The seismicity of Iran. The Turshiz (Kashmar) Khorassan earthquake of 25 September, 1903

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Summary. — The Turshiz (modern Kashmar), Iran earthquake of the 25th September 1903 occcurred in a semi-desertic region, just south of the Dorunch fault; it had a magnitude of about 6.5, it was felt within an area of 200,000 square kilometres and it was followed by aftershocks for at least 13 weeks. The earthquake killed about 350 people within an area which extended from Turshiz to the Kavir in the southwest. There is no evidence that the earthquake was associated with faulting, but it did cause a temporary change in the flow of underground water.

Riassunto. — Il terremoto del 25 Settembre 1903 avvenuto a Turshiz (la moderna Kashmar, Iran) in una zona semidesertica a sud della faglia di Dorunch; ebbe una magnitudo di 6.5, un'area macrosismica di 200.000 km² e fu seguito da repliche per almeno 13 settimane. Vi furono 350 morti in un'area compresa fra Turshiz e Kavir in direzione SW. Non vi è alcuna testimonianza che il terremoto fosse associato o meno ad una faglia, ma è certo che causò un cambiamento temporaneo nel flusso di acque sotterranee.

Introduction.

On 25 September 1903, an earthquake affected the district of Turshiz, one of the most fertile parts of Khorassan, in eastern Iran,

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Figure 1. This district, the modern Shahrestan-i Kashmar, is a valley, 80 kilometres long and about 20 kilometres wide, which runs in an east-west direction between two mountain ranges, Figure 2. To the north, the Kuh-i surkh and the Siah-Kuh rise 1,000 metres above the

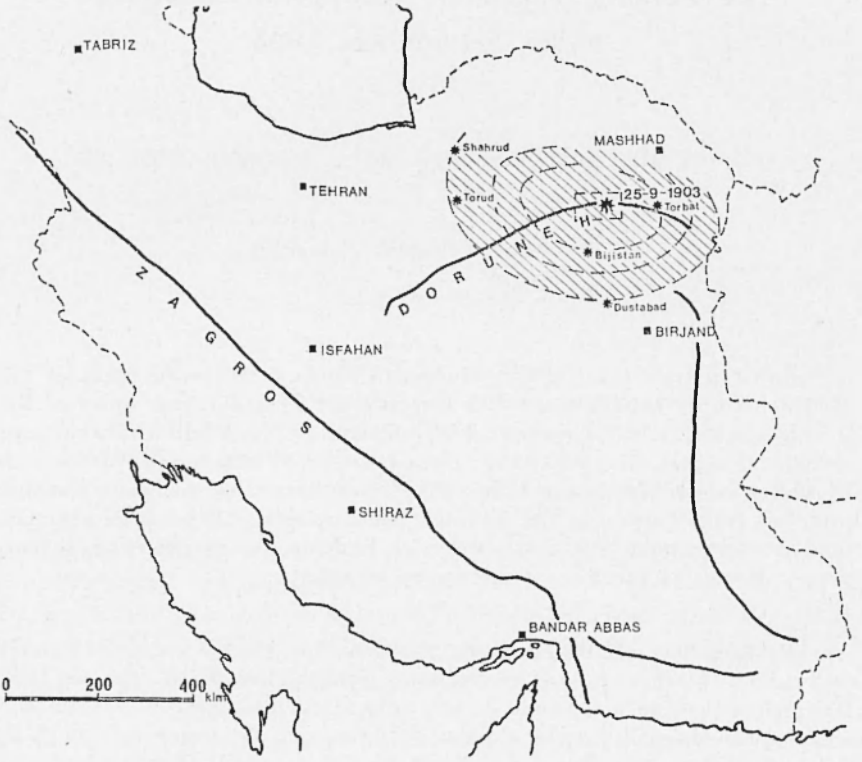

Fig. 1 – Location map of the Turshiz earthquake of 25 September, 1903. Shaded area shows extent of perceptibility of the shock (I = III) with approximate contours for higher intensities (IV, V). Inset shows area covered by Figure 2.

valley and provide it through most of the year with ample water, which is carried across it in many streams and canals, both on the surface and underground (in qanats). The range on the oposite side of the valley, the Kuh-i Begu, is discontinuous and much lower, and separates the Turshiz valley from the low-lying desert of Kavir-i Namak to the south. The fertility of the valley decreases westwards

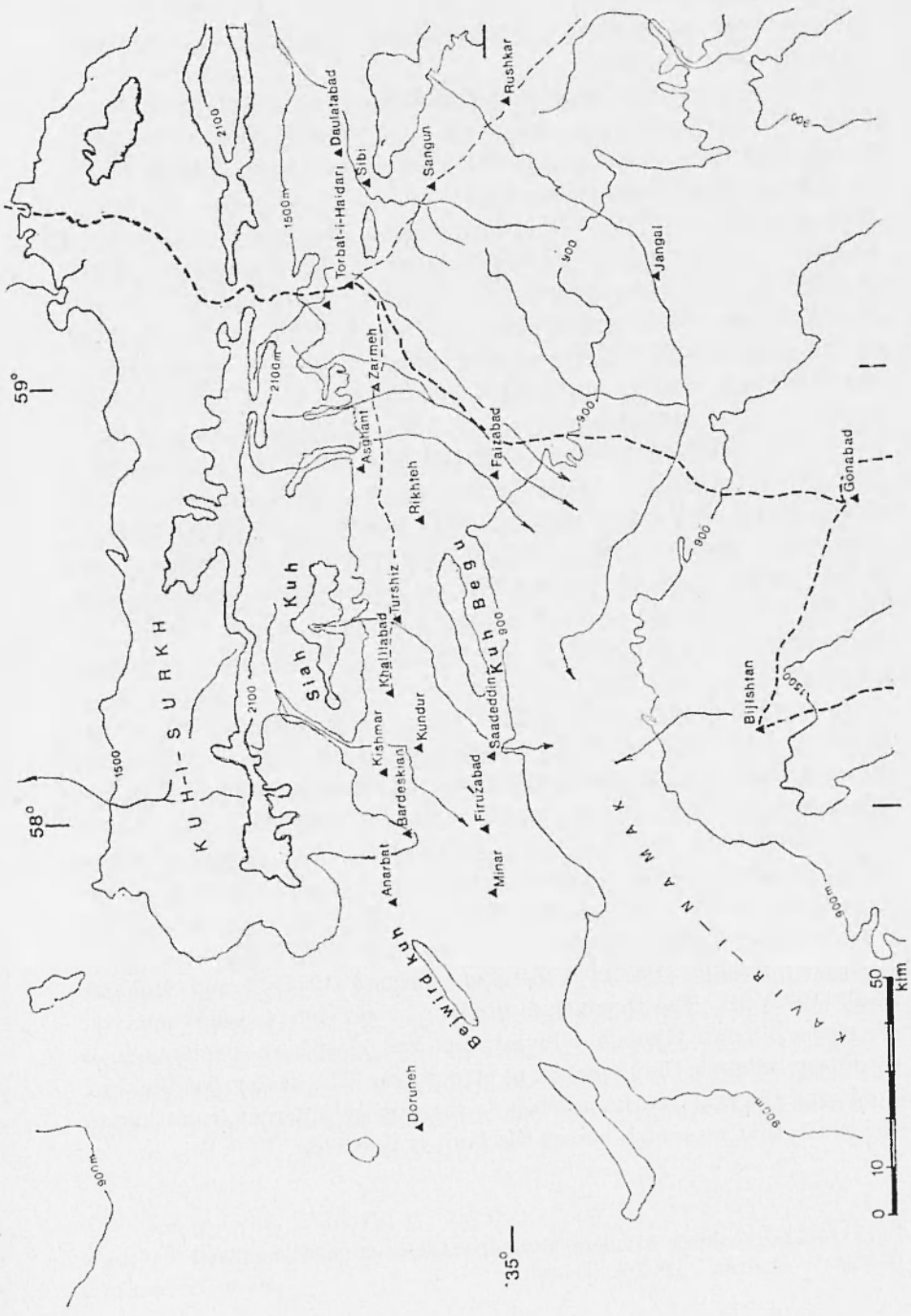

Fig. 2 – Topographic relief of the Turshiz earthquake 1903.

as water becomes more scarce, and past Bardeskan (*) towards Anarbat one enters the desert route to Shahrud via Doruneh, or the more direct caravan track, via Turun.

In early times this northwest corner of Kuhistan was known as the district of Busht, of which the chief towns were Turshiz and Kundur. The large village of Kundur is still existing on the west bank of the Rudkhaneh Shishdiraz, but ancient Turshiz is in ruins, abandoned since the 13th century. Today, the village of Firuzabad has sprung up to the west of the ruins of Turshiz. It seems that the modern village of Kishmar marks the earliest site in the district, being built around an old settlement of the same name. There is an old legend pertinent to the seismicity of the region; a cypress-tree grew to be larger than any other that had ever been. Such too was its power that in the village of Kishmar no earthquake was ever felt, although, in various other places, of all the neighbourhood round and about, earthquakes were common, Mustawfi ([19]). However, in the middle of the 9th century Caliph Mutawakkil caused this tree to be fell. It is not known whether after this Kishmar was damaged by earthquakes. As a matter of fact we have been unable to find any information relating to earthquakes in the Turshiz valleys prior to 1903. As for the cypress-tree it is possibly the origin of Marco Polo's "arbre sol", Le Strange (1966) ([26]), Gabriel (1935) ([10]).

The special importance of the Turshiz earthquake of 1903 is that it is the first known seismic event to occur on the Doruneh fault zone, an active throughgoing structural element that runs for more than 650 kilometres from the Afghan border in the east into the Dasht-i Kavir in the west (see fig. 1). This fault is shown on the Geological Map of Iran (1959) ([12]) and it was well known to the geologists of the Geological Survey of Iran before 1959, Gansser (1969) ([11]). The whole or parts of the zone were surveyed or studied by Wellman (1966) ([32]), Tchalenko et al. (1973) ([30]) Stöcklin (1973) ([25]), Eftekhar-Nezhad (1971) ([7]) and Mohajer et al. (1975) ([18]). The Doruneh fault shows every sign of recent activity. In places it cuts through alluvial fans and elsewhere displaces in a disorderly manner the most recent structures. The geology of the area bordering the fault to the north is so thoroughly different from that to the south that no match across the fault is possible,

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(*) The spelling of place-names is taken from the official "Village Gazetteer of Iran" 1965-9, Tehran.

The Turshiz (Kashmar) earthquake of 1903.

The Turshiz earthquake of 25th September 1903 (3rd Rajab 1321) occurred at 01 hours 20 minutes GMT. The shock was recorded at more than fifteen stations of the primitive seismic network of the time, and as far away as Kew and Irkutsk, more than 4,500 kilometres from the epicentre. Seismographic results were reported by Glasek (1903) [13], Weigand (1903) [31], Belar (1904) [4], Levitski (1905) [15] and in regular station Bulletins. In 1910 Milne using macroseismic data datermined the origin time of the earthquake at 01h 20m and the approximate position of the epicentre at 34°N–58°E, that is, 140 kilometres due south of the macroseismic epicentre, near Ferdows, Milen (1911) [17]. More recently, an equally erroneous location is given by Berberian (1973) [5]. The earthquake is noticed by Tams (1908) [28].

The effects of the earthquake received little attention in the Persian and foreign press. The first detailed account of the earthquake we find in the confident: diary of the British consul in Mashad for the week ending 10th October 1903, entered by Capt. J. Fisher, acting H. M. Consul (*). He says that there have been severe shocks in Turshiz and that the total deaths resulting are put down at 350. All the carpet manufactories were destroyed, the loss being estimated at 50,000 tumans. He adds that Capt. Yass and the Russian doctor of Torbat-i Haidari had both been for some days at Turshiz to report on the damage and look after the numerous injured. Capt. Fisher does not say wheter the shocks were felt in Mashad. The earthquake is not referred to subsequently in the Mashad consular diaries.

The Russian doctor to whom Capt. Fisher refers in his diary, was V. Almatov (**) director of the Central Medical Station at Torbat-i Haidari. After visiting Turshiz, he submitted a report which was published by Levitski (1905) [15], and recently translated into English by Tchalenko (1973) [29]. According to Almatov's report, the earthquake in Turshiz occurred at 02 hours 31 minutes; it lasted 25 to 30 seconds and the general direction of the shocks were from the northwest. Out of 1,200 houses in the town, 600 were destroyed and about 400

(*) I.O.L/P & S/7/159 no. 1637.

(**) In some documents the doctor's name is written Almazov and in others Almatov.

were severely damaged, the rest were slightly damaged. In the town, most of the damage was concentrated in the south and in the suburbs to the northeast. The nearest of the surrounding villages were also badly damaged. Almatov assessed a maximum intensity at Turshiz of IX on the Rossi-Forel scale and points out that much of the damage was due to the poor materials and methods of construction employed, particularly for roofs, which were heavy made of thick layers of compacted soil. He reckoned that the area of destruction extended 21 kilometres to the north, south and east of Turshiz and about 37 kilometres to the west of the town. Within this area 25 villages were destroyed or damaged. In Turshiz alone, 100 people were killed and 100 injuried, Almatov (1905) ([1]).

Turshiz was the name of the present town of Kashmar, which today has a population of about 23,000. It is a comparatively new settlement founded in the middle of the 18th century by Abdul Ali Khan, governor of Herat. Since its foundation the town had has its name changed a number of times, from Turshiz to Sultanabad, Sultanieh, back to Turshiz and recently to Kashmar. When Forster passed through it in December 1783, Turshiz consisted of two parts, the old town called also Sultanabad which was a small settlement surrounded with a wall, and a new one built by Abdul Ali being a prosperous town in which 100 Hindu families were established in their own quarter. Among its chiefs exports was iron wrought in thick plates, Forster (1798) ([8]). At the beginning of the 19th century the revenue of Turshiz was estimated at £ 60,000 a year but although still prosperous, Uzbegs were annually laying waste its fields and plundering its villages, Malcolm (1829) ([16]). In 1822 Fraser found Turshiz a ruin, containing 3 to 4,000 inhabitants, having fallen from its prosperity due to bad administration and heavy taxes, Fraser (1825) ([9]). The situation in Turshiz was even worst when Clark passed through it in 1857; it returned an annual revenue of only £ 9,000 and the town was in ruins; all he could find in the Turshiz valley was ruined remains of villages, Clark (1861) ([6]). It seems that in the following generation Turshiz began to fluorish again but lost its original name. Stewart, who was in the town in November 1880, remarks that all maps marked a town called Turshiz, but there was no such town and it was only the name of the district, the chief town of which was Sultanabad: a small fluorishing place of some 5,000 inhabitants with a good deal of trade, silk and wheat being the chief articles exported, Stewart (1881) ([24]). In 1894 Baumgarten reckoned that Turshiz had a population of about 6,000 inhabitants and

about 1,200 dwellings which covered an area of about half a square kilometre; he estimated that about 80 to 120 villages belonged to Turshiz with a total population of 24,000, Baumgarten (1896) ([3]).

A series of field studies were carried out by the authors late in 1962 and in the spring of 1975. During their stay in the region the authors collected a considerable number of interviews with the inhabitants, mostly with sedentary octogenarians who as young boys remembered the earthquake, as well as with local people knowledgeable about the history of the district. The general consent of opinion was that only about 150 houses collapsed completely in Turshiz, killing about 80 people. In Bulurian's mahaleh (district of the town) 27 people were killed and another 7 in the Kujet-i mahaleh. Damage was extensive, particularly in the southern parts of the town where almost all houses were shattered, but few collapsed completely. In the northern suburbs of Turshiz no houses collapsed but almost all of them were badly cracked and remains of the old town walls fell down. Part of the bazar also fell down and the Ivan of the mosque collapsed. There was no damage to the minarets but bricks, detached from the parapets of the mosque, were thrown out. In all about half of the houses in Turshiz were either totally ruined or damaged to the extent that they had to be pulled down and rebuilt, all of them at the same place; there was no need to relocate the whole or part of the town. It seems that immediately after the earthquake many of the survivors from nearby settlements and villages, many of them injured, flocked into Turshiz, and although Almatov's casualty figures may be out by a small difference they may include casualties from neighbouring villages. Al-Qussy (1906) ([20]) puts the casualties in Turshiz to only 35 people, possibly a mistake for 350, and Major Sykes who was in the town in November 1909 (*) says that it contained a population of 7 to 8,000 inhabitants and adds that the town had suffered considerably during the earthquake, Sykes (1911) ([27]).

Almatov points out that the water in wells and in the qanats increased after the earthquake, especially in the qanat of Fadafin where the flow of water doubled. This may be true for the days immediately following the earthquake. Our information is that there were no long-term effects in any of the qanats in the Turshiz valley, including those of Fadafin. In some wells and qanats the flow of water increased

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(*) Cf. *Tchalenko* (1973, p. 34) ([29]).

and in others decreased temporarily, eventually coming back to the normal flow it had before the earthquake. The qanats of Dasht-i Shahru were not affected at all.

The damage extended mainly west-southwest of Turshiz. At Zendejan, a small settlement of a few houses at the time of the earthquake, there were no casualties but almost all the houses were ruined, and the roof of a number of covered wells (*ab-ambars*) collapsed. In Dehnow one out of seventy houses collapsed and the rest were badly damaged; no one was killed but a few people were injured. In Khalilabad out of 160 houses a dozen of them collapsed killing two people and injuring many; the rest of the houses, some of them in a ruinous state even before the earthquake, were shattered. It is said that damage in Khalilabad was a serious as in Turshiz and that the village was abandoned for sometime. Damage was equally widespread in Nasratabad, Sarmozdeh and Mozdeh. At Nasratabad only one house collapsed completely but the whole village was ruined and most of the houses had to be rebuilt. The shock had no permanent effect on the water supply but the ground opened up in places by as much as 10 centimetres, cracks 50 metres long running in a southwest-northeast direction to the north of the village. In Mohammadabad four people were killed and many injured; the village was badly damaged and a large rest-house in the middle of it collapsed. In Argha all houses were ruined and a number of old water-mills collapsed. For Kundur the information we have been able to collect is conflicting; it seems that the damage was equally serious as in neighbouring villages but it is not clear whether about 20 people were killed in this village or in outlying settlements to the west of Kundur. In Jabuz no one was killed but all houses were ruined and four collapsed completely, injuring many people. It is alleged that a small number of people, 10 to 20 were killed in two settlements to the northwest of the village, the ruins of which are still extant. The shock was felt very violently in Jabuz, and aftershocks which continued for about 10 days caused additional damage. At Shefiabad only half of the 60 houses in the village were ruined; it is reported that as a result of the shock, which was very violent, the yield of the qanat water increased permanently. Unconfirmed information alleged that the small village of Kadughan was also ruined. At Bardeskan the part of the village inside the walls was shattered and part of the fort collapsed. The rest of village suffered little damage and no one was killed. However, many outlying settlements to the southwest of Bardeskan are said to have been destroyed with causualties. Although we have not been

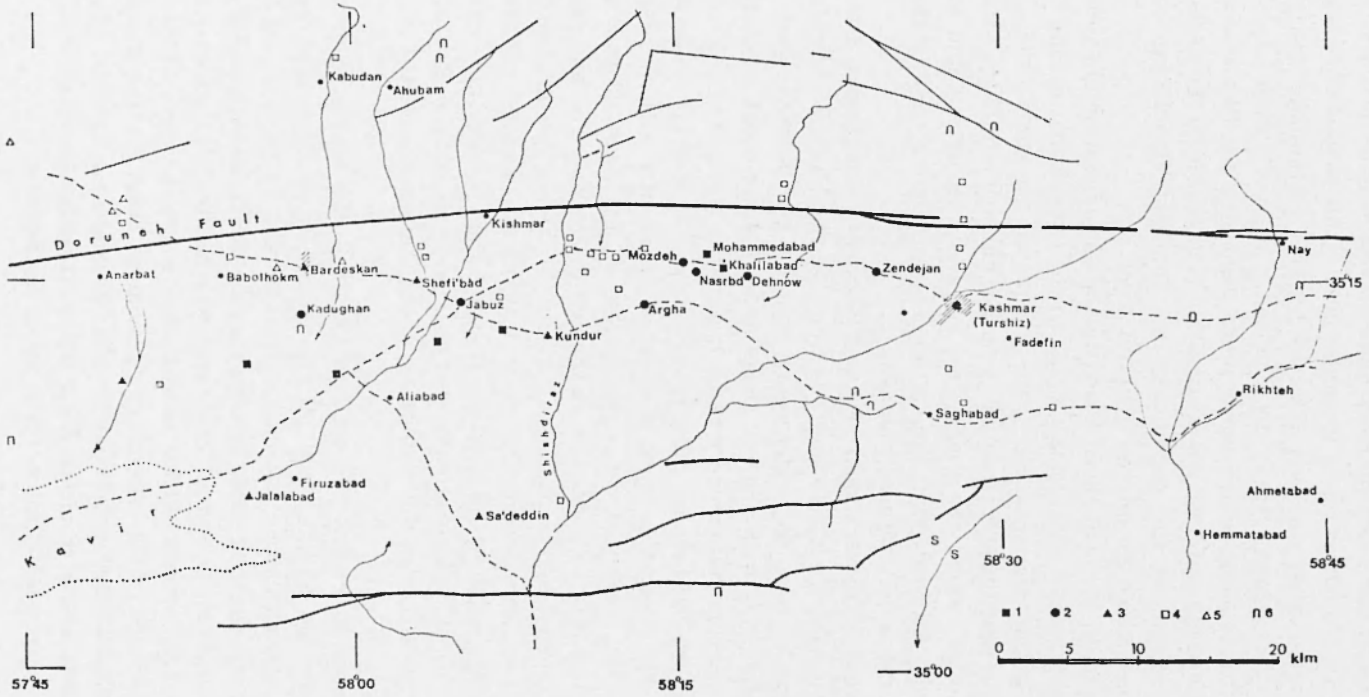

Fig. 3 – Epicentral region of Turshiz earthquake of 1903. 1) – villages almost totally destroyed with fatalities; 2) – villages heavily damaged with casualties; 3) – sites that suffered considerable damage without casualties; 4) – oldsites and water mills extant, as well as abandoned villages; 5) disused *ab-ambars*; 6) – springs and wells.

able to identify the exact location of these settlements it is perhaps interesting that al-Qussy on a marginal note of his manuscripts adds that the region most seriously affected by this earthquake was the section of the caravan track to Shahrud, west of "*Badr Askar*" (= Bardaskan?) along which many wells went dry for two seasons, al-Qussy (1906:249 top) ([20]). No information is available to the authors about the effects of the earthquake at Anarbat, Babolhokm and Ebrahimabad which lie off the Shahrud track.

To the south of the Shahrud track, Jalalabad suffered small damage but the shock caused considerable panic to the extend that during the aftershock period the settlement was evaquated for some time. It seems certain that the shock caused no serious damage to villages south-east of Aliabad, where the shock was, however, widely felt and still remembered. At Saadeddin, the earthquake was strongly felt, lasting almost a minute, but without damage.

At Torbat-i Haidari shocks began at 02 hours 28 minutes and they lasted 25 seconds; their direction was from the northwest. They were accompanied by a strong underground sound which started about 5 seconds before the main shock. Doors and windows shook violently, beds were swaying and crockery rattled. Almatov assessed an intensity VI on the Rossi-Forel scale for Torbat-i Haidari. The shock was also felt in Bijistan, 80 kilometres south of Turshiz, apparently with the same intensity. The earthquake was perceptible at Dustabad, Torud and Shahrud; there is no evidence that it was felt in Mashad. The minimum radius of perceptibility, therefore, should be about 250 kilometres.

Apart for some evidence for ground deformations, most probably of local nature north of Nasratabad, it seems that the shaking caused some of the steep banks of streams east of Dehnow to collapse. Rockfalls were also reported from the mountains, about 9 kilometres to the north of Turshiz.

According to Fisher, the earthquake killed 350 people. Almatov puts this down at 199 killed and 261 injured and he considers that there should be more casualties. Al-Qussy gives 35 killed in Turshiz and 284 injured throughout the region; he adds that the earthquake destroyed all the rug factories in the region. Stahl also, who had travelled extensively in western Iran mentions this earthquake, which he says killed 35 people, Stahl (1911) ([23]). According to Sieberg (1932) ([21]), the Turshiz earthquake killed 209 people in 25 villages excluding Turshiz. It is almost impossible to reconcile these figure, it seems however that at least 350 people were killed in the Turshiz earthquake.

The 1903 earthquake was preceded and followed by a rather long sequence of shocks.

1902 Jul. 20 – Two shocks, which were not felt in Torbat-i Haidari, damaged a few houses at Rud-i Majan, Almatov (1904) (1).

1903 Jan. 10 – At 13h 18m severe shocks caused panic in Daulatabad but no damage. These shocks were also felt in Torbat-i Haidari with an intensity IV Rossi-Forel, lasting for 4 seconds; the ground movements were from south-southeast to north-northwest; Glasek (1903:5) (13), Almatov (1905) (1).

Jun. 19 – Small shocks felt in Torbat-i Haidari; Glasek (1903: 25) (13), Almatov (1905) (1).

Jun. 20 – More, minor shocks felt in Torbat; Glasek (1903:25) (13) Almatov (1905) (1).

Jun. 21 – At 06h 58m accompanied by underground noise, a long-period vibration in Torbat-i Haidari, felt with an intensity III Rossi-Forel, lasting about 30 seconds in a direction from northeast; Glasek (1903:25) (13); Almatov (1905) (1).

Jun. 22 – At 23h 48m, sharp shocks felt in Torbat-i Haidari accompanied by underground noise, lasting for 2 minutes. The shocks, which were from northeast to southwest, were felt with an intensity V Rossi-Forel, causing people to flee their houses in panic; Glasek (1903:25) (13), Almatov (1905) (1).

Jun. 24 – At 01h 03m, more, rather weak shocks in Torbat; Glasek (1903:25) (13) Almatov (1905) (1).

None of these shocks was recorded at the nearest stations which are about 1,000 kilometres from Torbat-i Haidari. The main shock of 25th September 1903 was followed by the following aftershocks:

Sep. 30 – At 19h 00m; this was the strongest aftershock, felt as far as Torba-i Haidari. In Turshiz it lasted 5 seconds and caused additional damage to the town and villages. It was recorded at a number of seismic station and it was followed by another six shocks of intensity between III and V Rossi-Forel; Almatov (1905) (1), Belar (1905: v. 152) (4).

Oct. 10 – At 21h 03m, strongly felt at Turshiz, IV; Belar (1905) ([4]), Almatov (1905) ([1]).

Oct. 17 – Damaging aftershock in Turshiz, lasting 24 seconds, widely felt in the region, Belar (1904:6) ([4]).

Nov. 3 – Damaging aftershock in the region of Turshiz, Belar (1904:7) ([4]).

Dec. 17 – At 17h 05m strong aftershock at Turshiz, Almatov (1905) ([1]), Belar (1905: v. 218) ([4]).

During his stay in Turshiz, between the 29th September and 7 October 1903, Almatov experienced up to 40 aftershocks.

Discussion.

Until recently, Almatov's report was the sole source of information about the Turshiz earthquake of 1903, which was consequently thought to have been a relatively small magnitude event that caused damage within a comparatively restricted area. around modern Kashmar.

However, certain omissions from this report may lead one to suspect that, Almatov who spent nine days in Turshiz looking after the injured did not visit other parts of the epicentral area and that consequently much of what he says about the event, information which he acquired obviously at second hand, does not necessarily imply that either there was no serious damage elsewhere or that the town of Turshiz was the centre of destruction. For instance, Almatov says nothing about the damage to the water-mills west of Turshiz and the destruction of the carpet industry in the Kundur area, an estimated loss of 50,000 *tumans*. He should be pretty accurate for Turshiz as he was there, though clearly not accurate for places he did not visit. The fact that he never travelled west of Turshiz and the abrupt change in population density in 1903 west of Shishdiraz gave him the erroneous impression of an epicentral area of rather limited extent to the west, with Turshiz the centre of destruction. This is similar to more recent erroneous identifications of the real extent of meizoseismal areas reported in the press shortly after an earthquake in Iran; where the largest and most accessible town of the affected region is considered to be the macroseismic epicentre; for instance Qazvin in the Buyin Zara earthquake of 1962, Ferdows in the Dasht-i Bayaz earthquake of 1968 and Moraveh Teppe in the Karnaveh earthquake of 1970.

Taken in conjunction with other sources of information and field evidence, Almatov's report suggests that Turshiz was located at the eastermost part of the epicentral zone of the 1903 earthquake which must have extended considerably to the west. Al-Qussy talks about "*ab-ambars*" along the desert track to Shahrud gone dry for two seasons after the earthquake and local information suggests heavy damage with casualties in the Jalalabad – Kadugan region. Clearly maximum damage should have occurred southwest of Turshiz. Surely what emerges from the various reports is not so much that Turshiz was not badly damaged, but more that it was not as badly damaged, comparatively speaking, as other areas. Sykes who visited Turshiz six years after the earthquake found that the town had "*suffered considerably during the earthquake which fortunately affected only a small area*"; a statement in agreement with Almatov, that is in that Turshiz was badly damaged, but that the area of destruction was small.

Although the actual extent, particularly to the west, of the region affected by the 1903 earthquake cannot be demonstrated, all the available evidence points to an epicentral area which extended from Turshiz in the east, to somewhere between Kadughan and the Kavir, a distance of about 50 kilometres, with a probable epicentre near 35.2°N–58.2°E. For a more precise assessment of the extent of the meizoseismal region additional data from local sources of information is needed, for which no foreseeable means of data gathering seems likely.

The extent of the meizoseismal region deduced from the available evidence is greater than it is currently thought to be. However, it is compatible with an earthquake of magnitude 6½, which seems to be the magnitude of the Turshiz earthquake. The shock was recorded up to distance of 5,700 kilometres from the epicentre by very imperfect instruments of low magnification (15 to 125) without damping. Table 1 shows the recorded amplitude at different stations at epicentral distances between 10 and 50 degrees. Average magnitudes calculated from amplitudes of the horizontal components of the maximum phase result in an average value of 6.4, with only small variation in azimuth. This magnitude is consistent with shallow Iranian shocks associated with radii of perceptibility of 250 kilometres and with aftershock sequence of about 100 days. As a matter of interest, the aftershock of 30th September was recorded only in Tashkent, and it should have been of a magnitude 5½.

The connection of the Turshiz earthquake with the Doruneh fault is of course only too obvious. However, there is no evidence whatever

TABLE 1

Station	Δ°	I	Onset Time h m s	A_m (mm)	A_o (micr)	T (sec)	M
Tashkent	10.4	R	01 17 54	22.0	367	9	6.60
Tiflis	12.5	E	01 23 12	10.9	156	10	6.31
		E		7.7	110	10	6.16
		E		8.2	117	10	6.19
		M		1.0	100	10	6.12
Bombay	20.6	M	01 27 54				
Yur'ev	30.4	S	01 33 54	4.0			
		R		3.5	50	12	6.38
		R		4.0	57	12	0.00
Krasnoyarsk	31.2	B	01 51 42	1.0	67	12	6.53
		B		0.4	27	12	6.13
Kremsmünster	35.0	E	01 28 18	3.0	30	14	6.20
Triest	35.1	E	01 27 56	3.3	33	14	6.24
Irkutsk	36.4	R	01 28 36	10.0	100	14	6.75
Hamburg	38.2	E	01 28 36				
Strasbourg	39.2	E	01 29 50				
Kew	44.4	M	01 45 30				
Shide	45.0	M	01 46 18				
Bidston	46.0	M	01 41 18				
Edinburgh	46.0	M	01 47				
S. Fernando	51.4	M					

I = type od instrument without damping; M = Milne, horizontal pendulum with optical registration; E = Rebeur-Ehlert, critical horizontal pendulum with optical registration; R = Zöllner-Repsold, horizontal pendulum with optical registration; B = Omori-Bosch, horizontal pendulum with mechanical registration; S = Stuckrath, horizotal pendulum.

A_m = maximum recorded double amplitude; A_o = maximum ground amplitude; instrument constants and calibration taken from Kirnos et al (1961) [14]; T = period of oscillation, Soloviev et al (1957) [22]; undiferentiated magnitude based on:

$M = \log (A_o/T) + 1.66 \log (\Delta^\circ) + 3.3$,

Δ° = focal distance in degrees.

that the 1903 earthquake was associated with movements of this particular major tectonic structure. In the first place, sites located literally on the fault or to the north of it, such as Chenar, Kishmar, Kabudan, Ahubam and a number of old mills, suffered practically no damage. Also, the concentration of widespread damage is in the Shishdiraz plain, which extends for about 50 kilometres south-southwest of Turshiz, and so lies to the south of the Doruneh fault. With the absence of any evidence of recent faulting in this segment of the Doruneh fault, the 1903 earthquake should have been associated with the tectonics of the valley between Kuh Begu and Siah Kuh, and further to the west with the Bejwird-kuh. This is also the suggestion that arises from the occurrence of the Rikhteh-Ahmatabad earthquake of the 5th October 1962, which also occurred south of the Doruneh fault and not connected with movements there, Ambraseys (1963) (2).

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