MICROEARTHQUAKE STUDIES AND SEISMICITY OF AKKUYU (TURKEY) NUCLEAR POWER PLANT SITE

K.Ergin[I] and S.Büyükaşıkoğlu[I]

SUMMARY

Microearthquakes were recorded in the field during 1977-78. 1973 version of HYP071 programme was used for determination of the hypocenter. Local magnitudes were calculated from the duration of events. Epicenter maps indicate very low activity in number and magnitude, near the site. Some epicenters line-up in NE direction from the site. Historical as well instrumentally calculated earthquakes were catalogued for seismicity studies within a radius of 450 km. Distribution of epicenters and focal depths indicate that (a) region around the site has low seismicity; (b) region between Ecemiş fault and Amanos Mountains and that around Gulf of Antalya and the Island of Cyprus have all high seismicity with shallow and intermiate depth events; (c) two relatively deep shocks off the northern coast of Cyprus caused damage near Farmagusta which implies a north dipping major fault.

INTRODUCTION

After the site for the first nuclear power plant of Turkey was selected to be at AKKUYU (Silifke), it was decided by TEK that a survey of seismicity of the region surrounding the site and field recordings of microearthquakes within the immediate vicinity of the site, be carried out by a group of seismologists of the Faculty of Mining Engineering of İ.T.Ü. The existing catalogues of earthquakes, epicenter maps and other published materials on seismicity, tectonics and geology of the region indicate that the seismic activity in the area surrounding the AKKUYU site is much less than it is in the near-by seismic regions, such as Gulf of Antalya, the area north of this Gulf, region of Adana and Antakya (Antioch), Northern Syria, and the Island of Cyprus. All these regions have complex seismicity and tectonics.

MICROEARTHQUAKE STUDIES

The main purpose of the microearthquake studies was to substantiate the current tectonic activity of the site and to check whether or not the faults observed near the site are active.

Field recordings

Field recordings were carried out during the summer 1977 and spring-summer 1978 for a total of seven months. A ten station network were used in 1977, 6 stations on an inner semi-circle around the site and 4 stations

---

[I] Institute of Physics of the Earth, Technical University of Istanbul

around an outer circular arc of about 70 km radius. In 1978, a network of five stations around the site were used. In both cases, the national network stations were used also. Short period seismic systems were used to record the microearthquakes. Seismometers were SS-1 Ranger and Geotech Model 18 300 portable types, both vertical components. Visual recording technique were used with Kinemetrics PS-1A portable and Geotech helicorder RV-301 recorders. Crystal oscilator type timing systems were used.

Reading of seismograms and computations

Times of first arrivals, i.e., the times of P type waves were used for computations. The times of S type waves were read and used also, whenever they could be identified accurately. Readings of 13 stations of the Kandilli observatory and 3 stations of ITU network were also used for computation. A computer programme, 1973 version of HYPO71, by Lee and Lahr (1975) was used for determination of origin time, coordinates and the depth of focus. The following crustal P-velocity structure model was chosen: for 0-2 km, 4 km/sec; 2-7 km, 5.4 km/sec; 7-17 km, 6.2 km/sec; for 17-35 km, 7.1 km/sec; and for h>35 km, 8.1 km/sec. In the HYPO71, the magnitude of the local earthquakes is computed according to an emprical formula based of the recorded duration of the earthquake, by Lee, Bennett and Meagher (1972).

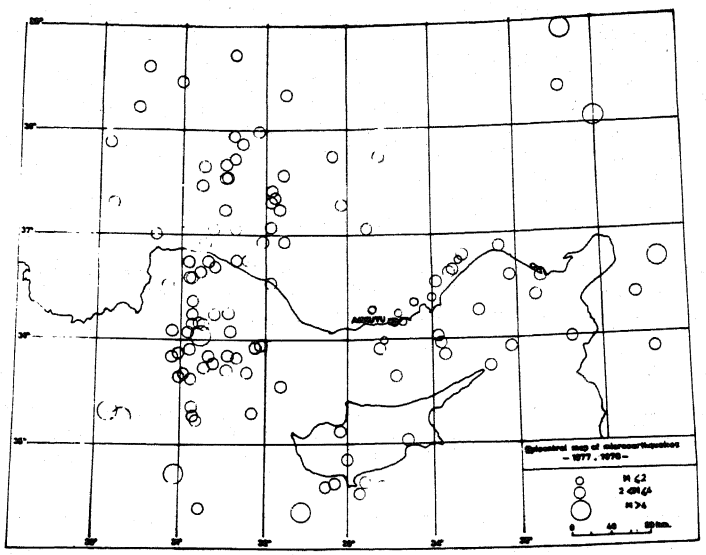

Fig.1 Epicenter map of microearthquakes 1977-1978.

Results

Parameters were determined for a total of 122 microearthquakes. Coordinates of epicenters and the focal depths were classified according to the limits of standard errors. Magnitudes vary as 0.6-4.4 Microearthquakes with large magnitudes are at great distances from the site. There were 31 microearthquakes within 150 km from the site. Focal depths vary between 0-15 km, but there are 8 events with depth range 19-34 km. Magnitude range is 0.6-3.4 13 of the 31 events are located 100-150 km from the site. Magnitudes of events within 100 km from the site are in the range 0.6-2.6 , except one event at 50 km with M=3.4 There were 13 additional small events recorded at two stations and 47 events recorded at one single stations only with M<2.1 The majority of comparatively larger magnitude earthquakes lie outside an area of 200 km radius from the site as can be seen on the map of "Fig.1" 80 of the total number of microearthquakes are located in the region that covers the Gulf of Antalya and extends further north and south. These events are outside a circle of radius 150 km around the side.

The epicentral maps of microearthquakes, "Fig.1." and "Fig.2.", of the whole region of interest and the region within 150 km from the site respectively, indicate that the seismic activity is rather small around the site, compared with the activities of the seismic regions in the east and in the west. The results do not show any direct correlation with the surface faults. However, the microearthquake activities near the site concentrate along a strip that extends in SW-NE direction along the coast between Akkuyu and Mersin.

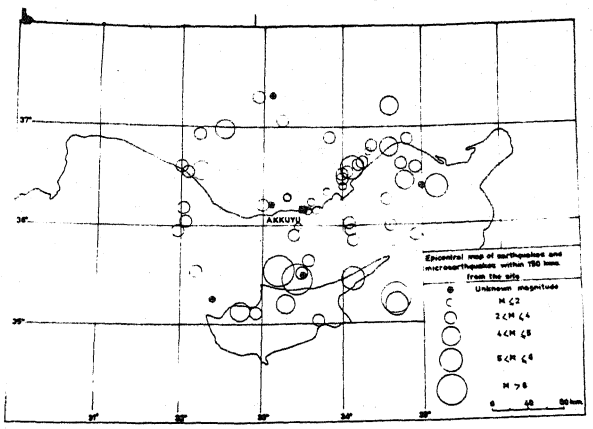

Fig.2 Epicenter map of earthquakes and microearthquakes within 150 km from the site.

SEISMICITY

Determination of SSE and OBE starts with the seismotectonic evaluation of the region around the site. Correct location of seismic activity and its relationship to the tectonics is an essential part of seismotectonics.

Sources of Data

Cataloguing of historical earthquakes begins with Pinar and Lahn's (1952) studies. A more complete earthquake catalogue that includes both historical and instrumentally recorded data has been prepared by Ergin et al.,(1967), and Ergin et al. (1971), in which earthquakes between 11 A.D. to 1970 have been documented. Another comprehensive study on cataloguing of Turkish earthquakes has been undertaken by Alsan et al. (1975). In the last catalogue, most of the earthquakes were relocated by a computer programme. There are other published and unpublished catalogues such as Plassard (1960), Karnik (1968), Öcal (1968a and 1968b), etc... For the seismicity of Cyprus, Ergünay (1973) has provided further information. In this study, we have tried to compile every information available for the region bounded by 33-39°N and 30-38°E. ISC Bulletions were used for recent events. Descriptive information of the historical earthquakes from 590 B.C. to 1902 A.D. (There is one event reported in 1500 B.C.) were taken from Sieberg (1932) and Ambrasseys (1962), for the area bounded by 31-39°N and 29-38°E. Sieberg (1932) catalogue includes isoseismal maps of some important historical earthquakes. Some examples are given in "Fig.3".

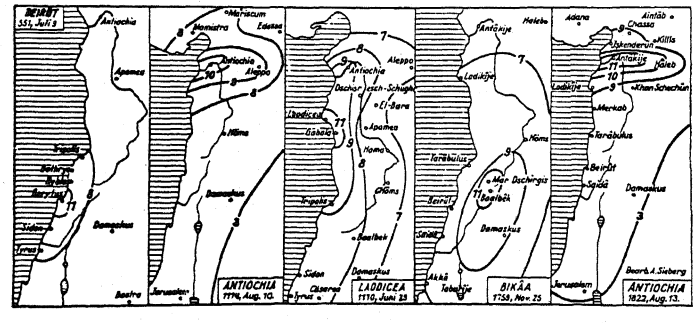

Fig.3 Isoseismal maps of some historical earthquakes (after Sieberg).

Gorshkov has studied the historical earthquakes of Syria, Lebanon, Israel, Africa, Iraq and Turkey. Two maps of seismicity given in his work, indicate very high seismic activity for the cities of Antioch and Aleppo as well as the coastal areas of Syria and Lebanon. The seismic

activity decreases from the coast to the east. Ambrasseys has provided an excellent catalogue for the Island of Cyprus.

All available catalogues of historical earthquakes include good description of destructive events, although there may be exaggeration in some cases. Maximum intensities were assigned in many instances. Coordinates of epicenter could be estimated for some events. There are a number of cases where the size of the area is very large which makes it impossible to fix a narrow epicentral area. There are numerous shocks with intensities IX or X, and some with XI. All these informations make the coastal areas of Syria very dangerous. On the other hand, the area of the sea between Cyprus and Syria has comparatively low activity, especially during 1903-1976 period, when instrumental determination of the coordinates of the shocks on sea covered areas were possible.

In order to improve the accuracy of data, parameters of a number of selected earthquakes (1903-1976) were relocated. Events tabulated in ISC Bulletins and most of the events in the catalogue of Alsan et al. (1975) were taken as they are. All magnitude values were included in our catalogue, without any preference. Nine events (M=4-6.6) within the radius 150 km, all events with M>5 within 150<r<300 km and all events with M>6 within r>300 km were revised. A computer program prepared by Julian (1974) and modified by DWM (1977) were used for relocation of hypocenters. Revised parameters are classified according to the standard error limits. Total number of earthquakes tabulated is 606. There are 25 events with M>6, and 3 events with magnitude little more than seven. An epicenter map of the region is given in "Fig.4".

Isoseismal maps and attenuation curves are lacking for the area. Sieberg (1932) has produced isoseismal maps "Fi.3". For typical curves of attenuation of intensity with distance see Ergin (1969).

There are different b-values calculated for the whole or part of the region of interest. The fact that the data is not homogeneous in space and time causes discrepencies in the results. Generally speaking, b-values valid for M_S>5 and truncated for very large magnitudes give more realistic results. b=0.7-0.8 may be taken as representative values. In our opinion, the data do not warrant better precision.

Focal mechanism solutions of some earthquakes in the area were compiled by Alptekin and Ezen. This topic is the subject of another paper by Büyükaşıkoğlu who has revised and interpreted the focal mechanism solutions.

CONCLUSIONS

The results of the seismicity study can be summarized as follows:

(1) Region of the Gulf of Antalya and the land area just above it are characterized by relatively deep earthquakes.

(2) Region just north of the Region-1 is highly seismic with destructive earthquakes.

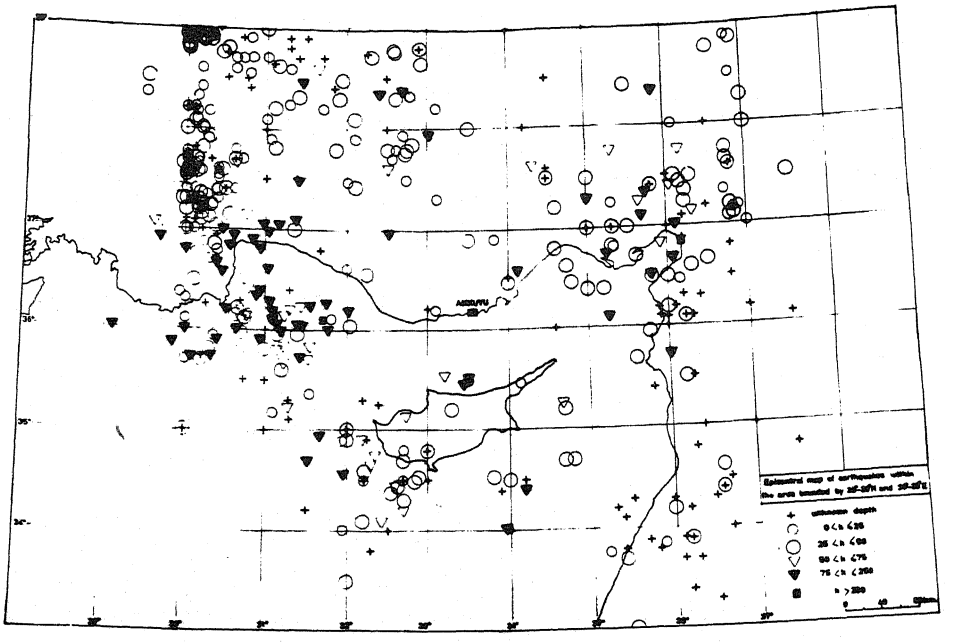

Fig.4 Epicenter map of earthquakes according to their focal depth.

(3) The Island of Cyprus have experienced severe and destructive earthquakes in the historical times as well as during the instrumental period. Most of the damage reported is around the larger cities along the SE, South and SW coastal area of the island plus the city of Nicosia. Hypocenters of known events are mostly concentrated around the SW corner on land and in the sea. These hypocenter varies from very shallow to intermediate depth. Two relatively deep events are off the north coast of Cyprus, but their reported damages are around Farmagusta in the SE. These two events are the closest large magnitude shocks with M=6.6 and 5.8 and with the depth of focus 73 and 92 km respectively, to the site. It is interesting to note that their damaging effects are further away from the site. This results indicate that there is a north dipping fault in this section.It is interesting to note that the Romanian earthquake has produced similar effect.

(4) The region around the Gulf of Alexandretta appears to have deeper shocks in the Gulf as well as the land area that lies NE of the Gulf. This region extends to include the neighbouring area of the city Antioch, northern Syria in the east, and in the south and the area around Misis, Kozan, Adana, Tarsus up to Mersin in the west. It extends further

to the south as far as the Dead Sea. This region had experienced very destructive earthquakes in the historical past. Earthquakes of magnitude eight can be expected in the region. It should be considered as the most seismic area in the whole region of interest.

(5) The region surrounding the city of Konya and the area to W and NW of it, seem to be quite seismic with some deep shocks.

(6) The region around the nuclear power plant site, especially along the coast of the Mediterranean Sea does not seem to be as seismic as the regions to the east, west and south. There is one deep earthquake with magnitude ≈ 5.6 and focal depth 80 km. Its epicenter is 71 km away from the site. Damage due to this shock is reported to be at the cities Mersin, Tarsus, Adana and Ceyhan to the east,i.e., away from the site. There are very few known earthquakes between Anamur and Mersin along the coast line. But the microearthquake survey of 1977-1978 recording periods have suggested a line-up of epicenters along a strip around the sea coast from Akkuyu to Mersin. The least active zone along the sea shore lies west of Akkuyu. We would- like to recommend that the coastal area west of Akkuyu be considered for the sites of future nuclear power plants.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the Turkish Electricity Anthority for financial support.

REFERENCES

Alsan,E., Tezuçan,L. and Bath,M., (1975); An Earthquake Catalogue for Turkey for the Interval 1913-1970, Kandilli Observatory, Istanbul.

Ambraseys,N.N., (1962); A note on the Chronology of Willis's List of Earthquakes in Palestine and Syria. Bull. Seismol. So. Am., Vo.52, pp. 77-80. Contains further references.

Ergin,K., Güçlü,U., and Uz,Z., (1967); A Catalogue of Earthquakes for Turkey and Surrounding Area (11 A.D. to 1964 A.D.), Technical University of Istanbul, Institute of Physics of the Earth, Publ. No.24, 169 pp.

Ergin,K., (1969); Observed Intensity Distance Relations in Earthquakes, Bull. Seismol. So. Am., 59(3), pp. 1227-1238.

Ergin,K., Güçlü,U., and Aksay,G., (1971); A Catalogue of Earthquakes of Turkey and Surrounding Area (1965-1970), Technical University of Istanbul, Institute of Physics of the Earth, Publ. No.28, 74 pp.

Ergin,K. and Büyükaşıkoğlu,S., (1978); Final Report, Microearthquake Study in Akkuyu Region, (Field Recording in Summer 1977), Project No. TEK-77-01.

Ergin,K. and Büyükaşıkoğlu,S., (1978); Final Report, Seismicity of Akkuyu Power Plant Site and Vicinity, Project No. TEK-77-02 Contains further references.

Ergünay,O. and Yurdatapan,O., (1973); Studies on Seismicity and Investigation on the Seismicity of Cyprus (in Turkish)

Gorshkov,G.P., Seismicity of Africa, UNESCO Publication, UNESCO/NS/NR/2 Add. 1-WS/0661.189.

Karnik,V., (1968); Seismicity of the European Area, Part 1. Academia (Publ. House Czech. Acad. Sci.), 364 pp.

Öcal,N., (1968a); Seismicity of Turkey and Earthquake Geography, Catalogue of Earthquakes in Turkey 1850-1960 (İn Turkish), Istanbul Kandilli Obs., Seis. Publ. 8, 119 pp.

Öcal,N., (1968b); Catalogue of Earthquakes in Turkey 1960-1964 (in Turkish), Istanbul Kandilli Obs. Seism. Publ. 9, 24 pp.

Pinar,N. and Lahn,E., (1952); Descriptive Cataloğue of Turkish Earthquakes (in Turkish), Bayındırlık Bakanlığı, Yapı ve İmar İşleri Reisliği Yayınları, Seri: 6, No.36.

Plassard,J., (1960); "Catalogue des seismes du Proche - Orient 1903-1956" Observatoire de Ksara.

Sieberg,A., (1932); Untersuchungen über Erdbeben und Bruchschollenbau im Ostlichen Mittelmeergebiet, Jena.