El programa utiliza tres tipos de filtrado, BandPass, LowPass y HigPass. Aplicando cualquiera de estos filtros, será posible observar con mucha claridad la señal sísmica.

SIPASS utiliza una arquitectura 2 capas: cliente-servidor; se desarrolló sobre la plataforma Java Standart Edition (JSE), bajo el entorno de desarrollo Netbeans 7.1, que se ejecuta en el servidor de aplicaciones Apache Tomcat 6.0 y utiliza SQL Server 2008, como sistema de gestión de base de datos. La arquitectura Cliente Servidor es importante, ya que la aplicación está instalada en diferentes estaciones de trabajo, mientras que la base de datos se encuentra centralizada en un servidor.

Varios usuarios pueden acceder a la base de datos desde cualquier estación de trabajo y a la vez estos mismos usuarios pueden trabajar analizando, clasificando y procesando las señales de un mismo volcán o de diferente volcán.

PalabrasClave: Sistema informático de Análisis y Procesamiento, Señales Sísmicas de volcanes, Código de Análisis Sísmico, Transformada Rápida de Fourier.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
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Enjambres sísmicos en el Volcán Pico de Tancítaro, Michoacán, México. ¿Intrusión magmática o sismicidad tectónica?

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ABSTRACT

En el año 2006 se presentó un importante enjambre sísmico, con 700 eventos localizados, que ocurrió entre finales de mayo hasta principios de julio, entre los volcanes Pico de Tancítaro y Paricutín, que nació en el año 1943, en Michoacán, dentro del campo volcánico monogenético Michoacán-Guanajuato (MGVF) en el oeste de México. Esta actividad sísmica fue registrada por la red sísmica temporal desplegada entre enero del 2006 y junio del 2007 por el Proyecto Mapping the Riviera Subduction Zone" (MARS). Un estudio preliminar de este enjambre propone que la profundidad del enjambre es entre 9 y 5km y que se debe a una intrusión magmática. En los años de 1997, 1999 y 2000 también se reportaron enjambres sísmicos en la misma área de estudio, de estos enjambres solo se estudió el último período de la secuencia de 1997 y se concluyó que la sismicidad era de origen tectónico, con profundidades entre 18 y 12 km; para los episodios de 1999 y 2000 se reportó que la actividad sísmica eran similar a la de 1997. En este trabajo se hace una revisión de los datos del Proyecto MARS para el período del 21 de mayo al 28 de junio relocalizando 563 eventos utilizando Hypo71 y el modelo regional de velocidades de onda P de la RESAJ (Red Sísmica y Acelerométrica de Jalisco), posteriormente se realizó un análisis de correlación cruzada a partir del cual se obtuvieron 15 familias que presentan un migración en tiempo y en profundidad, iniciando a los 16 km y terminando a los 9 km. Esto lo interpretamos como una intrusión magmática.

PalabrasClave: Sismicidad volcánica, intrusión magmática, Michoacan.

EARTH SCIENCES
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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Actividad sísmica de los volcanes del segmento Norte de Colombia 1985-2014

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ABSTRACT

A lo largo de 27 años, el Observatorio Vulcanológico y Sismológico de Manizales se ha encargado del monitoreo de los volcanes del segmento norte de Colombia. La instalación de una pequeña red de estaciones sismológicas en el Volcán Nevado del Ruiz (VNR) a mediados de la década de los 80s, dio inicio al monitoreo volcánico en esta región del país. Con el paso del tiempo la red sismológica fue densificándose y extendiéndose a otros volcanes. Actualmente, se realiza vigilancia directa de ocho volcanes e indirectamente de otros tres.

La actividad sísmica de los volcanes del segmento norte, está dominada por eventos de fracturamiento de roca, generados por cambios en el campo de esfuerzos al interior de la estructura volcánica y por la interacción del sistema volcánico con las fallas activas que atraviesan los volcanes de esta región. Estos sismos denominados volcano-tectónicos (VT), aportan la mayor parte de la energía sísmica liberada en los centros volcánicos, no solo por el número sino también por sus magnitudes, las cuales han superado 4.0 M_L (magnitud local), en volcanes como el VNR y el Cerro Machín (VCM), los dos volcanes más activos del segmento.

El volcán con mayor actividad sísmica en esta zona es el VNR; su línea base de sismicidad ha cambiado significativamente con las variaciones en la actividad volcánica, mostrando incrementos importantes en los periodos pre-eruptivos y eruptivos del volcán en 1985, 1989 y 2012. A diferencia de los demás volcanes, el VNR ha presentado una intensa sismicidad asociada a dinámica de fluidos hidrotermales y magmáticos al interior del volcán. Las fuentes sísmicas del volcán, tanto de fractura como de actividad de fluidos, están bien determinadas, mostrando un carácter superficial en cercanías al cráter activo, y más profundas cuando éstas están más alejadas del cráter (fuentes distales).

El segundo volcán más activo sísmicamente del segmento norte, es el VCM. Éste volcán presenta una sismicidad casi exclusivamente de tipo VT, manifestada predominantemente en enjambres sísmicos. La sismicidad está distribuida en fuentes que rodean el domo principal, y que se extienden en dirección sur-suroriente hasta límites con la Falla de Ibagué. La mayoría de las fuentes cercanas al domo son poco profundas, y a medida que se alejan en dirección suroriental van aumentando su profundidad hasta llegar a 18 km. La actividad del VCM está íntimamente ligada a la tectónica local y ha sido más intensa desde el año 2002.

Otros volcanes del segmento norte con actividad sísmica, son el Nevado del Tolima, Nevado de Santa Isabel y Cerro Bravo (VCB). Estos han mostrado niveles de actividad bajos, con predominio de sismicidad superficial tipo VT, y eventualmente sismos asociados a actividad de fluidos, algunos de ellos profundos, particularmente para el VCB.

En otros centros volcánicos como los paramillos de Santa Rosa, Cisne y Quindío, y Cerro España se ha registrado sismicidad esporádica, en forma de enjambres y sismos aislados, en su mayoría de baja magnitud. Finalmente, en los volcanes más septentrionales como San Diego y Romeral no se ha registrado hasta ahora actividad sísmica.

Palabras Clave: Monitoreo volcánico, actividad sísmica, volcanes, segmento norte.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Análisis de la sismicidad tipo Drumbeat y su relación con la erupción del año 2008 del Volcán Nevado del Huila, Colombia

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ABSTRACT

La sismicidad del volcán Nevado del Huila (VNH) ha sido monitoreada desde el año 1993 y estuvo predominantemente representada por la ocurrencia de sismos tipo VT hasta el año 2007, momento en que los fuertes cambios en sismicidad reflejaron un fuerte y rápido cambio en el sistema volcánico, el cual conllevó a tres eventos eruptivos entre el año 2007 y 2008. Durante este período el VNH presentó diversos y acelerados cambios en su actividad, los cuales desencadenaron dos erupciones freáticas y una magmática, siendo este último evento el de mayor impacto en la superficie y zona de influencia del VNH. Esta actividad estuvo enmarcada en sus etapas iniciales por la aparición de una serie de señales sísmicas antecesoras nunca antes vistas en este volcán, las cuales han sido denominadas en la literatura como Drumbeats, entendiéndose en el sentido estricto como señales de corta amplitud, con un espaciamiento y recurrencia muy regulares, en general de tipo LF (Low Frequency) y HB (Hybrid) y estando asociados a procesos de extrusión de domos. La intención de este trabajo es la de mostrar la tendencia general de los más de 18.000 eventos de este tipo que se registraron en un lapso de 37 días, enfocándose en las variaciones de parámetros como amplitud, frecuencia y espaciamiento entre eventos, y como estos cambios se relacionaron con la dinámica extrusiva del domo volcánico, eruptado el 2 de noviembre de 2008 en la cima del VNH.

Palabras Clave:Erupción, Drumbeat, Amplitud, Frecuencia, Espaciamiento entre eventos, extrusión de domo, volcán Nevado del Huila.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Análisis espectral de fuentes sismogénicas de sismos volcano-tectónicos en el Volcán Nevado del Huila, Colombia

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ABSTRACT

Se llevó a cabo un cálculo comparativo entre espectros de eventos VT del volcán Nevado del Huila (VNH), los cuales fueron seleccionados y diferenciados según la fuente sísmica donde se generaron - SW, NE, Pico Central (PC) -, durante un período comprendido entre el año 2009 y 2013. A través de un proceso de conteo de espectros se resaltaron los picos dominantes que presentaban mayor recurrencia; con esto, se logró identificar aquellos que se presentan con mayor frecuencia en cada una de las fuentes propuestas. Los resultados obtenidos han permitido hacer relaciones respecto a los efectos de fuente, trayectoria y sitio en el sistema volcánico del VNH, asociados a la profundidad donde se registra la sismicidad más recurrente, los cambios temporales de esta para el período evaluado, así como las condiciones estructurales y tectónicas del medio, y la incidencia de la estratigrafía en los registros sísmicos. A través de la relación entre el promedio de espectros asociados a la trayectoria, por aquellos relacionados a una fuente y estación, se encontró una ventana espectral muy corta (7 a 9 Hz) presente en todas las fuentes sísmicas para todas las estaciones involucradas en el cálculo, permitiendo inferir un proceso geológico mayor, común a todo el sistema volcánico e interactuando directamente con este, lo que ha permitido referirse a una fuerte correlación con los procesos tectónicos de la zona de estudio; por otro lado, las frecuencias no comunes en cada caso han indicado un fuerte efecto de sitio en los lugares de emplazamiento de las estaciones. A través del cálculo que relaciona los espectros de todas las señales asociados a todas las fuentes sísmicas en cada estación, se pudo reconocer cambios asociados al efecto de sitio, correlacionados con las condiciones geológicas de cada lugar de emplazamiento de las estaciones, donde se tienen variaciones en el tipo de depósito así como del tipo de estructura volcánica y su grado de conservación. El análisis normalizado, que se realizó a los contenidos espectrales de las fuentes sísmicas, también permitió hacer relaciones asociadas al nivel de profundidad donde ocurren los cambios del sistema volcánico así como del tipo de procesos involucrados; es así como se encontró un pico espectral marcado con un valor entre 2.5 y 5 Hz, asociado a la fuente Pico Central (estructura central del edifico volcánico), la cual ha tenido una marcada predominancia de eventos superficiales asociados a la dinámica de fluidos, durante los últimos 8 años de actividad del VNH. Estas relaciones permiten caracterizar la actividad del VNH así como mejorar el modelo interpretativo del sistema volcánico en condiciones de crisis.

Palabras Clave:Fuente sísmica, pico espectral, efecto de fuente, sitio, trayectoria, volcán Nevado del Huila.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Redefinición de las fuentes sismogénicas volcano-tectónicas en el Volcán Nevado del Ruiz a partir de la actividad reciente 2010-2014

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ABSTRACT

La actividad sísmica volcano-tectónica en el área del Volcán Nevado del Ruiz (VNR) está concentrada en un área de aproximadamente 100km^2 y muestra una amplia distribución espacial. Después de las erupciones de noviembre/1985 y septiembre/1989, la sismicidad estuvo principalmente concentrada en el Cráter Arenas y fuentes próximas localizadas al Sur-Suroeste y Sureste del mismo, y ocasionalmente al Oeste.

A partir de la distribución espacial observada de la sismicidad durante 2012- 2014, se redefinieron las fuentes sismogénicas activas en el sector del VNR. Diez fuentes sismogénicas se consideran activas actualmente, en un radio de 5km tomando como centro del cráter activo (Figura 1a). La energía sísmica liberada y el número de sismos diarios en dichas fuentes presentan cambios temporales importantes.

Se destaca la fuente cráter (C) que ha estado activa en la mayoría de las crisis volcánicas. Así mismo, la fuente WSW ha estado activa antes de las erupciones de 1985 y 1989 con valores energéticos importantes, mientras que para las otras crisis registró valores energéticos bajos. Las Fuentes SSW y SE, han sido recurrentes en el tiempo con valores energéticos relativamente bajos. Recientemente, fuentes distales han aparecido en los sectores N (NNE) y NW (F-NW), con altos niveles energéticos y de número de sismos. Las demás fuentes no han mostrado cambios importantes relacionados con la actividad volcánica (Figura 1b).

Con base en los resultados anteriores, se plantea una hipótesis de trabajo, en la que la sismicidad actual puede estar relacionada con una intrusión profunda, evidenciada en la ocurrencia de sismos en zonas factibles de acumulación de esfuerzos, como son los trazos de fallas existentes en el sector y su intersección, así como las manifestaciones geoquímicas y geodésicas (deformación) que se han registrado. Sin embargo, se observa una tendencia general de la sismicidad a alejarse del cráter activo en el último año, siguiendo trazos lineales, que podrían sugerir la propagación de los esfuerzos y rupturas asociadas a zonas más distales de la intrusión inicial.

Esto implicaría que la actividad actual del VNR puede evolucionar en dos posibles sentidos: uno, con un incremento relacionado a la intrusión previa, la cual afectaría la zona proximal -predominando un régimen de esfuerzo local, asociado a la actividad magmática-, el cual podría culminar con erupciones volcánicas. El otro, con una transferencia de esfuerzos hacia zonas distales, predominando un régimen de esfuerzo regional, el cual se reflejaría en actividad sísmica distal sin afectación importante de la actividad volcánica.

Palabras Clave: Fuentes sismogénicas, Volcán Nevado del Ruiz.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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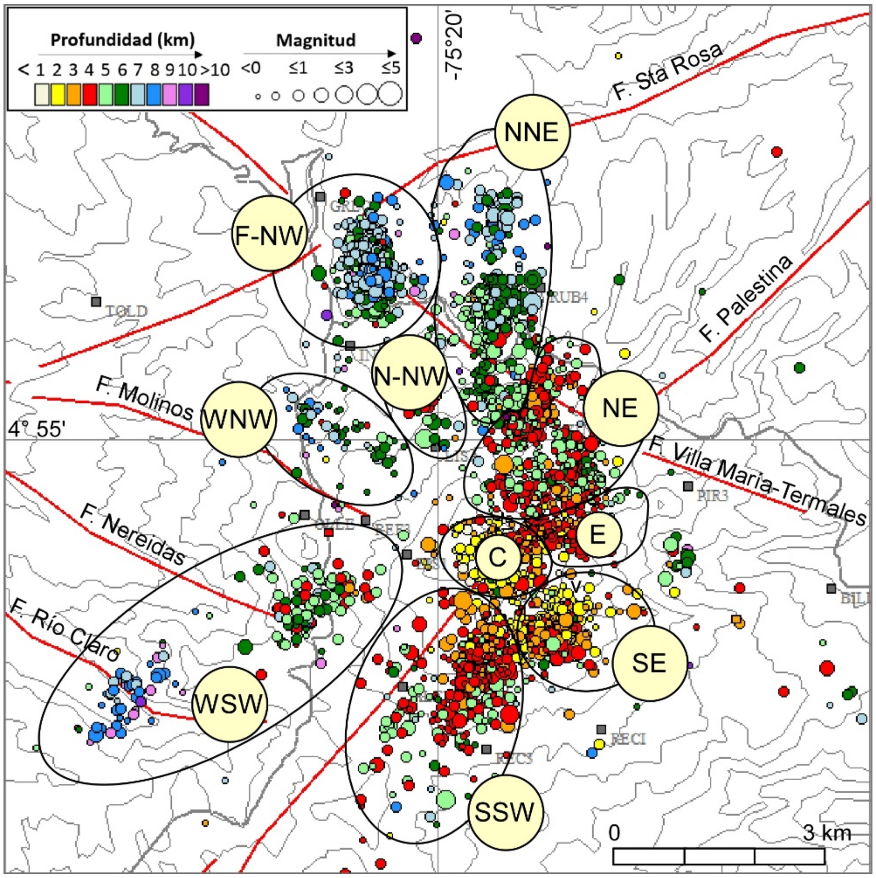
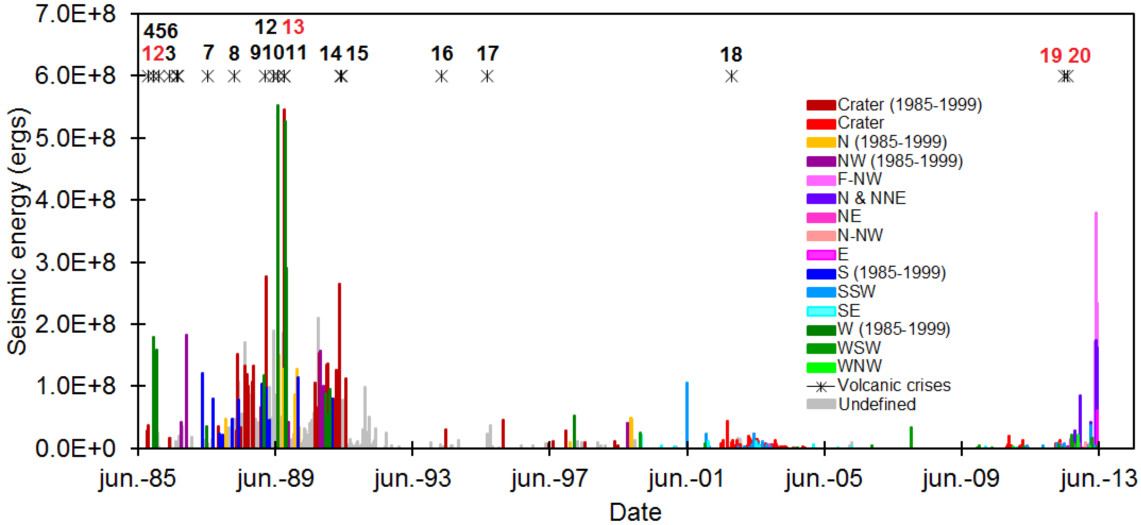


Figura 1a.Fuentes sismogénicas determinadas para el área del Volcán Nevado del Ruiz. C: Cráter, E: Este, NE: Noreste, NNE: Nor-Noreste, F-NW: Noroeste lejano o distante, N-NW: Nor-Noroeste, WNW: Oeste-Noroeste, WSW: Oeste-Suroeste, SSW: Sur-Suroeste y SE: Sureste.



volcanic crises date								
1	2	3	4	5	8	9	10	11
sep-85	nov-85	ene-86	may-86	jul-86	mar-88	feb-89	may-89	**jun-89**
12	13	14	15	16	17	18	19	20
ago-89	sep-89	abr-91	may-91	abr-94	ago-95	sep-02	may-12	jun-12

Figura 1b.Energía liberada diaria para las fuentes sismogénicas del área del Volcán Nevado del Ruiz. C: Cráter, E: Este, NE: Noreste, NNE: Nor-Noreste, F-NW: Noroeste lejano o distante, N-NW: Nor-Noroeste, WNW: Oeste-Noroeste, WSW: Oeste-Suroeste, SSW: Sur-Suroeste y SE: Sureste. Recuadro inferior fechas de crisis volcánicas, en rojo erupciones volcánicas.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Tomografía sísmica del Volcán Puracé

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ABSTRACT

Se llevó a cabo el modelamiento de la estructura interna del volcán Puracé (VP) por medio de una tomografía sísmica. Con la selección de 850 sismos VT (volcano-tectónicos) se efectuó el procesamiento de 4863 arribos de ondas P y de 3517 de ondas S. Se logró definir varias zonas de baja velocidad para ondas P y S distribuidas en diferentes sectores de la estructura volcánica. La tendencia general de los resultados mostró un predominio de zonas de baja velocidad, es así como se obtuvo una primera zona de anomalía (dVp <3%) ubicada bajo el cráter activo, extendiéndose desde los 10 km hasta los 14 km en profundidad, lo cual se ha interpretado como la zona de alimentación magmática profunda o reservorio delVP. Mientras que en el flanco NE de la estructura volcánica, se encontró otra anomalía de baja velocidad a niveles más superficiales (3- 4 km de profundidad), lo cual se relacionó con la actividad del sistema hidrotermal del VP, por la presencia expresiones estratigráficas y superficiales de hidrotermalismo. En la zona del cráter activo y su flanco SE, se observó que la anomalía de baja velocidad inicia a los 4 km de profundidad y finaliza a los 8 km. Esta se interpreta como la fuente de transmisión de calor y fluidos de la actividad actual en el VP. Otraestá ubicada en el costado SW del VP, allí el contraste se extiende hasta los 4 km de profundidad, y coincide con el cruce de la Falla Moras con la Falla Coconucos. Una zona de alta velocidad para onda P (dVp >6%) parece asociarse, en profundidad, con una estructura remanente, posiblemente una antigua caldera, asociada con el edificio pre-Puracé, que yace debajo del cráter principal; así mismo, en la parte central de dicha zona de alta velocidad, la anomalía se hace más fuerte, generando un fuerte contraste de velocidad limitado al cono del edificio volcánico, que se extiende hasta los 2-3 km de profundidad, y que se interpreta como un cuerpo dómico antiguo.
La gran cantidad de actividad de fluidos que actualmente presenta el VP, puede explicarse por la presencia de estas extensas zonas de baja velocidad bajo el volcán, que podrían actuar como las fuentes generadoras de los mismos por su intercambio de calor y fluidos con el medio.

Palabras Clave:Tomografía sísmica, estructura interna, modelamiento, zona de baja velocidad, sistema hidrotermal, volcán Puracé.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Variaciones de la concentración de gas radón y SO_2 asociadas a actividad sísmica en el sector del Volcán Galeras, Colombia, 2005-2013

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ABSTRACT

Se realizó un análisis de las emisiones de gas radón (^{222}Rn) en suelo en el sector del Volcán Galeras (VG), con miras a detectar posibles correlaciones con sismicidad en la región y actividad volcánica, para el período 2005-2013. Se pudo establecer que existe una correlación entre anomalías de gas radón (consideradas como tal para el caso del VG, aquellos valores de concentración por encima del promedio más la mitad de la desviación estándar, 1900 pCi/L) con la ocurrencia posterior de sismos volcano-tectónicos (VT) o tectónicos locales (TL), con magnitudes mayores a 3 (ML>), en un radio de 35km del cráter activo, en un lapso entre 1 y 52 días, con promedio 24 días. En el 100% de los casos de ocurrencia de sismos con ML>3 se detectó una anomalía previa de gas radón.

Sin embargo en un 50% de los casos se presentaron anomalías de gas radón sin la ocurrencia posterior de sismos con ML>3. Esto se puede explicar a partir de datos de emisión de SO2 por el volcán hacia la atmósfera, los cuales parece tener una relación con las emisiones de radón; cuando tanto los valores de radón como los valores de SO2 (>2000 Ton/día para el caso del VG) fueron anómalos, no se generaron sismos con ML>3 en el 90% de los casos. Cuando los valores de radón fueron anómalos y los valores de SO2 fueron bajos (<2000 Ton/día) se produjeron sismos con ML > 3 en el área del VG en el 100%. Al parecer, cuando el volcán está más abierto (más grietas abiertas en su interior), tanto el radón como el SO2 salen libremente en mayores cantidades y es difícil generar sismos con ML>3; en el caso contrario, cuando el volcán está cerrado, se dificulta más la salida de SO2, pero se empieza a acumular esfuerzos que generan valores anómalos de radón y sismos ML>3, posteriormente. Éste patrón parece servir como ayuda en el pronóstico de ocurrencia de sismos importantes en el área del VG.

Palabras Clave: radón, Volcán Galeras.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Variaciones en la atenuación de las ondas sísmicas en el Volcán Nevado del Ruiz asociadas a la reciente reactivación 2010-2014

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ABSTRACT

Se realizó un estudio de la atenuación sísmica en el volcán Nevado del Ruiz (VNR), para el período 2010-2014, lapso en el cual el VNR ha experimentado un incremento importante en su actividad.
Se calculó el factor de atenuación, Q-1 usando un modelo de dispersión única isotrópico, y se calculó la relación de amplitudes espectrales de ondas S y P (As/Ap) para la banda de frecuencias 8-16Hz, con frecuencia central 12Hz.
Durante los períodos que anteceden aumentos importantes en la actividad volcánica, el factor de atenuación (Q-inverso) aumenta paulatinamente, alcanzando diferencias hasta de 0.0045 desde el inicio del cambio y el incremento en la actividad volcánica. Para las dos pequeñas erupciones ocurridas en 2012 (Mayo y Junio), el promedio mensual del valor de la atenuación evidenció un cambio importante cuatro meses antes de las erupciones.
Por otra parte, Se pudieron evidenciar cambios temporales en la relación espectral As/Ap para las diferentes fuentes sismogénicas alrededor del VNR; antes de las pequeñas erupciones de mayo y junio de 2012, se pudo detectar un aumento en dicha relación, y una posterior disminución días antes de las erupciones. Así mismo se detectaron incrementos antes de la ocurrencia de enjambres sísmicos de tipo volcano-tectónico.
Con base en los resultados anteriores, se concluye que la atenuación de las ondas sísmicas evaluada por dos métodos diferentes mostró cambios relacionados con la actividad del VNR, lo que permite usar éste parámetro como una herramienta más para el pronóstico de cambios en la actividad del VNR y como parámetro que puede ser usado en el monitoreo rutinario de dicho volcán.

Palabras Clave: atenuación, Volcán nevado del Ruiz.

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Characterization of Seismo-volcanic Activity in Peteroa Volcano, Central Chile-Argentina

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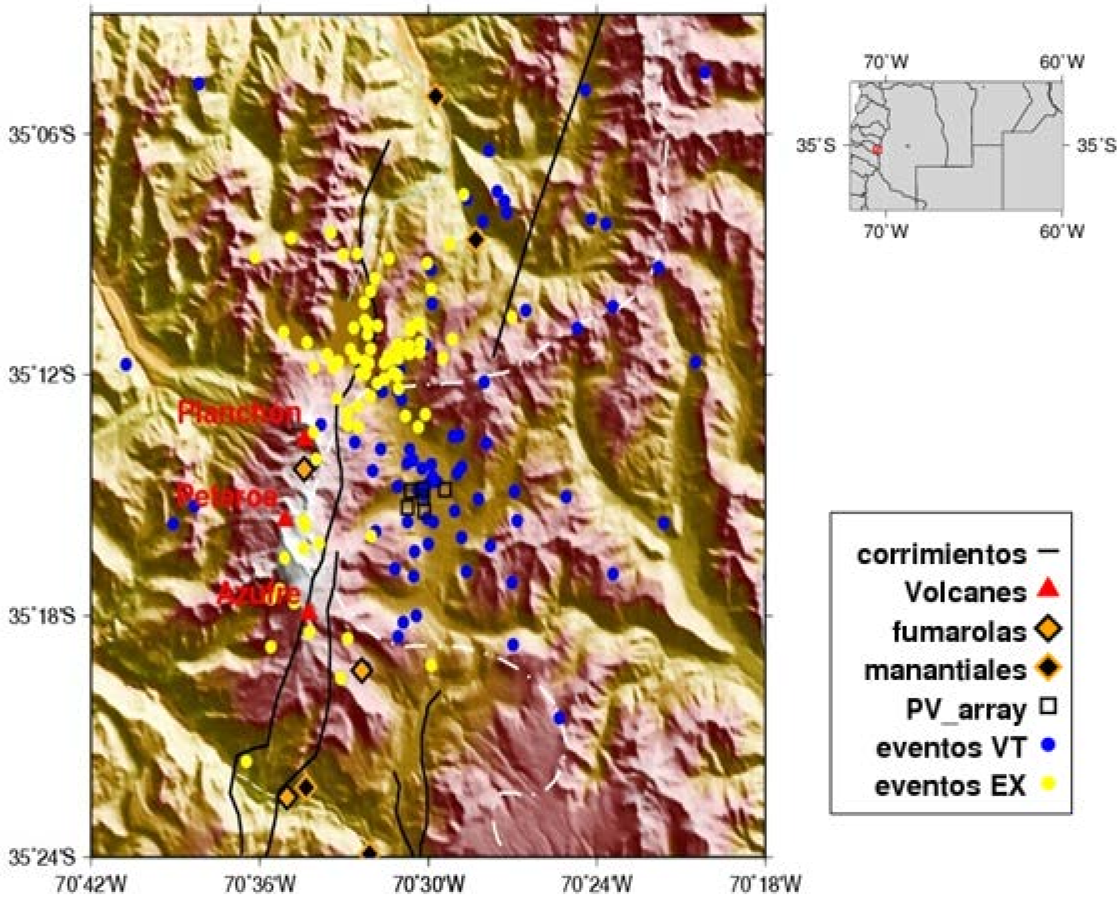
ABSTRACT

The Peteroa volcano is the youngest stratovolcano of the Azufre-Planchón-Peteroa Volcano Complex. It is located in the Southern Volcanic Transition Zone of the Andes that extends between 34.4°S and 37°S. In this area, NW-SE and NE-SW fault systems enable ascent and emplacement of magma causing spatial control of calderas, stratovolcanoes and geothermal activity. Historical activity records of Peteroa have shown about twenty eruptive events, most of them weak. Bibliography highlights the associated processes of the 1837 and 1991 eruptions, and those occurred in 2010 and 2011 that indicate a system reactivation.
The aim of this work is to characterize the seismo-volcanic activity in Peteroa volcano and locate its seismic sources. This information will be useful to understand the volcano's behavior and to implement its monitoring. This work represents a new contribution to the existing tools in volcanic monitoring, allowing the characterization of seismo-volcanic activity systematically and sequentially as a result of the development of scripts which compose a processing sequence performing several tasks.
The analyzed data was provided by a seismic array deployed on the east flank of Peteroa volcano by the international cooperation project MalARRgue (TUDelft-ICES) in 2012 for a period of one year. An analysis in time and frequency domains allows us to discriminate events and assign them a possible source model, which is related to the activity level of the volcano. We have developed a command sequence to characterize the events originated in the volcano. This script enables us to convert the format of seismic data, visualize it, analyze the evolution of its spectral content, apply filters and get necessary information for events localization and to build a seismic catalog. During 2012, Peteroa volcano showed seismic activity with continuous low-energy signals and a high number of transient signals with slightly higher energy. We have identified long-period Tremor, Volcano-Tectonic events associated with fractures, and Explosions and Long-Period events associated with degassing and hydrothermal phenomena.
We have developed a processing sequence to group events in families that share the same focal mechanism and path based on cross correlation technique. As of the writing of this abstract, only one event family has been identified for both high and low frequency events. The spectral evolution throughout the recording period helps identify changes in the activity state.
The source locations were calculated by inversion of arrival times, by comparative analysis of particle motion between stations and/or by a cross correlation method, searching for the parameters that generate the higher signal coherence through the array, taking into account the type of event. Volcano-Tectonic event sources were found to be distributed to the E and NE of the active volcano, while Explosion sources were found to be related to known fumarolic and hydrothermal phenomena.

Key Words: Peteroa volcano, seismo-volcanic activity, families of events, source's localization.


Planchón
Peteroa
Azufre
35°06'S
35°12'S
35°18'S
35°24'S
70°42'W
70°36'W
70°30'W
70°24'W
70°18'W
70°W
60°W
35°S
corrimientos
Volcanes
fumarolas
manantiales
PV_array
eventos VT
eventos EX

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Análisis del campo de esfuerzo actual a partir de mecanismos focales en el área del Volcán Nevado del Ruiz, Colombia

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ABSTRACT

Con el propósito de encontrar las relaciones entre la sismicidad del sistema de fallas existente en el área del Volcán Nevado del Ruiz (VNR) y la actividad sísmica del volcán, se realizó como primera aproximación una estimación del campo de esfuerzos actual en el área con base en datos sismológicos.

Para tal fin, fueron compilados un total de 644 mecanismos focales simples (FMS) o soluciones de plano de falla (FPS). Los mecanismos focales corresponden a las soluciones obtenidas para sismos volcano-tectónicos (VTs) con una magnitud local ML>0.5, registrados durante el periodo comprendido entre el 1 de Enero de 2010 al 31 de Octubre de 2013.

Se asumió que todos los mecanismos focales tienen un alto porcentaje de componente doble cupla (%DC). Los mecanismos focales óptimos para el análisis fueron aquellos procedentes de VTs con una buena localización. Los FMS fueron agrupados por año y por proximidad geográfica a las fuentes sismogénicas determinadas para el área del VNR. Para cada año y cada fuente sismogénica fue calculado el tensor de esfuerzos reducido usando el método de Yamaji et al. (2011).

El patrón de esfuerzos obtenido refleja una interacción compleja entre los esfuerzos locales y el esfuerzo regional. La heterogeneidad de las fuentes sismogénicas es evidenciada en los altos valores de dispersión. Las orientaciones y magnitudes relativas de los esfuerzos principales encontradas a partir de la inversión, indican para el área del VNR un régimen tectónico dominantemente extensional, con tendencia a extensional radial y frecuentes variaciones a un régimen de strike-slip. Únicamente la fuente WNW muestra un régimen diferente que varía de strike-slip a compresional. Ésta configuración de esfuerzos, podría explicarse por la interacción de la actividad volcánica, relacionada con una intrusión magmática y regímenes tanto locales como regionales que interactúan en el mismo sector.

Palabras Clave: campo de esfuerzos, mecanismo focal, Volcán Nevado del Ruiz.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Descripción de la actividad sísmica relacionada a erupciones estrombolianas violentas: Vn. Llaima, Chile (2007 – 2010)

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ABSTRACT

El volcán Llaima (38°42'S y 71°44'W) un estratovolcán basáltico-andesítico, localizado en la Zona Volcánica Sur de los Andes, ha sido catalogado como uno de los más activos y voluminosos de Suramérica, con una recurrencia eruptiva de ~6 años. El último ciclo eruptivo (2007-2010), inició con una pequeña manifestación superficial en mayo de 2007, seguida por erupciones mayores en 2008 y 2009 y posterior culminación en junio de 2010, ciclo eruptivo que de acuerdo a sus características es el más importante después del ocurrido en 1957. Para el año 2009, el Observatorio Volcanológico de los Andes del Sur (OVDAS) del Servicio Nacional de Geología y Minería, había instalado tres estaciones sismológicas ubicadas entre 7 y 20 kilómetros con respecto al cráter, instrumental complementado con motivo de la conformación del nuevo OVDAS en noviembre del 2009, adicionando siete estaciones, instaladas a distancias hasta de 2 km con referencia al cráter activo. Una primera erupción descrita como paroxismal de tipo estromboliana violenta, inicia el 1 de enero de 2008, con cerca de 15 horas de actividad energética, y una segunda, originada el 3 de abril de 2009 catalogada como estromboliana vigorosa con una duración aproximada de 80 horas, destacan los hechos más relevantes y comparables de este periodo. Esta descripción de la sismicidad, se convierte en la primera oportunidad de exhibir a la comunidad científica, aspectos relacionados con el registro sísmico para el Llaima, en las etapas pre, sin y post-eruptivas. Haciendo una comparación de las erupciones, la de abril de 2009 se caracterizó porque el registro sísmico fue de menor intensidad, pero constante y de mayor duración que la desarrollada en enero de 2008. Ambos episodios en su punto más vigoroso, se identificaron por presentar registros continuos de señal tipo Tremor, con bandas frecuenciales entre 0.8 y 3.0 Hz principalmente y peaks dominantes en 1.0, 1.2 y 1,5 Hz. Además, las erupciones se distinguieron por presentar un nivel de ocurrencia bajo relacionado con sismicidad volcanotectónica (VT), provenientes de una fuente ubicada 18 km al sur-suroeste del cráter activo. La sismicidad de Largo Periodo (LP) cuyas formas de onda presentaron una variedad de familias, se caracterizó por presentar un incremento paulatino en la energía, alcanzando amplitudes máximas al momento del clímax eruptivo, evolucionando hacia episodios de tremor continuo durante el proceso de la erupción, el que finalizó abruptamente. Posterior a la culminación, sismicidad LP y Tremor de corta duración se hacen visibles en los registros. El contenido espectral de los eventos LP y Tremor comparten peaks dominantes, sugiriendo un origen común. El último ciclo eruptivo del Llaima, llevó a reconocer que el aumento en la energía de los LP y la ocurrencia de sismicidad VT en forma esporádica, enmarcan un escenario de pronóstico volcánico el cual sugiere que estos parámetros podrían ser usados como premonitorios en futuras crisis volcánicas.

PalabrasClave: Palabras claves: Volcán Llaima, erupciones estrombolianas, sismicidad de largo periodo, tremor.

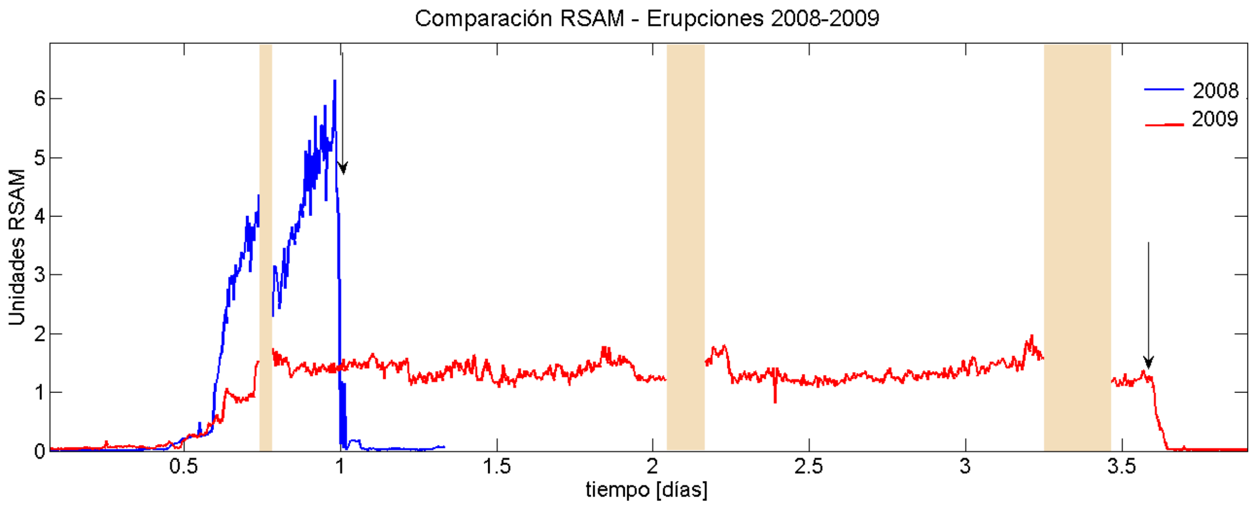

Figura 1. Comparación del tamaño de la energía RSAM de las erupciones en el volcán Llaima, color azul y rojo, erupciones del 2008 y 2009, respectivamente. La flecha negra indica la culminación abrupta de cada episodio energético (bloques en colores cálidos indica que no hay datos).

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Anomalías de gas radon asociadas a la sismicidad en el region volcánica Puracé

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ABSTRACT

El monitoreo continuo de emisiones de gases difusos en el volcán Puracé se inició en 2006, de manera esporádica en los inicios de la vigilancia y de forma continua en los últimos años. Para estudiar la relación entre la sismicidad de fractura y las emisiones de radón (222Rn) en la región volcánica del Puracé (RVP), se realizó un análisis de las emisiones de este gas presente en suelo empleando los datos de tres estaciones isotópicas (Agua Tibia (AT), Agua Hirviendo (AH) y Tabio (TB)), ubicadas estratégicamente sobre una zona de fallamiento activo en el área de influencia volcánica. Los datos fueron obtenidos mediante el método de cámaras ionizantes EPERM (electret-passive environmental radon monitor) para determinar la concentración de radón.
Se pudo establecer que para ésta región, en más del 80% de los casos, existe aumento en la concentración de gas radón por encima de 1800 pCi/L antes de la ocurrencia de sismos volcano tectónicos (VT) o tectónicos locales (TL), con magnitudes mayores a 2.8 (ML>), en un radio de 30km, tomando como centro el sitio ubicado en la distancia media entre las estaciones de medición. Las anomalías ocurren en un rango de 3 a 80 días antes del sismo de ML>2.8, predominando 36 días como rango promedio.
Éste resultado permite concluir que el monitoreo de emisiones de gas radón es una herramienta útil en el pronóstico de sismos en el área donde se tiene instalada la red de monitoreo, si se determinan apropiadamente, tanto el radio de influencia, como el valor de concentración de gas radón considerado una anomalía.

Palabras Clave: sismicidad, gases difusos (^{222}Rn), volcán Puracé.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic attenuation around Peteroa Volcano, Argentina

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ABSTRACT

The seismic activity of a volcano is one of the elements that best describes its dynamics. The different seismic signals registered depend on the type of source, the characteristics of the medium through which they have propagated (such as the presence of fluids and heterogeneities), and their variations in time. Along their path the amplitude of the waves is attenuated. The analysis of this decay can reveal variations inside the volcanic structure. This information is indispensable for a better characterization of seismo-volcanic activity, the comprehension of its dynamic and implementation of monitoring.

The quality factor (Q) describes the attenuation effects, including the intrinsic attenuation due to anelasticity of the medium and the loss of energy due to scattering from heterogeneities. This factor is intimately related with the medium parameters like viscosity, density, temperature and fluid presence. Therefore, spatial and temporal variations of Q could help us understand the volcano dynamics and how it changes due to both internal and external factors. It was observed that, in local earthquakes seismograms, Q varies with frequency and can be estimated from direct and coda waves.

In the last decades the Peteroa volcano (Central Chile and Argentina) has suffered a series of phreatomagmatic events, as well as seismic activity related with rock fractures and fluid dynamics that were located on the Argentinean flank, according to information provided by SERNAGEOMIN, Chile. For this reason, the proximity of population centers and for a future volcanic monitoring, it is essential to improve the knowledge about attenuation in the area.

The objective of the present work is to obtain information about the area surrounding Peteroa volcano through the analysis of seismo-volcanic signals attenuation. The data was acquired by six short period stations installed on the eastern flank of the volcano by the MalARRgue project (ICES-CNEA, TUDelft) during 2012.

The quality factor of direct waves, Qd, is determined by the spectral ratio method which analyzes variations in amplitude of ground displacement related with propagation. Qd is obtained as a function of frequency by analyzing all the explosive and volcano-tectonic events registered in each station as a function of travel time for consecutive frequency intervals (Rojas Arce, 2013). Such dependence is assumed to be a power law of the form Q = Qo*f^a, where Qo=Q(1Hz). The estimation of quality factor for coda waves, Qc, is obtained using the Single Back-Scattering model (Aki y Chouet, 1975) on volcano-tectonic events.

Up to this moment, the results show the highest attenuation towards the southwest of the array. This variation could be related with the relative position of volcanic and glacial deposits as well as plutonic outcrops around the volcano.

PalabrasClave: Peteroa Volcano, attenuation, quality factor, volcanic monitoring.

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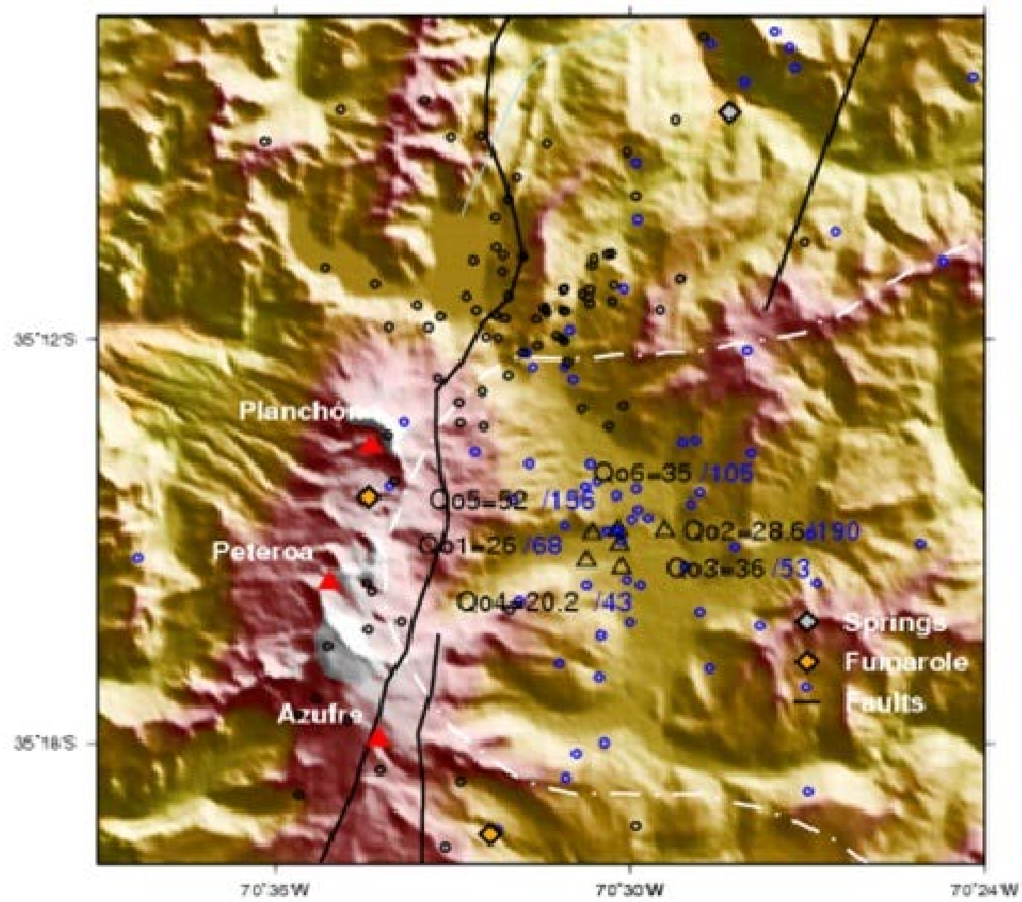

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sismicidad volcano-tectonica y registros de periodos de deformación en el volcán Sotará, "Segmento central de Colombia"

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ABSTRACT

El volcán Sotará (4420 msnm) es un estratovolcán ubicado en la Cordillera Central, en el límite entre los departamentos del Huila y Cauca, a 37 km al SW de la ciudad de Popayán, hace parte de un complejo volcánico conformado también por los volcanes Cerro Azufrado, Cerro Gordo y Cerro Negro. Es un volcán activo, sin registros históricos de actividad eruptiva (últimos 500 años), que ha sido monitoreado por el Servicio Geológico Colombiano (Ingeominas) desde el año 1993 y de manera continua desde el año 2007. Evidencias de su actividad es la existencia de campos fumarólicos, fuentes termales, lavas, domos con morfología post-glaciar (Acevedo & Cepeda, 1982) y el registro de actividad sísmica principalmente asociada con eventos de tipo *volcano-tectónico* (VT) proximal y distal.

La sismicidad en el volcán Sotará hasta antes del 24 de junio de 2012 se había caracterizado por ser de baja ocurrencia y de bajo aporte energético, en promedio se registraban 6 eventos por mes, a partir de esta fecha la actividad sísmica se incrementó, contabilizándose hasta 9861 sismos de tipo VT, de estos, 7521 han sido de bajo aporte energético; mientras que los 2340 restantes se han caracterizado por presentar aportes energéticos mayores. Durante los meses de junio hasta agosto de 2012 se registraban en promedio 120 sismos por día, los cuales fueron localizados en una zona comprendida entre 0.1 y 5 km hacia el sector NE del edificio volcánico, con un rango hipocentral que oscilo entre 2 km y 6 km, y magnitudes de entre 0.1 y 2.4 ML (Figura 1). Ninguno de estos eventos fue reportado como sentido por las comunidades que habitan el área de influencia.

Este aumento en la ocurrencia de eventos y en la energía acumulada, junto con el análisis comparativo provisto por la red de inclinómetros del volcán Sotará, evidencio un posible proceso inflacionario hacia el sector noreste del edificio volcánico que alcanzó los 80 microradián, el cual coincidió con la zona epicentral de la sismicidad, lo que motivo al cambio de nivel de actividad a Nivel III el 8 de agosto de 2012 (Figura 2).

En la actualidad de acuerdo con el análisis de la información obtenida a través de las diversas estaciones que componen la red de monitoreo del volcán Sotará, este presenta un comportamiento estable. No obstante, se destaca que los niveles de actividad sísmica registrados durante el periodo evaluado, permanecen por encima de los niveles básicos históricos para este volcán. Por lo anterior el OVS-Popayán mantiene el nivel III Amarillo y continua reforzando la red de monitoreo para comprender e interpretar mejor los procesos volcánicos que se están generando.

Palabras Clave: volcán, Sotará, sismicidad, VT, inclinómetro.

Figura 1. Mapa de localización de la sismicidad VT en el volcán Sotará 2012.

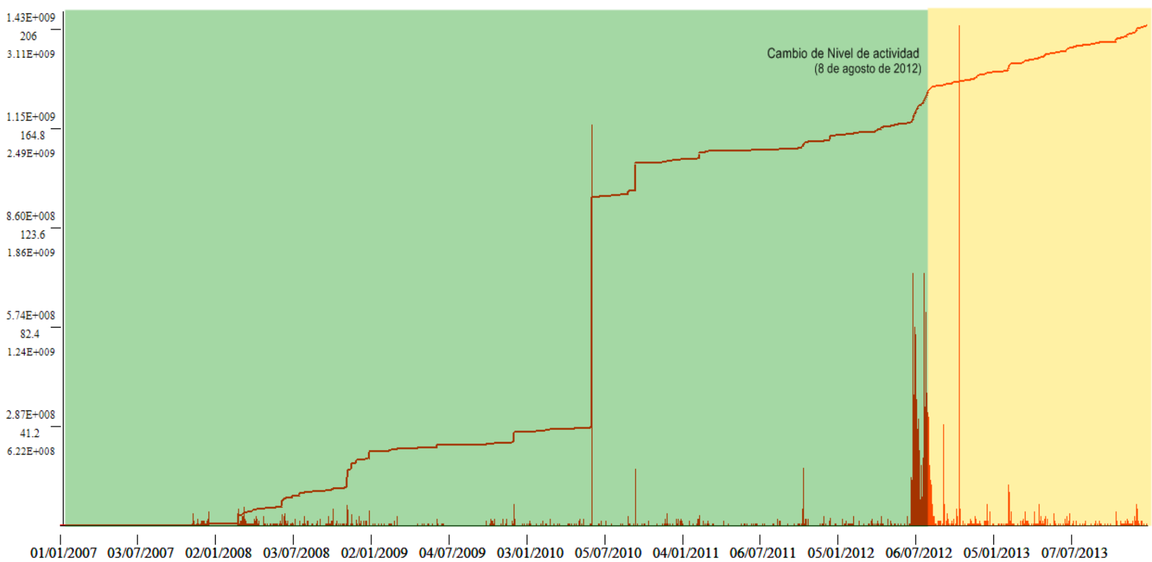

Figura 2. Numero de eventos y Energía sísmica liberada de forma acumulada por eventos VT en el volcán Sotará 2007 – 2014.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Caracterización de fuentes sísmicas de eventos tipo tornillo en el volcán Puracé mediante el análisis de frecuencias complejas

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ABSTRACT

Se realiza la caracterización de la fuente productora de sismos de largo período, conocidos como tipo "tornillo", que hacen parte de la sismicidad característica del Volcán Puracé (Colombia) y que se han asociado a tránsito y variaciones de presión de fluidos bajo el volcán. La caracterización de la fuente se logra a través de la determinación de las frecuencias complejas (f) y el valor del factor de calidad (Q) y de manera práctica mediante la implementación del método de análisis espectral conocido como Sompi, un método de análisis autoregresivo que permite modelar con precisión la coda de los sismos de largo período. Los resultados preliminares indican que durante el período 1994-2012 las frecuencias complejas están en el rango 1-15 Hz y los valores de Q se ubican entre 100-700.

Palabras Clave: Frecuencias complejas, Método Sompi, sismos tipo Tornillo, Volcán Puracé.

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Aplicación del Método Sompi en la evaluación temporal de las propiedades características de sismos tipo tornillo en el Volcán Galeras

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ABSTRACT

En este trabajo se realizó una evaluación temporal de las propiedades características de la fuente que origina los eventos tipo Tornillo (TO) en etapas pre-eruptivas y no pre-eruptivas del Volcán Galeras (VG). Se utilizó el método de análisis espectral Sompi que se basa en una ecuación autorregresiva homogénea y usa espectros en el espacio de la frecuencia compleja para proveer las características del decaimiento y los periodos de oscilación de una señal, brindando una estimación espectral de gran resolución y confiabilidad (Figura 1). El método se aplicó a los eventos tipo TO del registro sísmico histórico del VG y se realizó un análisis de los resultados teniendo en cuenta valores de frecuencia y del factor de calidad Q dado por: $Q = Q_r^{-1} + Q_i^{-1}$ (Aki, 1984) donde Q_r representa el factor de calidad por radiación de energía y Q_i es el Q intrínseco del fluido. Para realizar este análisis los sismos TO fueron clasificados en dos grupos, aquellos registrados en etapas previas a erupciones y aquellos en las que el periodo de registro de tornillos no terminó con erupción. Los resultados mostraron diferencias significativas en ambos grupos. Se encontró promedios más bajos de Q para etapas pre-eruptivas que para etapas no pre-eruptivas, por otro lado en ambos casos se encontró descensos en la frecuencia a medida que el periodo se acerca a la erupción (Figura 2). Las variaciones temporales son el resultado de los cambios en la fracción de gas de la mezcla y aunque este cambio se ve como una constante en la gran mayoría de etapas pre-eruptivas, no es el único que determina si el periodo culmina o no en erupción. Se pudo relacionar valores de Q asociados a periodos en los que predomina la mezcla de gas y ceniza y otros en los que domina la componente hidrotermal.

Palabras Clave: Método Sompi, sismos tipo tornillo, Volcán Galeras.

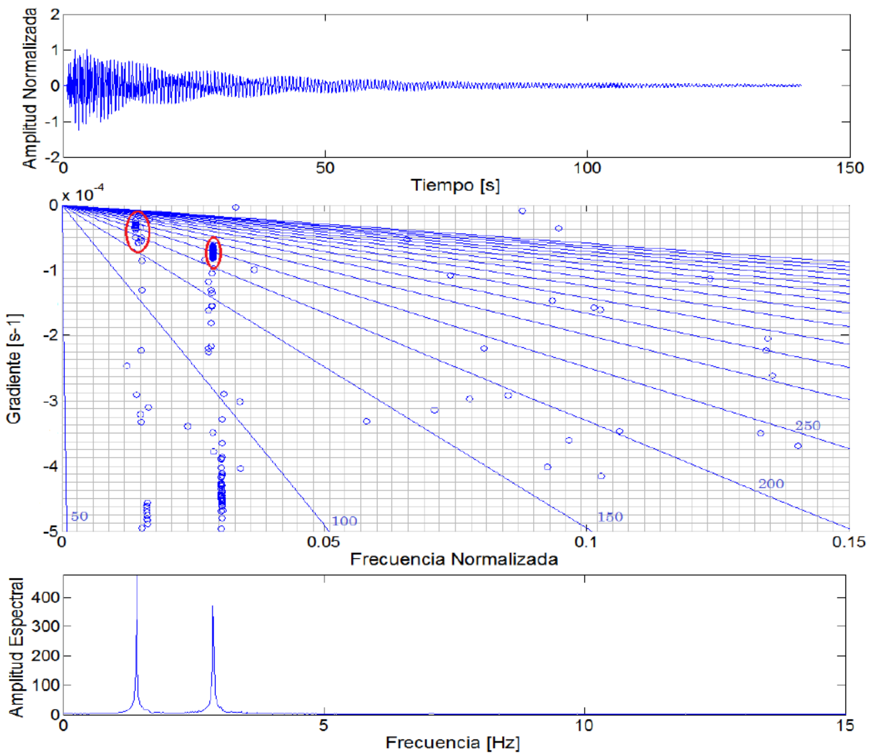

Figura 1. Aplicación del método Sompi, al evento TO registrado el 20 de abril 2005. Traza (arriba), diagrama f-g, las líneas diagonales indican los valores de Q (centro) y espectro (abajo). Obsérvese para este caso la presencia de dos armónicos en su espectro.

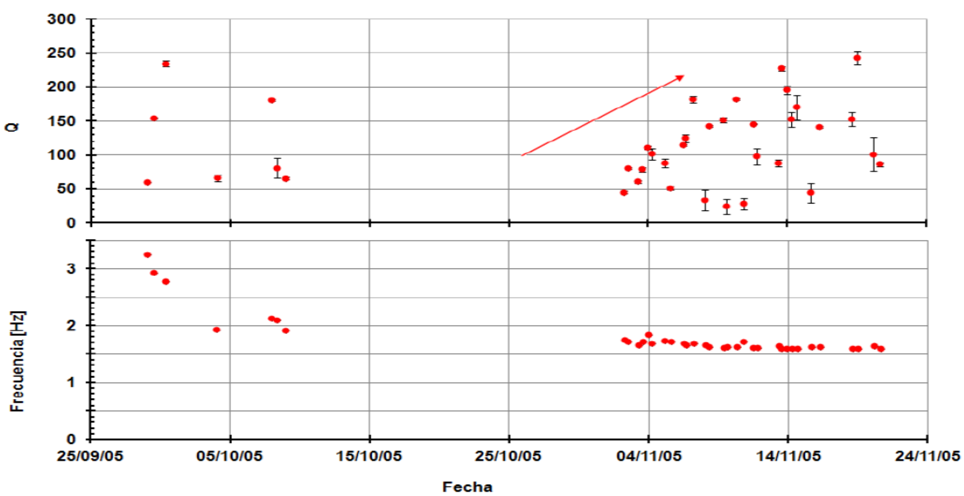

Figura 2. Tendencias de f y Q para el periodo pre-eruptivo entre el 28/09/05 y el 24/11/05.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Sismicidad volcano-tectónica en el Volcán Puracé

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ABSTRACT

El volcán Puracé es un estratovolcán ubicado en el departamento del Cauca, a una distancia de 26 km al SE de la ciudad de Popayán y hace parte de la cadena volcánica de los Coconucos, compuesta por 15 centros eruptivos alineados con una orientación N40°W, siendo el Puracé el más joven y septentrional de la cadena. La actividad del volcán ha sido reportada desde 1801 y su registro histórico más reciente muestra que dicha actividad es predominantemente explosiva. Desde 1827 se han registrado 15 erupciones históricas bien documentadas, que causaron daños materiales y pérdida de vidas; siendo la última en marzo de 1977 (*Monsalve M. y Pulgarín B. 1993)*. El monitoreo sísmico en el Volcán Puracé comenzó en 1986 con la instalación de una estación por parte del Observatorio Sismológico del Sur Occidente, posteriormente en 1990, la señal es registrada en las instalaciones del OVSPo, quien en 1993 instaló las primeras dos estaciones propias. En la actualidad el volcán Puracé cuenta con una red de vigilancia con 10 estaciones sismológicas en su gran mayoría de Banda Ancha.

La sismicidad en el Volcán Puracé se distingue entre sismicidad debido al transporte de fluidos: Largo Periodo (LP), Tornillo (TO), Tremor (TR); sismicidad por fracturamiento de roca: Volcano Tectónica (VT) y sismicidad Híbrida (HB), según los criterios de Lahr et al (1994). La actividad sísmica que predomina en el volcán Puracé corresponde a eventos Tipo LP. Sin embargo, se han registrado un gran número de eventos de fracturamiento de roca alcanzando magnitudes hasta de 4.8 en la escala de Richter. En este trabajo se presenta una recopilación de la sismicidad tipo VT en el Volcán Puracé, identificando cuatro fuentes sismogénicas a partir de registros sísmicos analizados en el Observatorio Vulcanológico y Sismológico de Popayán (OVSPo) (*Rodriguez, F. 2012 & Cardona, E. 2000*). Las cuatro fuentes sismogénicas mencionadas son: la fuente circundante al cono activo del volcán (cráter central), la fuente localizada en el sector denominado la Mina a unos 5 km al NW del cráter central, la fuente localizada en el valle de San Rafael en un área ubicada a 12 km en dirección NE de la cima del volcán Puracé y la fuente activa del valle de Paletará localizada a 15 km al SW del edificio volcánico. En esta última fuente, se presentó el sismo de mayor magnitud registrado a la fecha.

A partir de la actividad sísmica registrada tipo VT, se han realizado trabajos de investigación al interior del Grupo de Sismología para la determinación de las características físicas del medio en términos de atenuaciones, velocidades y estructuras internas del edificio volcánico. El trabajo de investigación más reciente realizado en el volcán Puracé es la determinación de anomalías de gas radón asociadas con actividad volcano-tectónica.

Palabras Clave: volcán, Puracé, volcano-tectónica, fuente sismogénica, gas radón.

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Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

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Seismic forecasting of eruptions at dormant stratovolcanoes

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ABSTRACT

From 1900-1985, the fatality rate for volcanic eruptions averaged 820/yr. However since the disastrous 1985 Nevado del Ruiz eruption, the rate has dropped to 35/yr, a dramatic 95% improvement owing primarily to improve seismic monitoring and analysis. The seismic data provide important constraints on magmatic ascent and eruption. Precursory trends include deep (e.g., >20 km) low-frequency (LF) seismicity as magma rises from the base of the crust, distal volcano-tectonic (dVT) earthquakes as rising magma pressurizes aquifers unlocking adjacent faults, shallow proximal VT (pVT) and shallow LF seismicity as magma interacts with the shallow hydrothermal system and finally, hybrid seismicity. Recent petrologic studies implicate magma mixing from deep basalt as trigger for most to all explosive eruptions. Deep LF seismicity, though difficult to record owing to small magnitudes and great depth, correlates well with deep magma movement and appears to be a good early indicator of explosivity. dVT seismicity is a much more easily and widely recorded early precursor to eruptions. A survey of >100 eruptions at 80 volcanoes, including all explosive eruptions of VEI >4 since 1950, shows that virtually all volcanoes which haven't erupted for >25 years are preceded days to months or more by major dVT seismicity. This seismicity, though induced by magmatic intrusion, originates on tectonic faults a few to >30 km from the eventual eruption vent, not beneath the vent itself. Most importantly, the cumulative dVT energy correlates well with the volume of intruded magma. As magma intrudes to shallower depths, interaction with the hydrothermal system produces pVT and shallow LF seismicity. As magma continues to rise, gases eventually escape to the surface producing additional pVT events, greatly increased shallow LF events and LF tremor, and phreatic explosions while the dVT seismicity dies off. As magma rises to 1-2 km beneath the surface, LF and hybrid seismicity dominate the record, often increasing dramatically. These observations support a simple model with basaltic magmas from the base of the crust feeding a silicic magma mush-filled reservoir at ~5 to >15 km depth which connects to the surface during eruptions through narrow conduits. The seismic energy release rate, deformation, and gas emissions are correlated and controlled by magma ascent and degassing rates. If ascent rate is fast, more gas is retained, pressure increases, resulting in very explosive eruptions; if slow, degassing and crystallization may "freeze" the magma in place without erupting.

KeyWords: eruption forecasting, volcano-tectonic, hybrid, tremor low frequency, prediction, seismicity.

EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol 18 Special Issue (July, 2014)

UNIVERSIDAD NACIONAL DE COLOMBIA
SEDE BOGOTÁ
FACULTAD DE CIENCIAS
DEPARTAMENTO DE GEOCIENCIAS
RESEARCH GROUP IN GEOPHYSICS

Sismicidad Frontera Colombia-Ecuador en la región volcanes Chiles y Cerro Negro

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ABSTRACT

Los volcanes Chiles (4748 m) y Cerro Negro (4470 m) se ubican en la frontera Colombia-Ecuador, en el Departamento de Nariño y la Provincia del Carchi. Estos volcanes son considerados como activos y son monitoreados conjuntamente por el Servicio Geológico Colombiano y el Instituto Geofísico de la Escuela Politécnica Nacional del Ecuador.

En la región de estos volcanes, entre mediados de agosto hasta octubre de 2013, se evidenció un incremento en la sismicidad en ocurrencia y energía liberada con registros y reportes de sismos sentidos por las comunidades vecinas. Similarmente, a partir de marzo hasta mayo de 2014 se tuvo otro incremento en la sismicidad, registrándose el sismo con mayor ML (4.8 en la escala de Richter) el 30 de abril de 2014. De acuerdo con la evolución temporal de la energía sísmica liberada por estos sismos, la secuencia corresponde a enjambres, los cuales se caracterizan por no seguir un patrón de un sismo principal de mayor magnitud secundado por sus correspondientes réplicas de menores magnitudes, sino que obedece a la ocurrencia de varios sismos en un área específica limitada con magnitudes relativamente similares. La reactivación de esta sismicidad parece remontarse a septiembre de 2012.

El número de sismos registrados de la zona es inusualmente alto, contabilizándose más de 85000 eventos desde noviembre de 2013, alcanzando valores diarios de hasta 2000 sismos por día (Fig. 1). La mayoría de los eventos son de baja energía con magnitudes inferiores a 3 y solo 47 sismos tienen magnitudes entre 3 y 4.8, con un reporte de 81 eventos sentidos por los habitantes del resguardo indígena de Chiles. Se ha observado un escalonamiento ascendente en la ocurrencia y la energía en el tiempo, con periodos más intensos en abril de 2013, agosto-octubre de 2013 y marzo-mayo de 2014.

La mayoría de los sismos se caracterizan por arribos impulsivos de ondas P y S, con energía distribuida en una amplia banda de frecuencias y predominio de altas frecuencias (> 5 Hz) y un decaimiento rápido de la envolvente de las formas de onda que es característico sismos VT. Estos sismos se asocian con procesos puramente elásticos resultantes de fracturas de tensión o cizalla en el medio sólido de la estructura volcánica debido a deformación del medio como propagación de un cambio de volumen por presiones inducidas por el magma. Con el sismo del 30 de abril, se identificó una componente de muy baja frecuencia que se asocia con entornos de aberturas por tensión y que podría evidenciar una intrusión de magma a través de un dique. Esta sismicidad está concentrada espacialmente y distal de los posibles centros eruptivos. Los epicentros de los sismos se localizan preferentemente en el flanco sur y suroccidente del volcán Chiles a distancias entre 0.5 y 6 km, con profundidades entre 1.5 y 6 km respecto a la cima del Chiles (Fig. 2).

El análisis de esta sismicidad, sugiere posibles intrusiones de magma o ascenso de fluidos magmáticos que están afectando el campo de esfuerzos en la base de la zona frágil de la región volcánica del Chiles-Cerro Negro y produce el fracturamiento de fallas pre-esforzadas en vecindades a estos volcanes, aunque aún no es posible atribuir a cuál centro volcánico está asociada.

Palabras Clave: Volcán Chiles, Volcán Cerro Negro.

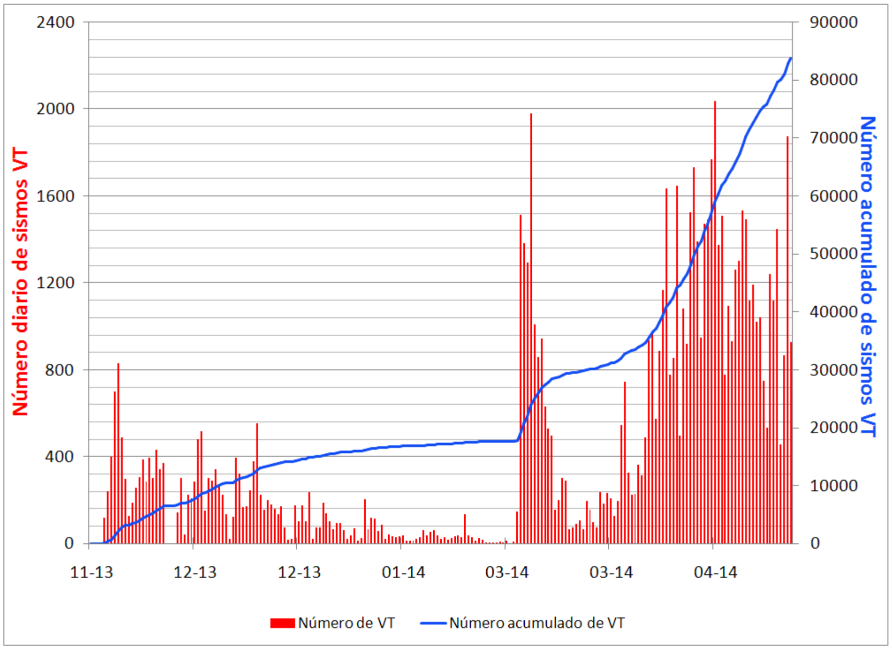

Figura 1. Histograma de ocurrencia diaria de sismos VT entre nov-5 de 2013 a may-21 de 2014.

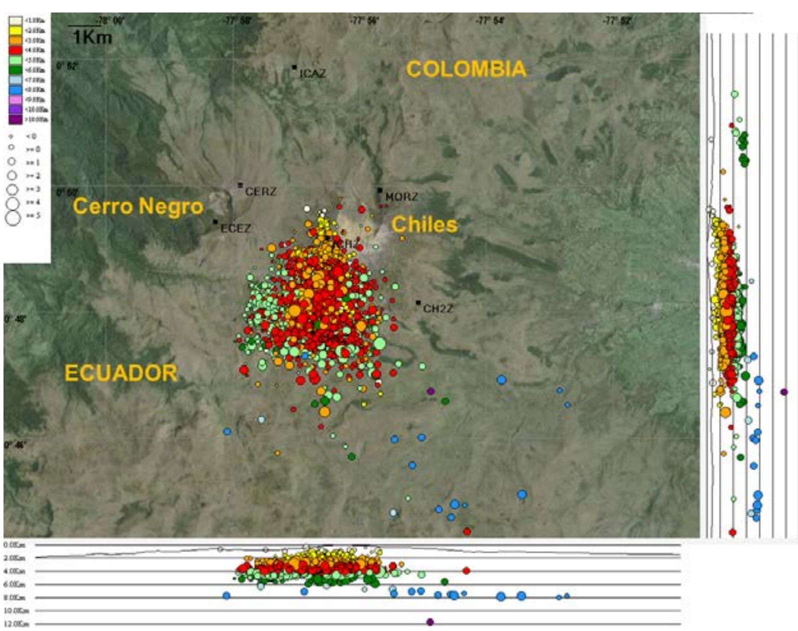

Figura 2. Localización de las fuentes de los sismos VT entre nov-5 de 2013 a may-21 de 2014. El tamaño de la circunferencia se corresponde con la ML del sismo y el color con la profundidad. Los cuadrados negros muestran la localización de las estaciones sísmicas.

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RESEARCH JOURNAL

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Un modelo geofísico de la estructura interna del Volcán Galeras, Colombia

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ABSTRACT

Se plantea un modelo geofísico tridimensional de estructura interna para el volcán Galeras a partir de la integración de información de una tomografía sísmica local pasiva de velocidades de la onda P, con sismos Volcano-Tectónicos (VT) registrados entre 1989 y 2009 y la interpretación de anomalías gravimétricas y magnéticas evaluadas a partir del levantamiento de información entre junio de 2008 y abril de 2009, con un área de cubrimiento aproximada de 1200 km^2.

El modelo de velocidades de onda P a partir de los resultados de la tomografía sísmica con un alcance en profundidad de 8 km bajo la cima y la ausencia de focos sísmicos de eventos VT, muestran dos zonas de bajas velocidades al NW y SE, donde no existe la suficiente fragilidad para generar fracturas. En estas zonas, los bajos gravimétricos observados a partir de la componente residual de la anomalía gravimétrica confirman el predominio de bajas densidades (Figura 1), y a partir de la anomalía magnética se tiene un estimativo una profundidad de 6 km para la isoterma de Curie. Estas zonas sugieren la existencia de anomalías térmicas, que posiblemente asocian con sistemas hidrotermales o remanentes de magma no solidificados.

Por otra parte, la tomografía sísmica muestra también dos zonas con altos valores de velocidades de la onda P, una bajo el cráter y otra al NE bajo los trazos superficiales de las fallas Buesaco y Silvia-Pijao. En la zona al NE donde se tiene un alto gravimétrico y donde se observa también una concentración de hipocentros de sismos VT con las mayores magnitudes, exhibe velocidades concordantes con valores medidos en magmas andesíticos solidificados o con cuerpos metamórficos rígidos (Figura 2). En la zona bajo el cráter, el modelo gravimétrico 3D, sugiere la existencia de una estructura vertical que se perfila a manera de conducto ramificado o de grietas hacia la superficie; el modelo 3D de tomografía sísmica muestra una fuerte alineación de hipocentros de sismos VT hasta unos 4 km de profundidad que podría corresponderse con una estructura estimada a partir del modelo magnético 2D donde se devela un posible dique que se extiende hasta una profundidad ~ 5 km. Esta zona sugiere un sistema por el asciende magma desde niveles más profundos hacia la superficie.

Palabras Clave: Tomografía sísmica, anomalías gravimétricas, anomalías magnéticas, modelo estructural.

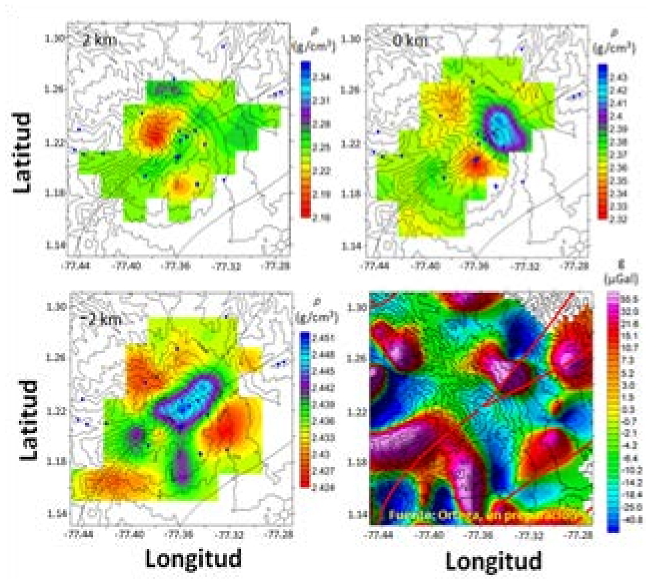

Figura 1. Con base en las relaciones empíricas de Nafe-Drake (1963) se estiman valores de densidad a partir de los valores de Vp. Si se considera el apilamiento de tomogramas de densidades y se comparan con el mapa de la componente residual de la anomalía gravimétrica, se encuentran zonas muy comparables entre la densidad y la anomalía gravimétrica.

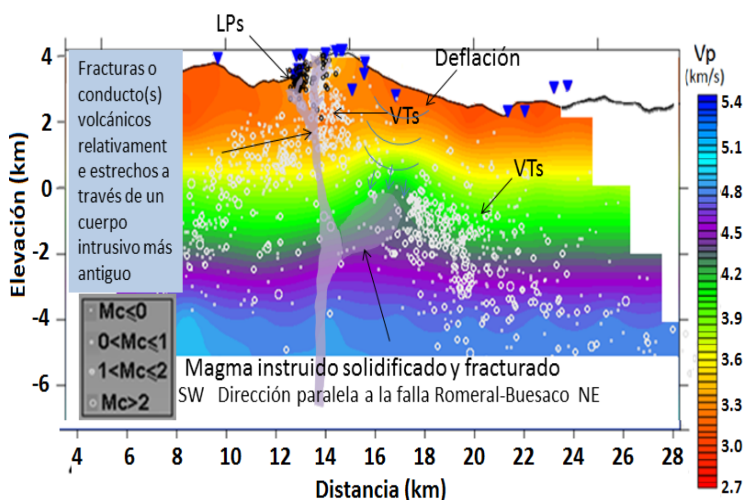

Figura 2. Modelo conceptual 3D del volcán Galeras, utilizando tomogramas de velocidades. Los puntos en negro representan los eventos asociados con el movimiento de fluidos, los puntos blancos los hipocentros de los eventos VT. En gris se presenta el posible conducto de ascenso.