REPORT

on the

LAR EARTHQUAKE OF 24th APRIL 1960

by

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1.   General Information

In the long past and in the early days of the country's history
earth tremors accompanied by volcanic activities have been narrated and
passed down from generation to generation.

In the recorded history of the country we notice cities completely
demolished and newly rebuilt, such destruction has been mythically
and theologically associated as a sign of punishment of those nations
deviating from moral codes and clean methods of life.

In the last few decades, the occurrence of a series of earthquakes
in the various regions of the country has caused a certain degree of
terror and uneasiness.

Only in the last 10 years some of the 40 major shocks registered
throughout the world have had their epicenters in the Plateau of Iran
with a total loss of some 3000 people.

Prior to the Lar earthquake five other major shocks in the country
caused a loss of 2000 lives.

The earthquake of 2nd July 1958 in Mazanderan killed 45 people and
destroyed 200 villages. These villages centred round Damavand Mountain.

The earthquake of December 1957 in Hamedan killed 1130 people and
destroyed 200 villages.

The earthquake of 1958 at Nahavand killed 128 people and destroyed
a number of villages.

The earthquake of Lar of 24th April 1960 destroyed 75 per cent of
the city of Lar with a loss of 400 people.

The material damage is estimated to be of the order of 20,000,000
dollars and some 50,000,000 dollars would be required for the construction
of the new town and the urbanic requirements.

The destruction of Lar is instructive from the point of view of aseismic
designs in countires situated in the seismic belts.

It is rather fortunate that the population density in Iran is very
low, otherwise the consequences of these earthquakes which have been so
frequent could be tragically far more serious.

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The case is aggravated by the fact that practically most of the buildings in the country in the past have been designed without due regards to the technical necessities as considered in countries situated in seismic regions.

In order to deviate the public attention and diminish the prevailing awe, terror and the mental stress, a scientific investigation and explanation was deemed necessary and this would remedy the existing subconscious fear and provide a psychological aid in case of future accidents.

After the tragic incident of Lar and the previous cases as explained above, Teheran University decided to prepare a report on the subject that could be at the same time presented to the Second World Conference on Earthquake Engineering in Tokyo and Kyoto.

In order to provide the scientific data necessary for this report, three scientists from the Institute of Geophysics, Teheran University, one geologist, one seismologist and one construction engineer, expert in aseismic designs, were assigned to the task of a reconnaissance local investigation of the damaged areas from the geologic and tectonic points of view, nature, extent and assessment of damages, failures due to material and design of constructions and an evaluation of the intensities and magnitudes of the earthquakes in the Lar valley and based on the accumulated and scientific investigations prepare the project for the new town that has to be reconstructed on the side of the ruins of the present city.

It is hoped that this meager information in a quasi-scientific language, will elucidate to some extent the causes and consequences of the Lar accident and will prove benefitial to those interested in earthquakes and seismology.

2.   Geographical Location

The Lar valley with its 15000 inhabitants, southeast of Shiraz, lies in the plains of Zagros range, a range which is occasionally cut by depressions and discontinuities, but, nevertheless, the range continues in parallel series with tectonic accidents which are mostly due to the orogenic movements of the tertiary period. Lar village which has been the victim of the accident has the following coordinates:

$$\varphi = 27.7° \text{ N.}$$

$$\lambda = 54.3° \text{ E.}$$

The epicentral region, as calculated, is believed to have been on the extreme southern border of the Zagros mountains, having the approximate coordinates

$$\varphi = 27.6° \text{ N.}$$

$$\lambda = 54.1° \text{ E.}$$

This is one of the delineated zones in Iran, which has been historically in the past and also instrumentally at the present, known to seismologists to be the most active zones of the region.

This is the region where the general orientation of the mountain ridge changes from a direction of NW-SE to a direction of E-W.

3. Topography and Geology of the Region

The valley extends in the east-west direction and is bordered by hilly formations in its north and south edges. The geological formation of the northern hills is oligo-miocene composed of conglomerates, calcareous, marn, argil, and gyps. The height of this part is 1020 meters from the sea level. The formation of the Lar valley is alluvium, the thickness of which is about 50 meters, and the height of this plain is 900 meters and the width is 5 kilometers. The geological formation of the southern hills is calcareous Eocene, and the height of this region is 960 meters. An aerial view is shown in the accompanying photograph No. 1.

4. Lar Earthquakes in the last 50 years.

In the last 50 years 30 earthquakes, the magnitude of which has been between 5 and 6, took place around Lar in an area within a radius of 140 kilometers.

5. Distribution of Seismic Intensities

The distribution of seismic intensities is shown in Fig. 1. The intensity scale of Mercalli has been employed.

6. Distribution of Damages

The damaged region was confined only to the Lar valley.
A thorough investigation revealed the most significant point that the total destruction took place in a rather narrow region of the city, which is shown in the aerial photograph. The population density has been greatest in this region. Outside this totally collapsed region only cracks on the walls have been noticed. The foundation of the ruildings in this narrow strip is on very soft alluvium formations, while the houses and buildings on the rocky mountain side have only suffered small cracks. None of the villages outside the city of Lar exhibit signes of damage.
The statistical analysis of the damages to the buildings are as follows:

40 % of the houses	completely demolished
30 % of the houses	damaged
20 % of the houses	unsafe for dwelling
10 % of the houses	slightly damaged

7. General Description of Buildings in Lar

At the present there are two prevailing types of constructions, and an entirely advanced and properly designed type is also existing and under rapid development.

The first type is the construction having the basic material as the sundried bricks and timber roofs. The main walls carrying the load and stress have a thickness of 75 cm.

The second type is the stone masonry with a mixture of clay and slaked lime mortar and timber for roofing.

The third type is the building with properly furnace baked bricks. The buildings of this type are most resisting and have shown the least damage.

The roofing material in the first two types is generally timber beams covered with bamboo mats, and a layer of mud and clay mixed with straw with a thickness of about 40 cm covers the top part of the roofs.

Metallic beams are used for the third type and are arched by bricks in between the beams. It has been this third type of building with proper foundation that has survived the severe shocks.

It is significant to study the effect of the role of beams used for roofing. The buildings which had these beams covering the total width of side walls suffered the greatest collapse, while in the buildings on which these beams had enough support on the side walls and thus possessed a certain degree of freedom, damage and collapse were considerably less.

8. Seismometrical Data

a. Epicenter of the main shock
The epicenter and origin time preliminarily determined by USC & GS are:

$$28^\circ N., \quad 54 \frac{1}{2}^\circ E. \text{ and } 12h \ 14m \ 26s. \quad (GMT)$$

The epicenter determined by Shiraz station is

$$27.6^\circ N., \quad 54. \ 1^\circ E.$$

b. Depth of the main shock
The seismological station in Shiraz is the only source of instrumental data available in the near-by region, and considering the fact that more information is necessary from near-by stations in order to estimate the depth of the focus, the accurate determination of the depth has not been possible. However, preliminary analysis gives a rough estimation that the depth in question is very shallow.

c. Magnitude of the main shock

The magnitude of the main shock has been estimated as follows:

      5.4   by Strasbourg
      5.6   from the surface waves recorded in Teheran station
      5.8   from the body waves recorded in Teheran station

Therefore the magnitude of the earthquake itself is not very large, but owing to the fact that the foundations are based on soft alluvium formations of the plain of Lar valley and this coupled with the fact that the construction materials have been very poor and of unsuitable design especially from the view-point of aseismic structure, therefore the apparent destruction exceeds the recongnized Mercalli scale of intensities.

d. Foreshocks

Two foreshocks were recorded in Shiraz station, which is located at $29.5°$ N, $52.6°$ E and about 280 km from the epicenter

e. Aftershocks

Fifty eight aftershocks were also recorded at Shiraz till 18th of May. Time of occurrence, magnitude, and time interval from the main shock are listed in the table. The magnitude of aftershocks has been estimated as follows:

The magnitude of the main shock has been tentatively set to 5.6 as the mean value of the three different magnitudes. Amplitudes of the aftershocks are measured on the seismograms and the magnitude of the largest aftershock is set to have been 5.2 by comparing the records of the main and this aftershock registered at Teheran, because the amplitude of the main shock was not properly recorded at Shiraz station. This comparison is made according to an assumption that the difference in magnitude of two shocks, which occur in the same region, is equal to the logarithm of the ratio of the amplitudes of these two shocks. The magnitude of other aftershocks are similarly determined on the seismograms registered at Shiraz station.

The cumulative frequency of aftershocks against magnitude is shown in Fig. 2 and the summation curve of the number of aftershocks is shown in Fig. 3. Both figures have been drawn from the data up to 18th of May.

The gradient of the curve in Fig. 2 is about 0.77 which seems to be quite normal, except for the fact that the aftershocks, of magnitude about 5, had a greater frequency than expected.

9. Recommended Aseismic Designs for Buildings

The following types of buildings as indicated by the corresponding plan and elevation drawings have been proposed for the reconstruction of the residential units of the city of Lar.

A-1. This is an open type of dwelling for medium size families of 4 persons. The construction is so designed that, if necessary, another story could be added, and they are designed for the inner ring of the

town. The surface occupied by this type of building is $34.m^2$.

B-1. This type is designed for the minimum size families of 2 persons and could be constructed in any region of the town. The surface occupied by this type is $24.m^2$.

C-1. This is the largest unit for families of 7 persons having an independent court yard with the possibility of an additional story.
    This type is designed for the outer ring of the town and the area occupied by this type is $51.m^2$.

D-1. This type is a closed system for medium size families of 3 persons and designed for the central region of the town. The area occupied by this unit is $34.m^2$
    In order to provide sufficient rigidity and resistance against deformation and twist, the following points in the designs have been taken into consideration.

1- Walls are solidly jointed together and uniformly continuous.

2- The minimum height of 2.67 meters provides the optimum connecting stregth between the walls and the reinforced concrete roofs.

3- The connecting walls are by necessity either in the form of T, U, or L.

4- In order to cope with the climatic conditions and in order to have the dwellings heat-proof and isolated, a minimum surface of windows and doors are allowed.

5- The sanitary arrangements of the units are planned as close together as possible. This will reduce not only the plumbing and isolation problems, but will be also more economical.

10. Constructional Recommendations

As the city of Lar has to be entirely rebuilt, it seems necessary, from the point of view of foundations, materials and design of construction and the general urbanic requirements of the town to consider a few points of vital importance.

a- Foundation.
    The depth of the alluvium in the area on which the city was built is about 30 meters and as this alluvium has proved to be unresistible to shocks and has caused the greatest damage and this coupled with the fact that the two valleys of Lar and Kurdeh are tectonically unstable and future immunity to construction and human life cannot be guaranteed, therefore by necessity the site of the new city should be displaced some kilometers north on the rocky formations where the resistance is stronger and less possible damage.

b- Materials
    No proper bricks could be manufactured in Lar and the existing factory has proved a failure, and therefore the alternative is to

utilize the sand and gravel of the locality for the preparation of
concrete blocks and this seems to be the only economical replacement.
Sample materials of this type are already under test and analysis in
the soil laboratory at Teheran. Beams of the same material properly
reinforced could be used for roofing.

11. Necessity of Formulating the Construction Code

The ever increasing population density of the country in certain
industrial regions and areas under rapied development and in an endeavor
to safeguard the people and the property from the unforseen and un-
predictable catastrophes of such earthquakes it seems imperative to
apply the aseismic deisgns to the multistoried buildings, tunnels,
dams, airports, etc.

Detailed and comprehensive technical codes, for construction,
aseismically designed, with due consideration as to the availability
of material and technical possiblilites, will be compiled from the
existing codes in Japan and U.S.A. and other countries in seismic
regions.

The application of the technics used in aseismic and earthquake
engineering in Japan is already operative in some modern buildings of
Teheran and intensive inquiries are frequently made by construction
engineers engaged in dam, tunnel, and airport construction.

It is hoped that the contemplated construction code when duly
compiled in accordance with the prevailing construction laws and
regulations of the country will be legalized and duly enforced in
regions suspected of future tremors.

Plans are likewise drawn for the establishment of an earthquake
research center where all the related problems of earthquake engineer-
ing, so vital to the future development of the country, could be
centralized and will, no doubt, be working in collaboration with the
existing international centers.

Thanks and acknowledgements are due to the valuable assistance
rendered by the Japanese scientist, Prof. T. Naito and Prof. T. Hagiwara
during their visit to Iran and the significant results obtained through
their investigations and the subsequent recommendations on the building
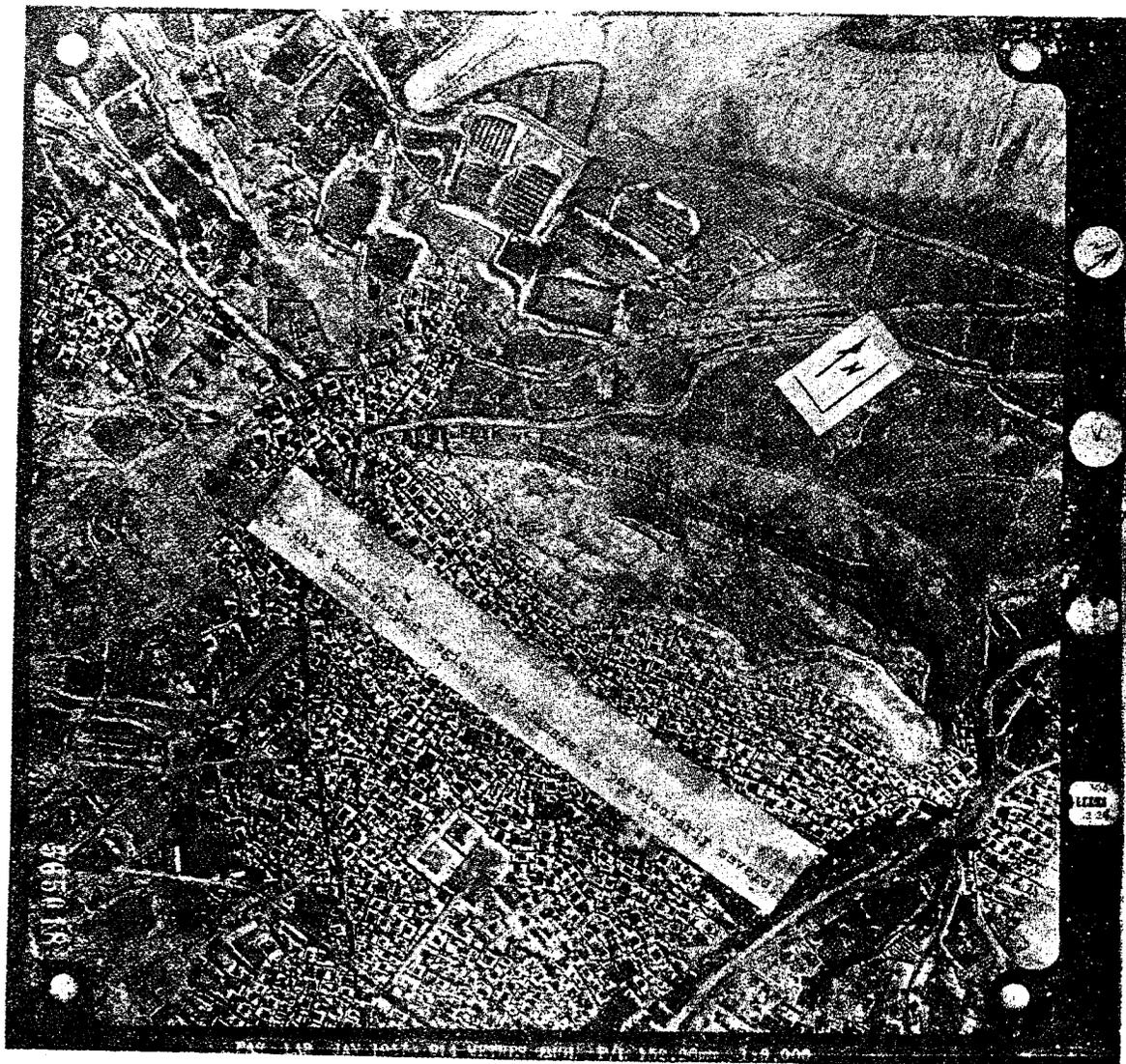design in seismic regions of the country.

Photo. № 1
Aerial photograph of the city of Lar before the shock.
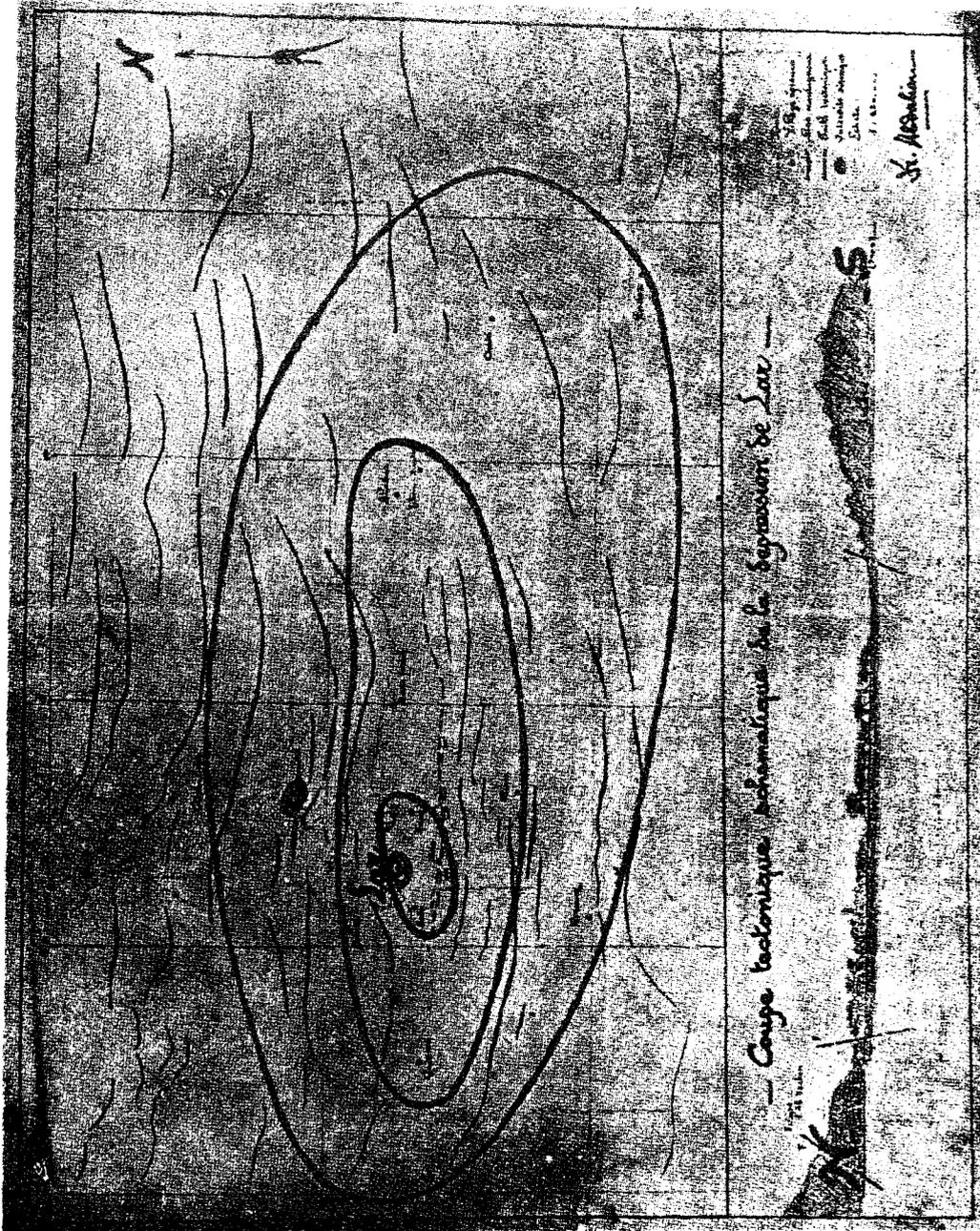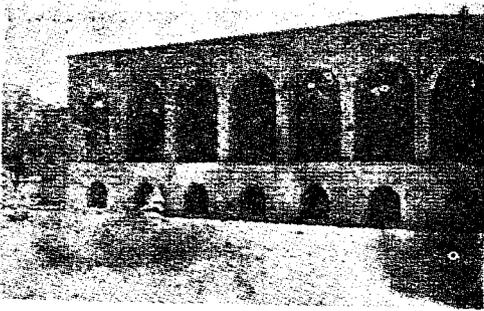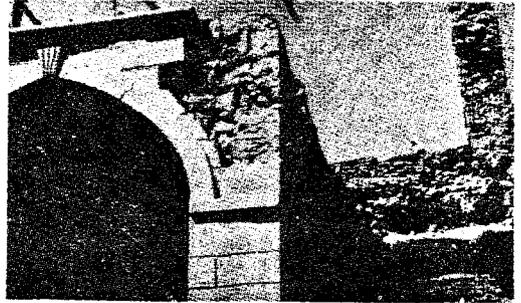The photograph was taken by the Iranian Air Force.

Fig. 1
Isoseismal lines of the Lar Earthquake of 24th, April 1960, and the geological cross-section of the Lar Valley.
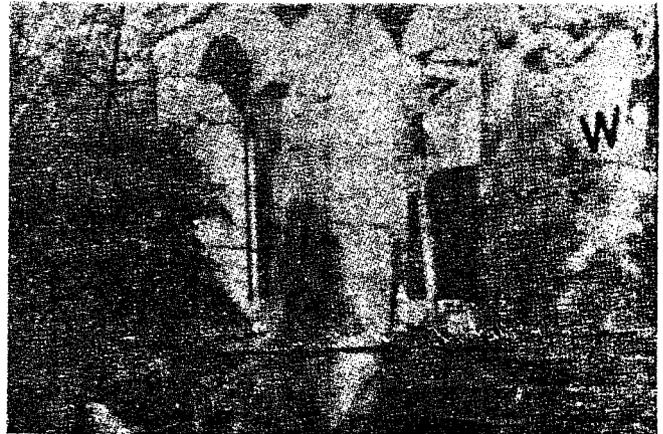
Example of the buildings which were properly constructed and have survived the shock.

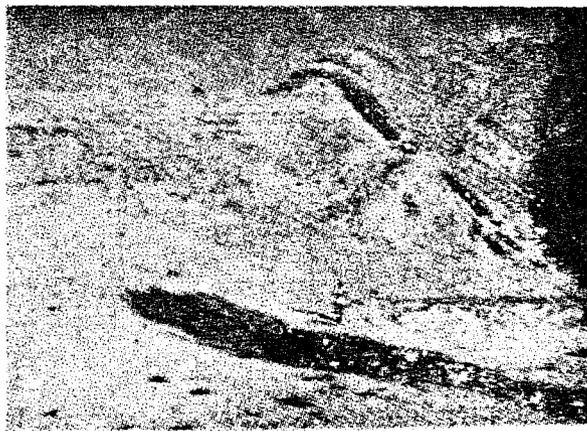Example of the buildings which were properly constructed but damaged.

Cracks on the wall

Example of the buildings which were poorly constructed and damaged.

Example of the buildings which were poorly
constructed and severely damaged.

Small landslide on the hill in the vicinity
of the town.

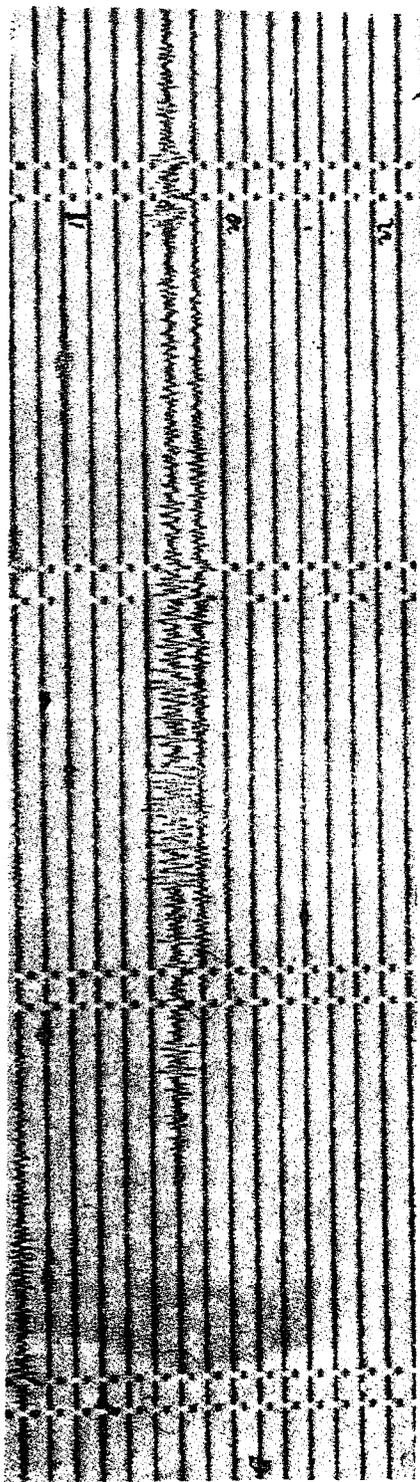Fissures on the ground in the vicinity of
the town.

Seismogram of 1st Main Shock register-
ed at Tehran Station.
$\triangle$ is about 930 km.
Seismometer: Stuttgart Ililar type with
transistor amplifier
T_o and T_g 1.1 sec and 0.25 sec respec-
tively
Maximum magnification 15,000
Size reduction: 4/10

Component: N-S
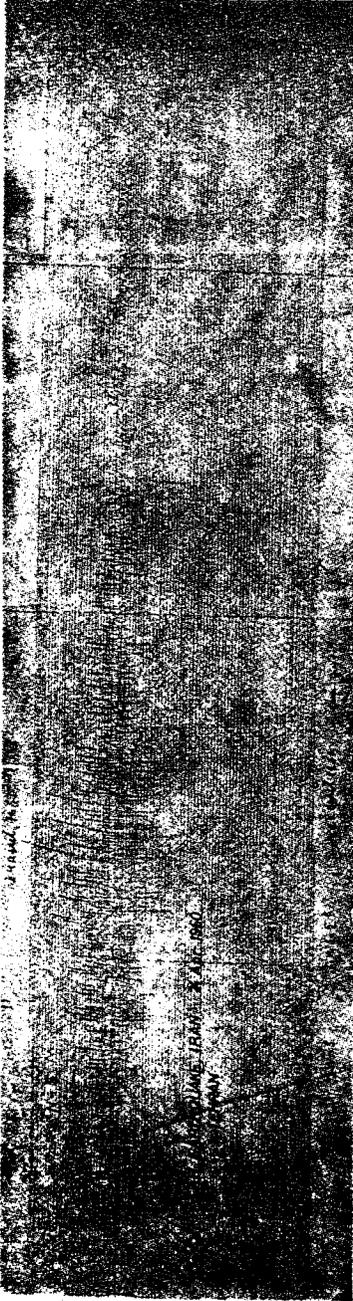
Component: E-W
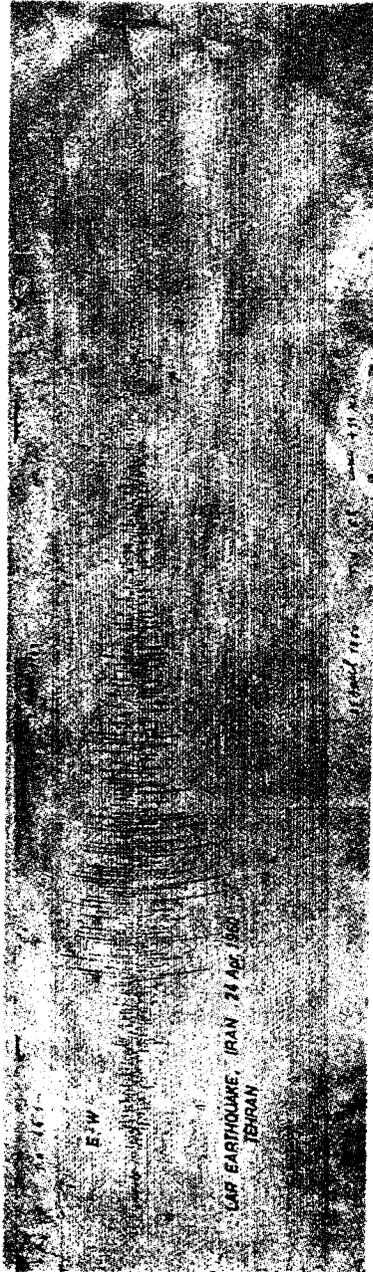
Example of Aftershocks registered at Shiraz Station.
$\triangle$ is about 280 km. Seismometer: Electromagnetic type.
T_o and T_g: 1.1 sec and 0.45 repectively
Maximum magnification: 94,000. Size reduction to original size: 1:1
Component: N-S. Magnitude of the first shock in this seismogram: 4.0
Magnitude of the second shock: 3.7

Fig.3
Summation curve of the number of aftershocks.
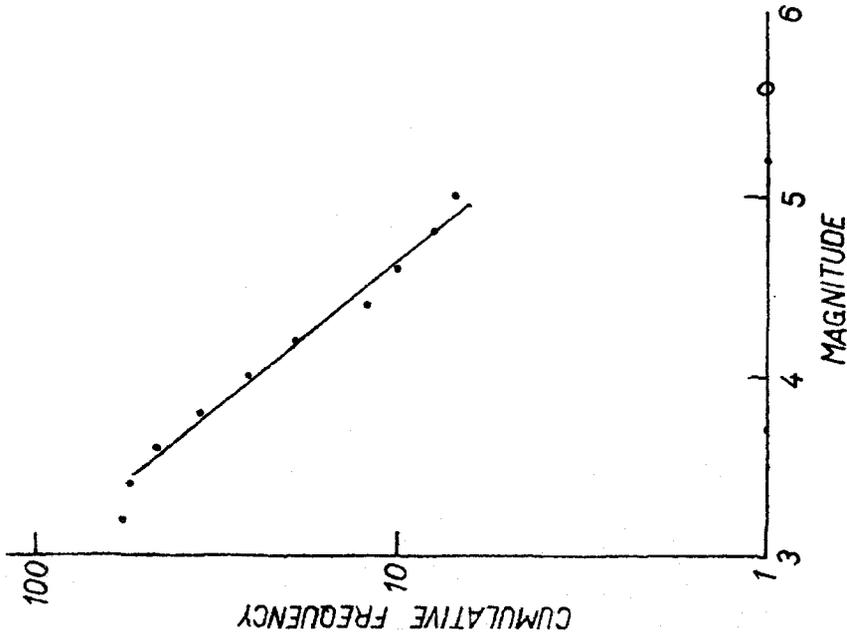Material used covers only till 18th of May.

Fig. 2
Cumulative frequency of aftershocks with respect
to magnitude. Material used covers only till 18th
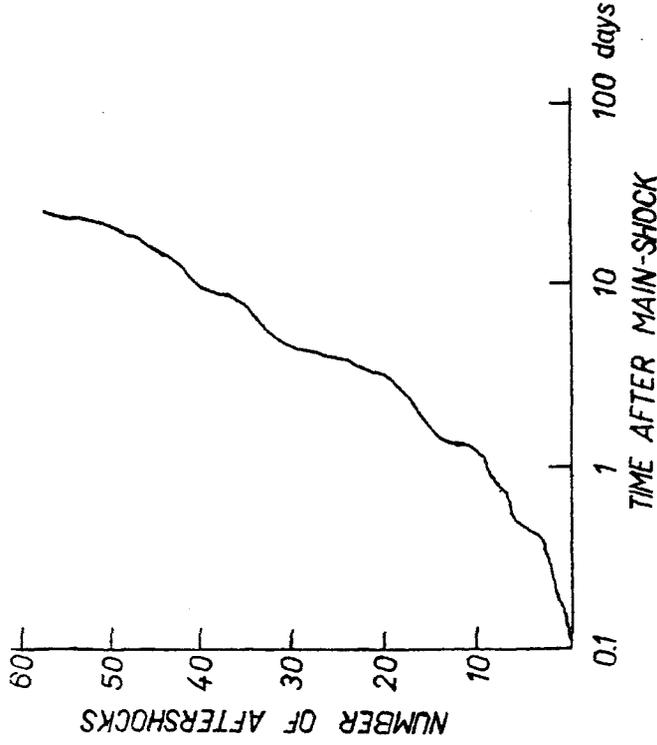of May. White circle shows the magnitude of the
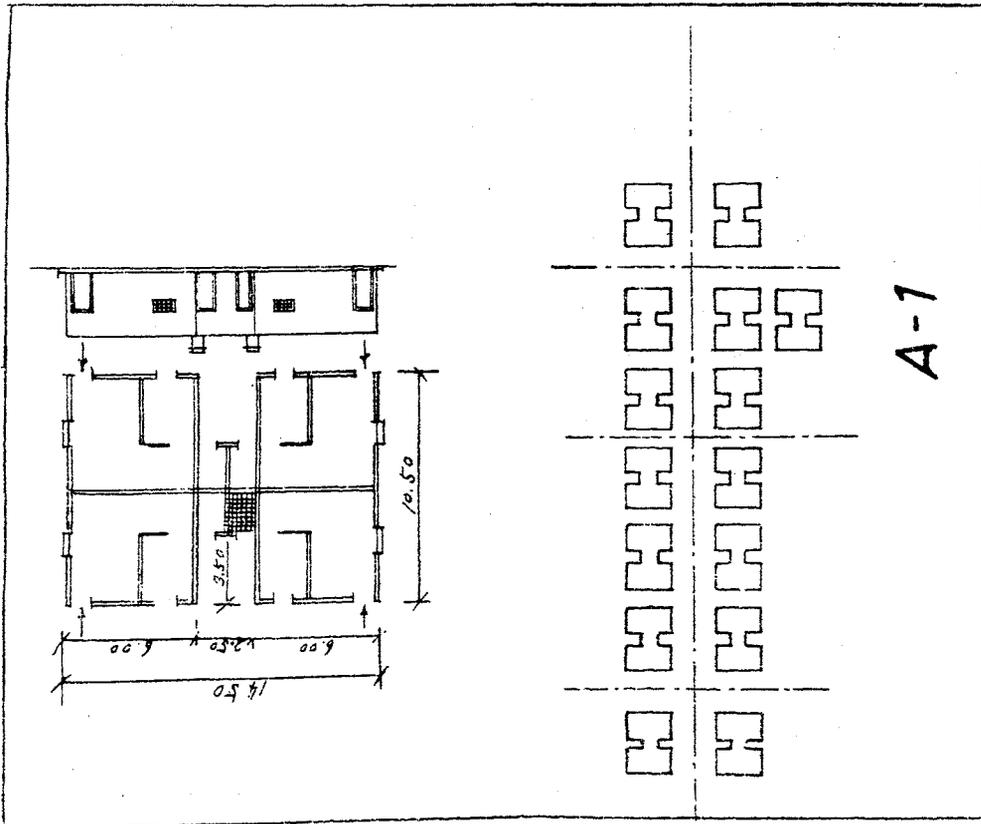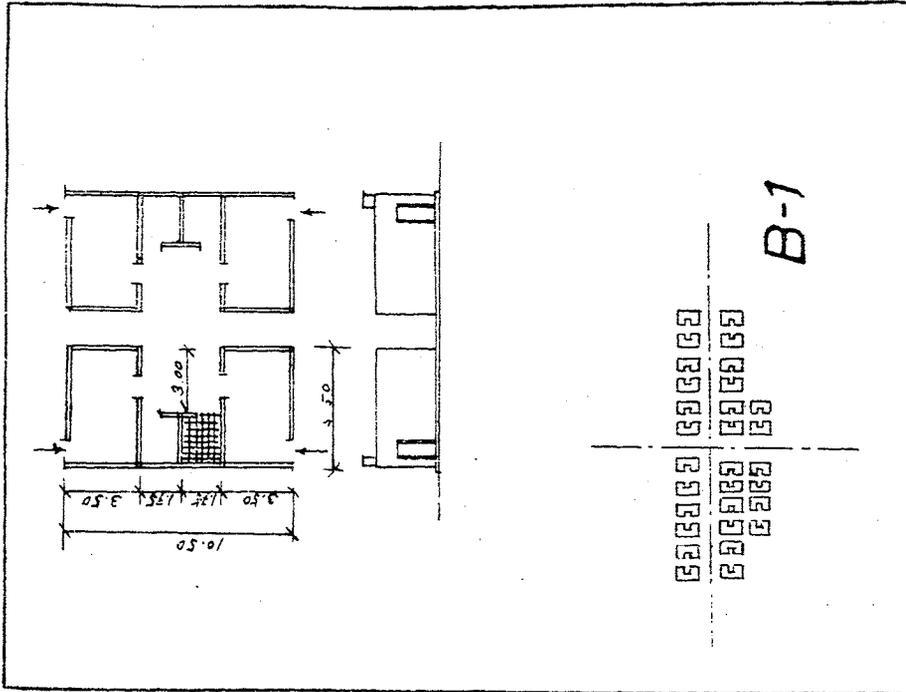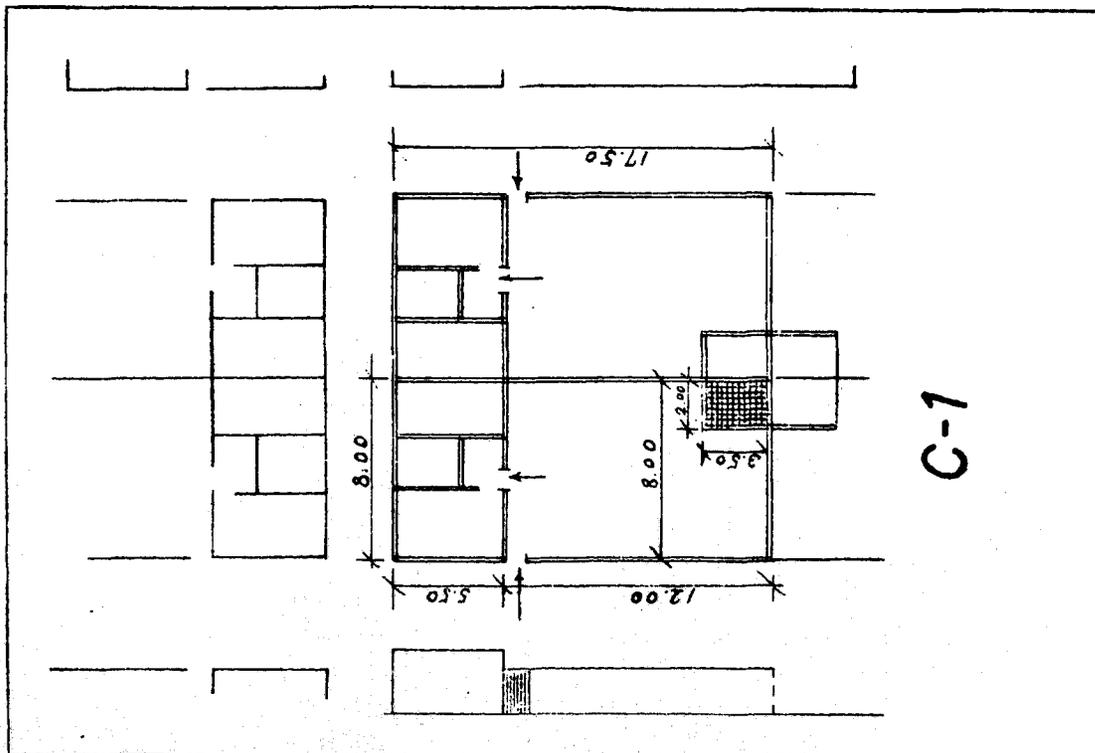main shock.

D-1

C-1
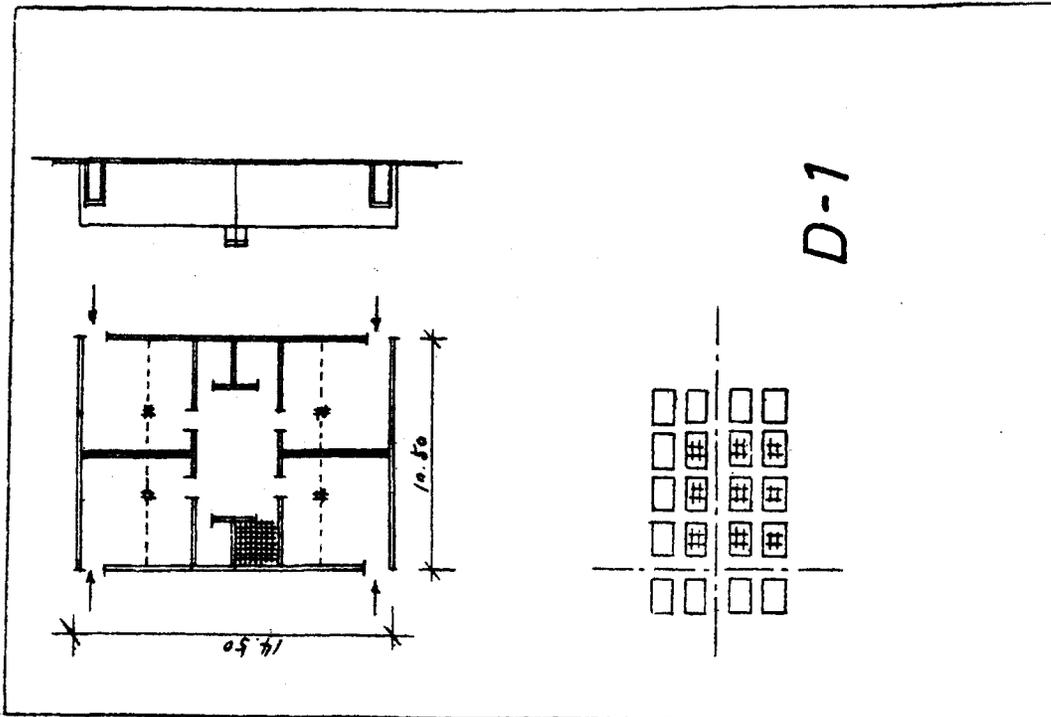
Table of After shocks Registered at Shiraz

Date	Time GMT h m	Magnitude	Time interval from main shock (days)	Date	Time GMT h m	Magnitude	Time interval from main shock (days)
April				29	00 08	3.4	4.5
24	16 54	4.2	0.19	29	07 55	4.3	4.8
24	18 46	3.8	0.27	29	12 23	3.8	5.0
24	22 09	4.2	0.41	29	23 52	3.8	5.5
24	22 45	3.4	0.43	May			
24	23 24	3.3	0.46	1	00 52	4.6	6.5
25	00 12	3.5	0.50	1	22 56	3.6	7.5
25	06 13	4.3	0.75	2	06 06	3.9	7.7
25	07 01	3.7	0.78	2	22 49	5.0	8.4
25	17 16	3.6	1.2	3	05 35	3.7	8.7
25	19 17	4.0	1.3	3	06 59	5.0	8.8
25	19 38	3.7	1.3	3	08 18	4.2	8.8
25	19 50	3.6	1.3	6	20 27	3.8	12
25	20 27	3.8	1.3	7	04 32	3.8	13
25	23 01	3.5	1.4	7	17 47	3.7	13
26	04 54	4.4	1.7	10	06 08	4.0	16
26	09 00	3.5	1.9	10	19 47	3.5	16
26	20 40	3.3	2.3	10	21 53	5.0	16
27	06 53	3.7	2.7	10	22 03	3.9	16
27	15 47	3.8	3.1	11	15 54	4.0	17
27	17 40	5.2	3.2	12	00 41	4.0	18
27	18 04	3.5	3.3	15	03 02	4.5	21
27	18 10	4.7	3.3	15	17 25	3.7	21
27	22 47	3.7	3.4	16	05 29	4.1	22
28	05 57	4.8	3.7	17	01 03	3.5	23
28	07 08	4.0	3.8	17	02 53	5.0	23
28	13 01	4.1	4.0	17	06 40	4.3	23
28	21 16	3.6	4.4	18	08 41	5.1	24
28	22 09	3.2	4.4	18	14 00	5.0	24
28	22 16	3.7	4.4	18	20 35	4.3	24