

The Seismicity of Iran
The Farsinaj (Kermanshah) earthquake
of 13 December 1957

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SUMMARY. — The Farsinaj (Iran) earthquake occurred on the 13th December 1957. A field investigation carried out 16 years later shows that this earthquake caused heavy damage within an area of 2,800 square kilometres in which 1,119 people were killed and 900 injured. The earthquake, which had a magnitude of 7.1, was followed by many strong aftershocks which progressing gradually outward from the epicentral area, enlarged the meizoseismal region in a northwest-southeast direction. Macro seismic evidence suggests a somewhat more moderate epicentral intensity of VII+(MM) over a much wider area than comparable magnitude earthquakes have shown in other parts of Iran. The shock was felt over an area of 180,000 square kilometres, mainly to the northeast of the epicentral area. Recently re-located foci of the main shock and of some of its aftershocks lie outside the meizoseismal region. There is some inconclusive evidence that the main shock or most probably some of its larger aftershocks were associated with ground deformations of tectonic origin.

RIASSUNTO. — Il terremoto di Farsinaj (Iran), avvenne il 13 Dicembre 1957. Ricerche fatte 16 anni più tardi, hanno dimostrato che questo terremoto ha causato gravi danni in un'area di 280 km², con 1119 morti e 900 feriti. Il terremoto di magnitudo 7.1, fu seguito da molte e forti repliche che, allontanandosi gradatamente dall'area epicentrale, hanno allargato la zona meizosismica in direzione NW-SE. I dati macrosismici portano ad un valore dell'intensità epicentrale di poco meno del VII+(MM) su un'area molto più vasta di quella interessata da terremoti di pari magnitudo, avvenuti in altre parti dell'Iran. La scossa è stata sentita in un'area di 180.000 km², soprattutto in direzione NE della zona epicentrale. La ridisposizione dei fuochi della scossa principale e di alcune repliche fatta recentemente, porta questi

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al di fuori della regione meizosismica. Gli Autori concludono che c'è qualche prova, anche se non del tutto determinante, che la scossa principale o molto più probabilmente qualcuna delle repliche più forti, siano state associate a deformazioni del terreno di origine tettonica.

INTRODUCTION

The Zagros, perhaps one of the most interesting areas of active tectonics in Iran, has recently been the subject of intense study. Much effort has been put and progress made into the relocation of hypocentres, the interpretation of source mechanisms and in the mapping and understanding of regional tectonics.

In contrast, very little progress has been made with the macroseismic investigation of earthquakes originating in this part of Iran, beneath which the velocity structure of the crust is so little known. Out of about twenty large earthquakes that we know have occurred during the present century in the Zagros, only two have been studied in some detail in the field and five have been summarily reported in the literature. Thus, in spite of the efforts made so far in the instrumental and geological study of active tectonics in this part of Iran, there are still insufficient field observations that could effectively help one to resolve ambiguities of source mechanisms and to control the relocation of epicentres.

This paper is the first of a series intended to form a record, as precise as possible, of the macroseismic study of the most significant earthquakes in the Zagros. It is written with the aim of reporting solely field observations and facts relating to particular earthquakes that are important to the understanding of the Zagros tectonics. At this stage no attempt will be made to interpret facts or draw conclusions from field observations.

The earthquake studied in this paper, the Farsinaj Earthquake, occurred late in December 1957. Early in January 1958 one of the authors had the opportunity to visit the meizoseismal area and prepare a number of reports ^(6,7,8,9). Other summary reports, based mainly on newspaper information, were published by Montadon ⁽¹⁾ and Rothé ⁽¹⁰⁾. Also, a Japanese Mission which visited the southeast part of the meizoseismal region in 1958, published a brief report, which, apart from an incomplete intensity distribution map, contains very little original information ⁽²⁾.

Sixteen years later, in the spring of 1973, the two senior authors of this paper, having collected and studied almost all reports from the national and local press, as well as a considerable number of unpublished official documents, visited the region of the Farsinaj earthquake. They found that press reports were vrey useful for the general assessment of the situation that the earthquake had caused, but rather unreliable sources for the estimation of the extent of damage at particular sites. Misspellings and confusion of place-names in these reports, if they had passed unnoticed, could have easily distorted the actual picture of the distribution of damage. Unpublished documents compiled by welfare societies and lists of damaged villages prepared by the Red Lion and Sun Organisation were found to give reliable casualty figures, but somewhat exaggerated accounts for the damage sustained by some of the more remote villages. During their field trip, the two senior authors collected interviews with local inhabitants with the dual object of ascertaining the degree and extent of damage brought about by the main shock alone, and of clasifying the areal limits within which the main shock and separately its aftershocks had been particularly destructive; limits within which ground deformations of tectonic origin associated with these events which might have occurred in 1957, were still visible.

THE FARSINAJ (IRAN) EARTHQUAKE OF THE 13TH DECEMBER 1957

The earthquake occurred at 5 hours 15 minutes local time, on the morning of Friday, 13th December 1957, and caused serious damage within an area of about 2,800 square kilometres in the Zagros mountains in Iran. This area lies between 1,500 and 2,500 metres above sea-level and administratively it belongs partly to Luristan and partly to Kurdistan, Figure 1.

With the exception of a single foreshock which preceded the main earthquake by about 26 hours and which was strongly felt at Kangavar, records of the nearest seismological stations show no trace of important seismic activity in this part of the Zagros during the preceding four months.

Table 1 shows the computed hypocentre by a number of centres as well as the focus relocated by Nowroozi⁽⁵⁾. With the nearest seismic stations a few degrees, away, his computed focus should be correct to within 30 kilometres. An Intensity attenuation study of

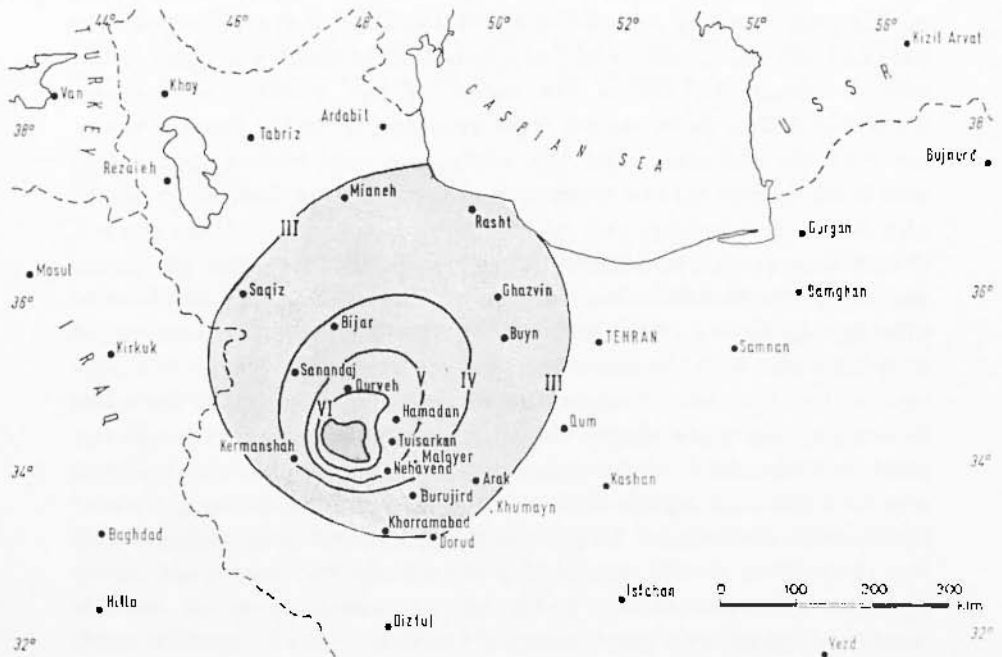


Fig. 1 - Modified Mercalli (MM) Intensity distribution map of 13th December 1957 earthquake.

the main shock carried out by the authors suggests a focal depth of about 35 kilometres (± 5 km) and an attenuation coefficient of 0.5% to the north-east and 2.5% to the southwest of the focus⁽¹¹⁾. The magnitude of the shock calculated by 17 stations varies between 6.0 (OBM) and 7.4 (ATH), with an average of 6.9. The standard magnitude was 7.1 (UPP).

Figure 2 shows a detailed map of the meizoseismal area. The main shock lasted about 10 seconds, and of a population of about 50,000, 1,119 were killed and 900 injured, making 15,000 people homeless. At the time of the earthquake very few of the villagers had left their homes and the loss of life was considerable. The earthquake also killed more than 20,000 animals who were kept indoors because of the intense cold. Many more animals and about 20 people perished after the earthquake from exposure to temperatures well below freezing, particularly during the snow-storm of the 21st December.

The earthquake and its numerous aftershocks destroyed or damaged beyond repair 5,000 housing units out of a total of about 9,000. Most of the local type of dwellings were, and still are, one-storey adobe or rubble masonry houses set in mud and covered with heavy flat roofs of tamped earth. In the larger villages there were a few two-storey adobe houses as well as some one-storey brick masonry buildings covered with Iranian jack-arches or with light roofs of galvanised iron sheets. This latter type of construction was found more frequently in villages on the main road from Hamadan to Kermanshah and in few of the larger mountain villages where it was employed in government buildings. In the meizoseismal area there were no modern engineering structures of any kind.

The worst-hit region was located in small, east-west running mountain valleys, in the upper reaches of the Kangarshahi River, between Kamarah-Kuh and the 3,300-metre high Kuh-i-Nakuchai, Figure 2.

Farsinaj, the largest of the villages with a population of about 1,400, was totally destroyed and 702 people were killed. With the exception of about 30 houses, the walls of which were left standing, all other man-made structures in the village were razed to the ground, including the governor's two-storey brick building. Today, the site of old Farsinaj is an abandoned heap of ruins and a new village has grown about one kilometre away on the east side of the road to Sonqor.

A few kilometres to the southwest of Farsinaj, the small settlement of Dehasiyab was also totally destroyed, and of its 200 inhabitants 34 were killed and 23 injured. The new site on which the village was rebuilt is situated a few hundred metres away, on the west side of the road to Sonqor.

Near-by, the village of Soltantaher was also ruined and two-thirds of its houses collapsed. Out of 443 people, 6 were killed and about 20 injured. The village was rebuilt almost on the same site, with the same materials and methods of construction as before the earthquake.

In the immediate vicinity of Farsinaj, other villages, most of them situated on thin fan deposits, were also ruined and quite a few houses collapsed but without casualties. Some of the settlements to the northeast of Farsinaj, particularly those situated along another east-west running valley, were destroyed. Kalbikhani, a small village on thin gravels, was totally destroyed and 22 out of its 168 inhabitants and all their animals were killed. Further up the valley on weathered rock, the two settlements of Cheqa-Bala and Cheqa-Payn, were totally

ruined with a loss of 63 lives and 65 injured; all their livestock perished in the ruins or killed by rockfalls in the mountains. A few kilometres further east in the same valley, the village of Kabriz on thin alluvium was completely destroyed and 41 of its 201 inhabitants were killed and 12 injured. In contrast, the villages of Kotar and Aqbolaq further southeast, on alluvium, suffered comparatively little damage and no one was killed or injured. At the extreme edge of the valley on thick alluvium, Pirysud and also Bitervan suffered heavy damage; in the former village 8 out of its 240 inhabitants were killed and in the latter one out of 453. With the exception of Teppeshahrak, a mountain village further east of Parsinaj, which was almost totally ruined with the loss of one life, no other settlement within a radius of about 15 kilometres from Parsinaj suffered excessive damage or casualties. At Sonqor, a few houses cracked but nothing collapsed.

To the west and south of Kuh-i-Nakuchai, the earthquake caused considerable damage but no destruction. However, further to the south, Sarab Bidsorkh was almost totally destroyed and 46 of its 346 inhabitants were killed and 44 injured. There, the only spring of water in the region dried up, and rockfalls from the hills to the north of the village killed many cattle. Three kilometres to the west, the damage at Bidsorkh was appreciably less important, most probably because of the better type of houses and the use of light roofing materials. Nevertheless, three quarters of the dwellings in the village were rendered uninhabitable, including the gendarmery which was ruined but without casualties.

Another locality away from Parsinaj which suffered considerable damage was Hemmatabad, a small settlement 4 kilometres north of Sahneh, which was totally ruined and 4 of its 280 inhabitants were killed and 24 injured. In contrast, at Sahneh no one was killed or injured; only a few old houses collapsed and about 50% of the dwellings in the town including the gendarmery buildings were damaged.

To the east of Kuh-i-Nakuchai, damage was comparatively small, varying erratically from place to place but nowhere did the shock cause destruction. Only southwest of Asadabad, at Dawlatabad, 5 people were killed in 7 old houses that collapsed; the remaining 34 houses of the village suffered only minor damage.

Further to the southeast of Parsinaj and to the east of Kuh-i-Bazann in the region of Kangavar, damage was widespread but not serious. Almost all adobe houses in the region were damaged in varying degrees but very few collapsed, and although quite a few

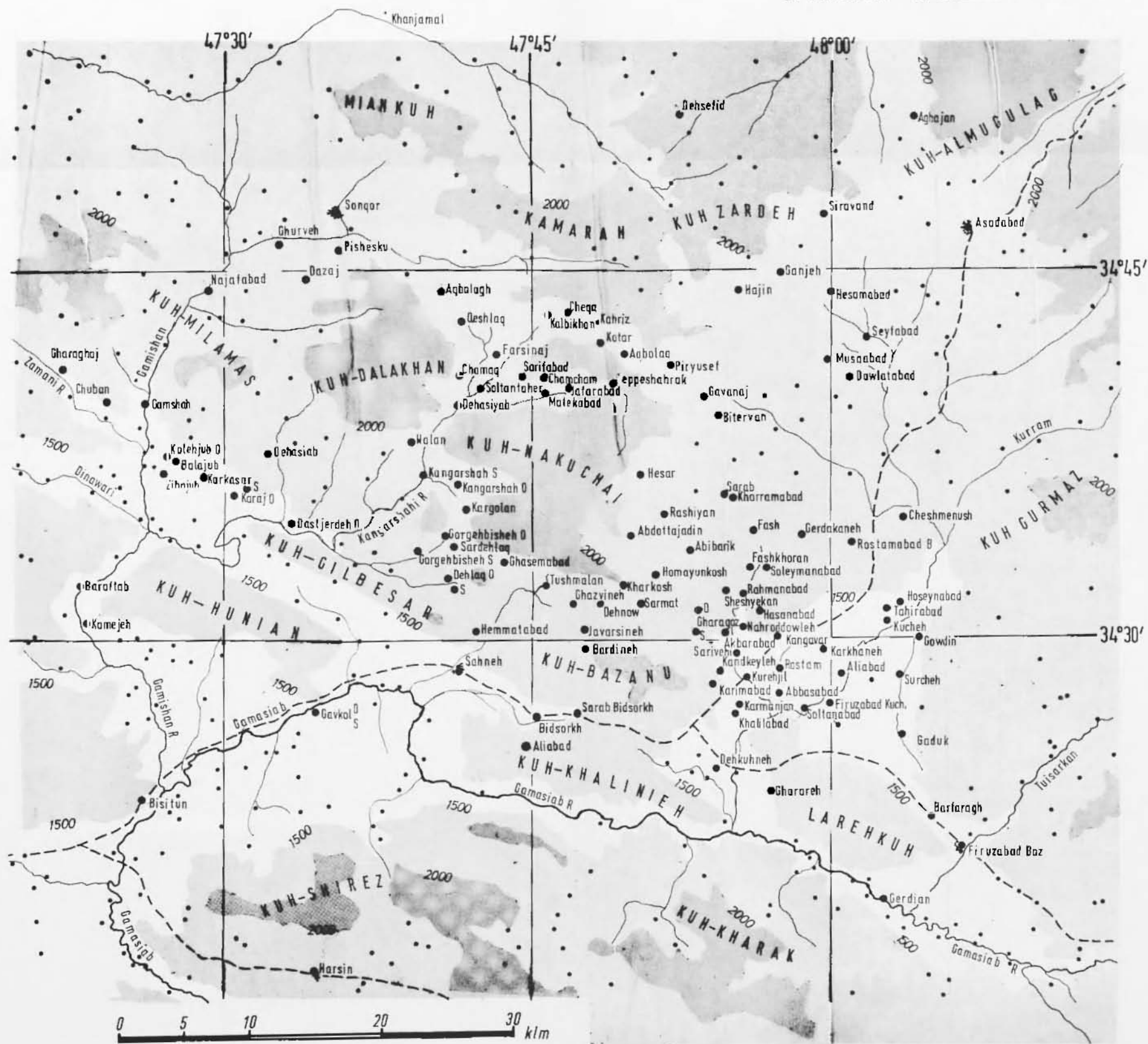


Fig. 2 - Location map showing meizoseismal region of the 13th December 1957 Farsinaj earthquake. Large dots indicate localities affected by the main shock and by its aftershocks. Small dots show localities not affected or at the time of the earthquake uninhabited. Altitude in metres.

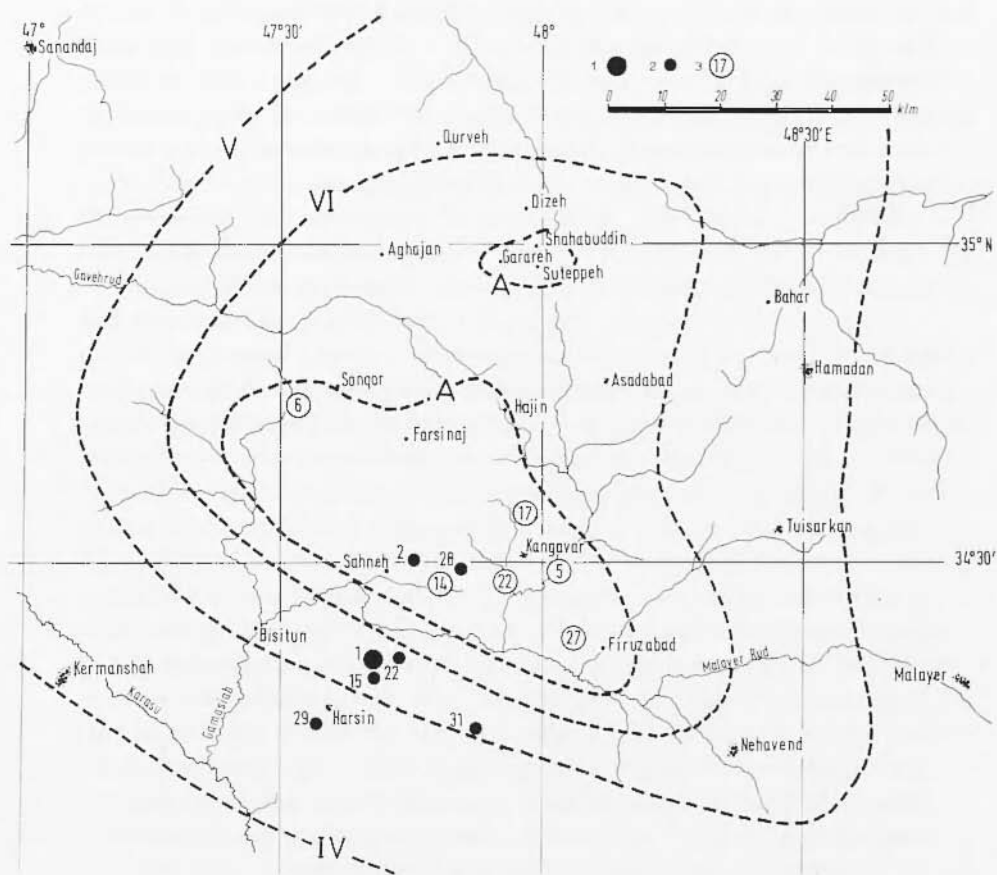


Fig. 3 - Intensity distribution in epicentral region and damage. Within area A, more than 50% of all adobe houses destroyed or damaged beyond repair by main shock and aftershocks. (1) Epicentre of main shock; (2) Epicentres of aftershocks; (3) Approximate locations of macroseismic epicentres of aftershocks. Numbers refer to events listed in Table 1. Isoseismals very approximate.

people were injured, no one was killed. At Kangavar the main shock ruined a few adobe houses and old shops in the bazaar, killing two children but otherwise better built houses suffered little damage.

Villages around Lareh-Kuh also suffered some damage and at Karmanjan and Gaduk a few old houses, including the gendarmery at Gaduk, were ruined.

The region on the northern slopes of Kuh-i-Gilbesar, west of Kuh-i-Nakuchai, was badly shaken and a few adobe houses in the small settlements of Dinawar were totally ruined. Damage was exceptionally high at Zibaju where a few houses fell down killing a child. In the vicinity of Dastjerdeh, Karaj and Karkasar, almost all the houses were cracked but only about 10 collapsed without casualties.

Figure 4 shows the distribution of damage in the meizoseismal region deduced from the study of the effects of the main shock and its aftershocks on more than 150 villages (region A in Figure 4).

Outside this region, the shock was felt at Harsin and Kermanshah with an intensity IV; it lasted 4 to 5 seconds. According to unauthenticated reports, the shock caused minor damage to oil pipes near Kermanshah, most probably due to differential settlement of their supports. At Hamadan, Tuisarkan and Nehavend the earthquake, which lasted more than 10 seconds, caused considerable panic but no damage, except at Qurveh where it caused a few plaster cracks and the ruin of an old house. The shock was felt with an intensity IV at Bijar, Sanandaj and Malayer; it lasted about 20 seconds and caused great panic but absolutely no damage. The limits of the generally felt area were from Khorramabad to Rasht and from Saqiz to Araq, Burujird, Ghazvin and Mianeh. At Rasht, about 350 kilometres to the north, the shock was strongly felt locally, lasting almost one minute. At Araq a few people were awakened. The earthquake was not felt in Tehran, Qum or Tabriz and it has not been reported from Kirkuk, Bagdad and Dizful. According to the Iraqi press only one person on an upper floor in Bagdad felt the shock.

The area within which the Farsinaj earthquake was felt, therefore, is approximately 180,000 square kilometres; it is eccentric with respect to the epicentre and to the northeast of it.

AFTERSHOCK SEQUENCE OF THE FARSINAJ EARTHQUAKE

One of the standard questions we used in our interviews with local inhabitants in order to check their memory was regarding the time of the day or night at which the main shock or the most damaging shock was experienced in their village. Since the main shock had taken place at 05^h15^m local time, we naturally expected the interviewee to reply "at dawn" or "before the first prayer". Most of the subjects we used were exceedingly informative and well aware of natural phenomena

such as earthquakes. However, in certain parts of the meizoseismal region, the answer to this question was systematically different from the one we expected. This, as well as the fact that in some cases villagers insisted that their homes were destroyed after the Farsinaj earthquake, made us suspect that perhaps some of the reported damage was in fact due to strong aftershocks. This suspicion was soon confirmed by the times shown in some press reports for the most damaging aftershocks, as well as by the approximate origin times of a number of shocks we deduced from arrival times at stations within 10 to 20 degrees from central Zagros.

Within two months of the main shock, more than 40 comparatively large aftershocks were felt. Some of them were strong enough to cause additional damage in the epicentral area or to enlarge the meizoseismal region in a southeast-northwest direction. Half of these aftershocks were recorded by near-by seismic stations, but to only 7 of them was it possible to assign relatively accurate epicentres, Figures 3, Table 1.

Aftershocks were being felt intermittently in Farsinaj and to the north of the ruined town for about 22 hours after the main shock. At about 02^h30^m local time of the following day, a violent aftershock, causing serious damage in the region of Kangavar for the first time, ruined 15 villages, including Aliabad and Surcheh. The region which was affected had so far escaped with minor damage; it is located near the southeast extremity of the epicentral area, and the shock of the 14th December killed more than 20 people and injured 50, Figure 3.

Two hours later, at dawn, another shock ruined many houses in the region of Najafabad, Dazaj and Ghurveh, a region located to the northwest of Farsinaj at the northwest extremity of the epicentral region. The main shock of the 13th of December had caused considerable panic there and a few walls cracked but otherwise there was no serious damage. The aftershock of the 14th of December killed one and mortally wounded 4 people, bringing about the complete ruin of a number of settlements in the Najafabad area.

A few days later, on the 16th of December, two very strong aftershocks in the region south of Farsinaj, caused fresh damage, heavier than that produced by the main shock, particularly in the region of Javarshineh, Kharkosh and Sarab. Villagers from Ghasemabad and Kharkosh were fully aware of the Farsinaj earthquake which a few days earlier had caused great concern and some minor damage to their villages. They insisted, however, that it was the shock of the 16th that caused the ruin of their homes.

Damage to villages in the Fash area had, up to the 18th of December, been insignificant. Previous shocks and the main shock had caused panic and some minor damage, which on the afternoon of the 18th was seriously aggravated by a strong aftershock. It ruined many houses in a number of settlements around Fash, particularly at Sheshyekan where 14 people were killed and as many injured.

On the 25th of December, another strong aftershock caused additional damage in the region between Javarshined and Sarab Bid-sorkh, where many ruins collapsed and a few houses were seriously damaged. The shock was strongly felt at Sahneh and Kangavar where it caused minor damage and great panic.

Throughout late December aftershocks of damaging intensity continued to occur and these were being strongly felt mainly in the southeastern extremity of the meizoseismal region. At noon on the 31st December, a violent aftershock enlarged the damaged area in a southeasterly direction. In Kangavar the shock killed 3 people and ruined a number of houses causing new damage to some of those already repaired. At Dehkuhneh and in the neighbouring villages most houses were ruined, and at Gerdian, Gharareh and Firuzabad many adobe walls cracked and a few roofs caved in.

During the first two weeks of January 1958 aftershocks were being felt mainly in the region of Firuzabad, Kangavar and to the southeast of the epicentral area. There are no reports of damaging aftershocks from the region of Farsinaj for that period.

Figure 3 shows the extent and approximate location of the region affected by the largest aftershocks of the Farsinaj sequence. Although it is not possible with the data available at the moment to establish how aftershock activity changed with time, there is, however, good macroseismic evidence that suggests a progressive expansion of the area of aftershock activity to the northwest and particularly to the southeast of the region of Farsinaj towards Kangavar and Firuzabad.

GROUND DEFORMATIONS

A cursory reconnaissance survey, based on information received from local inhabitants, disclosed a fracture between Karaj Olia and Karkasar, probably of tectonic origin, Figure 4. Villagers from Karaj recall ground fractures appearing after the Fatsinaj earthquake as a result of which the mountain-side (northeast part of the valley) was

TABLE I

N.	Date	Origin Time GMT h m s	Epicentre N E	Focal depth km	M	Local Time h m	Macroseismic effects
0	1957 Dec. 12	01 20	—	—	—	04 50	Foreshock, strongly felt at Kangavar.
1	13	01 45 04	34.35°-47.67° 34.62°-47.82° 34.60°-47.80° 34.41°-47.67°	40 7 11 42	7.1	05 15	Main Shock, Nowroozi (1971) " Peronaci (1959) " BCIS " ISS
2		04 12 57	34.50°-47.75°	—	—	07 40	Damaging shock in the region north of Farsinaj; strongly felt at Sonqor and Sanandaj.
3		06 36	—	—	—	10	Violent shock with damage in the region of Farsinaj.
4		08 31	—	—	—	12	Farsinaj totally ruined.
5		23 05	—	—	—	26 30	Violent shock responsible for the main damage in the region of Kangavar and to the southeast of the town where 15 villages were ruined and a number of people killed; strongly felt at Malayer.
6	14	00 19 24	34.50°-47.75°	—	—	04	Very strong shock responsible for the main damage at Glurveh, Dazaj Najafabad and Ghararch Kolyai; strongly felt at Sanandaj, Hamadan, Kermanshah and to a lesser extent in Kangavar.
7		09 11	—	—	—	12 30	Strongly felt at Kangavar.
8		11 58	—	—	—	15 30	Damaging shock at Sahneh and Kangavar.
9		16 45	—	—	—	20 20	Mild shock at Kangavar.
10		22 01	—	—	—	25 30	Strong shock at Kangavar.
11	15	03 30	—	—	—	07	Series of shocks lasting a few minutes in Sahneh and Kangavar.
12		08 29	—	—	—	12	Damaging shock at Sahneh.
13		18 29	—	—	—	22	More shocks at Sahneh.
14	16	17 31	—	—	—	21	Violent shock responsible for the main damage in the region between Karkosh and Javarshineh. The village of Ghasemabad was ruined.
15		23 05 36	34.33°-47.67°	68	—	26	Very strong earthquake causing additional damage and casualties at Sarab Bidsorkh and Javarshineh.
16	17	04 19	—	—	—	08	Long series of shocks in the region of Farsinaj, continuing intermittently throughout the day.
17	18	13 22	—	—	—	16 50	Damaging shock in the region southwest of Asabadad, in the Fash area.
18	21	—	—	—	—	20	Three violent shocks causing some damage in the region to the north of Harsin; strongly felt at Sonqor, Sahneh, Kangavar and Nahavand.
19	22	—	—	—	—	16	Strongly felt at Kangavar.
20	23	—	—	—	—	08	Felt throughout the region, particularly at Kangavar and Kurveh.
21	24	12 27	—	—	—	15 50	Strong shock, followed by others, felt over a large area, particularly at Sahneh, Sonqor, Kangavar, Khan-Jamal and Ghaitas.
22	25	11 26 39	34.35°-47.72°	53	—	15 10	New damaging shock in the region of Javarshineh and Sarab Bidsorkh; many ruins collapsed; strongly felt at Sahneh and Kangavar. More damaging shocks occurred in the night.
23		20 40	—	—	—	24	Strong shocks in the region of Sarab Bidsorkh and Farsinaj.
24	27	—	—	—	—	08	Strong shocks caused the collapse of ruins at Farsinaj, Najafabad and Sonqor.
25	28	—	—	—	—	—	Weaker shocks felt in the Farsinaj region throughout the day.
26	29	—	—	—	—	04 30	Three strong shocks at Farsinaj.
27	31	—	—	—	—	11 35	The most damaging shock in Kangavar where a number of houses collapsed killing 3 people. At Dehkuhneh most houses were ruined; minor damage at Gararch, Gherdian and Firuzabad Bozorgh.
28	1958 Jan. 2	15 45 29	34.40°-47.48°	53	4.75	19	Strongly felt at Kangavar; minor damage at Aliabad and Firuzabad.
29		22 14 45	34.25°-47.56°	85	—	25 40	Violent at Kangavar with minor damage; strongly felt at Asabadad, Nehavend and Hamadan.
30		08 14	—	—	—	12	Felt at Sahneh.
31		09 54 18	34.23°-47.87°	89	—	13	Strongly felt throughout the region, particularly at Sahneh, Harsin and Malayer. Minor damage at Kangavar and Firuzabad.
32		7	—	—	—	—	Series of violent shocks caused additional damage to villages in the region of Kangavar.
33		8	—	—	—	—	Numerous shocks at Kangavar without damage.
34		9	—	—	—	—	Two shocks causing minor damage in the region of Kangavar.
35		13	—	—	—	—	Series of shocks in the region of Sahneh and Kangavar, without damage.
36		15	—	—	—	00	Strongly felt at Kangavar.
37		17	—	—	—	—	Series of weaker shocks in Kangavar.
38		21	—	—	—	—	Two sharp shocks felt in Kangavar and Gaduk; felt in Asabadad and Hamadan.
39		28	03 10	—	—	04 30	Damaging shock at Shahneh and Kangavar; felt in Malayer.
40	Feb. 4	10 53	—	—	—	14 30	Felt in Kangavar.
41	12	—	—	—	—	—	Felt in Sahneh.
42	14	—	—	—	—	07	Violent shock caused some damage at Kangavar and Sahneh; felt in Hamadan, Kermanshah and Saqiz.
43		—	—	—	—	21 50	Strongly felt in Hamadan where it caused panic.
44		—	—	—	—	23 30	Strongly felt in the region between Hamadan and Asabadad where it caused panic.
45	15	—	—	—	—	—	Strongly felt at Kangavar.
46	17	—	—	—	—	—	Series of minor shocks at Kangavar.

downthrown by one metre (!). This fracture, they attest, could be followed all the way to Karkasar. As a matter of fact, about 900 metres to the northeast of the village, linear topographic features in the form of terraces and shallow saddles bearing 130°E , do follow the projected trend of fractures alluded to by the villagers. These fractures, which are mainly in alluvium and in one place in conglomerates, suggest very recent normal faulting and show no evidence of lateral motion. There is little doubt that these linear features, which northeast of Karkasar are quite clear, are in fact on the extension of the ground fractures referred to by the inhabitants of Karaj. However, movements on this alignment in 1957 are not corroborated by the villagers of Karkasar. Their impression is that to the south of this lineament the ground settled and in places opened up over short distances after the earthquake of the 21st September 1958.

Another location where there is some evidence of significant ground fractures is 3.2 kilometres from Sahneh, on the new road to Farsinaj and 0.5 kilometres to the east of that point. Here, villagers from Hemmatabad remembered that the rocks were shattered over a wide zone which could be followed in a southeasterly direction to the old road and from there all the way to Bidsorkh. Again here the direction of the alleged fracture zone coincides with linear trends across limestone ridges and small valleys on which 16 years after the earthquake no clear evidence of recent movements could be found.

A less convincing case of ground deformations of tectonic origin was found between Ghasemabad and Tushmalan. Here all indications point to the occurrence of rockfalls and slides, although the drying up of two springs of water and the "breaking up of the ground into steps" may have some bearing on the reactivation of a local tectonic lineament.

The following information refers indirectly to faulting. Extensive upheaval of the ground was reported between Kangarshah Olia and Kargolan with landslides and rockfalls along a zone bearing N-120-E . Along the same direction as well as between Soltantahir and Chomaq-teppe springs of water dried up and ground settlements disrupted footpaths for a few kilometres from Dehasiyab all the way up to Kuh-i-Nakuehai.

According to Mitchell⁽³⁾, near Gahvareh the earthquake had caused a "fault to develop on the mountain-side" and at the time of his visit, in December 1957, a mass of rock, about half a million cubic metres, was in the process of descending to the river by gravitational creep. Gahvareh, on the Ab-i-Zimkan, is more than

120 kilometres west-southwest of Farsinaj and the shaking there was very slight, but strong enough to trigger an incipient slide.

DISTRIBUTION OF DAMAGE

Although it is not possible to completely separate the effects of the main shock from those of its aftershocks, it appears that the region within which cumulative damage to the Iranian adobe house was serious, did not exceed about 7,000 square kilometres, a region within which intensities should have been equal to or greater than VI (MM), an average intensity above which adobe houses begin to show serious signs of distress, Figure 3.

Within this region maximum damage was spread over a large area, Figure 3, shown in some detail in Figure 4, but in this area it was not possible to assess intensities nor define precisely parts of the region which were affected more by aftershocks than by the main shock. A reevaluation of all available data suggests that the predominant epicentral intensity of the Farsinaj earthquake did not exceed VI (MM), i.e. a more moderate surface intensity over a much wider area (2,800 square kilometres) than comparable magnitude earthquakes in other parts of Iran. Local site conditions and the effect of some of the aftershocks apparently resulted in heavier damage in places to which an intensity of VII may be assigned (areas B and C in Figure 4).

Of the three zones of relatively heavy damage inside the generally affected area, only zone C_1 , in the vicinity of Farsinaj, should be considered to be the immediate result of the main shock. The other two zones of heavy damage are most certainly associated with the combined, effects of the main shock and of its aftershock. Thus zone C_2 , to the northwest of Farsinaj, depicts the approximate location and limits of the area primarily damaged by the aftershock of the 14th of December, while the much larger zone C_3 and also the extension of zone A towards Firuzabad should be considered to be the combined result of the aftershocks of the 16th, 25th and 31st December 1957.

As can be seen from Figures 1 and 4, the highly asymmetric distribution of the macroseismic effects of the Farsinaj earthquake about the Firuzabad-Sarab-Gharaghaj meizoseismal axis, is indeed remarkable. Both intensity and damage fall off with distance to the southwest of the axis almost 20 times faster than to the northeast. As a matter of

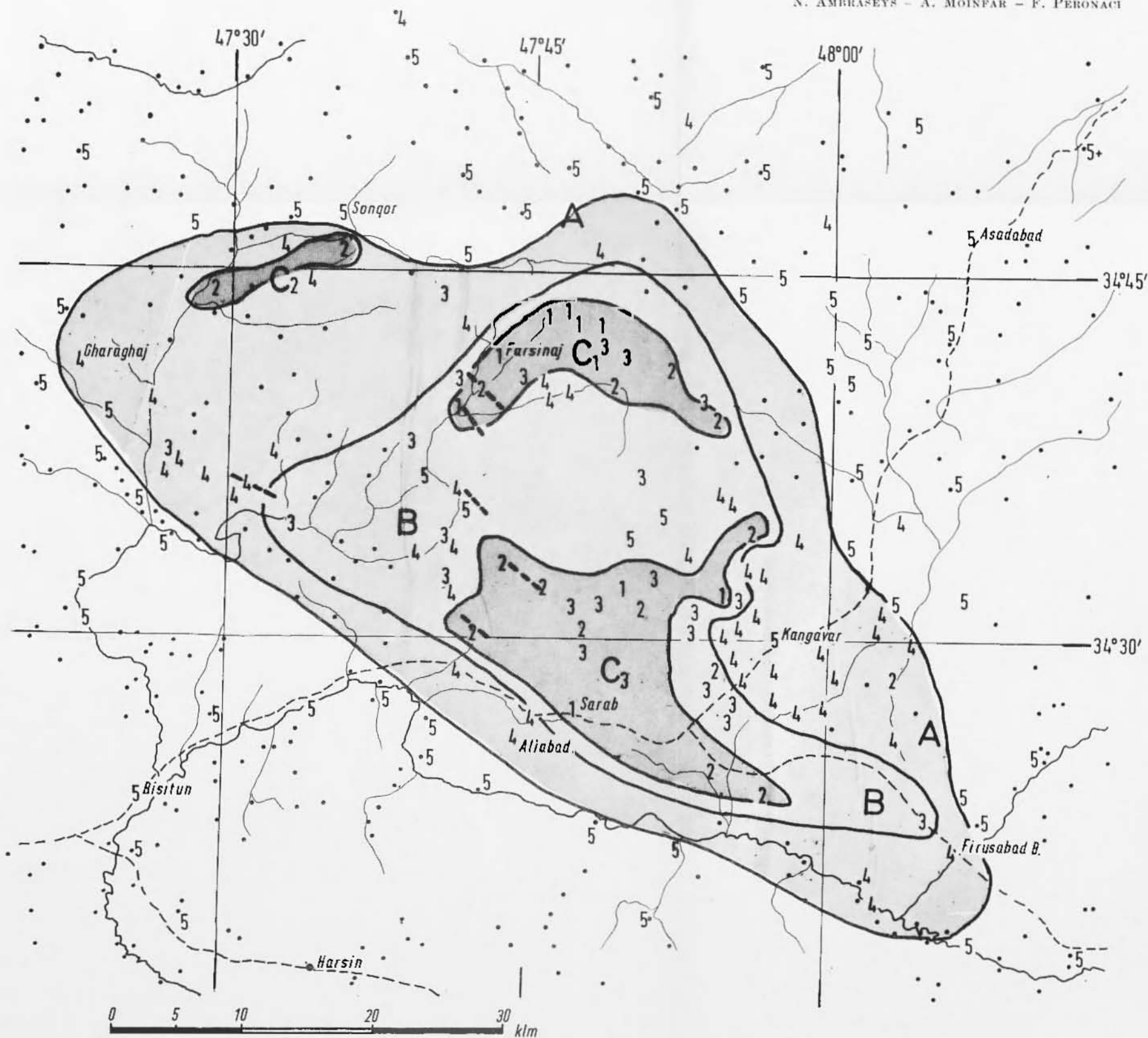


Fig. 4 - Damage map. Numerals show location of affected villages and degree of damage. (1) 100% of adobe houses destroyed or damaged beyond repair with more than 10% casualties; (2) 100% destruction with less than 10% casualties; (3) 100% of adobe houses damaged beyond repair or destroyed without fatalities; (4) 50% to 99% of adobe houses destroyed or damaged beyond repair without casualties; (5) damage less than 50%. Dots indicate sites not damaged or uninhabited at the time. Area marked A - more than 50% of adobe houses ruined; B - all adobe houses destroyed or ruined and subsequently abandoned with small loss of life; C - total destruction with heavy loss of life. Dashed lines indicate location and approximate extent of ground deformations most probably associated with the Farsinaj earthquake and its aftershocks. Thin dashed lines show main roads.

fact villages to the south of the road between Sahneh and Bisitum, along the Gamasiab river, suffered absolutely no damage and at Harsin the main shock was felt with an intensity hardly greater than IV.

CONCLUSIONS

It has proved perfectly feasible to carry out field investigations of an earthquake in Iran which happened 16 years ago. Both published and unpublished information as well as interviewees with local inhabitants suggest that the Farsinaj earthquake is larger than any previously known earthquake in this part of the Zagros.

The main shock was responsible for widespread but not excessive damage over a comparatively large area to the northeast of an axis aligned in a northwest-southeast direction. Both damage and intensity distribution show quite clearly that vibrational energy radiated away to the northeast of this axis far more efficiently than to the southwest of it. The comparatively large size of the meizoseismal region suggests a focus in the lower portion of the crust.

The main earthquake was followed by a rather long series of comparatively large damaging aftershocks. These shocks not only aggravated damage but also progressively enlarged the meizoseismal region in a southeasterly direction along a northwest-southeast trending axis.

From Figure 3 it can be seen that the epicentres of the main shock and of 4 of the 6 aftershocks (5) lie outside and to the south of the meizoseismal region; they are aligned in a southwest-northeast direction, at right angles to the trend of the meizoseismal axis. A similar alignment of epicentres in the Zagros has been observed by *Gansser* (1). However, in the present case the accuracy of the hypocentres of the Farsinaj sequence and their number are not sufficient to evaluate the significance of these observations.

There is some evidence that the Farsinaj earthquake or perhaps some of its larger aftershocks, were associated with ground deformations, which in some places aligne with, and elsewhere define structural trends or coincide with Recent faults. There is insufficient evidence, however, to show conclusively that these deformations were of tectonic origin. Their significance lies in the fact that they have been found in the vicinity of, or aligned with pronounced structural trends and Recent faults.

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