

## Recent destructive earthquakes in the Central Alborz (Iran)

J. S. TCHALENKO (\*)

Received on January 21st, 1973

**SUMMARY.** --- Macroseismic data based on field work and bibliographical research is given for six little-known destructive earthquakes which occurred in the Central Alborz, Iran, during the 20th Century. They are: Ah-Mobarakabad 1930, Alborz 1935, Garmsar 1945, Musha 1955, Sangechal 1957 and Babol-Kenar 1971. The locations of the two largest of these earthquakes (1935, and 1957) were fortunately at some distance from the densely populated regions of Tehran and the coastal towns of the Caspian Sea.

**RIASSUNTO.** — Sono stati raccolti dati macrosismici, mediante ricerche in loco e bibliografiche, relativi a sei terremoti distruttivi poco conosciuti che sono avvenuti nel XX secolo nella regione dell'Alborz centrale (Iran). Località ed anni sono i seguenti: Ah-Mobarakabad, 1930; Alborz, 1935; Garmsar, 1945; Musha, 1955; Sangechal, 1957; Babol-Kenar, 1971. I più forti di questi terremoti (1935-1957) avvennero fortunatamente ad una certa distanza dalle zone più densamente popolate di Teheran e delle città costiere del Mar Caspio.

### 1. - INTRODUCTION

The study of the seismicity of the Central Alborz mountains in Iran is of particular importance because the region is bordered by two of the most populated areas of the country, i.e. the Tehran agglomeration in the south, and the coastal towns of the Caspian Sea in

---

(\*) Engineering Seismology, Imperial College, London sw7.

the north. Yet, due to a lack of reliable published macroseismic data, very little is known of these events, even of the more recent destructive ones which took place less than two decades ago. After about 1960, instrumental determinations of earthquakes have increased in accuracy, and new microseismic techniques are being applied to the study of the seismicity of the Middle East (<sup>12,13,16,17</sup>), but the uncertainty in epicentral, depth and magnitude determinations for Iran, especially for the earlier periods, makes it increasingly important to acquire accurate macroseismic information, at least for the larger destructive events.

The present note collates the information available on 6 destructive earthquakes which occurred this century in the Central Alborz region of North-central Iran. It is not an exhaustive compilation, as more data will no doubt be obtained from a systematic study of the Persian press and literature, and from further field investigations. It is hoped however that this note may constitute a starting point for future research on the problem.

## 2. - SOURCES CONSULTED

Most of the existing macroseismic data on the earthquakes described here is contained in earthquake catalogues (<sup>18,20,23,27</sup>) which were usually found to be too general for the present study. Further information was obtained from various published and unpublished reports, from Persian and European press reports, and from interviews of survivors conducted by the author in 1971 with the help of H. Iranmanesh and A. Mohajer-Ashjai. The main sources used in addition to the earthquake catalogues are as follows: *1930 earthquake*, Field Mission (1971) and Etela'at (3 Oct. 1930); *1935 earthquakes*, Field Mission (1971), British Embassy reports and Etela'at (20 April 1935); *1945 earthquake*, Bozorgnia (<sup>8</sup>) and Etela'at (12 May 1945); *1955 earthquake*, Field Mission (1971), Bozorgnia (<sup>8</sup>) and Etela'at (25 Nov. 1955); *1957 earthquake*, Vrolyk (<sup>26</sup>), Savage (<sup>21</sup>) and Field Mission (1971); *1971 earthquake*, Tchalenko, Iranmanesh and Mohajer-Ashjai (<sup>24</sup>).

The instrumentally determined parameters of the earthquakes are given in Table 1 and the locations and areas covered by the large scale maps are shown in Fig. 1.

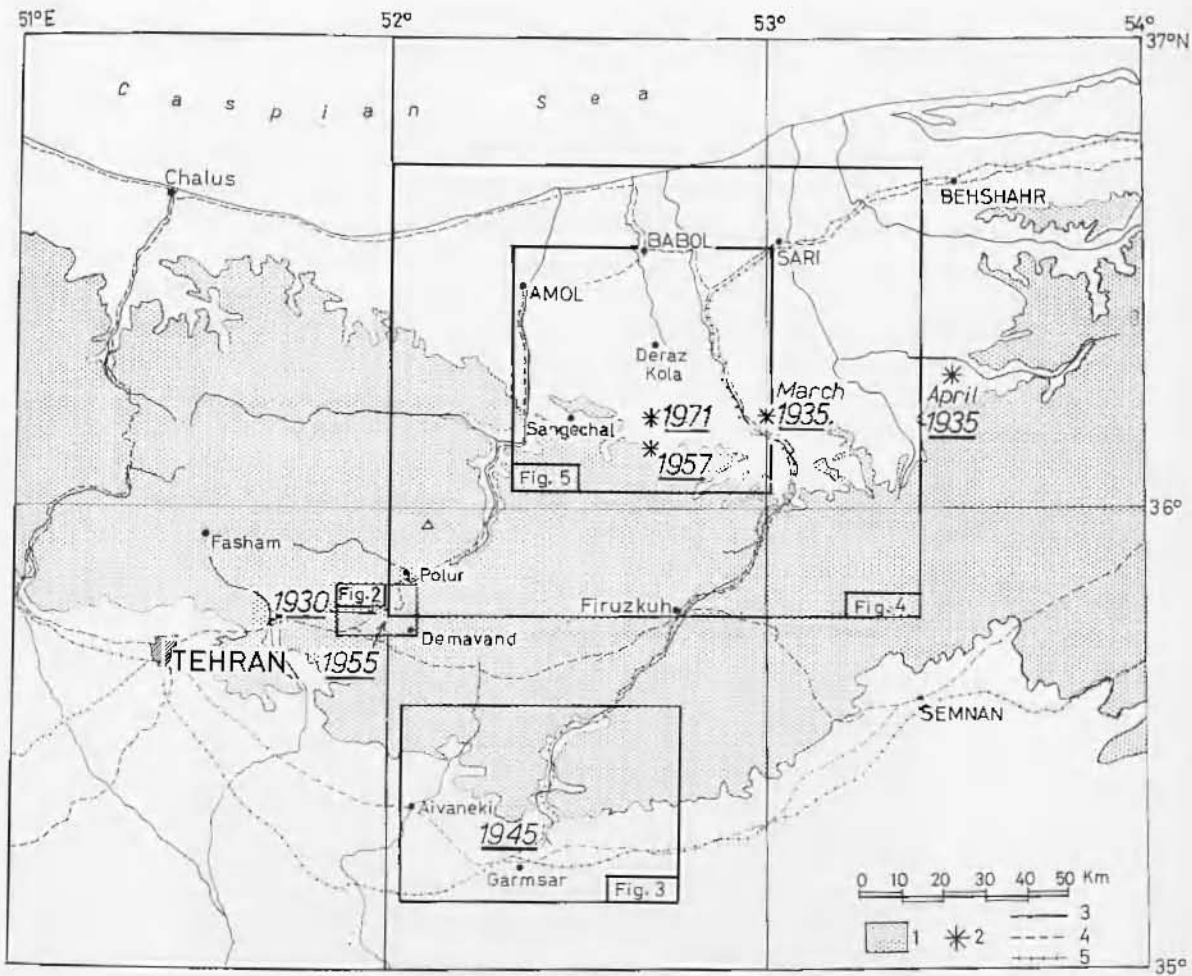


Fig. 1. - Location of 20th C. Destructive Earthquakes in the central Alborz. - 1. Regions above 1500 m. - 2. Instrumental epicentre. - 3. Principal river. - 4. Major road. - 5. Railroad. Inserts refer to maps given in the text.

### 3. - DESTRUCTIVE EARTHQUAKES

#### 3.1. - *Ah-Mobarakabad Earthquake, 1930*

The earthquake occurred on 22nd October, 1930 at 15<sup>h</sup>33<sup>m</sup>12<sup>s</sup> GMT. The instrumental epicentre was determined by ISS at 35.8°N, 52.1°

and the magnitude estimated to be above 5 (Table 1). A few villages in the Ab-Ali valley (Fig. 2 and Pl. I) were partly destroyed: in Ah, 28 houses collapsed and one person was killed; in Sarpurak most houses collapsed and two persons were killed, and in Mobarakabad (Pl. II) a few houses collapsed and many others were severely damaged. Further away from the epicentre, the walls of some houses in Damavand and Dasht-e Mazar were fissured; and in Tehran, some qanats were damaged. Ground fractures, probably of landslide origin, were reported in the mountains north-east of Mobarakabad. Some further damage was caused to the villages mentioned above by two aftershocks which occurred at about 5 minutes interval on 7th October, 1930, and which were felt in Tehran, Firuzkuh, Kashan and Nantaz.

Despite its low magnitude and the relatively small amount of damage caused, the earthquake is important because of its proximity to Tehran and its location on the Musha-Fasham fault zone, a branch of which, the North Tehran Fault, passes through the northern suburbs of the capital (23).



Pl. I - AB-ALI VALLEY -- S = Sarpurak; A = Ah. The large building with the white roof is the Ab-Ali casino. Looking south (see Fig. 2).

3.2. — *Alborz Earthquakes, March and April 1935*

Very little is known of the two earthquakes which occurred in the Alborz mountains east of the Talar Rud and caused destruction in the Shahi and Sari administrative districts. The first shock which took place on the *5th March 1935* at  $10^{\text{h}}26^{\text{m}}37^{\text{s}}$  GMT was located at  $36.2^{\circ}\text{N } 53.0^{\circ}\text{E}$  and had a magnitude of less than 6 (Table 1). The Persian press and the British Embassy in Tehran stated that 27 villages were affected and that over 60 people lost their lives. The second and more severe earthquake, on the *11th April, 1935* at  $23^{\text{h}}14^{\text{m}}49^{\text{s}}$ , was located at  $36.3^{\circ}\text{N}, 53.5^{\circ}\text{E}$  and had a magnitude of about  $6\frac{3}{4}$  (Table 1). About 500 people were killed in this earthquake, many mountain villages were destroyed and buildings were damaged in Sari and Bandar Shah. The railway line east of Sari was also slightly damaged and a large rockfall was reported at the confluence of the



Pl. II — MOBAREKABAD — The village of Mobarakabad is at the head of the Ab-Ali valley which crosses the picture from left to right. The subsidiary valley in the left background marks the trace of the Musha-Fasham fault zone. Looking west (see Fig. 2).

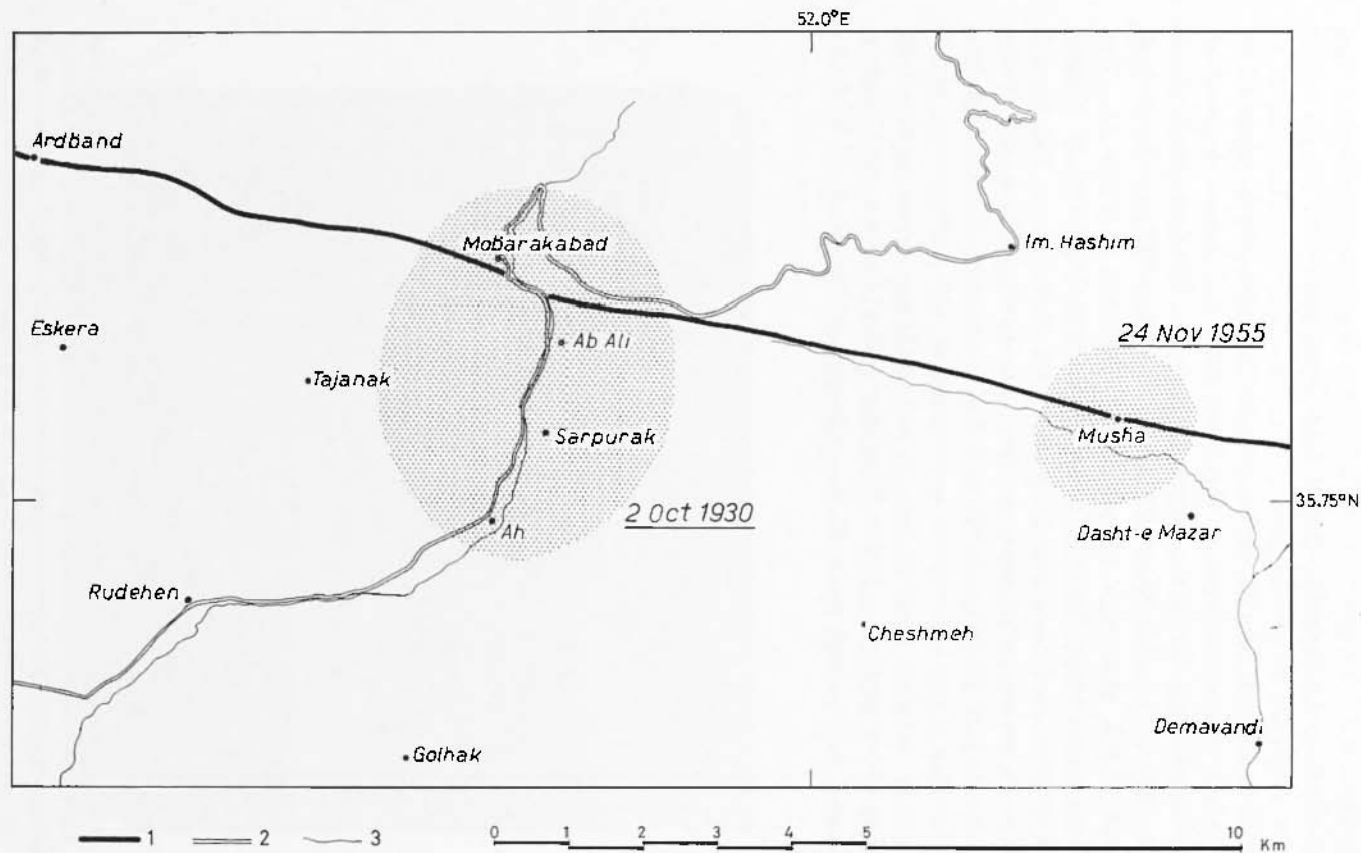


Fig. 2. - Epicentral Regions of the Ah-Mobarakabad 1930 and Musha 1955 Earthquakes. - 1. Masha-Fasham fault zone. - 2. Tehran-Amol road. - 3. River. Shaded areas indicate approximate limits of damage.

Table 1 - INSTRUMENTAL PARAMETERS FOR THE DESTRUCTIVE EARTHQUAKES IN THE CENTRAL ALBORZ

Earthquake	Date	Time (GMT)	Epicentre		Magnitude	Focal Depth Km	Source	
			N	E				
Ah-Mobarakabad	2 Oct. 1930	15 33 12	35.8	52.1	$5\frac{1}{4}$ - $5\frac{1}{2}$ (*)		ISS (11)	
		15 33 —	35.8	52.1	5		CCP (6)	
Alborz	5 Mar. 1935	10 26 37	36.2	53.0	$5\frac{1}{2}$ - $5\frac{3}{4}$ (*)		ISS (11)	
		10 26 35	$36\frac{1}{2}$	$53\frac{3}{4}$	6		GR (9)	
		10 26 37	36.2	53.0	$5\frac{1}{2}$		CCP (6)	
		10 26 —	37	53	5.8		BCIS (4)	
Alborz	11 Apr. 1935	23 14 49	36.3	53.5			ISS (11)	
		23 14 43	$36\frac{1}{2}$	$53\frac{3}{4}$			$6\frac{3}{4}$	GR (9)
		23 14 43	36.1	53.5			$6\frac{1}{2}$	CCP (6)
		23 14 49	37	53			6.3	BCIS (4)
Garmsar	11 May 1945	20 17 28	34.8	52.1	$4\frac{3}{4}$ (*)		ISS (11)	
		20 17 38	36	$52\frac{1}{2}$			BCIS (4)	
Sangechal	2 Jul. 1957	00 42 23	36.14	52.7	average		10	
		00 42 22	36.21	52.72	magnitude		0	Nowroozi (16)
		00 42 23	36	53	7.3		ISS (11)	
		00 42 24	36.1	52.3			USCG (25)	
Babol Kenar	9 Aug. 1971	02 54 36	36.2	52.7	5.2	27	USCGS (25)	

For Source abbreviations see References.

(\*) After Nabavi (1972).

Farim Rud and Saidabad Rud. This earthquake was followed by many aftershocks, one of which occurred during the 3rd week in April and caused further damage to the buildings in Sari.

At least one of the 1935 earthquakes was strongly felt in Babol Kenar, the epicentral region of the 1971 earthquake. It would appear that the 1935 and 1971 earthquake concerned the northern foothills of the Alborz below about 1500m (Fig. 1), whereas the 1957 earthquake was mainly confined to the mountainous regions further south (see also section 3.5).

### 3.3. - *Garmsar Earthquake, 1945*

The earthquake occurred on the 11 May 1945 in the afternoon and caused heavy damage in the Garmsar region (Fig. 3). The instrumental data for Iran on that day indicates an earthquake at  $20^{\text{h}}17^{\text{m}}28^{\text{s}}$  and of magnitude about  $4\frac{3}{4}$ , but located 50 km southwest of Garmsar (Table 1). As the data is generally poor for the Middle East during the 2nd World War years, it is not known whether this epicentre is very inaccurate or whether it refers to a different event. From the Persian press we know that Baramch, Garmsar, Bonkuh and Qeshlag were damaged (Fig. 3). In Garmsar nearly all the houses were destroyed, in Qeshlag 60 houses collapsed, and in Bonkuh the railway station was damaged and two persons were thrown down. Altogether, the reports state that a total of about 2,000 houses were severely damaged, but they vary as to the number of persons killed (between 8 and 20) and injured (between 17 and 80).

Ground fractures of unknown origin, and landslides, were reported at Bonkuh.

The main event was felt as three distinctive shocks and continuous shaking lasted for about one hour. Aftershocks continued for about one week. Approximately one month later on 19th June 1945, another shock caused slight damage in Garmsar.

The epicentral location of this earthquake seems to be the same as that of the earthquake of 743 A.D. mentioned by Ambraseys<sup>(2)</sup>.

### 3.4. - *Musha Earthquake, 1955*

On 24th November 1955 a small shock damaged most of the houses in Musha, a village located north of Damavand village (Fig. 2).



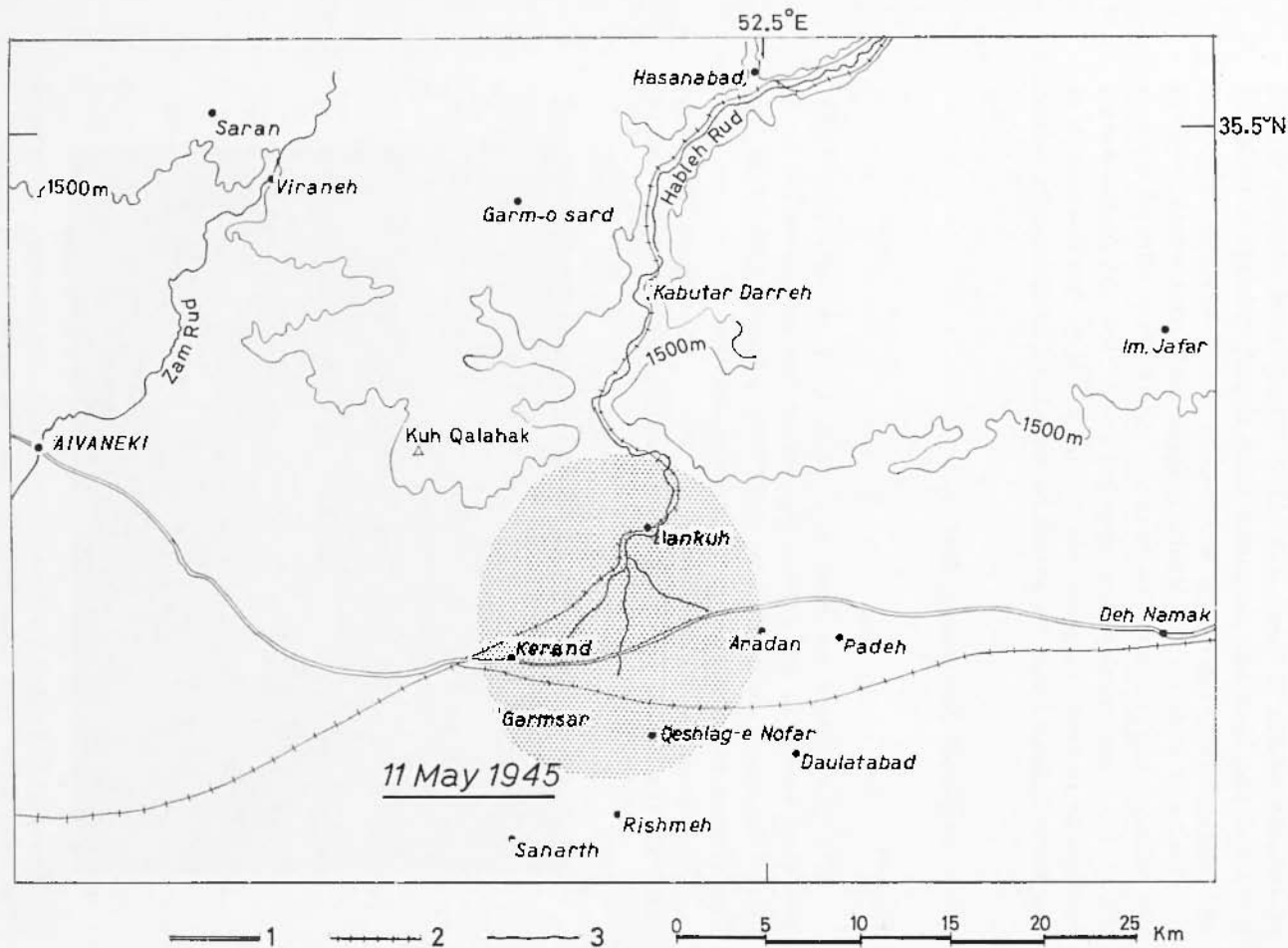


Fig. 3. - Epicentral region of the Garmsar 1945 Earthquake. - 1. Tehran-Semnan road. - 2. Railroad. - 3. Principal river. Shaded area indicates approximate limit of damage.

There is no instrumental data for this event which was presumably in the magnitude 4 range. In 1971 the villagers confirmed that there had not been any casualties even though one house collapsed and most of the others were fissured.

Musha is built on the Musha-Fasham fault zone which, west of the village, can be seen to truncate Quaternary alluvial terraces (Pl. III). This earthquake, together with the Ah-Mobarakabad earthquake of 1930, suggests that the fault and its branches, such as the North Tehran Fault (23), should be considered as seismically active.

### 3.5. - *Sangechal Earthquake, 1957*

#### *General*

The earthquake occurred on 2 July 1957 at 00<sup>h</sup>42<sup>m</sup>23<sup>s</sup> GMT. The most recent of the various epicentral determinations (Table 1) locates the shock at 36.14°N 52.70°E with a focal depth of 10 km. The average magnitude from several stations was 7.3.

The epicentral region covered an area of the Alborz mountains north of the median drainage divide and approximately contained,



Pl. III - MUSHA-FASHAM FAULT ZONE NEAR MUSHA --- The ridge in the right foreground is the trace of the fault through Quaternary fan or terrace material cemented by travertine. Looking west from Musha.

between the Haraz Rud and Talar Rud Valleys (Fig. 4). Even under normal circumstances, parts of this region are of extremely difficult access, and after the earthquake the situation was aggravated by numerous rockfalls which blocked all the main access routes. In

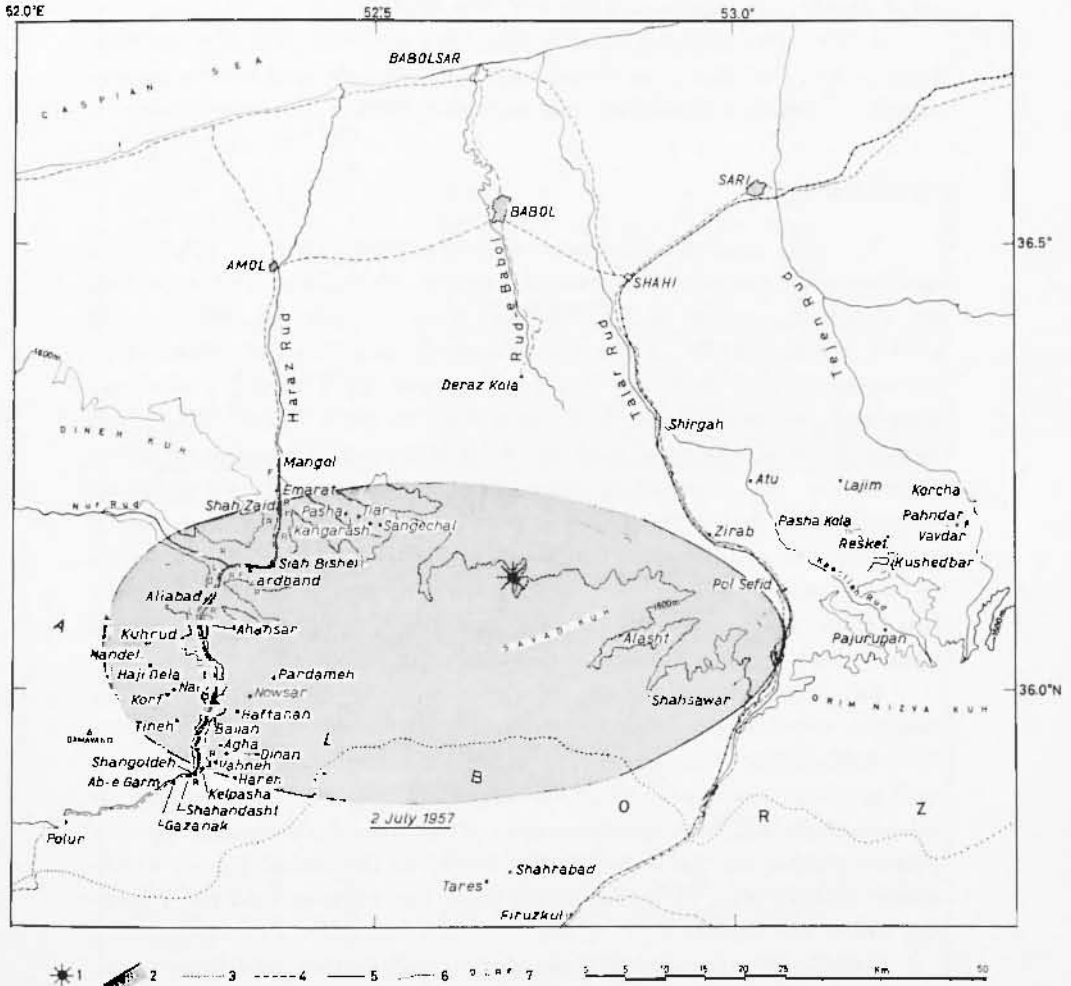


Fig. 4. - Epicentral Region of the Sangechal 1957 Earthquake. - 1. Instrumental epicentre. - 2. Approximate limits of the region of total destruction. - 3. Median Alborz drainage divide. - 4. Major road. - 5. Railroad. - 6. Principal river. - 7. D = damaged bridge or tunnel; L = landslide; R = rockfall; F = ground fracture. Only villages and towns for which macroseismic data is available are shown on the map.

consequence, the macroseismic data is often incomplete and, for some regions, lacking entirely.

The total number of people killed was variously estimated at 480<sup>(19)</sup>, over 1000 (Persian press) and more than 1200<sup>(19,20,26)</sup>. The information collected here for 50 towns and villages shows that the total number of fatalities exceeded 970 (Table 2).

Relief was organised by the Red Lion and Sun and the military forces, and coordinated in Tehran for the southern part of the region, and in Babol and Shahi for the northern part.

### *Epicentral region*

The only published account of the earthquake<sup>(19,20)</sup> places the macroseismic epicentre near the village of Ab-e Garm and considers the epicentral region to be "circular, with a radius of 100 km and centre approximately at the Damavand Volcano". The information on which this account was based is a report by Vrolyk<sup>(26)</sup> who was impressed by the damage to the new hotel in Ab-e Garm. The hotel however was an untypical case (see further on) and the region of severe destruction was located further north and east of Ab-e Garm. Hagiwara and Naito<sup>(19)</sup>, without actually entering the area, estimated correctly that the highest intensities occurred about 60 km south of Babol and 30 km west of Zirab. As already mentioned, the destruction of the main access roads made it difficult to enter the epicentral region after the earthquake.

The unpublished reports of C. Savage<sup>(21)</sup> constitute the only reliable information on the situation in the epicentral region after the earthquake. Savage visited the Haraz Rud and Kaselian Rud valleys about one month after the event and reported in detail on his observations. A few special points were also investigated by the present author on the occasion of a study of the Babol Kenar earthquake of 1971<sup>(24)</sup>. It is mainly on these two sources that the following notes are based.

Despite the unevenness of population distribution, and the paucity of reliable information, the limits of the region of maximum destruction can be established with reasonable confidence. Maximum destruction occurred between the Haraz Rud valley in the west, the Talar Rud valley in the east, the Caspian foothills in the north (above 1500 m) and the median Alborz drainage divide in the south (Fig. 4). The macroseismic information is summarized in Table 2.

Table 2 - CASUALTIES AND DAMAGE OF THE SANGECHAL 1957 EARTHQUAKE

Village	Killed	REMARKS
Ab-e Garm	0	Hotel under construction partly destroyed.
Agha	24	
Alansar	3	
Alasht		Severe damage.
Aliabad	0	One house only: badly damaged.
Amol	0	Tobacco warehouse damaged.
Atu		Worst damage of Kaselian Valley. Some houses collapsed. Casualties?
Babol	0	Damage to water tower and 100 year old tree.
Baijan	10	Nearly all houses (well built) collapsed. Bridge damaged. 6 injured.
Chigar		Location unknown. Badly damaged?
Deraz Kola	0	No damage. Weaker than 1935 earthquake.
Dinan	63	Buried by rockfalls.
Emarat	0	All ten houses (badly built) damaged. 1 injured.
Gazanak	0	
Haftavan	3	15 houses destroyed.
Hajidela	56	
Hareh	6	
Kangarash	45	
Kelpasha	15	
Khushedbar	0	Slight damage.
Korcha	0	Hardly any damage.
Korf	12	
Kuh Rud	12	5 or 6 houses destroyed but other part of village not collapsed.
Lajim	0	No damage to houses or 11th c. AD tower.
Mangol	0	Badly built yet very little damage.
Nandel	65	
Nowsar	13	
Nal	4	
Pajurupan	0	Badly damaged, 6 houses collapsed.
Palmdar		Casualties? Cracks in ground?
Pardameh	84	
Pasha		Casualties? Badly damaged.
Pasha Kola	0	Houses well built, some partial collapse.
Pol Sefid	(60)	Quite badly damaged.

Village	Killed	REMARKS
Polur	(30)	Great damage?
Resket		Casualties? Badly damaged?
Sangechal	180	All houses destroyed. Landslides. Ground fractures?
Sari	0	
Shahandasht	13	Imamzadeh badly damaged.
Shahi	0	Only 2 buildings damaged.
Shahrabad		Completely ruined.
Shahsavar	0	Many buildings ruined.
Shah Zaid	6	Very bad damage to well built houses. Ground fractures?
Shangoldeh	30	Very bad damage nearly entirely by rockfalls.
Shemiran	0	No damage.
Siahbisheh	5	All 14 houses (well built) destroyed. Animals killed.
Slurgah		Less damage than Atu.
Tares		Completely ruined.
Tiar	3	Damage less than Sangechal. Landslides.
Tera	28	
Vannch	0	Imamzadeh damaged but village only slightly.
Vavdar		Casualties? Ground fractures?
Zardband	6	All 20 houses (badly built) destroyed. Much damage by rockfalls.
Zirab	(200)	
<i>Total</i>	<i>970</i>	

Figures shown in ( ) indicate that numbers refer to unidentified nearby villages.

In the Haraz Rud Valley, the following villages were totally destroyed and suffered a large number of casualties: Agha, Baijan, Dinan, Kangarash, Haji Dela, Kelpasha (?), Korf, Nandel, Nowsar Pardameh, Sangechal, Shah Zaid, Shangoldeh, Siah Bisheh, Tineh (?) and Zardband. In Baijan, for example, where the houses were relatively well built, all the buildings including the police post, flour mill and public baths collapsed, killing 10 people and injuring 6. An 80 m long bridge north of the hamlet was damaged. Some of the villages, particularly Shangoldeh, Dinan and Zardband were at least as much damaged by rockfalls as by the shaking. Next in the degree of destruction was a group of villages which were also very severely damaged

but which generally had only a few fatal casualties: Ahansar, Aliabad, Haftanan, Hareh, Kuhrud, Nal, Pasha, Shahandasht, Tiar and Vanneh. In Kuhrud, for example, where 5 or 6 houses collapsed, killing 12 people, part of the village was still standing after the earthquake. The severe destruction in the Haraz Rud Valley decreased appreciably near Emarat and Mangol in the north, and Polur and Ab-e Garm in the south. In Ab-e Garm, the reinforced concrete hotel described by Vrolyk<sup>(26)</sup> as completely destroyed, "... had never been completed and many of the slabs were still resting on their shattering... one had to wonder if it would have stood up even if it had been completed... the main trouble seems to have been the too heavy roof/floor slabs on too slender columns"<sup>(21)</sup>.

A very great number of landslides and rockfalls were caused by the earthquake, both in the Haraz Rud and in its tributary valleys. Many villages were damaged or destroyed by rockfalls and the Tehran-Amol road was blocked at several points (\*). The largest rockfall occurred on the east bank of the Haraz, about 3 km south of the Nur Valley confluence. About 10,000 m<sup>3</sup> of rock fell from a 500 m cliff, blocking the valley, forming a dam about 20 m high and creating a reservoir about 1 km long and 100 m wide.

The Talar Rud Valley at the eastern limit of the epicentral region is less well documented than the Haraz Rud. The Persian press reported more than 200 people killed in Zirab, and 60 in Pol-e Sefid, but in both cases there are indications that these casualties occurred in fact in the mountain settlements west of these two villages. Alasht and Shahsavar were seriously damaged but seemingly without fatal casualties.

Further east in the Kaselian Rud and Tejen Rud Valleys some villages such as Atu, Pajurupan, Pasha Kola and Resket were partially damaged and a few houses collapsed in each. Slight damage was observed in Khushedbar, Pahndar and Vavdar, but Lajim and Koreba were hardly damaged at all.

In the north the destruction did not extend into the Caspian foothills below about 1500 m. Shirgah and the Babol Kenar villages around Deraz Kola were unaffected (\*\*). Some isolated cases of light damage did however occur in the towns of the plain: the tobacco

---

(\*) See also Figs. 8 and 9 in Fookes and Knill (1969).

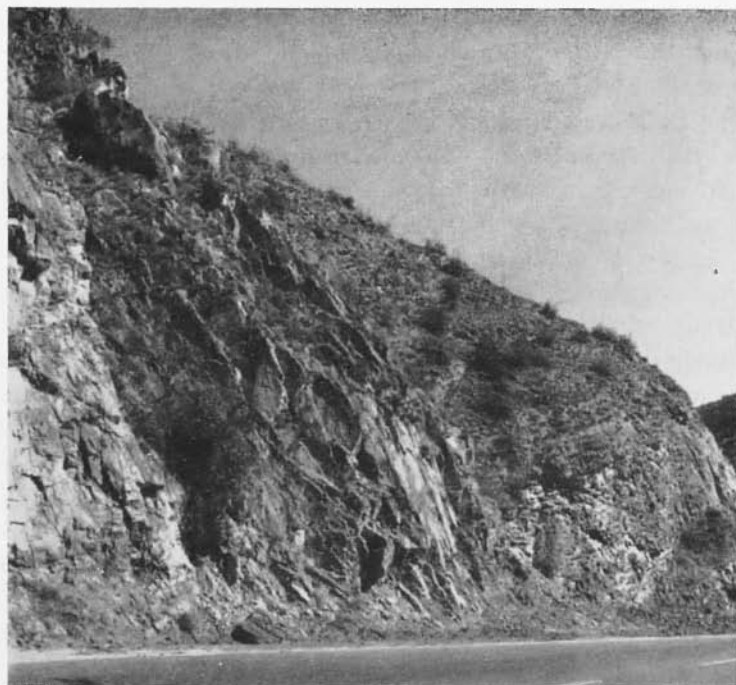
(\*\*) The Sangechal earthquake was felt here less strongly than the 1935 earthquakes.

warehouses in Shahi, Sari (?) and Amol (?), and the water tower in Babol were slightly damaged.

In the south, Shahrabad and Tares near Firuzkuh were damaged but without reported casualties. None of the villages on the Polur-Tehran road seemed to be seriously affected. The shock was strongly felt in Tehran (8) and in Shemiran but did not produce any visible damage to buildings.

#### *The question of faulting*

Rothé (19,20) states that a fault-break was observed to cross the half-destroyed hotel at Ab-e Garm, his information being based on the following remark by Vrolyk (26): "J'ajoute (car j'ai un péché mignon, celui d'être radiesthésiste) que le pendule m'a permis de reconnaître sur place une faille...". In fact, photographs of the hotel taken by



PL. IV - AMIR FAULT ZONE — The fault zone in the foreground is a steep south dipping reverse fault in thin-bedded limestone. Left-bank of the Haraz Rud. Looking south-east.



Savage suggest that the fracture in question was due to slumping or incipient sliding, and a recent geological map of the region confirms the absence of a fault in the vicinity of Ab-e Garm (?).

Some fault movement seems however to have taken place along the Amir Fault zone which is located along the Amir Rud, a small eastern tributary which joints the Haraz at Mangol. The geological fault is well known here even though not mapped in detail: it is a steep south dipping reverse fault with a shear zone about 25 m wide there where it crosses the Haraz valley (Pl. IV). In 1957 after the earthquake it was noted that "a small fault was seen beside the road with fresh cracks" (21). There were also unconfirmed reports of large ground fissures, several kilometers long, in the mountains north of Sangechal, one of the most severely damaged villages of the earthquake (Pl. V). Sangechal is situated on a steep hill showing numerous



Pl. V - HOUSE IN SANGECHAL -- The large amount of timber used in the walls is an innovation after the 1957 earthquake. The roof is (as in 1957?) of wood shingle. The mound and garden in the left foreground mark the foundations of a house which was destroyed in the 1957 earthquake. 180 people out of a population of about 4000 were killed by the earthquake in Sangechal.

landslide scarps (Pl. VI); these landslides are occasionally reactivated, as after the Babol Kenar earthquake in 1971, and this probably explains the ground fissures observed in 1957. Both the Haraz and its tributary valleys are very prone to landslides and rockfalls, and these can be triggered-off by earthquakes or other natural causes.



Pl. VI -- WESTERN ENTRANCE TO SANGECHAL --- The path on the right is located along one of many old landslide scarps.

### 3.6. - *Babol-Kenar Earthquake, 1971*

The Babol-Kenar earthquake of magnitude 5.2 occurred on 9th August 1971 at 02<sup>h</sup>54<sup>m</sup>36<sup>s</sup>.7 GMT; the instrumental epicentre was located at 36°.2N, 52°.7E, i.e. slightly north of the 1957 earthquake. About 900 houses in 42 villages suffered light damage and one person died and 39 were injured. The epicentral region was situated along the northern foothills of the Alborz (Fig. 5), with the severest damage around Deraz Kola. Damage did not extend into the mountains above about 1500 m in the region of the 1957 earthquake.

Details of the worst hit region have been previously reported<sup>(24)</sup>. Some further information obtained recently on the villages in the

southwest and east enables a clearer picture to be drawn of the area over which the shock caused damage (Fig. 5).

4. - POPULATION DISTRIBUTION AND EPICENTRAL REGION

The amount of damage and the number of casualties resulting from an earthquake is, to a large extent, dependant on the population

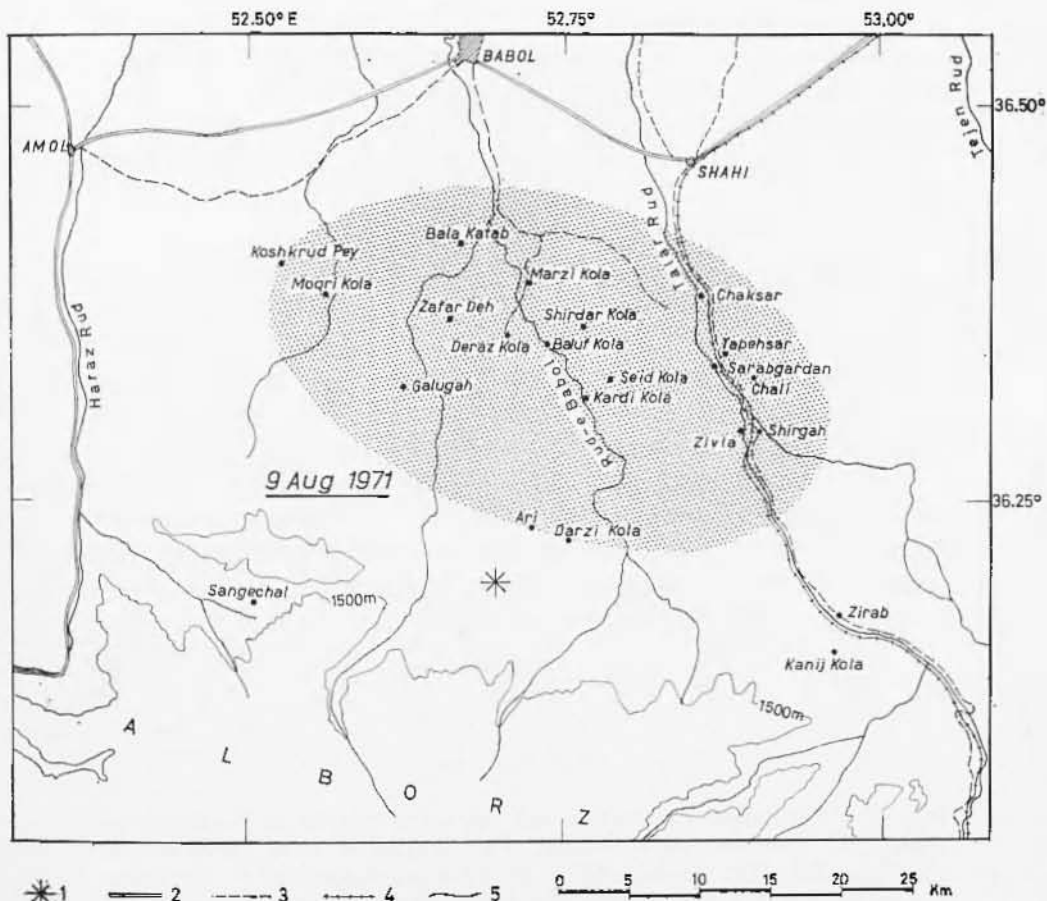


Fig. 5. - Epicentral Region of the Babol-Kenar 1971 Earthquake. - 1. Instrumental epicentre. - 2. Major road. - 3. Other road. - 4. Railroad. - 5. Principal river. Only villages and towns for which macroseismic data is available are shown on the map. Shaded area indicates approximate extent of damage.

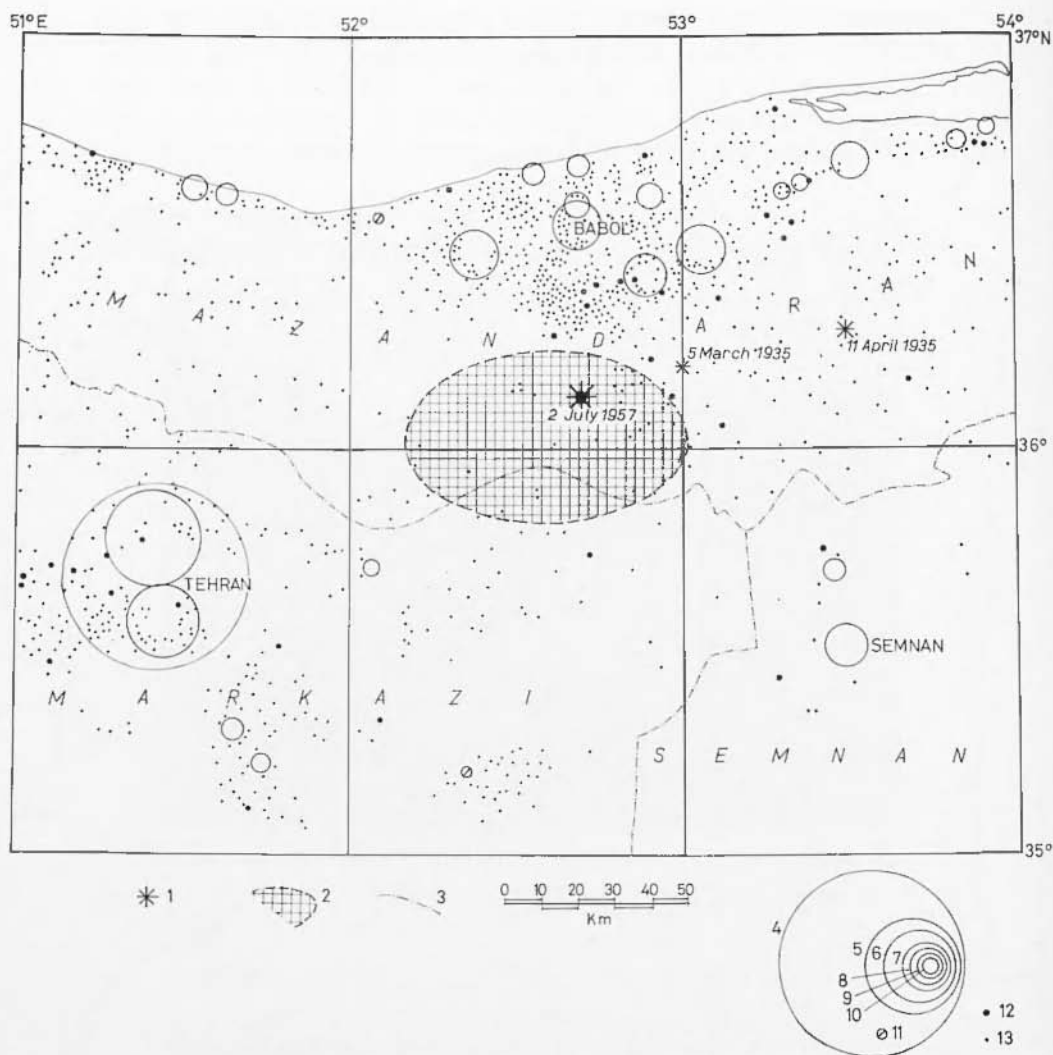


Fig. 6. — Population distribution and epicentral regions in North-central Iran. — 1. Instrumental epicentres. — 2. Region of total destruction of the Sangechal 1957 earthquake. — 3. Province boundary. — 4. Urban population 500,000. — 5. Urban population 250,000. — 6. Urban population 100,000. — 7. Urban population 50,000. — 8. Urban population 25,000. — 9. Urban population 15,000. — 10. Urban population 5,000. — 11. Urban population less than 5,000. — 12. Rural population 2,000 to 5,000. — 13. Rural population 1,000. After the 1966 population census published by the Statistical Centre of Iran.

density in the epicentral region. Fig. 6 shows the population distribution in North-central Iran. The 1957 epicentral region covers one of the least populated areas of this part of the country; had the earthquake occurred further north near Babol or further south-west near Tehran, a catastrophe of much greater proportions may have resulted. Similarly, the earthquakes of March and April 1935, even though less precisely located, also occurred in regions of low population density. Research into earthquakes prior to 1900 does however show that this had not always been the case, as both Tehran (Shahr Rey) and the Caspian coastal towns have been destroyed a number of times in the past<sup>(2,3)</sup>. It is one of the reasons why the study of smaller events located near the population centres, such as Ali-Mobarakabad 1930, Musha 1955, and Babol-Kenar 1971, are of vital importance to the assessment of the seismic hazard of the region.

#### ACKNOWLEDGEMENTS

The field work reported here was undertaken as part of a joint project between the Geological Survey of Iran and the Engineering Seismology section, Imperial College, London, the latter being supported for this work by a grant from the National Environmental Research Council, London. I am grateful to Sir Alexander Gibb and Partners, London, for access to C. D. W. Savage's reports. Part of the field investigation was carried out with H. Iranmanesh of the Geological Survey of Iran and A. Mohajer-Ashjai presently at Imperial College, and it is only with their help and cooperation that this study became possible.

#### REFERENCES

- (<sup>1</sup>) ALLENBACH P., 1966. - *Geologie und Petrographie des Damacand und seiner Umgebung (Zentral-Elburz), Iran*. "Mitt. Geol. Inst. Eidgen. Tech. Hochsch. Univ. Zürich", N.F., **63**, pp. 144.
- (<sup>2</sup>) AMBRASEYS N. N., 1968. - *Early earthquakes in North-Central Iran*. "Bull. Seism. Soc. Am.", **58** (2), 485-496.
- (<sup>3</sup>) AMBRASEYS N. N., 1973. - *Historical seismicity of North-central Iran*, in Materials for the Study of Seismotectonics of Iran: North-central Iran. "Geological Survey of Iran", Report No. 29 (forthcoming).

- (4) B.C.I.S. Bureau Central International de Seismologie, Strasbourg, France.
- (5) BOZORGNIA H., 1962. - *Statistics on Earthquakes in Iran*. "National Iranian Oil Company", Geological Report 253, pp. 23.
- (6) CCP - *Atlas of Earthquakes in the USSR*. "Acad. Sci. USSR", 1962 (in russian).
- (7) FOOKES P. G. and KNILL J. L., 1969. - *The application of engineering geology in the regional development of northern and central Iran*. "Eng. Geol.", 3, 81-120.
- (8) GANSSER A., 1969. - *The large earthquakes of Iran and their geological frame*. "Eclogae Geol. Helv.", 62, 443-466.
- (9) GR-GUTENBERG B. and RICHTER C. F., 1954. - *Seismicity of the Earth and Associated Phenomena*. 2nd Ed. Princeton, New Jersey. Princeton University Press.
- (10) HAGIWARA T. and NAITO T., 1959. - *A report of the Japanese Mission sent to Iran for investigating the problems related to disastrous earthquakes in Iran*. Unpublished report, January 1959, pp. 100.
- (11) ISS International Seismological Summary, Edinburgh, G.B.
- (12) MCKENZIE D., 1970. - *Plate tectonics of the Mediterranean region*. "Nature", 226, 239-243.
- (13) MCKENZIE D., 1972. - *Active tectonics of the Mediterranean region*, "Geophys. J.R. astr. Soc.", 30, 109-185.
- (14) MONTANDON F., 1957. - *Les grandes catastrophes en 1956-1957*. "Rev. pour l'Etude des Calamités", 35, 52.
- (15) NABAVI M. S., 1972. - *The Seismicity of Iran*. M. Sc. Thesis, University of London, 1972.
- (16) NOWROOZI A. A., 1971. - *Seismo-tectonics of the Persian Plateau, Eastern Turkey, Caucasus, and Hindu Kush regions*. "Bull. Seism. Soc. Am.", 61, 317-341.
- (17) NOWROOZI A. A., 1972. - *Focal Mechanism of earthquakes in Persia, Turkey, West Pakistan, and Afghanistan and plate tectonics of the Middle East*. "Bull. Seism. Soc. Am." 62, 823-850.
- (18) REZANOV I. A., 1959. - *Tectonics and Seismicity of the Turkmeno-Khorassan Mountains*. Acad. Sci. USSR, Inst. Phys. Earth, pp. 243 (in russian).
- (19) ROTHE J.-P., 1959. - *Chronique seismologique*. "Rev. pour l'Etude des Calamites", 36, 16-17.
- (20) ROTHE J.-P., 1969. - *The Seismicity of the Earth 1953-1965*. Unesco, Paris.
- (21) SAVAGE C. D. W., 1957. - *Earthquake of 2nd July and Safari Memorandum*. Sir A. Gibbs and Partners, London, Internal Reports B.45 dated 20 July 1957, and B58 dated 12 August 1957.

- (22) SIEBERG Z., 1932. - *Die Erdbeben*, in G. Gutenberg's *Handbuch der Geophysik*, 4, Ed. G. Borntraeger.
- (23) TCHALENKO J. S., 1973. - *The tectonic framework of the Tehran region*, in Materials for the Study of Seismotectonics of Iran: North-central Iran. "Geol. Surv. Iran", Rep. No. 29 (forthcoming).
- (24) TCHALENKO J. S., IRANMANESH M. H. and MOHAJER-ASHJAI A., 1972. - *The Babol-Kenar (1971) earthquake and the seismotectonics of the Central Alborz (Iran)*. "Ann. di Geofisica", 25 (1), 27-36.
- (25) USCGS - United States Coast and Geodetic Survey, Washington. Preliminary and Monthly determination of epicentres.
- (26) VROLYK F., 1957. - *Mission de protection civile en Iran*. Report of the Government of Algeria, September 1957, pp. 15 (in french).
- (27) WILSON A. T., 1930. - *Earthquakes in Persia*. "Bull. Sch. Oriental Studies", 6 (1), 103-131.
-