A REPORT ON THE BUYIN EARTHQUAKE (IRAN) OF SEPT. 1, 196.

by

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SYNOPSIS

On September 1, 1962, a great earthquake broke out in the north-western part of Iran. Very heavy damage was caused by this earthquake, more than 270 villages suffered damage, 22000 houses were destroyed and 9500 were killed. The Government of Japan dispatched a mission on earthquake engineering for six weeks from 9th October. We investigated in detail the damage caused to buildings and other structures. By means of a microtromometer we carried out measurement of characteristic period of ground which were related to the seismic damage. Accompanying the earthquake a big earthquake fault was formed in the distance of about 100 km having east-west trend.

I. INTRODUCTION

On September 1, about midnight, at 23 h. 36 m. of the local time, an earthquake broke out in the north-western part of Iran. The Government of Japan, in accordance with its Technical Cooperation for Near and Middle East and Africa, dispatched a Mission on Earthquake Engineering to Iran for six weeks from 9th October, 1962. This is to report the result of investigations carried out by our mission at the site.

The mission paid three visits to the devastated area to make investigations on the distribution of the damage, destruction of destroyed buildings and structures, and to trace the fault that appeared in consequence of the earthquake and to carry out measurements with microtromometer in order to get scientific data on the ground conditions. After they came back to Tehran they made a vibration test of the model house which had just been constructed by the Construction Bank. By using the tromometer they also carried out the measurement of the natural vibration periods of four tall buildings in Tehran.

Iran is situated in a broadened part of the Alpide-Himalaya seismic zone, so that, consulting the seismicity map of Iran, we find that the epicenters are distributed covering the whole area of Iran excepting only a small area in the central Iran. There are, however, not so much materials to study the seismicity of Iran. Consulting the materials referred in the references (1, 2, 3), general seismic activity in Iran is shown on Fig. 1 by an open circle having a figure in it. The figure in the circle indicates the magnitude of each earthquake and the figure "d" gives the class of earthquake defined by

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Gutenberg-Richter (magnitude 6 3/4 $<$ d $<$ 6). It has long been considered that the Plateau of Iran was frequently attacked by grade c earthquake but not so often by grade b earthquakes. However, it must be pointed out that above conclusion was derived mainly from the data based on the Gutenberg-Richter table which is the only data for reliable location of epicenters but could be traced back only to 1904. Now, if we just look back the major earthquake in Iran, in the past ten years, we find that fairly large number of big earthquakes are actively taking place in this country. These big earthquakes are:

i) The earthquake of 1956 near the Persian coast (M = 6.8)
ii) The Mazandaran earthquake of July 2, 1957, which caused a heavy damage to 500 villages around Mount Damavand involving a loss of 480 lives (M = 7.5)
iii) The Hamadan earthquake of December 13, 1957, which killed 1130 persons (M = 7) (4)
iv) The earthquake of 1958 of Nehavand district (M = 6.75 - 7)
v) The Lar earthquake of April 24, 1960, which caused a loss of 400 lives and destruction of 75 percent of the Lar city (M = 5.75) (5)
vi) The earthquake of July 11, 1961 near Lar (M = 5.75 - 6)
vii) The Buyin earthquake of September 1, 1962 (M = 7.2) (6, 7)

As we have seen in the above paragraph, the Plateau of Iran has been attacked by a strong earthquake every 1.5 years on an average in these recent ten years. This frequency of occurrence of strong earthquakes may be considered to be considerably higher than that for many years prior to the decade.

Now, focusing our eyes on the area around Buyin in the seismicity map of Iran, it will be noticed that no earthquake has attacked the wide area west to Tehran in the course of many years in the past. And in the midst of this wide area, now, one mark was newly put denoting the epicenter of the Buyin earthquake. This is enough to attract our deep attention in considering future earthquakes that might happen near Tehran.

II. SEISMOMETRICAL FEATURES

i) TEHRAN SEISMIC STATION

The commencement time of the p phase measured at the Tehran station is To = 1962, IX, 1, 22h 50m 59.5s (Local time); p-s duration time is between 21 and 23 seconds, owing to the difficulty in the reading of the S beginning. According to the Gutenberg-Richter travel time table the epicenter is presumed at the location 160 km distant from the Tehran Station. First impulsions of the p of the Hiller seismographs in the Tehran Station are:

N: + with very large amplitude
E: - about two mm in trace amplitude
Z: - having a large amplitude

and these results indicate the location of epicenter to be about 160 km due west but slightly north from Tehran.

ii) USCGS

USCGS gives following seismometrical reports tentatively:

Location of epicenter:
Longitude: 50.0 E
Latitude : 35.6 N
Depth of focus: 21 km
Origin time: *IX 01, 19h 20m 38.5s (GMT)*

iii) MAGNITUDE

The reported magnitude of this earthquake at different stations are; M = 7 1/2 Pasadena; M = 7 3/4 Berkeley; M = 7 Palisades; M = 7.0 - 7 1/4 *Tsukuba; and M = 7.2 Matsushiro.*

iv) AFTERSHOCKS

On the seismograms of the Tehran seismic stations there are recorded a great many aftershocks that have taken place accompanying the great earthquake. 1355 aftershocks have been recorded on the seismograms of the Tehran Station in 70 days after the main shock. Unfortunately, as there are only two stations in operation in this country, it was difficult to determine the accurate locations of these aftershocks.

III. TOPOGRAPHY AND GEOLOGY OF THE DISTURBED AREA

As will be seen in a later paragraph the area most severely damaged by the earthquake is nearly covered by a triangle formed by the three cities of Qazvin, Hamadan and Saveh, of which the sides are about 215, 165 and 150 km respectively. Roughly speaking the northern half of this area is constituted by a plateau having an altitude of around 1000 meters, between the two mountain ranges, Alborz to the north and a branch ridge of Zagros to the south. Behind the latter mountain range and to the south we see a small plain along the Valley of Kara Bou. However, the topography in this southern area is complicated and the mean altitude is still greater than that of the northern plateau. Consulting with the geological map (8) we see that alluvium covers a wide area in the northern plateau. In the mountainous region there appears miocene formation almost adjoing the tertiary volcanoes to the south running almost in the east-west direction. Then there appear eocene sediments in contact with oligo-miocene marine rocks. Along these boundaries we see there are many old faults most of which run in east-west or northwest-southeast direction. As will be seen in a later paragraph, there came out a long new fault accompanying this great earthquake. So it is a matter of great concern to study the relation between the location of this new fault and that of old ones.

IV. ISOSEISMAL MAP

In Fig. 1, an isoseismal map is reproduced for the area outside of the meizoseismal region. In spite of the great effort to find out necessary data for the determination of seismic intensity at as many places as possible, we could obtain very few materials which could be of use for this purpose, especially for the small intensity. We proposed to apply a questionary post card method to this earthquake, but the collection of filled cards was very poor. During our stay in Iran, we could have three occasions to go to the places far from the earthquake area, for the purpose of making inspections to the site of the Lar earthquake of 1960 and others. Taking this occasion we tried to observe the seismic intensity at as many villages as possible. Results of observed intensity in the Modified Mercalli Scale are shown in the map in Fig. 1.

The isoseismal lines in the area of great destruction are shown in the map of Fig. 2. In Fig. 2, there is also shown the percentage of demolished houses for each village. The most reliable data of the statistics of demolished houses were appeared in the report prepared by the Ministry of Health of the Government of Iran. In accordance with the investigation of our survey, we made some modifications to the data described above. These modified figures of percentage for demolished houses are given in Fig. 2. As will be explained in the following paragraphs, houses in the area of great destruction were, having unbalanced structures, built by poor building material, heaving a very heavy roofing, and also built on inadequate foundations. In such situations, it was observed that these houses were destroyed beyond repair by the earthquake shock not greater than intensity VII by Modified Mercalli Scale. In the meizoseismal area we visited more than 70 villages. In all villages we visited, we invèstigated carefully the damage of buildings and estimated the seismic intensity. On the basis of these estimations, iso-seismal lines were drawn on the map. In drawing these iso-seismals, it was very difficult for us to make a line that bounds the area of intensity greater than X. As is clearly seen in some villages or towns we see houses were completely destroyed, say 100%, so that one may incline to put the intensity X or more. However, if one makes a further detailed inspection one finds many tall walls remain standing without being destroyed. Intensity X represents the ground accelerations greater than 430 gals. We consider that it is very difficult for these tall walls of mud construction to withstand such a large acceleration. It is for this reason that we hesitate to mark intensity X even for the area that was most severely damaged. The areas in which the intensity was greater than IX by Modified Mercalli Scale are seen in two places, one around Rudak and the other near to the town of Abegarme. The both areas are traversed by the fault in the middle. In the area of intensity VIII, very heavy damage to buildings is observed. However, it is noteworthy to remark that this area covers both plain and hilly region.

V. SEISMIC FAULT

Accompanying the great earthquake a seismic fault was formed in the meisoseismic area. Such a conspicuous earthquake fault as appeared in consequence of this earthquake has never been reported in the past earthquake in Iran. The fault shows clear appearance at the location about 4 km east from Ipak, where clear indication for the horizontal displacement of 5 cm could be observed by the matching of the roots of a bush. It was also observed that north side landmass of the fracture moved westward and south side eastward. Very small vertical displacement was observed, however, it was clear that south side was up and north side down. The fault runs from Ipak to west almost in the direction N 85°W. At the location about 7 km west from Ipak and about 5 km south from a village of Aquchamazar, the fault crosses a bed of drought river, then passes through cotton fields. Here a large number of cracks run in echelon. Vertical displacement was clearly seen and the greatest displacement was measured at 22 cm by one big crack and summing up five other smaller cracks running in parallel, total vertical displacements at this location was measured to be more than 40 cm. Horizontal displacement could be measured at 15 cm by a offset of ridges in a wheet field. About here it was observed a new fissure started to run in the direction in parallel to the former one but aparting at about 150 m to the south.

Near to the town of Aresanji and Tofok, as we see in Fig. 3, fault fissures could be seen running in parallel in a rather wide zone having a breadth of about 2 km. Conspicuous fissures are shown in the map. In this area, it was observed that southern landmass moved eastward and was elevated. The vertical displacement of 40 cm was observed at the location about 6 km south-east from Aresanji on the slope of a hill facing north. After passing through Rudak the fault again appeared in Chennar where the fault cut the southern slope of a steep and high mountain. Here the fault showed southern landmass subsided and northern one upheaved.

However, just at the foot of the mountain where land becomes level the continuation of the fault showed a very clear cut with the north side mass subsided. It seemed that on the slope of the mountain, after the formation of the fault, southern mass had slipped down along the slope so that it was shaped as if southern land moved downward and northern upward.

The continuation of the fault again makes its appearance at the village Sakmesabad about twenty kilometer due west from Chennar. In the area between Chennar and Sakmesabad mountains rise one above another so that we could not trace the fault. After Sakmesabad the fault changes its running direction and can be traced up to Abegarme. In this area, horizontal and vertical displacements between the both sides of a fissure became very small. However at Saranolya, there was clearly observed again the upheaval of southern mass by the amount of 10 cm.

In short, the fault can be clearly seen in the distance of more than 100 km, horizontal displacement was observed at least at four places where it was observed that north side mass of the fault moved westward and southern mass eastward, amount of displacement was only 15 cm at its maximum. Vertical displacement of the fault was more conspicuous. Maximum displacement was observed as much as 40 cm. The movement of landmass was observed invariably south side up and north down through the whole length, although in the part near to the western end of the fault, there was observed very little vertical displacement.

VI. DAMAGE TO BUILDINGS

The distribution of general damage due to the earthquake is mentioned in section IV. As to the damage to civil engineering structures, damage to ganates was most conspicuous. As to the bridges, we noticed that only one stone bridge, which was constructed more than 400 years ago, suffered large damage (Photos 1, 2). In this section there are explained the processes by which the destruction of buildings have taken place. Before we give these explanations, in the first place, we shall classify the types of buildings that are found in the damaged area into following four types:

A. Masonry structure with steel beams
wall: Brick construction, materials of joint being cement mortar, pure mud or mud with lime.
Roof and floor: Steel beams and brick arch and some finishing on them.
B. Masonry structure with wooden beams

Wall: Sun-dry brick, mud block or stone, thickness is 40-60 cm (sometimes over 100 cm) and material of joint is mud (sometimes with lime).
Opening: Very small in size and with wooden lintel.
Roof: Logs are put as beams on the top of a wall spacing 30-40 cm apart. Lepironia mats or small wooden branchs are spread over these logs and covering all these, a thick layer of mud, having a thickness of 30-50 cm, is laid to form a flat roof. In a case of a large building, sometimes a girder and a column are employed in order that they may support these logs. A girder is formed by a big log or a bundle of logs which is often plastered with mud. Acolumn is of nearly the same construction as a girder (Photo 4).
C. Masonry structure with brick arch and dome
Wall: The same construction as B.
Opening: The same construction as B. Sometimes brick arch is used.
Roof: A dome is supported by brick arches and or walls, diameter of the dome is about 3-4 m, thickness of a brick arch or wall is about 20 cm. The dome is made of sun-dry bricks and is covered with mud. The thickness of the sundry brick is about 20 cm and that of mud is 20-30 cm. Sometimes a cylindrical roof is employed as a modification of the dome shaped roof (Photo 3).
D. Masonry wall
Height: 100-200 cm (sometimes 300 cm or more).
Thickness: About 50 cm at the base.
Material: Mud block or stone. Height of each mud block is about 50 cm.

Typical damage that has taken place in the respective structures mentioned above is described in the following:
A: Masonry structure with steel beams
There are not many buildings of this structure in the damaged area. One of them which was found in A-be-garme seemed to have received only a slight damage on its wall. However, examining it in detail we found very clear shearing cracks, especially on the wall facing south. Steel beams and brick arches were not destroyed but it was considered that this building was not safe enough to be dwelt in. Another example of building of the same structure which was found in Danesfahan suffered heavy damage. The roof had fallen down and the walls had also been destroyed almost completely. There being not many examples of this type of structure the area investigated by us, somewhat hesitate to make any conclusions (Photo 5).
B. Masonry structure with wooden beams
In the southern part of the damaged area this is the most common type of structure, while in the other parts of the damaged area, buildings of a structure combining type B and C are more common. Generally, these structures have small openings such as windows and doors. The process in which such structures are destroyed is as follows:
1. Some cracks are formed on a wall at a corner of a room.
2. Wall is overturned toward outside on the weakest side.
3. If the wall of the fallen side is not supporting the wooden beams, then the roof may remain on the other walls.
4. If the fallen wall is supporting the wooden beams, then roof falls down and this is turn pushes the other walls towards outside.
5. In this way the walls are made to stand alone just like a cantilever, so that they easily overturn separately (Photos 6, 7).
C. Masonry structure with brick arch and dome
In general, the processes by which the destruction of buildings of this type of structure takes place are as follows:

1. The top of wall is displaced by the formation of cracks.
2. By this dislocation, even though it might be only a very small one, cracks are easily formed in the arch or dome, then these cracks run up towards the top of the dome.
3. As will easily be understood, the arch and dome are of no use for binding up the top of walls. On the contrary, they produce a force to push the top of wall outside, and the walls are destroyed more easily.
4. Structures having an arch or dome roof usually have large openings and this in turn causes the structures to be destroyed easily by the earthquake motions (Photos 8, 9, 10, 11, 12).

Considering these processes, we find that this type of structure is like a box structure. However, in reality, it makes no use of excellent points of box structure. The walls do not cooperate with each other and slabs and domes are of no use for binding the top of the walls. In addition to this, before the earthquake many cracks must have been formed on the wall by shrinkage, so that these cracks must have accelerated the destruction of the building. For this reason steel binder at the top of the wall is very useful for an anti-seismic reinforcement. Considering the damage from the point of materials, we find that a stone wall is destroyed most easily, a sun-dry brick wall follows it, and mud wall is rather strong having a stronger nature in its structure. But it must be kept in mind that the strength of a wall would greatly be affected by the condition of filling.

D. Masonry walls

Everywhere in many villages we saw some walls that had suffered no damage in spite of their considerable height. In the case of these walls it seems that the joint material between the blocks contributed nothing to resisting the bending moment of the wall, so that we can assume that they are a simple body. By this assumption we can estimate the seismic acceleration statically from the overturning of a simple body. According to this consideration it can be estimated that the acceleration of ground movement had not exceeded 0.2g, anywhere in the whole area excepting Rudak. However, it must be kept in mind that among those destroyed ones some had cracks before the earthquake.

From these observations we had the following conclusions on this problem:
1. Maximum ground acceleration in Rudak is 0.2-0.25g. But in the other places ground accelerations are not over 0.2g.
2. Buildings in the damaged area were originally too weak in their construction to resist earthquake motions.

VII. RELATION BETWEEN THE DAMAGE OF BUILDING AND THE GROUND CONDITION

VII. 1 TOPOGRAPHICAL PROBLEM

Damage of building is deeply related to the ground condition. In the case of Japanese earthquakes such as the Kwanto earthquake 1923 (9), Fukui earthquake 1948 (10), Tokachi-oki earthquake 1952 etc., we find that big damage was caused mostly on thick alluvium. For the purpose of examining this relation in the Buyin earthquake we draw 3 lines on the map and topographic sections along these lines are related to the damage rate of villages along the lines respectively. The results are shown in Fig. 4. In these figures the relation between the damage of buildings and the altitude of villages is not clear. This indicates that the damage is not concentrated only on the alluvium. In

Buyin area buildings are of masonry construction, and in Japan they are mostly of wooden construction, or some flexible ones, so that there may be some different phases in the relation between the damage and the ground in the case of Buyin earthquake.

VII. 2 DAMAGE DUE TO LAND-SLIP

The southern part of damaged area covers a mountainous district, so that many villages are located on hill slopes. In such circumstances, a land-slip is liable to occur on the slope of a hill causing the destruction of buildings standing on the slope. For instance, in Ali Shar, the down town of this village suffered no severe damage while the up-town on the slope of a hill was destroyed completely. This type of damage must be attributed to the slipping of foundation of the building caused by the land slide. This type of damage represents one of the important causes of heavy damage, especially in the mountainous region.

VII. 3 OBSERVATION OF THE MICROTREMOR IN DAMAGED AREA

We carried out the measurement of microtremor about 39 points in the damaged area. The typical examples will be described in the following.
1. In Aresanji heavier damage was observed in the northern part of the village and somewhat lighter one in the southern part. In the map of air photo (Photo 13), we notice that northern part seems black which shows heavy damage and southern part white with lighter damage. We carried out microtremor observation in the village at five locations of different extent of damage. These locations are marked in a map of Fig. 5. Frequency-period curves analized from the records of microtromometer are shown in Fig. 6. It is clear from this figure that locations Nos. 1 and 2, where damage was severe gave a sharp predominant period around 0.1 sec., whereas at the locations Nos. 4 and 5 where damage was not so severe, the frequency-period curves give rather flat shape.
2. Another example of frequency-period curves analyzed from the records of microtromometer is shown in Fig. 7. Three curves observed at Rudak, Rustamabad and Buyin show clear peak of predominant period again at about 0.1 sec., whereas those of Ismatabad and Kushkak where damage was quite slight show a flat shape and no clear predominant period.

These graphs of period-frequency, which were observed in the damaged area of the Buyin earthquake, indicate that at the ground where a short period is predominant greater damage to buildings is caused.

The Mission wishes to express its sincere thanks to His Excellency, Mr. Elahi, President of the Construction Bank of Iran and members of his staff as well as to professor Dr. Farhad, Chancellor of the Tehran University and other members of the said University for the kindness and cooperation given to the Mission.

Our deepest thanks also go to the Association of Red Lion and Sun, and other authorities concerned for their sincere cooperation. It would be our great pleasure if our investigations and suggestions might be helpful to the Government of Iran in taking adequate measures to decrease earthquake damage.

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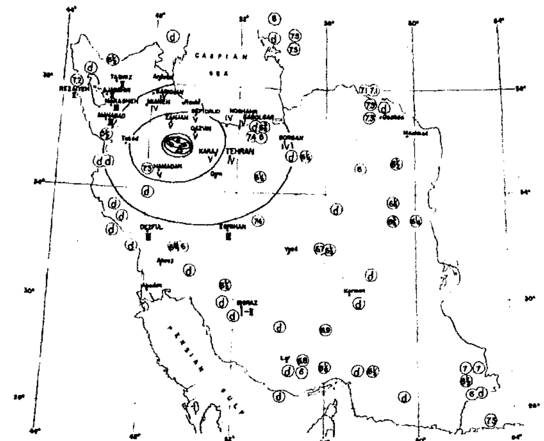
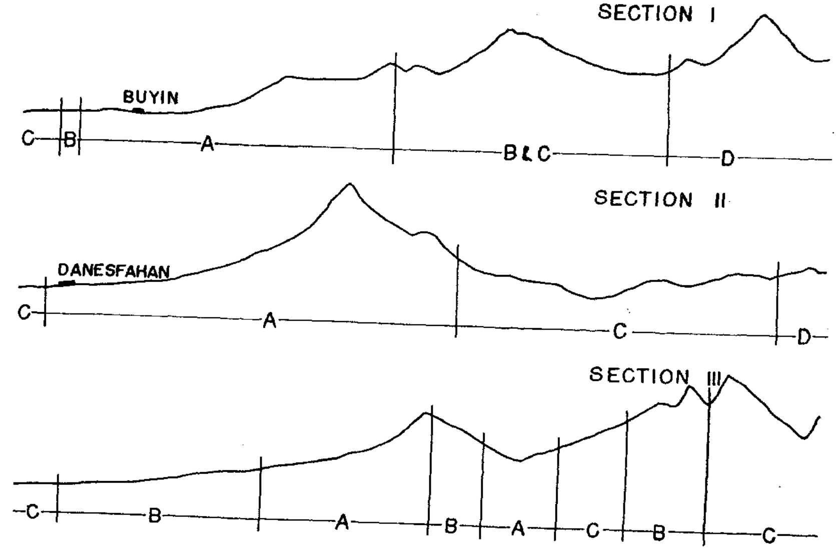
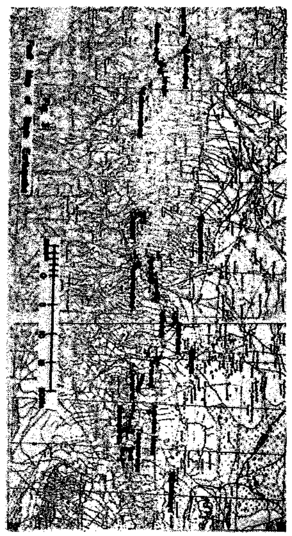


Fig. 1
Seismicity map of Iran and isoseismal lines of the Buyin Earthquake



A:95-100% B:50-95% C:5-50% D:0-5%
PERCENTAGE OF DAMAGE

FIG. 4



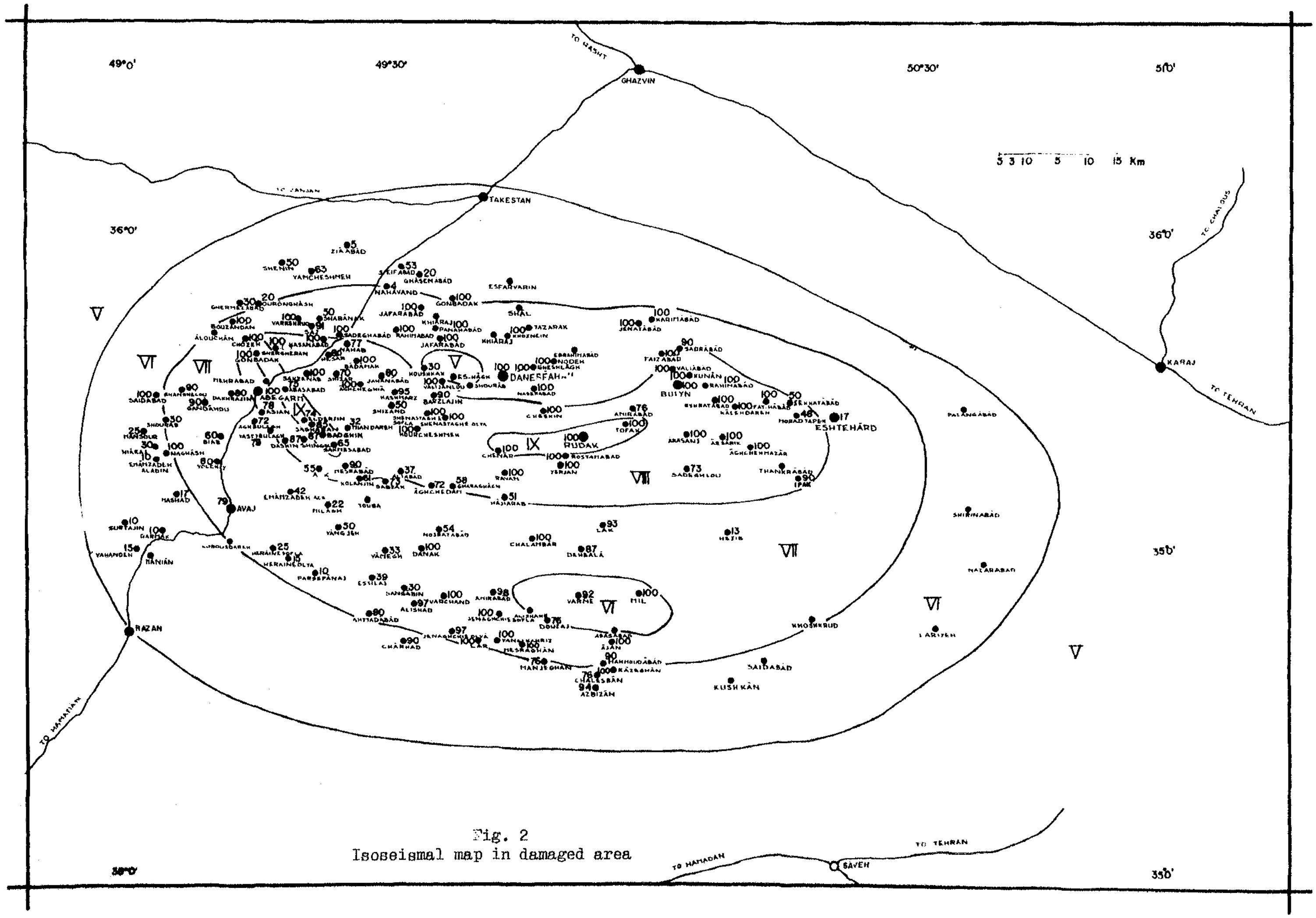


Fig. 2
Isoseismal map in damaged area

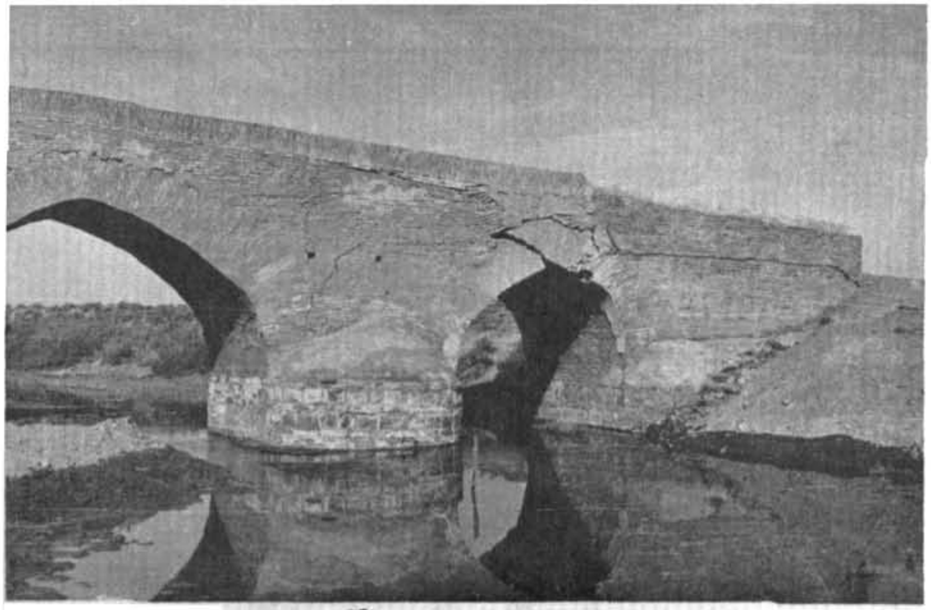


Photo 1 Bridge between Qazvin and Buyin

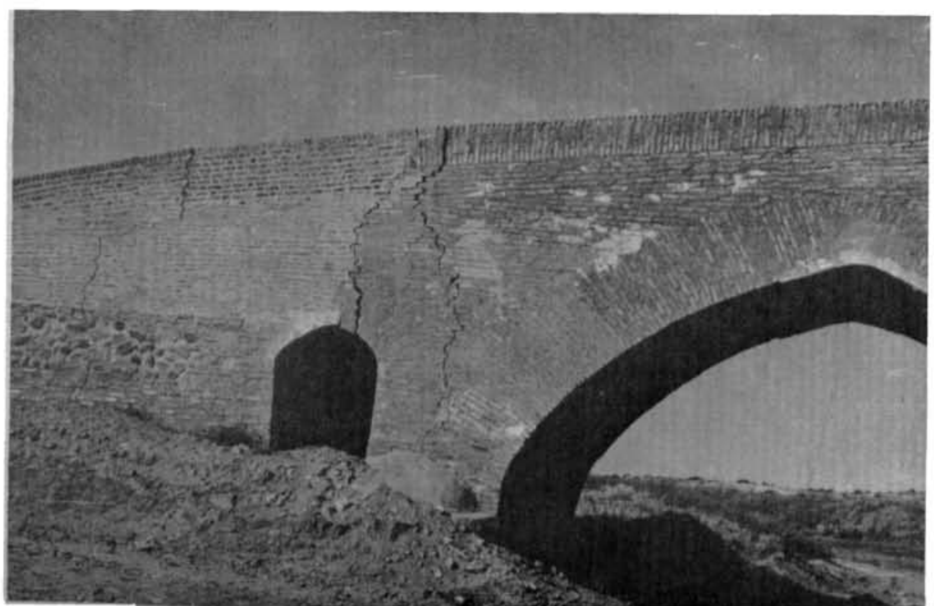


Photo 2 Ditto

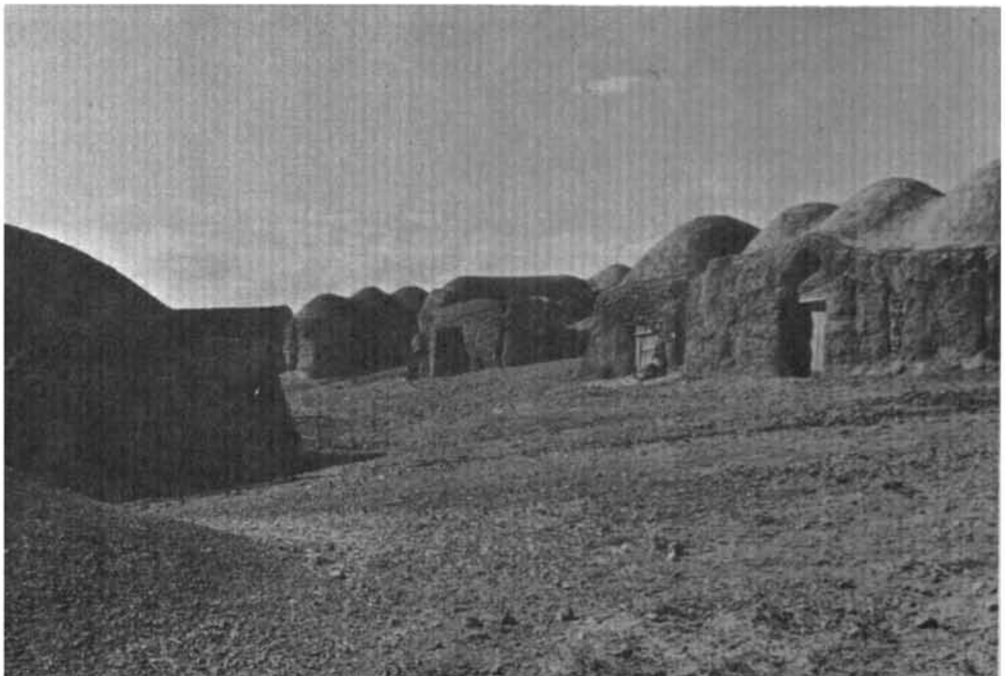


Photo 3 Qaraturbaq

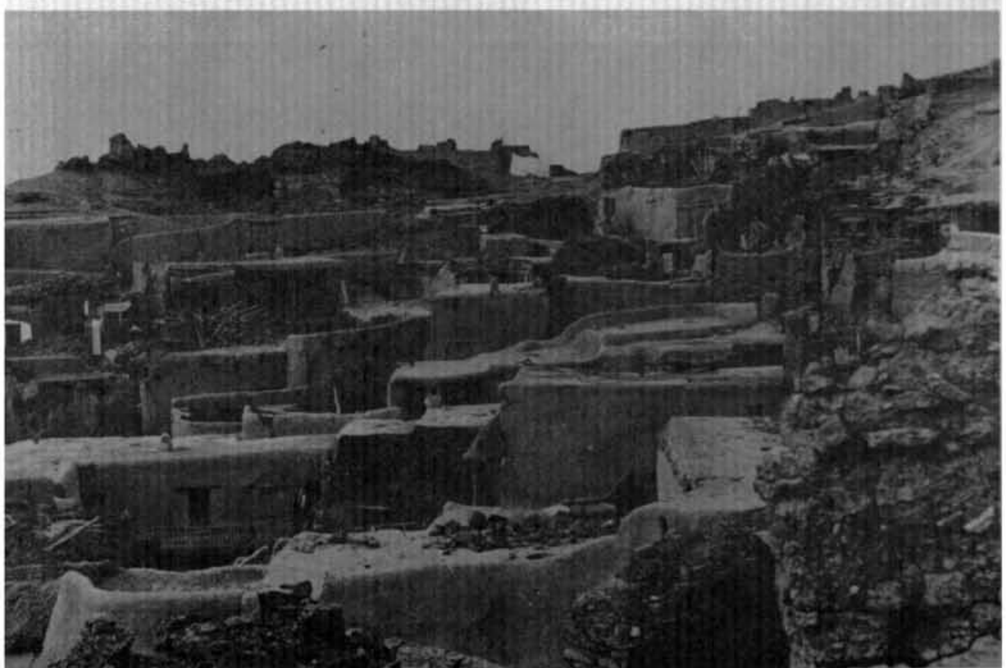


Photo 4 Qulanjin

Photo 5 Danesfahan

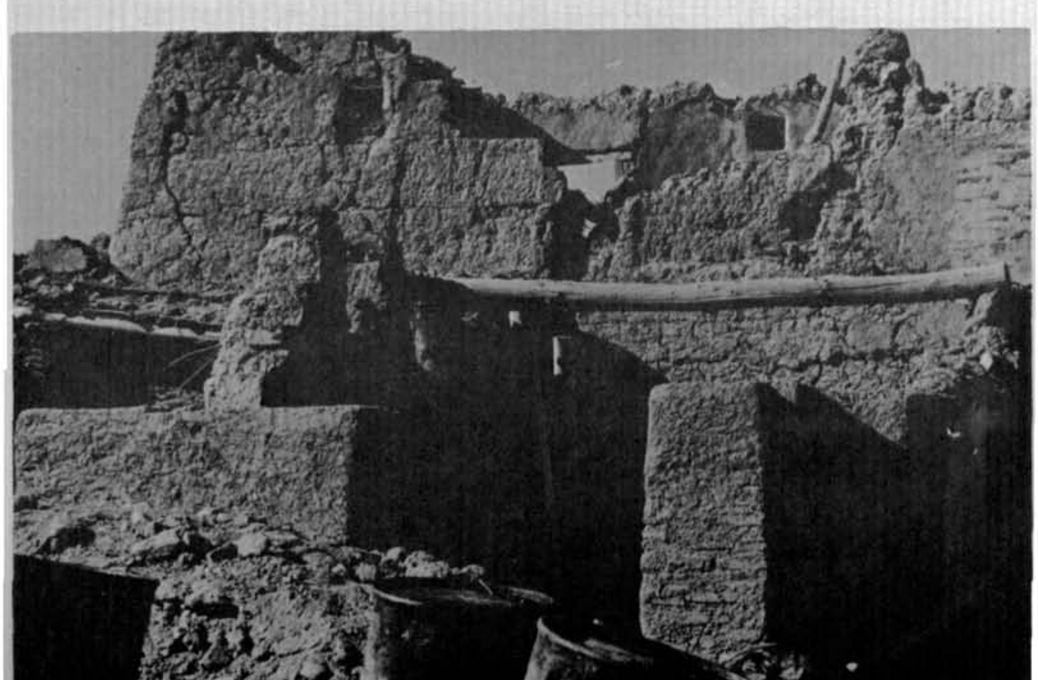


Photo 6 Danesfahan

Photo 7 Rudak

Photo 8 Buyin

Photo 9 Buyin

Photo 10 Abarik

Photo 11 Ipak

Photo 12 Buyin

Photo 13 Aresanij

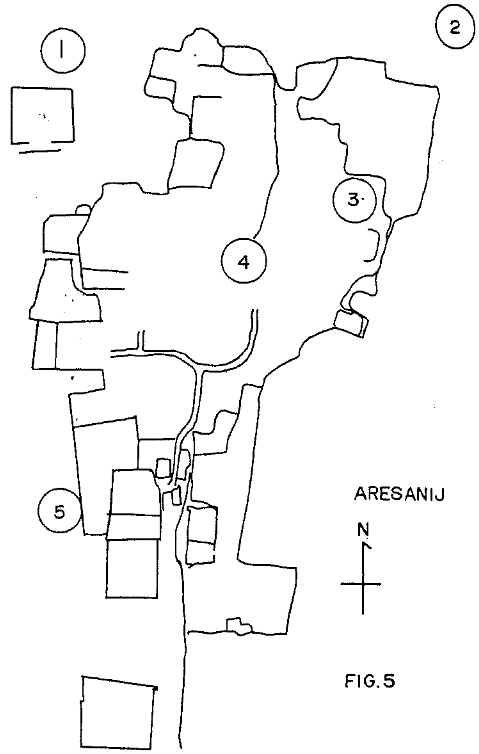


FIG. 5

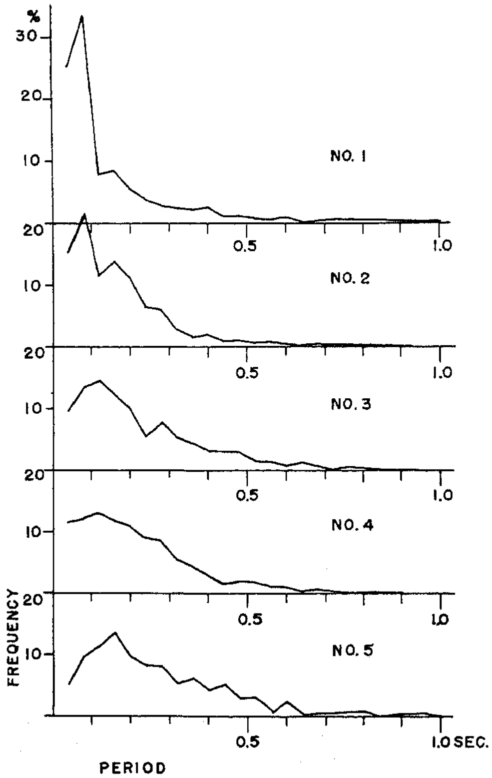


FIG. 6

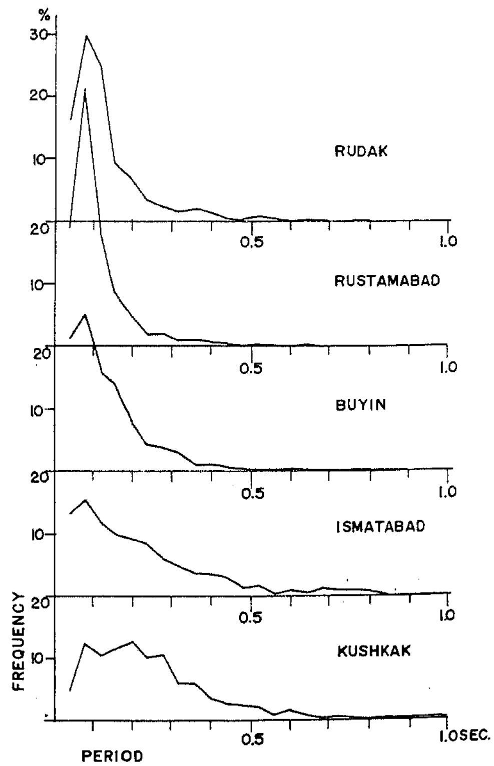


FIG. 7