1. TECTONIC SETTING, GEOLOGICAL STRUCTURE AND SURFACE FAULT

1.1 TECTONIC SETTING AND GEOLOGICAL STRUCTURE

The epicenter and the damaged area are located in a fold and thrust (low-angle reverse fault) belt in the north of Zagros tectonic boundary (**Fig. 1.1**). This belt trends NW-SE direction. Mountain ranges and valleys of about 30 km wide run along the belt. Reverse fault movements have been responsible for large earthquakes including 1962 Ipak (Buin-Zahra) earthquake.

In this barren area, its surface geology is easily observed. Hills are mainly composed of Miocene siltstones with their southern area covered with Quaternary fan deposits. Two deformation lines are recognized in the valley. The northern deformation line is near the main stream of the valley. Bedding of Miocene siltstone dips north, while on the southern deformation line near Abdarreh, siltstone layers dip south The 1:200,000 scale tectonic map of this area shows these deformation lines as thrusts. The topographic feature is consistent with its geologic structure. The Quaternary terraces are deformed along the northern line, and a low land extends behind the hill near the south line.

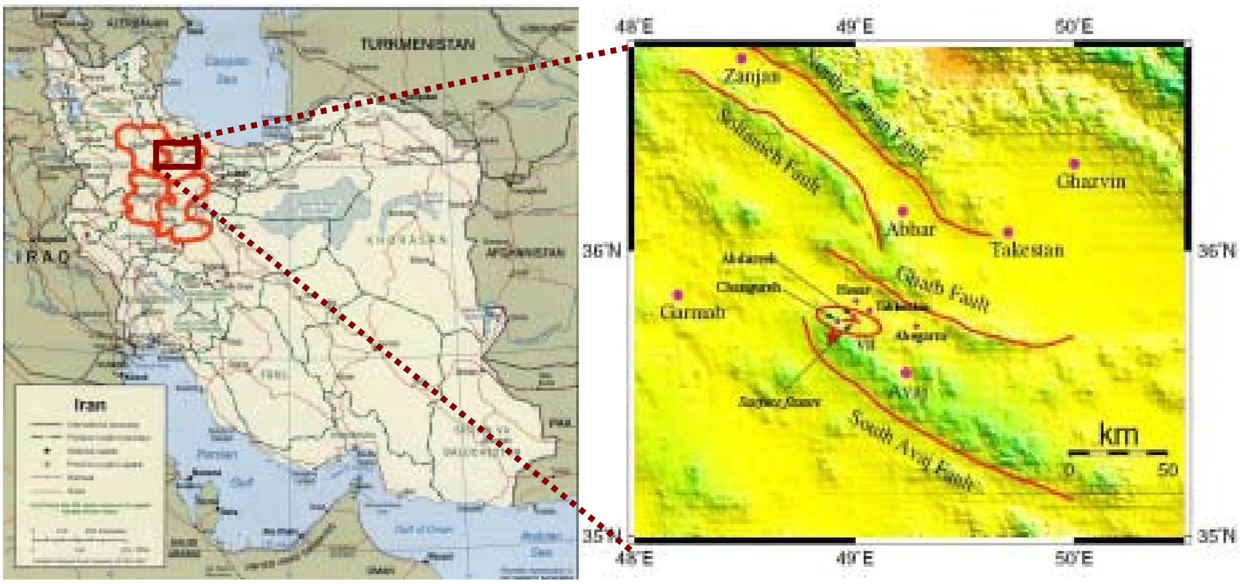


Fig. 1.1 Faults and seismicity of the zone:

☆ Epicenter

Magnitude (MW): 6.5
Time: 07:28:21.61 (local)
Location: 35.63N 48.95E
Focal Depth: 10 km
Fault Mechanism: reverse
(Source: USGS, NEIC)

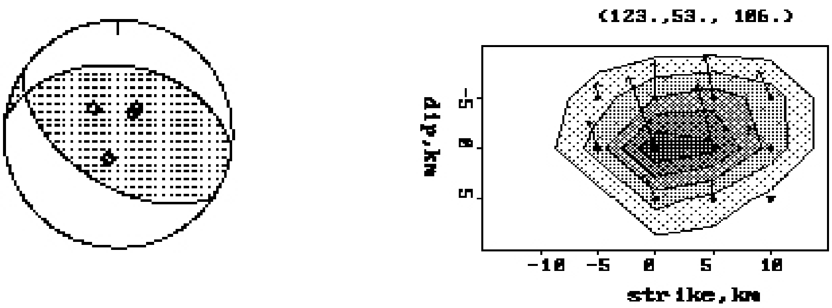


Fig. 1.2 Focal mechanism and slip distribution (Kikuchi and Yamanaka, 2002, ERI)

Kikuchi and Yamanaka, Earthquake Research Institute, University of Tokyo, put up their fault plane solution (**Fig. 1.2**, **http://wwweic.eri.u-tokyo.ac.jp/EIC/EIC_News/020622.html**) that indicates that the main shock occurred on a reverse fault of about NW-SE trend. That mechanism is consistent with the tectonic setting of this area. The Moment Magnitude M_W of 6.4 was calculated for the main shock, while 6.5 was calculated by USGS. The focal depth was about 7 km (ERI, 2002).

1.2 DAMAGE STATISTICS

Damage extents in the affected four provinces are summarized in **Table 1.1**. Major destructions of dwellings were reported in a region among those villages including Avaj in the south, Abegarm in east, Shirinsoo in the west and Abhar in the north. Most dwellings were non-engineered structures like single-story adobes and/or masonries. Almost all dwellings were flattened in Changureh and Abdarreh on the hanging-wall side of the activated fault.

Table 1.1 Damage outline in 4 provinces

	Qazvin	Hamedan	Zanjan	Markazi	Total
Affected villages	122	147	103	1	373
Affected cities	2	-	2	-	4
Damaged houses (units)					
50-100 %	6055	5491	3406	-	14952
20-50 %	6000	9973	2097	63	18133
Monetary damages (10^9 Rls.)					
Residential	340	256	156		752
Agricult. & Animal husbandry	45	24	52		121
Infrastructure	152	64	36		252
Governmental grant (10^9 Rls.)					
Housing	95	70	35		
Emergency	90	30	30		

Ref.:
Disaster Management Center, Ministry of Interior, Iran

1.3 ACTIVATED FAULT

A surface fault related to this earthquake appeared across the epicenter area of the main shock. According to Sassan, Eshighi, Mehdi Zare and Mohammad R. Mahdavifar, IIEES, surface fissures are continually lined up 3 km straight across the barren terraces between Changureh and Abdareh (**Fig. 1.3**).

The authors traced an about 700m part of the surface fault extending east from Abdareh. The rupture runs straight across the mountain ridges, and is related to the compressional mechanism. The southern hanging wall side has been pushed about 5-10 cm up. This trace of the fissures trends N70°W, and is approximately orthogonal to the axis of the focal solution for this earthquake given by NEIC and Harvard university (2002).

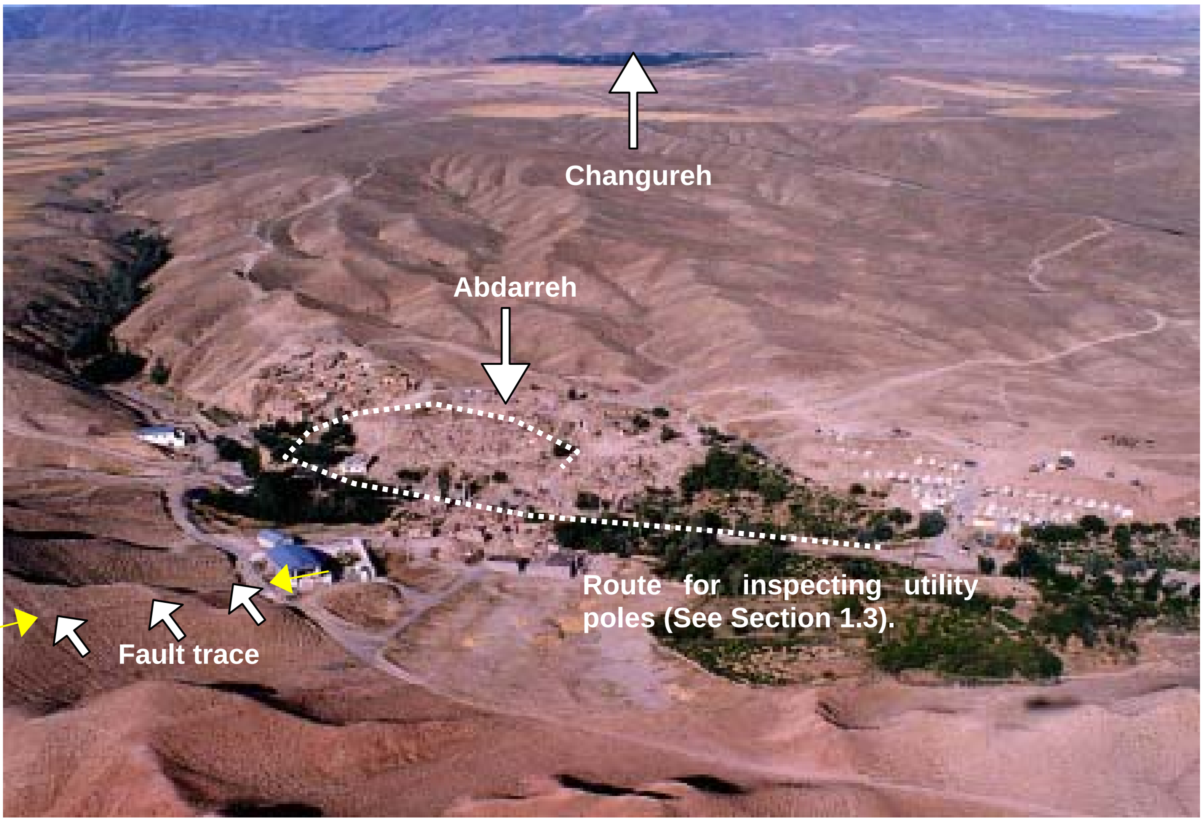


Fig. 1.3 Surface fault trace and affected areas

A trench was excavated at a narrow valley approximately 500 m east of Abdareh (**Fig. 1.4**). The site was chosen in expectation of finding charcoals that would allow dating possible previous events. Since the location was inaccessible by any machines, the trench was dug by hand, and was 3 m wide, 5 m long and about 1.2 m deep with east and west side walls cutting straight in the middle of the valley and along the mountainside (**Figs.1.5, 1.6**).

Fig. 1.6 shows a sketch of the east and west walls of the trench. Layer A is the weathered soil covering thin both the mountainside and the valley. Layer B is composed of granule and less matrix. Layer C contains semi-angular pebbles. Layer D is a matrix rich bed. Maximum grain size of 2 cm is reached in this layer. Layer E is a clearly imbricated gravel bed. The average and maximum gravel sizes are about 1 cm and 5 cm, respectively. Layer F is a paleo-soil covering a gravel bed of layer G. Layer H is also a paleo-soil bed, but is overlain by gravels of layer G. Layer I is a gravel bed covered by layer H. Maximum gravel size of layer I is about 5 cm. Layer F, G, H are overlain by layer E with unconformity. The fault found clearly from surface to layer E. It is recognized as open rupture and there is no displacement along the fault. In the layers below layer F, the fault is hardly recognized.

On the west-side wall, layer H and I are considered to be extensions of those on the east wall. The uppermost bed of the valley sediment, layer J, is a sandy soil with much matrix. Layer K is a thin bed of silt or very fine sand. Layers L and M are sand and gravel beds. The matrix is rather rich in layer L than layer M. Layers N and O are paleo-soil and gravel beds overlain by layer I. Though the surface fissures lined up across the valley have clearly proven the presence of the fault at the slope foot, no clear fault dislocation was observed on the west-side wall probably because the strain caused by the faulting has spread over the uncemented soil. Nothing indicating previous fault dislocations was found in the trench.

On the east edge of Abdarreh, surface soil was scraped off to observe the fault trace on a silt rock (**Fig. 1.7**). The silt rock dips to south. Tufficious fine sand and silt film is caught thin in the silt rock and faulting occurred on its bedding plane. Most southern part of the tufficious sand has developed into clay of 2-3 cm thick probably because of the continual fault dislocations. Siltstone among the thin tufficious sand film has been weakened.

A "bedding plane fault" can be considered as a by-product of folding, and causes a moderate earthquake of M6 class.

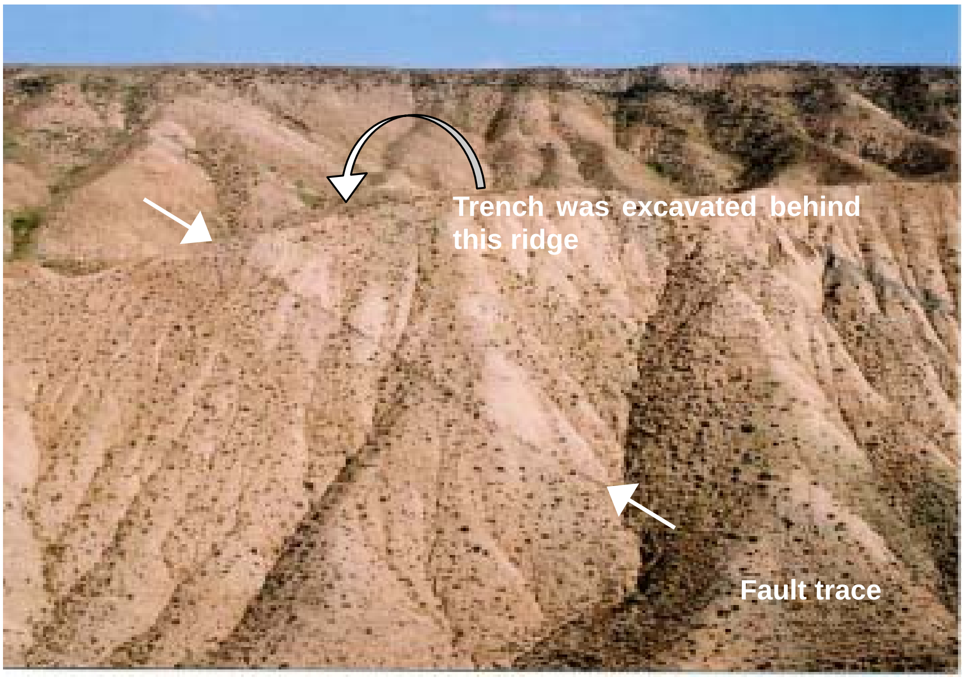
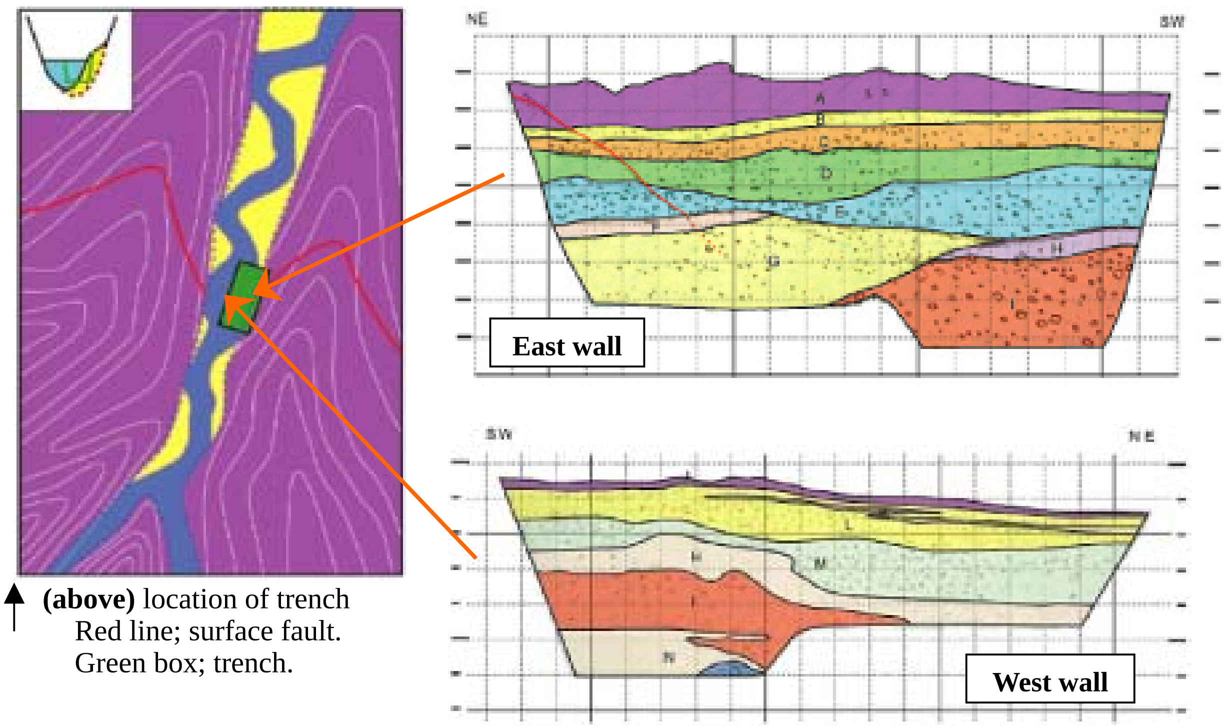


Fig. 1.4 Surface fault trace and location of trench

Fig. 1.5 Excavated trench



(above) location of trench
Red line; surface fault.
Green box; trench.

Fig. 1.6 Illustration of trench.

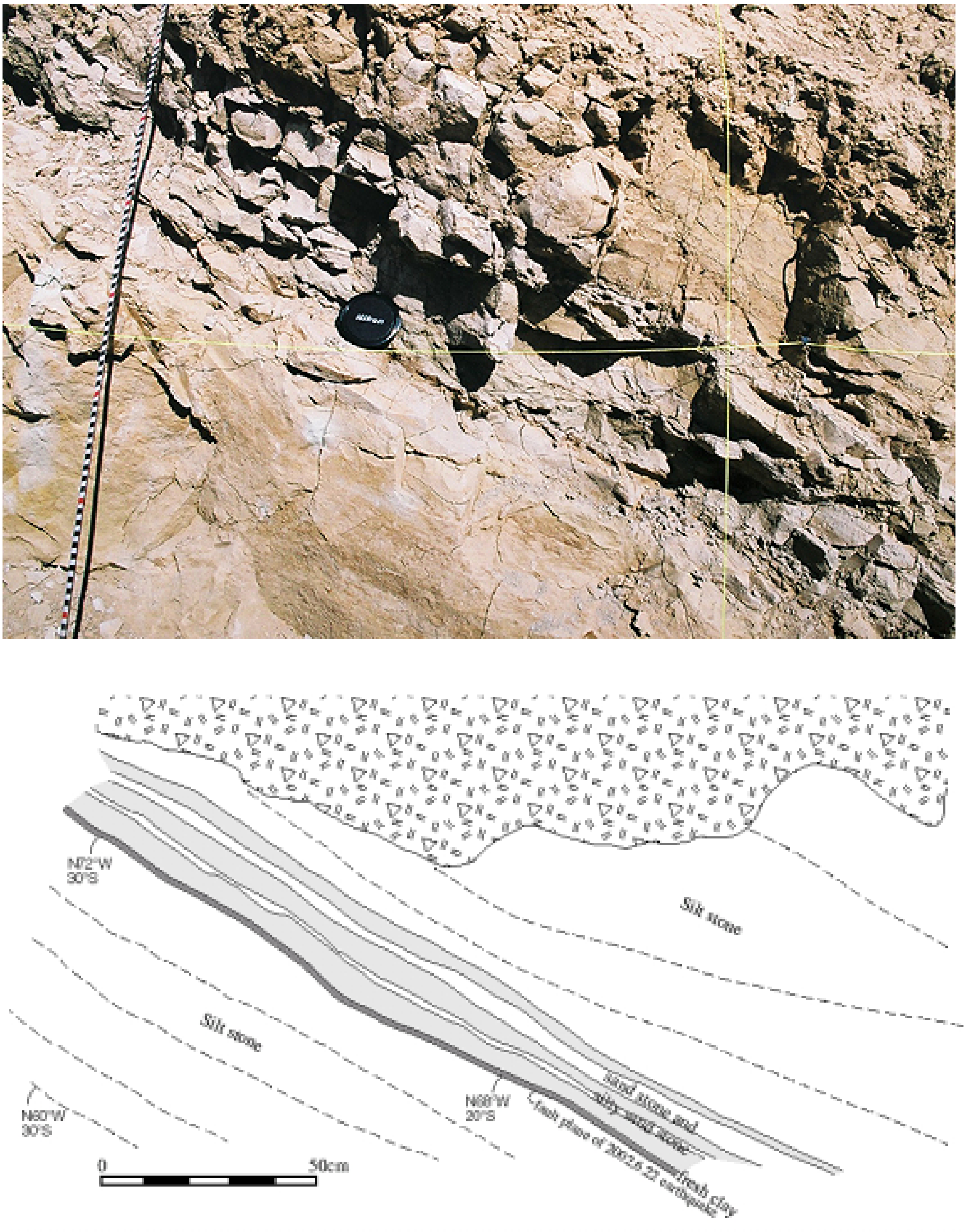


Fig. 1.7 Exposed surface of silt rock

1.4 FAULT AND DAMAGE TO ABDARREH

Abdarreh was one of the hardest hit villages by this earthquake. A gentle ridge, the northeast extension of a sand rock terrace rising behind, dips gently towards its northeast lowland. This ridge is densely covered with adobe dwellings, and most of them were flattened in the earthquake.

Distribution of cracked utility poles is considered to be a good index for estimating possible spatial distribution of intense ground motions. Observed crack intensities on total 28 utility poles were roughly classified into the following 5 groups:

Group 1: no visible crack. (**White**)
Group 2: with hair cracks (>0.1 mm, **Light yellow**)
Group 3: with cracks (0.1-0.2 mm, **Yellow**)
Group 4: with cracks (0.2-0.3 mm, **Dark yellow**)
Group 5: with cracks (<0.3 mm, **Brown**) that can be seen at a distance of about 2m

Figure 1.8 shows the observed distribution of crack intensities. In this figure, the route taken for the inspection is lined up with the utility poles (colored circles). The route goes straight from right to left along a valley, and turns sharply up towards the ridge when it reaches the southern edge of the village. Then it comes slightly back along the ridge. Several arrows near the bend of the route indicate the inferred directions of strong ground motions. The other line of dark sphere marks is the fault trace. It goes across another mountain ridge that rises east of the village, and meets the route. It is noted that the fault trace seemingly divides the utility poles into two groups; cracked poles on the hanging wall side and less damaged on the foot wall side. This clear contrast suggests that the shake on the hanging wall side must have been more intense than that on the foot wall, and thus must have been responsible for serious destruction of the village. The arrows show that the motion was intense in the normal direction to the fault trace.

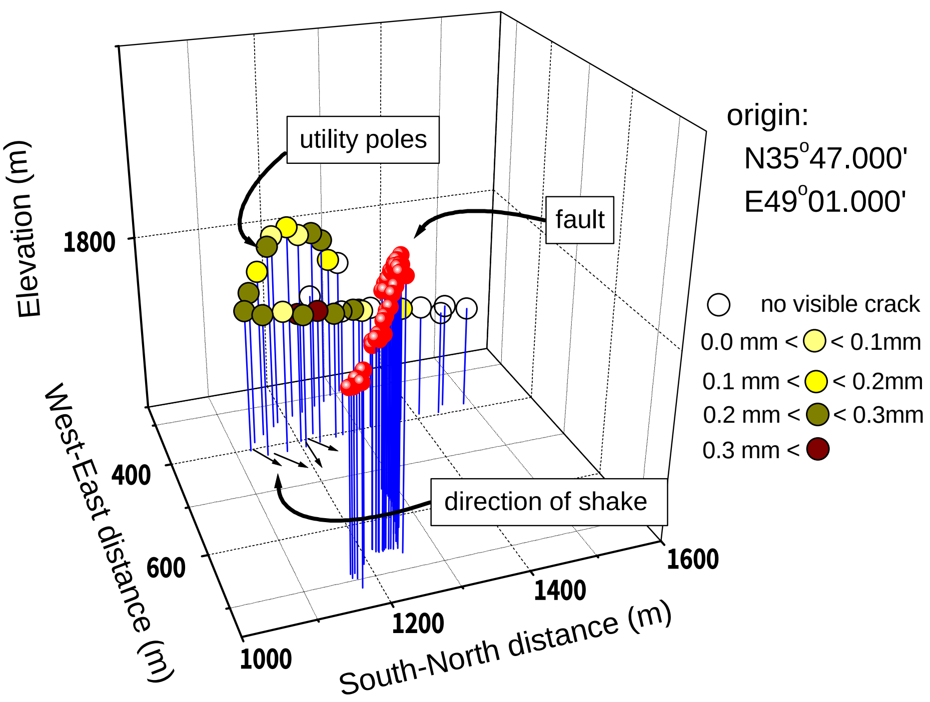


Fig. 1.8 Locations of cracked utility poles

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(**1.4** and **Edition of Chapter 1/** *Kazuo KONAGAI*, IIS, University of Tokyo)

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