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Evaluation of the instrumental and relocated epicentres of Iranian earthquakes

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Summary. Comparison of the instrumentally located and relocated epicentres (ISS, BCIS, USGS, Nabavi (IGS), Nowroozi, etc.) of Iranian earthquakes with the macroseismic epicentres of the largest magnitude and best studied earthquakes, reveals deficiencies in the determination of the earthquake epicentres. The errors of determination appear to be random rather than consistent and are substantially larger than those quoted by the various agencies or individuals. This suggests that the incompatibility of seismicity and tectonic structures revealed by seismotectonic maps is at least partly due to location errors.

It is important to recognize the active trends in a seismic country. In Japan and California earthquake location has increasingly been demonstrated to correlate with geological structures and there is little disagreement between epicentres determined seismically and by macroseismic information (ground deformation, damage areas, etc.). Iran has a high density of Quaternary faults and frequent destructive earthquakes which reactivate some existing faults at the surface. Several attempts have been made by preparing the epicentre and seismotectonic maps to correlate distribution pattern of epicentres with geological features and tectonic lineaments (McKenzie 1972; Nowroozi 1971, 1972, 1976; Berberian 1973, 1976, 1977). Whenever a new list of instrumental or relocated epicentres becomes available, the temptation is to plot them on a geological or tectonic background map and to draw seismotectonic conclusions. Unfortunately these efforts have not led to as great an understanding of the seismotectonics of the country.

A feature of Iranian seismicity is that many instrumentally determined epicentres fall at a considerable distance from the area of maximum ground deformation and damage. The distance is commonly much greater than the estimated location error. From this one either must conclude that some unknown process causes epicentres and damage areas to be separated (in contrast to the California and Japanese experience) or that the instrumental epicentres are in greater error than suggested by the quoted location error.

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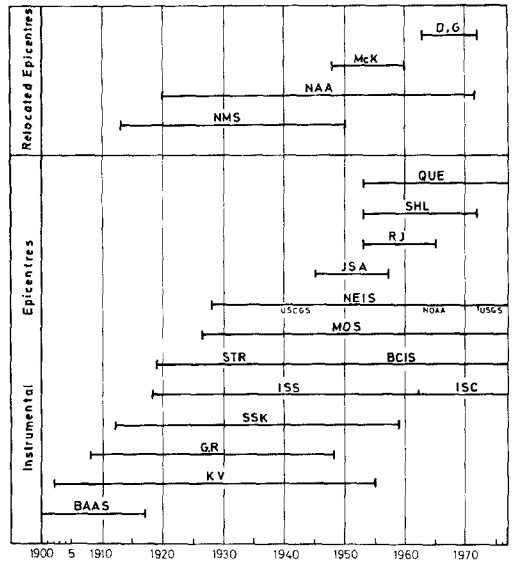

Figure 1. Various seismological agencies and individuals together with their operational or coverage period of Iranian earthquakes. BAAS: British Association for the Advancement of Science. KV: Karnik 1969. G, R: Gutenberg & Richter (1954). SSK: Savarenski, Soloviev & Kharin 1962. ISS: International Seismological Summary, UK. ISC: International Seismological Centre, UK. STR: Strasbourg Observatoire Seismologique, France. BCIS: Bureau Centre Internationale Seismologique, France. MOS: Moscow Institute Earth Physics, USSR. USCGS: United States Coast and Geodetic Survey. NOAA: National Oceanic and Atmospheric Administration, USA. USGS: United States Geological Survey. NEIS: National Earthquake Information Service, USGS. JSA: Jesuit Seismological Association. RJ: Rothé 1969. SHL: Shillong, India. QUE: Quetta, Pakistan. NMS: Nabavi (1972) and IGS files Edinburgh. NAA: Nowroozi (1971, 1976). McK: McKenzie (1972). D, G: Dewey & Grantz (1973).

In this study we examine the locating errors on the assumption that the macroseismic determination based on the detailed field study is correct. For this purpose 140 well-studied major twentieth century earthquakes are available which provide a sufficiently large sample to be statistically significant. The various agencies and individuals whose locations have been used are shown in Fig. 1, together with the time period.

For each earthquake the distance from the macroseismic epicentre and the instrumental epicentre is plotted on a map. These maps were used to determine if there was any systematic epicentral shifting. Except for three earthquakes and aftershock sequences (foreshock–mainshock of Salmas destructive earthquake of 1930 May 6; mainshock–aftershock of Penjevin earthquakes of July 27 and 1946 August 17; and Dustabad earthquake of 1947 September 23 and its aftershocks of September 25 and 26) in which location was consistently offset from the macroseismic epicentre, no consistency was found.

The error magnitude of the individual shocks presented by NEIS and ISS–ISC together with their mean values are plotted in Figs 2 and 3. In order to compare the mean error value of the earthquakes located by different agencies reporting the Iranian earthquakes between 1902 and 1978, Fig. 4 is presented. It is clear from these figures that the mean error ranges from 300 km (1918) to 30 km (1963) and the error decreases progressively between 1918 and 1963. Even the commencement of operation of WWNSS (in 1963) produced no immediate improvement, although the error gradually decreases from 30 km (1963) to 15 and 10 km (in 1977) presumably as the number of operational station increased. It is concluded from Fig. 4 that the locations given by SHL, JSA, MOS, QUE and PEK were the most

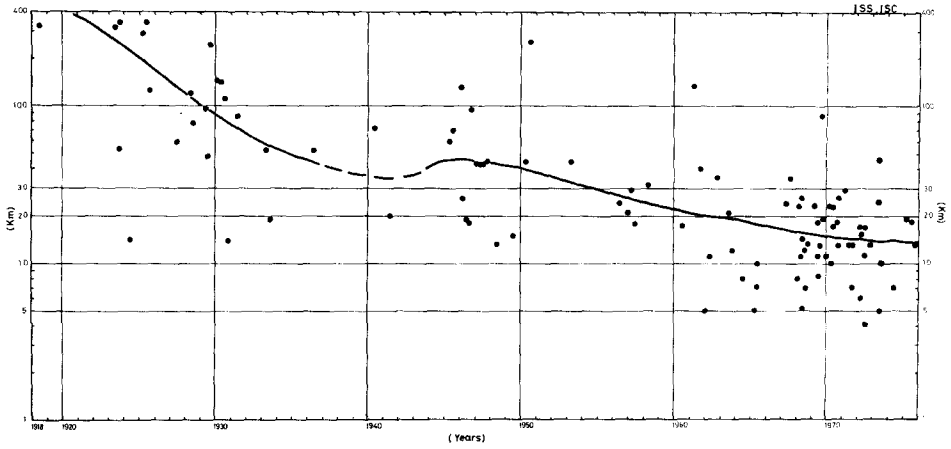

Figure 2. Magnitude of the errors of the individual shocks and the mean error of the earthquakes located by ISS–ISC, with respect to the macroseismic epicentres for the period 1918 to 1975. Shifting from the macroseismic epicentre in km is plotted as ordinate and the time in years as abscissa.

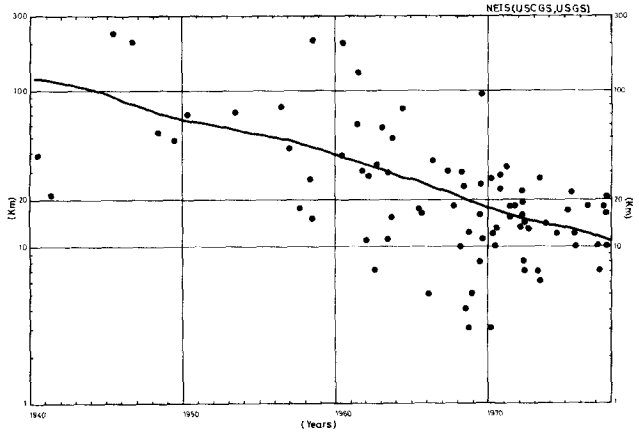

Figure 3. Magnitude of the errors of the individual shocks and the mean error of the earthquakes located by NEIS (USCGS, NOAA, USGS) with respect to the macroseismic epicentres for the period 1940 to 1977. Shifting from the macroseismic epicentre in km is plotted as ordinate and the time in years as abscissa.

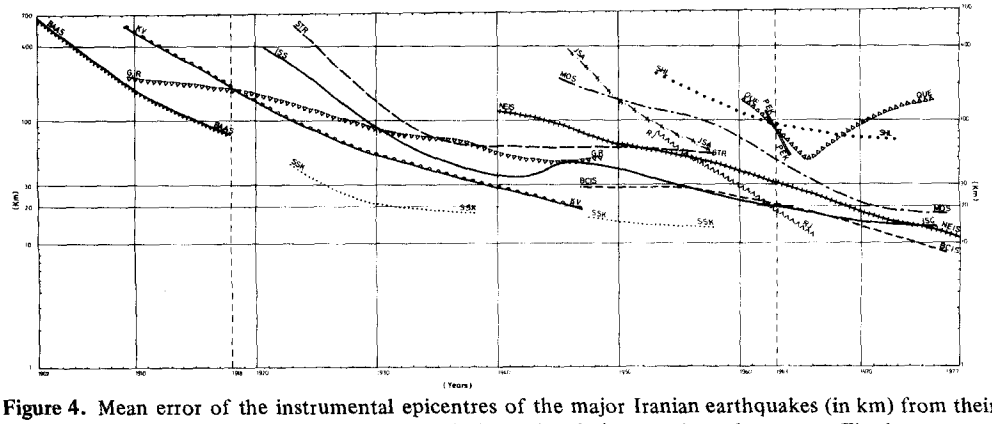

Figure 4. Mean error of the instrumental epicentres of the major Iranian earthquakes (in km) from their macroseismic epicentres for the period 1902 to 1977. Abbreviations used are the same as Fig. 1.

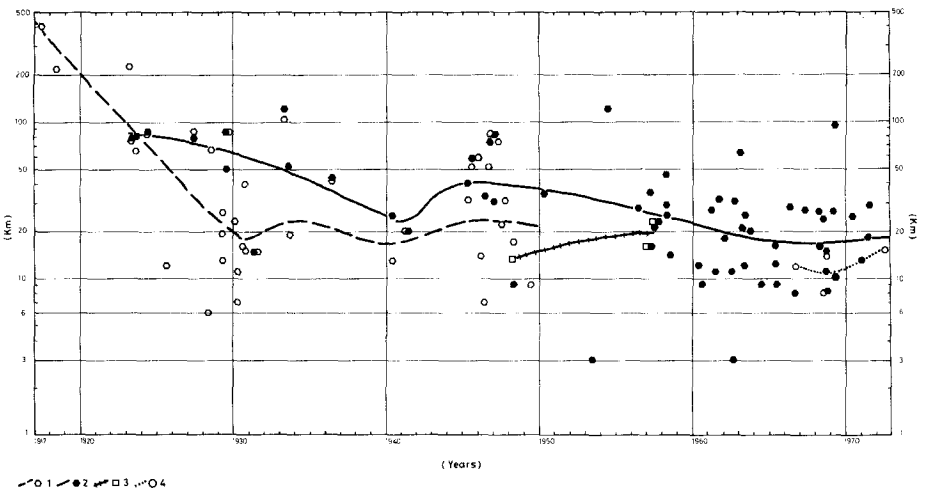

Figure 5. Magnitude of the errors of the individual shocks and the mean error of the relocated epicentres of the major Iranian earthquakes (in km) from their macroseismic epicentres for the period 1917 to 1972. 1 – Nabavi–IGS (1972); 2 – Nowroozi (1971, 1976); 3 – McKenzie (1972); 4 – Dewey & Grantz (1973).

unreliable ones for the Iranian earthquakes because of the relative wide range of errors. These locations seem to be based on the short-period data and are located without using computers.

In recent years a number of attempts has been made to improve epicentral reliability by relocation (Nowroozi 1971, 1976; Nabavi-IGS-1972; McKenzie 1972; Dewey & Grantz 1973; see Fig. 1). It is clear from Fig. 5 and comparing it with Fig. 4, that no obvious improvement has been made. Therefore the relocated epicentres could not provide a better clue in the assessment of the seismic risk evaluation and dividing the country into several seismotectonic provinces in the manner of Nowroozi (1976). Ambraseys (1978) demonstrated that routine computer relocation of pre-1950 epicentres in Iran seldom result in new positions which are much more reliable than the original instrumental location. He added that this is because the early arrival data are generally of such poor accuracy and azimuthal distribution that the epicentre can be resolved only to the average limits given by the data. In this study it has been demonstrated that his argument for the period prior to 1950 also applies subsequently.

Many Iranian earthquakes are reported at depths greater than 90 km (i.e. Nowroozi 1976) and have quoted errors of depth location that suggest that they could not be shallower than 30 km. However events of 1924.02.19 (h = 115 km), 1935.04.13 (h = 140 km), 1945.05.11 (h = 149 km), 1948.06.30 (h = 114 km), 1957.07.02 (h = 262 km), 1961.04.04 (h = 230 km), 1962.09.02 (h = 105 km) and 1968.09.04 (h = 92 km) have such localized intense destruction that it appears that depth estimates must also be in considerable errors. The accuracy of the instrumental depth is recently questioned after a microearthquake survey in south-west Iran (Niazi *et al.* 1978).

Conclusions

It is concluded that epicentral locations of large magnitude earthquakes in Iran suffer from errors of 30 km since 1963 and were considerably worse before that time despite the fact that quoted errors are smaller. The errors mentioned in this study is the minimum existing

error, however for the low magnitude earthquakes the amount of location error is much more. On the other hand it has been observed that the instrumental epicentres are scattered in different directions around macroseismic epicentre, and no consistency has been found to help to minimize the amount of the location error.

It seems that factors such as seismological station distribution, earth models used in location programmes, timing error of the instruments and finally reading errors of the seismograms are presumably the cause of the error in instrumental epicentre location of the Iranian earthquakes. Fitch & Jackson (1977) suggest some possible reasons for this, and, it seems clear that the improvement required to correlate seismicity and tectonics in a similar way to California and Japan will only be achieved when an adequate station distribution is available. Errors in the focal depth estimate add some more doubts on different proposed tectonic and seismotectonic models given for this part of the world.

If the macroseismic epicentres, which are based on detailed field studies and bibliographical research, are correct, then the routine locations and relocation of epicentres of Iranian earthquakes did not improve substantially the data. The inaccuracy is such that a good and detailed correlation between epicentres and tectonics should not be expected. Using or interpreting these types of data by preparing some epicentre and seismotectonic maps for the country has already shown that there is a limit to the use of the instrumentally located and relocated epicentres of the Iranian earthquakes with the existing data. Therefore at this stage the macroseismic information is invaluable for the seismotectonic studies in Iran where international data is not always sufficient in quantity or accuracy to locate active faults.

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