

The Seismicity of Iran

The Silakhor (Lurestan) earthquake of 23rd January 1909

N. AMBRASEYS (*) - A. MOINFAR (**)

Received on September 7th, 1973

SUMMARY. — The Silakhor earthquake of the 23rd January 1909 is one of the largest earthquakes of this century in Iran. It devastated a sparsely populated area of at least 3 to 4000 square kilometres in the Zagros mountains in which more than 5000 people were killed in 130 villages. The earthquake, which was associated with at least 40 kilometres of faulting, was felt over an area of about half a million square kilometres, mainly to the north and northwest of the meizoseismal area. Aftershocks continued for almost six months.

RIASSUNTO. — Il terremoto di Silakhor del 23 Gennaio 1909, è stato uno dei più forti avvenuti in Iran in questo secolo. L'area devastata, scarsamente popolata, nei monti Zagros fu almeno di 3 o 4000 km² e in 130 villaggi vi furono più di 5000 morti. Il terremoto, associato ad una faglia di 40 km, è stato sentito in un'area di circa 500.000 km², specialmente a nord e a nord-ovest dell'area meizosismica. Si ebbero repliche per più di sei mesi.

INTRODUCTION

The Silakhor earthquake of the 23rd of January 1909 is one of the very little known, large earthquakes of this century in Iran which killed more than 5000 people in 130 villages, and devastated an area of at least 3000 square kilometres in the highlands of central Zagros, Figure 1. The earthquake, which was associated with at least 40 kilo-

(*) Imperial College of Science & Technology, London.

(**) Plan and Budget Organisation, Tehran.

metres of fresh faulting, occurred at a time when the country, particularly its northwest provinces, was in a state of anarchy and disorder. The Persian revolution had begun in 1906 but it was early in 1909, after the Nationalists failed to persuade Muhammad Ali Shah to convene a National Assembly and restore the Constitution, that disorder and violence spread throughout the country.



Fig. 1 — Location map of the Silakhor earthquake of 23rd January 1909. Note that the earthquake was felt in Baghdad, Harput, Borjoni, Tbilisi and Zurnabad.

A few weeks prior to the earthquake, on the 5th of December, Bakhtiyari forces occupied Isfahan and expelling the Shah's representative, declared for the Constitution. Isfahan's example was followed soon by Hamadan and by other towns and a few weeks after the earthquake, Silakhor, a comparatively remote and isolated district in Bakhtiyari country (Figure 2) was found to be surrounded by Nationalist centres which, as far as the difficulties of communication allowed, were in contact with each other and controlled by local provisional governments. In contrast, and inspite of the telegraph line between Burujird and the capital, contact of Tehran with those decreasing areas in western Iran including Silakhor, in which the Shah's authority was maintained, was very poor and irregular.

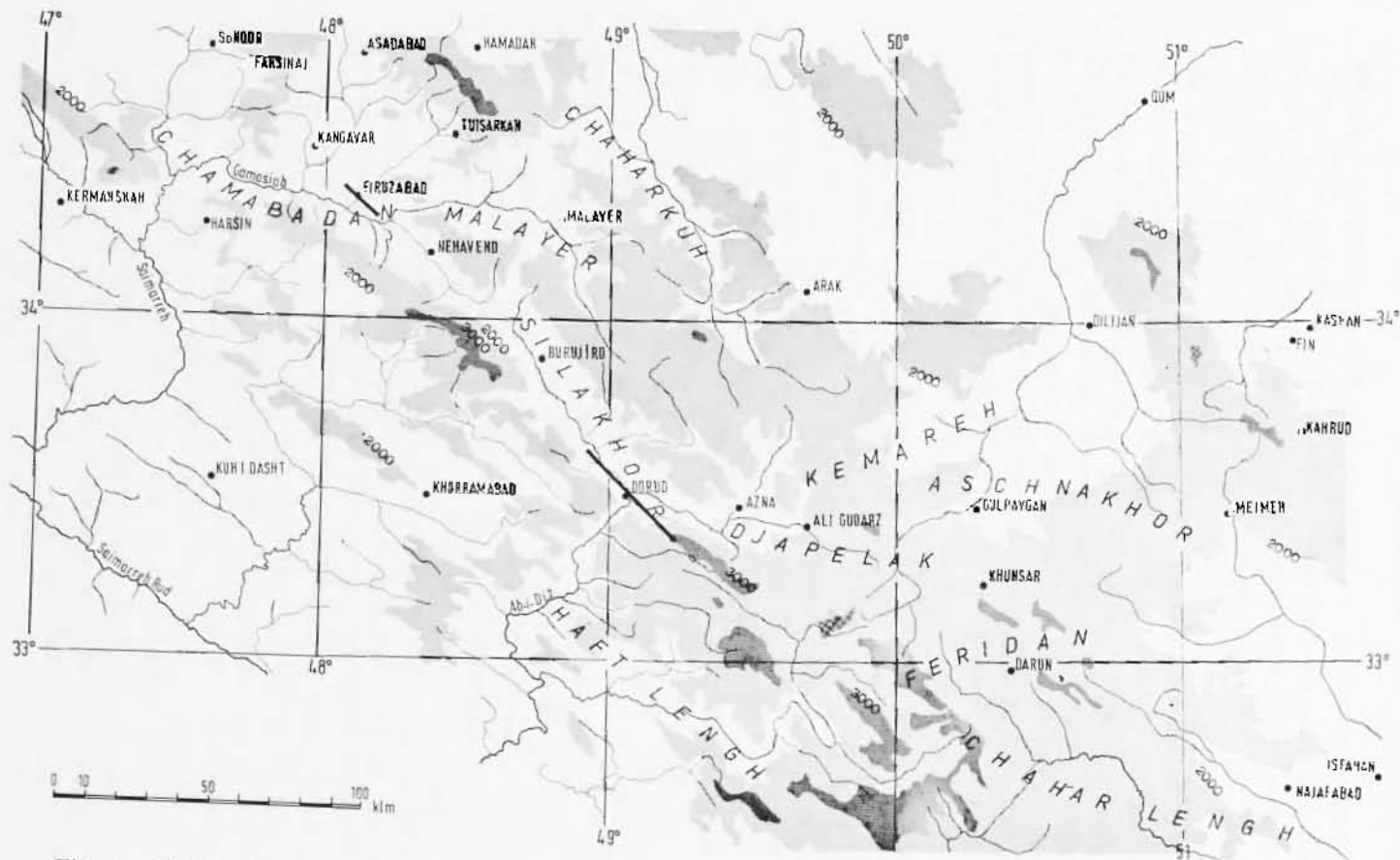


Fig. 2 - Epicentral area of Silakhor earthquake and sub-districts of the Bakhtiari in 1909. Altitudes in metres.

Early in 1909 the state of roads in Western Persia had become extremely insecure, particularly the routes to Hamadan, Kermanshah and those to the south through Silakhor to Isfahan, *Command Papers* (1909: no. 4581/68-80) to the extent that communication by courier had ceased.

It is not surprising, therefore, that unofficial news about the earthquake reached Tehran, through consular couriers three weeks after the event, while the full extent of the disaster did not become known through the official press until late in April 1909, *Iran* (no. 61, Rabi-awwal 1327). The reason for the belated news in the Tehran press is that after the *coup d'état* of June 1908, all, or nearly all, newspapers were immediately suppressed while those which were allowed to continue were issued at irregular quarterly or monthly intervals containing no news of interest.

However, the earthquake was felt outside Iran, in the Caucasus⁽²⁶⁾, in Baghdad and at Harput in Turkey⁽²⁷⁾, and news of its occurrence appeared in the European press almost immediately. The shock was also registered by seismographs in Europe, Russia, India and at the Cape of Good Hope, and it would probably have passed without notice but for the attention directed to earthquakes at that time, only three weeks after the disastrous earthquake in Calabria, Italy, of the 28th December 1908. By the end of January 1909, seismic recordings of the Silakhor earthquake had attracted world-wide scientific interest^(25,3,5,6), *Times* (1909: 25/1.8), but there was still no information about the region in which the shock had been felt. On the 25th of January, the Russian press reported the results of instrumental studies based on Russian recordings of the event, locating the earthquake within the confines of Chinese Turkestan, the amplitude of the recordings suggesting an event that should have been much more serious than the one which destroyed Messina [*Russki Slovo* (25/1/1909), *Times* (27/1/1909:5)]. The following day improved calculations, reported in the European press, indicated that the earthquake should have occurred not in Chinese Turkestan, but somewhere in the Persian Gulf or the Indian Ocean, while seismologists in Leipzig predicted a more distant volcanic origin in the Pacific Ocean; this theory they found supported by news of extraordinary sea-waves on the coasts of British Columbia and California, *Times* (28/1/1909:5). By the end of January 1909, still without any information about the actual origin of the earthquake, seismologists predicted an improved epicentral location somewhere in western Central Asia, the large amplitude

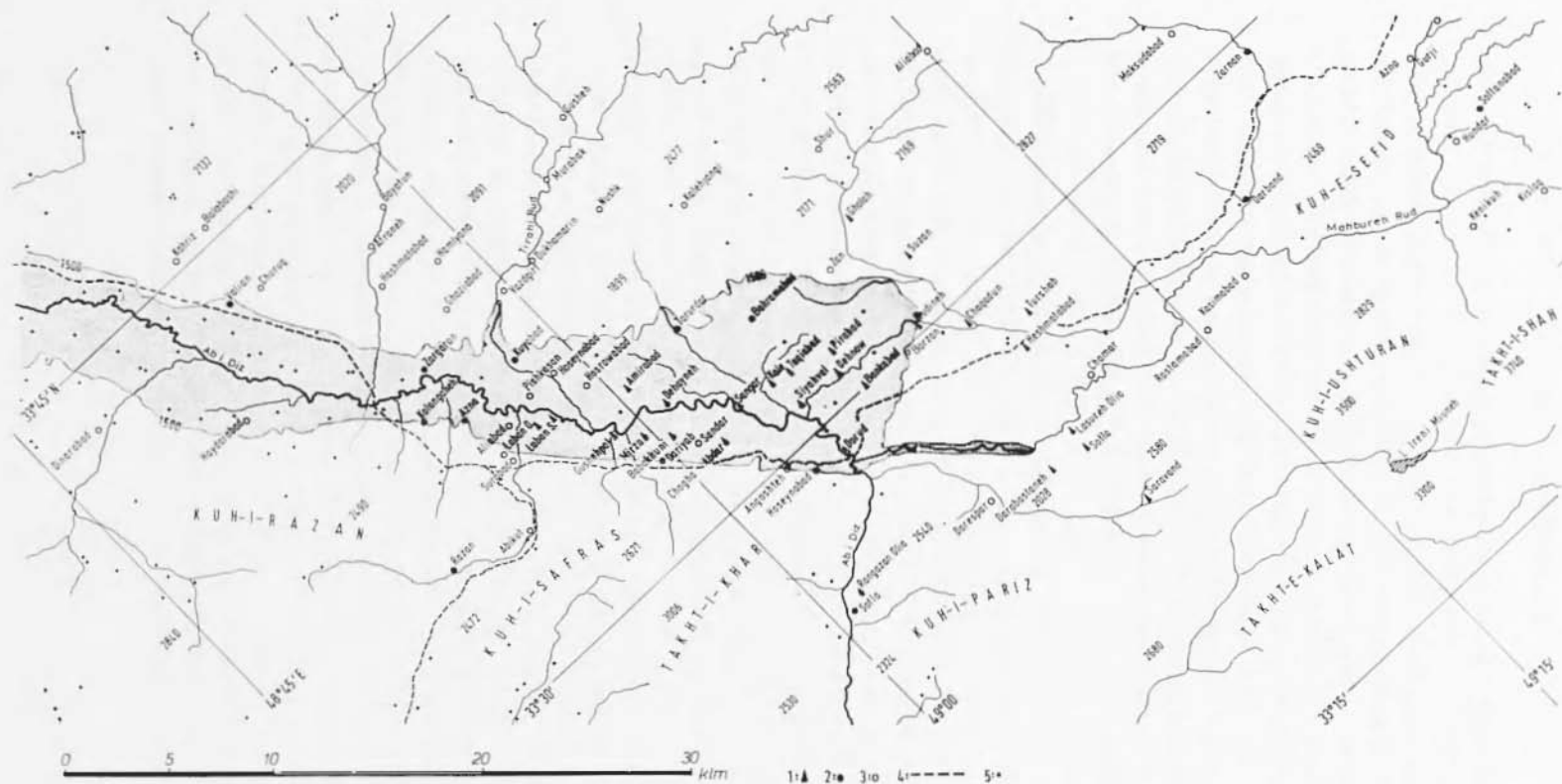


Fig. 3 - Meizoseismal area of the Silakhor earthquake. 1 = villages totally destroyed with casualties; 2 = villages heavily damaged, in some cases with casualties; 3 = villages damaged without serious loss of life; 4 = post-1909 roads; 5 = other villages and settlements not seriously damaged or built after the Silakhor earthquake; shaded area shows extent of Silakhor valley below 1,500 metres.

recordings implying an earthquake as large, if not larger, than the Italian earthquake of 1908 (^{17,6}).

In the meantime, Prince Galitzin, doyen of the Imperial Seismological Commission in St. Petersburg, using origin times and phases cabled to him from the seismological stations of Tiflis, Irkutsk and Pulkovo calculated the origin of the earthquake at 36°N-56°E south of Astarabad in the Dasht-e-Lut, not far from where the earthquake of the 25th September 1903 has caused great damage. This he reported on the 30th of January at a meeting of the Seismological Committee and again on the 3rd of February at a meeting of the Academy of Sciences in St. Petersburg (^{13,14}). Galitzin's new location of the earthquake was soon carried by almost all European newspapers, *Novoi Vremja* (3/2/1909) (^{6,10}).

About the same time, the Russian consul in Kermanshah, N. Nikolski who like everybody else in the town had felt the earthquake, decided to send a reconnaissance mission to find the origin of the earthquake and assess the extent of damage. It is not clear whether he did this at the instigation of Prince Galitzin who was anxious to verify the origin that he had fixed from distant recordings or on his own initiative. The Russian mission consisted of Major Sukhenko, the Russian consular agent Asadolla-Mirza, sargent Kurkin and two cossaks from the Russian contingent stationed in Kermanshah, a town which was still under the Russian sphere of political and commercial influence. The mission left Kermanshah by the end of January in search of the earthquake region. Guided either by local information that should have reached the mission in Kermanshah before their departure, or by Prince Galitzin's epicentral location, the mission proceeded eastwards and reached Burujird ten days later. On the way the field party visited almost all villages and interviewed local people from whom they learnt that the earthquake had happened in Silakhor, about two days' journey from Burujird, where 50 villages were said to have suffered and 5000 lives to have been lost. From Burujird the mission applied to the government in Tehran for permission to enter Luristan to study the effects of the earthquake. While the mission was tarrying for a reply from Tehran, destitute survivors began flocking to Burujird applying to the governor for help. They reported that the district of Silakhor was totally destroyed and that 60 villages had been wholly or partially ruined, while several villages had been destroyed completely. The loss of life they estimated between 5000 and 6000 and the loss of cattle to twice as many. They

also reported that the Bakhtiyaris were looting and pillaging the less affected districts of Djapelak and Feridan south of Silakhor and that the roads throughout the region, particularly those passing through Chahar-Lengh, were unsafe. After a long delay at Burujird, the mission was allowed to proceed to Silakhor on the 16th of February.

About the same time, most probably from the cables sent by the mission to Tehran, the actual origin of the earthquake became known in the capital and in Europe [*Times* (18/2/1909:7), *Russki Słoro* (19/2/1909:1)] (3.6.49). On the 1st of March, Prince Galitzin reported to the Imperial Academy in St. Petersburg a revised location of the earthquake with an epicentre in the Burujird region (45).

Travelling by easy stages on the trunk road to Isfahan, Major Sukhenko's field party began to survey the damage in the Silakhor district. The country was frostbound and covered with snow, particularly the mountainous regions where temperatures were below freezing. From Laban to Bahrein (modern Dorud), the mission found almost all villages totally destroyed and abandoned, littered with unburied corpses and dead animals. From interviews with the few Luris and Bakhtiyaris who had survived the earthquake, the mission learnt that people in the Silakhor valley having had no previous experience of earthquakes, were caught by the shock in their sleep and killed under the ruins of their adobe houses. In many places the mission noticed that the ground had opened up to a depth of two metres, and that large cracks, gaping open for a few tens of centimetres, ran along the ground for many kilometres. Major Sukhenko's report uses the old Russian units: *arshin* = 0.711 metres, *vershk* = 4.44 centimetres, and *verst* = 1.07 kilometres. Approaching Babrein the picture of destruction became more bleak; almost all villages were levelled with the ground and in a few of them not a single person had survived. In the Silakhor valley alone, the mission estimated that the loss of life, excluding women and children, was about 1,500. The field party visited 27 villages and collected reliable information from another 31 in the Silakhor area, in the Chahar-Langh district and in rest of the Bakhtiyari country. Additional information collected by the consular agent Asadolla-Mirza suggests that the total number of villages affected in the region between Burujird and Isfahan, including those in the district of Haft-a-Lengh, was 128.

It is not known how long Major Sukhenko's field party stayed in the Silakhor valley collecting information. Early in March they reported that inspite of the cold weather there was danger of an epidemic

and even greater danger of famine, and the mission was ordered back to Kermanshah before they had an opportunity to visit the region to the southeast of Bahrein, reaching Burujird late in March. It is very probable, however, that the order for the mission to return was given not so much because of the danger of an epidemic but because at that time the Kalkur Kurds, after considerable skirmishing with the garrison of Kermanshah, were preparing to invest the town and cut off its communications with the rest of Iran.

From Burujird details about the earthquake were cabled by the consular agent to Tehran, and these were published in the local press on the 31st of March 1909⁽⁸⁾. The full text of Major Sukhenko's report together with six photographs were dispatched to St. Petersburg, and a summary of his report was presented at a meeting of the Seismological Committee of the Imperial Academy on the 24th of April^(32,33). Almost all information on the Silakhor earthquake published in Europe after April 1909 is based on Shtelling's summary report^(11,24,34,35,37). However not all of this is either factual or correct. For instance, *Lysakowski* maintains that the Silakhor earthquake was felt as far as Morocco; that it caused damage in Asia Minor, particularly in Izmir and in the villages around that town where many houses collapsed and that in Messina and Reggio houses, left standing after the earthquake of the 28th of December 1908 were ruined. He asserts that the damage extended to Tunisia and Morocco where two villages were destroyed by rockfalls triggered by the shock. But in fact, Messina and Reggio were damaged at 19^h24^m GMT of the 23rd of January 1909 by a strong aftershock of the 1908 earthquake, and Asia Minor was damaged at 06^h40^m GMT on the 19th of January 1909, the macroseismic epicentre of this earthquake being around Phocaea, Menemen and Cassaba. These and other local earthquakes were reported in the European press from other parts of the world, and not unnaturally a connection was assumed with the Silakhor earthquake which had no foundation^(12,25). *Anonymous*⁽⁴⁾ misunderstood Shtelling's old Russian units of length and *Wilson*⁽³⁷⁾ not only gives the wrong year for the Silakhor earthquake but also the wrong epicentres. *Rustanovich*⁽²⁸⁾ on the authority of *Stahl*⁽³¹⁾ place the Silakhor earthquake at Bujnurd, about 600 kilometres northeast of Burujird.

Sixty four years after the earthquake, in the spring of 1973, the authors made a field study of the Silakhor earthquake. One of their tasks was to find and interview people who still remembered the effects of the 1909 earthquake, particularly octogenarians who might have

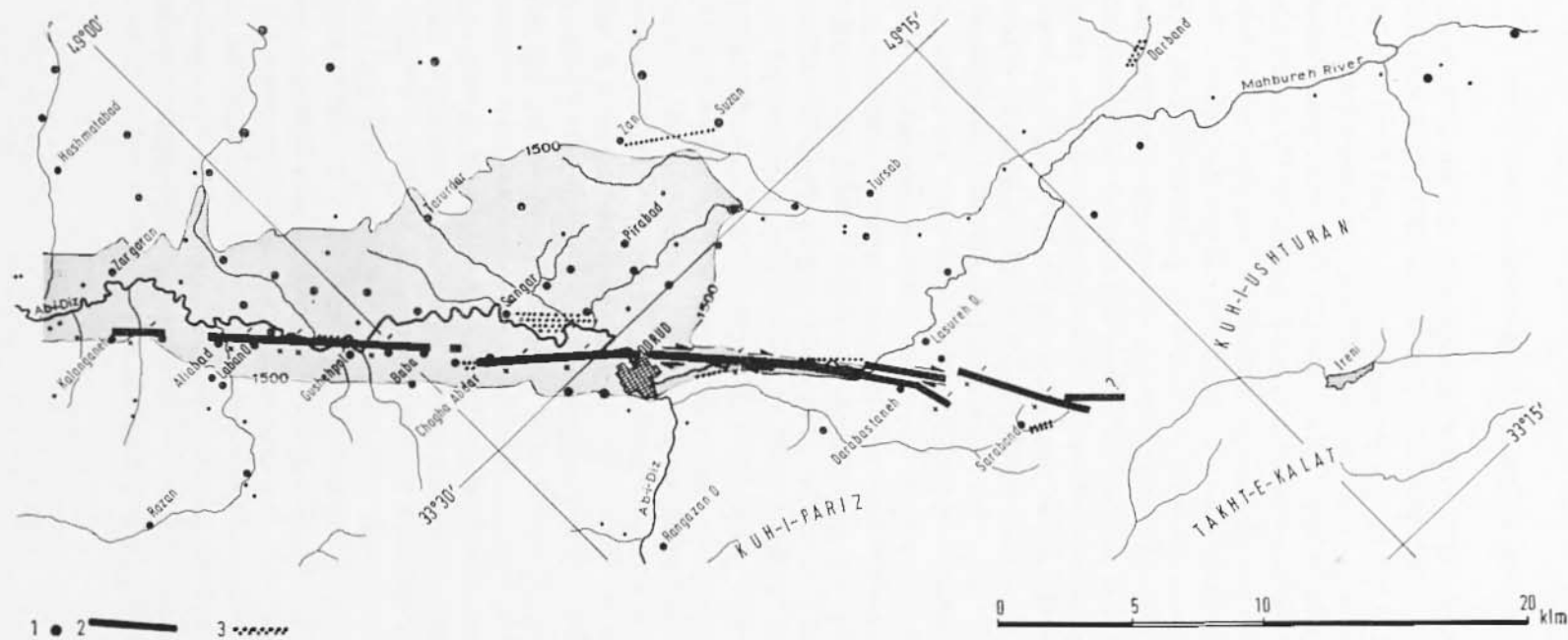


Fig. 4 - Ground deformations associated with the Silakhor earthquake. 1 = villages and sites destroyed or damaged beyond repair; 2 = faulting associated with the 1909 earthquake; northeast side downthrown -- right lateral displacement shown deduced from geological evidence -- displacements not necessarily connected with the Silakhor earthquake; 3 = areas of slumping of the ground and landslides.

been in the Silakhor valley during the earthquake and who still remembered the event. In all, five such interviewees were found. *Hakkari* was 15 years old at the time of the earthquake; he had lived a sedentary life in Darabastaneh and he recalled very little apart from what had happened in his village. *Abu'l Hassan Khakademi Darabastani*, a learned elder from Darabastaneh, who at the time of the earthquake was 10 years old, was exceedingly informative and gave the authors valuable and extremely accurate information about the location and extent of the ground deformations that were produced by the earthquake south of Behrein. *Mashdi Rahim Lavani* was rather moronic; he did not remember how old he was at the time of the earthquake but as he had an accurate recollection of "ferenghis" visiting Laban soon after the earthquake, he must have been at least 10 years old. The "ferenghis" he referred to were perhaps from Major Sukkenko's mission or, most probably the cossaks that raided Silakhor late in November 1911 after the battle of Buruijrd. *Mohammad Tahir Pirbadi* was 9 years old when the earthquake happened; he had an excellent memory and his long narrative about the earthquake effects in the southeast part of the valley was found to be invaluable. *Nader Ali Turshabi* gave the authors a wealth of detailed information about the damage and faulting to the south of Bahrein and he claimed that at the time of the earthquake he was 6 years old. With the exception of *Hakkari*, the other four interviewees remembered correctly the time of the day and year of the earthquake; they remembered also the names of many abandoned sites and ruined imamzadehs. In many instances two or three out of the four witnesses gave almost exactly the same details about certain effects of the earthquake, confirming thus the reliability of the information. Second hand information supplied by younger people was equally valuable, on several occasions verifying formerly unreported damage to villages and fault displacements along suspected scarps. Once more, local information proved to be the single most important tool in the study of historical earthquakes.

This paper is written with the aim of reporting facts and field observations, in some respects incomplete, relating to the Silakhor earthquake and it is in the same series of recent papers written on the seismicity of Iran (1-3). No attempt will be made to interpret facts and synthesize observations or draw conclusions with regard to the seismotectonic implications of the Silakhor earthquake. A detailed study of the faulting associated with the Silakhor earthquake and with other Iranian earthquakes will appear elsewhere.

THE SILAKHOR EARTHQUAKE OF THE 23RD JANUARY 1909.

The earthquake occurred early Saturday morning at 06 hours local time, on the 23rd of January 1909 (1st Muharram 1327 Hijri). The shock was recorded, imperfectly by modern standards, by almost all stations in Europe, Asia and Africa, giving sufficient data for a low accuracy epicentral determination at 33°N-53°E with an origin time of 0248.3 GMT and magnitude 7.4 (19).

Owing to the absence of accurate reports outside the Silakhor region, the full extent of the meizoseismal region is difficult to assess today. We know that the northwestmost site that was damaged is the stopping place of Valian on the old trunk road to Isfahan. [For the location of villages relative to the old trunk road to Isfahan through the Bakhtiyari country see (20,22)]. The earthquake destroyed the caravansarai, killing many horses belonging to a recruiting Bakhtiyari contingent, Figures 3 and 4.

Further south on the same route, at Zargaran (Zarginah) a large village of 200 houses, damage was more serious. The shock demolished ten houses killing many animals; no one was killed but the village was badly damaged. Today, the old village is abandoned and two smaller settlements of the same name and of not more than 100 houses have grown near the edge of the old site.

Off the old road, on the west side of the Ab-i-Diz, the village of Kolanganeh was heavily damaged and a few houses collapsed without loss of life. A clear fault scarp extends southeast from Kolanganeh and may well be related to the ground deformations to which *Labani* was referring when he said that large cracks, running for many hundreds of metres could be followed all the way to the river near Aliabad.

Near Azna, eroded scarps up to 1.5 metres high, with the northeast side downthrown, are still visible on the ground skirting the village from the northeast. At Azna damage was heavy and as far as we could tell some houses were thrown down but no one was killed. Early in 1911, *Wilson*, who was carrying out a survey for the new railways line, found almost all village between Valian and Azna deserted and very few houses still standing (26).

Between Azna and the new (?) village of Aliabad there is no visible evidence on the ground of recent faulting. However, past Aliabad, an impressive series of linear rises can be followed for almost 8 kilometres to the southeast, all the way to Kale Mirza (modern Baba

Khuni). Here, the fault-break appears as a gentle northeast facing closely spaced series of rises, one to two metres high which interrupt the smooth southeastward slope of the plain. The main scarp is easily distinguished by its relative straightness, and generally by its steeper slopes. Narrow, shallow sags, covered with markedly richer vegetation have developed in front of the old scarps. The margin of the sags is not well defined today but its depth is usually about one metre. The fault-break passes between Laban Olia and Laban Sofla and it shows there a cumulative throw of at least 2.5 metres. The east-west dirt road that leads to Laban Sofla crosses the fault-zone and two smaller eroded scarps with an abrupt change of gradient. In 1909, Laban Olia was completely destroyed and at least 25 people were killed in the village. At the time of the earthquake Laban Sofla, built around a ruined fortified hillock, was a much more important village than today. The village was almost totally destroyed but comparatively few people lost their lives. As a result of the earthquake many fields were flooded with water and mud which exuded from the ground.

From Laban the fault trace crosses the new course of the Ab-i-Diz a number of times, and in places disappears completely, becoming clear again near Gushehpol. From local information it appears that the village was not totally destroyed and that although many people lost their lives, few houses collapsed completely. However, about a kilometre and a half to the northeast of Gushehpol, at Amirabad (old Mirabad) the destruction was complete; nothing was left standing and about 120 people were killed together with more than 500 animals.

About a kilometre to the southeast of Gushehpol, near the site of the old village of Mirzah Kaleh, the fault-scarp becomes very faint, almost impossible to follow on the ground. There is some evidence, however, that it continues to the southeast in the form of a gentle rise with a distinctly richer vegetation on the downthrown side, passing between the old village of Baba Khuni and a small settlement nearer to the river. Baba Khuni was totally destroyed and the village was abandoned for many years. According to local information, those of its inhabitants who survived the earthquake returned later and built two smaller settlements near-by. One of them is Sandarkhaneh and the other is Sandargan, the latter being an abandoned village at the time of the earthquake. Two other villages in the vicinity known as Eskumirzai and Kale Mirza seem to have been settled by some of the survivors of Baba Khuni, and it is not clear whether they existed in 1909.

To the west of Baba Khuni on higher ground the village of Dariyab was seriously damaged but few houses collapsed and only about 10 people were killed. The village was abandoned for many years and it was resettled early in 1930. To the northeast of Baba Khuni, on the east bank of the Ab-i-Diz, the old village of Delhayueh (or Yusefabad) was completely destroyed and more than 50 people were killed together with all the animals that belonged to the village.

Between Baba Khuni and Chogha Abdar, we could find no clear evidence of continuous faulting running uninterrupted for more than 100 metres. A large number of eroded low terraces and rises, striking roughly northwest-southeast, and arranged en echelon cover almost all the flood plain from Chogha Abdar, to the river, suggesting widespread slumping. As a matter of fact, local information has it that for many years after the earthquake the ground was so badly cracked that it was impossible for people or animals to follow a direct route to the river. The village of Chogha Abdar was totally destroyed with great loss of life.

Less than a kilometre to the northeast of Chogha Abdar, on the northeast bank of the Ab-i-Diz, the village of Sangar (or Sangiyareh) was totally destroyed and out of 400 people only 3 survived. In 1909 the Ab-i-Diz flowed much closer to the village which was built literally on its banks. As a result of the earthquake the ground around the village slumped and in places it slid into the river. From Sangar to Siyahval the northeast banks of the Ab-i-Diz and those of many streams running into it, slumped and large cracks in the ground made this part of the region impassable for many years after the earthquake. Siyahval was totally destroyed and about 80 people were killed. Damage was equally heavy at Taqiabad; the village was razed to the ground and more than 200 people were killed. Pirabad Olia, also suffered heavy damage and 4 out of 500 people were killed. In Pirabad Sofla more than 60 people were killed with all the animals in the village.

Southeast of Chogha Abdar the fault-trace is quite clear and it can be followed across cultivated fields all the way to Dorud. It passes one kilometre east of Angoshteh and Hoseynabad in the form of a rather abrupt rise, one to three metres high, distinguishable by its linearity from the irregular curving fronts of erosion terraces.

In places the scarp was planed off by erosion filling in the sags in front of it; many of these elongated in-filled moats are characterized by their thicker vegetation, and darker colour. The fault-trace can be followed to Dorud where it passes near the marshalling yard of the

railway station and crosses the Ab-i-Diz near the eastern part of the modern town. From this point the trace continues for another 18 kilometres to the southeast, all the way to Saravand following a pre-existing geological fault.

Dorud (old Bahrein) was almost totally destroyed and about 150 people were killed. Two mosques, public baths and an old imamzadeh collapsed. Rockfalls from the hills to the southeast of the town destroyed a number of outlying houses. Near Dorud, Bankabad (or Bunakabad) was razed to the ground and all 180 of its inhabitants were killed. Also Kale Gead Mohammad Reza, a small settlement near Bankabad, was totally destroyed and 58 people were killed. The village was abandoned for many years and it was re-settled late in 1920. The name of the settlement in 1909 was Gharin (?). Southwest of Dorud on the Ab-i-Diz, Rangazan (Rangrazaan or Rakan) was wholly destroyed and for a period of time it was abandoned.

Where the trace crosses the Mahbureh Rud there is evidence of at least two landslides. It is very probable that one of these is the slide mentioned by *Shtelling* (³⁹) that dammed the river at Karin. The mountain Karin is locally unknown; there is, however, a mountain peak of Kuh-i-Pariz which is called Takht-i-Zarrin by the local villagers. Both Darabastanabi and Turshabi confirmed that the Mahbureh Rud was dammed where it forms a narrow gorge by the collapse of a large mass of rocks and that river remained blocked up for many years. The high hills to the west of Laban, they used to call Gharin but now they use different names.

The fault-trace crosses the Mahbureh Rud, Plate 1, and continues to the southeast while the river turns sharply to the east. The trace, cutting through limestone and sandstone, passes through the old site of Darabastaneh and to the southeast of Imamzadeh Abdula Esku. The village of Darabastaneh was totally destroyed and out of 500 people 218 were killed. The shaking of the ground was so strong that people and animals were thrown down and tombstones were dislodged. The old Imamzadeh Abdulah was ruined and it was later rebuilt in the new village.

Between Darabastaneh and Lasureh Sofla the trace is double; one trace activated in 1909 continues in limestone gradually turning southwards and another shorter trace, perhaps a geological fault which did not move in 1909, runs parallel to, and northeast of the former. Both traces show a throw of at least one metre to the northeast and a substantial pre-existing right lateral displacement. Local people

recalled the exact location where the ground had deformed and insisted that the throw was at least two metres, with what they described as a deep frontal moat, which could admit a man. According to *Darabastani* the trace began to deteriorate soon after the earthquake but it was still visible 15 years after the event. However, there is no visible evidence of such a large movement today; all that one can see now is a wide zone, forming a shallow sag in front of a weathered scarp about one metre high facing northeast. Because of erosion it is impossible



PLATE 1 - Fault zone in the Mahbureh valley looking southeast.

to assess today the sense and magnitude of lateral motion from the few linear features that are still available as markers across the trace. There is, however, geological evidence in at least three locations between the crossing of the trace with the Mahbureh Rud and Darabastaneh which suggests pre-existing right-lateral motion.

From Darabastaneh to Saravand the new road leads around peak-2028 and then follows the river-bed of the Darcaspar-ab to Saravand. The old track, although in places becoming impassible, follows the east flanks of peak-2028 and runs almost parallel with the fault-break which is still very clearly seen, particularly where it crosses low saddles. Old Saravand was located in a small valley and the earthquake killed about 130 people demolishing all houses. Rockfalls added to the damage. The village was rebuilt higher up, Plate 2.

To the southeast of Saravand there are no villages for at least 25 kilometres and the country is almost totally uninhabited, the ground rising rapidly to altitudes in excess of 3000 metres. The question of whether faulting extended to the region of Lake Ireni-Miuneh and beyond remains to be answered from future field trips.

East of Dorud, damage extended across the valley to Turshab, a large village in 1909, which was totally destroyed and half its population killed. The villages of Chaquadn, Budineh, Suzan and particularly



PLATE 2 - The village of Saraband.

Gholah (Ghol-e-Gurchak) were razed to the ground with heavy loss of life. *Pirbadi* recalled large cracks in the ground extending from Zan to Suzan (Suran?). This part of the Silakhor valley was not visited by the authors. Damage was equally heavy at Bahramabad and Tarudar where a spring of water, not far from Tarudar dried up after the earthquake.

Further to the southeast the ground rises rapidly to altitudes of 2,500 metres with the Kuh-i-Ushturan (3,500 metres) standing to the southeast of the Mahbureh Rnd valley. At Heshmatabad and Mahmudabad, near modern Darband, the damage was rather serious but very few people lost their lives. At Zarnan (Zarneh) and at Darrehtakht, near Soltababad in the Djapelak district, no one was killed but quite a few houses were ruined. In the Djapelak district damage was widespread but not serious apparently with little or no loss of lives.

The earthquake was strongly felt, causing slight damage in the districts of Chamabadan and Malayer to the north of Silakhor, as well as in the districts of Haft-Lengh, Feridan and Chahar-Lengh in the southwest and southeast of the Silakhor valley. Details about earthquake effects in these districts are somewhat lacking. According to *Stelling* (1909b) the shock had caused damage to all the districts (dehestans) between Burujird and Isfahan, but we could find no convincing evidence in support of this statement.

In Burujird the shock consisted of a long series of violent shocks which altogether lasted about 4 minutes, the ground moving perceptibly in an east-west direction. It caused absolutely no damage but it was strong enough to throw dishes and glassware from shelves and to cause waves on ponds. In some instances water was thrown out of open water tanks, even from deep puddles in the streets, mainly from west to east. The shock which was accompanied by underground rumbling noise, caused great panic in the town as well as in villages in the Chamabadan district.

In Kermanshah the main shock was felt by everyone, including consul Nikolski. It lasted not more than a few seconds but the ground motions were perceptibly felt from west to east. They were accompanied by many other weaker ones which lasted for many minutes altogether. Apparently the shock was very weak; we could find no mention of the event in the dispatches of the British Consul Cpt. Howarth, *Command Papers* (1909, 4581/no. 78) ⁽⁴⁰⁾.

Evidently in Isfahan as well the shock was neither sufficiently strong to cause any concern nor to merit special mention in the diplomatic reports of January and February 1909 dispatched to Tehran by the British Consul G. Grahame, *State Papers* (1909: no. 78/46) ⁽⁴⁰⁾; nor is there any mention of the event in the local newspapers which began to reappear just before the abdication of Muhammad Ali Shah [*Kashghul* (no. 2, Rabi-accher 1327), *Anjuman-e-Isfahan* (no. 24, Rabi-accher 1327)] ⁽⁴⁰⁾. Also we could find no evidence that the earthquake had caused undue concern in Khorramabad and further south in Ahwaz. As a matter of fact, trade during the period 1909-1910 in the consular districts of Kermanshah and Isfahan, was not affected by the Silakhor earthquake, and showed no marked changes compared with that of 1908 [*Command Papers* (4581-4962/1909-1910), *State Papers* (1909-1910/nos. 4559-4365), *Kermanshah* (no. 1, Dhul'-Qa'da 1327)] ⁽⁴⁰⁾.

The shock, at 0251 GMT, was felt in Baghdad as well as in Borjom, Tbilisi and Zurnabad, where at least two shocks were felt by almost everyone (¹⁷). It was also felt rather strongly at Harput, at 0258 GMT with an intensity IV (RF) (²⁷).

So far, we have been unable to find any evidence that the shock was felt in Hamadan, Tehran or Rasht. Both British and Russian consular correspondence for January and February 1909 makes no mention of the event.

Gorshkov (¹⁸) mentions an earthquake which was strongly felt at Piyatigorsk, about 1,200 kilometres from Silakhor, on the 23rd of December 1909 at 03 hours GMT. The shock caused slight damage to masonry building in the town, including the gymnasium, as well as cracks in the ground along newly laid water-pipes; he assigns an intensity VII (RF?) to the shock and *Karnik* (²¹), on the authority of *Gorshkov* (¹⁸) alone, assigns an epicentre at 44.0°N-43.1°E, as well as a magnitude of 5.1.

Damaging aftershocks in the Silakhor district continued for almost six months. One of these shocks was felt by Major Sukhenko's mission at Burujird on the 13th of February at 8 pm. local time. The shock was rather weak and it lasted only a few seconds. The following night, another violent shock which lasted about 20 seconds caused one of the cossacks of the mission to fall off his bed. Minor shocks, at least four every day, continued to the end of March (⁸). They continued till the end of June, some of the aftershocks causing damage in the region of Bahrein and particularly in the vicinity of Pirbad (¹⁰). There is some evidence (²⁶), that much of the damage brought about in the Djapelak region was due to aftershocks (or from earthquakes that followed the 1909 event) as a result of which a number of springs dried up and a number of people were killed by rockfalls or landslides. Late in 1909, many villages in the Djapelak region were abandoned as a result of the frequent earthquakes.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Messrs M. Salur and Gh. Leylabadi of the Fars and Khuzestan Cement Co. for their great help as well as to Mr. M. Papazian of the Hamadan Office of the Plan and Budget Organisation for his advice.

This work was supported by the Natural Environment Research Council, London and the Plan and Budget Organization, Tehran.

REFERENCES

- (1) AMBRASEYS N., MOINFAR A. and PERONACI F., 1973. — *The Farsinaj, Iran, earthquake of 13 December 1957*. "Annali di Geofisica" XXVI, 4.
- (2) AMBRASEYS N. and MOINFAR A., 1974a. — *The Piruzabad, Iran earthquake of 16 August 1958*. "Annali di Geofisica", XXVII, 1, in press.
- (3) AMBRASEYS N. and MOINFAR A., 1974b. — *The Karkhaneh, Iran earthquake of 24 March 1963*. "Annali di Geofisica", XXVII, 1, in press.
- (4) ANONYMOUS, 1909. — *Über das Erdbeben in Luristan*. "Jahrbuch der Astronomie und Geophysik", 20, p. 266, Leipzig.
- (5) ANONYMOUS, 1909b. — *Nouveau tremblement de terre*. "La Nature", 1862, p. 66, Paris.
- (6) ANONYMOUS, 1909c. — *Mystère sismique dévoilé*. "La Nature", 1865, p. 89, Paris.
- (7) ANONYMOUS, 1915. — *Ezhemesiachii meteorologicheski byulletin*. "Tiflisskoi Fizicheskoi Observatorii", 1898, Tbilisi.
- (8) ASSADOLLAH-MIRZA, 1909. — *Iran*, year 61, Rabi-awwal 1327, p. 2, Tehran.
- (9) BYUS E. N., 1948. — *Seismicheski uslovi' zakavkazi*. "Ikonologii zemletrasenii v zakavkazi", vol. 1, p. 109, Tbilisi.
- (10) DARABASTANI, Abu'l Hasan Khakademi (private communication).
- (11) DONGIER R., 1909. — *Notes et actualities; sismologie*. "Revue Scientifique", 47, p. 310.
- (12) EVERDINGEN E. VAN 1915. — *Seismische registrierungen in De Bilt*. "Koninklijk Nederlandsch Meteorol. Inst.", 108, p. 19, Utrecht.
- (13) GALITZIN B., 1909a. — *Protokol 1909-1-30/16*. "Izvest. Postovnu. Tsentr. Seism. Kommiss. Imperat. Akad. Nauk", Ser. 6, 3, p. 17, St. Petersburg.
- (14) GALITZIN B., 1909b. — *Kratkoe soobshchenie o zemletrasenii 10/23-go ianvaria 1909-g.* "Izvest. Imperat. Akad. Nauk.", ser. 6, 3, no. 3, pp. 159-160, St. Petersburg.
- (15) GALITZIN B., 1909c. — *Dopolnitelnoe soobshchenie o zemletrasenii 10/23-go ianvaria 1909 goda*. "Izvest. Imperat. Akad. Nauk", ser. 6, 3, no. 4, pp. 243-244, St. Petersburg.
- (16) GLASEKI S. V., 1909. — *Ezhemesiachii seismicheski byulletin*. "Tiflisskoi Fizicheskoi Observ.", no. 1903-1909, Tbilisi.
- (17) GLAZEBROOK R. T., 1909. — *Seismograms of the earthquake of January 23*. "Nature", 79, no. 2050, p. 428, London.
- (18) GORSNIKOV G., SPESIVTSEV V. and POPOV V., 1941. — *Katalog zemletrasenii na territorii SSSR 1908 po 1936 goda*. "Trudi Seism. Instit.", no 95, part 3, p. 14, Moscow.
- (19) GUTENBERG B. and RICHTER C., 1965. — *Seismicity of the earth*. "Hafner Publ.", p. 210.

- (20) HAKKARI, Darabastani (personal communication April 1973).
- (21) KARNIK V., 1968. - *Seismicity of the European area*. Publ. "Czechosl. Acad. Sci.", Part 1, p. 140, Praha.
- (22) KIEPERT H., 1910. - *Nouvelles cartes des provinces asiatiques de l'Empire Ottoman*. Istanbul-Paris, (1:1,500,000 & 1:750,000).
- (23) LAVANI, Mashdi Rahim (personal communication April 1973).
- (24) LYSAKOWSKI C., 1910. - *Tremblements de terre de la Perse du janvier 13, 1909*. "Bull. Soc. Astronom. Franc.", **24**, pp. 45-47.
- (25) OLDIAM R. D., 1909. - *Recent earthquakes*. "Nature", **79**, no. 2048, p. 368, London; "Geograph. Journal" **33**, p. 296.
- (26) PIRBADI, Mohammad Tahir (personal communication April 1973).
- (27) RIGGS H. H., 1909. - in "Jahrbuch der Astronomie und Geophysik", **20**, p. 166, Leipzig.
- (28) RUSTANOVICH D. N., 1967. - *Seismichnost' territorii Turkmenskoy CCP ü Ashkhabadskoe zemletrasenie 1918 g.* "Vapros. Inzenier. Seism. Byul.", no. 12, p. 15, Akademi. Nauk, Moscow.
- (29) SAWER H., 1891. - *Reconnaissance survey of the Bakhtiari country*. Report RN/4C-QM, Survey of India, Calcutta.
- (30) SIEBERG A., 1909. - *Makroseismische Nachrichten Über das Erdbeben in Persien*. "Kaiserliche Hauptstation für Erdbebenforschung in Strassburg", no. 3, p. 2.
- (31) SIEBERG A., 1932. - *Die Erdbeben*, "Handbuch der Geophysik", **4**, p. 815, B. Gutenberg, Berlin.
- (32) SHTELLING E., 1909a. - *Protokol Izvest. Postoyynnoi Tsentraln. Seism. Komissii Imerator*. "Akademi. Nauk", ser. 6, **3**, p. 29, St. Petersburg.
- (33) SHTELLING E., 1909b. - *Svedenia o zemletrasenii v Persia 10:23 ianvaria 1909-g.* "Izvest. Postoyynnoi Tsentraln. Seism. Komissii Imerator. Akademi. Nauk", **3**, no. 3, pp. 32-36, St. Petersburg.
- (34) STAHL A. F., 1911. - *Handbuch der Regionalen Geologie; Persien*, **6**, no. 1, p. 5.
- (35) STELLING P., 1914. - *Ezhemesiachii seismicheski byulletin*, "Tiflisskoi Fizicheskoi Observ.", no. 12, Tbilisi.
- (36) WILSON A. T., 1911. - *Luristan and Arabistan*. "S.D.O. Topo. Dy." no. 119, Calcutta.
- (37) WILSON A. 1930. - *Earthquakes in Persia*. "Bull. School Oriental Studies", **6**, pt. 1, p. 124, London.
- (38) WILSON A. 1942. - *Southwest Persia*. Oxford Univ. Press.
- (39) TURSHABI, Nadch Ali (personal communication April 1973).
- (40) PRESS REPORTS: *Iran, Najaf, Kashgul, Anjuman-e-Isfahan, Kermanshah, Russki Slovo, Novoi Vremja, The Times, Daily News, Daily Chronicle, Manchester Guardian*.