

MAXIMUM INTENSITY, ISOSEISMAL AND INTENSITY ZONE MAPS OF IRAN (4th CENTURY B.C. TO 1977)

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ABSTRACT

The real extent of earthquake shaking can be estimated from the isoseismal maps rather than from the maps of epicentres. The first Intensity Zone Maps of Iran (4th century B.C. to 1900; 1900–1977; and 4th century B.C. to 1977) based on documented felt data, and the Isoseismal Map of Iran, are presented in this paper.

INTRODUCTION

Usually a greater density of epicentres of the seismicity maps is interpreted as indicative of greater seismicity. Epicentral location maps however sometimes be misleading, since these depend on the distribution of seismological networks in the region, which in most cases is not uniform (see Berberian, 1977, report No. 3, this volume). Seismicity maps based on intensity isoseismals give a better indication of the real extent of strong shaking.

The intensity data establishes some understanding of the level of damage which can be expected to occur in a given region. Certainly such information is invaluable towards solving the problem of assigning seismic risk zones for a country. The intensities can indicate broadly the extent of ground shaking and, by using empirical relationships, structural designers can make use of this information in the absence of more

reliable data. However, this practice is not recommended where avoidable, because the correlations between intensity and ground acceleration have a large scatter and selection of a suitable value of acceleration is merely a matter of judgement (Krishna et al. 1976).

From the isoseismal maps it is possible to estimate the real extent of earthquake shaking. One of the most basic problems in assigning appropriate intensities for Iranian earthquakes involves the use of the Modified Mercalli Intensity Scale (MMI) to describe damage to Iranian constructions. The interpretations of various authors when applying this scale to Iranian earthquakes have produced quite different results for the same earthquake. For example, compare the six different isoseismal maps of the Dasht-e-Bayaz earthquake of 31 August 1968 (Fig.1.); the four isoseismals of Buyin Zahra earthquake of 1 September 1962 (Fig. 2); the three isoseismal maps of Farsinaj earthquake of 13 December 1957 (Fig. 3); or the three maps for the Sangechal (Fig. 4); and two isoseismal maps for the Nahavand earthquake of 16 August 1958 (Fig. 5).

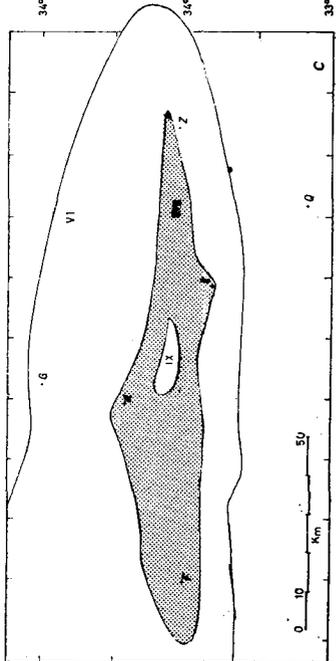
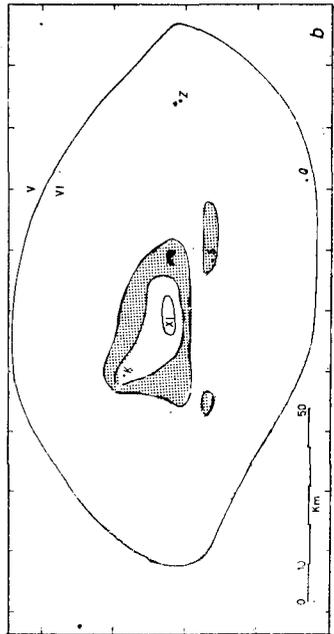
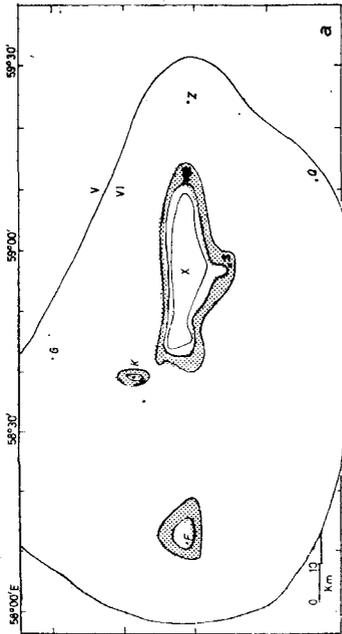
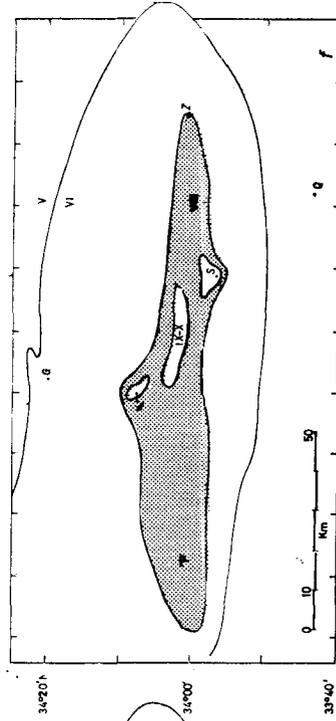
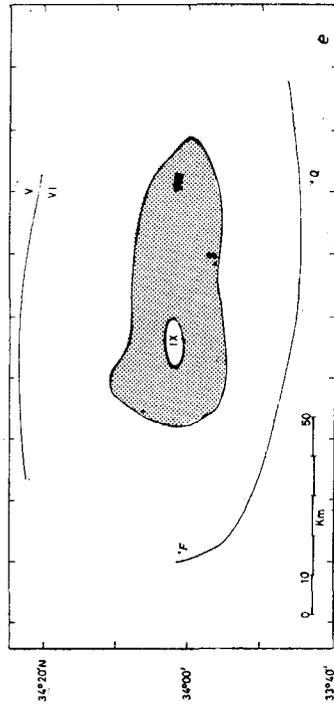
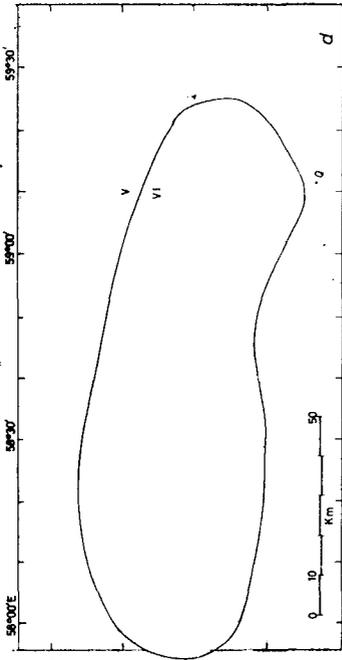
Ambraseys (1963) has attempted to correlate the scale with local Iranian construction methods but the diversity of method in such a large country renders the correlation almost impossible to apply. In any case, the resulting intensity steps assigned in the field in Iran may not correspond precisely in terms of ground shaking to similar steps in California or elsewhere. It is, however, apparent that investigators are aware of the difficulties in applying the Modified Mercalli Scale in Iran and have attempted to minimize differences.

The scope of this report is to present such earthquake intensity data as could be found for the regions of Iran. All the existing isoseismals have been gathered and presented on a new map on the basis of the Modified Mercalli Intensity Scale. The assignment of the intensity grades is necessary in order to standardize the data and thereby provide the opportunity for a regional division of the country on the basis of intensity zones.

Only a limited number of the recorded earthquakes have been identified by both instrumental and non-instrumental data in Iran, but these identifications are usually based on a small number of observation points (see Table 1 and 2, report No. 3, this volume). Although this small number of intensity reports per earthquake has some value, the ultimate situation would be to have intensity reports from a great number of locations uniformly distributed about the hypocentre.

Fig. 1. Comparison of isoseismal maps for the Dasht-e-Bayaz earthquake of 31 August 1968. a: Bayer et al. 1969, b: Inst. Geoph. University of Tehran 1968, c: Eftekhari-Nezhad et al. 1968, d: Pakdaman 1968, e: Moinfar 1969, f: Gansser 1969. Outer limit is between isoseismals V and VI. Shaded area is from VIII to IX. Central figure is maximum intensity proposed. F: Ferdows, G: Gonabad, K: Kakhk, Q: Qaen, Z: Zigan (after Tchalenko and Ambraseys 1973).

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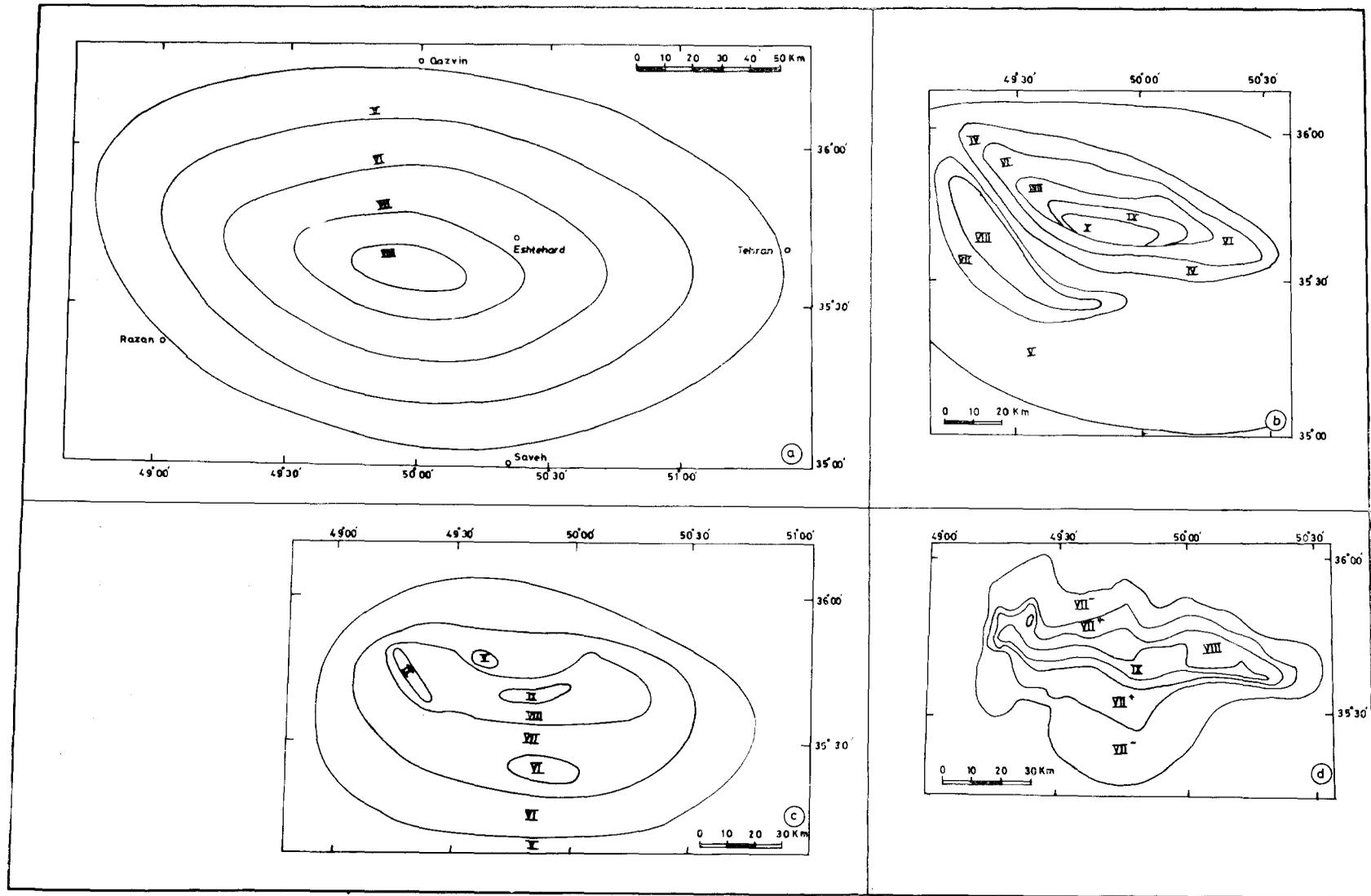


Fig. 2. Comparison of isoseismal maps for the Buyin Zahra earthquake of 1 September 1962. a: Mohajer and Pierce 1963, b: Abdalian 1963, c: Omote et al. 1965, and d: Ambraseys 1963.

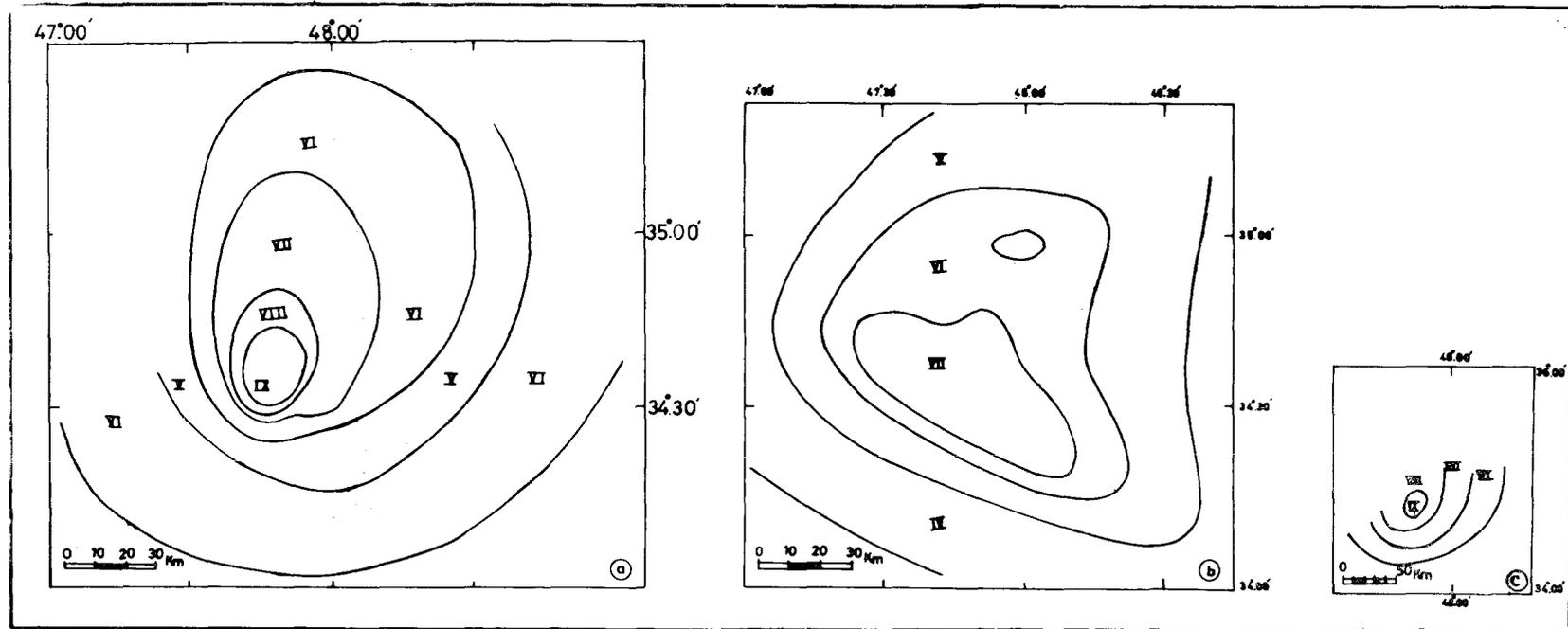


Fig. 3. Comparison of isoseismal maps for the Farsinaj earthquake of 13 December 1957. a: Peronaci 1958, b: Ambraseys et al. 1973, and c: Hagiwara and Naito 1959.

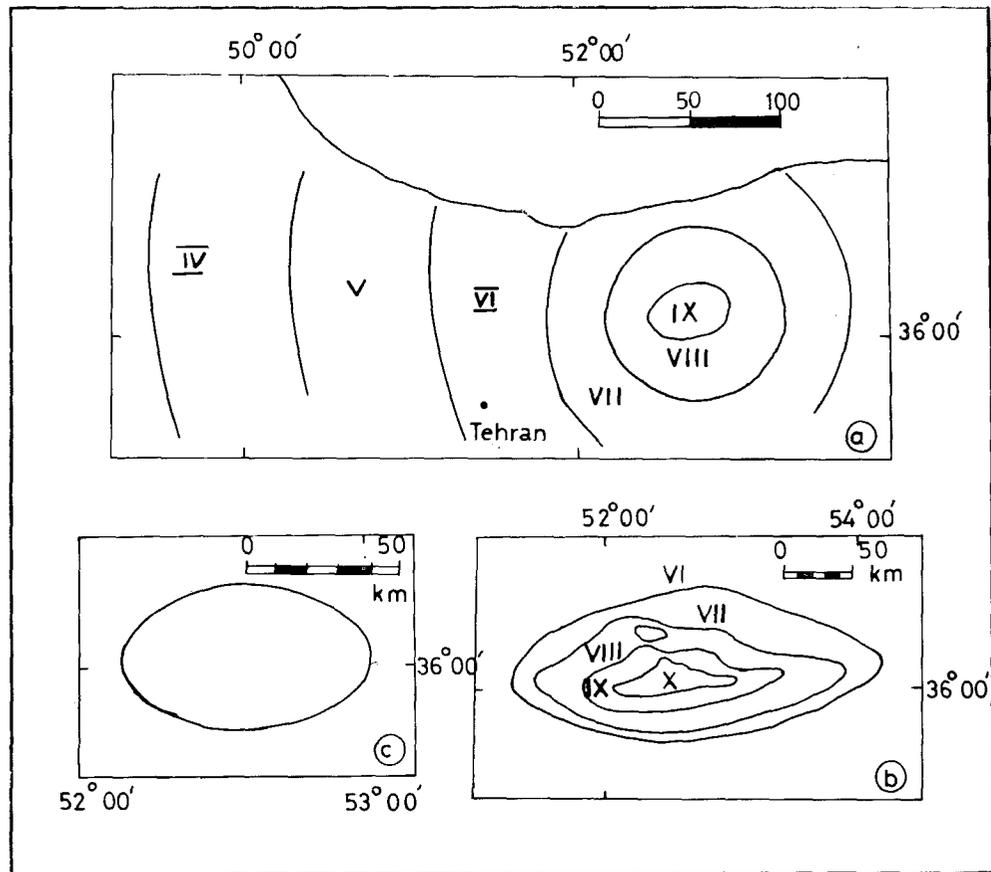


Fig. 4. Comparison of isoseismal maps and epicentral region map of Sangechal earthquake of 2 July 1957, a: Hagiwara and Naito 1959, b: Gansser 1969, and c: Tchalenko 1974.

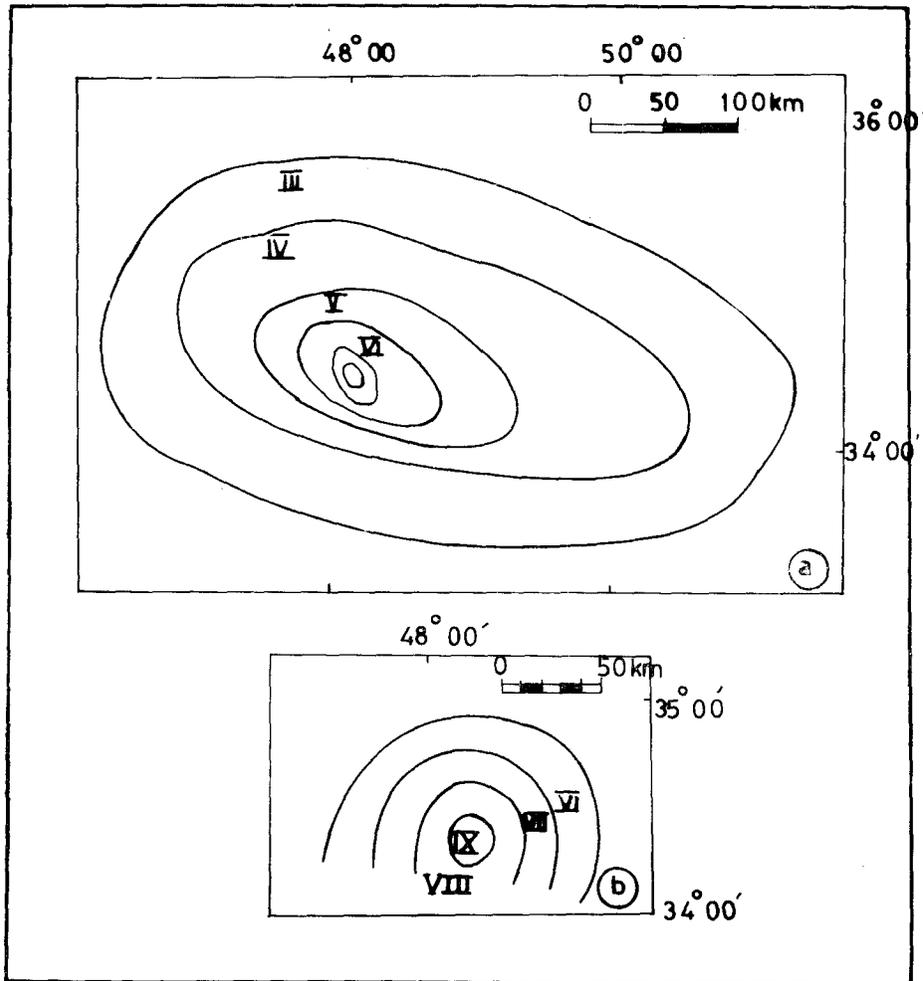


Fig. 5. Comparison of isoseismal maps of Nahavand earthquake of 16 August 1958. a: Ambraseys and Moinfar 1974, and b: Hagiwara and Naito 1959.

In some cases in Iran, only the epicentral intensity is available and not the entire isoseismal map. In these cases the macroseismic epicentres (taken as the centre of the area of maximum destruction) of the shocks have been plotted on the map and the related intensity (MM) is given.

The first isoseismal map in Iran was made by Abdalian (1953) for the Torud earthquake of 12 February 1953 (Fig. 6). Before that no reliable isoseismals were prepared for major earthquakes. Peronaci (1958) presented the isoseismal map of Farsinaj 13 December 1957 earthquake. In 1959 Hagiwara and Naito gave three approximate isoseismals for the Sangechal earthquake of 2 July 1957, the Farsinaj earthquake of 13 December 1957, and the Nahavand (Firuzabad) earthquake of 16 August 1958 (Fig. 7). Abdalian (1960) published his isoseismal map of the Lar 24 April 1960 earthquake (Fig. 8). Four different isoseismal maps have been published for the Buyin Zahra

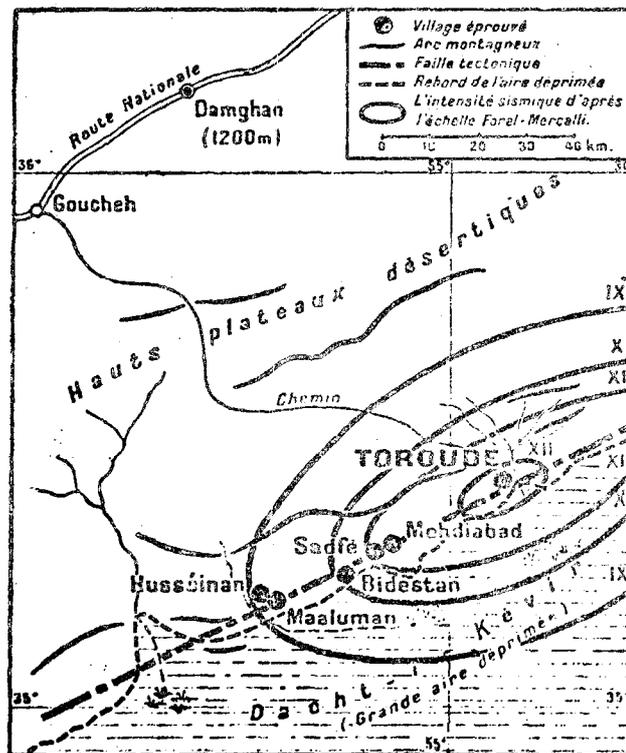


Fig. 6. Isoseismal map of the Torud 12 February 1953 earthquake (after Abdalian 1953).

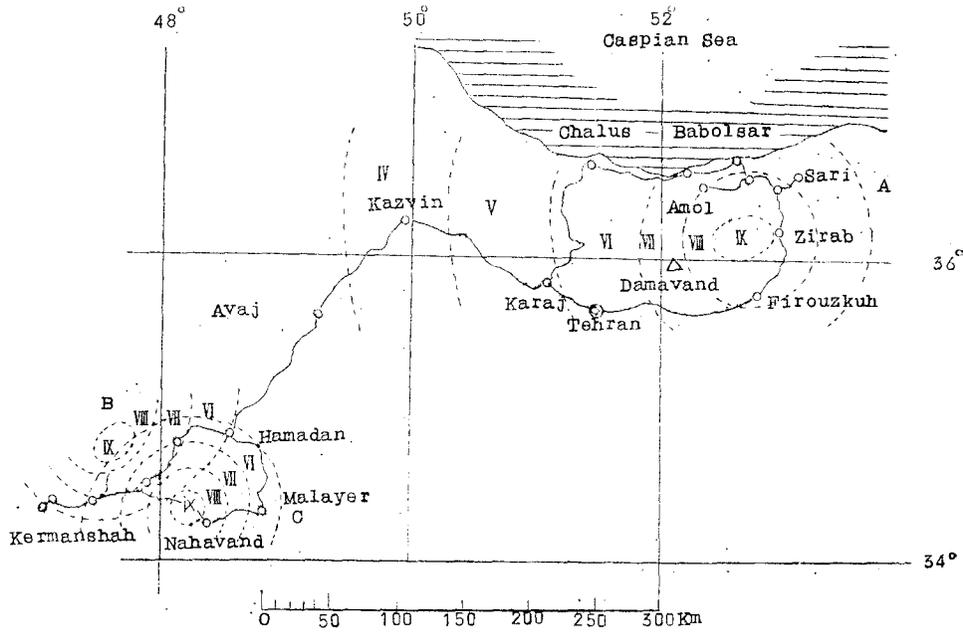


Fig. 7. Isoseismal lines of the Sangechal 2 July 1957 earthquake (A), the Farsinaj 13 December 1957 earthquake (B), and the Nahavand (Firuzabad) 16 August 1958 earthquake. Open small circles are observed route (after Hagiwara and Naito, 1959).

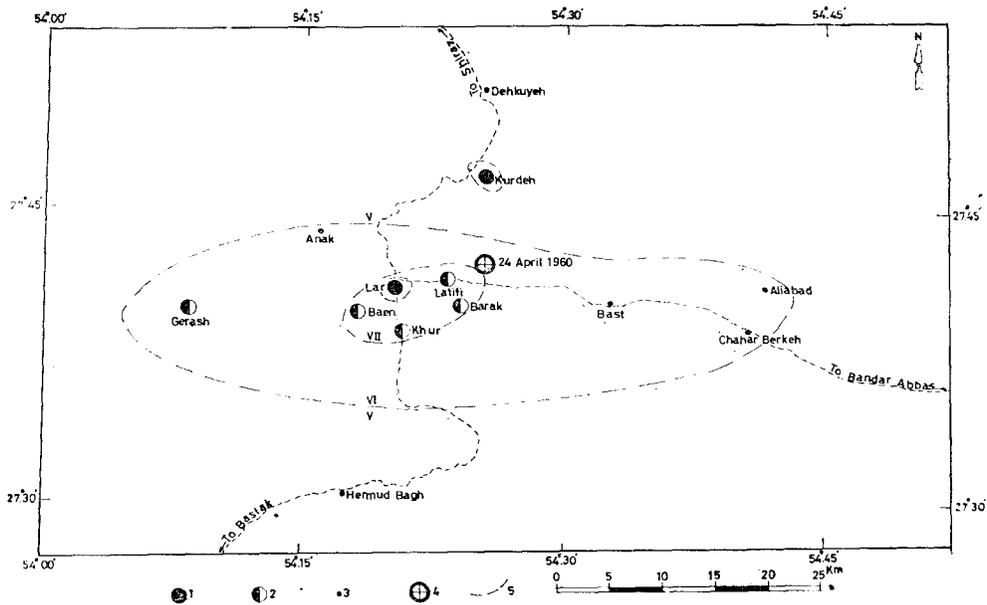


Fig. 8. Isoseismal map and epicentral region of 24 April 1960 Lar earthquake. 1. extensive damage, 2. slight damage, 3. insufficient data, 4. instrumental epicentre, 5. isoseismal lines (taken from Abdalian 1960), (after Berberian, 1976).

earthquake of 1 September 1962, by Ambraseys (1963), Abdalian (1963), Mohajer and Pierce (1963) and Omote et al. (1965) (Fig 2). Ambraseys (1963) gave an approximate isoseismal map for a small shock south of Torbat Heydariyeh which took place on 5 October 1962. Ambraseys (1965) presented a preliminary seismic zoning map for Semnan - Kermanshah region (Fig. 9). There are six isoseismal maps for the Dasht-e-Bayaz earthquake of 31 August 1968 (Fig. 1). The isoseismals are published by Eftekhari-Nezhad et al. (1968), Pakdaman (1968), Bayer et al. (1969), Moinfar (1969), Gansser (1969) and the Institute of Geophysics (1970). For the Bedavli (west Maku) earthquake of 29 April 1968, only one isoseismal map was given by Nabavi (1970) (Fig. 10). In 1970, Sobouti and Eshghi presented an isoseismal map for the Qarnaveh 30 July 1970

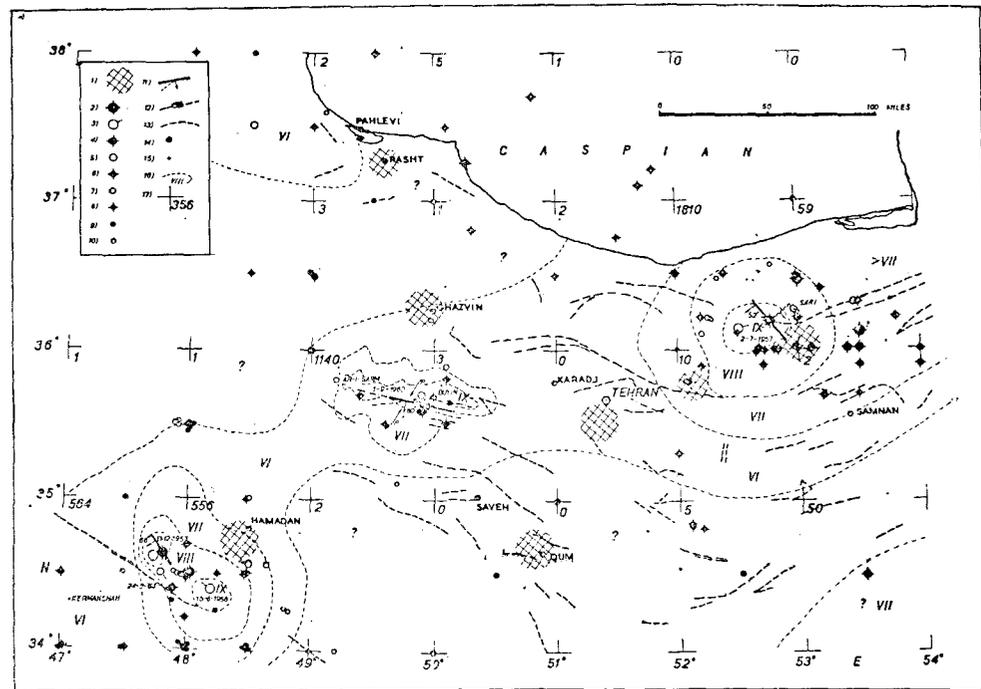


Fig. 9. Preliminary seismo-tectonic plan of the Semnan-Kermanshah zone. (1) Regions devastated by earthquakes between 850 AD and 1872. (2), (4), (6), (8), Microseismic epicentres of intensity group II, III, IV, and V respectively. (9) Microseismic epicentre of unknown intensity group. (3), (5), (7), (10), Macroseismic epicentres of intensity groups II, III, IV, and V respectively; small lines point to corresponding microseismic epicentres. (11) Fault-plane solution data. (12) Fault-breaks from field evidence. (13) Major regional fault trends. (14) Towns. (15) villages, settlements. (16) Maximal isoseismals for the period 1933-1963, (17) Unit energy values in ergs 10^{16} per year per 100 sq. kms. Intensities in MM (After Ambraseys 1965).

earthquake (Fig. 11). Haghypour et al. (1972) published the isoseismals of the Qir earthquake of 10 April 1972 (Fig. 12). Ambraseys et al. (1973) presented a revised isoseismal map for the Farsinaj 13 December 1957 earthquake, and Ambraseys and Moinfar (1974) published the isoseismals of the Nahavand (Firuzabad) earthquake of 16 August 1958. For the Khurgu earthquake of 21 March 1977 and the Naghan earthquake of 6 April 1977 two isoseismal maps were given by Berberian and Papatamatiou (1977) and Berberian and Navai (1977; Figs. 13 and 14).

For some Iranian earthquakes the epicentral region, together with some information on the type of destruction in different villages, have been presented on maps by the investigators. These maps of the epicentral regions were collected and published by Berberian (1976). For some of these shocks for which enough data were available, approx-

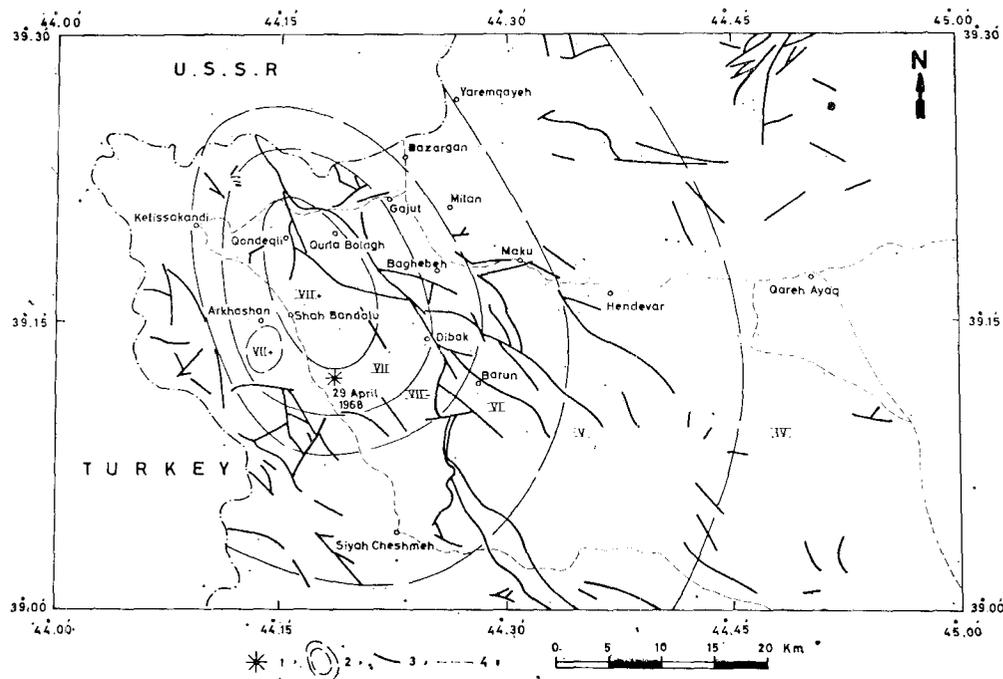


Fig. 10. Isoseismal map and epicentral region of Bedavli (west Maku) 29 April 1968 earthquake (isoseismal lines after Nabavi 1970); after Berberian 1976.

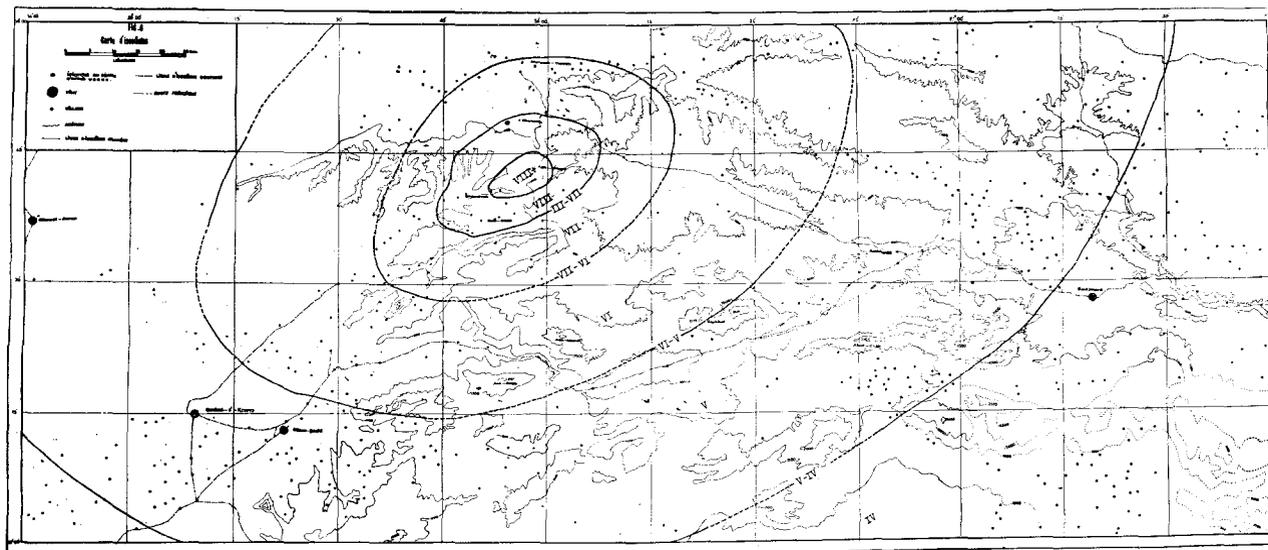


Fig. 11. Isoseismal map of the Qarnaveh 30 July 1970 earthquake (after Sobouti and Eshghi 1970).

imate isoseismals were drawn to give some idea of the epicentral region. The problem of intensity assessment in epicentral regions of Iranian earthquakes requires much further detailed study.

Based on the all data mentioned above, two sets of maps are presented in this report for the first time: first the "Isoseismals of Iran" (1900–1977), which has been prepared from different sources; and second, the "Intensity Zone Map of Iran" (4th century B.C. to 1900; 1900–1977; and 4th century B.C. to 1977) which not only includes the recorded isoseismal maps but covers the maximum intensities of different shocks (on MMI) which have no isoseismal lines. In this case the location of the Macroseismic Epicentres (Berberian 1977, report No. 3, this volume) have been chosen instead of the instrumental epicentres.

On the "Isoseismal Map of Iran" (1900–1977), about 52 individual isoseismal maps of different twentieth century earthquakes have been plotted based on the Modified Mercalli Intensity Scale. Unfortunately this number is very low for the earthquakes of the twentieth century of a large seismic country as Iran.

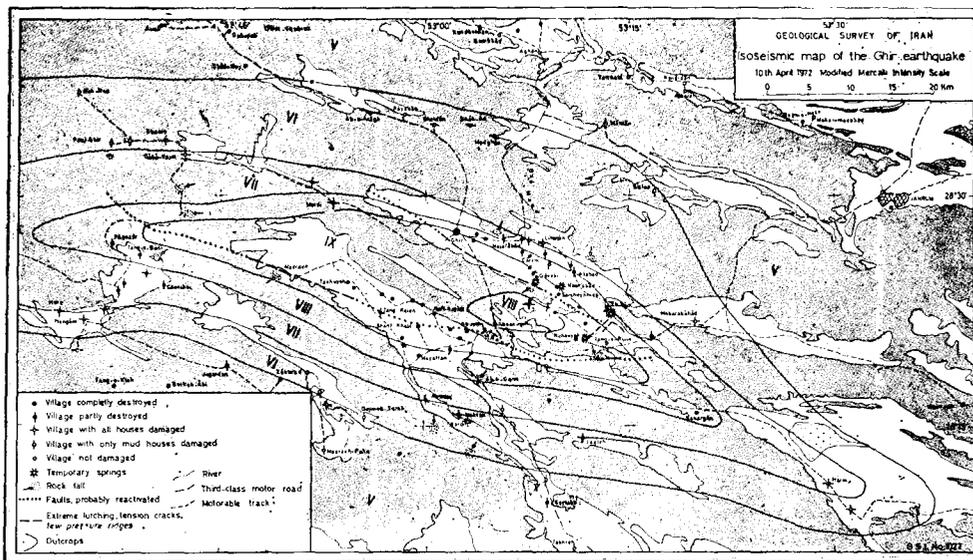


Fig. 12. Isoseismal map of the Qir earthquake of 10 April 1972 (after Haghypour, Iranmanesh and Takin, 1972).



Fig. 13. Isoseismal map and epicentral region of Khurgu (north Bandar Abbas) 21 March 1977 earthquake. showing the main tectonic and damage features. The intensity grades correspond to the Modified Mercalli Scale ($I_0 = VIII+$), (after Berberian, Papastamatiou 1977). 1. Severely damaged, 2. Considerable damage, 3. Light damage, 4. The shock strongly felt, 5. Fault, 6. Anticline axes, 7. Isoseismals of Naghan 21 March 1977 earthquake, 8. Isoseismals of Sardareh destructive aftershock, 9. Homoz Salt dome.

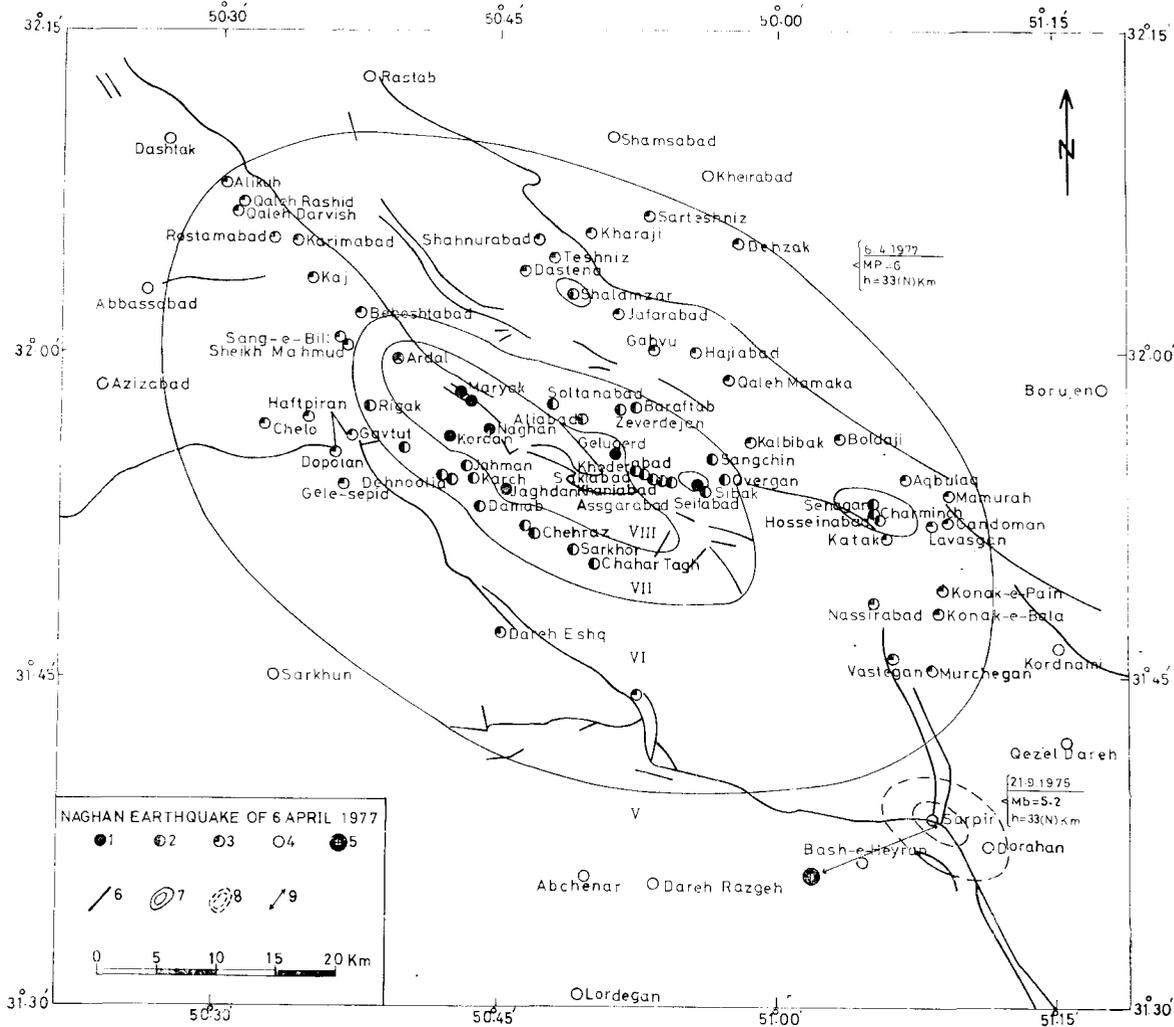


Fig. 14. Isoseismal and epicentral region map of the Naghan (south Shahr-e-Kord) earthquake area showing the main tectonic and damage features. The Intensity grades correspond to the Modified Mercalli Scale ($I_0=VIII$).

1. Severely damaged, 2. considerable damage, 3. light damage, 4. the shock strongly felt, 5. instrumental epicentre, 6. fault, 7. isoseismals of Naghan 6. 4. 1977 earthquake, 8. isoseismals of Sarpir 21. 9. 1975 earthquake, 9. distance between macroseismic and microseismic epicentres (after Berberian and Navai 1977).

The second sets of maps show the distribution of intensity in Iran based on data collected for the 20th century and historical earthquakes. The data are presented on three maps, namely "Intensity Zone Map of Iran" for the periods from 4th century B.C. to 1900, 1900 to 1977, and 4th century B.C. to 1977. It must be recognized, however, that the earthquakes of a 77 year period do not provide an adequate basis for estimating the seismicity of the country. There is little to justify the common assumption that the strongest earthquake known to have occurred in a given area in the past will never be exceeded there.

Only scanty data about some major historical shocks are available. Unfortunately the approximate intensity and corresponding magnitude of these shocks is very difficult to ascertain because of the deficiency of data. Berberian (1977, Table 1, Report No. 3, this volume) has collected some reliable data on historical Iranian earthquakes and has tried to estimate their relative intensities. In this table the approximate macroseismic data of some of the historical earthquakes have been given. Thus the "Historical Seismicity (Pre 1900) Map of Iran" has been prepared.

Based on the Historical Seismicity (Pre 1900) Map of Iran, a new "*Intensity Zone Map of Iran (4th century B.C. to 1900 A.D.)*" was prepared. On this map the country is divided into five seismic zones according to the recorded felt and documented seismic data. The zones are based on the Modified Mercalli Intensity Scale and range from: VIII (and above) to VII, VI and V. Since it is very difficult at this stage to separate the corresponding approximate intensity of the historical earthquakes above VIII (MMI), they have been shown in one zone marked by VIII (see Map No. 2). The regions of the country for which there are no data are categorized in a special zone and given the title: "No information available". The areas included in this zone should not be considered a-seismic; there are simply insufficient reliable historical data for these remote and unpopulated parts of the country.

With the data on Table 2 (Report No. 3 this volume) the first "*Map of Maximum Intensity of Earthquakes in Iran (1900 - 1977)*" has been prepared. The maximum intensities of some of the twentieth century earthquakes are given on this map, based on the Modified Mercalli Intensity Scale. The collected maximum intensities of the earthquakes are divided into six categories ranging from V to X (MMI), (see Map No. 3, and Report No. 3 this volume).

On the basis of the Isoseismal Map of Iran, Maximum Intensity of Earthquakes in Iran (1900-1977) and the first Seismotectonic Map of Iran, the "*Intensity Zone Map of Iran for the period 1900 to 1977*" was prepared. According to this Map, the country is divided into eight zones for the twentieth century based on the recorded and felt seismic data. The zones range from X to III on the Modified Mercalli Intensity Scale.

All the data presented on the above-mentioned maps were gathered together for preparation of a new map named "*Intensity Zone Map of Iran*" (4th century B.C. to 1977 A.D.). Since the estimation of the intensity zones of the historical earthquakes of Iran especially those of VIII and above is difficult at present, so on this map the intensities VIII, IX, X are shown in one category. Therefore, on this map the country is divided into six different zones from Zone 1 (Intensities VIII, IX, X) to zone 6 with intensity of III (MMI). This map represents the level of earthquake

intensities experienced in different parts of Iran from 4th century B.C. to 1977, to the extent permitted by the available data.

The Map shows that Iran has undergone damaging and destructive earthquakes (VIII,IX,X on MMI) in two different continuous zones. The first zone, which has a sine shape, starts from NW Iran (Azarbaijan) and continues towards east to Alborz (south Caspian) and Khorassan (NE Iran), then it changes its E-W direction to a nearly N-S trend and covers the eastern part of the country, going to Baluchestan. The second zone is a continuous linear zone starting from the western part of the country(Iraq border) towards southeast Iran, through the Zagros Active Folded Belt. There are also a few scattered and separate zones of NW-SE trend between the major zones, in the central part of the country.

The Map also shows that the average rate of the destructive earthquakes(VIII, IX,X, on MMI) was higher in Alborz and East Iran than Zagros and Central Iran.



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