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KARST GEOMORPHOSITES OF MONTE ALBO (NORTH-EAST SARDINIA)

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ABSTRACT: J. De Waele *et al.*, *Karst Geomorphosites of Monte Albo (north-east Sardinia)*. (IT ISSN 0394-3356, 2005).
In this paper the Authors present the results of a study performed on the geomorphosites of the Monte Albo chain (North-East Sardinia), an important karst area elongated in a NE-SW direction for a length of 30 km and a width of 5, starting from 50 m a.s.l. and reaching altitudes of more than 1100 m. This relief consists of Middle Jurassic-Lower Cretaceous sometimes intensely karstified dolostones and limestones covering with an unconformity a metamorphic Palaeozoic basement.
Although the geomorphosites of Monte Albo are not so impressive as in other Sardinian karst areas it seems noteworthy presenting them in the framework of this spectacular landscape unit that, in its whole, represents an area of great geomorphological interest.
Among the described geomorphosites many places with didactic surficial karst phenomena (Karren fields of Monte Turuddò, suspended valley of Janna Nurai, Solution flutes and kamenitza of Punta Catirina, macro-dolines of Campu 'e Susu, Sas Puntas and Altudè, ruin-like landforms of Nuraghe Litu Ertiches, canyon of Riu Siccu), the structural geosite of Punta Azza Ruja, the overthrusts and the conglomerates of Cuile su Ramasinu, the vertical cliffs of N-Monte Albo, the geological landscape of Punta Cupetti and the landslide of Punta Ervare 'e Chervos and two places of hydrogeological interest can be mentioned (Sinkhole of Bonaettè and karst spring of Fruncu 'e Oche). Furthermore many subterranean places are enclosed, two vertical karst shafts (Tumba 'e Nudorra and Tumba 'e Nurai), several horizontal caves (Sa Conca 'e Crapa, Omines Agrestes, Locoli, Su Santuariu, Cane Gortoé) and a natural tunnel (Listincu).
All these geomorphosites should be connected in a local network inserted in the Monte Albo landscape unit, already part of the Geomining, Historical and Environmental Park of Sardinia (Area 6), through the realisation of equipped pathways and the elaboration of explicative maps and panels and a website in which geology, geomorphology, karst, fauna, flora, archaeology and industrial archaeology are described. The explanation of the chain's genesis, its evolution, its geodiversity and the single elements it contains can help the visitors in understanding the importance of geology and geomorphology on landscape evolution, flora and human activities, that combine in an educational model of great suggestion and efficiency.
This proposal of valorisation of these landscape units and their geomorphosites could well be connected to other areas of the region, and the Authors hope that the local and regional stakeholders will commit themselves in the valorisation of their territory, giving an important service to the many tourists that come and visit the Monte Albo.

RIASSUNTO: J. De Waele et al.*,* Geomorfositi carsici del Monte Albo (Sardegna nord-orientale)*. (IT ISSN 0394-3356, 2005).*
In questo lavoro gli Autori presentano i risultati di una ricerca effettuata sui geomorfositi della catena del Monte Albo (Sardegna nordorientale), un'importante area carsica allungata in direzione NE-SW per una lunghezza di 30 km ed una larghezza di 5, con quote che variano dai 50 m s.l.m. della piana fino ad oltre 1100 sulle cime più alte. La catena è costituita da dolomie e calcari di età Giurassico medio-Cretaceo inferiore, più o meno carsificati, che poggiano in discordanza sul basamento paleozoico metamorfico.
Anche se i singoli geomorfositi del Monte Albo non raggiungono l'importanza di quelli riscontrati in altre aree carsiche sarde, tuttavia essi caratterizzano questa spettacolare unità di paesaggio e ne fanno un'area di grande interesse geomorfologico.
Tra i geomorfositi scelti riportiamo molte morfologie carsiche di elevato interesse didattico e turistico-culturale (campi careggiati di Monte Turuddò, la valle sospesa di Janna Nurai, le scannellature e le vaschette di corrosione di Punta Catirina, le macrodoline di Campu 'e Susu, di Sas Puntas e di Altudè, le città di roccia di Nuraghe Litu Ertiches, la gola di Riu Siccu), i geositi strutturali di Punta Azza Ruja, di Cuile Su Ramasinu e del versante Nord della catena, il paesaggio geologico di Punta Cupetti, la frana di ribaltamento di Punta Ervare 'e Chervos e due luoghi di interesse idrogeologico (inghiottitoio di Bonaettè e sorgente carsica di Fruncu 'e Oche). Inoltre, molte sono le grotte incluse nell'elenco, tra cui due voragini (Tumba 'e Nurai e Tumba 'e Nudorra), molte grotte suborizzontali (Sa Conca 'e Crapa, Omines Agrestes, Locoli, Su Santuariu, Cane Gortoé) ed un traforo naturale (Listincu).
Tutti questi geomorfositi potrebbero essere collegati in una rete locale all'interno dell'unità di paesaggio del Monte Albo e facente parte del Parco Geominerario, Storico ed Ambientale della Sardegna (Area 6), mediante la realizzazione di sentieri attrezzati, l'elaborazione di carte tematiche e pannelli informativi e la creazione di un sito web con l'illustrazione degli aspetti più significativi del paesaggio naturale ed umano. L'illustrazione del paesaggio e della sua evoluzione, della sua geodiversità e dei caratteri dei singoli geomorfositi che esso contiene può aiutare il visitatore a comprendere l'importanza della geologia e della geomorfologia per l'evoluzione del paesaggio e delle molteplici attività antropiche che vi si svolgono, creando un modello educazionale di grande suggestione ed efficienza.
Questa proposta di valorizzazione dell'unità di paesaggio e dei geomorfositi in essa contenuti potrebbe essere estesa anche ad altre aree della regione. Gli Autori auspicano che gli amministratori locali e regionali elaborino proposte di valorizzazione di questo territorio caratterizzato da molteplici valenze, dando un importante servizio non solo ai molti turisti che visitano il Monte Albo ma anche alla popolazione locale.

Keywords: Jurassic limestones, Karst, Geomorphosites, Monte Albo, Sardinia.

Parole chiave: Calcari giurassici, Carsismo, Geomorfositi, Monte Albo, Sardegna.

1. INTRODUCTION

The study of geomorfosites in karst areas has already brought our research team in many parts of the Island; the Gulf of Orosei (Barca *et al*., 1995), the Iglesiente-Sulcis area (De Waele *et al*., 1998), the Tacchi area (Ardau & De Waele, 1999; De Waele *et al*., 2004). Furthermore the twenty most important karstic geosites of the Island have already been described (De Waele et al., 1999) and at the moment one of us (De Waele) is working on the inventory of natural hypogean geosites in the framework of a national research program performed together with the National Geological Survey (Piccini *et al*., 2004).

In the framework of the National Project COFIN 2001-2003 "Geomorphosites in the Italian Landscape" our research team has continued these researches, and in this paper the results of a study on Monte Albo are presented.

2. GEOLOGY

Monte Albo is a karst area located in north-east Sardinia, elongated from NE to SW for a length of 30 km and a width of 5 and reaching altitudes of more than 1100 m a.s.l..

The outcropping rocks can roughly be subdivided in a Palaeozoic mainly metamorphic basement and Mesozoic sedimentary sequences (Fig.1).

The characteristics of the Palaeozoic rocks are related to the tectonic and metamorphic events of the Hercynian orogeny (Carboniferous-Permian). In the south-eastern part of Monte Albo the basement is characterised by Hercynian granites of Permian age, while to the north the outcropping rocks are more or less metamorphic. Petrographical and mineralogical studies have allowed to distinguish two important crystallisation episodes (Franceschelli *et al.*, 1982; Elter & Sarria, 1989) and four complexes of different metamorphic degree. The outcropping metamorphic rocks are, roughly from south to north, constituted of metasandstones, phyllites, micaschists, paragneiss, granodioritic orthogneiss and bird's eye gneiss.

After a long-during continental period, estimated from Permian to Lower Jurassic, the sea started occupying the hilly Hercynian peneplain during Bajocian-Bathonian. The Jurassic-Lower Cretaceous ocean never reached great depths in the Monte Albo area, and the different carbonate facies evidence several shallow depositional environments, going from lagoons to coral reefs. This sedimentary sequence starts with dolostones containing limestone lenses, oolithic limestones and massive fossil-rich outer-shelf, reef, interreef and backreef limestones.

The Jurassic transgression starts with clastic sediments of the Genna Selole Formation, represented by quartz conglomerates and sandstones with plant fossils typical of a fluvial or delta environment influenced by tidal movements (Amadesi *et al*., 1961; Fazzini *et al.*, 1974; Dieni *et al*., 1983). Traces of this transgressional facies can be found at Punta Casteddu (south Monte Albo) (Dieni & Massari, 1971). Upwards this facies becomes marly, typical of a littoral depositional environment, and the alternation of marl and dolostone beds preludes the Dorgali Formation dolostones (Amadesi *et al*., 1961; Calvino *et al*., 1972; Dieni & Massari, 1985; 1987). These dolostones are sandy in the basal levels becoming pure brownish dolostones in the upper beds and locally contain Brachiopods, Echinoids, Ammonites, Belemnites and Foraminifers of Bathonian-Kimmeridgian. At Monte Albo this Formation reaches a thickness of at least 300 meters in the western part (Lula), but reduces to only a couple of meters in the eastern extremity (Monte Gutturgios).

Upon these dolostones two heterotopic limestone Formations are reported: the s'Adde Limestones and the Monte Bardia Formation (Dieni & Massari, 1985). The first Formation is characterised by brownish microcrystalline limestones sometimes containing chert nodules, not well stratified at the bottom but extremely well bedded in the upper part. The fossil fauna (Ammonites, Belemnites, Brachiopods, Echinoids and Foraminifers) gives an age of Callovian-Kimmeridgian. The Monte Bardia Formation instead is composed of typical reef and bioclastic limestones, with frequent fossil corals (sometimes in life position) and their debris. The age of these limestones, based on Corals, Gastropods, Algae and Foraminifers is Kimmeridgian-Berriasian (Upper Jurassic-Lower Cretaceous). The uppermost part of this Formation is characterised by marly limestones sometimes with mud cracks and fauna of brackish water environments, introducing the deposition of Lower Cretaceous Purbeckian sediments after a short interruption of sedimentation (Massari, 1968). These last sediments, composed of marls and marly limestones locally rich in pyrite and organic material, have been deposited in a relatively deep and confined sea and can be found only in two tectonically disturbed areas southwest of Siniscola (Dieni *et al*., 1987). Their age has been determined on the basis of Foraminifers to Valanghinian (Dieni & Massari, 1966).

Upper Cretaceous is not present in the Monte Albo region, but the discovery of Maastrichtian pebbles in the post-Middle Eocene conglomerate of Cuccuru 'e Flores, outcropping in the central-eastern part of Monte Albo, indicates that these sediments were eroded in Late Mesozoic-Early Cretaceous times (Busulini *et al.*, 1984). The syn-tectonic continental Cuccuru 'e Flores conglomerate was deposited after Middle Eocene during a tectonic instable and continental period related to the Pyrenean and Apennine collision (Dieni & Massari, 1965).

The geological sequence of Monte Albo is completed with Pleistocene gravitational deposits, mainly represented west of Siniscola (flanks of Punta Cupetti) and Quaternary deposits (alluvium, debris, etc.).

The tectonic situation is dominated by two main transcurrent fault systems, NE-SW and E-W, associated with local transpressive and pull apart sectors caused by the continental collision between the Apulian plate and the South-European margin during Oligocene-Lower Miocene. The most important fault system in the Monte Albo area is directed NE-SW (e.g. Nuoro Fault), running parallel to the national road that connects Nuoro with Siniscola (Carmignani *et al*., 1994; Pasci, 1997). The movement of the transcurrent Nuoro fault is left-handed and is believed to be several kilometres for a vertical displacement of approximately 1000 meters and has lead, in the Monte Albo area, to impor-

tant overthrusting. Along these overthrust surfaces many outcrops of the syn-tectonic Cuccuru ‘e Flores conglomerate can been found.

From a morpho-structural point of view these tectonic movements have determined the typical landform of cuesta or hogback to the entire chain, with the more or less gently dipping back towards SE (Fig.2).

3. KARST GEOMORPHOLOGY

The Mesozoic dolostones and limestones of Monte Albo have been interested by karst processes since their early emersion (Upper Cretaceous), even though the major karst landforms can be referred to the Plio-Quaternary.

Dolostones (Dorgali Formation, Dogger) are characterised by diffuse fractures and joints and a well-defined bedding causing ruin-like landforms (*pinnacles*) and scarcely developed micro-forms (essentially solution pans or *kamenitze*). Intense fracturing and jointing leads the meteoric water immediately underground with scarce superficial runoff. Caves in dolostones usually consist of vertical shafts in which the tectonic imprint is clearly distinguishable. Limestones instead (S’Adde Limestone and Monte Bardia Formation, Dogger-Malm) are generally microcrystalline and pure carbonates that are ideal for the development of micromorphologies

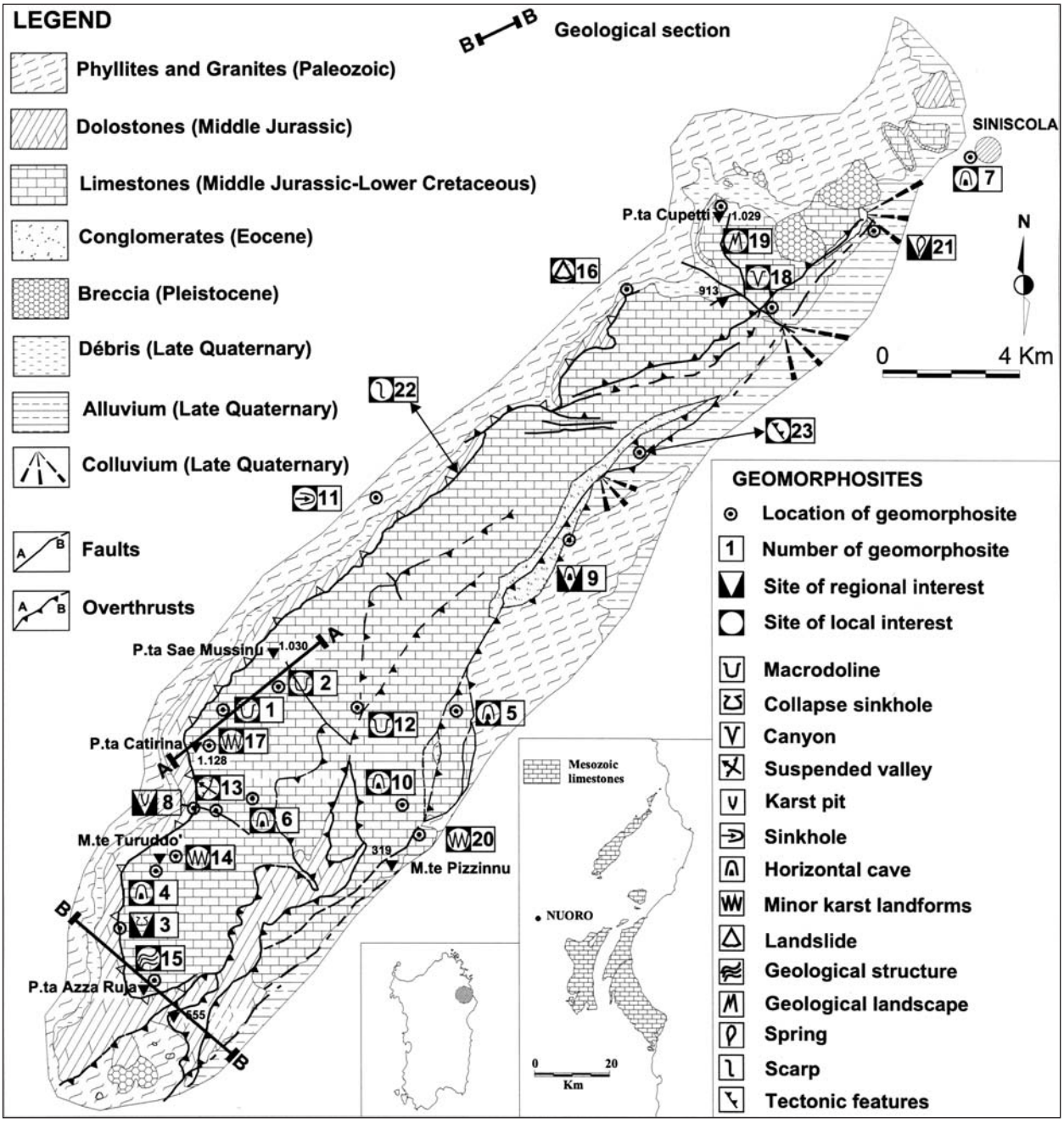

Fig. 1 – Geological sketch map of Monte Albo with the location of the geomorphosites.

Carta geologica schematica del Monte Albo con l’ubicazione dei geomorfositi.

such as *solution flutes*, *rillenkarren*, *kamenitze* etc. (Fig. 3). In these rocks interesting solution caves are also formed (e.g. Conca ‘e Crapa) characterised by phreatic rounded morphologies and well developed calcite concretions. In areas affected by important tectonics (e.g. the southwestern flank of Monte Albo) no important caves are known and landforms are very much influenced by the tectonic surfaces and subsequent differential erosion.

The North-western flank of the mountain is much more exposed to rain than the South-eastern one, also because here are located the highest altitudes (Punta Catirina and Monte Turuddò 1127 m a.s.l.). This difference is also clearly visible in the surface landforms. Karren fields are well developed especially on the southern slopes of Punta Sae Mussinu, Punta Ferulargiu and Punta Su Mutucrone. In many areas of high altitude (e.g. the flanks of Punta Catirina and Monte Turuddò) the exposed karren fields are much more rounded, being an ancient covered karst. In fact, deforesting of these areas probably goes back to the early 20th century and the covering soil has been washed away since then (Fig. 4).

A distinct feature on Monte Albo is the scarcely developed drainage pattern, meaning that seasonal runoff takes place along small river incisions generally directed towards the northwest and the southeast. Between Punta Gutturgius and Punta Cupetti the valley s’Adde cuts though the Monte Albo carbonates from NW to SE and ends with the canyon of Riu Siccu located on the vertical walls of the southern flanks. This valley has probably been inherited from a period in which the drainage on the north-western Palaeozoic basement was directed towards the SE and represents thus the initial stage of the formation of a suspended valley.

A beautiful example of this latter type is Janna Nurai, located between Monte Turuddò and Punta Catirina at an altitude of approximately 600 meters. This valley flows towards the east ending up in the macrodoline of Altudè. This large and complex depression still reflects an ancient drainage pattern with a southwest-northeast direction, finding its natural outlet in the steep Badde Viola canyon, probably of a much more recent origin.

But the most interesting karst landforms of Monte Albo are the two macrodolines of Campu ‘e Susu and Sas Puntas, located on the northeast flank of Punta Catirina, at an altitude of 950 and 900 m a.s.l. respectively (Fig. 5). These large depressions are characterised by relatively steep slopes and an almost flat floor, with considerable dimensions (average width of 500 meters and length of almost 1 km). They are probably formed on a palaeovalley, successively transformed in large depressed areas that take the form o macrodolines: their genesis is thus only partially controlled by dissolution of limestone. A small outcrop of “éboulis ordonnées” on the northern slope of Sa Puntas would represent a Pleistocene debris deposit produced by the breakdown of the valley walls.

Underground karst phenomena are not very well developed on Monte Albo, especially comparing this karst area with other neighbouring carbonate outcrops such as Supramonte or the Gulf of Orosei. The majority of caves are characterised by vertical development, mostly fracture-controlled shafts with no horizontal branches. The best example of such type of cave is Tumba ‘e Nurai, a 100 meters deep karst pit with an elliptical plant of 6x12 meters. Much more impressive is the spectacular Tumba ‘e Nudorra cave, a collapsed sinkhole of 45x30 meters width and a depth of 45 meters. This sinkhole resembles somewhat the famous

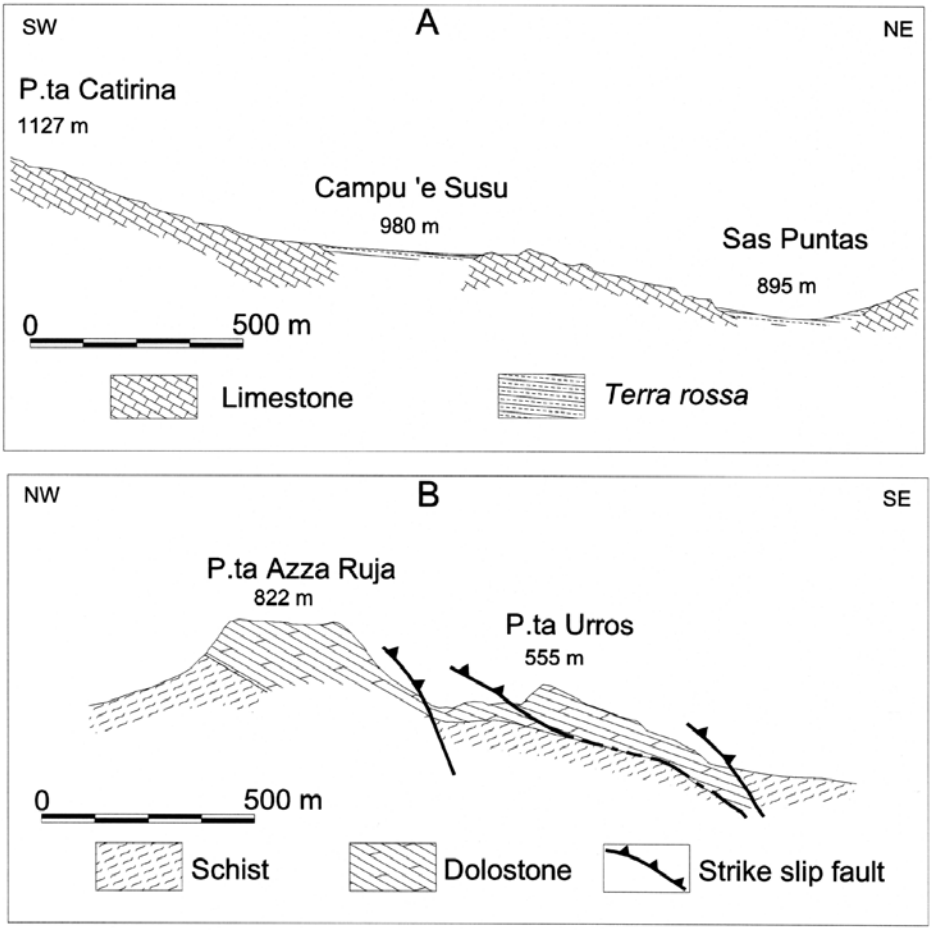

Fig. 2 – Schematic sections showing the structural and geological settings of: A) the two macrodolines Campu ‘e Susu and Sas Puntas; B) the two mountains of Punta Azza Ruja and Punta Urros. For location see Fig.1.

Sezioni schematiche che mostrano le condizioni geologico-strutturali di: A) le due macrodoline di Campu ‘e Susu e Sas Puntas; B) i due rilievi dolomitici di Punta Azza Ruja e Punta Urros. Per la localizzazione vedasi Fig. 1.

"cenotes" of Mexico, also for the presence of a luxuriant vegetation on its bottom.

The horizontal caves of Monte Albo can be subdivided in relict and active caves (Mucedda, 1991). Among the first Su Santuariu, Conca 'e Crapa, Omines Agrestes and Galleria Listincu can be mentioned. The first three are relic caves with quite well developed chambers and cave passages characterised by important *flowstones*, while the fourth is a 20 meter long fossil cave passage that crosses the Punta Listincu limestone ridge from side to side. The two active caves are Cane Gortoé and Locoli. The first is located in the village of Siniscola and is characterised by approximately 1 km of narrow horizontal cave passages occupied by two different subterranean rivers that join before emerging from the entrance. The second is located at the foot of the Monte Albo Southern flank and gives rise during heavy rainy periods to the Locoli river. This cave is characterised by impressive submerged passages for a total length of more than 1050 meters and a water depth of 80 (Perna & Murgia, 2002).

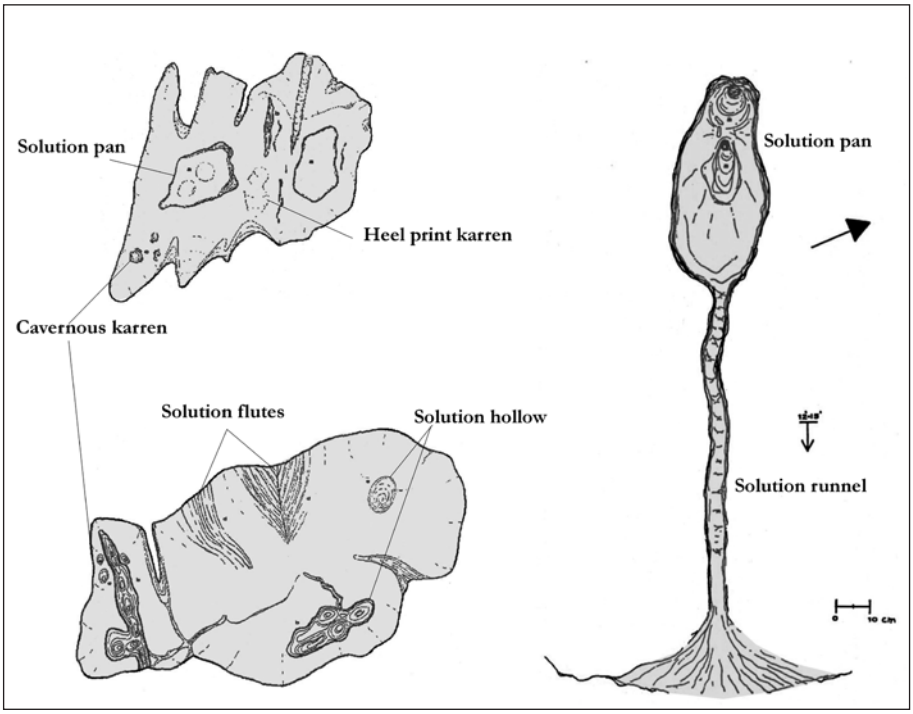

Fig. 3 – Some examples of karst microforms (Monte Turuddò and Punta Catirina).
Alcuni esempi di microforme carsiche (Monte Turuddò e Punta Catirina).

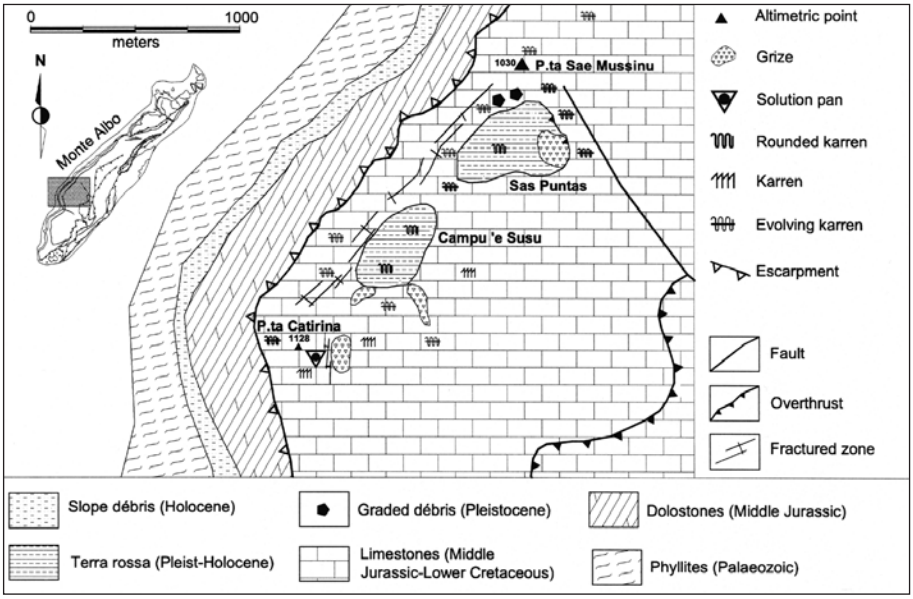

Fig. 4 – Geomorphological sketch map of the area of the two macrodolines Campu 'e Susu and Sas Puntas.
Carta geomorfologica schematica dell'area delle due macrodoline Campu 'e Susu e Sas Puntas.

4. GEOMORPHOSITES

In the framework of the National Project COFIN "Geomorphosites in the Italian Landscape" we have chosen the most interesting karst geomorphosites of Monte Albo on the basis of an exhaustive bibliographical research, on the analysis of aerial photographs and on detailed field work, inserting them in a geomorphosite database (Tab. 1). Karst morphology has previously been described by several Authors (Altara, 1964; Mucedda, 1991; Pala, 1998).

The largest karst landforms on Monte Albo are the macrodolines: three of these have been inserted in our geomorphosite database: Campu 'e Susu, Sas Puntas and Altudè. All three are located in the Southern part of the mountain, the first two northeast of Punta Catirina at an altitude of 950 and 900 m a.s.l. respectively, and Altudè two km East of these about 300 meters lower (Pala, 1998). All three have the shape of macrodolines, but are most likely genetically related to a post-tectonic Tertiary (Mio-Pliocene) palaeo-drainage system that had a general W-E direction and drained a morphological height located to the west, now mostly eroded. Especially the plain of Altudè still reflects the complex pattern of several converging rivers.

Smaller dolines are scarcely represented on Monte Albo, except for the spectacular Tumba 'e Nudorra collapse doline located right on top of the homonymous mountain. Tumba

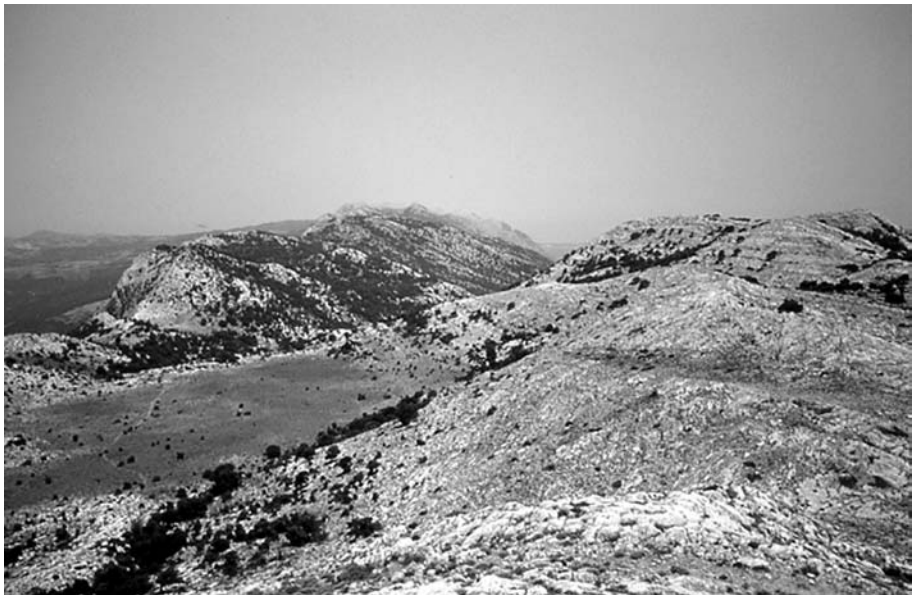

Fig. 5 – The macrodoline Campu ‘e Susu seen from Punta Catirina towards the NE. The whole hogback of Monte Albo is clearly distinguishable.

La macrodolina fotografata da Punta Catirina verso NE. L’intero hogback del Monte Albo è chiaramente visibile.

Table 1 – The main characteristics of the geomorphosites of Monte Albo.
Le principali caratteristiche dei geomorfositi del Monte Albo.

N°	Name	Commune	Altitude m a.s.l.	Morphotype	Access	Importance
1	Campu ‘e Susu	Lula	980	Macrodoline	B	L
2	Sas Puntas	Lula	895	Macrodoline	B	L
3	Tumba ‘e Nudorra	Lula	910	Collapse sinkhole	C*	R
4	Conca ‘e Crapa	Lula	1.055	Cave	B*	L
5	Su Santuariu	Lula	240	Cave	B*	L
6	Omines Agrestes	Lula	790	Cave	B*	L
7	Cane Gortoe’	Siniscola	45	Cave	A*	L
8	Tumba ‘e Nurai	Lula	670	Karst pit	B*	R
9	Locoli	Lula	70	Cave	A*	R
10	Listincu	Lula	635	Cave-tunnel	C*	L
11	Bonaette’	Lodè	550	Swallow hole	A	L
12	Altude’	Lula	575	Macrodoline	A	L
13	Janna Nurai	Lula	575	Suspended valley	B	L
14	M.Te Turuddo’	Lula	1.080	Karren field	B	L
15	P.ta Urros	Lula	475	Geological structure	B	L
16	P.ta Gurturgius	Lula	830	Palaeo-landslide	A	L
17	P.ta Catirina	Lula	1.090	Karst landforms	B	L
18	S’Adde-Riu Siccu	Siniscola	500	Canyon	C	L
19	P.ta Cupetti	Siniscola	1029	Karst landscape	B	L
20	Litu Ertiches	Lula-Irgoli	200	Ruin like landscape	A	L
21	Fruncu ‘e Oche	Siniscola	48	Karst spring	A	R
22	Albo N Flank	Lula-Lodè	500-700	Cliffs	A	L
23	Cuile Su Ramasinu	Lula	400	Tectonic features	A	L

Access: A=easy (close to roads), B=Difficult (close to equipped pathways), C=Very Difficult (far from existing pathways and roads), *Speleological; Importance: L=Local, R=Regional

'e Nudorra is a unique example of collapse sinkhole and can be classified as one of the most beautiful ones of Sardinia (Loru & Sechi, 1984).

Of different nature is the famous Tumba 'e Nurai pit, located close to the Janna Nurai pass, constituted of a 100 meter deep karst pit (Mucedda, 1983). This is the deepest pit of Monte Albo, known since a very long time also to local people who narrate fantastic stories about this hole, and it was explored for the first time by speleologist of Trieste in 1955 (Guidi, 2002).

The nearby suspended valley of Janna Nurai is the most beautiful example of Monte Albo and one of the most interesting of Sardinia. It is clearly visible from the village of Lula and constitutes one of the few natural gateways to the mountain from the west. This ancient valley reflects a palaeo-drainage system, connected to the one of the three macrodolines, that flowed towards the east where it continued in the valley of Altudè.

The only valley that can occasionally become active on Monte Albo is the S'Adde-Riu Siccu valley, that starts on the metamorphic rocks south of Punta Cupetti, directs towards the southeast and becomes a beautiful canyon before leaving the carbonate chain with a succession of vertical falls (Loru & Dore, 1994). From the southeast this valley is clearly visible and is also characterised by beautiful ruin-like landforms (*pinnacles*).

These typical ruin-like landforms are even more developed and easily accessible close to the Nuraghe Litu Ertiches where they form a labyrinth of dolomite rocks and pinnacles.

Karst micro-forms are not very well developed on Monte Albo and they are usually confined to Monte Bardia or s'Adde pure limestone facies where slopes are not too steep and vegetation (thus soil) is not too thick. Two places are of special interest and have been chosen as geomorphosites: the Monte Turuddò karren fields and the Punta Catirina micro-forms. The first is characterised by uncovered karren fields that have been developed under soil cover. Soil has probably been washed away since the early 20th Century, when intense deforestation changed the natural landscape of Monte Albo. At Punta Catirina, especially along the North-eastern slope, *rillenkarren*, *kamenitze* and *solution channels* are relatively well preserved, representing a good didactic example of small scale karst landforms. Similar in shape but located on the other extremity of the chain is Punta Cupetti from where the entire morphology of Monte Albo can easily be understood. Punta Cupetti is also characterised by the presence of rich micro-forms sculpted in the s'Adde limestones.

Many caves have been inserted in the database: Conca 'e Crapa, Su Santuariu, Omines Agrestes and Listincu caves are horizontal relics of an ancient underground and complex karst drainage system. While Omines Agrestes and Galleria Listincu are small caves (Dore *et al*., 1996), formed by karst solution along fissures, Conca 'e Crapa and Su Santuariu are much more complex and important testimonials of ancient karst processes. Conca 'e Crapa is one of the highest caves of Sardinia (1050 m a.s.l.), composed of several chambers connected by crawling passages (Dédé, 1976; Loru & Sechi, 1984), and represents a very important habitat for cave dwelling fauna (Grafitti, 1996). Su Santuariu, instead, is located almost 1000 meters lower and is characterised by the presence of massive and important concretions (Dore *et al*., 1996), probably testimonials of a much wetter and warmer climate.

At even lower altitudes, at the foot of the mountain, two active caves are classified as geomorphosites; the Cane Gortoé and the Locoli resurgences. The first, located in the centre of the village Siniscola at an altitude of 40 m a.s.l. has a development of almost 1000 meters and is very important for its cave dwelling fauna (Grafitti, 1996). Cane Gortoé contains two slowly flowing underground rivers that meet just before exiting the cave and represents the active base level of the karst acquifer of Monte Albo (Mucedda, 1991). Locoli instead has a much more impressive appearance and becomes active only after heavy rain periods. This cave, of great hydrogeological importance (Maccioni, 1976; Murgia, 1999) is located at an altitude of 100 m a.s.l. and has an important underwater development explored during the 80's by French cave divers (Le Guen, 1983; Pittalis *et al.*, 1983; Isler, 1990). The total at present explored development of this cave system reaches more than 1500 meters (Perna & Murgia, 2002).

The underground river that exits the mountain from the Locoli cave is believed to come from the Bonaettè sinkhole, located at a distance of approximately 4 km WNW at an altitude of 550 m a.s.l. (Sanna, 1990). This sinkhole, although not very beautiful and active only after heavy rains, is nevertheless one of the most didactic ones of the Monte Albo chain, and for its hydrogeological importance this swallow hole deserves its classification as geomorphosite.

The current main outflow from the Monte Albo aquifer is located close to Siniscola, near the San Giuseppe chapel, and has been known since a long time as the San Giuseppe or Fruncu 'e Oche spring. This karst spring, with a mean discharge of 80 l/s, is developed on important fault systems at an altitude of 48 m a.s.l. (Perna & Murgia, 2002).

To explain further geological interest of Monte Albo four non-karstic geomorphosites have been chosen: the geological and tectonic features of Punta Azza Ruja, the Punta Gutturgius palaeo-landslides, the Cuile su Ramasinu overthrust with outcrops of the Cuccuru 'e Flores conglomerates and the impressive vertical cliffs of the north-western side of the Monte Albo chain. At Punta Azza Ruja, in the southern part of the carbonate chain, a thick succession of basal dolomite beds dipping southeast clearly shows overthrusting and faulting, while at the foot of Punta Gutturgius Early-Quaternary landslides have determined unusual landforms with impressive isolated dolomite blocks. Near Cuile Su Ramasinu, instead, overthrusting has enabled the preservation of the Eocene Cuccuru 'e Flores conglomerate, important testimony of the Cretaceous erosion period.

5. CONCLUSIONS

Monte Albo is an important landscape unit that constitutes a characteristic landmark in the north-eastern part of Sardinia. Landforms are mainly related to karst processes and subordinately to tectonic features. The twenty-three geomorphosites described in this paper represent most of the morphological processes

that this mountain went through in the past millions of years. The connection of these geomorphosites in a local network, comprising the realisation of equipped pathways and the elaboration of explicative maps and panels and a website in which geology, geomorphology, karst, fauna, flora, archaeology and industrial archaeology are described, would be an interesting alternative to the conventional tourist offer of this region based on beaches and one-day trips to single tourist sites (nuraghi, show caves etc.). In fact, the explanation of the landscape, its evolution, its geodiversity and the single elements it contains can help the visitors in understanding the importance of geology and geomorphology on landscape evolution, biology and human activities, that combine in an educational model of great suggestion and efficiency.

This valorisation fits also well in the framework of the Geomining, Historical and Environmental Park of Sardinia of which the Monte Albo landscape unit, comprising the two abandoned mines of Guzzurra and Sos Enattos, is part (Area number 6). Furthermore, the evaluation of the geological and geomorphological heritage of Monte Albo enriches the classification of the area on a pure biological basis (Cassola & Tassi, 1973) and as a Site of Comunitary Interest (Directive Habitat 92/43, SIC ITB001107).

This proposal of valorisation of these landscapes and geomorphosites could well be connected to other areas of the region, and the Authors hope that the local and regional stakeholders will participate in the valorisation of their territory, giving an important service to the many tourists that come and visit the Monte Albo

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