The Salmas (Iran) earthquake of May 6th, 1930

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Summary. — Field investigations and bibliographical research into the little-known but important Salmas earthquake in Northwest Azarbaijan (Iran) provided the following results. The morning before the earthquake, a foreshock ($M_b = 5.4$) centered, as the main shock, in the Salmas Plain, killed about 25 people and incited a great part of the population to spend the following night out of doors. The main shock ($M_b = 7.3$) occurred the following night, on 6 May 1930 at 22h34m27s GMT and destroyed about 60 villages and 40 churches, killing about 2514 people, both in the Salmas Plain and in the surrounding mountains. Its macroseismic epicentre was at approximately 38.15N 44.70E. The main shock was associated with 2 surface faults, with a maximum horizontal displacement of 4 m and vertical displacement of over 5 m; the combined action of these faults was a relative lowering, and a displacement to the east, of the Salmas Plain. Two days later, the strongest aftershock destroyed one village at the northern edge of the Salmas Plain.

Riassunto. — Gli studi fatti e le ricerche bibliografiche hanno dato sul poco conosciuto ma importante terremoto di Salmas (Azarbaijan, nord-occidentale, Iran) le seguenti informazioni.

La mattina prima del terremoto, nella Piana di Salmas una scossa premonitoria ($M_b = 5.4$), ritenuta la principale, causò circa 25 morti costringendo una gran parte della popolazione a trascorrere la notte all'aperto. La notte seguente, 6 Maggio 1930 alle 22h34m27s GMT, avvenne la scossa principale che distrusse, nella Piana di Salmas e nelle montagne circostanti, circa 60 villaggi e 40 chiese provocando la morte di circa 2514 persone. Il suo epicentro macrosismico fu approssimativamente a 38.15°N e 44.70°E.

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La scossa principale si associò a due faglie superficiali, con uno spostamento massimo orizzontale di 4 m e verticale di oltre 5 m; l'azione combinata di queste due faglie provocò un abbassamento relativo ed uno spostamento verso Est della Piana di Salmas. Due giorni dopo, la replica più forte distrusse un villaggio all'estremo nord della Piana di Salmas.

Introduction

The Salmas earthquake of 1930 is one of the 8 earthquakes of magnitude equal to, or greater than, 7, which occurred in Iran since 1900, and one of the few which was accompanied by surface faulting. It is also the only recent catastrophic earthquake located in the northwestern part of the country, a fact which makes it important in regional seismotectonic studies. Yet, to date, the documentation on this event was practically reduced to entries in earthquake catalogues and to vague communiqués in the international press. The field study and the new bibliographical material reported here has, it is believed, produced enough data to make certain aspects of this earthquake, such as casualty distribution and faulting, as well documented as in the case of more recent destructive earthquakes (e.g. Buyin Zahra 1962, Dasht-e Bayaz 1968). This improved knowledge of the event is, to a large extent, due to several favourable circumstances which will become apparent in the course of this report.

The aim of this report is intentionally limited to a presentation of the observations that we collected on the earthquake and its immediate effects. No attempt is made to interpret this information, either in terms of the seismicity (historical or modern), or in terms of the regional tectonics, and this for the simple reason that very little is known, and even less is published, on either of these subjects. The geological mapping of the region, for example, has only just begun. The report is itself a summary of a more complete documentation in preparation (2).

The Salmas Plain, epicentral region of the earthquake, is located to the northwest of Lake Rezayeh, and has an area of about 300 km² (Figs 1 and 3). It lies between the levels of about 1500 m (N, W and S borders) and 1280 m, the latter being the average level of the Lake which forms its eastern border. The Plain is watered by the Zola Chay which is the mainstay of its agricultural prosperity. The most important villages are concentrated in the southwest, and many, such

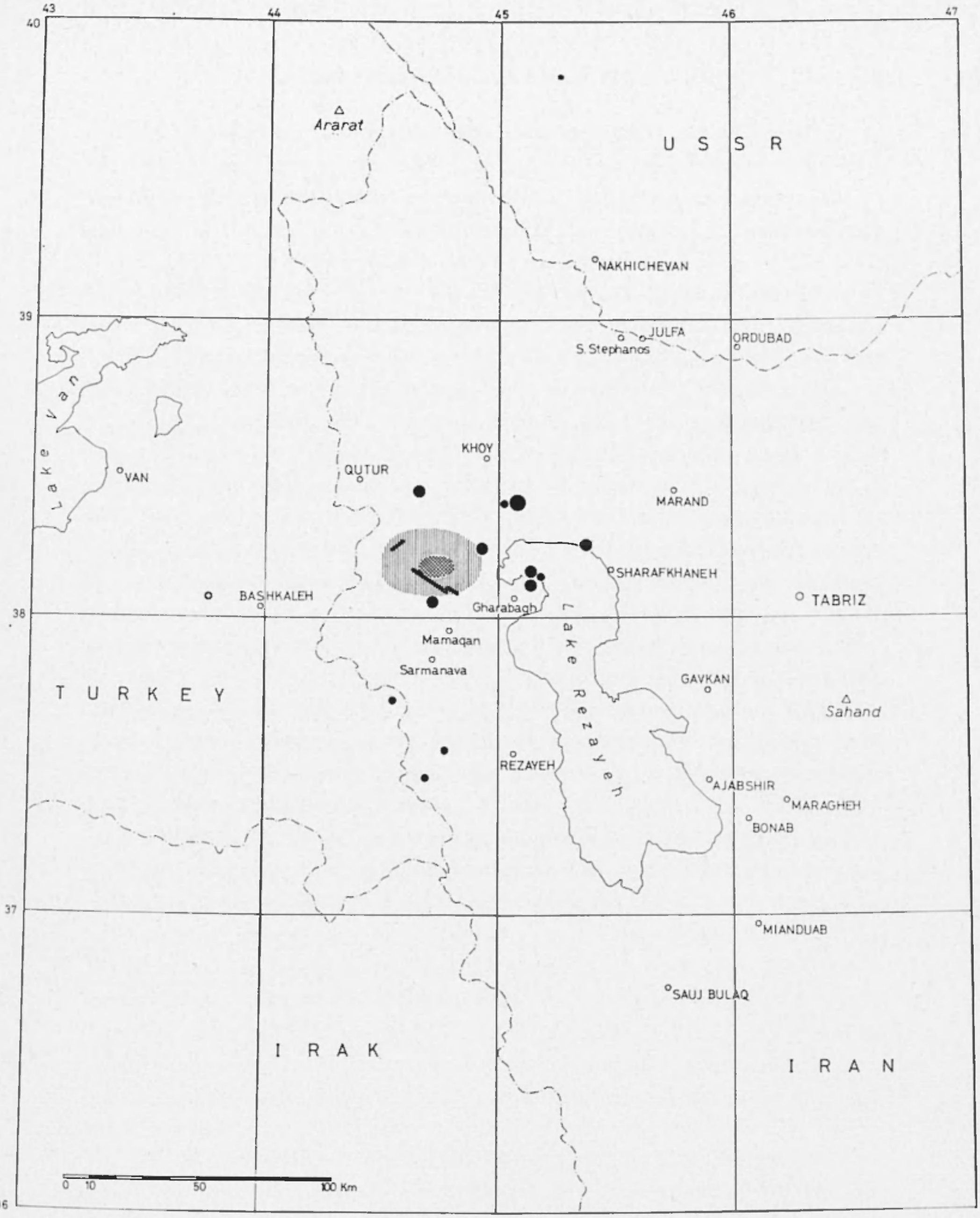

Fig. 1 – Epicentral regions, earthquake faults and main aftershocks

Epicentral regions of 6 May 1930 foreshock and main shock are shaded respectively with cross-hatching and vertical hatching. Fault breacks are shown with thick black line. Instrumental epicentres of main aftershocks (see Table 3) are shown with dots, largest dot $M \geqslant 6$, intermediate $5 \leqslant M < 6$, smallest $M < 5$. Largest aftershock occurred southwest of Khoy on 8 May 1930. Open dot west of Bashkaleh is an early shock on 16 April 1930. The instrumental epicentres of the foreshock and main shock are not shown because their accuracy is inferior to the macroseismic determination. Towns shown are those where the main shock was reported as felt, excep Leninakan and Tiflis which are located outside of this map.

as Kohneh Shahr (replaced after the earthquake by Tazeh Shahr), were of considerable antiquity ([14]). The Plain was populated by Christians of the Nestorian and Chaldean sects from a very early age (S. Hovanes in Ghezelja is thought to have been built in 1007), and at the time of the earthquake, 15 of its villages were either exclusively or partly inhabited by them. The town however, Dilman (or Dilmaghan renamed Shahpur after the earthquake), and villages in the north and east, were mainly of Turkish and Kurdish population.

The mountains bordering the Salmas Plain are much more sparsely populated, mainly by Kurdish people. The highest summit, the Aravil Dagi, is located in the west on the Turkish frontier; it is a volcano which fed the many Quaternary basalt flows forming the high plateaux between the Dowshivan Su and the Zola Chay (Fig. 3). The much lower Miocene hills in the north, and the metamorphic mountains in the south, separate the Salmas Plain respectively from the Khoy and the Rezayeh Plains. The mountain villages are small, isolated from each other and from the Plain, and live nearly entirely from wheat farming and cattle.

The method we used in this investigation was to visit each village, gradually defining the epicentral region, observing ground deformations and ruins of the earthquake which were often little changed since 1930. As many survivors as possible were interviewed in each village in their native dialect, i.e. Armenian, Assyrian, Turkish, Kurdish and Persian. New bibliographical material in the form of newspaper reports and private correspondence was used to check and supplement the field results.

Foreshock

General.

A moderately strong foreshock, of estimated magnitude $M_b = 5.4$ ([10]), occurred on 6 May 1930 at 07h03m26s GMT, i.e. about 15 ½ hours before the main shock. It caused destruction and some casualties in a small region centered at about 38.15°N 44.75°E corresponding approximately to the future macroseismic epicentre of the main shock. The foreshock was perceptible over all of Northwestern Azarbaijan and Southeastern Turkey, and was clearly felt by most of the inhabitants in the three nearest towns, Tabriz, Rezayeh and Khoy, as well as in Bonar and Maragheh. A large part of the population in the epicentral region spent the night following the foreshock out of doors, and was thus saved when the main shock occurred.

Casualties and destruction.

The effect of the foreshock on the villages, mainly of adobe construction, is summarized in Fig. 2. As the event occurred at about 10 a.m. local time, many people were out, or could escape quickly from their houses, and as a result the number of casualties remained relatively low.

Four localities, Haftavan, Dilman, Kuche Mashk and Kalashan, were severely damaged and had casualties. In Haftavan, some houses collapsed completely, and one woman and one child were killed by a falling wall. The roof of S. Thadeus, a large stone-masonry and kiln-brick church west of Haftavan, collapsed. In Dilman, many houses were badly damaged, and between 15 and 20 people were killed (Tabriz 8 May, Haratch 22 and 23 May). In Kuche Mashk and Kalashan nearly all houses were damaged, and one person was killed in each village. This region of maximum destruction is centered in the region of S. Thadeus which may be taken as the approximate macroseismic epicentre of the foreshock.

In the surrounding villages of Kohneh Shahr, Patehvir, Sarnaq and Payajuk, a few buildings collapsed partially, and most others were fissured. In Kohneh Shahr damage was said to have been more severe (Tabriz 8 May), but the subsequent departure from the village of many of its original inhabitants made it impossible to verify this information. In other villages such as Malham, Uleh, Khosrova, Drishik, Moghanjik, Sadaghian and Hamzekandi, most houses were fissured. Further away from the epicentral region, in Habashi, Akhtekhaneh, Yavshanli, Khantakhti, Tamar, Ayan and Senji, only a few isolated walls were fissured.

In all the villages mentioned above, and in a few other near-by ones, the foreshock was felt strongly enough for most of the inhabitants (with the exception of those of Malham) to decide to spend the following night out of doors (see Table 1). Outside this region however, and especially in the mountains to the north and west, the shock was felt too lightly to worry the population which consequently spent the night indoors and suffered a large number of casualties when the main shock occurred at about 01.30 a.m. local time. The villages

Table 1 – DAMAGE AND CASUALTIES CAUSED BY THE MAIN SHOCK

All information was obtained by field survey in 1973, except ST (Samson Tateossian in Haratch 31 May 1930) and AZ (Abel Zayia in Zayia, 1930a,b).

Village	Population (1930)	Earthquake Damage	Casualties	Remarks
Akhian	0			not inhabited in 1930?
Akhtekhaneh		village destroyed; church standing	4	most slept out
Alibolagh		destroyed		
Aqbarzeh		about 50% destroyed	1	
Aqziarat	110	about 10% collapsed	0	most slept out
Ashnak	120	destroyed	27	most slept in
Aslanik	110	completely destroyed	21	most slept in
Ayan	270	about 50% collapsed	12	
Bajergeh	90	not damaged	0	
Balghazan	50	about 10% collapsed	0	
Bardian		slightly damaged	0	most slept out
Borushqalan	40	destroyed	17	most slept in
Bostakabad		lightly damaged	0	
Chahar-Sutun	200	about 6% collapsed	0	
Chahriq	120	about 75% collapsed	4	most slept out
Chichak	270	about 50% collapsed	15	most slept out
Derik	180	village destroyed; church mostly collapsed	25	most slept out
Dikeh		not damaged	0	
Dilman	18000	completely destroyed	1100	more slept out than in
Dishivan	0			not inhabited in 1930
Djamlava		slightly damaged	0	(A.Z)
Drishik	390	completely destroyed	2	most slept out
Galvan	0			not inhabited in 1930
Gavilan		slightly damaged	0	(A.Z.)
Ghabrabad	140	completely destroyed	13	
Ghalasar	79	village destroyed; church partly collapsed	2	most slept out
Gharabagh	2400	about 30% collapsed; church undamaged	3	most slept out
Gharaqeshlagh	1650	slight damage	0	most slept out
Ghezelja	420	village destroyed; church standing	3	many slept out
Ghezelkandi	40	about 50% destroyed	1	
Gonieh		not damaged	0	

(continued)

Village	Population (1930)	Earthquake Damage	Casualties	Remarks
Guba	120	about 25% collapsed	0	most slept out
Guladar	30	completely destroyed	6	most slpet in
Gulan	90?	a few houses collapsed	0	
Gulizan		destroyed		
Guzik		destroyed	3	
Habashi	690	destroyed	2	most slept out
Hablaran	90	destroyed	35	most slept in
Haftavan	540	destroyed, including 3 of 4 churches	4	all slept out (ST)
Haji Jafan	90	not damaged	0	
Hamzeh Kandi	330	completely destroyed	16	most slept out
Hanik		damaged	2?	
Hagviran		destroyed		
Hasbashi	0			not inhabited in 1930
Hosseinabad		not damaged	0	
Howdar	360	mostly destroyed	0?	?
Issy Su		light damage	0	
Kahriz	50	destroyed	1	some slept in
Kaleshan	180	completely destroyed	19	many slept out
Kanyan	600	very little damage	0	most slept in
Kashkavich	120	about 15% collapsed	2	most slept in
Khanaqah		?		
Khantakhti	180	destroyed	0	most slept out
Khorkhora	40	destroyed	2	
Khosrowa	280	destroyed, including 7 churches	34	most slept out (ST, AZ)
Kohneh Shahr	2290	destroyed, including 5 churches	370	most slept out
Kuche Mashk	210	completely destroyed	0	most slept out
Kurdran	40	destroyed	3	
Kuzerash		destroyed	35	most slept in
Lashkaran	120	destroyed	0	most slept out
Mafi Kandi		no information		
Malham	327	completely destroyed, including 3 churches	48	most slept in (ST)
Mamaqan	600	destroyed	85	most slept in
Masdaqan		not destroyed		
Minas		destroyed	0	most slept out
Mingol	120	5% collapsed	2	most slept in
Moghanjik	1800	completely destroyed	75	many slept out
Nazirabad	130	completely destroyed	30	about 60% slept out

(continued)

Village	Population (1930)	Earthquake Damage	Casualties	Remarks
Patchvir	113	destroyed, including churches	11	many slept out (ST, AZ)
Payajuk	130	destroyed, including church	3	most slept out (ST)
Sadaghian	1050	completely destroyed	60	about 50% slept out
Sailab	600	partly destroyed	1	most slept out
Saramerik	960	completely destroyed	82	most slept in
Sarmanava	170	partly destroyed	8	most slept in
Sarnaq	180	village destroyed; church mostly collapsed	18	most slept out
Savran	626	completel destroyed; including 2 churches	151	most slept out (ST)
Senji	120	completely destroyed	21	most slept out
Shekar Yazi	960	little damaged	0	most slept in
Sheydan	90	about 80% destroyed	1	most slept in
Sheytanava	0			not inhabited in 1930
Shiveh		not damaged	0	
Shiveh Darreh		not damaged	0	
Shurgel	330	about 30% collapsed	0	most slept out
Shurik		moderately damaged	0	
Siavan		lightly damaged	0	
Sidan		not damaged	0	
Soltan Ahmed	1200	about 20% of the houses collapsed	0	most slept out
Sowfiabad	60	destroyed	11	
Sutunrash	0			not inhabited in 1930
Tamar	660	completely destroyed	52	most slept out
Uleh	1200	completely destroyed	12	most slept out
Urban	390?	moderately damaged	0	
Vardan	480	destroyed	25	most slept in
Yavshanlu	420	moderately damaged, many houses standing	0	most slept out
Yengijeh	110	completely destroyed	18	
Zavichjuk	240	destroyed; 1 church undamaged	10	most slept out
Zindasht		lightly damaged	0	
Zola	70	destroyed	3	about 50% slept out

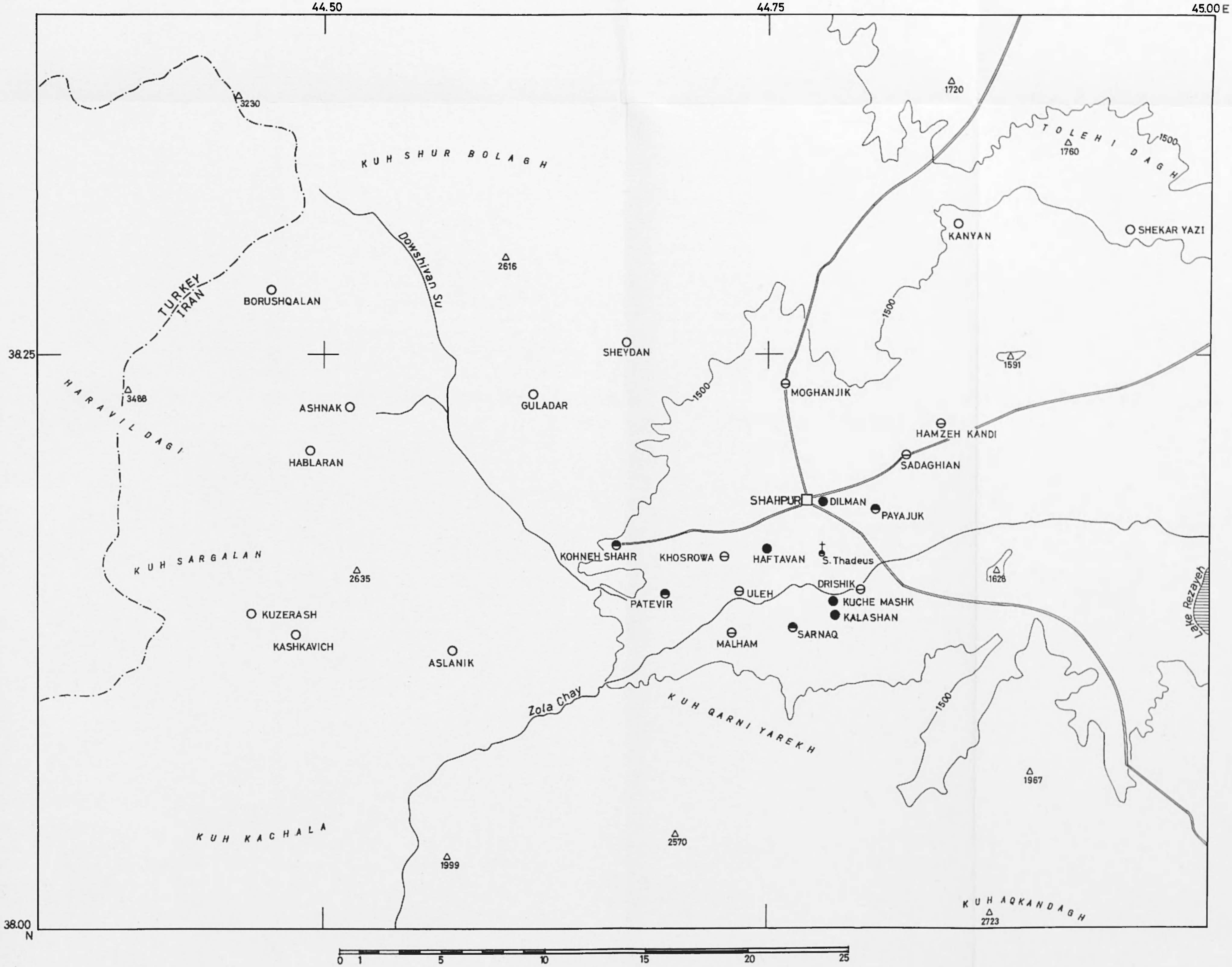

Fig. 2 – Foreshock of 6 May 1930

● severe destruction and fatalities; ◓ some buildings collapsed; ⊖ most buildings fissured; ○ foreshock not heeded or not felt. The approximate macroseismic epicentre was S. Thadeus church which was partly destroyed. Heights in meters.

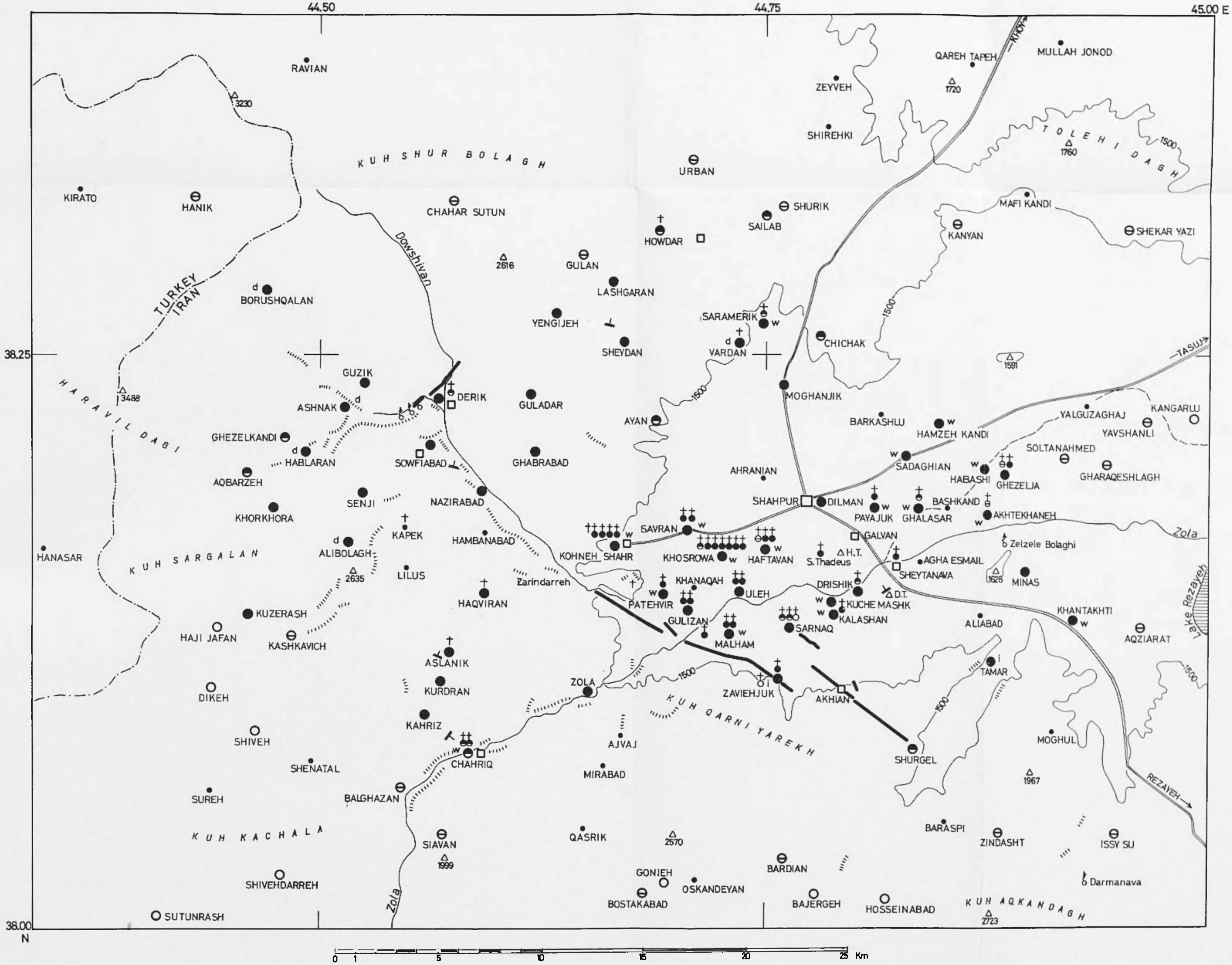

Fig. 3 – MAIN SHOCK OF 6 MAY 1930

Village destruction estimated at:

● 75-100% ◓ 25-75% ⊖ 0-25% ○ 0% • no information available

Damage to churches:

destroyed partly destroyed fissured undamaged

† church destroyed before 1930

fault-break changed thermal spring rockfall

landslide or rockslide w = waterlogging d = springs decreased i = springs increased

HT Haftavan Tepe, DT Drishik Tepe. New (post-1930) villages shown as squares. Heights in meters.

where the foreshock was not felt or heeded were Shekar Yazi, Kanyan, Sheydan, Guladar, Ashnak, Kuzerash, Kashkavich and Aslanik. In the extreme northwest, the shock was apparently not felt by anyone in Hablaran and Borushqalan.

Main shock

General.

The main shock occurred during the night which followed the foreshock, on 6 May 1930 at 22h34m27s GMT (or 7 May 1930 at 01h34m27s local time). Its magnitude was given as 7.2 ([8]), or 7.4 ([1]). About 60 villages located in the Salmas Plain and in the surrounding mountains were destroyed, and about 40 churches were destroyed or damaged (Tables 1 and 2). Casualties, which occurred nearly exclusively amongst the section of the population which had not heeded the foreshock, amounted to about 2,514 killed (Table 1). Two surface faults were formed with the earthquake: the first, oriented NW-SE, and located at the southern edge of the Salmas Plain, was about 20 km long and displayed a maximum right-lateral movement of 4 m and a maximum vertical throw (NE down) of about 5 m; the second, oriented NE-SW, and located in the western mountains, was over 3 km long, left-lateral, and had a vertical throw (NW down) of about 1 m. A recent recalculation located the instrumental epicentre at 38.22N 44.66E ([16]), which is in good agreement with the centre of the region of maximum destruction (macroseismic epicentre) found in this study to be approximately 38.15N 44.70E. Hence foreshock and main shock had, to a first approximation, nearly identical epicentres.

Outside the epicentral region, Khoy, Qutur and Sharafkhaneh were slightly damaged. In Tabriz, the shock caused panic, and part of the population fled the town. In the north, it was felt with intensities between 4 and 6 bals ([13]) in Julfa, Nakhichevan, Ordubad, and was even reported as felt in Leninakan and Tiflis. Near Julfa (North Iran), the eastern wall of S. Stephanos developed a vertical central crack (Fig. 4), probably as a result of unequal foundation settlement. In the west the shock was felt in Bashkaleh and as far as Van in Turkey, and in the south as far as Sauj Bulaq.

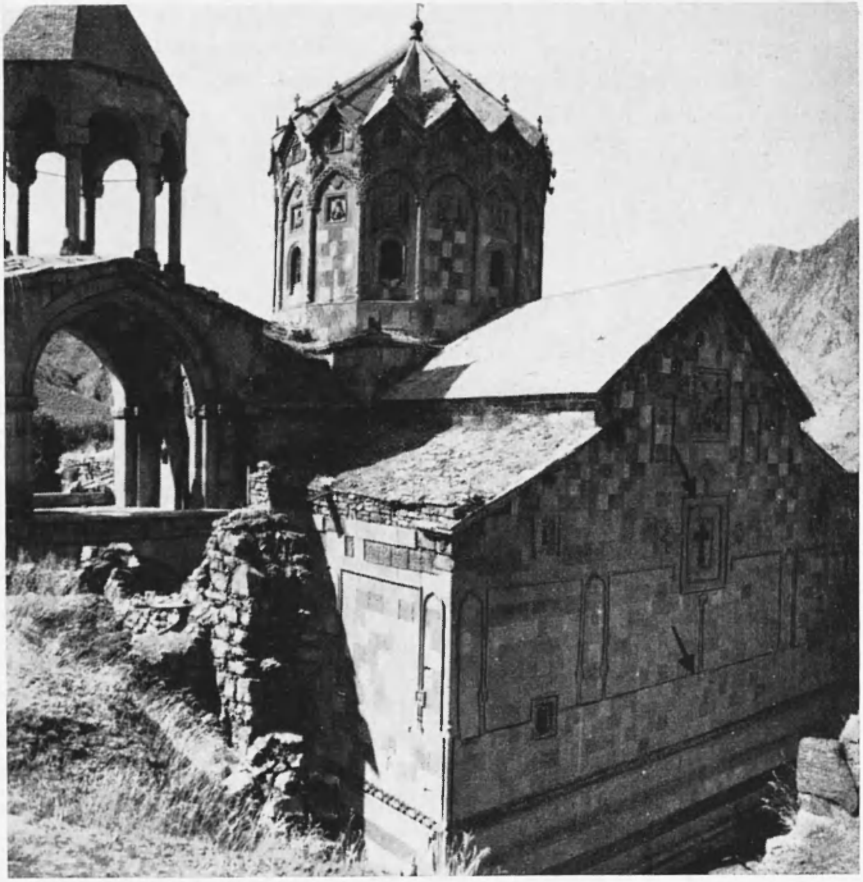

Fig. 4 – S. Stephanos near Julfa
Located over 100 km to the northeast of the epicentral region, the eastern wall of this 16th c. church developed a vertical fissure (shown by arrow) from apex to ground level.

Eyewitness account.

The main shock was witnessed by Abel Zayia, a Persian Lazarist of the French Mission in Rezayeh, who, at the news of the foreshock, left Rezayeh to investigate the damage in Salmas. The account given refers to the effects as felt in the southeastern part of the epicentral region, at a point on the Rezayeh-Dilman road just north of the present-day village of Aliabad, and south of the isolated mountain (marked

1628 in Figs 2 and 3) which contains a well-known Sassanian bas-relief. The extracts which follow are translated from the French by the present authors.

"At half-past one in the morning we were just in front of the Suratis mountain (bas-relief), one of the car's headlights broke-down, the driver got out to repair it. Suddenly I felt the car shake and thrown upwards; it was projected from south to north and displaced by 50 cm (*). The driver was thrown down onto the ground" [21]. "The driver was lying on the road. I thought that the car was out of control and instinctively reached for the brake and ignition key, when I heard a terrible noise: it was the rocks rolling down from the mountain. I quickly got out of the car, but what difficulty to remain standing. Not being able to advance or go back, we waited for two hours; I looked upwards to see the apparition of the sign of the Son of Man. During this time there were seven formidable shocks and more than one thousand weaker ones" [22].

Casualties and destruction.

Over 60 villages of the epicentral region were studied in 1973 in the field, and in most of them survivors of the earthquake could be found and interviewed. A limited amount of information was also compiled from existing contemporary accounts and newspaper reports. The results of this investigation are summarized in Fig. 3 and Tables 1 and 2, and are described in more detail below.

Two peculiarities distinguish this earthquake from most other recent destructive earthquakes in the Middle or Near East. Firstly, as the foreshock was felt and heeded by some but not all of the inhabitants, the geographical casualty distribution was not a reliable reflection of the local shaking intensity. Thus, casualties were low or nil in some villages near the epicentre which were completely destroyed but in which the population had slept out of doors; and conversely, casualties were relatively high in some villages near the periphery of the epicentral region when the inhabitants had slept indoors. Secondly, the Salmas Plain contained a number of churches

(*) The road is here E-W, and the car was displaced *sideways* towards the isolated "bas-relief" mountain, i.e. northwards. Zayia [22] is more precise: "it (the car) was projected 0 m 50 sideways".

Table 2 – Earthquake damage to churches
N.B. Dates of several churches have not yet been confirmed. See also Fig. 5.

Village	Church	Date	Type
Akhtekhaneh	Asdvadzadzin	1342, rest. 1891	rough stone masonry & kiln brick; 3 domes
Aslanik	Sarkis	1886	
Ayan	Asdvadzadzin	1781	sun-dried brick
Derik	Asdvadzazin	14th century	rough stone masonry
Drishik	Sarkis	1400	stone masonry; domed
Ghalasar	Sarkis	1806	rough stone masonry
Gharabagh	Gevork	1784	rough stone masonry
Ghezelja	Hovanes	1007?	stone masonry
	Boghos Petros		chapel; stone masonry?
Gulizan	Sarkis		sun-dried brick
	« Assyrian »		
Haftavan	Gevork	13th century	stone masonry; domed
	Boghos		kiln brick; domed
	Asdvadzazin	13th century	sun-dried brick
	Thadeus	13th century	sun-dried brick
Haqviran			
Hodar	Sarkis		
Chahriq (Jaraï)	Gevork	1203	rough stone masonry; "wooden" roof
	"Assyrian"		rough stone masonry; barrel vault roof
Kalashan	Hovanes		sun-dried brick; "wooden" roof
Khosrova	Sarkis	1717	sun-dried brick; "wooden" roof
	Givargis		stone masonry
	Mar Zaya		kiln brick
	Liba Ghucha Ishu		kiln brick
	Brashemoïl		chapel; sun-dried brick (open)
	Mary		chapel; stone masonry
	Mar Yosseb		kiln brick

Approx. dimension	Effect of earthquake	Present state	Present population
9 × 17	fissured	as in 1930	Turk
	destroyed before 1930		Kurd
10 × 16	roof collapsed before 1930	as in 1930 (walls standing)	Kurd & Turk
	mostly collapse	as in 1930	Kurd
16 × 24	part collapse	as in 1930	Turk
10 × 18	part collapse	as in 1930	Turk
11 × 15	undamaged	as in 1930	Turk
10 × 15	fissured	as in 1930	Turk
	destroyed		Turk
	destroyed	rebuilt	
	destroyed		
14 × 22	fissured; dome collapsed	repaired	Turk & Kurd & Armenian
	destroyed	rebuilt in adobe	Turk & Kurd & Armenian
	destroyed	rebuilt in new style	Turk & Kurd & Armenian
	destroyed	as in 1930	Turk & Kurd & Armenian
	destroyed before 1930		Kurd
	destroyed before 1930		Kurd
	partly destroyed before 1930	as in 1930 (walls standing)	Kurd
	roof collapsed	as in 1930	Kurd
10 × 17	destroyed	as in 1930 (1 wall stands)	Turk
7 × 12	destroyed	rebuilt in 1967 (in same style)	Assyrian, Turk & Kurd
15 × 25	part collapse	as in 1930	Assyrian, Turk & Kurd
10 × 14	destroyed	rebuilt in new style	Assyrian, Turk & Kurd
15 × 20	destroyed	rebuilt in same style	Assyrian, Turk & Kurd
	destroyed	rebuilt	Assyrian, Turk & Kurd
	destroyed	as in 1930	Assyrian, Turk & Kurd
	destroyed	as in 1930	Assyrian, Turk & Kurd

Village	Church	Date	Type
Kapek (Kiabik)	Asdvadzadzin		" wooden " roof
Kohneh Shahr	Hagop	1671	stone masonry; " wooden " roof?
	Sarkis	1671	stone masonry
	Hovanes	1825	
	Varar		
	Mar Ghoryagh		sun-dried brick
Malham	Zoravar	1641	stone masonry
	Gevork	1711	sun-dried brick; flat roof
	Vartan	1724	sun-dried brick; flat roof
Patchvir	Mar Yaghu		stone masonry
	Mar Yukhana		
Payajuk	Gevork	1751	stone masonry; domed
Sarmalek (Sanamerik)	Sarkis	1758	stone masonry
Sarmanava			rough stone masonry; vault roof
Sarnaq	Asdvadzadzin	1625	stone masonry
	Mar Khinah		sun-dried brick; " wooden " roof
	Hovanes		sun-dried brick
Savran (Sureh)	Hovanes	1200	stone masonry
	Mat Mariam		stone masonry
Sheytanava	Asdvadzadzin	1708	" wooden roof "?
Uleh	Sarkis		sun-dried brick; " wooden " roof
	" Assyrian "		sun-dried brick; domed
Vardan	Asdvadzadzin		sun-dried brick; flat roof
Zaviehjuk	Prishad (Hazara Pergich)	1892?	sun-dried brick; flat roof
	Hovanes		sun-dried brick

Approx. dimension	Effect of earthquake	Present state	Present population
	destroyed before 1930		Kurd
	destroyed	rebuilt as a chapel	Turk & Kurd
	destroyed	as in 1930	Turk & Kurd
	destroyed before 1930		Turk & Kurd
	destroyed	as in 1930	Turk & Kurd
	destroyed	rebuilt	Turk & Kurd
16 × 20	destroyed	as in 1930 (2 walls standing)	Armenian & Kurd
9 × 14	destroyed	rebuilt same style	Armenian & Kurd
7 × 12	destroyed	rebuilt in same style	Armenian & Kurd
10 × 20	destroyed	rebuilt at new location	Assyrian & Kurd
	destroyed by Turks in 1918		Assyrian & Kurd
13 × 21	destroyed	as in 1930	Armenian & Turk
	destroyed	as in 1930	Turk
7 × 17	undamaged	as in 1930	Kurd
12 × 20	part collapse	as in 1930 (3 walls standing)	Turk
10 × 13	part collapse	repaired	Turk
	destroyed	as in 1930	Turk
14 × 17	destroyed	as in 1930	Turk
	destroyed	rebuilt in sun-dried brick	Turk
	destroyed	as in 1930	uninhabited
	destroyed	as in 1930	Kurd
	destroyed	as in 1930	Kurd
	part collapse before 1930		Turk
8 × 10	undamaged	as in 1930	Kurd & Turk
	destroyed	as in 1930	Kurd & Turk

which, even though not all of uniform construction, were nevertheless much more resistant than the usual adobe house. Many of these churches can be seen to-day in the same condition as after the earthquake, and they provide a unique means of assessing the severity of the shock near the epicentre.

The effect of the earthquake on the villages of the Salmas Plain is described first, and followed by the description of the mountain villages and the isolated pocket of damage near Mamaqan south of the epicentral region.

a) *Salmas Plain.*

The region of maximum destruction, located in the southwestern part of the Salmas Plain, is approximately contained in the imaginary triangle with apexes at Kohneh Shahr, Payajuk and Zaviehjuk (Fig. 3). Here all the houses were completely levelled to the ground. The most intense destruction probably occurred near the Kohneh Shahr apex where all but one of the 20 churches located in the villages of Kohneh Shahr, Savra, Khosrova, Uleh, Malham, Gulizan and Patehvir were completely destroyed. The exception was Mar Givargis in Khosrova, a large stone, masonry structure with walls built in the traditional style, i.e. about 1.25 m thick, with an outer layer of hewn stone and an inner layer of rough stone and with good cement mortar. The 4 inner pillars and the vaulted roof collapsed, but most of the walls excepting the corners of the building remained standing (Fig. 5). In Malham, which, with Saramerik, was the only Christian village in which most of the inhabitants slept indoors and consequently suffered a large number of casualties (*), the southern and eastern walls of S. Zoravar — a construction similar to Mar Givargis — remained partly standing, but the rest of the church collapsed (Fig. 6). All the other 18 churches, which included at least 6 stone masonry and 3 kiln-brick constructions, were destroyed to the extent that none of the walls remained, even partly, standing. The medieval Miri-Khatun brick tower and the great mosque of Kohneh Shahr were similarly destroyed.

(*) The reader is referred to Table 1 for casualty figures which are not mentioned systematically in the text.

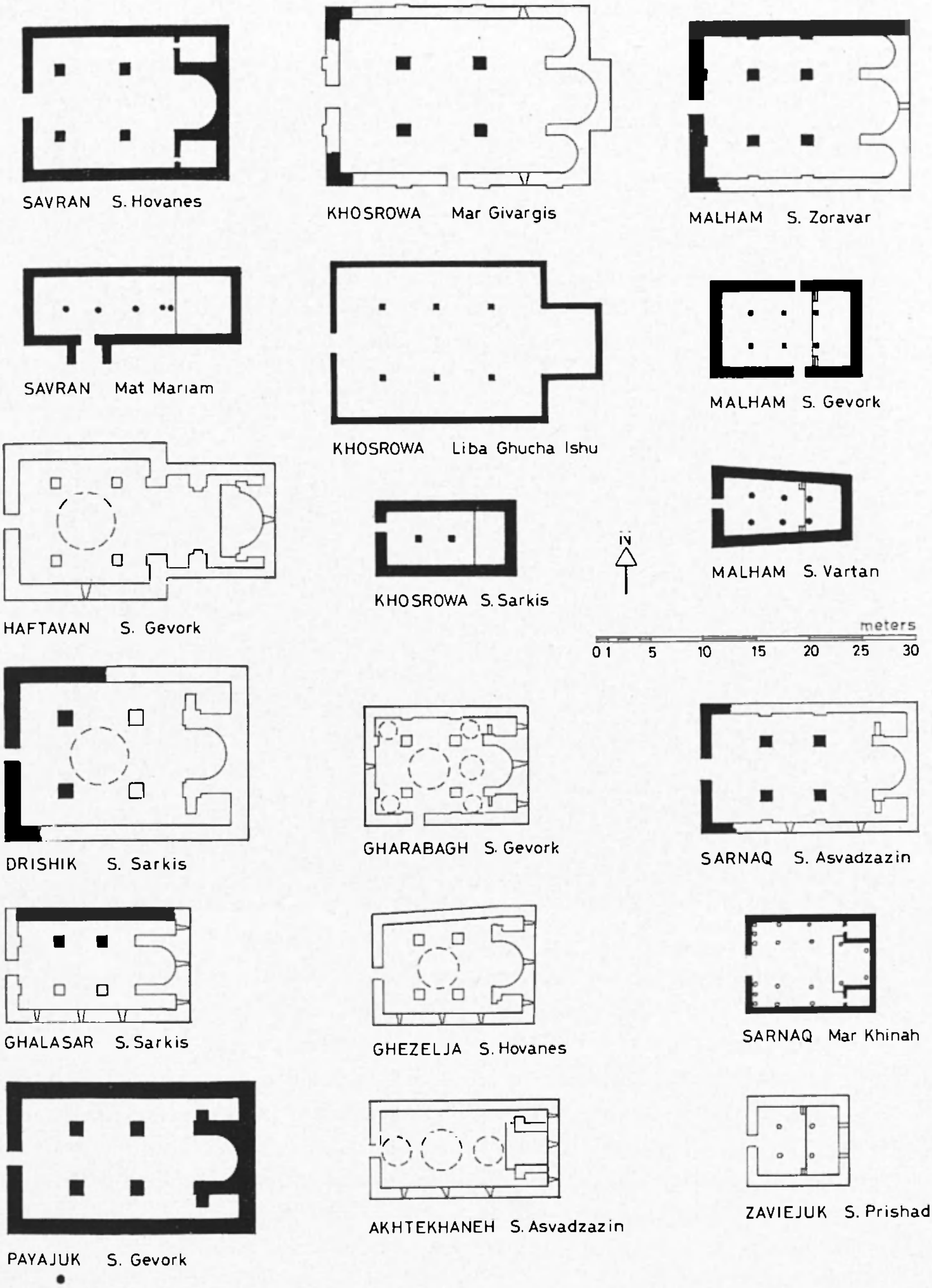

Fig. 5 – Earthquake damage to churches in the Salmas Plain
Features shown in black collapsed during the earthquake. Ground plans are schematic. See also Table 2 and Kleiss (1969).

Fig. 6 – S. Zoravar (Malham)
Interior side of southern wall seen from the partly collapsed eastern wall (lower left-hand corner). The roof and all other walls collapsed.

The intensity of ground motion in this region of maximum destruction is also indicated by the displacement of tombstones in the cemeteries of Khosrova, Haftavan and Malham. These, tombstones, sculpted in the local basalt, are generally made of two separate pieces, a horizontal slab typically about 30 cm thick and 80 × 185 cm in plan, placed on the ground above the grave, and a solid block about 66 cm high and 60 × 160 cm in plan, placed on the slab (Figs 7 and 8). The slab is generally partly lodged in the ground, but it was impossible to ascertain so many years after the event whether it had moved relatively to the ground during the earthquake. The upper block

Fig. 7 – Tombstones in Khosrova cemetery
In the foreground, some examples of rotation of the upper block with respect to the lower ground slab. Note some tilted tombstones in the background. Looking NW.

had however, in nearly all cases, moved from its original position on the slab. In the Khosrova cemetery, 183 cases of movement (about ⅓ all the tombstones) were clear enough to be measured: they showed 104 rotations (74 anti-clockwise and 30 clockwise), 55 N-S translations (40 to the N, 15 to the S) and 28 E-W translations (23 to the E, 5 to the W). As most of the cases of rotation did not seem to be accompanied by any E-W translation, they were probably due to a N-S or S-N sliding with unequal friction at the slab-rock interface. Examples of tombstone movement are given in Fig. 7 and 8 and their

Fig. 8 – Tombstones in Khosrova cemetery
Examples of translation of the upper block with respect to the ground slab. Looking W.

locations are shown in Fig. 9. A number of tombstones (not included in the above count) were also tilted sideways, generally to the N or to the S and often without any visible displacement of the block on its slab, probably as a result of foundation failure under the slab. The Khosrova cemetery is located about 4 km from the earthquake fault, the latter being oriented NW-SE and of right-lateral displacement with the NE side downthrown.

By an unusual coincidence, Zayia, the eyewitness of the main shock, not only observed the displaced tombstones in Khosrova the morning after the earthquake, but actually saw them move again during the principal aftershock of 8 May. "You know the tombstone of M. Darnis, one of the most massive of all the cemetery; it measures about 2 m in length, 0.60 m in width and 0.75 m in height. Well,

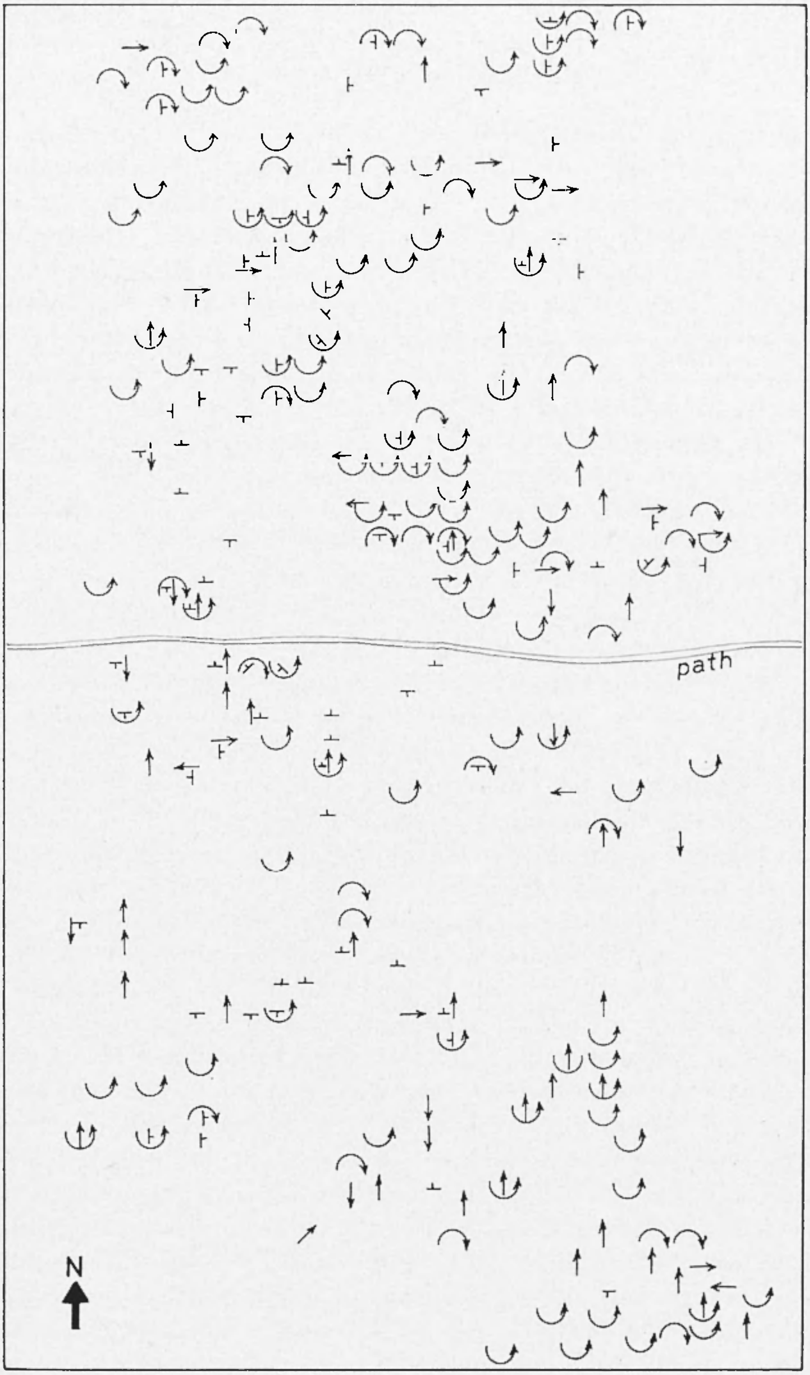

Fig. 9 – DISPLACED TOMBSTONES IN KHOSROVA CEMETERY

Sketch-plan showing approximate location of displaced tombstones. Arrows indicate movement of upper block with respect to ground slab; tilted tombstones shown with geological dip symbol. Justaposed symbols describe overall displacement of single tombstones. Tombstones showing no movement, or ambiguous cases, are omitted. Width of cemetery is approximately 150 m.

this enormous stone was projected about 0.50 m from the south to the north; it is no longer on the grave. The same happened to most of the other tombstones" ([20]). "Thursday evening at about 6 pm, I was sitting on Mr. Baduel's tombstone in the (Khosrova) cemetery and was reciting the rosary to replace the breviary which I hadn't been able to say, when I felt myself being lifted; all the other tombstones creaked. I didn't even get up but watched the other tombstones being lifted: by about 3 cm. The Resurection of the Dead came into my mind and onto my lips" ([21]).

The Malham cemetery which is crossed by the earthquake fault, contains only a few tombstones of the type described above, the majority being made of a single piece. Of the few that could be measured, several cases of translation were observed in which the upper block was moved in the same direction as the fault side on which it was located, i.e. to the E on the north side of the fault, and to the W on the south side of the fault (Fig. 10).

Several independant witnesses amongst the survivors of the earthquake, as well as contemporary written accounts, related that, in the region of maximum destruction, a first shock was felt as an upward motion, and that this was followed immediately by a horizontal shock from W to E and then by another one from E to W. In many churches, we observed that the central pillars or columns and the western façade collapsed towards the west. Likewise, in many of the less damaged churches in the region east of the epicentre (described below) only the western wall collapsed, and this always to the west. However, as the eastern end of these churches is usually formed by one or three apses, it is the most resistant regardless of the direction of strong ground motion. Other similar observations must first be obtained from other earthquakes before conclusions may be drawn.

In the Salmas Plain east of the region described above, but still in the Kohneh Shahr-Payajuk-Zaviehjuk triangle, the destruction was nearly as severe. In Dilman, the largest settlement of the whole region, it was estimated that about 1,100 of the 18,000 inhabitants were killed, constituting probably a large number of those that slept indoors. These casualty figures are however unreliable, due to two main reasons. Firstly, the size of the town: whereas in the smaller villages, people could remember, sometimes even by name, all those that had been killed, in the larger centres of Dilman and, to a lesser degree, Kohneh Shahr, the surviving inhabitants found it difficult to grasp the overall extent of the catastrophe. Secondly, the absence

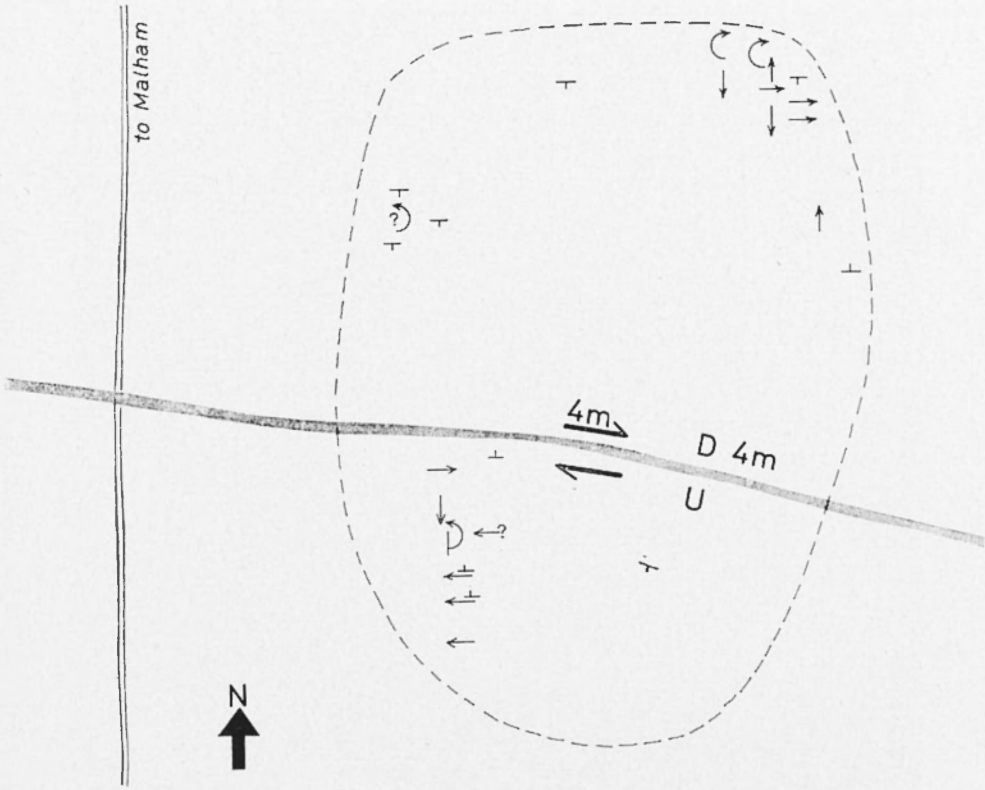

Fig. 10 – DISPLACED TOMBSTONES IN MALHAM CEMETERY

Only a small number of the tombstones were of the 'block on slab' type. Symbols are as for Fig. 9. Dashed line is approximate boundary of cemetery which measure about 75 m in the N-S direction. Shaded line is earthquake fault scarp with displacements in meters (U = up, D = down).

of a Christian community in Dilman: in the other Christian villages, the various massacres and persecutions that this minority had undergone in the decades preceding 1930, made them acutely aware of their numbers both before and after the earthquake, and several chroniclers came from Tehran and Tabriz to investigate and record the facts (9,15). Nothing similar seems to have been undertaken in Dilman or in the entirely Kurdish or Turkish settlements.

All the buildings in the town of Dilman, including the large Agha Mosque, were destroyed, with the exception of two newly built houses which were still standing, even though severely damaged. The town was subsequently rebuilt west of the ruins and renamed Shahpur. The other villages in the region of maximum destruction not described so far were Haftavan, Sarnaq, Drishik, Kuche Mashk, Kalashan, Zaviehjuk and Payajuk. In Haftavan, two of the three churches were destroyed, the survivor being the 13th century church of S. Gevork. The central dome of this massive construction collapsed and the eastern façade developed diagonal fissures, but otherwise the building was intact (Fig. 11). The nearby school and assembly hall, built in kiln-brick with a stone foundation, collapsed. In Sarnaq, the stone mansonry church S. Asdvadzadzin survived partly, even though its roof collapsed and 3 out of the 4 central pillars and the western façade fell to the west (Fig. 12). A similar church in Drishik, S. Sarkis, suffered much the same type of damage, and the adobe

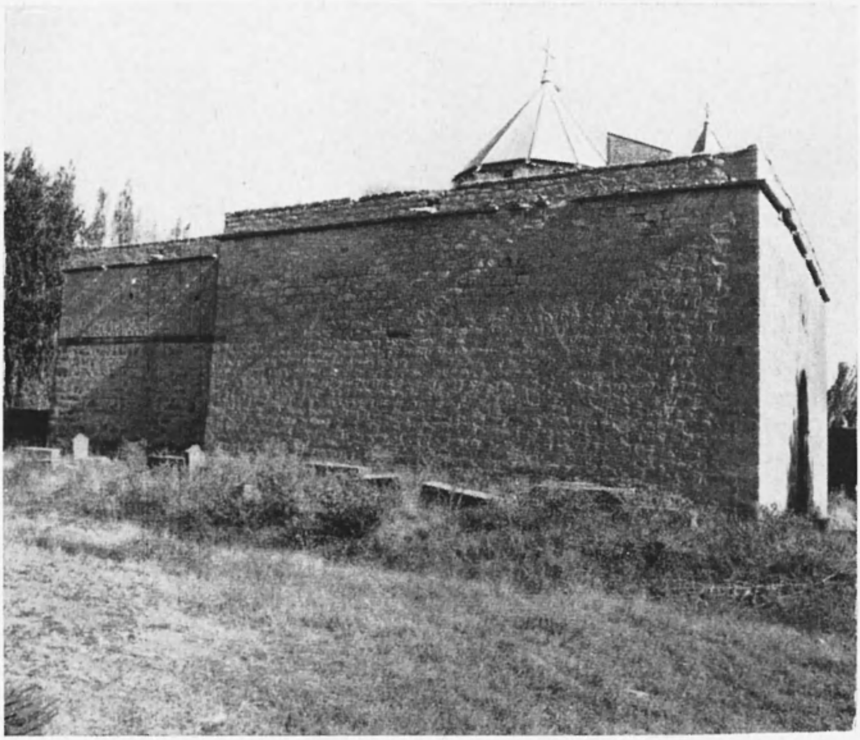

Fig. 11 – S. Gevork (Haftavan)
The central dome collapsed, and the eastern and northern walls (seen here) were fissured, but otherwise this 13th c. church withstood the earthquake remarkably well.

Fig. 12 – S. Asdvadzadzin (Sarnaq)
The western wall and 3 of the 4 central pillars fell to the west, a type of damage common to many of the Salmas churches. Interior of the church seen from the eastern apse.

church in Kalashan was destroyed except for one wall which remained partly standing.

Zaviehjuk is of particular interest as it is situated on the fault at the southern edge of the Salmas Plain. The village, and the adobe church of S. Hovanes were destroyed, but the adobe chapel of S. Prishad was completely intact. The latter is situated on rock, about 500 m west of the village and at about the same distance south of the fault. In plan it is nearly square (8 × 10 m) and its flat roof is made of poplar trunks as beams and covered with a mud/straw mixture. The only effect of the earthquake that could be detected was that the 4 tree-trunk pillars supporting the roof were leaning by about 3° to the east (Fig. 13), i.e. opposite to the damaged churches north of the fault which were generally leaning, or had collapsed, to the west. The survival of this building located nearly on the fault may be attributed in part to the fact that it was a compact, quasi-cubic structure, built on rock and near the southeastern limit of destruction. Even though this does not explain entirely its exceptional resistance,

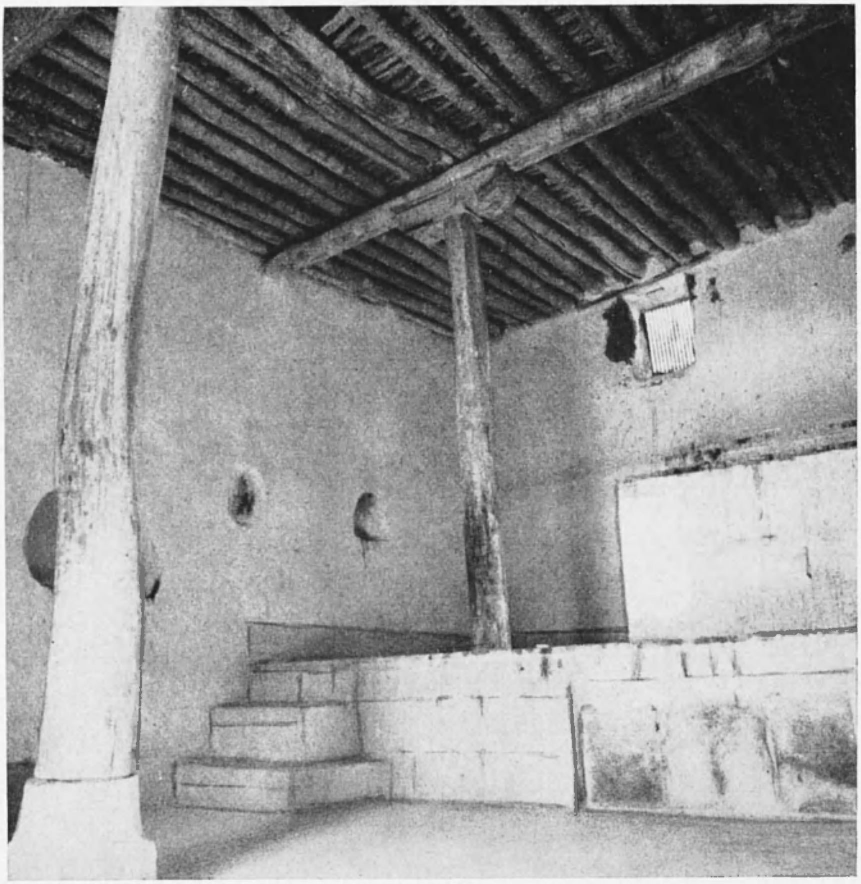

Fig. 13 – S. Prishad (near Zaviehjuk)
The only visible earthquake damage to this adobe chapel located about 500 m south of the Salmas Fault was that all 4 tree trunk pillars were leaning slightly to the east.

it does place S. Prishad in the same category as other undamaged structures located on, or very near, other earthquake faults (13).

In Payajuk, about 3 km due east of Dilman, destruction was still very severe, killing the only three inhabitants who slept indoors. The stone masonry church of S. Gevork was levelled to the ground, as was the near-by house of the Armenian writer and poet Rafi (Fig. 14). The new village was subsequently relocated south of the previous one.

Fig. 14 – S. GEVORK (PAYAJUK)

The church collapsed completely. View from the southeast corner towards the apse.

Fig. 15 – S. Sarkis (Ghalasar)
Part of the roof, and the northern wall, collapsed to the north. Looking SW.

The other villages destroyed in the Salmas Plain but located outside of the triangle of maximum destruction (Kohneh Shahr-Payajuk-Zaviehjuk) were Moghanjik and Saramerik in the north, Sadaghian, Hamzehkandi, Habashi, Ghezelja, Ghalasar and Akhtekhaneh in the east, Minas, Khantakhti and Tamar in the southeast. All these villages were destroyed and suffered casualties, but the state of the three stone masonry churches of the region in Ghalasar, Akhtekhaneh and Ghezelja, indicated that the shaking was here probably less severe. In Ghalasar, the roof of S. Sarkis collapsed partly, and the northern wall fell to the north, but the other walls survived at their full height (Fig. 15). This collapse towards the north, also observed for the small parapet wall surrounding the roof of the church, is exceptional, and

Fig. 16 – S. ASDVADZADZIN (AKHTEKHANEH)
The 14th c. church, located near the eastern limit of the epicentral region was only fissured by the earthquake.

may be compared to the dominant northward displacement of the tombstones in Khosrova (p. 171) and the northward shift of Zayia's car (p. 160). The church of S. Asdvadzadzin in Akhtekhaneh survived entirely even though it was fissured (Fig. 16). It is a 14th century construction with the traditional double wall (kiln-brick inside, rough stone masonry outside), and a roof with three kiln-brick domes. The northern and eastern walls were fissured, and the interior N-S arches developed cracks near their keystone (Fig. 17). In the near-by village of Ghezelja, S. Hovanes also survived, even though with more damage than S. Asdvadzadzin (Fig. 18). This church, which we dated

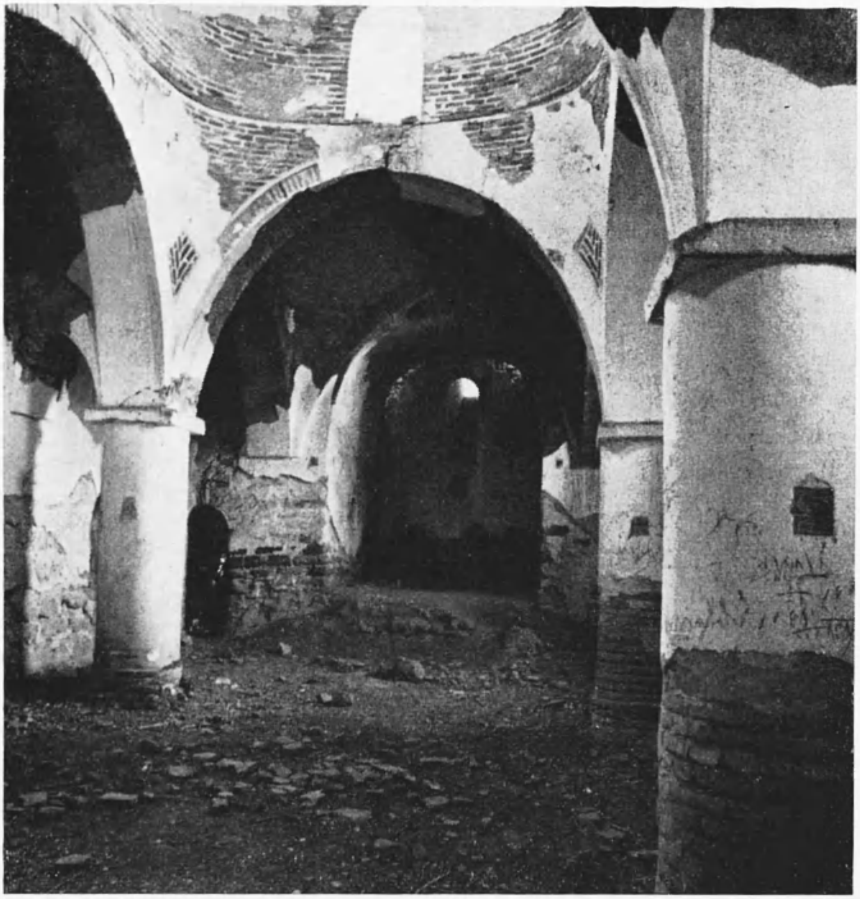

Fig. 17 – S. Asdvadzadzin (Akhtekhaneh)
The main interior damage was a central east-west fissure crossing the length of the building.

provisionally 1007 A.D. by an inscription on the doorway, is a rough stone masonry construction with 4 pillars supporting a central dome. All four walls were fissured diagonally, and an important central crack crossed the whole roof from E to W (Fig. 19).

The lesser damage suffered by the three churches in Ghalasar, Akhtekhaneh and Ghezelja described above when compared to all other churches of the Salmas Plain (with the exception of S. Gevork in Haftavan) leads one to situate in their vicinity the eastern limit of the epicentral region. Further east, towards Lake Rezayeh, damage

Fig. 18 – S. Hovanes (Ghezelja)
Eastern façade of the earliest dated church (1007 A.D.) in the Salmas Plain.
All walls were seriously fissured.

decreased very rapidly: Kanyan, Mafi Kandi, Shekar Yazi, Sultan Ahmed, Yavshanli, Gharaqeshlagh, and Aqziarat suffered little and had no casualties. Still further east, S. Gevork in Gharabagh, a church similar in plan and size to S. Hovanes (Ghezelja), showed no signs of earthquake damage (Fig. 20).

b) *Mountain region.*

About half the number of villages damaged or destroyed by the earthquake were situated in the mountains which surround the Salmas plain in the north, west and south. However, with the exception of Chahriq on the Zola Chay River, these villages were all smaller than those of the Plain. They were populated then (1930), as they are now, by Turks and Kurds, their Christian population having fled in 1918. For convenience of description, the region is subdivided into a northern sector east of the Dowshivan Su, a western sector between the Dowshivan Su and the Zola Chay, and a southern sector east of the Zola Chay (Fig. 3).

In the north, the villages nearest to the Plain were destroyed and had casualties: Vardan, Ayan, Ghabrabad, Sheydan, Yengijeh and Lashgaran. Sailab and Howdar were partly destroyed with very

Fig. 19 – S. Hovanes (Ghezelja)
As in Akhtekhaneh, the main interior damage was a central east-west crack crossing the whole building.

few or no casualties, the latter being abandonned after the earthquake and resisted in a more accessible location (Fig. 21). Further north, Shurik, Urban, Gulan and Chahar Sutun which were only slightly damaged, mark the limit of the region of destruction.

In the western sector along the Zola Chay, Zola was destroyed, and most of the houses in Chahriq collapsed. In the latter village, of the two stone churches, one had been destroyed before 1930 and the other collapsed during the earthquake. Further upstream, Balghazan and Siavan were only partly damaged. North of the Zola,

Fig. 20 – S. Gevork (Gharabagh)
The church (1784 A.D.), located east of the epicentral region (see Fig. 1), was unaffected by the earthquake.

Fig. 21 – Site of Howdar
One of several mountain villages destroyed by the earthquake and to-day relocated at a different site. Looking NE.

a line of villages on the basalt plateau overlooking the Salmas Plain were destroyed and had a large proportion of casualties: Kahriz, Kurdran, Aslanik, and Haqviran. The churches in the last two localities had been destroyed before the earthquake when the Christians left the region. Along the Dowshivan Su, Nazirabad, Sowfiabad and Derik were completely destroyed and had heavy casualties, and in the latter two cases, were relocated at new sites. Above the old village of Derik, which had been sold to the Kurds before the earthquake, a small stone masonry chapel forming part of a monastery, collapsed (Fig. 22). A group of villages located further up in the mountains were also destroyed: Guzik, Ashnak, Hablaran, Khorkhora, Senji and Alibolagh.

The limits of destruction of this western sector can be traced approximately east of the Turkey-Iran border. The furthest village to be destroyed was Borushqalan where the casualties were exceptionally heavy because the foreshock had not been felt. Indirect information from Hanik in Turkey would suggest that the village had been partly damaged. Further south in Iran, Aqbarzeh and Ghezel Kandi were only about half-destroyed. The villages in the extreme southwest are practically inaccessible due to the difficulty of the terrain. However, by interviewing some of their inhabitants who had moved nearer to the Salmas Plain after the earthquake, we could establish that Shiveh Darreh, Shiveh, Dikeh and Haji Jafan were undamaged.

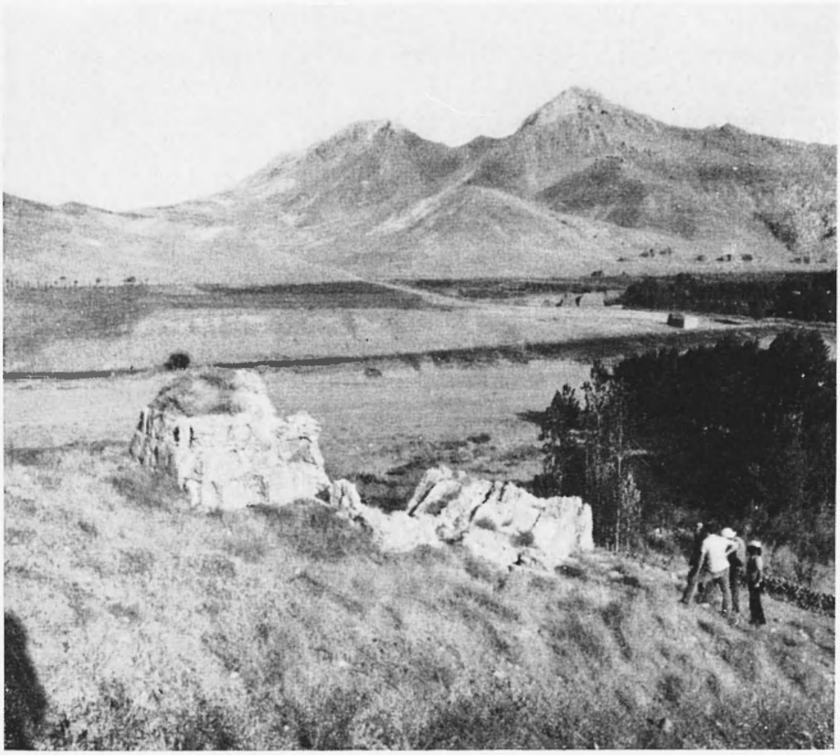

Fig. 22 – S. Asdvadzadzin (Derik)
The western part of the chapel collapsed, leaving only the apse standing. The old village, totally destroyed, was situated at the foot of the chapel. The present-day village is located near the trees in the background. Looking SE.

In Kashkavich, only 3 houses out of 20 collapsed, killing 2 people, the rest being damaged but standing. The heavy destruction in Kuzerash seems to have been due to some exceptional local condition (landslide?).

In the southern sector, Shurgel, located on rock at the south-eastern end of the earthquake fault, was about 1/3 destroyed, and further along the fault alignment, Zindasht and Issy Su were only lightly damaged. In the south, Bardian and Bostakabad were also lightly damaged, but the adjoining villages of Gonieh, Bajergeh and Hosseinabad were unaffected.

c) *Mamaqan pocket of destruction.*

Apart from the main region of destruction in the Salmas Plain and in the surrounding mountains, isolated pockets of damage occurred in a few regions away from the epicentre. Contemporary newspaper reports mention damage in the Qutur valley south of Khoy, but we were as yet unable to investigate this information. South of the epicentral region, 85 people were killed in Mamaqan which was completely destroyed, even though all the surrounding villages (Bajergeh, Hosseinabad, Sidan, Mingol, etc.) were undamaged. Mamaqan is situated in a loess valley which has a very shallow water table. South of Mamaqan, Sormanava was half-destroyed, but its vaulted church situated on rock west of the village was undamaged. In both villages of Mamaqan and Sormanava all the inhabitants had slept indoors as the foreshock had been felt only very lightly, and aftershocks did not increases appreciably the damage caused by the main event.

Faulting and thermal spring activity

General.

Two fault-breaks were associated with the earthquake: the first, termed here Salmas Fault, occurred in a NW-SE direction at the southern edge of the Salmas Plain; the second, termed Derik Fault, occurred in a NE-SW direction near the mountain village of Derik (Fig. 3). Maximum displacements on these faults were: for the Salmas Fault, 4 m right-lateral and over 5 m vertical (NE downthrown); for the Derik Fault, left-lateral by an unknown amount, and about 1 m vertical (NW downthrown). Both faults were briefly alluded to in contemporary reports and correspondence: Franssen [7], Zayia [21,22], Brunk [3], Tabriz and Haratch newspapers; to-day they are still perfectly visible on the ground and on aerial photographs.

Related to this faulting, several thermal springs changed their locations or outputs: Darmanava spring (Issy Su) in the southeastern extension of the Salmas Fault, Derik spring in the southwestern extension of the Derik Fault. A new spring, the Zelzele Bolaghi (literally, the earthquake spring), appeared in the Salmas Plain and is still responding to-day to local earthquake tremors.

Salmas Fault.

The Salmas Fault is the longer of the 2 faults, and the one that produced the larger displacements. It is formed by two separate *en echelon* segments referred to here as the Akhian segment and the Zaviehjuk segment, the latter being probably the result of the junction of two other *en echelon* segments (Fig. 23).

The Akhian segment starts at the Shurgel pass and follows the edge of the mountain, crossing the village of Akhian, and then disappears as it enters the Salmas Plain near Sarnaq (Fig. 24). Maximum displacements are 1.5 m (NE down). The slight curvature of the fault trace when referred to the local topography indicates a steep north dip of the fault plane at depth. At Akhian, the fault trace crosses a stream bed, exposing a shear zone in the underlying metamorphic rock and in which many new earthquake fissures can be seen crossing older joints and slickensided planes. A surface travertine cover about 1 m thick is interrupted at the edge of the fault zone. East of Akhian, and at about 500 m from the fault, a short N 160° fracture zone in the travertine cover is made of open *en echelon* fissures 20 to 30 m long and oriented about N 140°, and occasional ridges oriented about N 20° (Fig. 25). This disposition suggests local left-lateral shearing, probably conjugate with respect to the Salmas Fault.

The Zaviehjuk segment starts east of the village of Zaviehjuk and crosses its northern outskirts, striking N 125° (Fig. 26). Its throw (NE down), about 2 m at the village (Fig. 27), increases in the west to over 5 m (Fig. 28). Its strike changes gradually from the original N 125° to N 105° at the Malham cemetery. Up to this location it is entirely contained in the alluvial fans which originate in the moun-

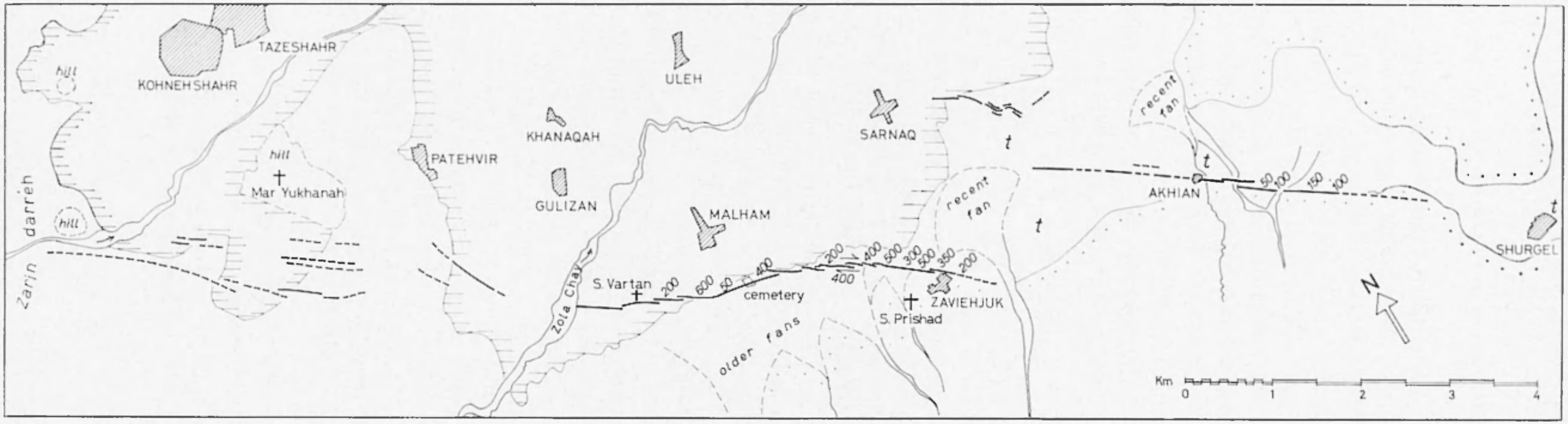

Fig. 23 – Salmas fault

The trace of the earthquake fault, dashed where uncertain, was drawn in the field with the help of 1:20,000 aerial photographs. Numbers indicate vertical displacement (NE downthrown) in centimeters; horizontal displacement was right-lateral, but could be measured precisely in only one location. Dotted shading is rock outcrop, line shading is cultivated fields. t, travertine cover.

tains to the south. About half-way between Zaviehjuk and the Malham cemetery, two narrow parallel gullies were displaced right-laterally by about 4 m. Even though other reliable markers for measuring horizontal movement could not be found, the overall trace of this segment is composed of characteristic right-lateral scarps oriented at about 20° to the overall strike (Fig. 29). The sides of the erosion gullies which have worked their way into the degraded scarp since 1930

Fig. 24 – SALMAS FAULT, AKHIAN SEGMENT

The eroded fault trace runs at the foot of the mountain, from the lower right-hand corner of the photograph to the Shurgel pass in the background. Average vertical displacement (NE, i.e. left side, down) was about 1 m. Looking SE.

Fig. 25 – Salmas fault, Akhian segment
Fracture zone in the travertine cover east of Akhian, about 500 m from the main fault trace. The *en echelon* pattern suggests local left-lateral shearing. Looking SE.

show an undisturbed bedding of the gravel fans, with occasional small fissures parallel to the scarp and dipping north by about 85°.

At the Malham cemetery, the fault shows clearly a feature observed at several localities, i.e. a narrow graben located immediately at the foot of the degraded scarp (Figs 30 and 31). This increases the apparent throw from about 2.5, to over 4 m, and suggests a tensional type of fracturing. Contemporary descriptions of the scarp after the earthquake also mention a vertical wall with a deep open crack at its base, and expulsion of water along its trace. West of the

Fig. 26 – SALMAS FAULT, ZAVIEHJUK SEGMENT
Aerial view of the fault trace (between arrows) passing through Zaviehjuk (Z) and the Malham cemetery (M). There are several topographical steps north of, and parallel to, the fault scarp, the most obvious one marking for a short distance the limit between mountain fans and cultivated fields northwest of Zaviehjuk. North is top of photo; area coveed is approximately 4 × 4 km.

cemetery, the fault enters cultivated fields with an apparent throw of about 6 m partly due to a pre-existing topographical step (Fig. 32). It gradually bends back to a N 125° direction near the Zola Chay river.

Fig. 27 – Salmas fault at Zaviehjuk
The two persons are walking along the eroded fault scarp which crosses the Zaviehjuk village in the background. The vertical throw is here about 3 m (NE, i.e. left side, down). Looking SE.

West of the Zola Chay, and up to the Dowshivan Su at Zarindarreh, the fault crosses a much flatter topography in a region subject to spring floods. The scarp is here rarely visible, but the fault trace is marked by a wide linear depression across the fields along which the cultivations are interrupted. Some witnesses mentioned that the fault continued along the valley in the direction of Nazirabad, but field evidence is lacking on this point. However, in the Dar Darreh valley, east of the pre-earthquake location of Sowfiabad, deep open

Fig. 28 – SALMAS FAULT, ZAVIEHJUK SEGMENT
5 m vertical throw west of Zaviehjuk. Note the undisturbed gravel bedding. Looking SE.

cracks were observed in a travertine plateau, somewhat similar in appearance but less systematic in pattern to those described east of

Fig. 29 – Salmas fault, Zaviehjuk segment
The persons in the foreground and middle background are standing on 2 seperate *en echelon* scarps indicating right-lateral wrench movement. The line of trees marks a topographical step probably due to a previous lowering of the Salmas Plain. Looking N.

Akhian (p. 190). The origin of these fractures is not clear, and tension cracks due to incipient landslides cannot be altogether discarded.

Immediately north of the Zaviehjuk segment, between Zaviehjuk and the Zola Chay, several topographic steps can be observed running approximately parallel to the fault trace. Three such steps can for example be seen between the scarp and Malham (Fig. 26). One of these steps constitutes the present-day boundary between the irrigated fields and the mountain fans. These steps are a few meters high and very similar in appearance to the degraded earthquake fault scarp. Their most likely interpretation is that they represent previous

Fig. 30 – Salmas fault: eastern part of Malham cemetery

The line of tombstones delineating the far edge of the cemetery shows the narrow graben located at the foot of the scarp. Scarp runs from right-hand side of photo to background. Apparent throw is about 4 m.

Fig. 31 – Salmas Fault: western part of Malham cemetery
Eyewitnesses claim that the fault scarp was originally nearly vertical. Apparent throw and estimated right-lateral movement are each of the order of 4 m. Looking W.

stages of subsidence of the Salmas Plain with respect to the mountains in the south.

The Darmanava thermal spring near Issy Su is located in the exact southeastern continuation of the Akhian segment, about 11 km beyond the point where the earthquake fault stopped. It is a sulphurous spring at a temperature of 37.5°C used for medical purposes, and depositing a whitish carbonate of soda. Its flow decreased appreciably after the earthquake. About 10 km north of the fault, at the northern foot of the isolated hill marked 1628 in Fig. 3, a cold (18°C) gazeous spring appeared during the earthquake and was subsequently named Zelzele Bolaghi. It is reported to have taken a muddy colour after a small shock felt in Shahpur on the 22 June 1973. Apparently there was also a hot medicinal spring near Sadaghian, but this was not visited by the authors.

Fig. 32 – SALMAS FAULT, ZAVIEHJUK SEGMENT
The earthquake fault scarp is here surimposed on a pre-existing topographical step, with a resulting apparent throw of about 6 m. Between Malham and the Zola Chay, looking NW.

Derik Fault.

The Derik Fault, which, like the Salmas Fault, was associated with the main shock, can be followed to-day from a point just east of the Dowshivan Su to the left bank of the Rud Aqbarzeh, and beyond this point, with an offset, along the right bank of the Rud Aqbarzeh (Fig. 33). Along its main section between the two rivers it marks the limit between a crushed amphibolite in the north and a crushed diorite in the south, with occasional pegmatite outcrops along the shear zone. The dip of the geological fault is N75°-80°, and the vertical earthquake displacement was about 1 m (NW down) (Fig. 34). Suitable markers could not be found to measure horizontal displace-

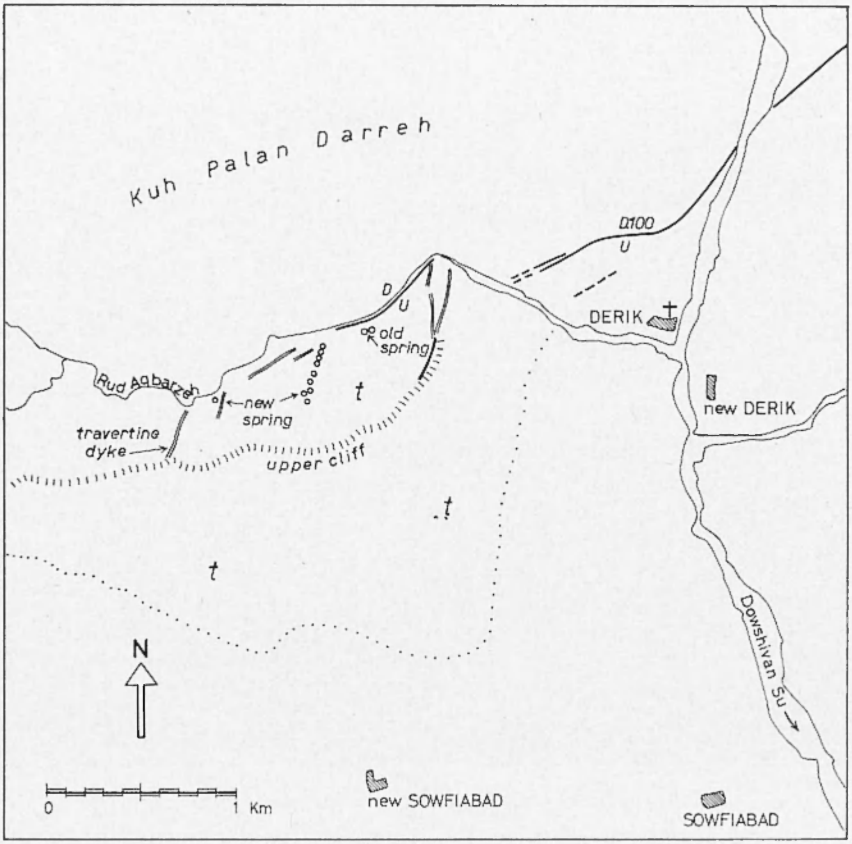

Fig. 33 – Derik Fault

Trace of earthquake fault from field mapping and 1:20,000 aerial photography. Number indicates vertical displacement in centimeters, *U* up, *D* down. Dotted line is approximate southern limit of travertine outcrop (*t*), northern limit being formed by the Rud Aqbarzeh.

ments. The overall trace of this section strikes approximately N45°, but includes also a central E-W kink. At its southwestern end, this section stops quite suddenly before reaching the Rud Aqbarzeh and no fractures could be found in the same alignment on the opposite (right) bank. However, about 300 m further upstream on the right-bank, long cracks were formed parallel to the river in the travertine deposits (Fig. 35). Their overall direction is about N45°. They mark the edge of a cliff along which travertine was deposited from two

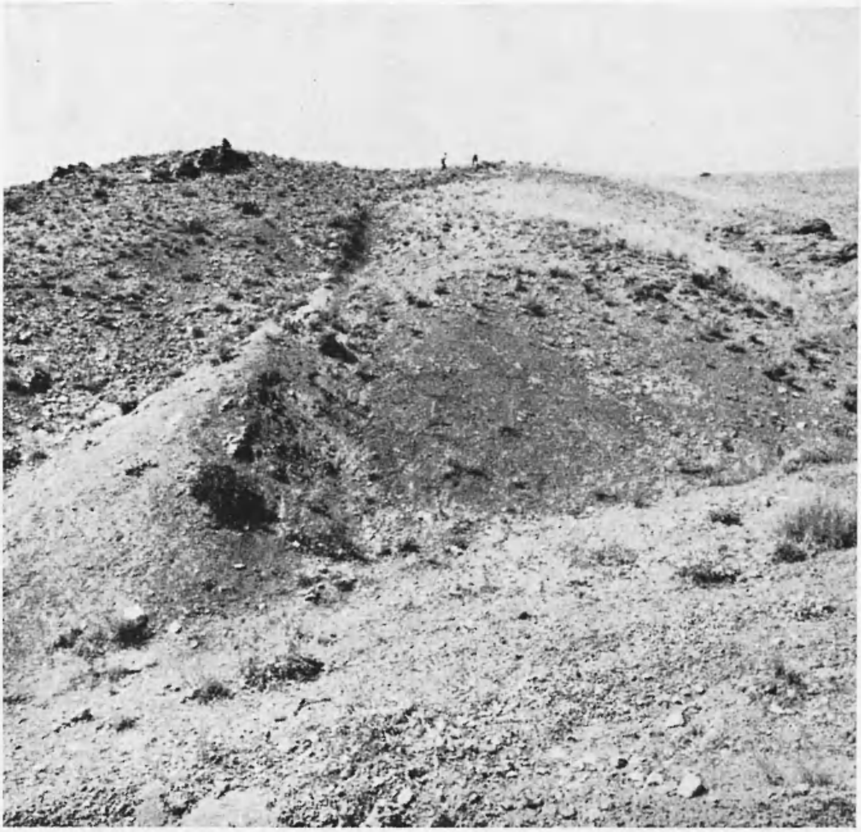

Fig. 34 – DERIK FAULT
Section north of the old village. Vertical displacement is about 1 m (NW, i.e. right side, down). Looking SW.

springs up to the time of the earthquake in 1930. At the earthquake, these springs ceased, and new springs appeared and are still active to-day, in two locations, respectively 200 m and 800 m further upstream. At the first location, 8 small springs are aligned along about 300 m in a N15° direction, and at the second location a larger spring (about 2 *l/s*) has already deposited since 1930 an appreciable amount of travertin (Fig. 36). The temperature of the water (33°C) is about 2.5°C lower than that of the pre-earthquake springs ([12]). The entire region of the right-bank of the Rud Aqbarzeh is covered by a massive outcrop of an older travertine in sub-horizontal deposits. A few

Fig. 35 – DERIK FAULT
Earthquake fractures in travertine on the right-bank of the Rud Aqbarzeh. The main fractures are linear and over several hundred meters in length. Looking SW.

thin dykes of the same travertine cut vertically through these deposits and stand out in the topography. They are oriented in two directions: N 15° and located in the approximate continuation of the earthquake cracks, and N5° i.e. approximately parallel to the new spring alignment (Fig. 33).

If the entire structure formed by the earthquake fault between the two rivers and the travertine structures on the right-bank of the

Fig. 36 – Derik thermal spring
The main spring which appeared with the earthquake in 1930 has already deposited an appreciable amount of new travertine. Layering in the background cliffs is formed by consecutive Quaternary basalt flows. Looking SW.

Aqbarzeh is considered, the simplest interpretation is that there are 3 *en echelon* segments in a left-lateral disposition, the first two being formed by the fault north of Derik and on either side of the E-W kink, and the third by the earthquake fractures in the travertine near the pre-1930 springs. In this interpretation the alignment of new springs and travertine dykes would correspond to the direction of the maximum principal stress of the left-lateral deformation.

Non-tectonic ground effects

Besides the ground deformations of tectonic origin described above, other ground features of secondary origin were also observed (Fig. 3). Many villages in the Salmas Plain reported waterlogging and flooding, often accompanied by ground fissures. These could be either due to the lowering of the Plain and a consequent relative rise of the water table, or to a liquefaction effect caused by shaking. Mountain springs in two villages at the edge of the Salmas Plain in-

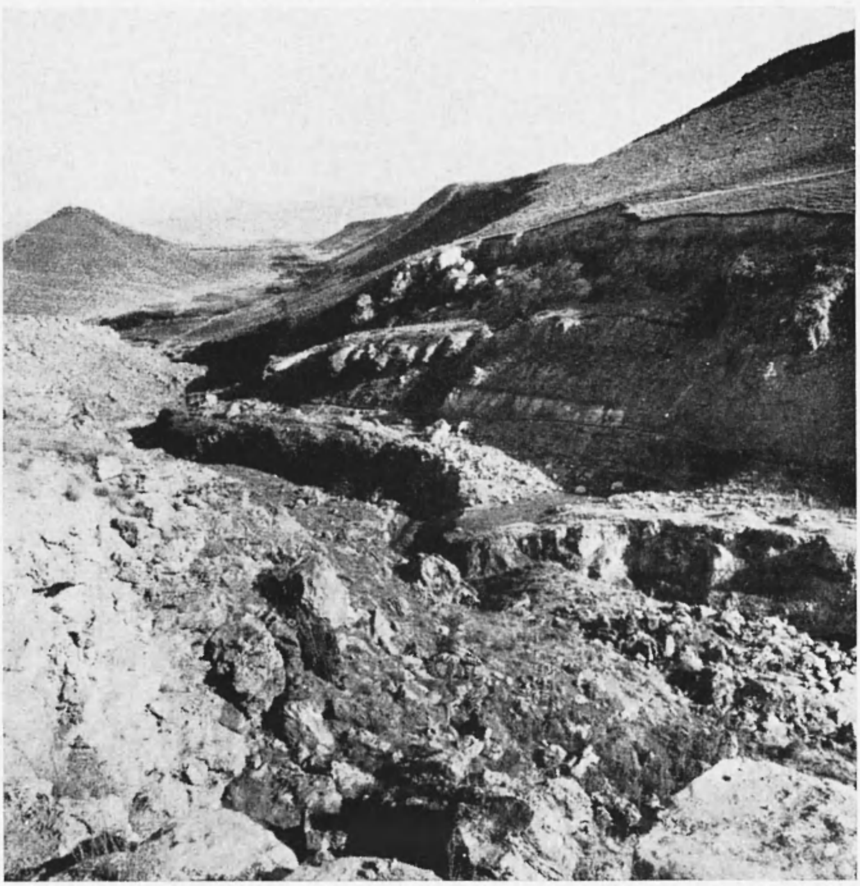

Fig. 37 – Earthquake triggered landslide
Landslide near Nazirabad. Looking SE along the Dowshivan Su valley in the extension of the Salmas Fault.

Fig. 38 – HAFTAVAN TEPE

Fractures thought to be of earthquake origin (arrows) revealed by the archeological dig.

creased their flow (Tamar and Zaviehjuk); in some of the higher mountain villages springs decreased, and in two cases ceased altogether (Alibolagh and Hablaran). Several landslides also occurred, the largest in the mountains near Nazirabad (Fig. 37) and at Drishik Tepe, an archeological mound south of the village of Drishik. Recent excavations at Haftavan Tepe also revealed fissures which may be interpreted as incipient landslide cracks [4] (Fig. 38). Large tension cracks resulted from a bedding-plane slip in Eocene conglomerates

Table 3 – Aftershocks of the Salmas earthquake
Instrumental and macroseismic data. Newspaper information is given as printed, i.e. in the persian calendar and local time (GMT, + 3hrs). Abbrevia-

INSTRUMENTAL								
N°	Date	GMT h m s	°N φ	°E λ	h	M	Ref.	Obs.
165	Tue 6 May	07 03 26	37.98	44.88	33	5 ¼	ISSR	21
166	Wed 11 May	22 34 27	38.22	44.66	33	7.3	ISSR	116
167	Wed 7 May	04 47 46				4	ISS	2
168	Wed 7 May	04 58 40				4 ¼	ISS	4
169	Ved 7 May	05 24 24				4	ISS	2
170	Wed 7 May	05 42 30				4 ¼	ISS	5
171	Wed 7 May	09 29 37	37.48	44.69		4 ½	ISSR	5
172	Wed 7 May	10 58 25				4 ¼	ISS	3
173	Wed 7 May	11 31 42				4 ¼	ISS	4
174	Wed 7 May	13 47 48				4 ¼	ISS	11
175	Thu 8 May	05 29 32	38.25	45.37	33	5	ISSR	7
176	Thu 8 May	14 23 52	40.09	44.39	33	4 ½	ISSR	6
177	Thu 8 May	15 05 28	38.13	35.13	33	5	ISSR	12
178	Thu 8 May	15 35 28	38.41	45.07	33	6 ¼	ISSR	79
179	Thu 8 May	23 38 22	37.56	44.73	33	5	ISSR	9
180	Fri 9 May	01 43 00				4 ½	ISS	6
181	Fri 9 May	08 — —				4.4	KV	
182	Sat 10 May	21 43 33	38.24	44.92	33	5	ISSR	16
183	Sat 10 May	23 59 20				4	ISS	5

tions KV = Karnik 1969; ISS = International Seismological Summary, Edinburgh; ISSR = ISS recalculated; E = Etela'at newspaper, Tehran; Egh = Egham newspaper, Tehran; T = Tabriz newspaper, Tabriz.

NEWSPAPER INFORMATION

Date	Time Local	Place	Reference
foreshock			
main shock			
Wed 17 Ord	after sunrise	Urmiah	T. 20 Ord
Thu 18 Ord	4 pm	Julfa	T. 21 Ord
Thu 18 Ord	5 pm	Ajabshir, Mianduab, Marand	T. 21 Ord
Thu 18 Ord	6 pm	*Sharajkhaneh, Khoy, Qutur,* Tabriz *Shakar Yazi*	T. 20 Ord E. 20 Ord Egh 20 Ord
Thu 18 Ord	night	Salmas	T. 20 Ord
Fri 19 Ord	11 am	Gavkan	T. 21 Ord
Fri 19 Ord	5 pm	Solduz	T. 21 Ord
Fri 19 Ord	6:15 pm	Maragheh	T. 21 Ord
Fri 19 Ord	6:30 pm	*Gavkan,* Ahar, Maragheh } Same as 178?	T. 21 Ord
Fri 19 Ord	no time	Sayen Qal'eh	T. 22 Ord
Fri 19 Ord	evening	Tabriz	T. 21 Ord
Sat 20 Ord	early morning	Tabriz	T. 21 Ord
Sat 20 Ord	afternoon	Salmas	T. 22 Ord
Sat 20 Ord	afternoon	Mianduab	Egh 21 Ord
Sun 21 Ord	1 am	Salmas	T. 23 Ord
Sun 21 Ord	3:30 am?	Gavkan	T. 23 Ord
Sun 21 Ord	no time	Sharafkhaneh	T. 23 Ord
Sun 21 Ord	?	Mahaleh Dezmar	T. 23 Ord
Sun 21 Ord	no time	?	E. 22 Ord
Sun 21 Ord	up to 5 pm	Salmas (4 shocks)	T. 24 Ord

INSTRUMENTAL								
Nº	Date	GMT h m s	°N φ	°E λ	h	M	Ref.	Obs.
187	Wed 14 May	02 59 – –				4.3	KV	
188	Wed 21 May	13 50 51				4 ½	ISS	7
189	Fri 23 May	09 48 23	38.09	45.15	33	5 ¼	ISSR	20
190	Thu 29 May	17 14 59	38.06	44.71	33	5 ½	ISSR	27
191	Wed 4 Jun	07 28 08	38.17	45.13	33	5 ¼	ISSR	42
193	Wed 9 Jul	04 35 57	37.73	44.55	33	4 ½	ISSR	7
194	Sun 3 Aug	22 05 59	38.43	44.64	33	5 ¼	ISSR	20
196	Thu 21 Aug	06 55 29	38.40	45.02	33	4 ½	ISSR	4

NEWSPAPER INFORMATION

Date	Time Local	Place	Reference
Sun 21 Ord	night	Salmas (4 shocks)	T. 24 Ord
Mon 22 Ord	no time	Salmas	E. 22 Ord
Thu 25 Ord	no time	Salmas	T. 31 Ord
Fri 26 Ord	no time	Salmas (3 shocks)	E. 31 Ord
Mon 29 Ord	10:15 am	Salmas	E. 31 Ord Egh 31 Ord
Mon 29 Ord	no time	Shabestar	T. 3 Kho
Mon 29 Ord	night	Salmas (3 shocks)	E. 31 Ord
Tue 30 Ord	early morn	Salmas	Egh 31 Ord
Tue 30 Ord	21 h	Salmas	Egh 31 Ord
Thu 1 Kho	7 pm	Tabriz	T. 3 Kho
Fri 2 Kho	12:50 pm	Tabriz, Salmas	T. 3 Kho
Mon 5 Kho	7:15 am	Salmas	E. 6 Kho
Thu 8 Kho	20 or 22 h	Salmas	E. 10 & 12 Kho
Sat 10 Kho	no time	Salmas (4 shocks)	E. 12 Kho
Sun 11 Kho	morning	Salmas	E. 12 Kho
Mon 12 Kho	afternom	Salmas (2 shocks)	E. 13 Kho
Wed 14 Kho	10:30 am	Tabriz, Salmas, Khoy, Marand, Julfa, Rezayeh, Sharafkhaneh, Maragheh, Bonab, Ajabshir	T. 15 Kho
Wed 14 Kho	4 pm	Tabriz	T. 15 Kho
Thu 15 Kho	16:00 h	Salmas	E. 21 Kho
Fri 16 Kho	midnight	Salmas (2 shocks)	E. 21 Kho
Sat 17 Kho	morning	Salmas	E. 21 Kho
Mon 19 Kho	02:30	Salmas	E. 21 Kho
Tue 20 Kho	no time	Salmas (2 shocks)	E. 25 Kho
Sat 24 Kho	10:30	Salmas	E. 25 Kho
Fri 20 Tir	08:00	Khoy	E. 21 Tir
Sat 21 Tir	07:00	Salmas	E. 21 Tir
Mon 23 Tir	15:30	Khoy (4 shocks)	E. 24 Tir
Wed 25 Tir	2 am	Khoy	E. 25 Tir
Mon 30 Tir	afternoon	Salmas (2 shocks)	E. 31 Tir
Thu 2 Mor	no time	Salmas	E. 6 Mor
Sat 4 Mor	14:00	Salmas	E. 6 Mor
Sun 5 Mor	02:30	Sayen Qal'eh	E. 5 Mor
Fri 10 Mor	no time	Salmas	E. 11 Mor
Sat 11 Mor	morning	Salmas, Khoy	E. 11 Mor
Sun 12 Mor	08:00	Khoy	E. 15 Mor
Wed 15 Mor	evening	Salmas	E. 16 Mor
Thu 16 Mor	no time	Salmas	E. 16 Mor

above Aslanik (Fig. 39). Finally, a very large number of rockfalls took place, especially in the Quaternary basalt outcrops along the banks of the Zola Chay and the lower Dowshivan Su.

Aftershocks

A large number of aftershocks, known both from instrumental recordings and macroseismic data, followed the main shock and are

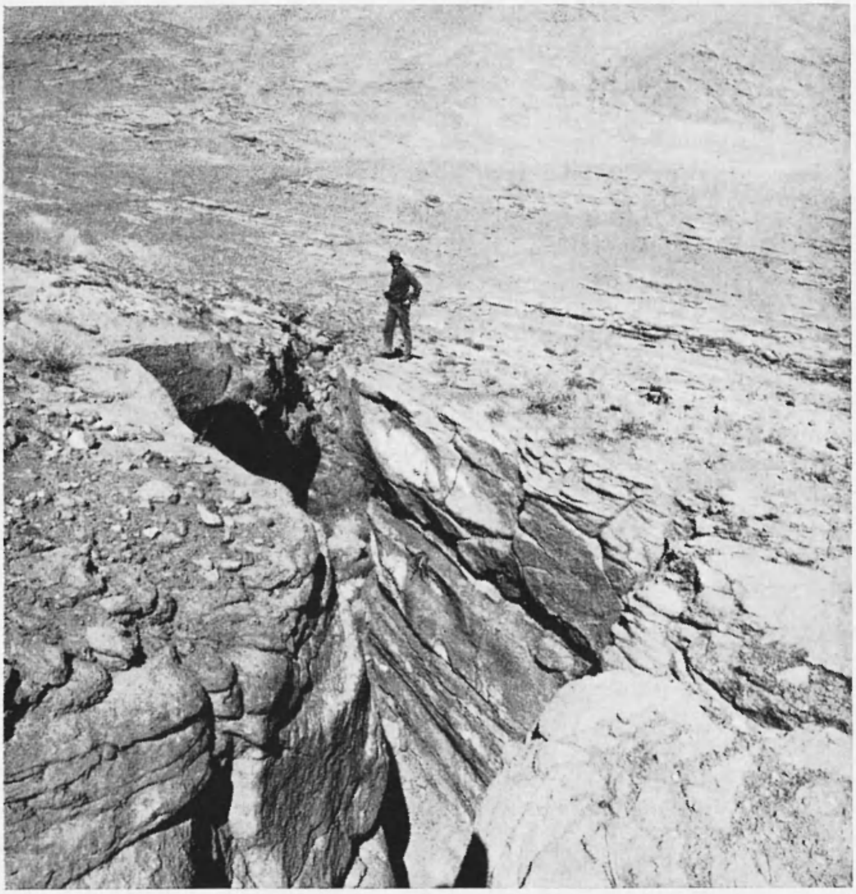

Fig. 39 – Earthquake triggered bedding-plane slip
Large tension crack resulting from bedding-plane slip in layered Eocene conglomerate west of Aslanik.

listed in Table 3. However, the epicentres of only the larger shocks were calculated with sufficient accuracy to give an approximate idea of their geographical location; these epicentres, plotted in Fig. 1, seem to delineate a wide N-S zone contained between Lake Rezayeh and the Turkish frontier, and extending from Rezayeh in the south to Khoy in the north.

The largest aftershock (M_b over 6) occurred about 40 hours after the main event, on 8 May 1930 at 15h35m28s GMT. Its instrumental epicentre was located south of Khoy in the Tolehi Dagh mountains bordering the northern edge of the Salmas Plain. It caused slight damage in Sharafkhaneh, Khoy and Qutur. In the Salmas Plain, Shekar Yazi was half-destroyed and 4 (?) people were killed. In this village, the foreshock had been felt only very lightly, and the main shock caused no damage. The aftershock was also strongly felt, but without damage, in the near-by village of Kanyan. In Khosrova, the shock was also strongly felt (p. 166), but no further damage seems to have resulted.

Conclusions

The documentation collected during this field investigation, supplemented by existing written contemporary accounts, provides a relatively complete picture of the Salmas earthquake, its foreshock and principal aftershock. The main facts are summarized below.

A foreshock, of estimated magnitude 5.4, occurred on 6 May 1930 at 07h03m26s GMT, preceding the main shock by about 15½ hours. Its macroseismic epicentre was determined at 38.15N 44.75E, and the region of damage was found to have a diameter of about 15 km. About 25 people were killed, and Dilman and 7 other villages were damaged. Less than 20 km from the epicentre, the shock was felt so lightly that the inhabitants did not consider it necessary to spend the night out of doors.

The main shock occurred in the night of 6 May 1930 at 22h34m27s GMT and was assigned a magnitude of between 7.2 and 7.4. The macroseismic epicentre was determined at approximately 38.15N 44.70E, i.e. nearly identical to the epicentre of the foreshock. It was felt in Tabriz and in many of the larger towns of Azerbaijan, and perceptible as far as Nakhichevan and Tiflis in the USSR. In the epicentral region it destroyed Dilman and about 60 villages located in the Salmas Plain and in the bordering mountains, in a region measuring approximately 40 km E-W and 20 km N-S. About 40 churches, mostly located in the Salmas Plain were also destroyed or damaged, and tombstones in 3 cemeteries were displaced, usually to the north. The total number of people killed was about 2514, casualties occurring mainly amongst the part of the population which had not felt, or not heeded, the foreshock. An isolated pocket of destruction was located at Mamaqan, about 25 km south of the macroseismic epicentre.

Faulting occurred during the main shock in two localities: at the southern edge of the Salmas Plain, in a NW-SE direction, with a right lateral displacement of up to 4 m and a vertical displacement of over 5 m (NE down); and in the northwest near Derik, in a NE-SW direction, left-lateral, with the NW side down by about 1 m. Changes in thermal springs were associated with both faults. The combined result of movement on the two faults is a lowering and a displacement to the east, of the Salmas Plain. Many secondary ground deformations were also observed.

Aftershocks were most numerous in a broad N-S zone between Lake Rezayeh and the Turkish frontier. The strongest aftershock occurred about 40 hours after the main event, on 8 May 1930 at 15h35m28s GMT, and was centered in the mountains bordering the Salmas Plain in the northeast. Here one village, Shekar Yazi, undamaged by both foreshock and main shock, was partly destroyed.

The fact that a relatively complete picture could be assembled of an earthquake which happened 43 years ago, and about which practically nothing was known so far, was partly due to exceptional circumstances: existence of a minority Christian population which remembered the event, presence of larger buildings (the churches) still visible to-day, accurate eyewitness account, etc. It confirms however an observation already made for less well documented early 20th century earthquakes in Iran, i.e. accurate information concerning these events is still available to-day in the field ([20]). To study these earthquakes is of special importance in cases such as Salmas for which instrumental determinations may be inaccurate and written macroseismic data virtually non-existent.

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