EARTHQUAKE HAZARD POTENTIAL IN OMAN

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SUMMARY

The assessment of seismic hazard involves in collecting and evaluating a wide range of data pertaining to the history and occurrence of earthquakes in a region and to their origin. Considerable efforts have already been made for assessing seismic hazard in the Sultanate of Oman and various other aspects to seismic monitoring. Through these efforts, it has been established that a major fault exists in the Gulf of Oman (offshore Muscat). Also, it is known now that recent earth movements have occurred in Jabal Salak, Jabal Khubayb and Batinah Coastal Plains area. Although, there are few instrumentally recorded earthquakes in Oman, but the available geological, geophysical and historical data do suggest a low to moderate level of seismicity such that an earthquake of Modified Mercalli (MM) intensity of VII or greater could occur. Therefore, the possibility of an earthquake in the Sultanate of could never be ruled out.

Prior to 1980 very few earthquakes had been reported in the Sultanate of Oman mainly because of the lack of local seismographic stations or perhaps it was difficult to receive signals from events in Oman. After 1980, new stations in Norway, Sweden and England reported nearly all earthquakes. Much development projects in different parts of Oman have been undertaken to develop its modern infrastructures. Therefore, seismic zoning map and other basic data are required for the development of standard code for seismic design of structures in Oman. In view of this, a study has been undertaken to collect and evaluate a wide range of seismic data to develop standard codes for seismic design of structures. The results of the study have been presented in this paper.

It turns out from the present study that much information, which have been collected and evaluated, are not enough for the development of the code of practice for earthquake resistant design of structures

INTRODUCTION

Middle East is known from historic records to be seismically active. In the recent past, major earthquake shocks have not been reported in the Arabian Gulf region. Mortimer-Lloyd [1983] reported active seismic zone along the Red Sea coast resulting in earthquakes in Yemen (1982) and Egypt (1992). He also reported that parts of the Sultanate of Oman and the United Arab Emirates (UAE) fall into a seismic zone in which an earthquake of Modified Mercalli (MM) intensity of VII or greater could occur. Also parts of Saudi Arabia, Kuwait, UAE and major part of the Sultanate of Oman fall into a seismic zone in which a seismic shock of MM intensity up to V or VI could occur. Many areas in the Middle East have witnessed much increase in construction activities in recent years. Therefore, it is important that structures such as telecommunication, airports and harbors, hospitals, schools and utility and other services should remain largely undamaged in the event of an earthquake shock.

There are several reports of felt earthquakes in the Sultanate (Fig. 1) during the period from years 977 to 1998 (Table 1). The historical records suggest a possibility of damage during the Qalhat earthquake of 15th century [Dickson, 1986]. Some major events, however, that occurred at a great distance away in southern Iran, Pakistan or Yemen have been reported in Oman. Several individuals reported [Dickson, 1986] effects of November 27,

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1945 earthquake (M = 8.2) whose epicenter was just off the southeastern Iranian Makran Coast about 470 km from Muscat (Oman). Witnesses reported damage, casualties, and a Tsunami surge. Also, April 18, 1983 earthquake (M = 6.5) that occurred in Baluchistan was felt by residents of multistory buildings in Muscat (590 km) and was also felt in Buraimi (Oman) at an even greater distance. Yemen earthquake (M = 5.7) of December 13, 1982 was also felt by resident in Salalah (Southern Oman) [Dickson, 1986].

Some faults were reported in the Batinah Coastal Plain in Oman north to the Daymaniyat islands (Fig. 2). Khaboura fault zone [Dickson, 1986] is located in south of Sohar about 80 km to the vicinity of Ras A'ssawadi along coast (Fig. 2). Earthquake magnitudes recorded along the northeastern margin of Arabian Plate have ranged up to the most severe record magnitude of 8.2 (November 27, 1945). However, there are some seismic data from the National Geophysical Data Center in Denver, Colorado (U.S.A). It turns out from such seismic data that all the earthquakes that occurred in an area between 45.0^0 E to 65.0^0 E and 10.0^0 N to 30.0^0 N (Fig. 3) show that the significant seismic activity is concentrated along the Zagrous fault zone in Iran. Also, it can be seen from Fig. 2 that there are numerous epicenters along the Batinah Coastal Plain and offshore. Prior to 1980 very few earthquakes had been recorded in Oman mainly because of the lack of the local seismographic stations or perhaps it was difficult to receive signals from events in the Oman area because of placement of seismic stations [Dickson, 1986]. It is important to note that new stations in Norway, Sweden and England reported nearly all of the earthquakes after 1980. The magnitude of these earthquakes ranges from 3.9 to 4.9 on modified Ritcher scale. Considerable efforts have already been made for assessing seismic hazard in the Sultanate of Oman and various other aspects of seismic monitoring in the Sultanate of Oman. In view of this, the available seismicity and neotectonic data are briefly described in the following sections.

TECTONICS AND NEOTECTONICS OF OMAN

Oman is a part of the Arabian plate, which comprises the continent of Arabia as well as oceanic areas consisting of parts of the Red Sea, Arabian Sea, Gulf of Aden and Gulf of Oman (Fig. 4). Along the northeastern margin, the Arabian plate is in continental collision, which has given rise to the folded Zagros Mountains. The oceanic part of the Arabian plate is subducting along the Makran Trench. The destructive plate-margin of the Arabian plate along the Zagros and Makran is marked by intense earthquake activity. As the Arabian plate moves northeastwards, parts of the plates are differentially deformed and periodic release of such stress accumulations causes earthquakes within the plate. The 1971 Al-Kamil earthquake in Oman and the 1982 Dhammar earthquake in Yemen are examples of such intraplate earthquakes.

Neotectonic structures are considered good indicators of present-day active zones. The basic idea is that the forces responsible for such structures could still be active. The Directorate General of Minerals (DGM), Ministry of Petroleum and Minerals, Sultanate of Oman has recently completed basic geological mapping of entire Oman at scales of 1: 1 00,000 and 1:250.000. An important aspect of this project was to map the Neogene (during the past 25 million years) and Quaternary (during the last 2 million years) periods. Along the coastal area of Oman (Fig. 2), several wave-cut platforms of presumably Pliocene-Quaternary age are located in excess of 500 m above the sea level suggesting enormous uplift of the region [Dickson, 1986]. Marine Pliocene-Quaternary terraces along the coast are found at elevations of 150-190m, which is considerably higher than the highest sea level suggesting uplift of several tens of metres. Normal faults on the continental shelf of the Gulf of Oman suggest very recent activity. These faults show a seafloor offset of about 200 m on seismic sections.

SEISMICITY OF OMAN

There are practically no instrurnentally-recorded earthquakes in Oman. The global database, however, lists an earthquake of magnitude 5.1 (Richter Scale) in AI-Kamil area in 1971. There are numerous reports of felt earthquakes in Oman (Table 1). Most of these reports represent ground shaking due to strong earthquakes occurring in the region at teleseismic distances. Figure 1 shows the felt earthquake locations. Along with felt earthquakes, this plot also shows earthquakes reported in old manuscripts including the late 15th Century Qalhat earthquake and earthquakes felt in Musandam region in the years 977, 1184 and 1483 AD. These data have been compiled in two ways. Senior citizens were asked to report on older events they had experienced in Oman. These kinds of data are not very reliable because of their dependence on human memory. In 1985, the Ministry of Petroleum and Minerals adopted a written survey form for felt earthquakes. Thus, the later reports of felt earthquakes are more reliable. It is clear from Figure 1 that Oman does experience earthquake tremors from time to time. The historical records suggest a possibility of damage during the Qalhat earthquake. The felt earthquakes are distributed mainly along the Batinah Coast Plains area and Oman Mountains region.

SEISMIC MONITORING IN OMAN

Considerable effort has been made during the last fifteen years for the assessment of seismic risk in Oman. The outcome of such effort is presented in the form of the technical reports. The conclusion from first report [Dickson, 1986] is that the historical and instrumental seismicity record is limited in Oman. It has also been reported that recent earth movements are recorded in the Sultanate. The committee recommended establishment of a permanent seismological observatory in Oman. The second report [Lewis, 1992] submitted by another committee agreed with the conclusion of the first report. But, they also recommended microseismic monitoring in Oman using portable seismograph. In the last report [Carbon et al., 1994], the committee has reported discovery of a major fault in the Gulf of Oman, offshore Muscat. Also earth movements in Jabal Salak, Jabal Khubayb, and Batinah Coastal Plains area have been reported. The DGM, Ministry of Petroleum and Minerals has documented recent earth movements during the course of geological mapping of Oman.

Assessment and mitigation of earthquake risk has been recognized as a major global problem [UNESCO, 1976]. Program of Assessment and Mitigation of Earthquake Risk in the Arab Region [PAMERAR, 1983] has been evolved under the UNESCO framework. As a starting point towards this goal many countries in the region, like Iran, Iraq, Turkey, Jordan, Egypt and Pakistan, have already established seismological observatories and networks. But, seismic monitoring in the Arabian Peninsula region is at now a very early stage. In view of this, the need for seismic monitoring in Oman has been well recognized. A national level committee known as 'Higher Committee on Seismic Monitoring', has been established in 1995. The Higher Committee then set up a Technical Committee on Seismic Monitoring (TCEQM) to design a plan for seismic monitoring in the Sultanate of Oman. The technical committee was formed involving experts from the Ministry of Communication, Ministry of Commerce and Industry, Ministry of Petroleum and Minerals and the Sultan Qaboos University (SQU). The objectives of the technical committee are as follows

- Compilation of information for historical and instrumental seismicity in Oman.
- Compilation of neotectonic in Oman.
- Study of earthquake monitoring programs in the Gulf and neighbouring countries.
- Designing a work plan for earthquake monitoring in Oman.

PORTABLE SEISMOGRAPHS

Sultan Qaboos University acquired three portable seismographs in December, 1997 to carry out a survey of natural ground vibrations aimed at selecting site for permanent stations. These instruments are temporarily deployed at different places from time to time. Besides the ground vibrations, they also record earthquakes in the region. Firstly, two portable seismographs were installed temporarily, one located at the SQU and the other at Qairoon Hariti, north of Salalah. The portable seismograph installed at the SQU recorded the Afghanistan earthquake and Pakistani nuclear explosions in May 1998 [TCEQM, 1998]. Records of the seismograph installed on the SQU campus were examined which confirmed the report that an earthquake was felt in the capital area (Muscat) on June 10, 1998. This earthquake was located in southern Iran and had a magnitude of 4.6 on the Richter scale.

Secondly, the portable seismographs were installed at Khutum and Bisya towns. A series of three earthquakes occurred in the Rustaq area on December 9, 1998. These earthquakes were felt by many people in the area and were recorded by the two seismographs, which were installed at Khutum and Bisya. The magnitude of these recorded earthquakes were between 1.8 to 2.8 [TCEQM, 1998]. Again, an earthquake of magnitude 2.7 occurred in the Rustaq area on April 27, 1999 and continued during the following four days recording 30 seismic shocks [TCEQM, 1999]. These seismic shocks were recorded on both Khutum and Bisya temporary stations with magnitudes in the range of 1.5 to 3.2. In view of the continued seismic disturbances around the Rustaq area, the three portable seismographs have been moved close to the affected area in order to record earthquakes and to calculate their parameters as precisely as possible. The seismic activities (highest magnitude recorded as 2.2) in the area were continuously monitored from May 14 to 31, 1999.

Since, many seismic activities have been instrumentally recorded in a span of about eighteen months only after the installation of the portable seismographs in the Sultanate. Therefore, the establishment of a permanent network is expected to provide much more and precise information on the earthquake activities in the Sultanate of Oman. Site selection to locate these permanent stations has already been completed. Now, the government has already approved [TCEQM, 1999] the revised project proposal submitted by the technical committee and

therefore, the follow up process has started. This project may also seek to collaborate with other neighbouring countries to better address the earthquake monitoring in the Arabian Peninsula region.

CONCLUSIONS

Based on the present study, the following conclusions are derived: The available geological and historical data suggest a low to moderate level of seismicity such that an earthquake of MM intensity of VII or greater could occur. This result may be corroborated by the fact that after the installation of the portable seismographs in the Sultanate, much seismic activities have been instrumentally recorded in a very short period of about eighteen months only. Finally, it is concluded from the present study that much information, which have been collected and evaluated, are not enough for the development of the code of practice for earthquake resistant design of structures.

REFERENCES

1. Carbon, D. R., P. Philip. H. and LeMetour, J. 1994. Recent Tectonics in the Northern Oman Mountains: Coexistence of Compressive and Extensional Structures, Report Submitted to the Ministry of Petroleum and Minerals, Sultanate of Oman, 14p.
2. Dickson, P. 1986. Preliminary Assessment of the Earthquake Hazard in the Sultanate of Oman. UNDP Consultancy Report, 30p.
3. Lewis, M. J. 1992. Requirement of Ministry of Petroleum and Minerals for Seismic Stations, UN Consultancy Report Submitted to the Ministry of Petroleum and Minerals, Sultanate of Oman, 116p.
4. Mortimer-Lloyd, J. D. 1983. Earthquakes and Seismic Zones in the Middle East, Building Research Establishment, Department of Environment, London, pp. 1-12.
5. PAMERAR. 1983. Assessment and Mitigation of Earthquake Risk in the Arab Region, UNESCO Report Prepared for the Arab Fund for Economic and Social Development, Islamic Development Bank, (Paris-UNESCO), 251p.
6. TCEQM. 1998. Reports on Earthquakes Recorded by Portable Seismographs, Technical Committee on Earthquake Monitoring, Sultanate of Oman (Unpublished).
7. TCEQM. 1999. Reports on Earthquakes Recorded by Portable Seismographs, Technical Committee on Earthquake Monitoring, Sultanate of Oman (Unpublished).
8. UNESCO. 1976. Intergovernmental **C**onference on the Assessment and Mitigation of Earthquake Risk, Paris 10-19 February 1976. Final Report (Paris-UNESCO), 50p.

Table 1: Felt Earthquakes in Oman

Site	Place/City	Year(s) of Felt Earthquake(s)
1	Shinas	1935,1945,1955,1965
2	Liwa	1969
3	Saham	1944,1945
4	Buraimi	1965, 1983
5	Al Qabil	1934, 1968, 1971
6	Nakhal	1965 (2)*
7	Seeb	1983
8	Muscat	1958, 1965 (4), 1967, 1969, 1983 (2)*
9	Quriyat	1965 (3)*
10	Musara	1965
11	Sumayyah	1965
12	Ghugrat Al-Tam	1965 (2)*
13	Sinaw	1945
14	Qalhat	Late 15th Century
15	Al Kamil	1949
16	Al Wafi	1955
17	Bilad Bani Bu Hasan	1969
18	Masirah	1965
19	Salalah	1982, 1994
20	Musandam	977, 1184, 1483
21	Al Hallaniyat	1995

* Number of earthquake occurrence

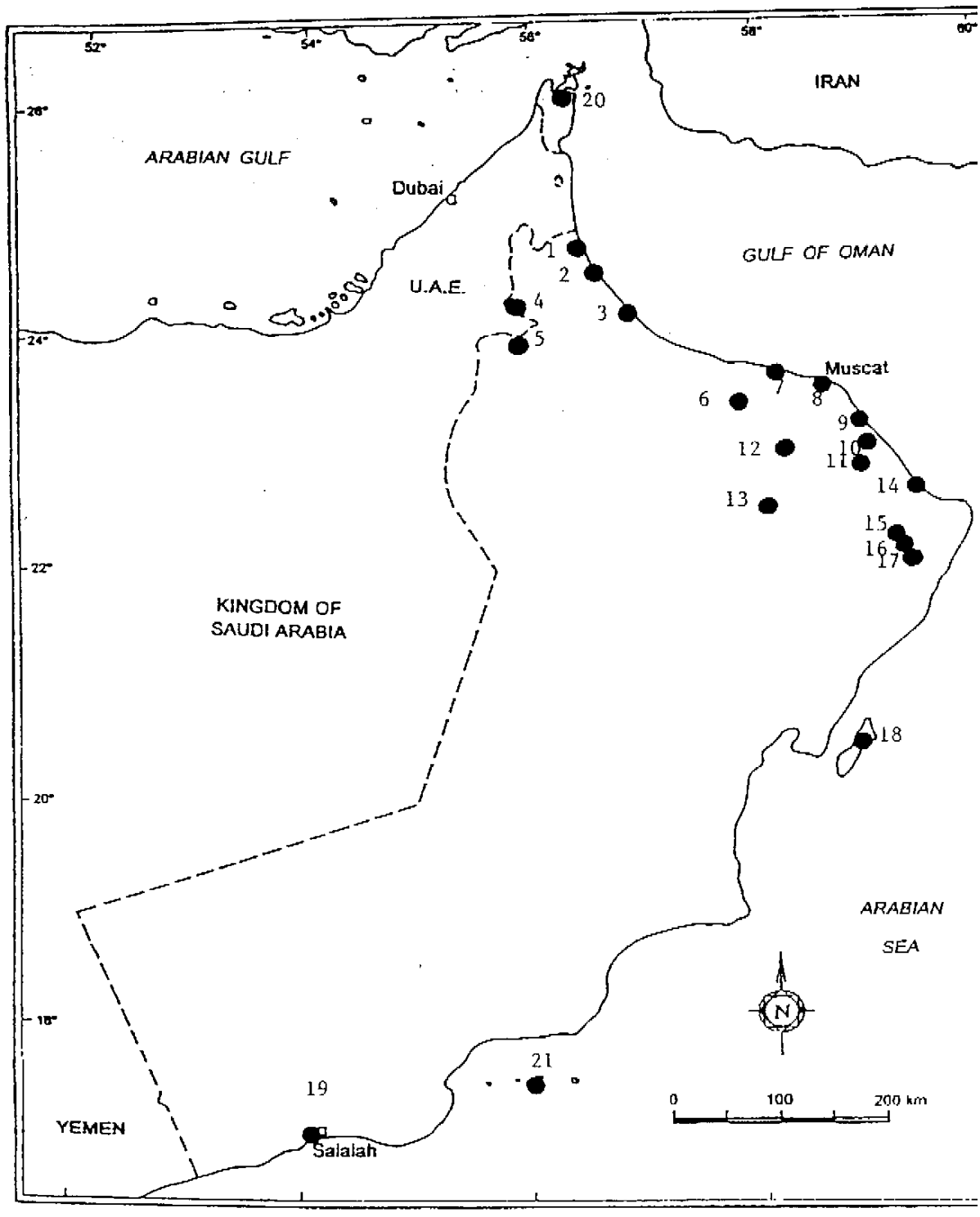

Figure 1 Felt Earthquake Locations in Oman

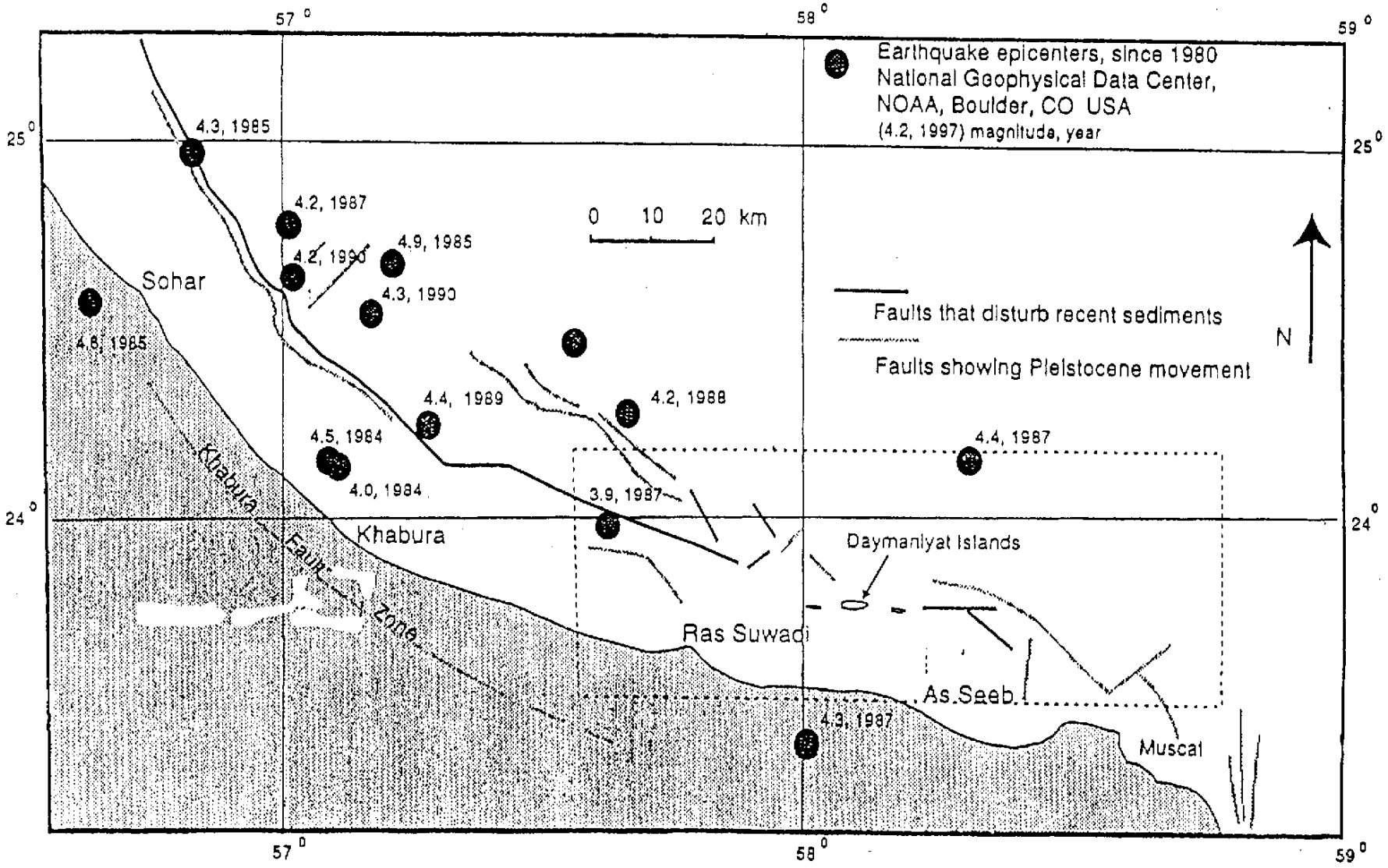

Figure 2 Epicenters and Active Faults along the Batinah Plain and Offshore in Oman

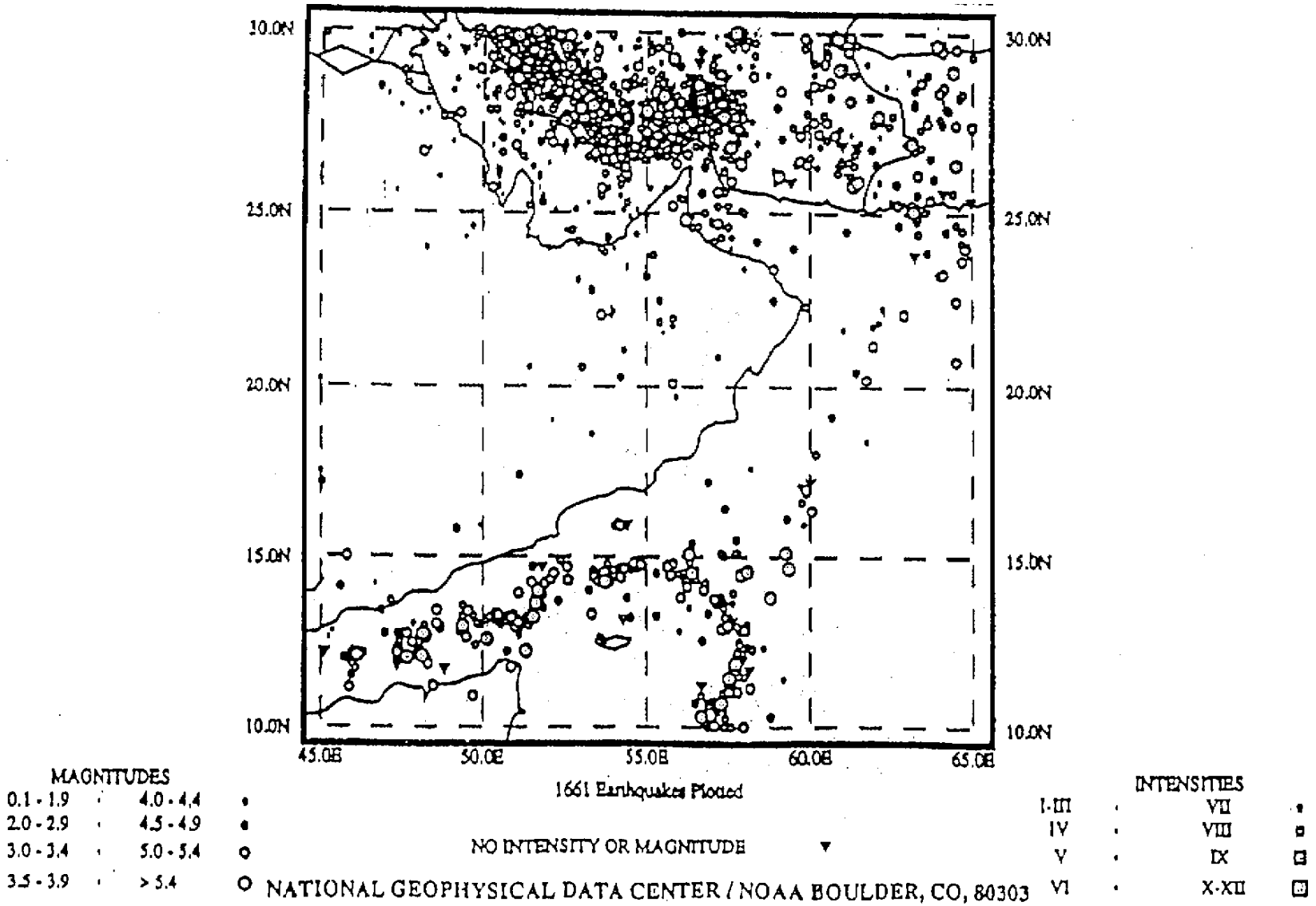

Figure 3 Seismicity Since 1980 in Oman

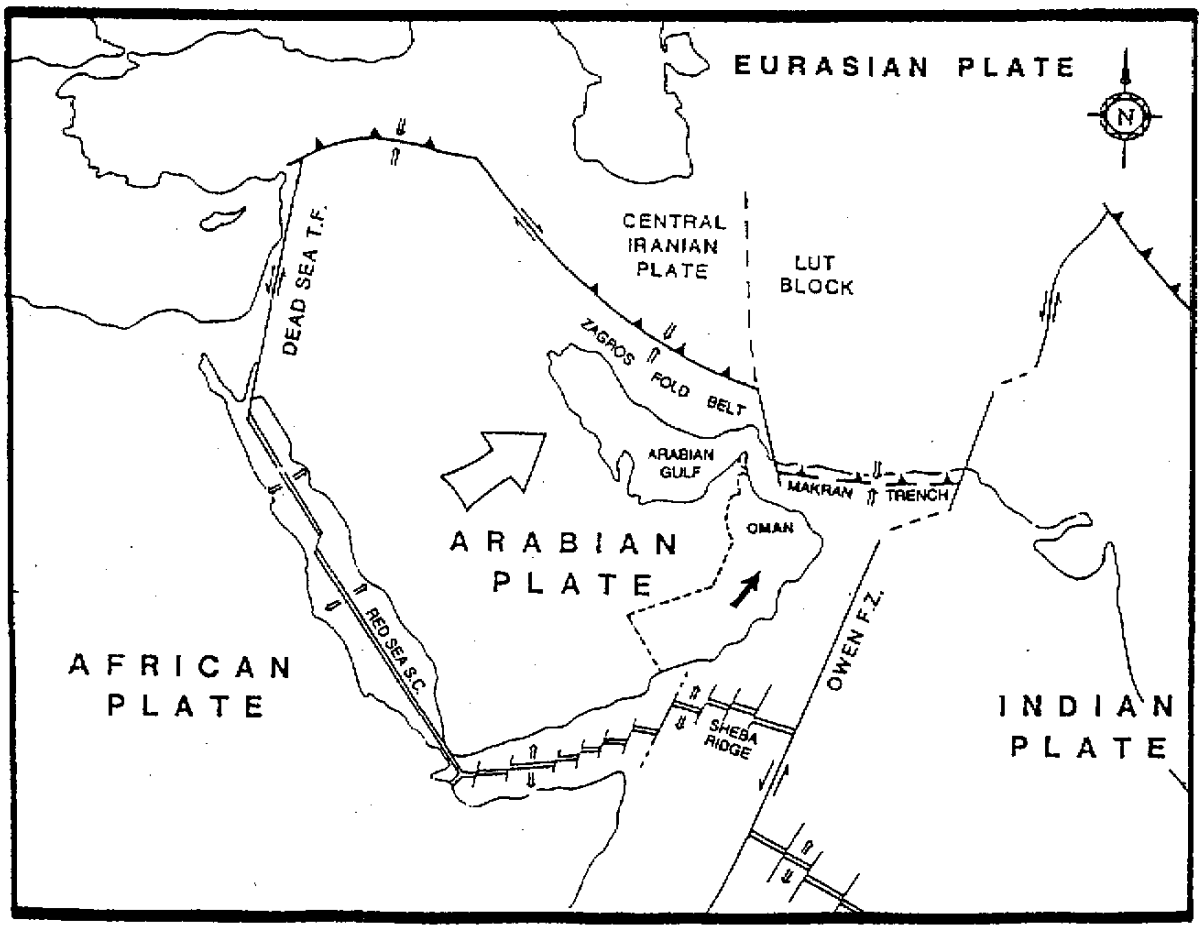

Figure 4 Arabian Plate and Surrounding Region