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FIELD STUDY AND DOCUMENTATION OF THE 1930 SALMAS (SHAHPUR - AZARBAIDJAN) EARTHQUAKE

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Abstract

Field investigations and bibliographical research into the little-known but important Salmas earthquake in Northwest Azarbaidjan (Iran) provided the following results. The morning before the earthquake, a foreshock (Mb=5.4) centered, as the main shock, in the Salmas Plain, killed about 25 people and incited the majority of the poulation to spend the following night out of doors. The main shock (Mb=7.3) occurred the following night, on 6 May 1930 at 22h 34m 27s GMT,and destroyed about 60 villages and 40 churches, killing about 2,514 people, both in the Salmas Plain and in the surrounding mountains. Its macroseismic epicentre was at approximately 38.° 15'N, 44°.70'E. The main shock was associated with 2 surface faults, with a maximum horizontal displacement of 4m and vertical displacement of over 5m; 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.

1. INTRODUCTION

The Salmas earthquake of 1930 is one of eight earthquakes of magnitude equal to, or greater than, 7, which have 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 north-western part of the country, a fact which increases its significance for regional seismotectonic studies. Nevertheless documentation on this event was limited to entries in earthquake catalogues and vague notices in the international Press. The field study and the new bibliographical material presented here have, it is believed, produced enough data to make certain aspects of this earthquake, such as casualty distribution and faulting, as well documented as more recent destructive earthquakes (e.g. Buyin Zahra 1962, Dasht-e-Bayaz 1968). This improved knowledge of the event is largely due to certain favourable circumstances manifest in the course of this report.

The aim of this report is restricted to a presentation of observations 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, since very little is known, and even less published, on these subjects. The geological mapping of the region, for example, is in progress.

The Salmas Plain, the epicentral region of the earthquake, is located to the northwest of Lake Rezaiyeh, and has an area of about 300km^2 (Fig. 1 and 3). It lies between about 1500m (N,W and S borders) and 1280m, 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 as Kohneh Shahr (replaced after the earthquake by Tazeh Shahr), were of considerable antiquity (Minorsky,1931).The plain was populated by Christians of the Gregorian, Nestorian and Chaldean sects from a very early date (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 of Dilman (or Dilmaghan, renamed Shahpur after the earthquake), and villages in the north and east, had, however, mainly Turkish and Kurdish inhabitants.

The mountains bordering the Salmas Plain are much more sparsely populated, mainly by Kurdish people. The highest summit, the Haravil Daghi, 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 Rezaiyeh Plains. The mountain villages are small, isolated from each other and from the Plain, and live nearly entirely from wheat cultivation and cattle farming.

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. In each village as many survivors as possible were interviewed in their native dialect, i.e. Armenian, Assyrian, Turkish, Kurdish and Farsi. New bibliographical material in the form of newspaper-reports and private correspondence was used to check and supplement the field results.

2. FORESHOCK

2.1. General.

A moderately strong foreshock, of estimated magnitude Mb=5.4 (Karnik, 1969), occurred on 6 May 1930 at 07 h 03m 26s GMT, i.e. about 15½ hours before the main shock. It caused destruction and some casualties in a small region centered around 38°. 15'N, 44°.75'E, corresponding approximately to the future macroseismic epicentre of the main shock. The foreshock was perceptible throughout northwestern Azarbaidjan and southeastern Turkey, and was clearly felt by most inhabitants of the three nearest towns, Tabriz, Rezaiyeh and Khoy, as well as in Bonab 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.

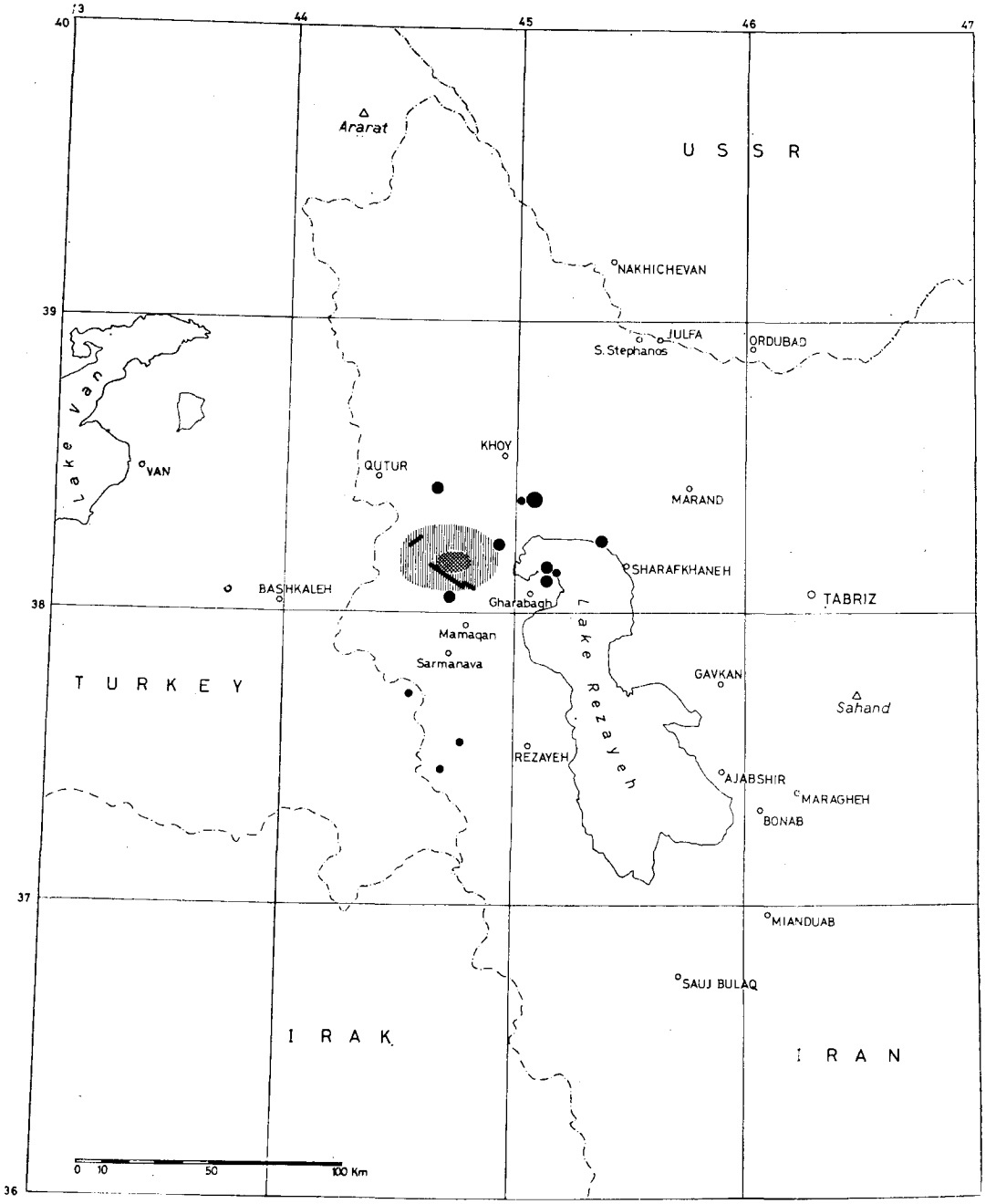


Fig. 1. Epicentral regions, earthquake faults and main aftershocks.

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.

2.2. 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 was 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 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 Kuché Mashk and Kalashan nearly all the 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 other 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 Hamzehkandi, most houses were fissured. Further away from the epicentral region, in Habashi, Akhtékhaneh, Yavshanli, Khantakhti, Tamar, Ayan and Senji, only a few isolated walls were fissured.

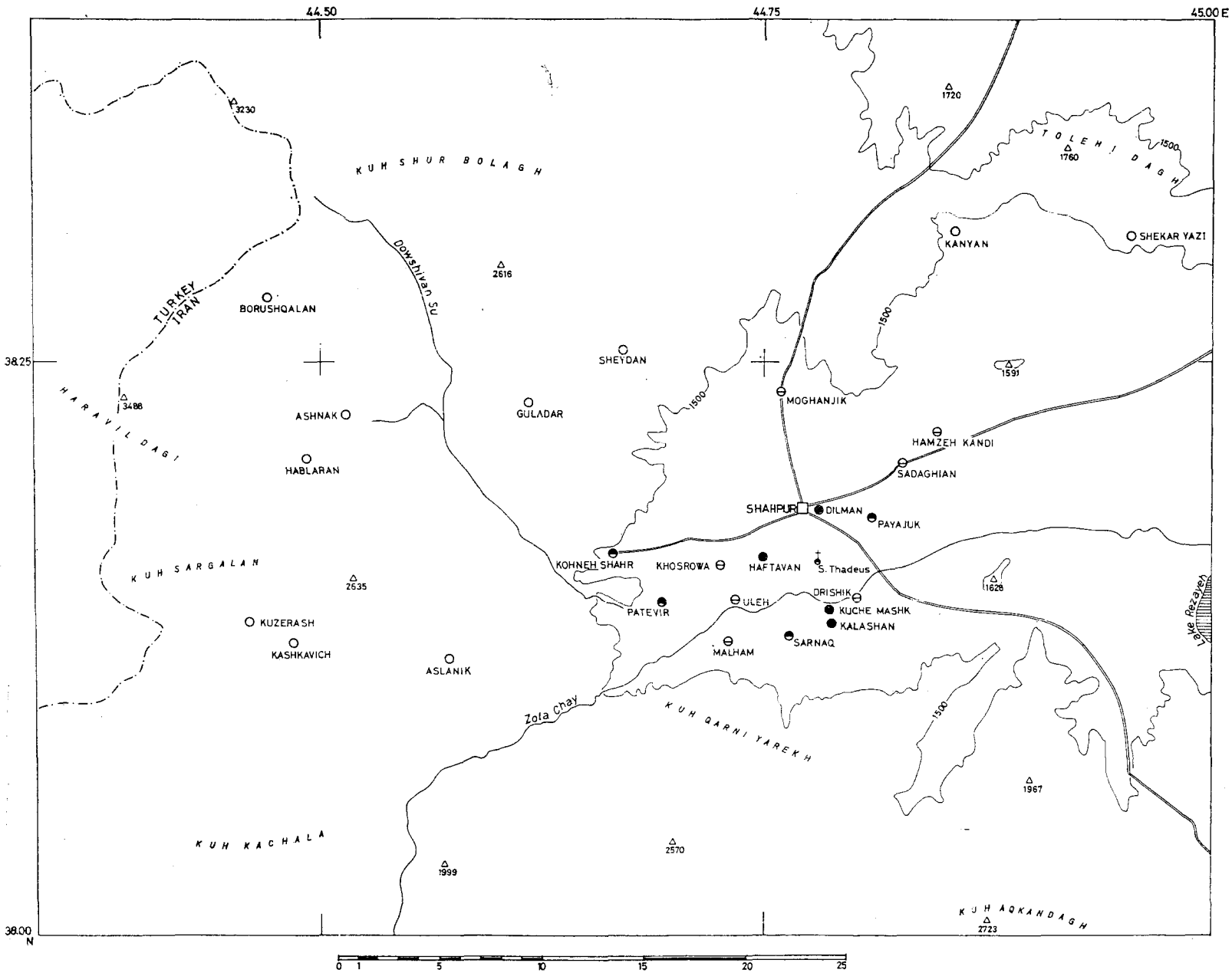
In all the villages mentioned above, and in a few others nearby, the foreshock was felt strongly enough for most of the inhabitants (with the exception of those of Malham) to decide to spend the following night out of doors (see Table 1). Outside this region however, and especially in the mountains to 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 where the foreshock was not felt or heeded were Shekar Yazi, Kanyan, Sheydan, Guladar, Ashnak, Kuzehrash, Kashkavich and Aslanik. In the extreme northwest, the shock was apparently not felt by anyone in Hablaran and Borushqalan.

3. MAIN SHOCK

3.1. General

The main shock occurred during the night which followed the foreshock, on 6 May 1930 at 22h 34m 27s GMT (or 7 May 1930 at 01h 34m 27s local time). Its magnitude was given as 7.2 (Gutenberg and Richter 1954), or 7.4 (B.C.I.S.). About 60 villages located in the Salmas Plain and in the surrounding mountains were destroyed, and

Fig. 2. (Facing page) Foreshock of 6 May 1930. Black circle: severe destruction and fatalities; half black circle:some buildings collapsed; circle with diameter: most buildings fissured; blank circle: foreshock not heeded or not felt. The approximate macroseismic epicentre was S. Thadeus church which was partly destroyed. Heights in metres.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BORUSHQALAN
ASHNAK
HABLARAN
HARAVIL DAGI
KUH SARGALAN
KUZERASH
KASHKAVICH
ASLANIK
SHEYDAN
GULADAR
KANYAN
SHEKAR YAZI
TOLEH I DAGH
MOGHANJIK
HAMZEH KANDI
SADAGHIAN
SHAHPUR
DILMAN
PAYAJUK
KOHNEH SHAHR
KHOSROWA
HAFTAVAN
S. Thadeus
DRISHIK
ULEH
PATEVIR
KUCHE MASHK
KALASHAN
SARNAQ
MALHAM
Zola Chay
KUH QARNI YAREKH
KUH KACHALA
KUH AQKANDAGH
Lake Rezayeh
3230
3488
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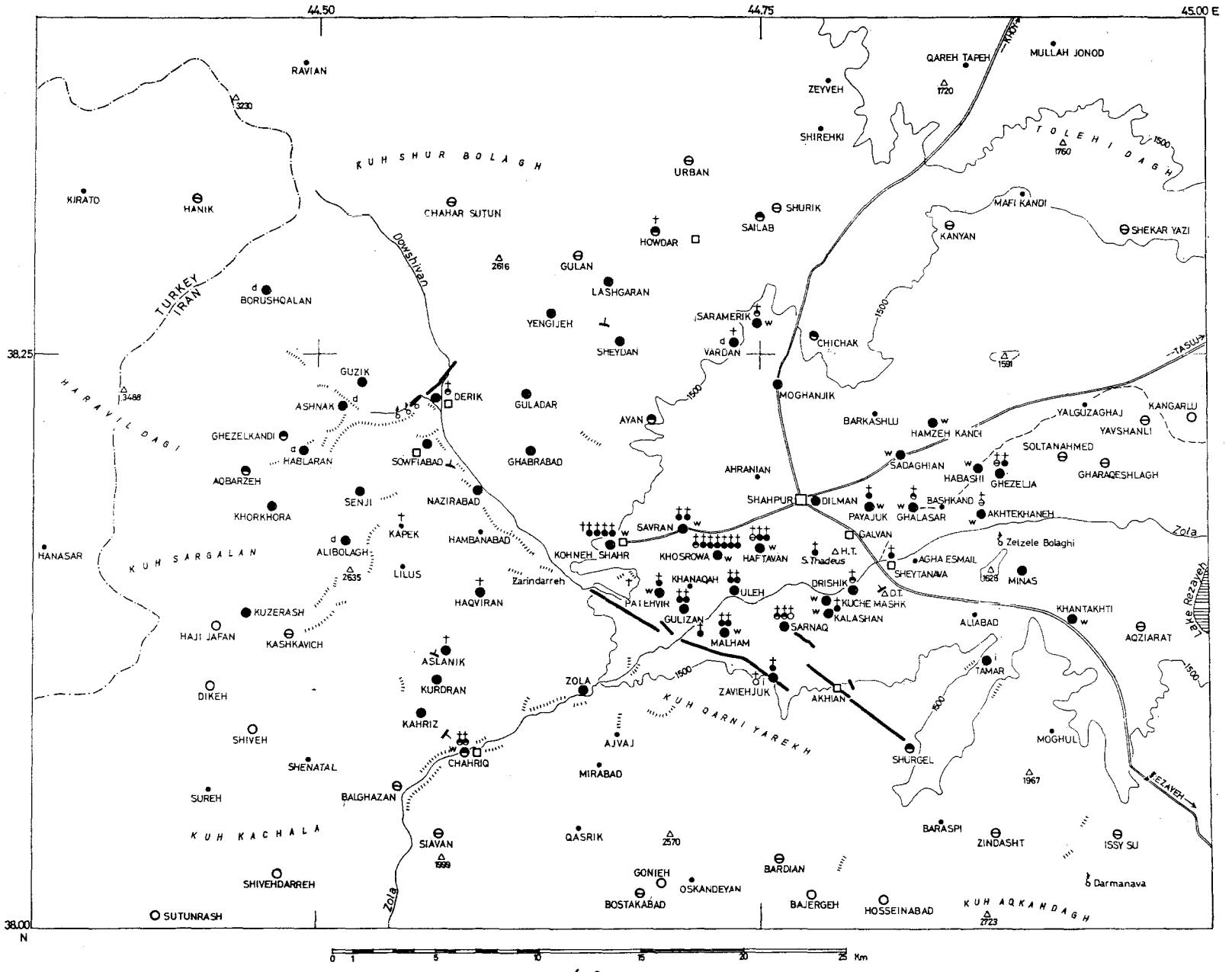
44.50
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ZEYVEH
QAREH TAPEH
MULLAH JONOD
TOLEHI DAGH
SHURIK
SAILAB
HOWDAR
KANYAN
MAFI KANDI
SHEKAR YAZI
TURKEY
IRAN
BORUSHQALAN
Dowshivan
GULAN
LASHGARAN
YENGIJEH
SHEYDAN
SARAMERIK
VARDAN
CHICHAK
TASUJ
GUZIK
ASHNAK
DERIK
GULADAR
AYAN
MOGHANJIK
BARKASHLU
HAMZEH KANDI
YALGUZAGHAJ
KANGARLU
YAVSHANLI
HARAVIL DAGI
GHEZELKANDI
HABLARAN
SOWFIABAD
GHABRABAD
SOLTANAHMED
SADAGHIAN
HABASHI
GHEZELJA
GHARAQESHLAGH
AQBARZEH
AHRANIAN
SHAHPUR
DILMAN
BASHKAND
PAYAJUK
GHALASAR
AKHTEKHANEH
SENJI
NAZIRABAD
KHORKHORA
KAPEK
HAMBANABAD
SAVRAN
GALVAN
Zola
HANASAR
KUH SARGALAN
ALIBOLAGH
KOHNEH SHAHR
KHOSROWA
HAFTAVAN
S. Thadeus
H.T.
Zelzele Bolaghi
AGHA ESMAIL
SHEYTANAVA
MINAS
LILUS
Zarindarreh
KHANAQAH
DRISHIK
ULEH
PATEHVIR
KUCHE MASHK
D.T.
KUZERASH
HAQVIRAN
GULIZAN
KALASHAN
SARNAQ
KHANTAKHTI
ALIABAD
AQZIARAT
Lake Rezaiyeh
HAJI JAFAN
KASHKAVICH
MALHAM
ASLANIK
TAMAR
ZOLA
KURDRAN
ZAVIEHJUK
AKHIAN
DIKEH
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AJVAJ
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TEZAYEH
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ZINDASHT
ISSY SU
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BARDIAN
Darmanava
GONIEH
OSKANDEYAN
SHIVEHDARREH
BOSTAKABAD
BAJERGEH
HOSSEINABAD
KUH AQKAHDAGH
2723
SUTUNRASH
Zola
0 1 5 10 15 20 25 Km

(P. 274B)

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 20km long and displayed a maximum right-lateral movement of 4m and a maximum vertical throw (NE down) of about 5m; the second, oriented NE–SW and located in the western mountains, was over 3km long, left-lateral, and had a vertical throw (NW down) of about 1m. A recent recalculation located the instrumental epicentre at 38°.22'N, 44°.66'E (Nabavi 1972), which is in close agreement with the centre of the region of maximum destruction (macroseismic epicentre), found in this study to be approximately 38°.15'N, 44°.70'E. 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 in Julfa (Medvedev, 1953), 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 Savej Bulaq (Mahabad).

3.2. Eyewitness account,

The main shock was witnessed by Abel Zayia, a Persian Lazarist of the French Mission in Rezaiyeh 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 Rezaiyeh-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 and 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 (Zayia 1930b, is more precise: " it (the car) was projected 50cm sideways"). The driver was thrown down onto the ground" (Zayia, 1930a). "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

Fig. 3. (Facing Page) 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 ⁿⁿⁿ 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.

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
Patehvir	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	
Zaviehjuk	240	destroyed; 1 church undamaged	10	most slept out
Zindasht		lightly damaged	0	
Zola	70	destroyed	3	about 50% slept out

there were seven formidable shocks and more than one thousand weaker ones" (Zayia, 1930b).

3.3. Casualties and destruction

In 1973 over 60 villages of the epicentral region were studied 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 figure 3 and Tables 1 and 2, and are described in more detail below.

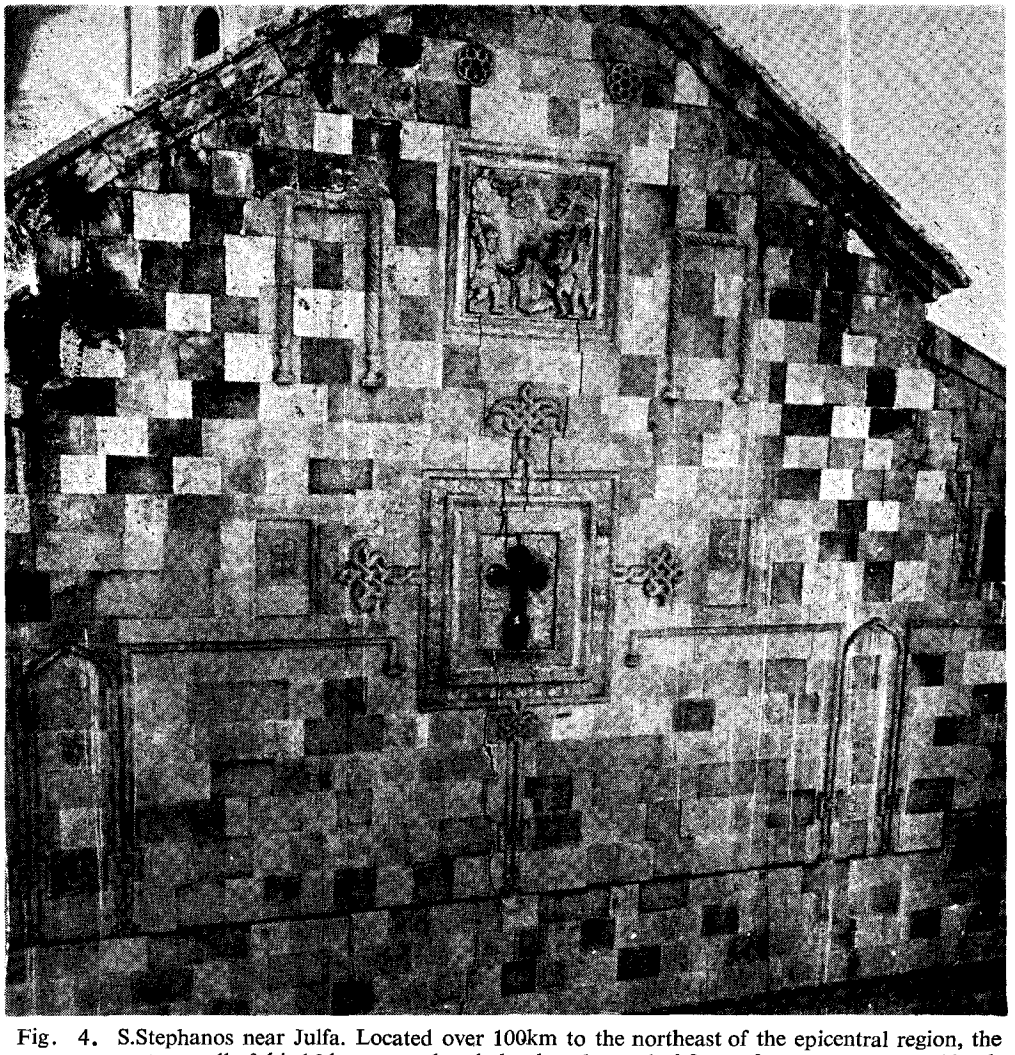


Fig. 4. S.Stephanos near Julfa. Located over 100km to the northeast of the epicentral region, the eastern wall of this 16th century church developed a vertical fissure from apex to ground level, probably as a result of uneven foundation settlement.

Table 2 – EARTHQUAKE DAMAGE TO CHURCHES
N.B. Dates of several churches have not yet been confirmed.

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 « Assyrian »		sun-dried brick
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 (Jarai)	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
Patehvir	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

Two peculiarities distinguish this earthquake from most other recent destructive earthquakes in the Middle or Near East. First, 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; conversely, casualties were relatively high in some villages near the periphery of the epicentral region where the inhabitants had slept indoors. Second, on the Salmas Plain there were a number of churches, which, even though not all of uniform construction, were nevertheless much more resistant than

Fig. 5. Site of Khosrova. The destroyed village photographed in 1973.

the usual adobe house. Many of these churches can be seen today 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, followed by a 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 an imaginary triangle with apexes at Kohneh

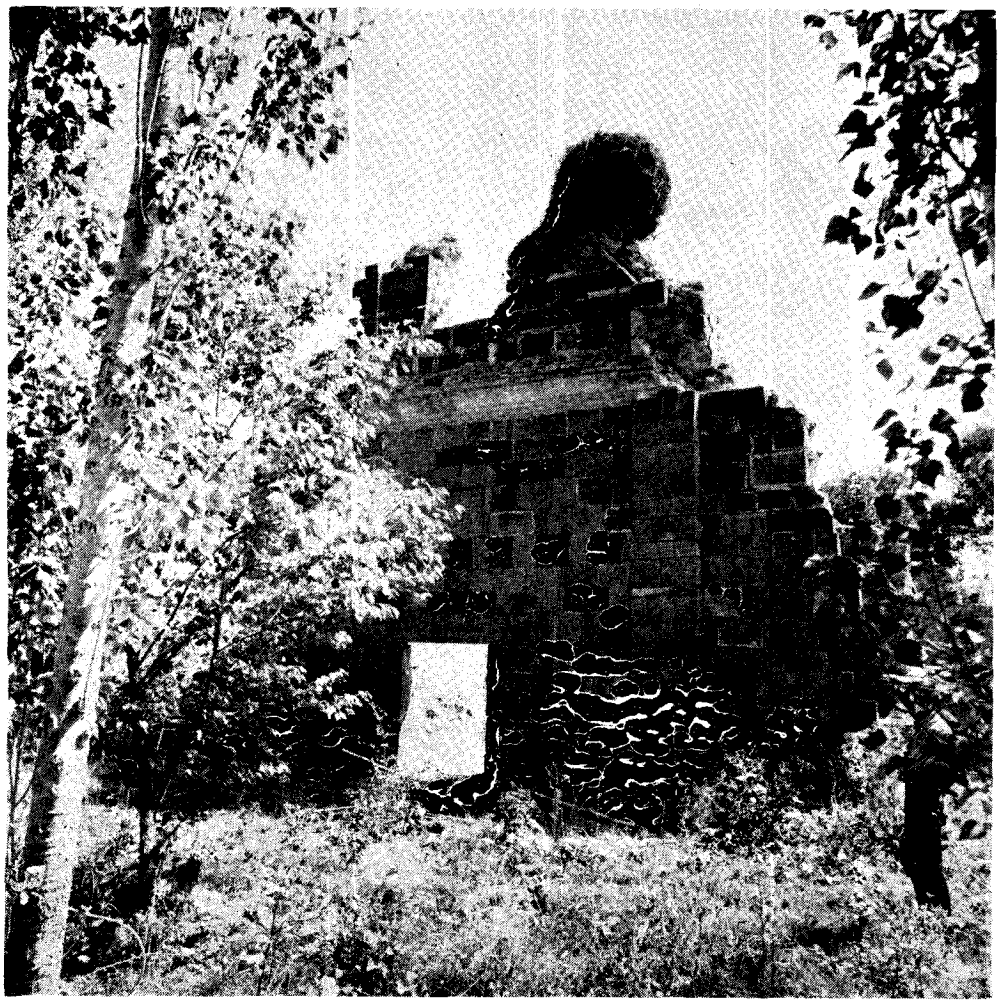


Fig. 6. S. Givargis (Khosrova). The only one of 20 churches which remained standing in the region of maximum destruction. Western facade.

Shahr, Payajuk and Zaviehjuk (Fig. 3). Here all the houses were levelled to the ground (Fig. 5). The most intense destruction probably occurred near the Kohneh Shahr apex where all but one of the 20 churches in the villages of Kohneh Shahr, Savra, Khosrova, Uleh, Malham, Gulizan and Patehvir were destroyed. The exception was Mar Givargis in Khosrova, a large, masonry structure with walls built in the traditional style, i.e. about 1.25m thick, with an outer layer of hewn stone, an inner layer of rough stone and 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. 6). In Malham, which, with Saramerik, was the only Christian village where most of the inhabitants

Fig. 7. S. Zoravar (Malham). Exterior of the southern wall. The eastern wall remained partly standing but the rest of the building collapsed.

slept indoors and consequently suffered a large number of casualties (see Table), the southern and eastern walls of S. Zoravar (a building similar to Mar Givargis) remained partly standing, but the rest of the church collapsed (Fig. 7). All the other 18 churches, which included at least 6 masonry and 3 kiln-brick constructions, were totally destroyed (Figs. 8 to 13). The medieval Miri-Khatun brick tower and the great mosque of Kohneh Shahr were also destroyed.

Fig. 8. S.Hovanes (Savra). The church destroyed by the earthquake. Looking northeast.

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 about 30cm thick and 80 x 185cm 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 (Fig. 14). The slabs are partly sunk into the ground, but it is impossible to ascertain so many years after the event whether they moved

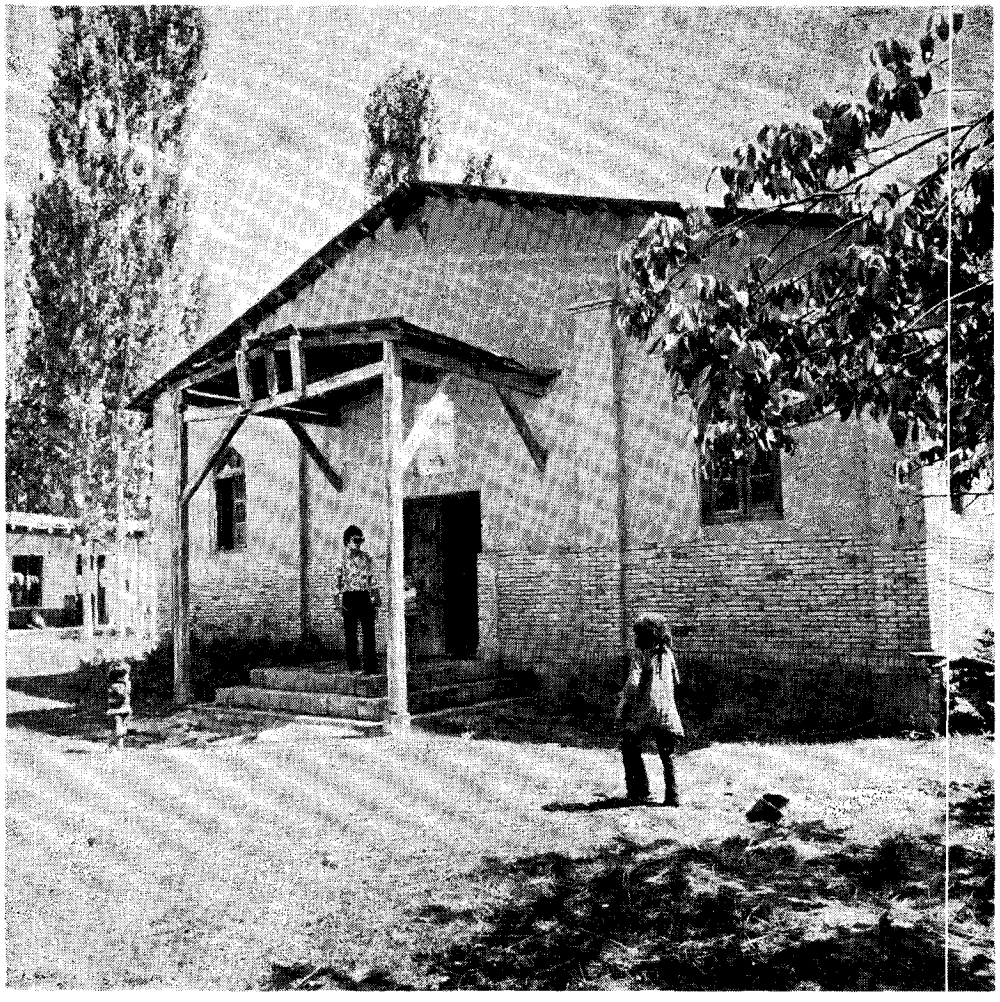


Fig. 9. Liba Ghucha Ishu (Khosrova). Western facade of the church which was destroyed by the earthquake and later rebuilt.

relatively to the ground during the earthquake. The upper block however, in most cases, moved from its original position on the slab. In the Khosrova cemetery, 183 cases of movement (about a third of 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 inter-

Fig. 10. S. Sarkis (Ulch). The church destroyed by the earthquake

face. Examples of tombstone movement are given in figure 15 and their locations are shown in figure 17. A number of tombstones (not included in the above account) were also tilted sideways, generally to the N or 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 4km 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

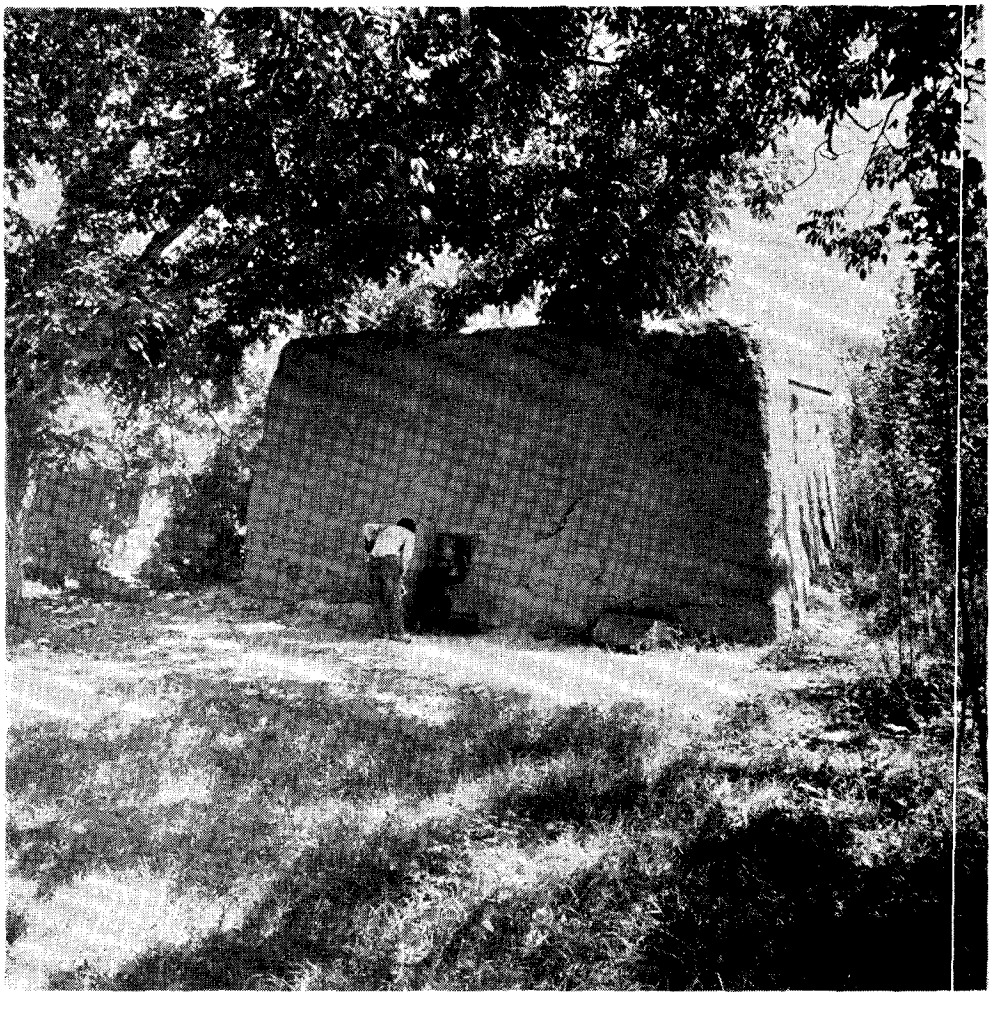


Fig. 11. S. Vartan (near Malham). The church was destroyed by the earthquake and later rebuilt completely.

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 2m in length, 0.60m in width and 0.75m in height.Well, this enormous stone was projected about 0.50m from the south to the north; it is no longer on the grave. The same happened to most of the other tombstones" (Zayia, 1930b). "Thursday evening at about 6 pm, I was sitting on Mr. Badul'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

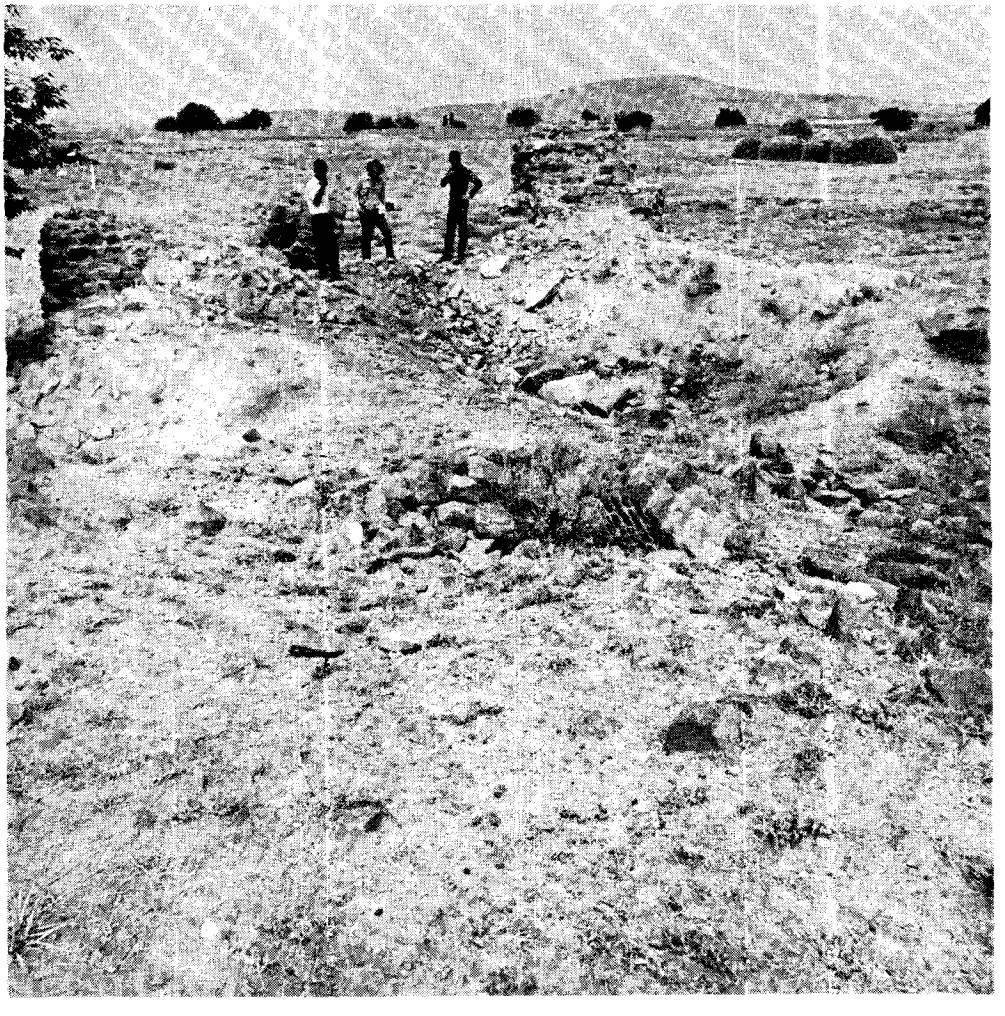


Fig. 12. Mar Yaghu (Patehvir). The church, located in the region of maximum destruction, collapsed completely.

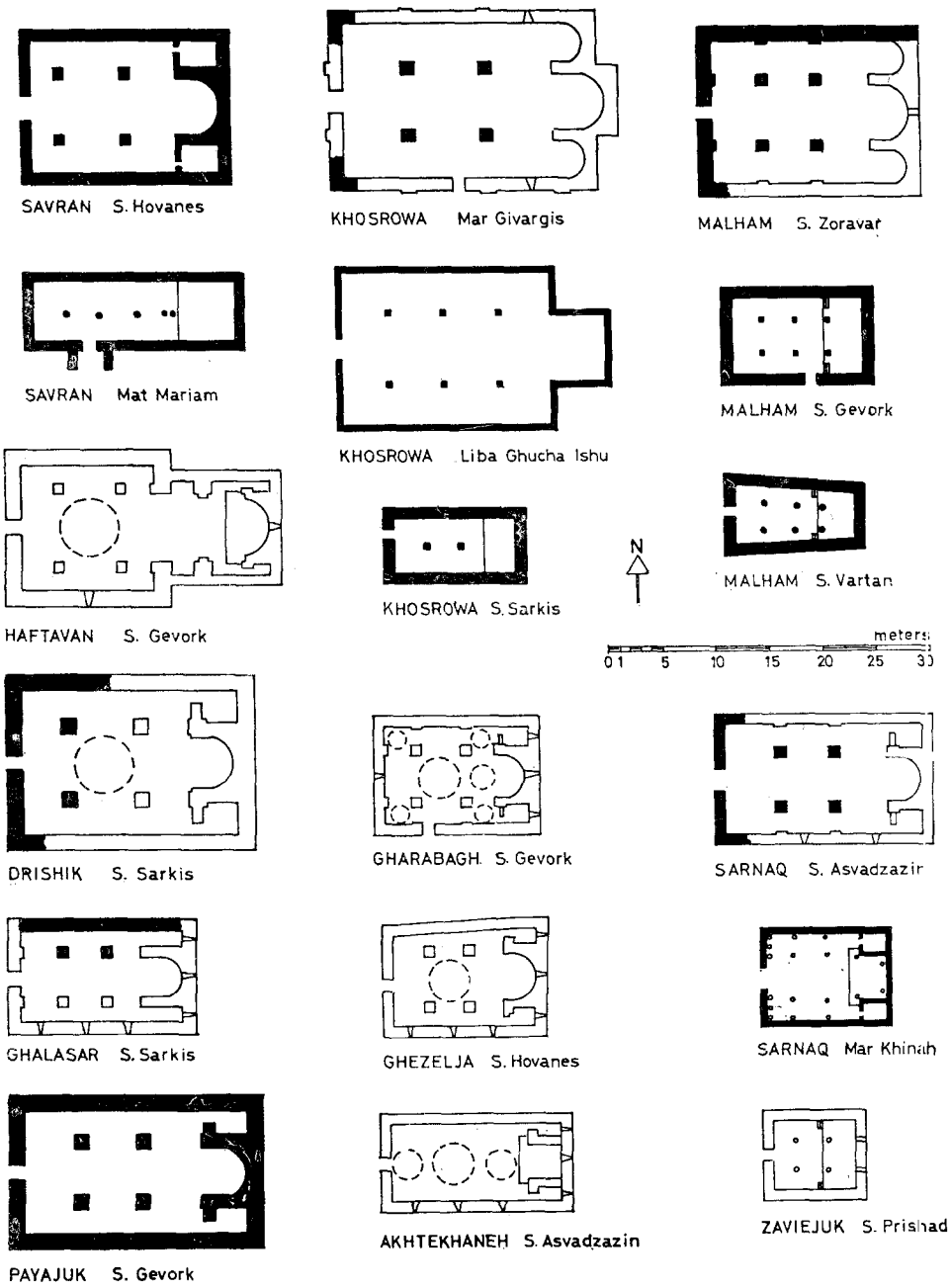


Fig. 13. Earthquake damage to churches in the Salmas Plain. Features shown in black collapsed during the earthquake. Ground plans are schematic. See also Table 2 and Kleiss (1969).

watched the other tombstones being lifted: by about 3cm. The Resurrection of the Dead came into my mind and onto my lips" (Zayia 1930a).

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 (Figs. 16 and 18).

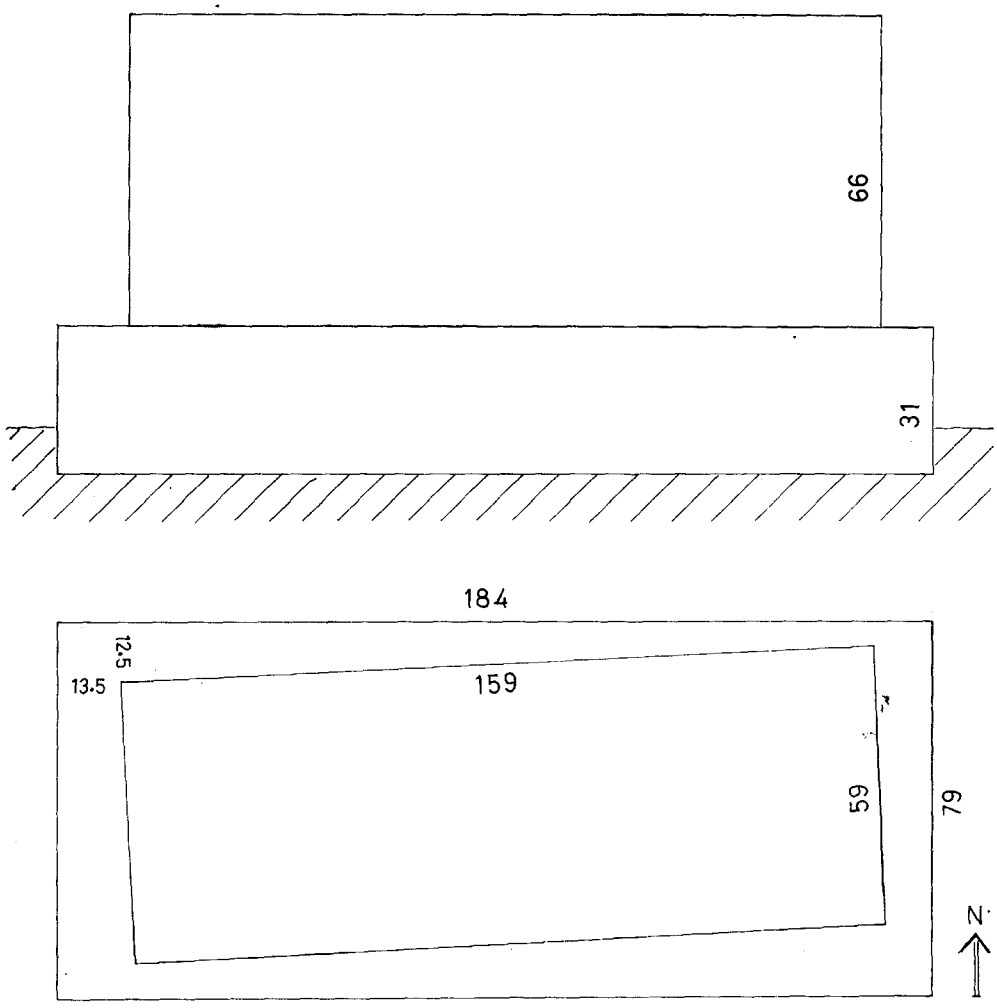


Fig. 14. Tombstone in Khosrova cemetery. Ground plan and elevation. Dimensions are given in cm.

Several independent witnesses amongst the survivors of the earthquake, as well as contemporary written accounts, related that, in the region of maximum destruction, the 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 from E to W. In many churches, we observed that the central pillars or columns and the western facade 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

Fig. 15. Tombstones in Khosrova cemetery. Examples of translation (left) and rotation (right) of the upper block with respect to the base. Note some tilted tombstones in the background.

to the west. However, as the eastern end of the these churches is usually formed by one or three apses, it is the most resistant regardless of the direction of strong ground motion. 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, probably including a large number of those who slept

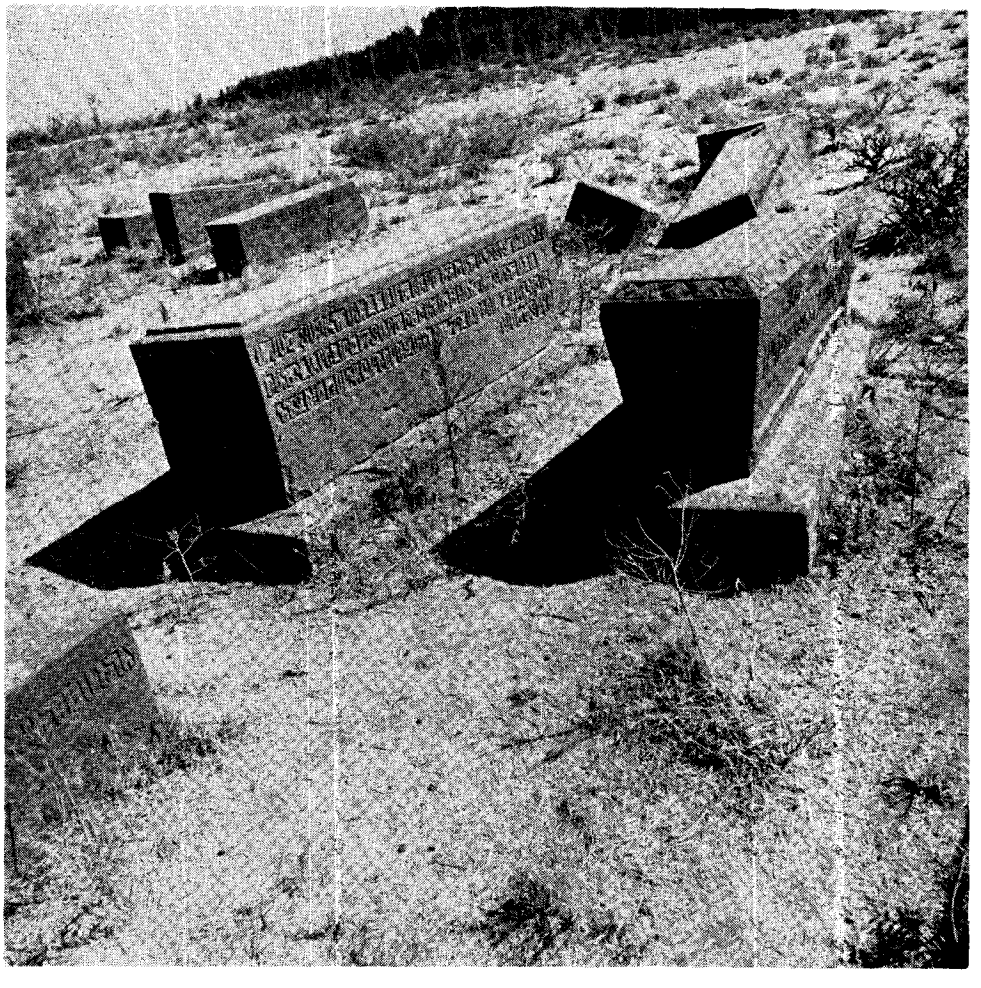


Fig. 16. Tombstones in Malham cemetery. Examples of displacement of the upper block with respect to the base.

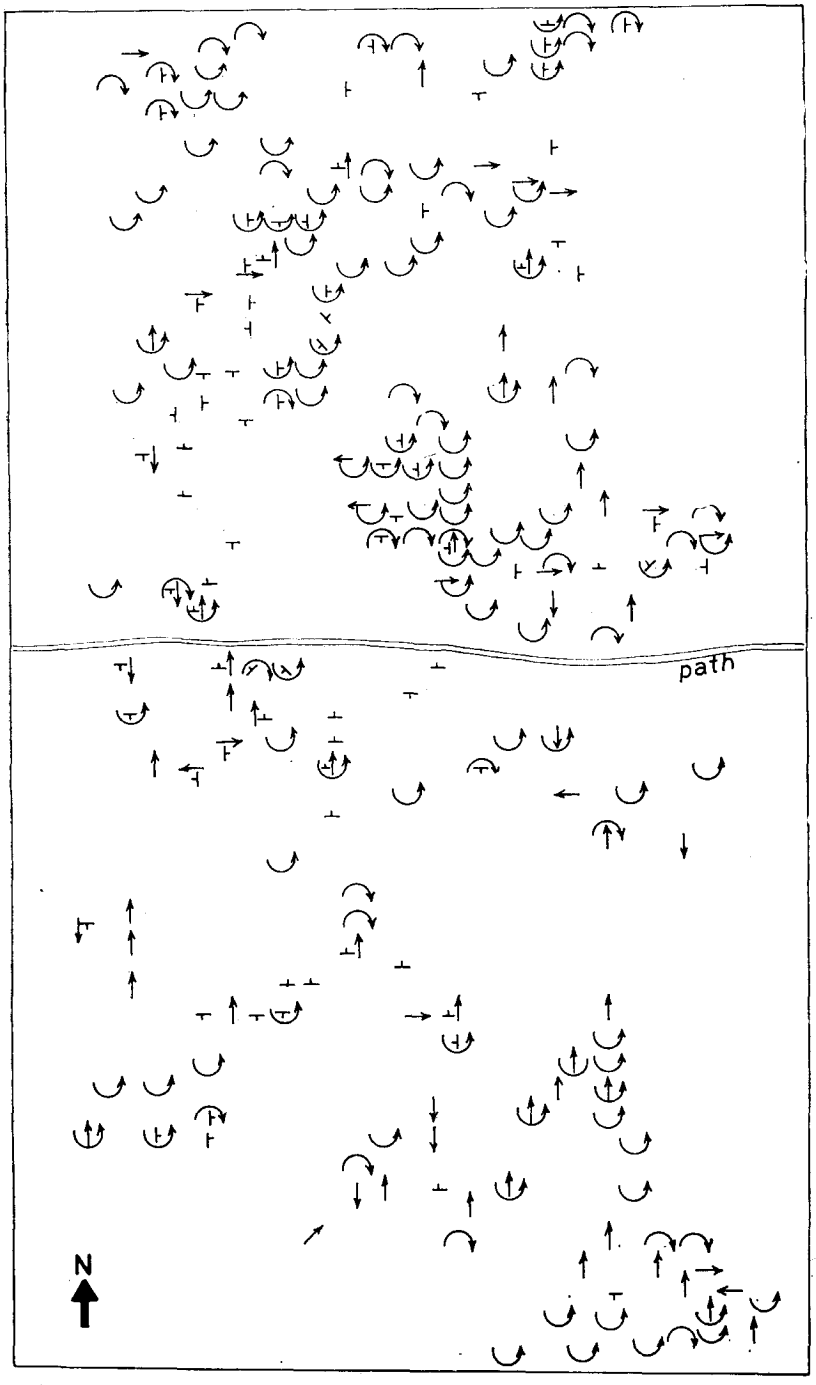


Fig. 17. Displaced tombsones in Khosrova cemetery. Sketch - plan showing approximate location of displaced tombstones. Arrows indicate movement of upper block with respect to ground slab; tilted tombstones shown with geological dip symbol. Juxtaposed symbols describe overall displacement of single tombstones. Tombstones showing no movement, or ambiguous cases, are omitted. Width of cemetery is approximately 150m.

indoors. However, these casualty figures are unreliable, due to problems arising from the size of the town; in smaller villages people could remember, sometimes by name, all those who died, while in the larger centres of Dilman and, to a lesser extent, Kohneh Shahr, the survivors found it difficult to comprehend the catastrophe.

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, Kuché Mashk, Kalashan, Zaviehjuk and Payajuk. In Haftavan, two of the three churches were destroyed, the survivor being

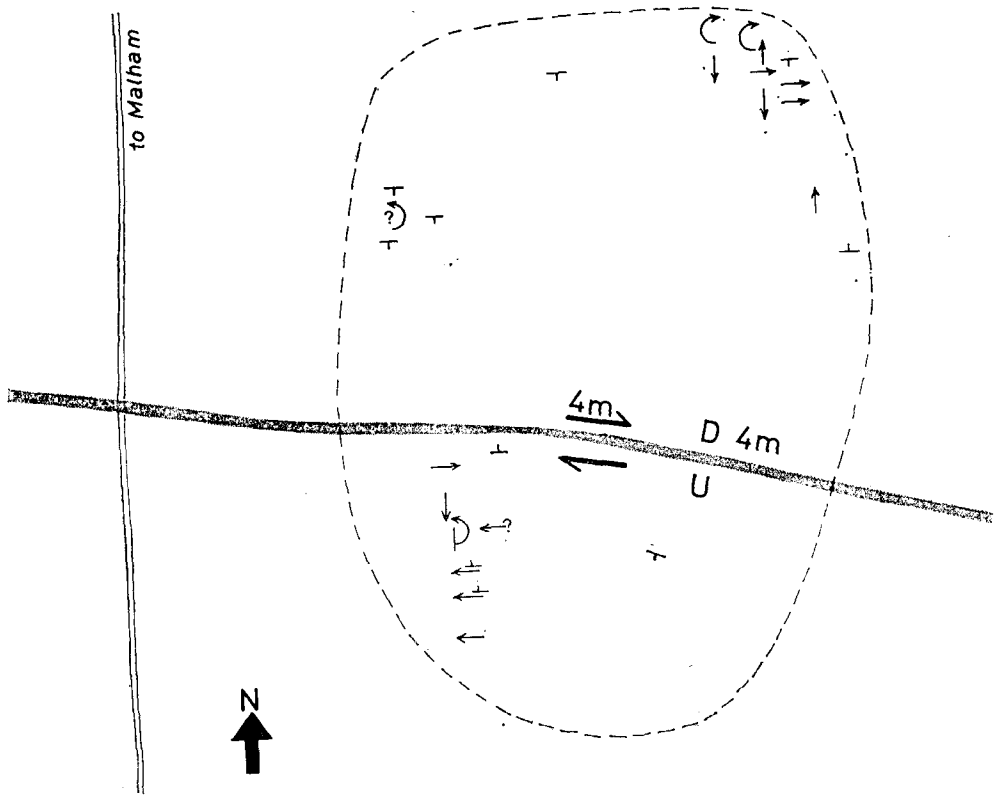


Fig. 18. Displaced tombstones in Malham cemetery. Only a small number of the tombstones were of the 'block on slab' type. Symbols are as for Fig.17. Dashed line is approximate boundary of cemetery which measures about 75m in the N-S direction. Shaded line is earthquake fault scarp with displacement in metres (U; up, D: down).

the 13th century church of S.Gevork. The central dome of this massive construction collapsed and the eastern facade developed diagonal fissures, but otherwise the building was intact (Fig. 19). The nearby school and assembly hall, built in kiln-brick with a stone foundation, collapsed (Fig. 20). In Sarnaq, the masonry church of S. Asdvadzadzin partly survived even though its roof collapsed and three of the four central pillars and the western facade fell to the west (Fig. 21). A similar church in Drishik, S.Sarkis, suffered much the same type of damage (Fig. 22), and the adobe church in Kalashan was destroyed, save one wall which remained partly standing (Fig. 23).

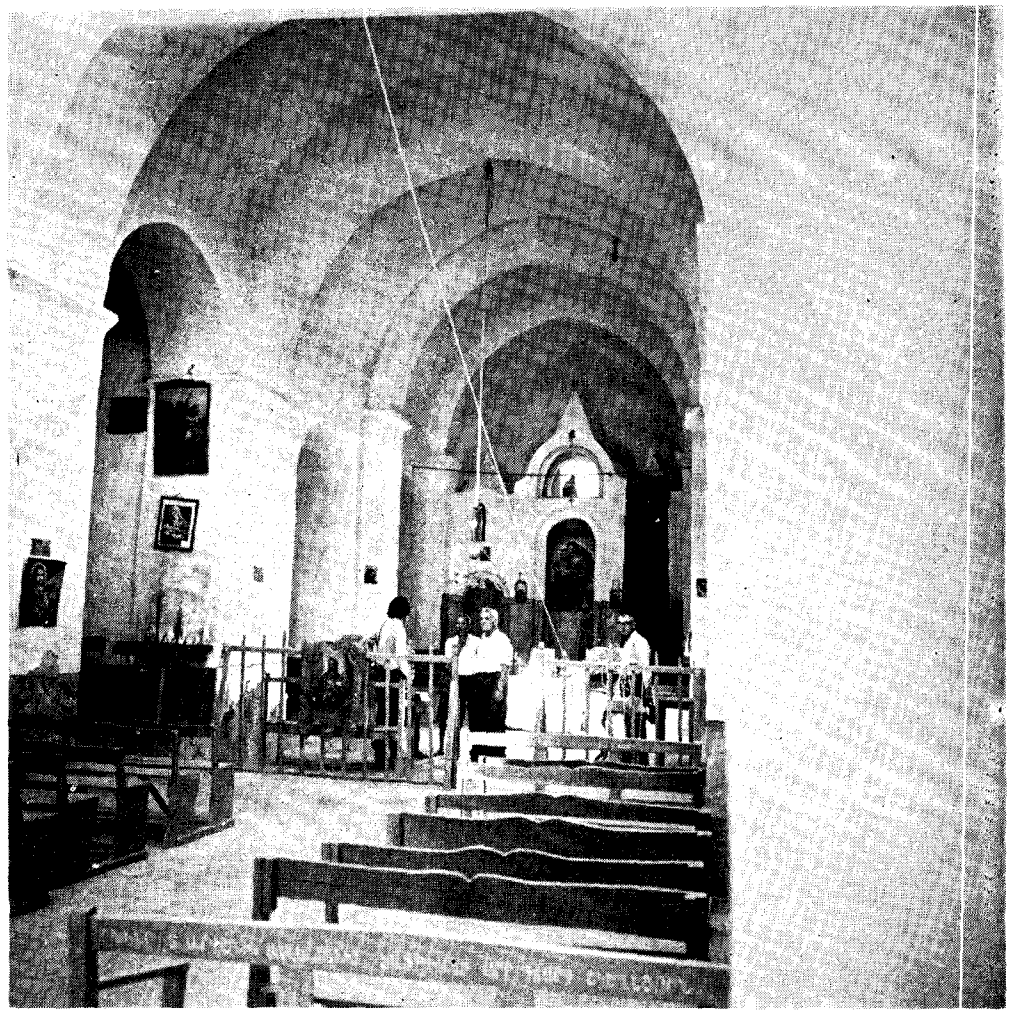
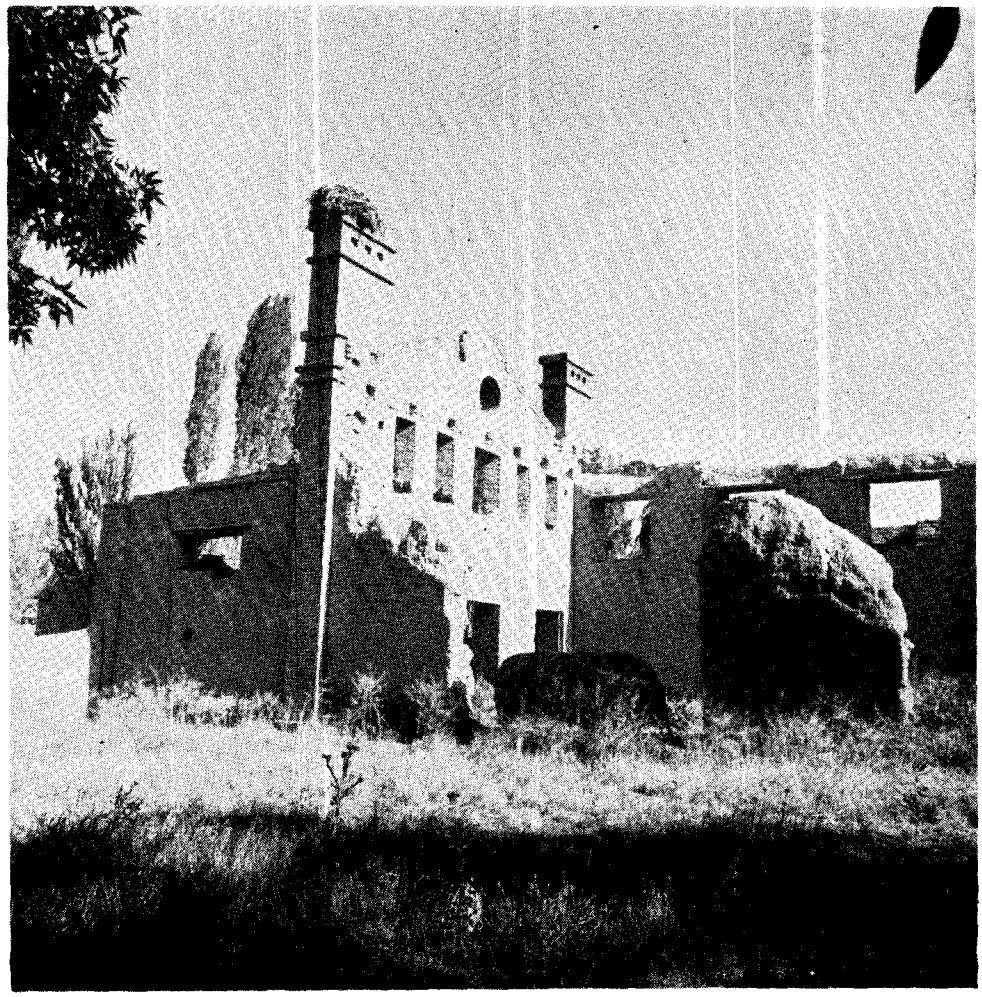


Fig. 19. S. Gevork (Haftavan). The 13th century church survived the earthquake with minimal damage. Central aisle, looking east.

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 remained intact (Fig. 24). The latter is situated on rock, about 500m west of the village and at about the same distance south of the fault. In plan it is nearly square (8 × 10m), and its flat roof is made of poplar beams covered with a mud/straw mixture. The only effect of the earthquake that could be detected was that the four treetrunk pillars supporting the roof were leaning by about 3° to the east, contrary to the damaged churches north of the fault which were generally leaning,



Fgi. 20. Assembly Hall in Haftavan.The ruined wall in the foreground remains from the time of the earthquake. The other walls were rebuilt but the building was not completed.

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, it does place S. Prishad in the same category as other undamaged structures located on, or very near, other earthquake faults (Medvedev, 1953).

In Payajuk, about 3km due east of Dilman, destruction was still very severe, killing the only three inhabitants who slept indoors. The stone masonry church of S.

Fig. 21. S. Asdvadzadzin (Sarnaq). Eastern wall of the church, which partly survived the earthquake.

Gevork was levelled to the ground, as was the nearby house of the Armenian writer and poet Rafi (Figs, 25a). The new village was relocated to the south.

The other villages destroyed in the Salmas Plain but located outside the triangle of maximum destruction (Kohneh Shahr-Payajuk-Zaviehjuk) were Moghanjik and Saramerik in the north, Sadaghian, Hamzekhandi, Habashi, Ghezelja, Ghalasar and Athtékhaneh in the east, Minas, Khantakhti and Tamar in the southeast. All these villages were destroyed and suffered casualties, but the state of the three masonry churches of the region in Ghalasar, Akhtékhaneh and Ghezelja indicated that the

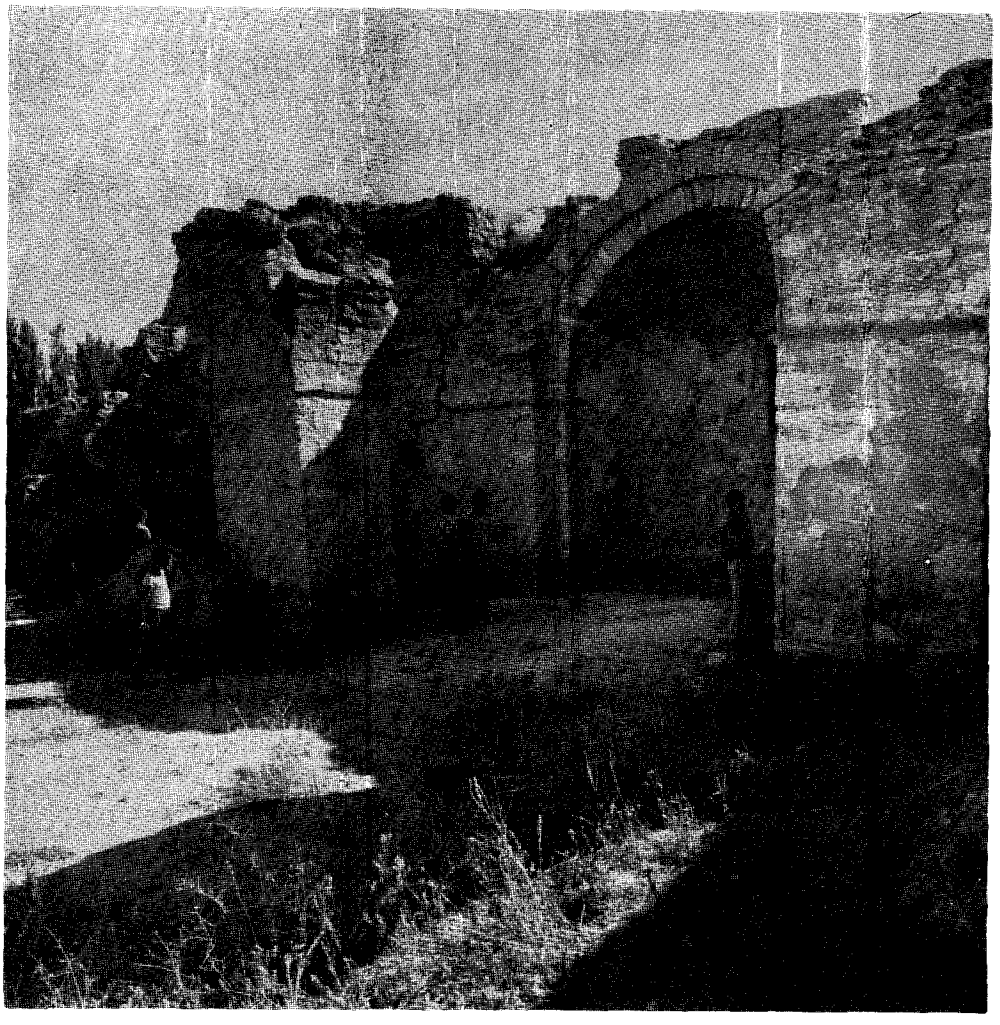


Fig. 22. S. Sarkis (Drishik). Eastern apse seen from interior of ruined church. The western facade and most of the northern wall were completely destroyed.

shaking was here probably less severe. In Ghalasar, the roof of S.Sarkis partly collapsed and the northern wall fell to the north, but the other walls survived at their full height (Fig. 26). This collapse towards the north, also observed for the small parapet wall surrounding the roof of the church, is exceptional, and may be compared to the dominant northward displacement of the tombstones in Khosrova and the northward shift of Zayia's car. The church of S. Asdvadzadzin in Akhtékhaneh survived, although it was fissured (Fig. 27); it is a 14th century construction with the traditional double wall (kiln-brick inside, rough masonry outside), and a roof with three kiln-brick domes. The northern and eastern walls were fissured, and the interior N–S arches developed

Fig. 23. S. Hovanes (Kalashan). Only the southern wall (left-hand side) of the adobe church remained partly standing after the earthquake.

cracks near their keystone (Fig. 28). In the nearby village of Ghezelja, S. Hovanes also survived, though more damaged than S. Asdvadzadzin (Fig. 29). This church, provisionally dated 1007 A.D. from an inscription on the doorway, is a rough masonry construction with four pillars supporting a central dome. All four walls were fissured diagonally, and an important central crack crossed the whole roof from E to W.

The minor damage suffered by the three churches in Ghalasar, Akhtékhaneh and Ghezelja, relative to other churches on the Salmas Plain (with the exception of S.

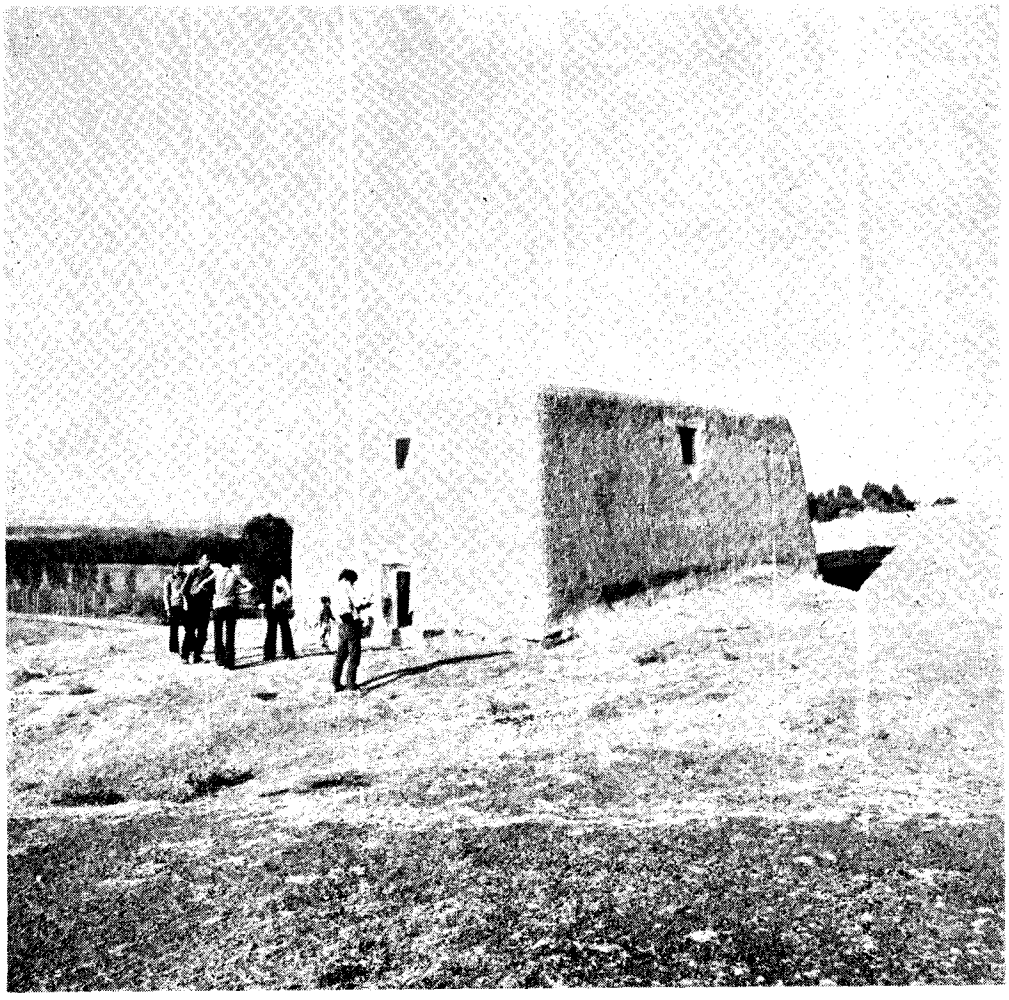


Fig. 24. Prishad (near Zaviehjuk). The chapel located about 500m south of the Salmas Fault was undamaged after the earthquake.

Gevork in Haftavan), leads one to postulate the eastern limit of the epicentral region in their vicinity. Further east, towards Lake Rezaiyeh, damage decreased very rapidly: Kanyan, Mafi Kandi, Shekar Yazi, Soltan Ahmad, Yavshanli, Gharaqesslagh, 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 (Ghezalja), showed no signs of earthquake damage (Fig. 30).

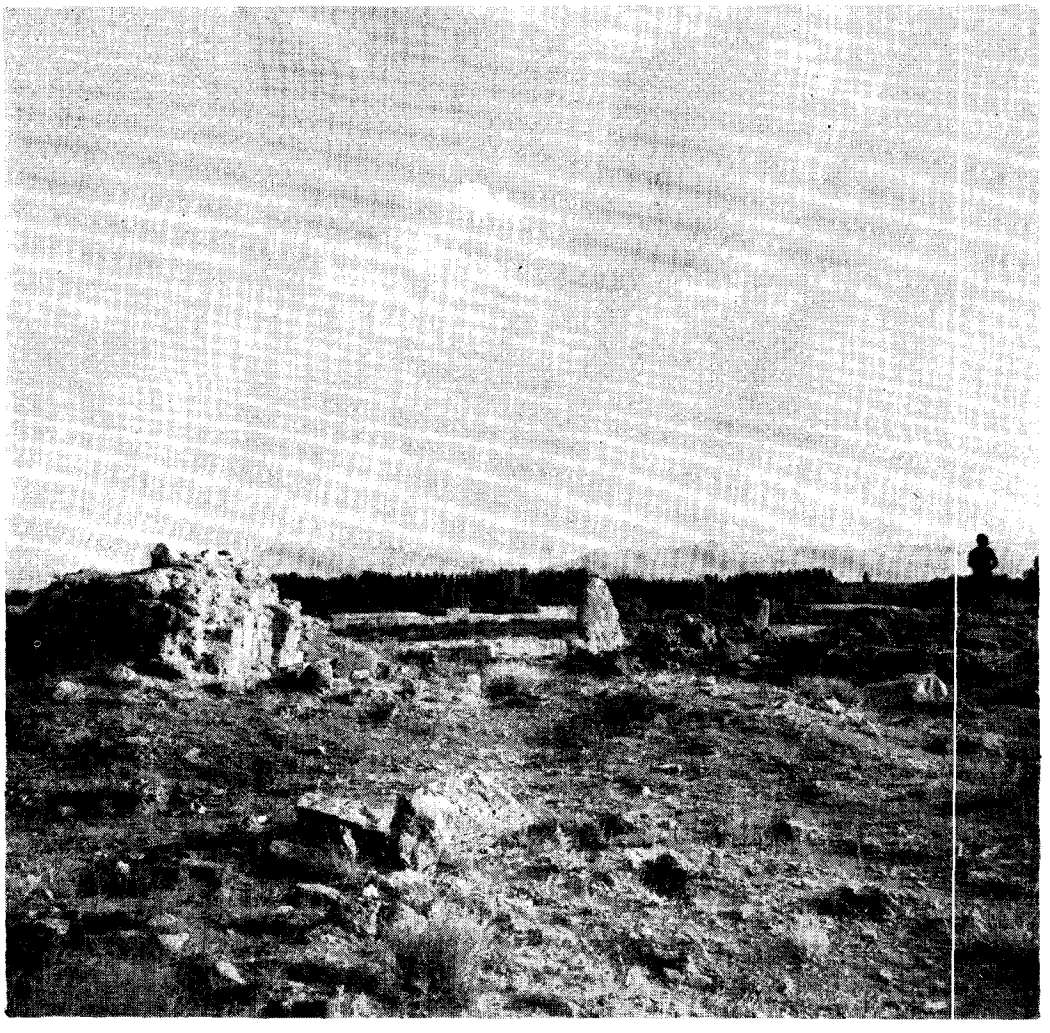
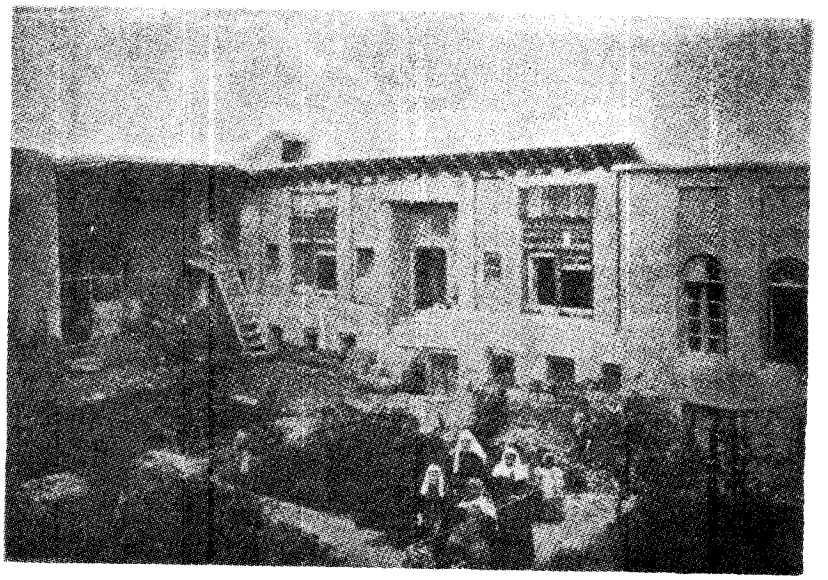


Fig. 25. S. Gevork (Payajuk). The church was completely destroyed. Looking south, apse on the left-hand side.



Eig. 25a. Unique photograph illustrating pre - 1930 domestic architecture. All the buildings in this style were destroyed in the earthquake of that year, and it can on longer be seen.

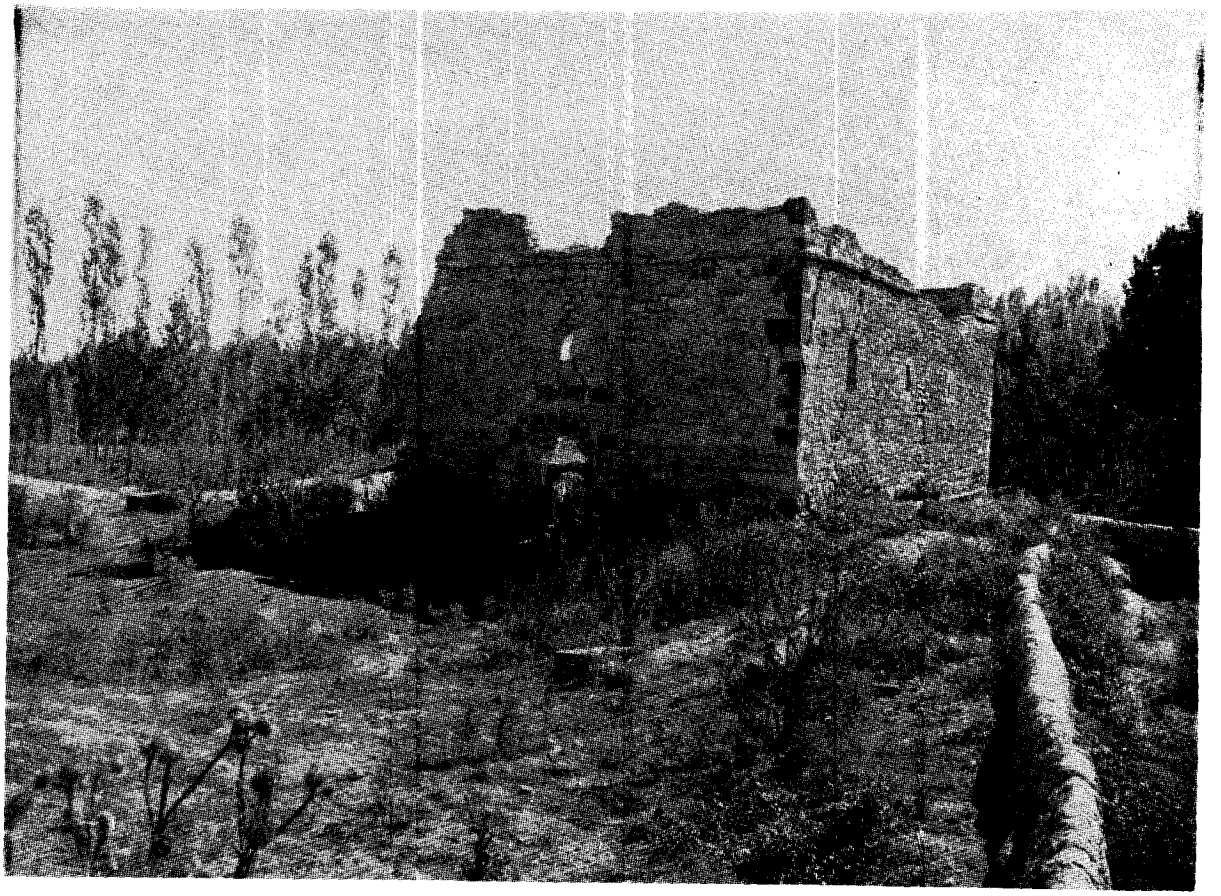


Fig. 26. S. Sarkis (Ghalasar). Western facade and southern wall. The northern wall collapsed to the north.

b) Mountain region

About half the 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

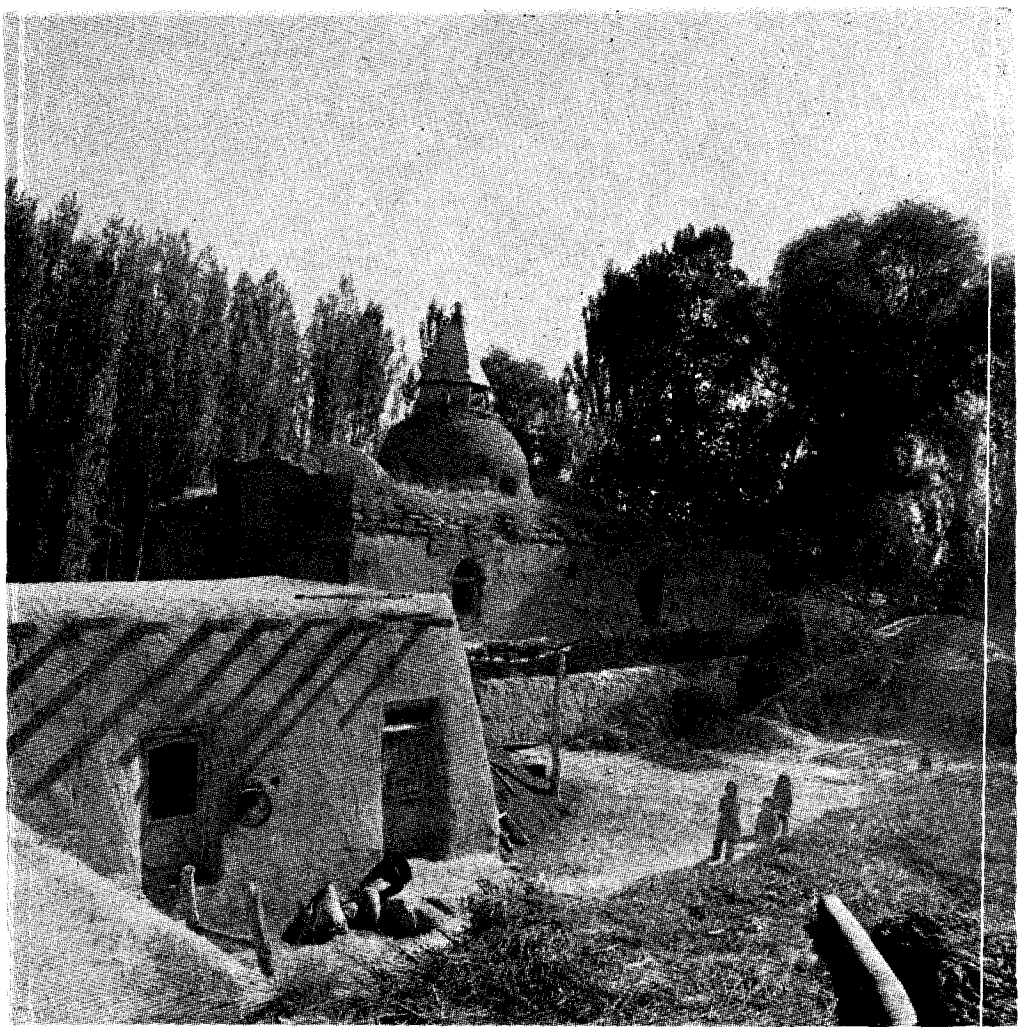


Fig. 27. S. Asdvadzadzin (Akhtékhaneh). The 14th century church was slightly fissured. Western facade and southern wall.

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 (Fig. 31), Ayan (Fig. 32), Ghabrabad, Sheydan, Yengijeh and Lashgaran. Sailab and Howdar were partly destroyed with very few or no causalties, the latter being abandoned after the earthquake and re-sited in a more accessible location.

Fig. 28. S. Asdvadzadzin (Akhtekhaneh). The main interior damage was a central east-west fissure seen near the keystones. Looking west.

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 (Fig. 33). Further upstream, Balghazan and Siavan were only partly damaged. North of Zola, a line of villages on the basalt plateau overlooking the Salmas Plain was destroyed

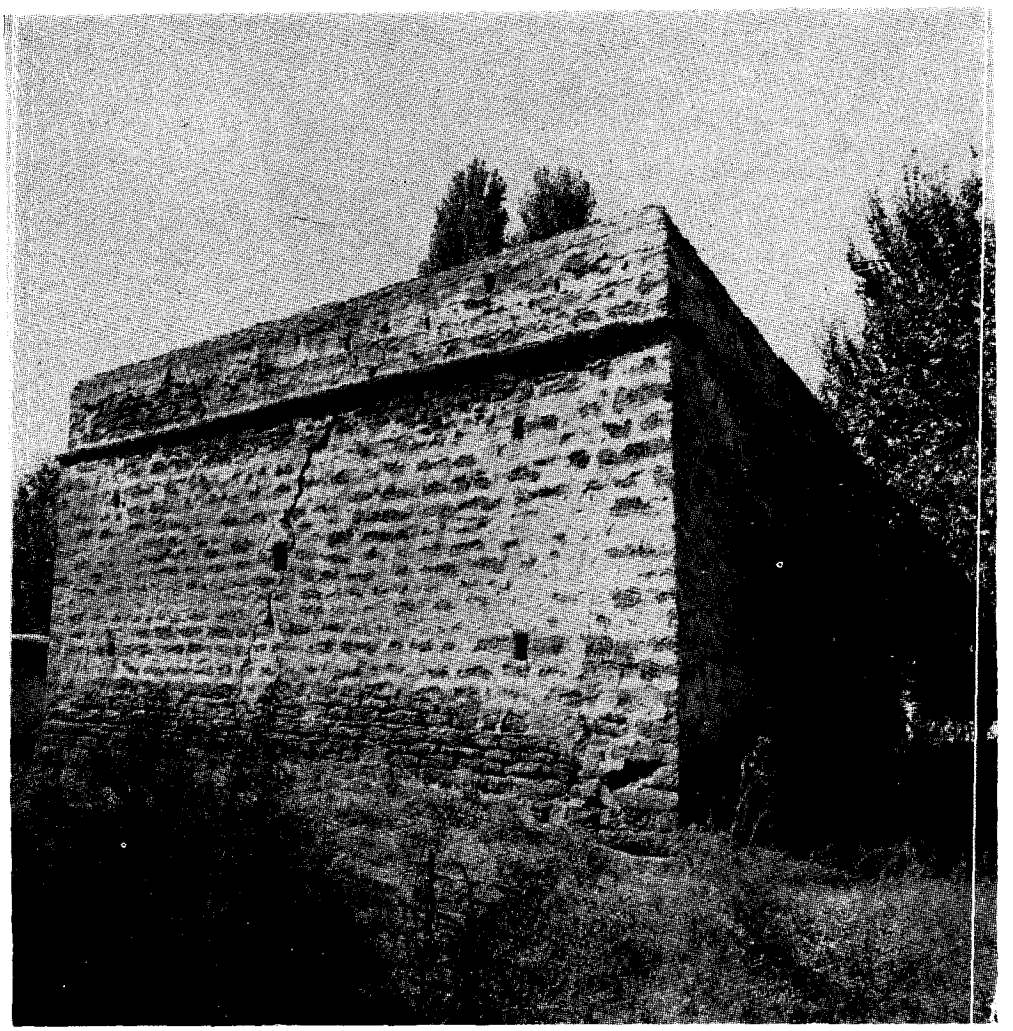


Fig. 29. S. Hovanes (Ghezelja). Eastern and northern walls, fissured during the earthquake.

and had a high proportion of casualties: Kahriz, Kurdran, Aslanik (Fig. 34), 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. Above the old village of Derik, which had been sold to the Kurds before the earthquake, a small stone masonry chapel, forming part of

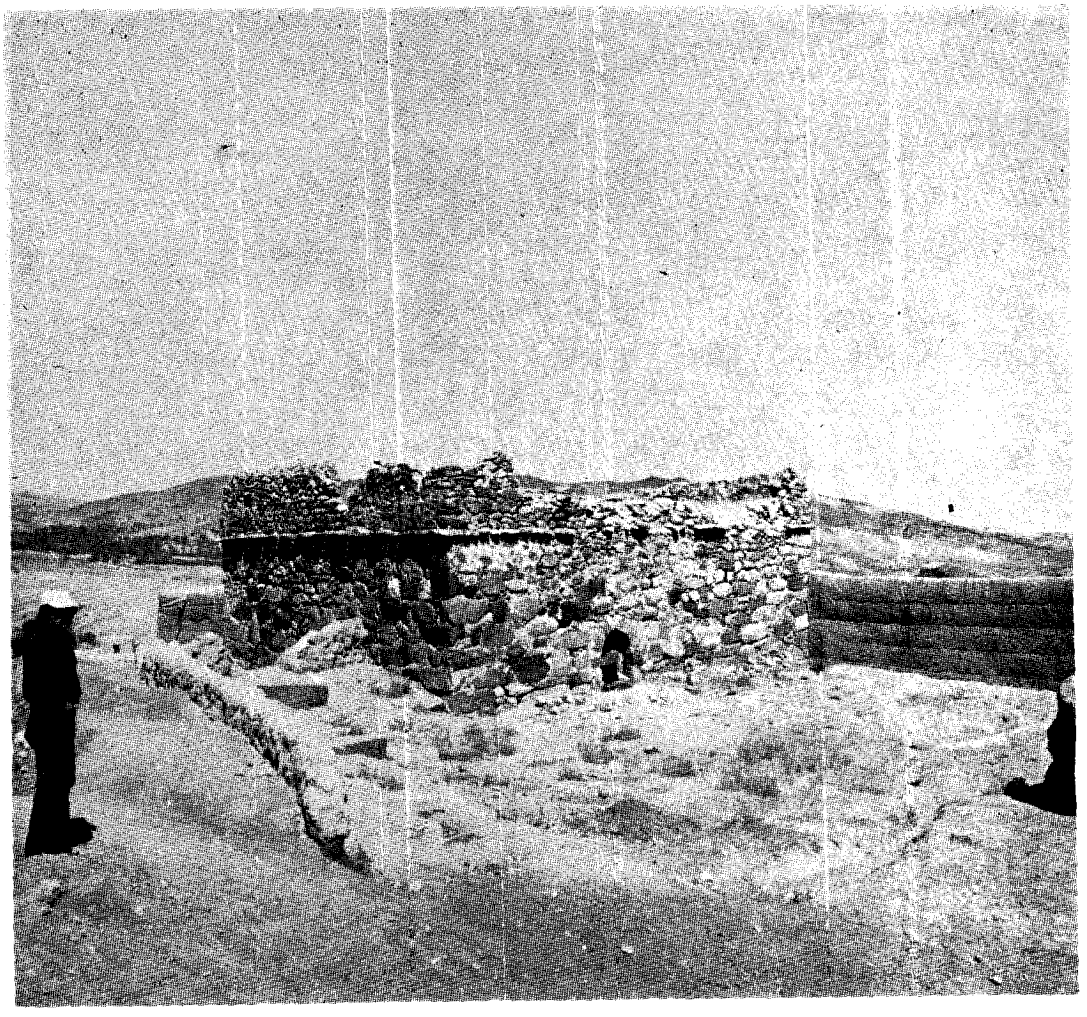


Fig. 30. S. Gevork (Gharabagh). Southern and western walls. The church, located outside the epicentral region, was undamaged.

a monastery, collapsed (Fig. 35). A group of villages located further up in the mountains, comprising Guzik, Ashnak (Fig. 36), Hablaran (Fig. 37), Khorkhora, Senji and Alibolagh, was also destroyed.

The limits of destruction of this western sector can be approximately traced east of the Turkey-Iran border. The most distant village to be destroyed was Borunshqalan 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

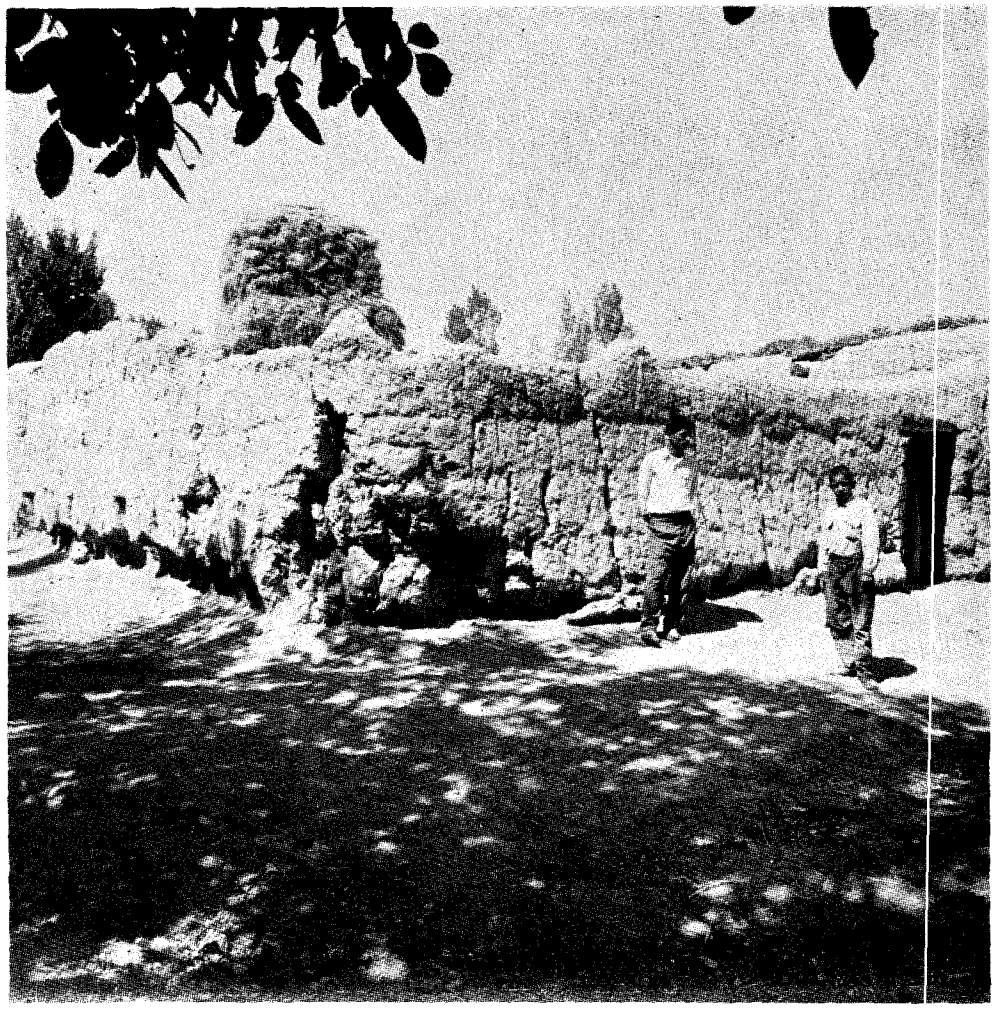


Fig. 31. S. Asdvadzadzin (Vardan).The church in sun-dried brick located at this site was already in bad repair before the earthquake.

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. In Kashkavich, only three houses of 20 collapsed, killing two 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, about one third of Shurgel, located on rock at the south-

Fig. 32. S. Asdvadzadzin (Ayan). The northern wall of the adobe church is still standing. It was already in bad repair before the earthquake.

eastern end of the earthquake fault, was destroyed, and further along the fault alinement Zindasht and Issy Su were only lightly damaged. In the south, Bardian and Bostakabad were also lightly damaged, while 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 unable to investigate this information. South of the epicentral

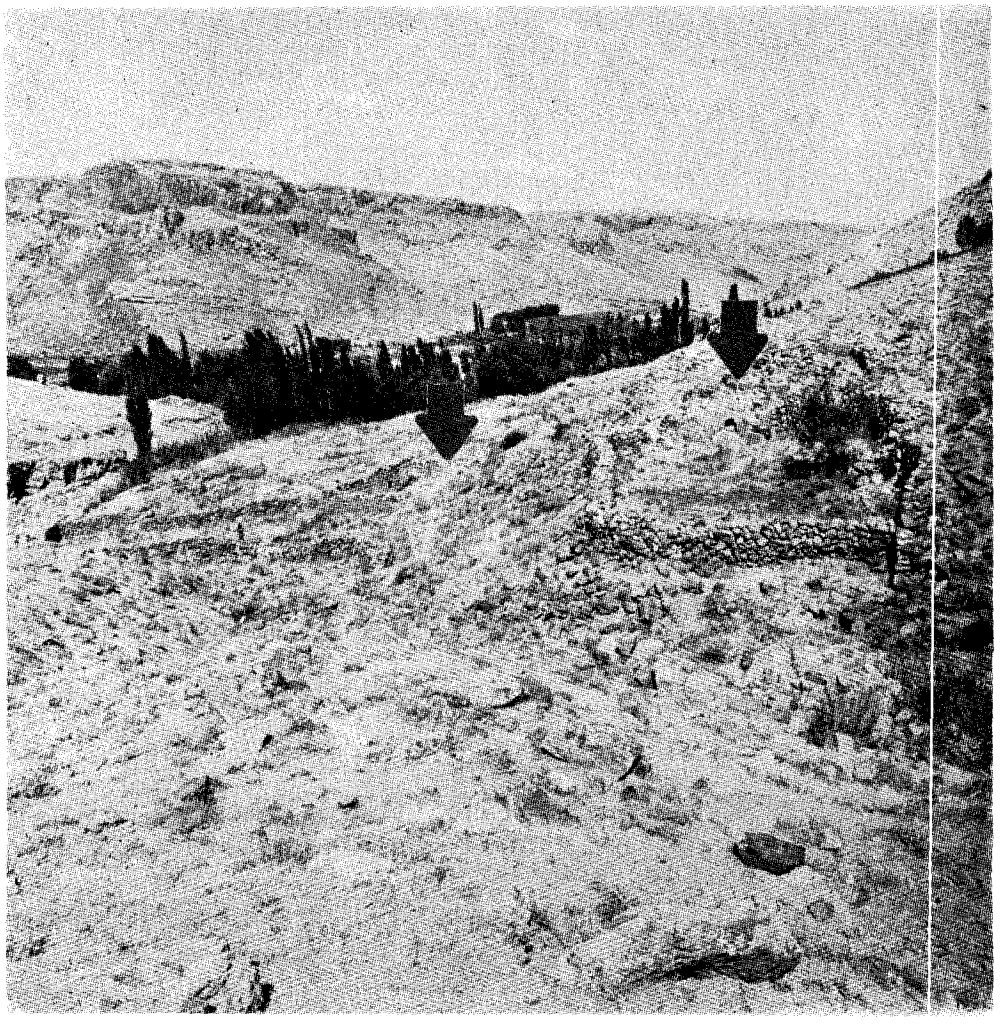


Fig. 33. Chahriq site. The village, which was badly damaged in the earthquake, is today abandoned. The two arrows indicate the two ruined churches.

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 (Fig. 38). In the villages of Mamaqan and Sormanava all the inhabitants had slept indoors as the foreshock had been felt only very lightly, and aftershocks did not increase appreciably the damage caused by the main event.

Fig. 34. Aslanik village. Located in the mountains southwest of the Salmas Plain, Aslanik was destroyed by the earthquake.

4. FAULTING AND THERMAL SPRING ACTIVITY

4.1. 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–SE direction near the mountain village of Derik (Fig. 3). Maximum displacements on these faults faults were:

Fig. 35. S. Asdvadzadzin (Derik). Only the apse of the small chapel survived the earthquake.

for the Salmas Fault, 4m right-lateral and over 5m vertical (NE downthrown); for the Derik Fault, left-lateral by an unknown amount, and about 1m vertical (NW downthrown). Both faults were briefly alluded to in contemporary reports and correspondence, for instance in Franssen (1930), Zayia (1930a,b), Brunk (1930) and the 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, for example Darmanava Spring (Issy Su) in the southwestern extension of the

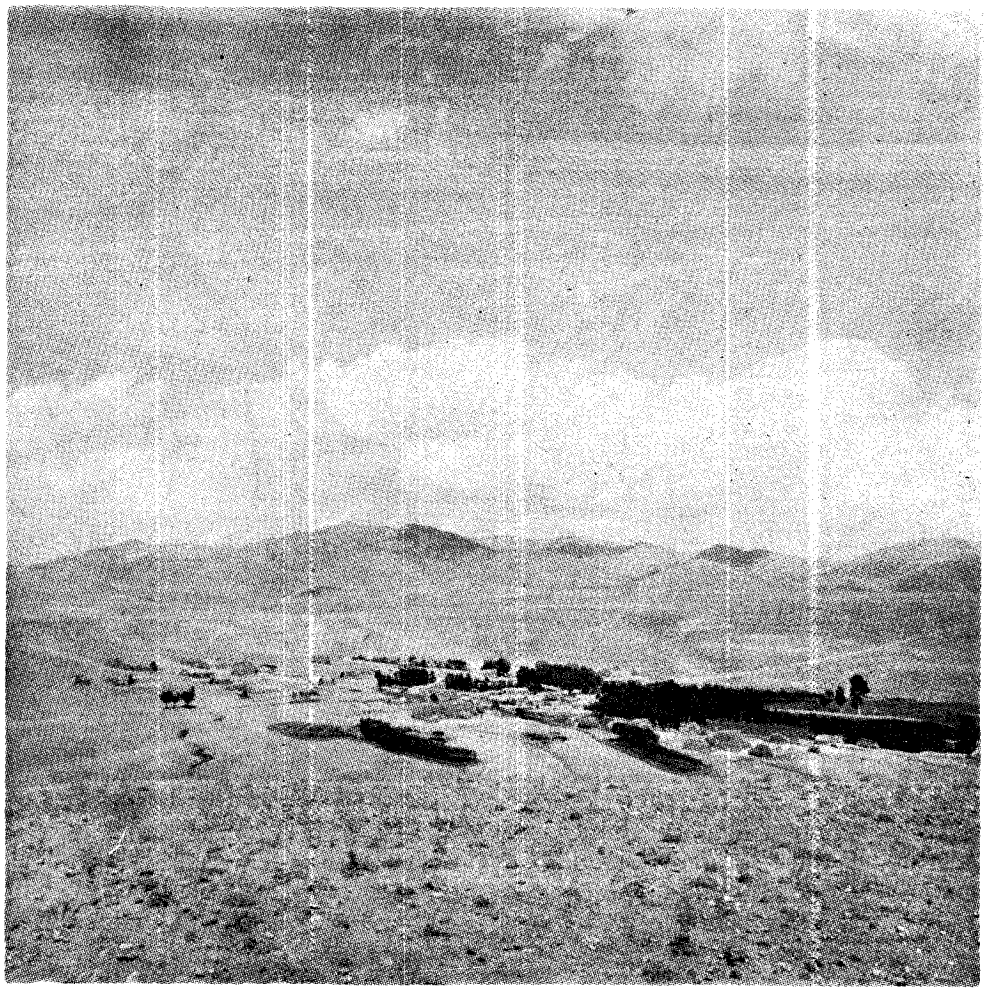


Fig. 36. Ashnak village. Mountain village situated at the western limit of destruction, near the Turkish border

Salmas Fault and Derik Spring in the southwestern extension of the Derik Fault. A new spring, the Zelele Bolaghi (literally, the earthquake spring), appeared on the Salmas Plain and is still responding to-day to local earthquake tremors.

4. 2. Salmas Fault

The Salmas Fault is the longer of the two faults, and the one that produced the larger displacement. It is formed by two separate en échelon segments referred to here

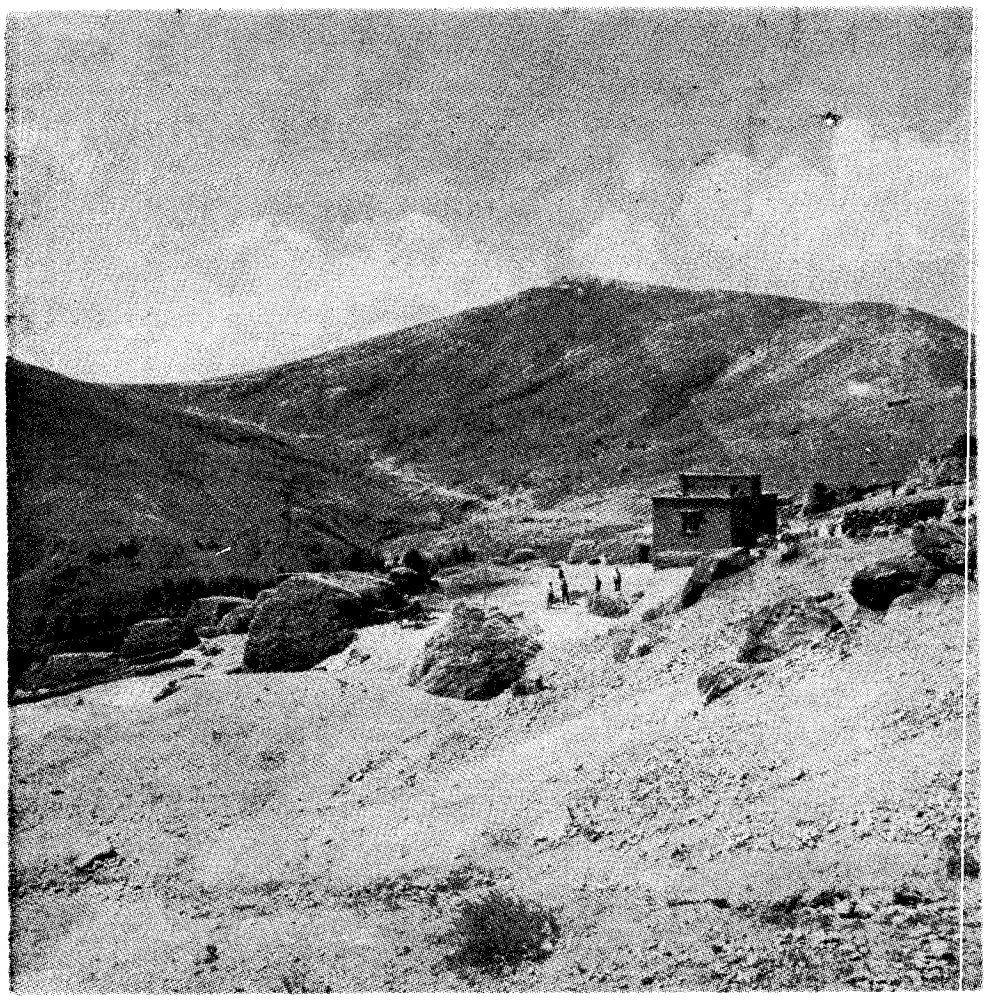


Fig. 37. Hablaran village. The village was destroyed and large rockfalls were started by the earthquake.

as the Akhian segment and the Zaviehjuk segment, the latter probably being the result of the junction of two other en échelon segments (Fig. 39).

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 (Figs. 40 and 41). Maximum displacements are 1.5m (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 (Fig. 42). At Akhian the fault trace crosses

Fig. 38. Sarmanava church. Located near the Mamaqan pocket of destruction, the village of Sarmanava was half-destroyed, but the church seen here was undamaged.

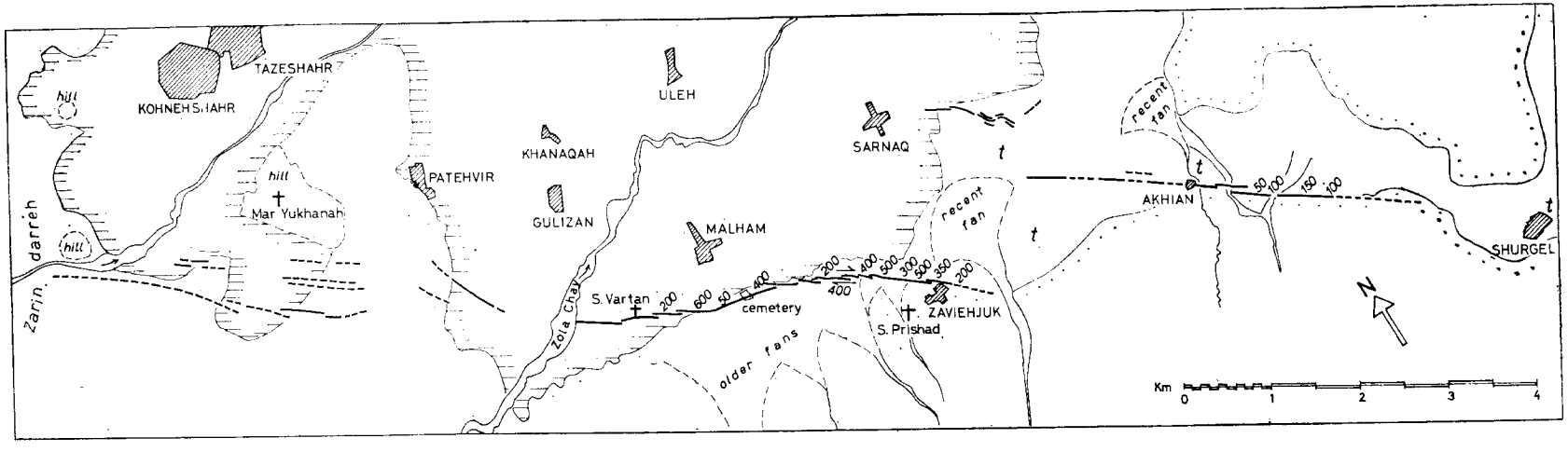
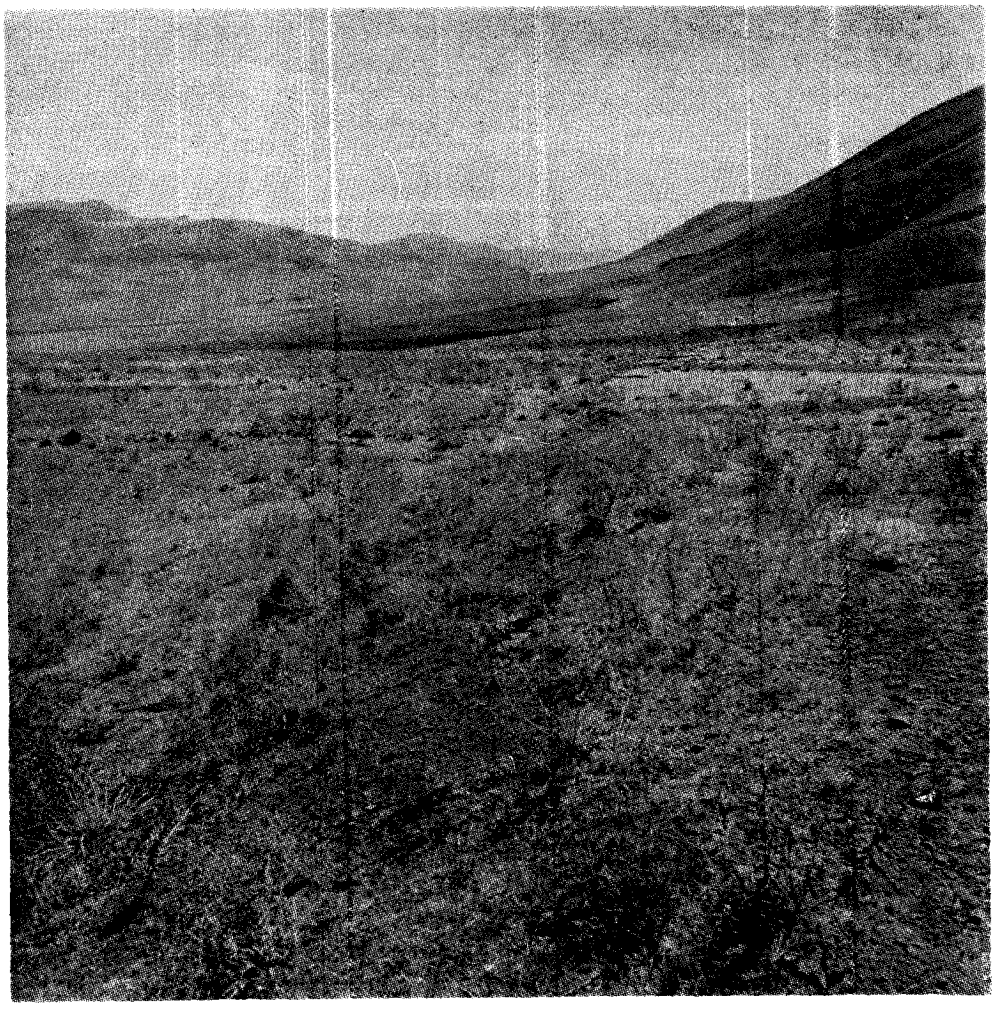


Fig. 39. Salmas Fault. The trace of the earthquake fault, dashed where uncertain, was drawn in the field with the help of 1:20,000 aerial photographs. Numbers indicate vertical displacement (NE downthrown) in centimetres; horizontal displacement was right-lateral, but could be measured precisely in only one location. Dotted shading is rock outcrop, line shading is cultivated fields. t: travertine cover.

a stream bed, exposing a shear zone in the underlying metamorphic rocks in which many new earthquake fissures can be seen crossing older joints and slickensided planes. A surface travertine cover about 1m thick is interrupted at the edge of the fault zone. East of Akhian, and at about 500m from the fault, a short N 160°E fracture zone in the travertine cover is made of open en échelon fissures 20 to 30m long and oriented about N 140°E, and occasional ridges oriented about N 20°E. This disposition suggests local left-lateral shearing, probably conjugate with respect to the Salmas Fault.



Fgi. 40. Salmas Fault, Akhian segment. The eroded fault trace runs at the foot of the mountain, from the lower righthand corner of the photograph to the Shurgel pass in the background. Average vertical displacement (NE, i.e. left side, down) was here about 1m. Looking SE.

The Zaviehjuk segment starts east of the village of Zaviehjuk and crosses its northern outskirts, striking N 125°E (Fig. 43). Its throw (NE down), about 2m at the village (Fig. 44), increases in the west to over 5m (Fig. 45), and its strike changes gradually from the original N 125°E to N 105° at the Malham cemetery. Up to this location it is entirely contained in the alluvial fans which originate in the mountains to the south. About half-way between Zaviehjuk and the Malham cemetery two narrow parallel gullies were displaced right-laterally by about 4m. Even though other reliable markers

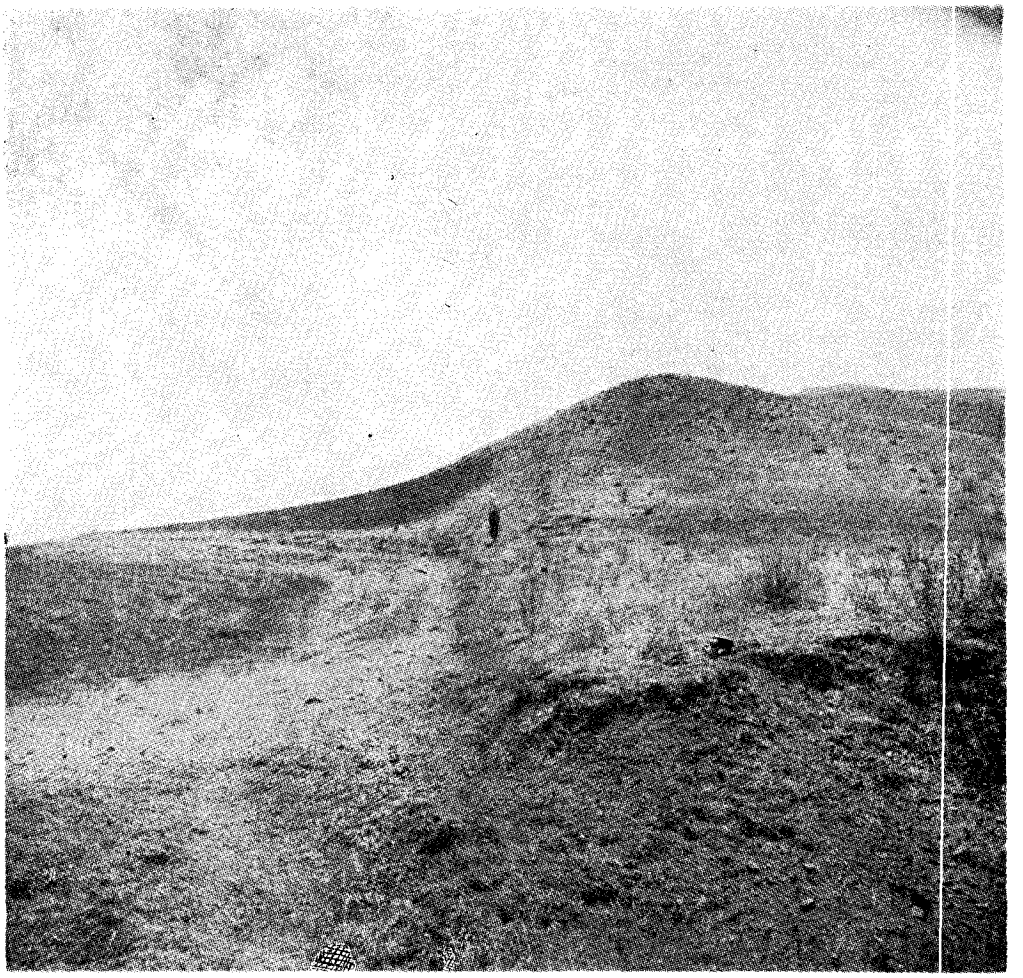


Fig. 41. Salmas Fault, Akhian segment. Fault trace east of Akhian. Two eroded scarps can be seen, one on either side of the figure. Looking SE.

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. The sides of the erosion gullies which have worked their way into the degraded scarp since 1930 show an undisturbed bedding of the gravel fans, with ocasional small fissures parallel to the scarp and dipping north by about 85° (Fig. 46).

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

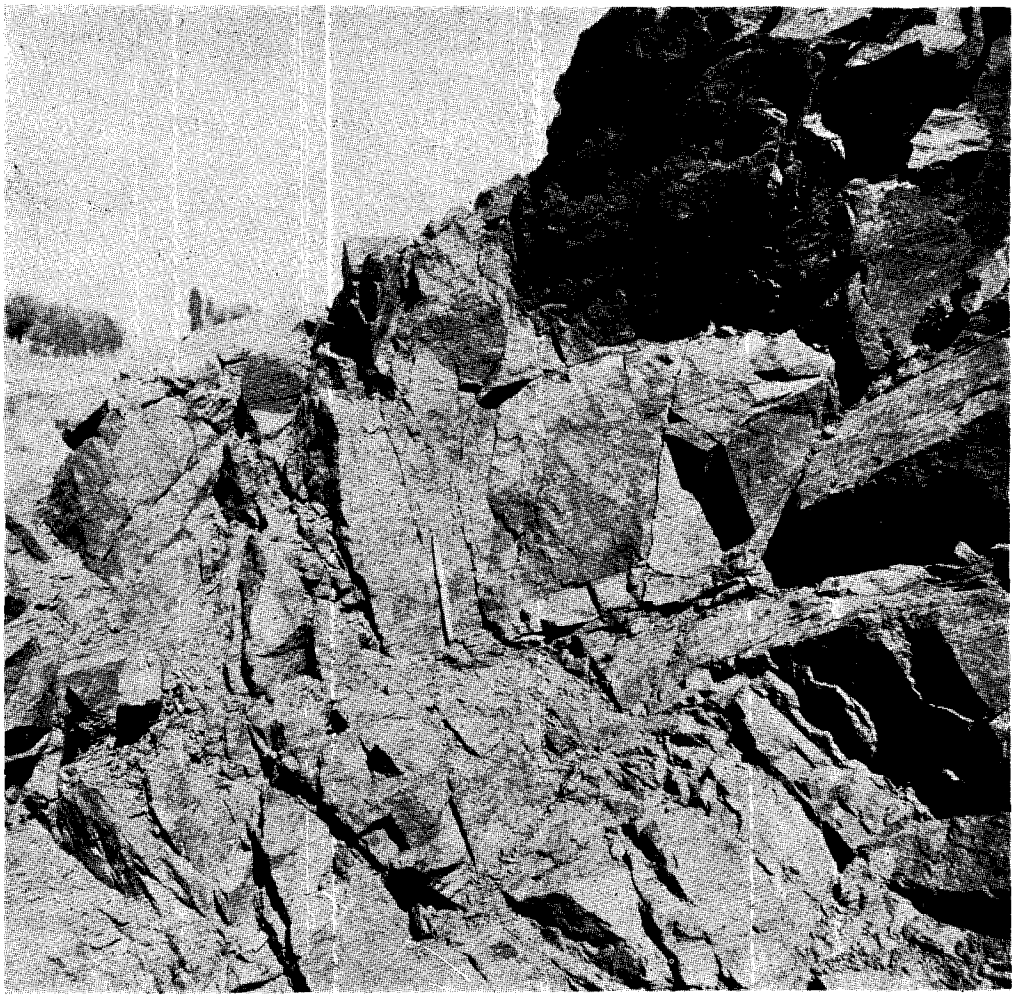


Fig. 42. Salmas Fault at Akhian. Earthquake fissures are the subvertical features near the pen. The metamorphic outcrop contains older joints and slickensided planes.

(Fig. 47). This increases the apparent throw from about 2.5m to over 4m, 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 cemetery, the fault enters cultivated fields with an apparent throw of about 6m, partly due to a pre-existing topographical step (Fig. 48). It gradually bends back to a N 125°E direction near the Zola Chay river.

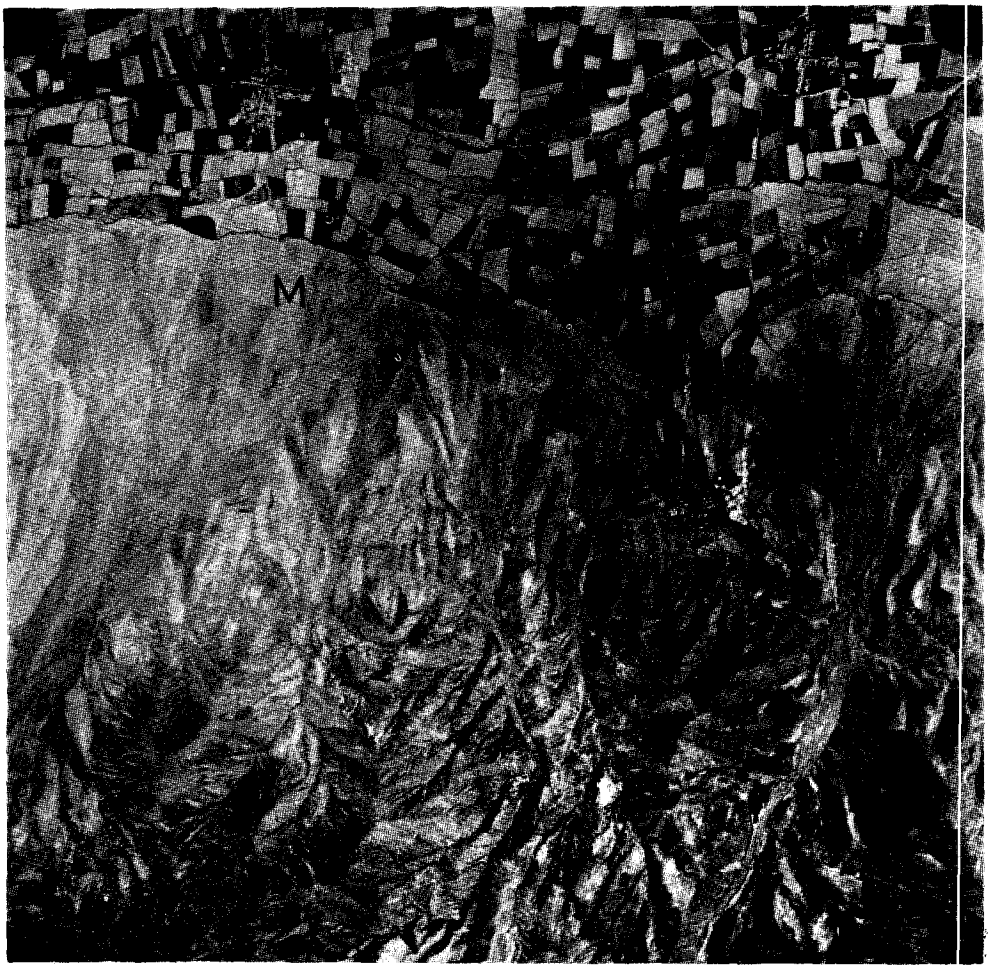


Fig. 43. Salmas Fault, Zaviehjuk segment. Aerial view of the fault trace (between arrows) passing through Zaviehjuk (Z) and the Malham cemetery (M). There are several topographical steps north of, and parallel to, the fault scarp, the most obvious one marking for a short distance the limit between mountain fans and cultivated fields northwest of Zaviehjuk. North is top of photo; area covered is approximately 4km^2.

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 rarely visible here, but the fault trace is marked by a wide linear depression across the field, along which the cultivation is 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 cracks were observed in a travertine plateau (Fig. 49), similar

Fig. 44. Salmas Fault, Zaviehjuk segment. Eroded fault scarp west of Zaveihjuk. The vertical throw is here about 3m (NE, i. e. right side, down). Looking NW.

in appearance but less systematic in pattern to those described east of Akhian. The origin of these fractures is not clear, and tension cracks due to incipient landslides cannot be altogether discounted.

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. 43). One of these steps contitutes the present-day boundary between the irrigated

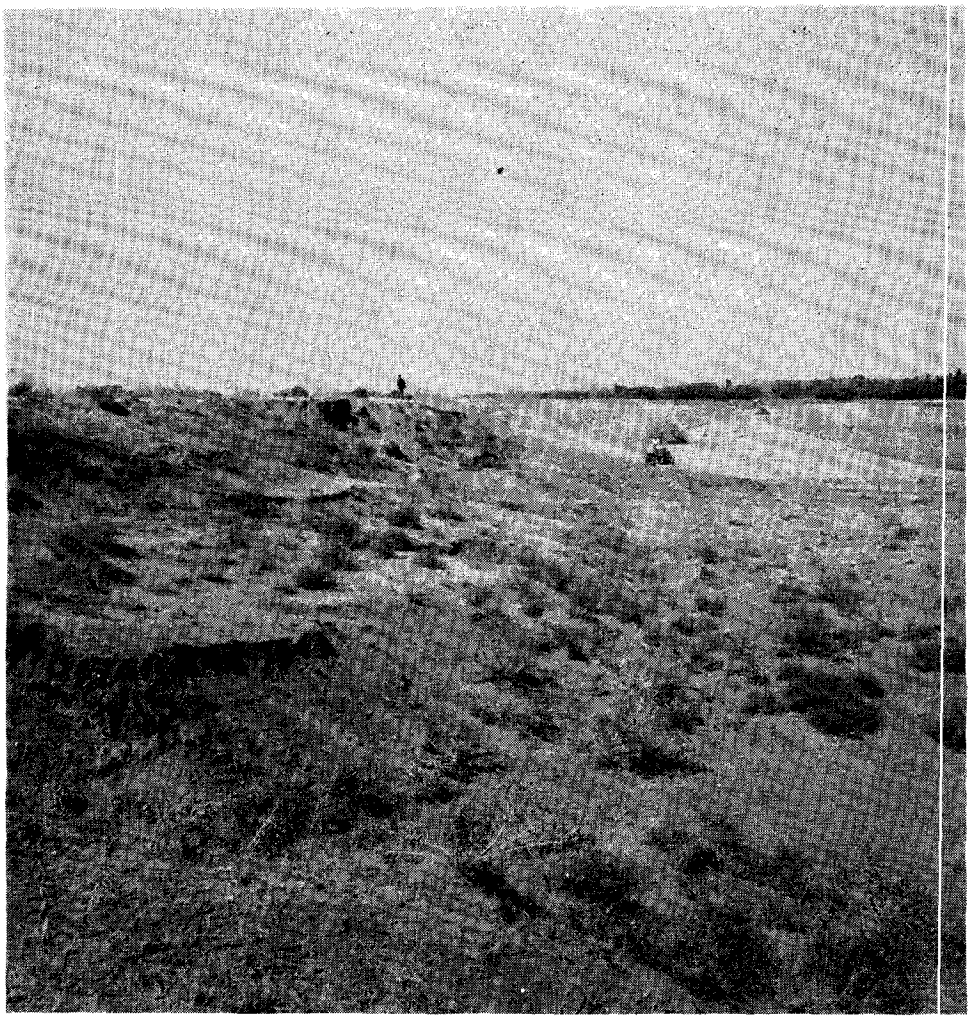


Fig. 45. Salmas Fault, Zaviehjuk segment. Vertical throw is here about 5m. Looking SE.

fields and the mountain fans. These steps are a few metres high and very similar in appearance to the degraded earthquake fault scarp. Their most likely interpretation is that they represent previous stages of subsidence of the Salmas Plain with respect to the mountains in the south.

The Darmanava thermal spring near Issy Su is located precisely in the south-eastern continuation of the Akhian segment, about 11km beyond the point where the earthquake fault stopped. It is a sulphurous spring at a temperature of 37.5° C, used

Fig. 46. Salmas Fault, Zavieḥjuk segment. Fault scarp, here dissected by a post-earthquake erosion gully, is located between the two standing figures. Looking NE.

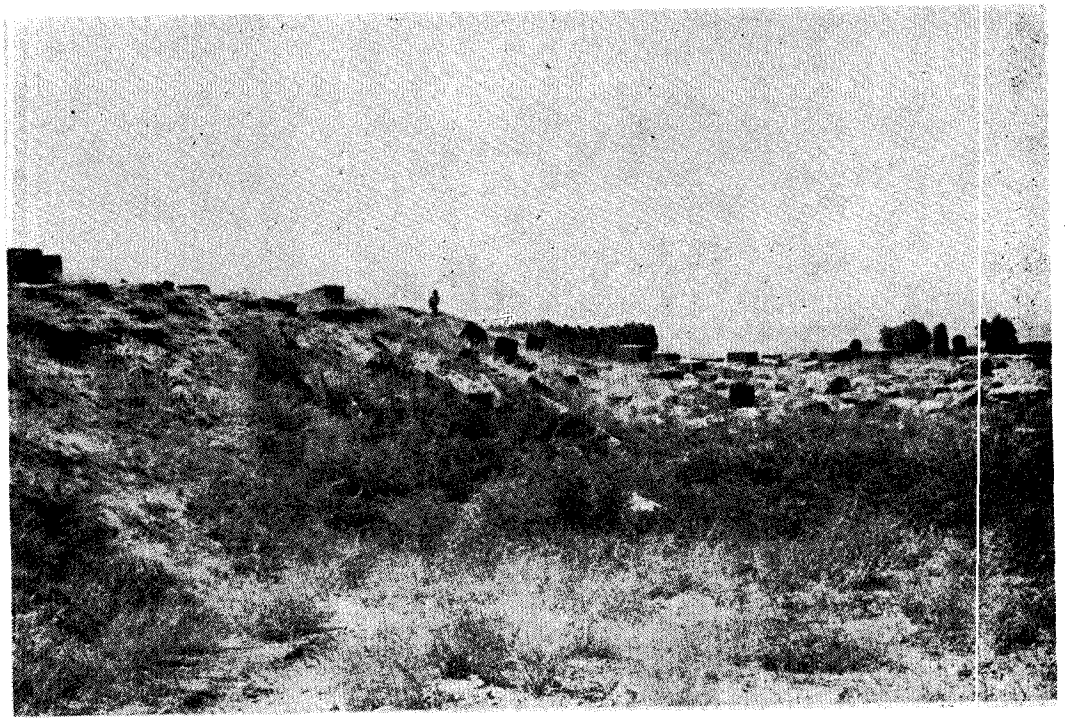


Fig. 47. Salmas Fault at Malham cemetery. Apparent throw is about 4m. Looking NW.

Fig. 48. Salmas Fault, Zaviehjuk segment. The earthquake fault scarp si here superimposed on a pre-existing topographical step, with a resulting apparent throw of about 6m. Between Malham and the Zola Chay, looking NW.

for medical purposes, and deposits a whitish carbonate of soda. Its flow decreased appreciably after the earthquake. About 10km north of the fault, at the northern foot of the isolated hill marked 1628 in Figure 3, a cold (18° C) gaseous spring appeared during the earthquake and was subsequently named Zelzele Bolaghi. It is reported to have developed 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.

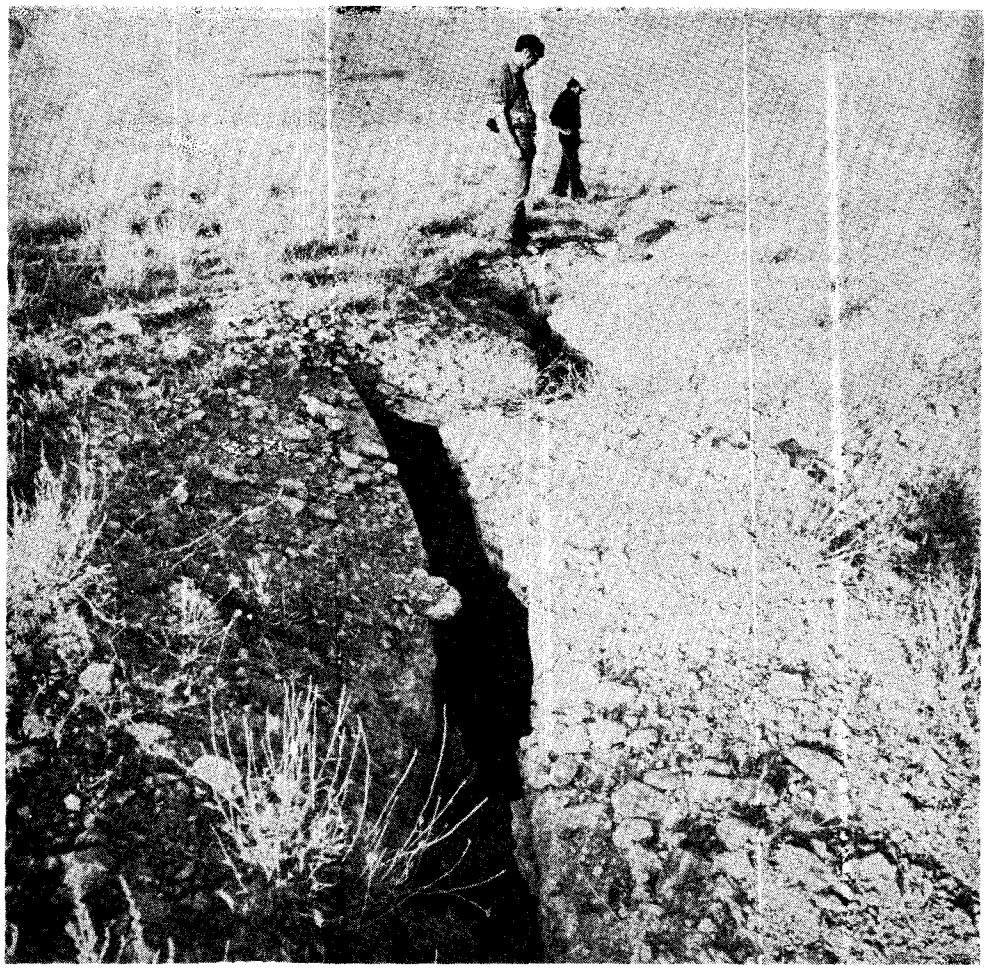


Fig. 49. Northwestern end of the Salmas Fault. Cracks of possible earthquake origin in travertine formation of the Dar Darreh Valley.

4.3. 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. 50). 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 N 75°–80°E, and the vertical earthquake displacement was about 1m (NW

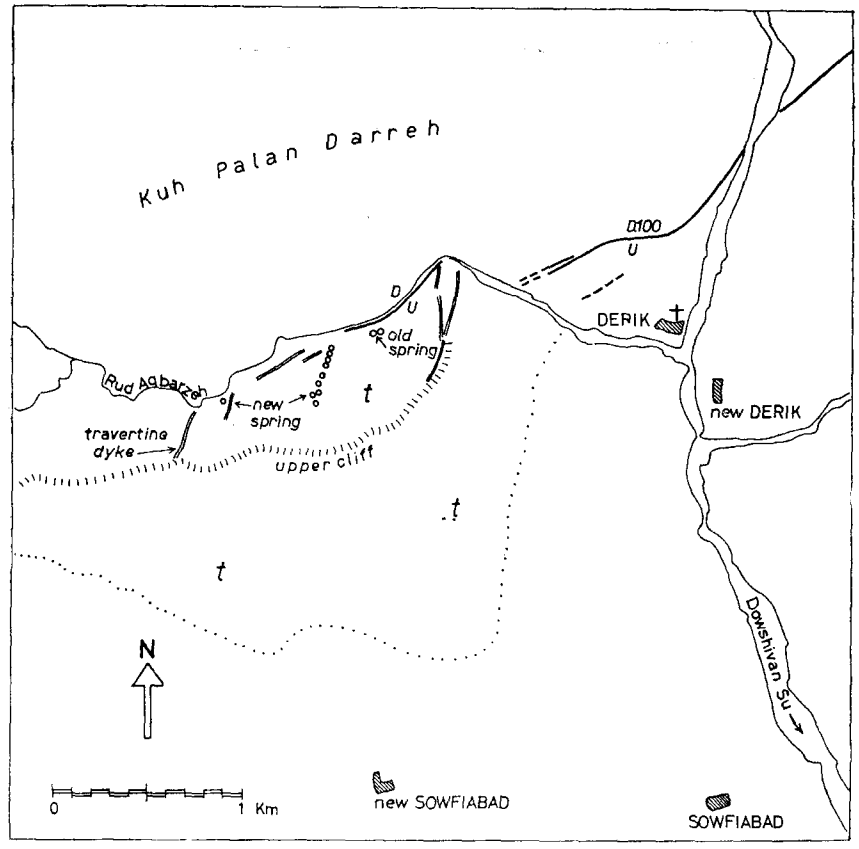


Fig. 50. Derik Fault. Trace of earthquake fault from field mapping and 1:20,000 aerial photography. Number indicates vertical displacement in centimetres, U (up), D (down). Dotted line is approximate southern limit of travertine outcop (t), northern limit being formed by the Rud Aqbarzeh.

down) (Fig. 51). Suitable markers could not be found to measure horizontal displacements. The overall trace of this section strikes approximately N 45°E, 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 alinement on the opposite (right) bank. However, about 300m further upstream on the right-bank, long cracks were formed parallel to the river in the travertine deposits (Fig. 50). Their overall direction is about N 45° E. They mark the edge of a cliff along

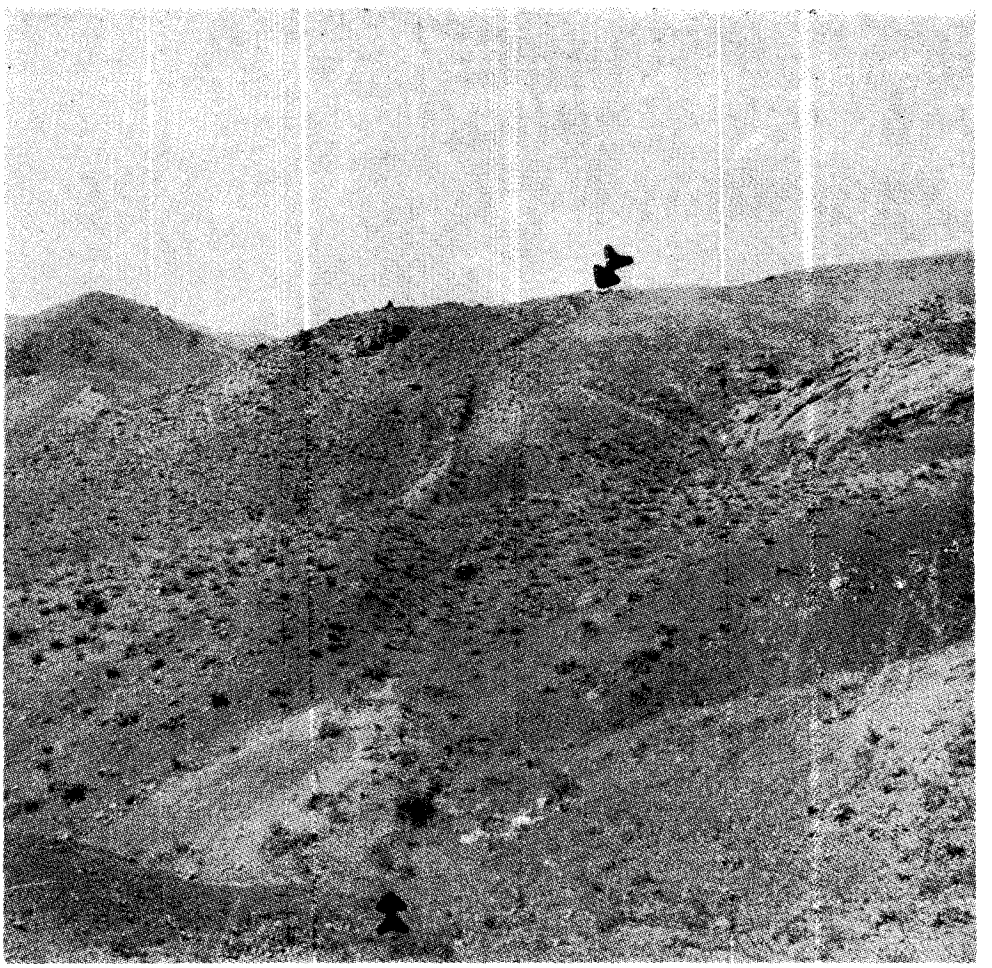


Fig. 51. Derik Fault. Section north of the old village. Vertical displacement is about 1m (NW, i. e. right side, down). Looking SW.

which travertine was deposited from two springs up to the time of the earthquake in 1930 (Fig. 53). At the earthquake these springs ceased, new springs appearing which are still active to-day in two locations, respectively 200m and 800m further upstream. At the first location, eight small springs are alined in a N 15°E direction for about 300m, and at the second location a larger spring (about 2 $^{D}/_{S}$) has already deposited since 1930 an appreciable amount of travertine (Fig. 54). The temperature of the water (33° C) is about 2.5 ° C lower than that of the pre-earthquake springs (Loftus, 1854).

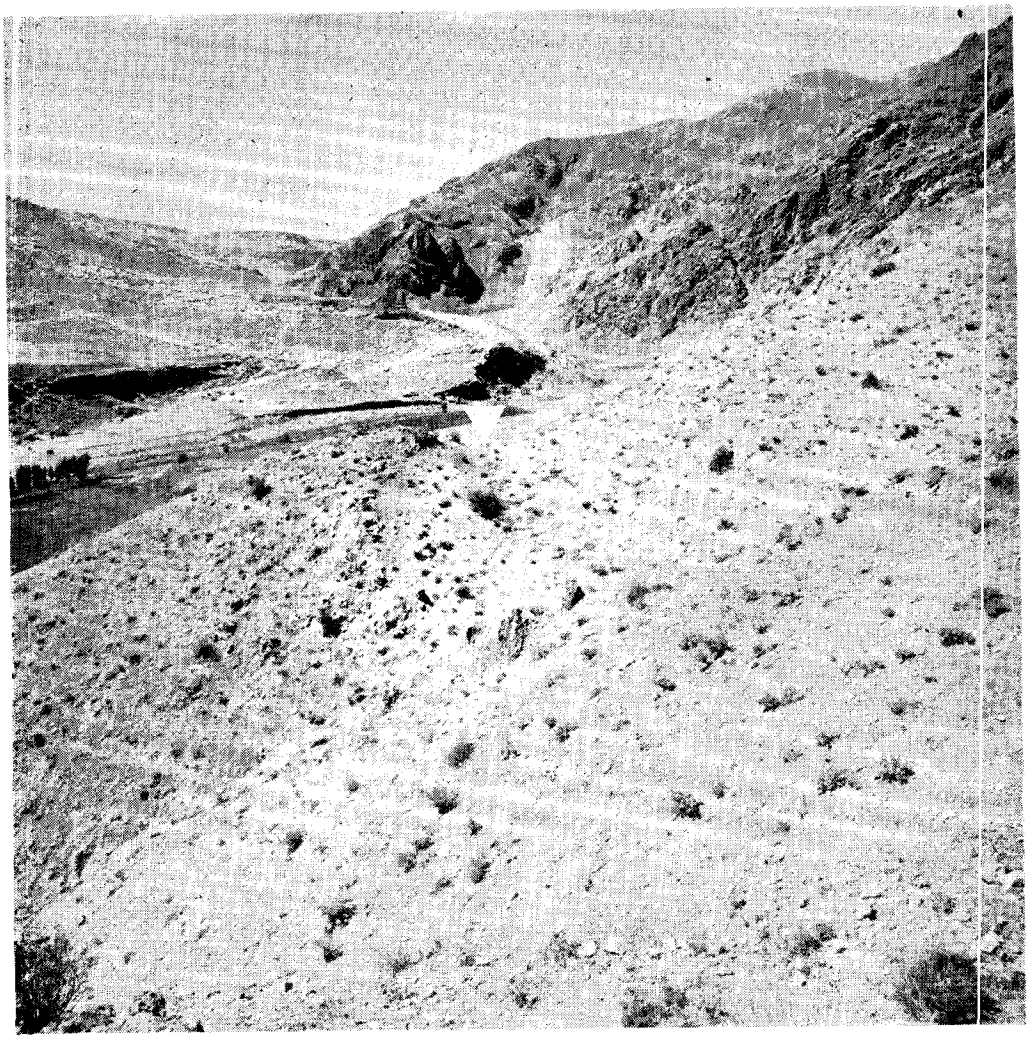


Fig. 52. Derik Fault. The earthquake fault trace (white triangle) stops before reaching the river, but earthquake fractures were found in an offset alinement in travertine further upstream (see Fig. 50).

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 thin dykes of the same travertine cut vertically through these deposits and stand out in the topography (Fig. 55). They are oriented in two directions: N 45°E, located in the approximate continuation of the earthquake cracks, and N 5° E, roughly parallel to the new spring alinement (Fig. 50).

If the entire structure formed by the earthquake fault between the two rivers

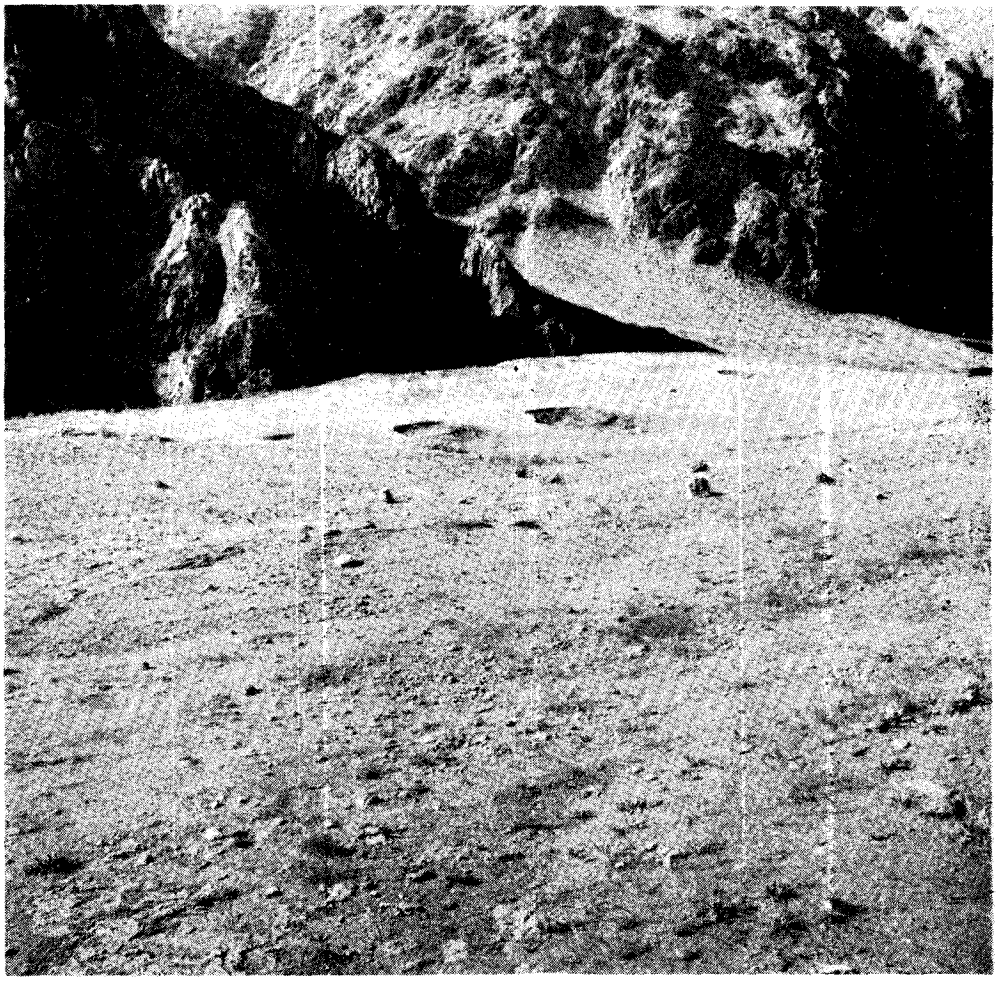


Fig. 53. Derik thermal springs. The two craterlets were the main travertine depositing springs which ceased at the 1930 earthquake. Looking N.

and the travertine structures on the right bank of the Aqbarzeh is considered, the simplest interpretation is that there are three en échelon 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 alinement of new springs and travertine dykes would correspond to the direction of the maximum principal stress of the left-lateral deformation.

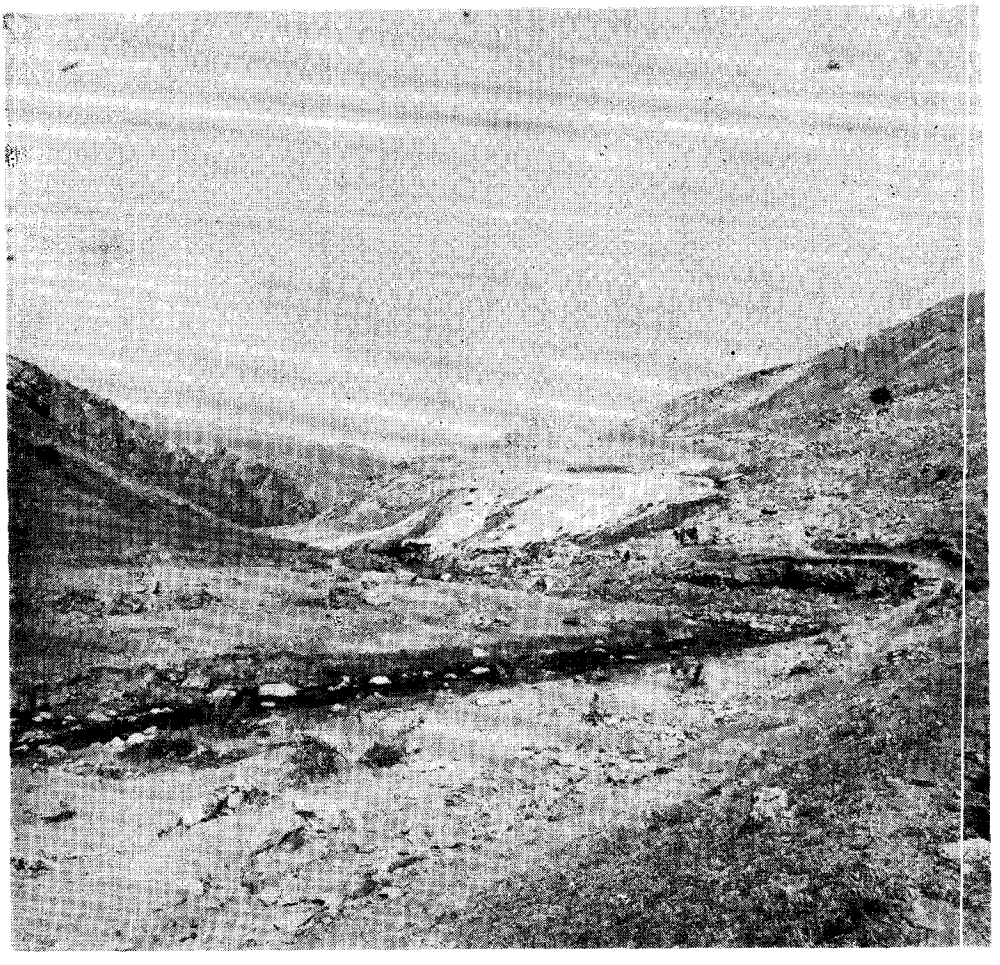


Fig. 54. Derik thermal springs. The white travertine outcrop in the mid-background was deposited after the earthquake by the main new spring.

5. 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 due either 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 increased their flow (Tamar and Zaviehjuk);

Fig. 55. Derik thermal springs. Older travertine dykes show a thin zone of vertical layering (white triangle) transecting the surrounding horizontal layering.

in some of the higher mountain villages springs decreased, and in two cases ceased altogether (Alibolagh and Hablaran). Several landslides also occurred, for example near Lashgaran (Fig. 56), near Nazirabad and at Drishik Tepe, an archaeological mound south of the village of Drishik. Recent excavations at Haftavan Tapeh also revealed fissures which may be interpreted as incipient landslide cracks (Burney, 1973) (Fig. 57). Largetension cracks resulted from a bedding-plane slip in Eocene conglomerates aboveAslanik (Fig. 58). 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.

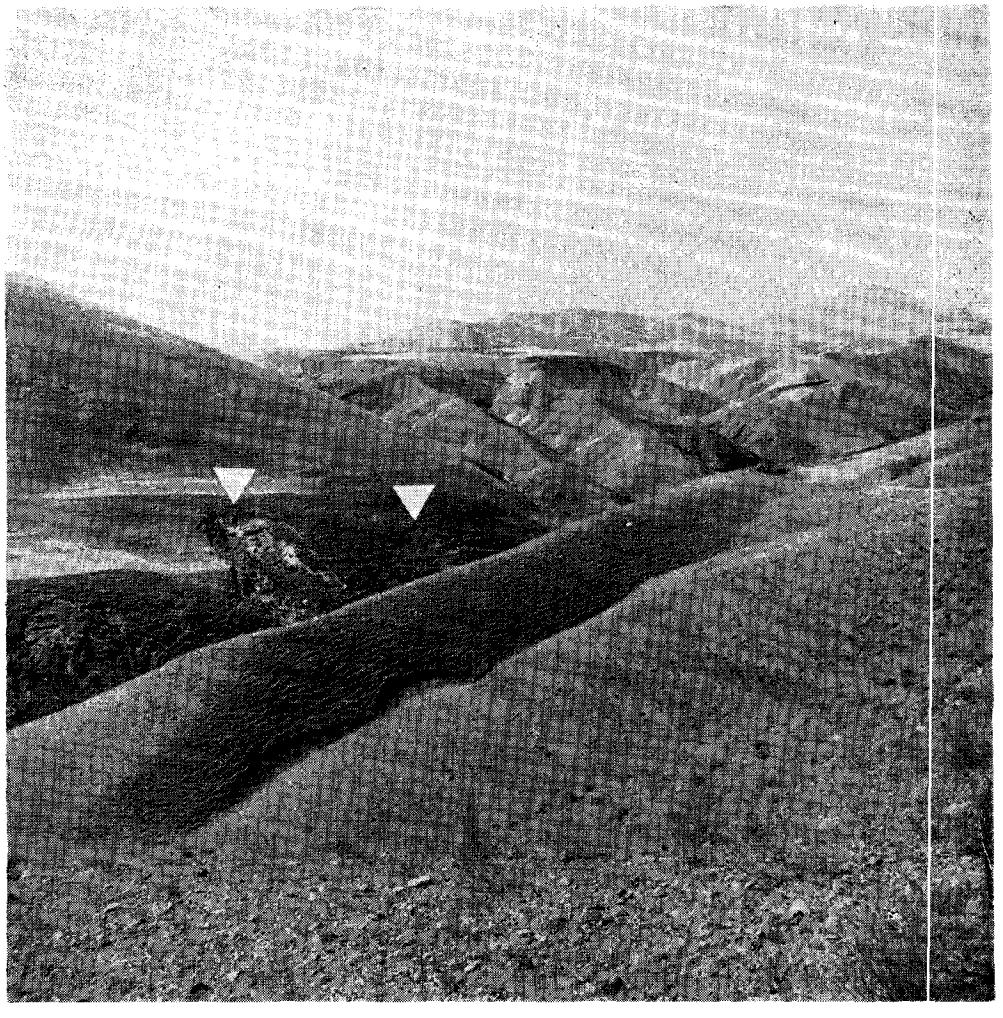


Fig. 56. Earthquake triggered landslides. Small slips (white triangles) near Lashgaran.

6. AFTERSHOCKS

A large number of aftershocks, known both from instrumental recordings and macroseismic data, followed the main shock and are listed in Table 3. However, only the epicentres of 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 Rezaiyeh and the Turkish frontier, and extending from Rezaiyeh in the south to Khoy in the north.

The largest aftershock (Mb over 6) occurred about 40 hours after the main event,

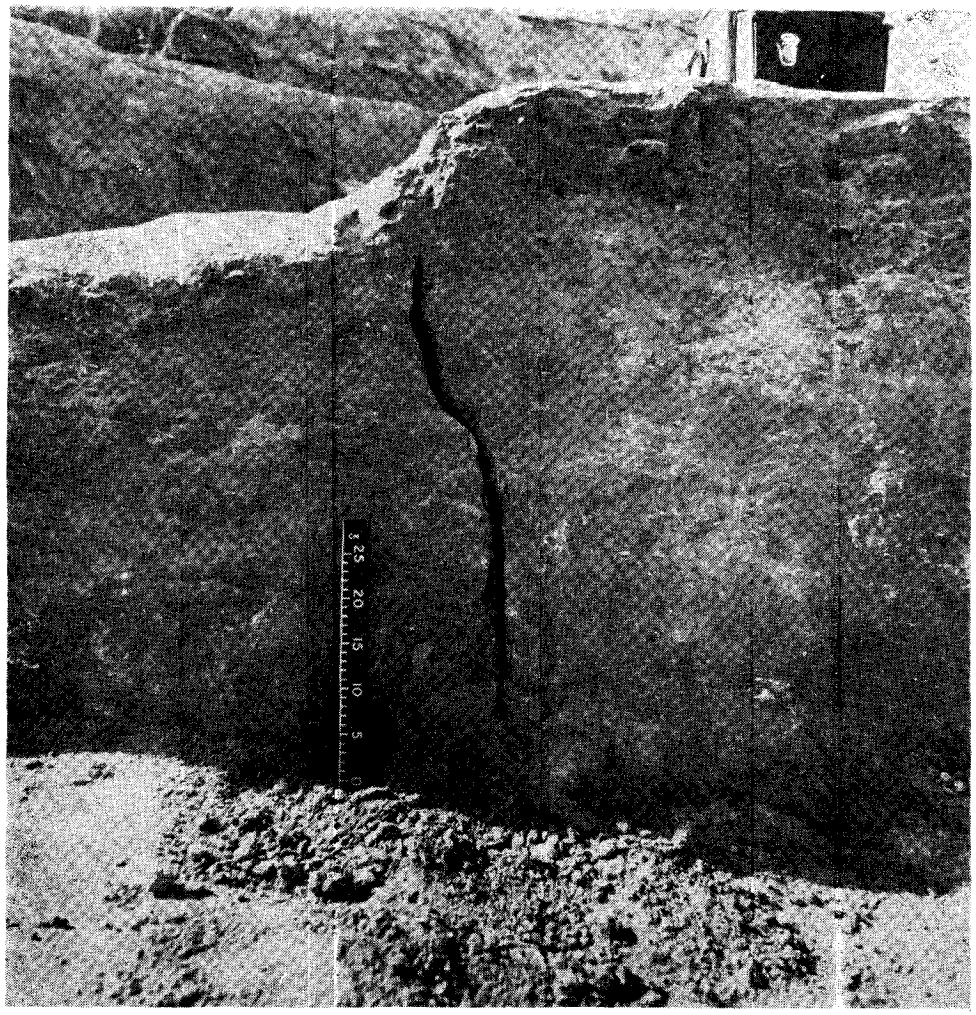


Fig. 57. Haftavan Tapeh. Fracture thought to be of earthquake origin in the archeological dig.

on 8 May 1930 at 15h 35m 28s 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 four (?) 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 nearby village of Kanyan. In Khosrova, the shock was also stongly felt, but no further damage seems to have resulted.

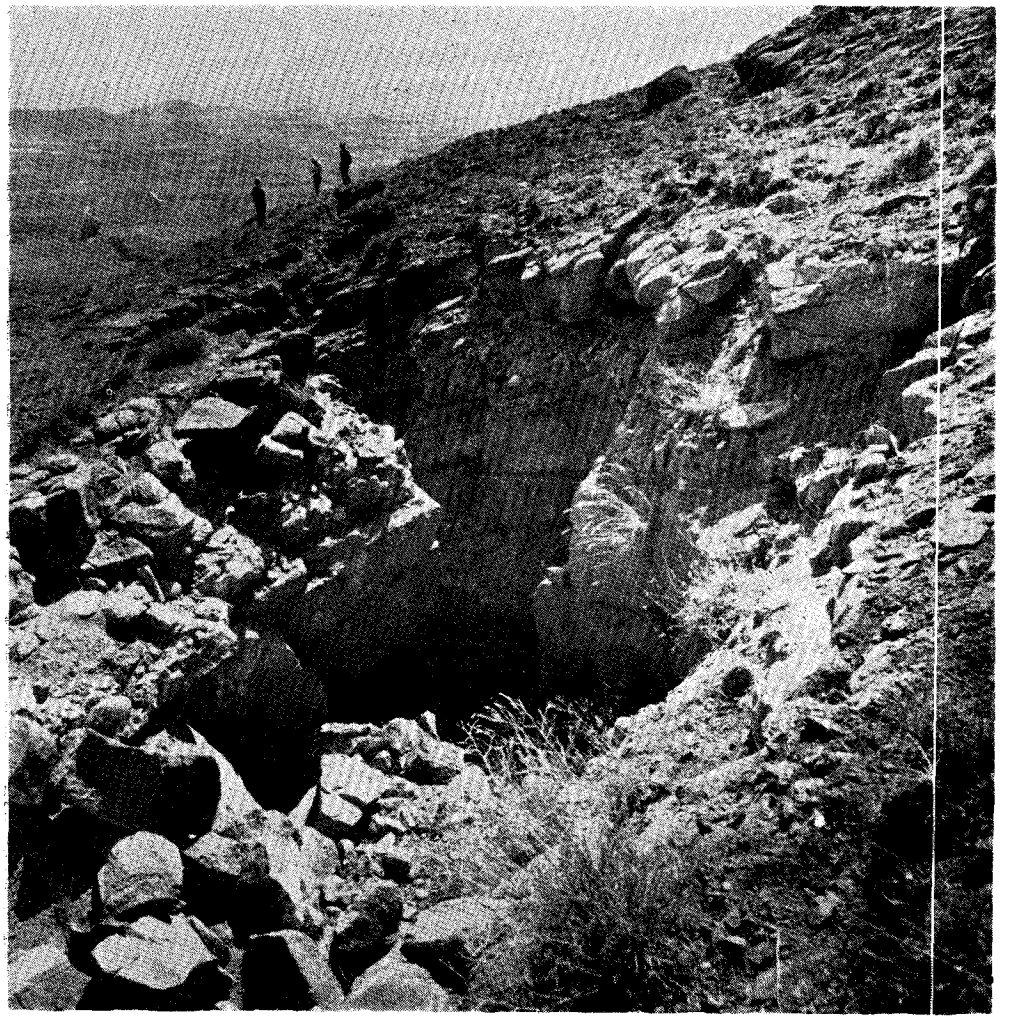


Fig. 58. Earthquake triggered bedding-plane slip. Large tension cracks resulting from bedding-plane in layered Eocene conglomerate west of Aslanik.

7. CONCLUSION

The documentation collected during this field investigation, supplemented by contemporary written 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 07h 03 m 26s GMT, preceding the main shock by about 15½ hours. Its macroseismic epicentre was determined at 38°. 15'N, 44°. 75'E, and the region of damage was found to have a diameter of about 15km. About 25 people were killed, and Dilman and seven other villages were damaged. Less than 20km 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 during the night of 6 May 1930 at 22h 34m 27s GMT and was assigned a magnitude of between 7.2 and 7.4 The macroseismic epicentre was determined at approximately 38°. 15'N,44°, 70'E, i.e. nearly identical to the epicentre of the foreshock. It was felt in Tabriz and in many of the larger towns of Azarbaidjan, and was 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 40km E–W and 20km N–S. About 40 churches, mostly located in the Salmas Plain, were also destroyed or damaged, and tombstones in three cemeteries were displaced, usually to the north. The total number of people killed was about 2,514, 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 25km south of the macroseismic epicentre.

Faulting occurred in two localities during the main shock: at the southern edge of the Salmas Plain, in a NW–SE direction, with a right lateral displacement of up to 4m and a vertical displacement of over 5m (NE down); and in the northwest near Derik, in a NE-SW direction, left-lateral, with the NW side down by about 1m. Changes in thermal springs were associated with both faults. The combined result of movement on the two faults was 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 Rezaiyeh and the Turkish frontier. The strongest aftershock occurred about 40 hours after the main event, on 8 May 1930 at 15h 35m 28s 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 occurred 46 years ago, and about which little was previously known, was due to exceptional circumstances: the existence of a minority Christian population which remembered and recorded the event, presence of large buildings (the churches) still visible to-day, accurate eyewitness accounts, etc. It confirms however an observation already made for less well documented early 20th century earthquakes in Iran, that accurate information concerning these events is still available today in the field (Tchalenko et al. 1974). The study of these earthquakes is of special importance in cases such as Salmas for which instrumental determinations may be inaccurate and macroseismic data virtually non-existent.

8. ACKNOWLEDGEMENTS

The field investigation, undertaken as a Geological Survey of Iran/Imperial College, London joint project (the latter being supported by a N.E.R.C. grant), was greatly helped by the hospitality of the inhabitants and local authorities of the region, and in particular by the guidance of several individual survivors of the catastrophe. Amongst these were Father Mesrob Minassian, Haji Ali Kassabi and Ali Behnia in Shahpur, Megerdich Galostian in Payajuk, Hike Sarvarian in Malham, Hagop Megerdichian in Savran, Yuseb and Ashor Khashilo in Khosrova, Josef Paul Heydari and Givargis Yuseb Khosrowabadi in Patehvir and Herand Melikian in Haftavan. Many others, not mentioned here, also provided us with invaluable information in the field. We are greatly indebted to Rev. D.V. Panossian, Patriarchal Vicar-General of the Armenian Diocese in Azarbaidjan, whose vast knowledge of the history of the region clarified many points, and who helped us in the dating of several churches. D. Boghossian and A. Badalian in Tehran, and A.Missakian, G. Miridjian and A. Kardachian in Paris helped us in the bibliographical research, as did the French Ministry of Foreign Affairs in Paris and the French Embassy in Tehran. The Lazarist Mission in Paris provided us with its published reports, even though we have not yet been able to consult its correspondence archives.

Translation Appendix 1

"At the entrance to the Salmas Plain, there is an E-W oriented fissure, three kms long, following the base of the mountain; the southern part of the fissure being about two meters higher than the northern part; this indicating a partial lowering of the plain. At locations I had never seen water before, I now found two springs whose water was delicious". (Zaiya 1930b.)

"At six o'clock in the evening, Orlikana Zendacht and Chorgol were not too tired; but hardly did I begin to descend in the Salmas Plain, that I saw the ground opened up to the left; on the Aghian and Zivadjouk side, on the slope of the mountain, a deep opening with a length of 4 kms. The water which previously came out 6meters lower down, is now coming out above the road...."(Zayia 1930a)

"I traveled all the areas situated between Keuhnachabar and Patavour, these being localities situated close to the supposed center of the earthquake. Every where the ground is crevassed. According to Mr. Abel, there is an opening which is two meters deep and about twenty kilometers long. I saw a whole field of barley lowered by at least one meter, and one has the impression of walking on moving ground." (Franssen, 26May 1930)

"It is to be noted that the fault resulting from this earthquake starts at Arawoul, in the direction of the lake, therefore from west to east; it measures a length of twenty kms. The depth of the fault is variable, but at certain localities it is more than 2 meters deep with a width of 3 meters." (Franssen, 8 June 1930)

APPENDIX 1

Contemporary Written Accounts Referring To Tectonic Faulting

"All lorries have been commandeered for Government relief work, but efforts are hampered by waterlogged ground. The vehicles are unable to approach Salmas as a new rift has formed between Urumyah and Salmas" (The Times, 13 May 1930, quoting a Reuter Despatch from Tehran on 12 May 1930).

"A l'entrée de la Plaine de Salmas, il y a une fente de l'est à l'ouest, de trois kilomètres de long, suivant le bas de la montagne; le côté sud de la fente est environ deux mètres plus haut que le côté nord, ce qui indique un surbaissement partiel de la plaine. Aux endroits ou je n'avais jamais vu de sources, j'en trouvai deux dont l'eau était délicieuse". (Zayia 1930b. The observation was made the morning after the earthquake).

"A six heures du soir, Orlikana Zendacht et Chorgol n'étaient pas très éprouvés; mais à peine je commencais à descendre dans la plaine de Salmas que je voyais la terre fendillée sur la gauche; du côté d'Aghian et Zivadjouk sur la pente de la montagne un sillon d'environ de profondeur et 4km de long. Cette plaine a baissé de plusieurs mètres; l'eau qui sortait autrefois 6 mètres plus bas, sort maintenant au-dessus de la route.... "(Zayia 1930a, see above).

"J'ai parcouru les régions situées entre Keuhnachahar et Patavour, localités voisines du centre présumé du séisme. Partout la terre est crevassée. Il y là une fente de deux mètres de profondeur, sur une longuer d'une vingtaine de kilomètres, suivant M. Abel. J'ai vu un champ de blé entier baissé d'un mètre au moins, et on a l'impression de se promener sur un terrain mouvant."(Franssen writing from Rezaiyeh on 26 May 1930).

"Il est à remarquer encore que la faille produite par ce séisme part de l'Arawoul, dans la direction du lac, donc de l'Ouest à l'Est, et mesure jusqu'à vingt kilomètres de longueur. La profondeur en est variable; mais, à certains endroits, elle dépasse 2 metres sur 3 de largeur. "(Franssen, from Rezaiyeh 8 June 1930).

"An mehreren Stellen hatten sich im Boden Risse gebildet. Gemessen wurden Spalten von 40m Länge, 10–15cm Breite, 15–20cm Tiefe." (Brunk 1930).

"The Tabriz," 10 May 1930, quotes a cable of 7 May which mentions that in Dir cracks appered in the mountains. (This presumably should read Derik instead of Dir). The same newspaper on 24 May 1930 describes ground fractures as follows:"In the western part of Kohneh Shahr there occurred rockfalls and cracks in the mountains. These cracks started from Boghaz-e-Zarindarreh and continued to the Kuh-e-Shumal. The cracks after Chahriq crossed the Aliguli hills, then turned towards the south and Qarni Yarekh".

APPENDIX 2

Derik Thermal Springs

A description taken from Loftus (1854) of the pre-1930 hot springs which ceased after the earthquake and are now no longer active:

"The springs are close to the village. They are numerous, though two only have any great flow of water. These are about 6 yards from each other, and rise from the bottom of irregular-shaped basins, between 4 and 5 feet in depth. The water rises with great force in the more northerly basin, at regular intervals, but in the other irregularly, at intervals of 5 or 7 seconds, gurgling from below, and throwing up a strong jet to the height of a foot above the surface. The temperature of the two springs is the same, viz. 96° Fahr., indicating a common origin. The water is strongly nitrous and chalybeate.

... From the hot springs to the bottom of the ravine is a depth of about 60 feet, a solid mass of travertine; while at three times that height above the springs the older and altered deposit rests on the slope of the felspathic rock.

Other springs flow in small streams from holes in the travertine;they are less saline, and more strongly chalybeate, while the temperature does not exceed 90° or 92° Fahr.

Above the village is the basin of an extinct spring. The hot springs of Derik are much resorted to for every species of complaint to which the Kourd is subject".

APPENDIX 3

Comparison of Casualty Figures Obtained From Contemporary Written Accounts and 1973 Interviews

Village	Haratch 31 May 1930	Zayia (1930)	Field interview in 1973
GHALASAR	2/79 Armenian		0 (no Arm. left to-day)
HAFTAVAN	4/540 Arm.	2	2 (foreshock)
KHOSROVA	34/280 Ass.	34	30 (36)
KOHNEH SHAHR	1/49 Arm. 150/350 Tur.		370 total
MALHAM	38/294 Arm.+10/33 Kurds.	70	42 (Arm.)
PATAVIR	11/113 Ass.	11	13
PAYAJUK	3/130 Arm.		2
SARNA		4	7 Arm.+11 Turk
SAVRA	1/26 Arm.+150/600 Tur.+Ku.		5 (Arm.)
ULEH		7	12 (Tur.)

APPENDIX 4

Summary of Information Collected by Samson Tateossian

(Haratch, 31 May 1930). Dispatch dated Tabriz 16 May 1930.

GHALASSAR: Population: 17 Armenian families (79 people).
Casualties: two killed.
39 cattle killed.
Village, including church, school, assembly hall and library, destroyed.
Ground fissures.

HAFTAVAN: Population: 26 Armenian families (140 people).
Casualties: Four killed, 17 injured.
Dome and one wall of church collapsed.
Chapels S. Boghos and S. Thadeus destroyed.
16 cattle killed.
Ground fissures with ejection of water.

KHOSROVA: Population: 280 Assyrians.
Casualties: 34 killed.
150 cattle killed.

KOHNEH SHAHR: Population: Eight Armenian houses (49 people)+350 Turks and Kurds.
Casualties: One Armenian killed and 150 Turks and Kurds.
1200 cattle killed.
Village including church and mosque destroyed.
Historical minaret collapsed.

MALHAM: Population: 294 Armenians and 33 Kurds.
Casualties: 38 Armenians and 10 Kurds.
Village, including church and school, destroyed.
264 cattle killed. Cemetery sunk. Large ground fissures.

PAYAJUK: Population: 26 Armenian families (130 people).
Casualties: Three killed.
Village and church destroyed.
Ground fissures. New springs appeared, then stopped.

PATAVIR: Population: 113 Assyrians.
Casualties: 11 killed.
Ground fissures as in Savran.

SAVRAN: Population: Four Armenian families (26 people) and about 600 Turks and Kurds.
Casualties: One Armenian died and about 150 Turks and Kurds.
Village and church destroyed.
1000 sheep and 150 cows killed.
Small W–E and N–E ground fissures.

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