Proc.Inter. Conf. 3o Years Cooper, PP. 475 - 497

PROPOSED GEOLOGIC STUDIES FOR MINIMISING EARTHQUAKES HAZARDS IN EL DABAA NUCLEAR POWER PLANT SITE,WEST ALEXANDRIA, EGYPT

Abdel Aty Badr Salman

Nuclear Materials Authority.

ABSTRACT

The 12 October 1992 earthquake which struck Egypt especially Cairo and Giza environs necessitates the importance of geologic studies for the safety of El Dabaa Nuclear Power Plant Site. The present work presents a review of some available information which treats the geology of the north Western Desert in general and El Dabaa area in particular. The reviewed investigations include regional surface geology and tectonics, geophysical data such as gravity, magnetic and seismic, seismicity and historical earthquakes, and some subsurface geogloical information from the deep drilling for petroleum exploration in El Dabaa Locality .

The fault lines interpreted from seismic time maps for the stratigraphic horizons in some oil fields were statistically treated in the present work to determine the significant fault sets. Moreover, a comparative study has been done between the significant photolinears based on Landsat imagery interpretation and those interpreted from geophysical data. the results show a remarkable concordance between them . The WNW-ESE and ENE-WSW are the most significant fault sets in the studied area.

The siting safety considerations for El Dabaa Nuclear Power Plant in relation to geological structures, rock units and earthquakes hazards are also discussed. The possibility of the presence of capable faults in the site vicinity of El Dabaa necessitates a through investigation of neotectonics , boundaries of seismotectonic provinces and microearthquake monitoring. The performance of these geologic studies will minimise the propable future earthquakes hazards on the plant site.

MAIN GEOPHYSICAL, SEISMICITY AND GEOLOGIC WORK

The available previous work is reviewed and the following pages include some important results. That are found in those works.

Geophysical Investigations:

Meshref and El Sheikh (1973) studied the magnetic tectonic trends in northern Egypt. It is noticed that the N85° E trend is the most significant . However, a wide range of distributions for these magnetic trends between NE and NW is noticed.

Nakhla and Podbelove (1973) analysed qualitatively and quantitaively the aeromagnetic survey data over the western part of the Western Desert. The basement surface in this area is represented by a fold system, composed of alternating zones of uplifts and basins. In the uplifted parts the depth of the basement surface ranges between 1 and 3 km. In the basins, it ranges between 2 and 4.5 km. Zones of dislocation having sublatitudinal, NE , NW and submeridional trends were recognized . The same authors noticed that the brachy form of structures predominates in the northern and central parts, while a linear form of structures predominates in the southern part of the studied area.

Riad (1977) determined the fault systems in the northern part of Egypt using gravity data. The interpreted faults show the presence of parallel shear zones following NW-SE directions. He considered Oliogocene as the starting date of the development of these shear zones and they are still active. The examination of the fault systems interpreted from gravity anomalies by Riad (1977) suggests that at least one of the faults extends to the NE and SW of El Dabaa Power Plant Site. An ENE-WSW fault trend may also extend parallel to the coastal zone from Alexandria to Arabs Gulf.

Tealeb (1979 a) studied the tectonic trends in north Egypt on the bases of Bouguer anomaly analysis. He classified the interpreted structures into shallow and deep trends. The same author found that there is an agreement between shallow and deep structural trends which follow E-W direction in the region that includes El Dabaa site. Moreover, he interpreted this phenomenon as due to the effect of tectonic movements in the paleo-geologic ages which were reactivated in recent geologic time .

Tealeb (1979 b) published a work about deep crustal studies in north Egypt using spectral analysis and Bouguer anomalies. He concluded that the depth of discontinuity surfaces increased from north to south. The thickness map, constructed by the same author, shows that a remarkable change in the thickness of the Earth's crust occurs to the south of El Dabaa. Moreover, it is noticed that the contours of the depth values of the Conrad-discontinuity show a remarkable change to the southeast of Alexandria and southeast of El Dabaa. The maximum curvature of the contour lines is more or less parallel to the present Arabs Gulf shore line.

Seismology and Seismicity :

Maamoun and Ibrahim (1978) studied the tectonic activity in Egypt as indicated by earthquakes. Their study includes : the geological structural pattern including major Egyptian tectonic faults, the pattern of seismicity, historical earthquakes and seismic zones. Egypt's Mediterranean coastal dislocation zone is considered to be one of the two main seismic zones in Egypt. It includes the seismically active regions of the Egyptian Mediterranean Coast. This zone is associated mainly with the continental shelf and may be related to probable deep faults parallel to the coast. These are more clear near Alexandria and continue toward the west to the seismically active region of northern Lybia. Moreover, of the three delineated local active seismic zones in Egypt, two are in the north of the Western Desert. These two zones follow Baharia-Fayum Abu Roash-Cairo and Gaghbub-Siwa Oases lines.

Allam and El Khashab (1978) estimated the seismic intensities of Nile Delta and Shedwan earthquakes that occurred during 1955 and 1969 respectively. They found that the intensity and maximum acceleration in north Western Desert (Qattara site) are 3.4 (M.M) and 20 (Gal) due to Shedwan earthquake and 5.7 (M.M) and 42 (Gal.) due to Nile Delta earthquake .

Allam et al., (1979) studied the seismicity in El Dabaa, Zaafarana and south Safaga Nuclear Power Plant proposed sites. They presented the structural geology and tectonics, earthquake catalogues and seismicity in the study areas. It is noticed from the intensity map (Figs 1 and 2) constructed by the same authors (Ibid, 1979) that the maximum intensity is up to VI in El Dabaa site. Moreover, they presented a map showing the geographical distribution of earthquakes for El Dabaa area (Fig. 4).

Maamoun (1979 a) described ten important historical earthquakes which occurred in different localities of Egypt and off shore of Alexandria. Two of them are recorded in Siwa Oasis and two in Fayum. In Siwa Oasis the maximum intensity was VIII at 221 BC and VII at 1811 .

In Fayum area the maximum intensity was VIII for one of them (August 8, 1303) . In August 7 , 1847 a large earthquake was recorded with maximum intensity of VIII. Heavy damage was associated with that earthquake . A severe earthquake happened off - shore of Alexandria on June 24, 1870. The maximum intensity was X with a focal depth of 10 Km (Maamoun 1979) .

The following points are noted from the distribution of those principal historical earthquakes and their isoseismal maps (Maamoun 1979) :

1. Presence of a remarkable seismic trend in the ENE-WSW between Siwa Oasis and Cairo.
2. Occurrence of another important seismic line between Gulf of Suez (El Zaafarana), east Delta and Rosetta and following NW-SE direction in the off-shore.

In the present author's opinion, these two main seismic trends are related to the main faulting which control the tectonic framework in Egypt in general and in north Western Desert in particular.

Ibrahim and Marzouk (1979) Considered the southeast Mediterranean area west of the Delta cone as seismically active. It includes a group of faults that follow the Gulf of Suez trend . They mentioned two earthquakes that occurred to the east of the Delta on March 5, 1978 and April 29, 1974 .They has body wave magnitudes of 4.5 and 4.9 and focal depths of 25 Km and 33 Km, respectively

Albert and Kebeasy (1988) surveyed the seismicity at El Dabaa area. They did not record any microearthquake activity during three months period from September to November 1984. Kebeasy (1990) , treated the historical and instrumental earthquakes and the space distribution of the main active seismic trends which include : A. Northern Red Sea- Gulf of Suez-Cairo Alexandria clysmic trend, B. East Mediterranean-Cairo-Fayum Pelusiac trend and C.levant-Aqaba trend.

Geologic Investigations :

El Etr et al. (1973) mapped some faults in the area of Sidi Barrani. They determined some faults that follow E-W, NW-SE, N-S and NE-SW trends. By examining their map and that of Abdallah (1966) for the same area, it is noticed that some of these faults are located in Miocene-Pliocene units.

El Shazly et al. (1979) found during their regional geological and hydrological investigations of Sidi Kreir Nuclear Power Plant Site, that the major physiographic features in the northern Western Desert are related to tectonics. They found that the fractures aligned with the Mediterranean Coastal zone are significant for Sidi Kreir Power Plant Site as well as for other sites at or near the Mediterranean Sea. These fractures appear to be responsible for the shape of the Mediterranean Sea shore. They cut the Pleistocene, Pliocene or Miocene rock units, and assume various trends including NW-SE, NNW-SSE and ENE-WSW. The same authors recorded a very significant fracture that extends hundreds of kilometers from the environs of the Mediterranean Sea traversing the northeastern part of the Western Desert towards the River Nile . This fracture zone occurs near the Mediterranean Sea shore some 60 Km to the West of Sidi Kreir itself.

However, the local geological studies at Sidi Kreir Site neither show evidence of faulting or folding nor do they reflect deeper structures. Moreover, the data collected from borings drilled in the site show no evidence of tectonic structures (El Shazly et al. 1978) .

Riad, et al., (1979) studied the tectonic trends and basement relief in the area of Minya. They recorded two main shear zones following NW-SE and NE-SW directions. The same authors consider the Qatara and E-W trends as most probably the oldest tectonic features in the area, which also control the basement block mosaic of the Western Desert of Egypt. The NW-SE shears are relatively fewer in number and are generally found at shallower depths and have small amounts of down-throw range between 500m and 3000 m.

Bayoumi et al. (1979) studied the major structural features of the basement complex in Egypt. He interpreted three normal faults forming a step faulting system along the coast between Matrouh and El Dabaa. Those faults follow NE trend in general and the downthrown blocks are to the southeast. The present author examined the map of Bayoumi et al. (1979) which includes the interpreted faults. It is noticed that a great fault, starting from Abu Roash and passing in the northeastern part of Qattara depression which follows a NW-SE trend extends to the Arabs Gulf, east of El Dabaa.

El Ghawaby (1979) studied the tectonic development of north Eastern. Africa. He presented a paleostructural map showing the faulting phase during Paleogene to Neogene times . On this map he delineated a major right-lateral strike-slip fault which trends NW-SE, " the Dabba-Cairo- Wadi Araba fault". This fault is parallel with that recorded by Said (1981) , El Shazly et al., (1981) and Riad (1977) . According to Siagaev's (1959) tectonic map of Egypt, El Dabaa is bounded by two normal faults trending NE-SW, forming a graben.

Meshref et al. (1980) studied the regional tectonic framework of the buried basement rocks in the northern part of the Western Desert. They recorded two episodes of folding affecting the basement rocks. The older one trends E-W and WNW, while the younger is. ENE. They found that the ENE trending structures is intersected by younger NW and NE trending faults. It is noticed from their interpreted basement tectonic map that a major right lateral strike-slip fault following NW trend bounds the western border of the Arabs Gulf to the east of El Dabaa area. Moreover, the northern extension of a similar fault passes through El Dabaa locality.

The present author examined the structural lineament map of Egypt based mainly on Landsat imagery interpretation and field investigations (El Shazly et al. 1981). It is noticed from this map that the extension of a major lineament is relatively close to El Dabaa Power Plant Site. This major lineament could reflect a major fault zone following NW-SE direction. It is noteworthy that other major lineaments are delineated in the northern Western Desert and follow the same trend in general. Moreover, NNW trending faults are often associated with the great bends on the Mediterranean coastal zone at Ras El Kenayis and Ras Alam El Rum. In addition major lineaments that follow ENE and NE are also delineated in the northern part of the Western Desert (Fig.1).

Said (1981) published a schematic map showing the major tectonic elements of northern Egypt . On this map Wadi Natrun fault is a remarkable major fault that extends more than 550 km. It is bounding Wadi Natrun from the southwest, following a NW direction and changes its trend near the western bend of Arabs Gulf to follow WNW where it dislocates the continental slope (Fig.2).

Meshref, (1982) studied the regional structural setting of northern Egypt using aeromagnetic data and plate tectonics concepts. He considers that northern Egypt seems to have been affected by three tectonic events;during Paleozoic to Triassic, Cretaceous,

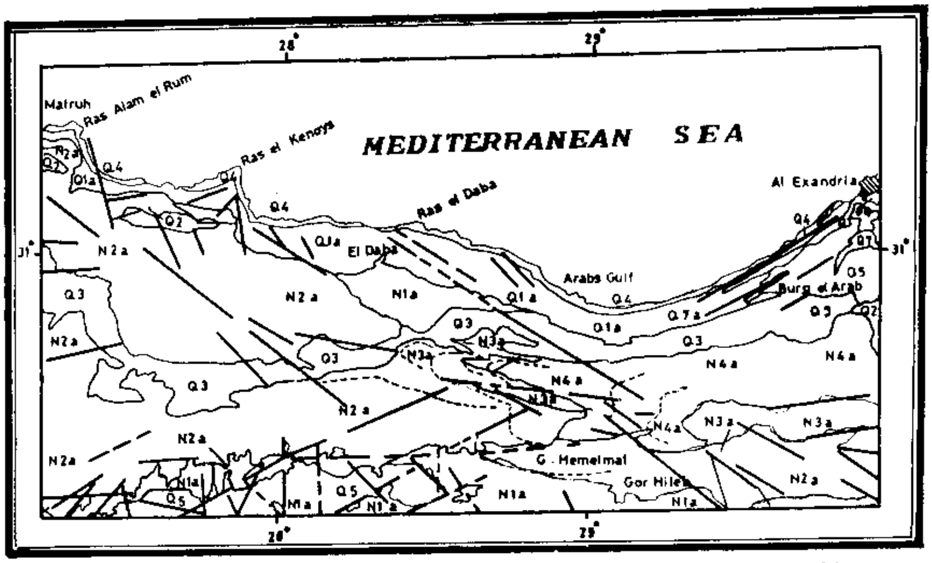

FIG.(1) GEOLOGICAL-STRUCTURAL LINEAMENTS MAP FOR NORTH WESTERN DESERT, BASED ON LANDSAT IMAGERY INTERPRETATION (AFTER EL SHAZLY et al., 1981 WITH MODIFICATIONS)

Holocene:
- Q 7 — Cultivated land
- Q 6 — Lake and water ponds
- Q 5 — Salt crusts, sabkha and marshes
- Q 4 — Beach deposits
- Q 3 — Alluvial deposits

Pleistocene:
- Q 2 — Gravel plains
- $Q_1{}^a$ — Alexandria Formation

Pliocene:
- $N4^a$ — Alam el Khadem Formation

Miocene — Late:
- $N3^a$ — Qaret el Dib Formation

Miocene — Middle:
- $N2^a$ — Gaghbub Oasis Formation

Miocene — Early:
- $N1^a$ — Gebel el Khshab Formation

Geological boundary

Photolineaments including Faults

Curved lineaments including fold traces.

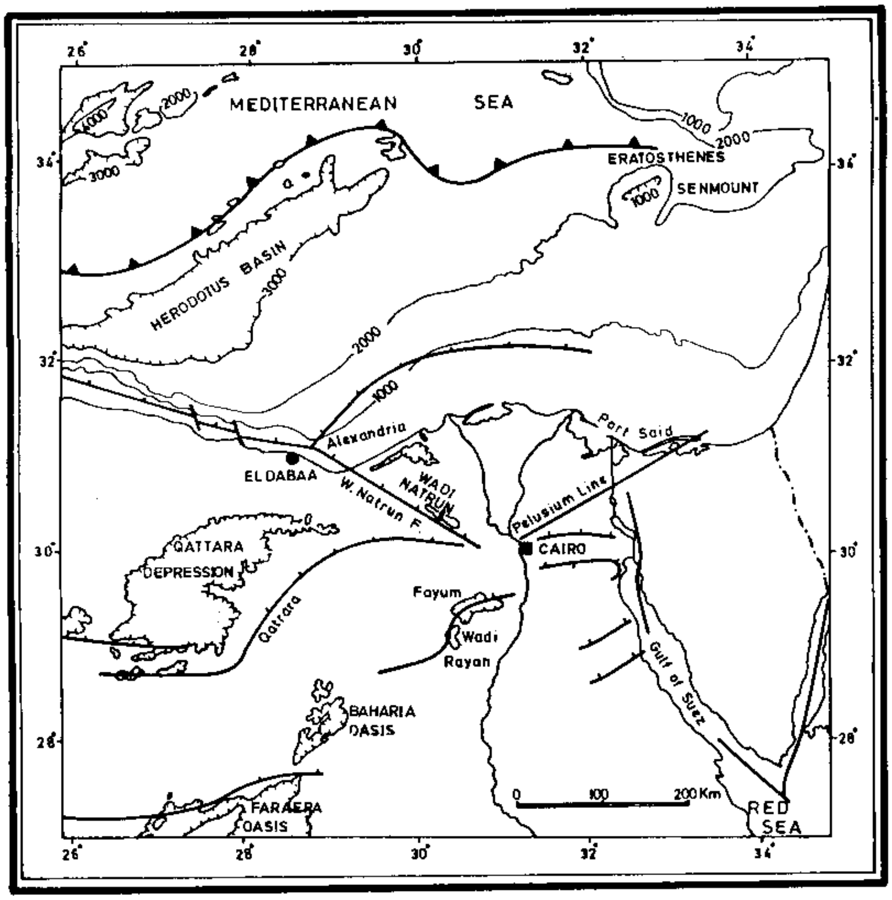

FIG. 2. SCHEMATIC MAP SHOWING MAJOR TECTONIC ELEMENTS OF NORTHERN EGYPT (AFTER SAID 1981).

and Late Eocene to Early Oligocene. On his basement tectonic map El Dabaa area includes some major basement faults following NW-SE, N-S and NE-SW trends. The basement depth is about 5 km to the south of El Dabaa locality.

LITHOSTRATIGRAPHY

The exposed sediments in El Dabaa site range in age from Miocene to Holocene.

The Holocene units include beach sand, calcareous aeolian sand, arenaceous aeolian sand, lagoonal deposits and alluvial deposits. The Pleistocene-Miocene units are composed of oolitic limestone, dolomitic limestone and marl (El Shamy, 1969) . Some gypsum deposits are present in El Alamein area (Ghanem et al., 1971) to the southeast of El Dabaa; mainly in Gabal Hagf and Deer El Biraqat localities. Some gypsum beds in Deer El Biraqat reach 10.50m in thickness. These are associated with clay, limestones and sandy limestone beds (El Shazly et al., 1976).

The composite lithologic well log for Dabaa-1 prepared by A.E.O. Company (Allam, et al., 1979) indicates the presence of the following rock units in the subsurface. The Kharita Formation represents the oldest rock unit encountered and is essentially formed of sand and sandstone with shale interbeds. It is 61.5m in thickness and is of Albian age.

The Bahariya Formation overlies the kharita Formation and is mainly of argillaceous sandstone. This unit is capped with a thick succession of argillaceous limestone and anhydrite which represent the Abu Roash Formation of Cenomanian age, and are 103 and 212m in thickness respectively. The upper part of Abu Roash Formation belongs to the Turonian-Santonian and is 326m in thickness. It is composed of sandstone with shale and limestone intercalations.

The Khoman Formation is composed mainly of chalk and limestone, 84.5m in thickness, and of Maestrichtian age.

The Apollonia Formation represents Middle Eocene sediments, composed mainly of bedded limestone with some shale interbeds and is 117m in thickness. The Dabaa Formation is composed mainly of thick shale beds and reaches 248m in thickness. It is of Oligocene age. The Moghra Formation represents the Early Miocene sediments , and is composed mainly of sandstone and shale intercalations. It is 590m in thickness. The Marmarica Formation is of Middle Miocene age and is composed mainly of hard limestone. It is 39m in thickness. El Hammam Formation represents the Pliocene sediments of chalky and clayey limestone beds. It is 73m in thickness.

DISCUSSION

It is found from reviewing the previous work in the north Western Desert in general and El Dabaa site in particular that this work can be classified into three main categories representing regional surface geology, geophysical survey and seismicity.

The regional geological studies indicate that the study area is dissected by some major structural lineaments including faults and exhibits two main trends ENE-WSW and NW-SE (Fig.1). A remarkable major linear zone that follows an ENE-WSW direction is associated with and crosses the northern edge of Qattara Depression. The extension of this zone often plays the main role in controlling the configuration of the coastal zone from Arabs Gulf to Alexandria. Moreover, the main trend of the coastal zone of the Mediterranean Sea and the associated physiographic features in the north Western Desert are often structurally controlled.

A major structural lineament zone passes very close to El Dabaa site following NW-SE direction and extends for about 100 km. This zone is important in the north Western Desert where it is repeated, forming parallel shear zones. Wadi El Natrun fault

(Said 1981) and Dabaa Cairo Wadi Araba fault (El Ghawaby 1979) belong to this set. It is also noticed that a series of NNW-SSE trending faults are associated with the abrupt change of the configuration in the coastal zone (Figs 1 and 2). These faults are strike-slip and mostly of right lateral separation. They are clear in Ras El Kenayis and Ras Alam El Rum (Matruh) to the west of El Dabaa.

The importance of the NW and NNW trending faults lies in their relation to Red Sea and Gulf of Suez. Some faults are still active. The author recorded some active faults in Gabal Zeit on the Red Sea coast (EGCO 1983). The faults dislocate the Plio-Pleistocene sediments as well as the recent coastal beds.

According to Said (1981), Wadi El Natrun fault extends more than 550 km following a NW-SE trend starting from a point very close to Wadi El Natrun, crossing the Mediterranean coastal zone to continue off shore, changing its trend to WNW. This postulated fault is intersected with another major fault following a NE and ENE direction to the north of the Nile Delta. The point of intersection is to the NE of Ras El Dabaa and the western extension of the north Nile Delta fault is passing very close to El Dabaa site (Fig.2). That point of intersection represents a remarkable weak zone at the environs of El Dabaa Nuclear Power Plant site. Moreover, El Dabaa locality is bounded by two normal faults trending NE-SW and forming a graben structure (Siagaev's 1959).

The main previous geophysical studies done in the north Western Desert include magnetic and gravity methods. These studies help to a great extent to delineate the main tectonic lines and the configuration of the basement relief. From these studies it can be concluded that the NW-SE,NE-SW and E-W are the most significant trends for fault systems and shear zones.

Moreover, some of the deep seated structural lines are more or less represented on the surface, e.g. there is a great fault starting form Abu Rowash and passing in the northeastern part of Qattara depression following NW-SE. This fault is clear in the map of Bayoumi et al. (1979). These results indicate a remarkable concordance of the major structural photolineaments based on Landsat imagery interpretation and the deep seated tectonic lines. The same conclusion is drawn by Salman (1981) during his structural study for the Gulf of Suez environs utilizing remote sensing applications. For this reason Landsat imagery is being used in several countries to evaluate potential nuclear power plant sites. Analysis of the imagery has led the possible extension of an existing fault along which earthquake activity has been associated. A potential site, which lies on this extension has been recommended to be withdrawn from consideration as a potential candidate site on this basis and known ground truth existing in the technical literature (Eggenberger, et al. 1975).

It is important to mention here that the comparison between major structural lineaments, that have been delineated from Landsat imagery covering north Western Desert, with results of seismic data in El Dabaa area (El Hefnawey et al. 1984) shows also a remarkable concordance (Table 1) . Moreover, the work of Jones and Taylor (1984) indicates that the main structural features in north central Egypt are NW plunging highs in Maryut, the Alamein-Qattara Ridge and the WNW-ESE trending Wadi Natrun fault system. These results are in agreement with the main regional surface structures.

From the seismicity point of view the north Western Desert includes three active seismic zones. The first is represented by the Egyptian Mediterranean coasstal zone which continues toward the west to the seismically active region of northern Lybia (Maamoun and Ibrahim 1979). The second and third zones are represented by Bahariya Fayum Abu Roash Cairo and Geghbub-Siwa local active seismic zones. It is also

Table 1: The significant fault sets based on geophysical studies and Landsat imagery interpretation, North Western Desert, Egypt.

Locations	Formations and age	Fault sets	Remarks
Razzak Rield	Abu Roash "G", Upper Cretaceous.	N65°W - S65°E N75 E - S75 W N55 E - S55 W N25 E - S25 W	Faults are interpreted from seismic time maps (1).
	Alamein, Lower Cretaceous	N55 W - S55 E N75 E - S75 W	
	Masajid, Jurassic	N55 W - S55 E N75 E - S75 W	
Abu Gharadig Field	Abu Roash, Upper Cretaceous	N75 W - S75 E N85 E - S85 W N45 E - S45 W	
	Bahariya, Upper Cretaceous	N75 W - S75 E N45 W - S45 E N75 E - S75 W N45 E - S45 W	
Dabaa area	Alamein, Lower Cretaceous	N65 W - S65 E N45 W - S45 E N55 E - S55 W N15 W - S15 E	Based on seismic data analysis, well velocity survey and continuous velocity logs. (2)
North Western Desert	Marmarica and El Hammam, Miocene to Pliocene.	N55 W - S55 E N65 E - S65 W N85 E - S85 W	Based on Landsat imagery interpretation (3).

(1) After Ezzat and Dia El Din, 1974, with contributions.
(2) After El Hefnawy et al., 1984.
(3) After El Shazly et al., 1981, with contributions.

noticed from the geographical distribution of earthquakes (Fig.4) that the main seismic center is present off shore to the north of Alexandria, about 150 to 200 km ENE of El Dabaa site (Allam et al. 1979). From'the macroseismic observations of different earthquakes El Dabaa site is located in an area of expected maximum intensity range of VI on NSK Scale (Fig.3) . Allam et al. (1979) calculated the expected intensity in El Dabaa site where some occasional earthquakes occurred. For example, if an earthquake 170km from Dabaa site occurred in the East Mediterranean belt, the calculated intensity might range from VI to VII, based on the Q-value of 350. However , when this is calculated for a historical earthquke that occurred in Siwa-Abu Roash, the intensity reaches IV.

It is noteworthy to mention that from the bathymetric map (Fig.5) it is noticed that the continental shelf in the north of El Dabaa site is very steep (Fig.6) and often includes step-like normal faults which form horst and graben structures (Ross and

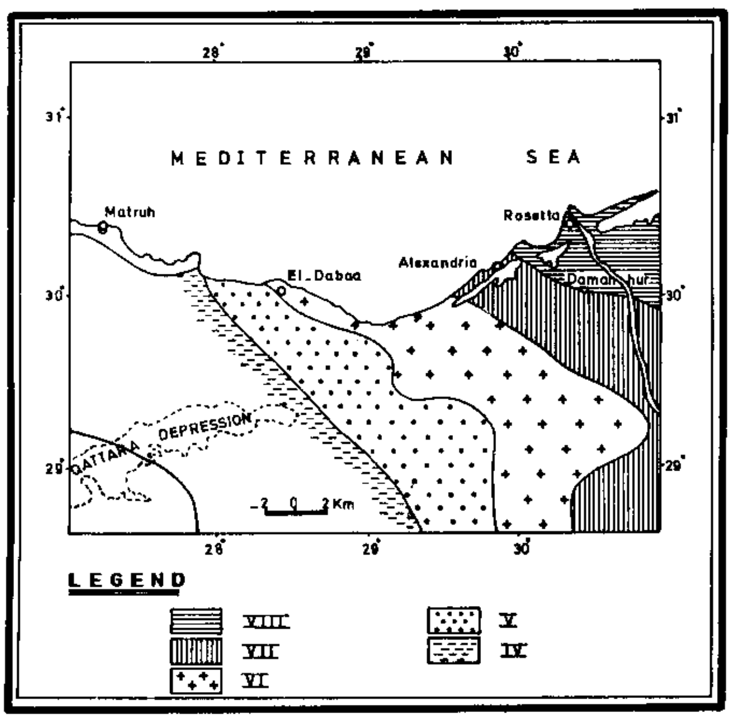

FIG. 3. INTENSITY MAP FOR EL_DABAA REGION AND NEIGHBOURING AREA, BASED ON MAXIMUM INTENSITY (AFTER ALLAM etal.,1979).

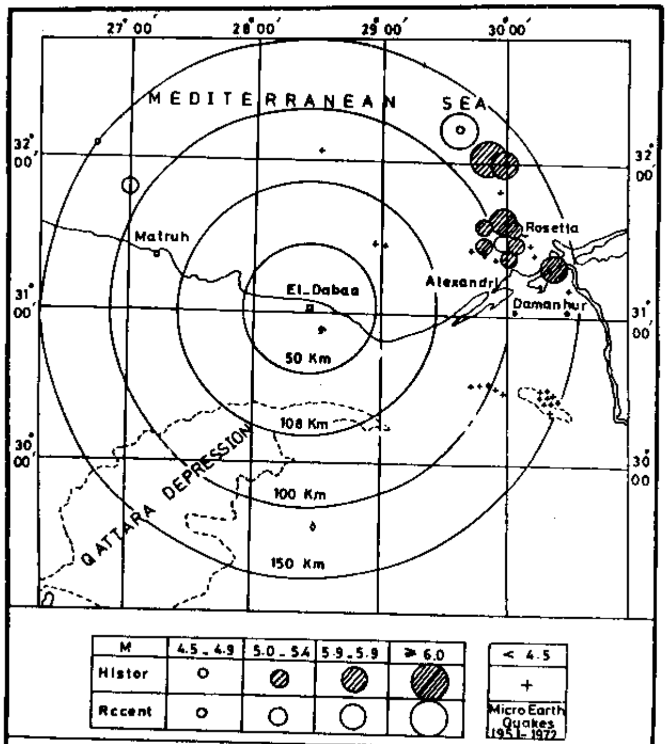

FIG.(4):GEOGRAPHICAL DESTRIBUTION OF EARTHQUAKES FOR EL _ DABAA AREA (AFTER ALLAM et al, , 1979) .

Uchupi , 1977 and El Shazly et al. 1979) . These faults have a general strike of ENE-WSW and often are located in the active seismic zone of the Egyptian Mediterranean coastal region.

The present author utilized statistical analyses in determining the significant fault sets that were interpreted from geophysical studies and Landsat imagery in the north Western Desert and the environs of El Dabaa site (Figs.7 to 12). The main fault sets in each formation at the various localities are presented in Table 1. It can be noticed from this table that the WNW and ENE are the most significant fault sets. Moreover there is a remarkable concordance between the fault sets interpreted on the bases of Landsat imagery interpretation and the deep seated structures based on geophysical studies (Table 1). For example, the significant faults interpreted from seismic time maps of El Masajid (Jurassic) and Alamein (Lower Cretaceous) follow N55° W-S55° E- and N 75° E-S75° W directions , while the significant fault trends based on Landsat imagery interpretation for the north Western Desert of Egypt follow N55°W-S55° E, N65° W and N85° E-S85° W directions.

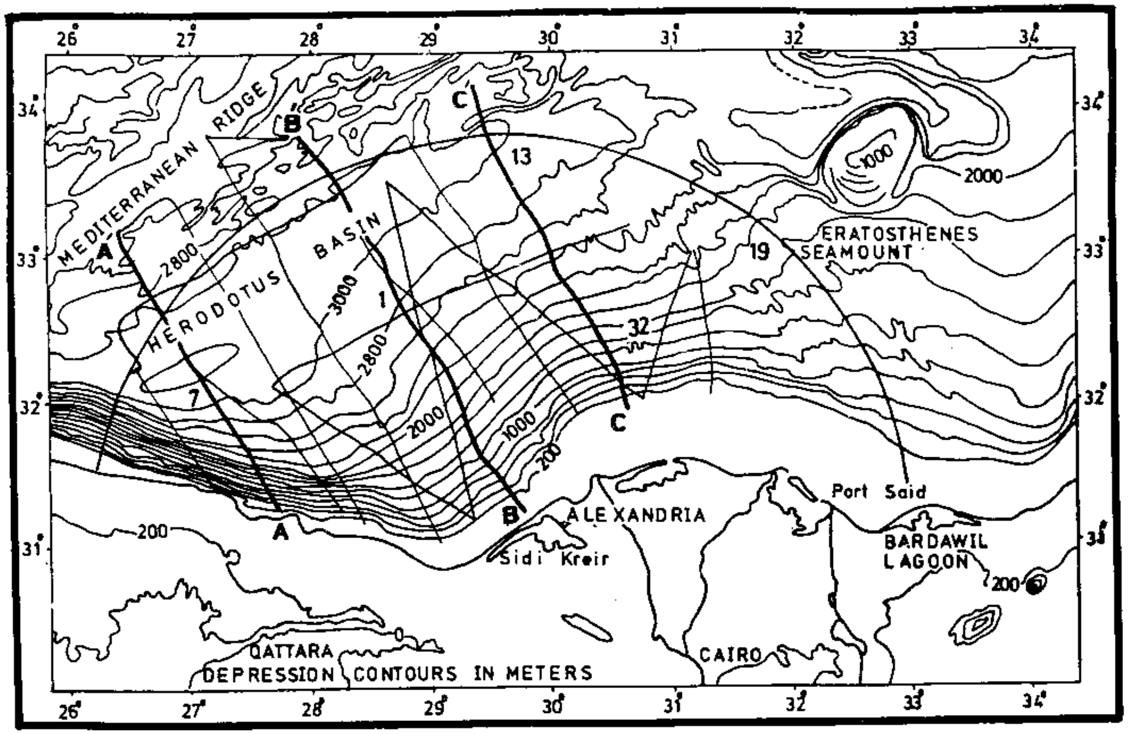

FIG. 5. BATHYMETRY OF THE CONTINENTAL MARGIN AND ADJACENT DEEP SEA IN THE EASTERN MEDITERRANEAN.(COURCE:ROSS AND UCHUPI,1977).NOTE:MAP WAS COMPILED USING DATA FROM R/V CHAIN CRUISE 119(CRUISE TRACKS INDICATED) SUPPLEMENTED BY DATA FROM CHARTS OF CARTER etal.,(1972)-CONTOURS IN METERS CORRECTED FOR SOUND VELOCITY USING MATTHEWS(1939)TABLES.LOCATION OF SEISMIC PROFILES SHOWN IN FIG.6 ARE INDICATED.

SAFETY AND PROPOSED GEOLOGICAL STUDIES

The International Atomic Energy Agency has published a Safety Guide (1979) for nuclear power plants site studies. These Safety Guides supplement IAEA safety standards and recommend a procedure or procedures that might be followed in implementing them. The site safety has been treated in eleven publications. The Safety Guide No. 50-SG-SI (1979) treats earthquakes and associated topics in relation to nuclear power plant siting, while No. 50-SG-S2 (1979) includes seismic analysis and testing of nuclear power plants. From reviewing some of these safety guides it is found that they concentrate on the relation between earthquakes and geological features, especially faulting and rock units. This relation is one of the most important factors in the determination of the design basis for the nuclear power plant.

Earthquke information and investigations are essential and they must include historical data, instrumental and reported data, tsunamis, seiches and the distribution of seismo-tectonic provinces.

The geological data and studies include regional geology, site vicinity and site area investigations.

The regional geological investigation should include determination of the characteristics of the various geological units and their stratigraphic correleations. The attitudes, characteristics and chronological relations of major faults and folds are of prime importance . These investigations should include the subsurface characteristics which can be derived from the regional geophysical studies such as seismic, gravimetric and magnetic surveys. The results of these geophysical investigations help in the determination of possible relationships between historic earthquake activity and deep tectonic structures, which may lack direct expression at the surface.

In the site vicinity, the geological and geomorphological characteristics of the area should be examined for indications of significant geological structures. In addition to these surface observations, the following investigations should be applied to the vicinity:

(1) Seismic reflection and refraction methods for the determination of thickness and dynamic material properties .It could help also in determining epicentral locations and trace of faults .

(2) Measurements of ground vibrations characteristics, the results can be used for reference purposes to select the eathquake ground motion to used for dynamic analysis of the nuclear power plant .

(3) Microearthquake studies to help in seismotectonic interpretation .

In the site area, detailed investigations concerning the foundation, such as borings test excavations and vibration testing of models are fundamental and laboratory tests (IAEA, 1979).These detailed investigations, are necessary for the determination of the thickness , depth, and static and dynamic properties of the different subsuerface layers. Moreover, the borings can be used to assess local foundation condition and provide additional information on geological structures in the site area.

The design basis ground motion in the nuclear power plant sites is affected by its geographic position in the seismotectonic provinces or its association of earthquakes with seismically active structures, and induced seismicity .

The seismotectonic provinces are identified by similarity of geological structures and the characteristice of seismicity (IAEA, 1979). The seismotectonic province boundary may separate areas showing strongly contrasting tectonic framework areas having different-contemporary stress, or areas having greatly different late tertiary and Holocene tectonic histories .

The association of earthqakes with seismically active structures necessitates an accurate study for surface faulting potential to identify capable faults. The present author considers this point as extremely important and suggests the following steps for studying surface faults to determine their relationship to recent tectonics :

A .Searching for evidence of recent faulting in elevated terraces and beaches for a distance of 25 km to the east , 25 km to the west and 20 km to the south of El Dabaa site.

B. Inspecting stream notches in terrace fronts at intersepts with linear trends for profile evidence of faults that offset terrace materials. Also , searching should be performed elsewhere in notches for faults that offset terrace caps.

C. Searching for evidence of modern faulting in alluvial materials on soil within bed streams in notches and along beach front. At these features offset roots, bushes, animal trails and man-made features, distorted by faulting should be identified.

If the presence of capable faults is proved, it is necessary to study their chronology . The dating of these faults can be determined by a number of techniques such as structural superposition, stratigraphic superposition, and geomorphological and isotopic dating methods (IAEA, 1979).

The relationship of the capable faults in the site vicinity to regional tectonics should be studied. Each seismically active fault which exhibits a trend towards, intersects or lies within the site vicinity should be examined to see whether movements on it can cause displacement at the surface directly or through branch faulting . Moreover, some supplemental detailed geophysical studies in the region of the site are often important in the areas of active tectonism.

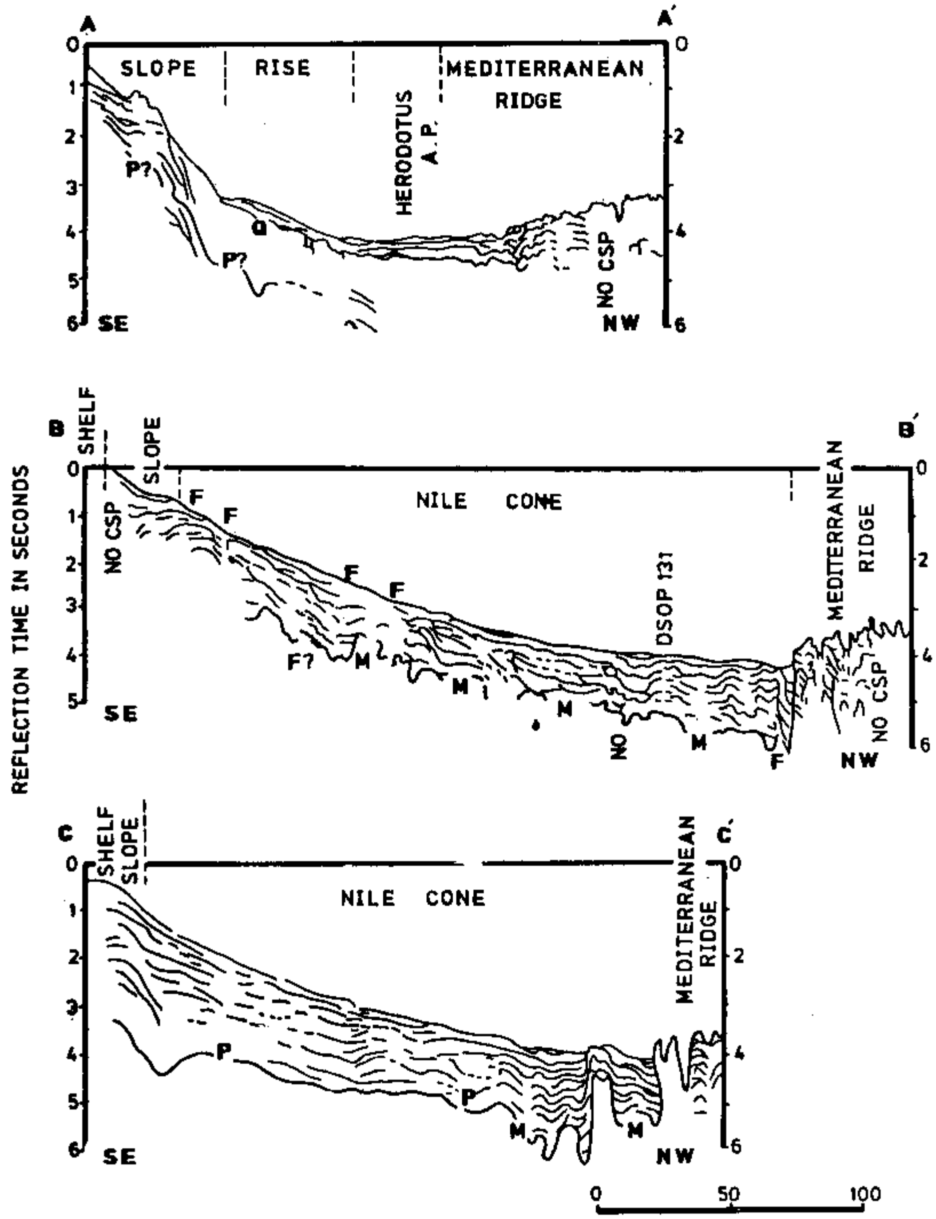

FIG.6. SEISMIC REFLECTION PROFILES OF THE CONTINENTAL MARGIN AND ADJACENT DEEP SEA OF WESTERN EGYPT. (SOURCE : ADAPTED FROM ROSS AND UCHUPI 1977) ROSS, UCHUPI, SUMMERTHAYES, KOELCH AND EL SHAZLY, 1978). FOR LOCATION OF THESE PROFILES SEE FIG. 5.

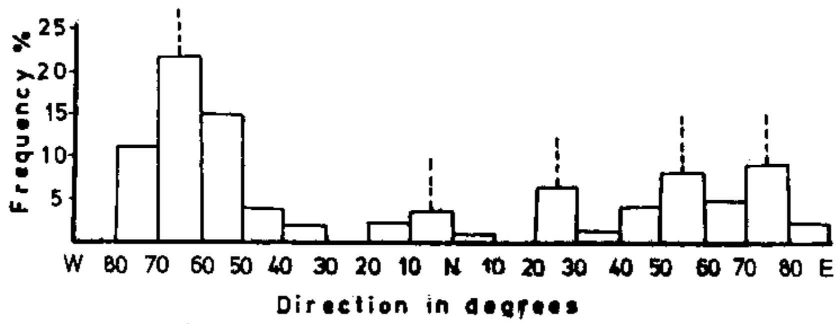

FIG.7.FREQUENCY DISTRIBUTION HISTOGRAM FOR FAULTS, TOP ABU ROASH G,RAZZAK FIELD,NORTH WESTERN DESTERT,EGYPT

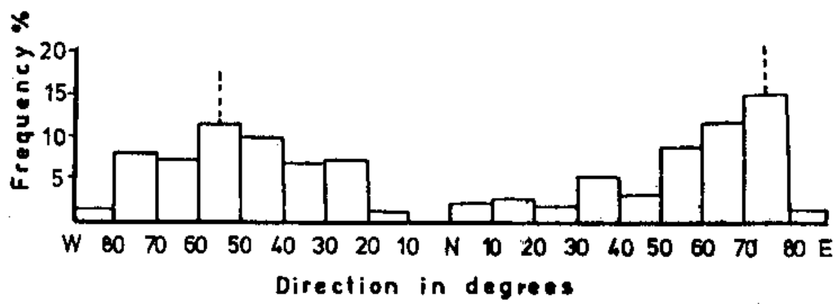

FIG.8.FREQUENCY DISTRIBUTION HISTOGRAM FOR FAULTS, TOP APTIAN DOLOMITE,RAZZAK FIELD,NORTH WESTERN DESERT,EGYPT.

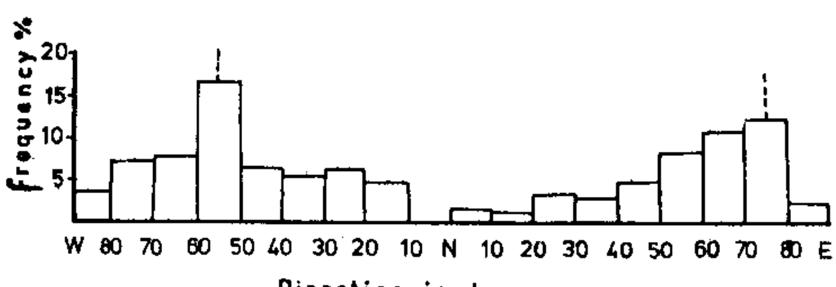

FIG.9.FREQUENCY DISTRIBUTION HISTOGRAM FOR FAULTS, TENTATIVE JURASSIC,RAZZAK FIELD,NORTH WESTERN DESERT,EGYPT.

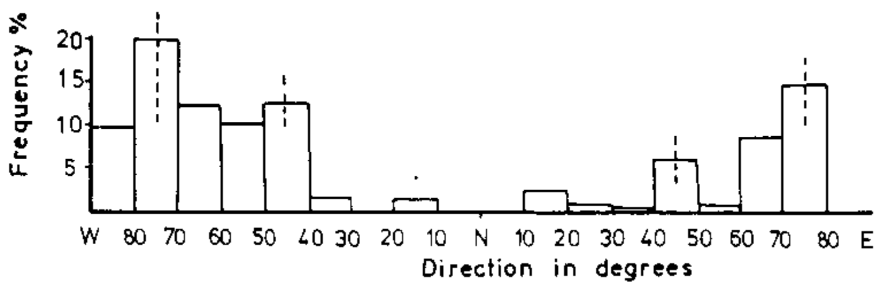

FIG.10. FREQUENCY DISTRIBUTION HISTOGRAM FOR FAULTS, TOP BAHARIYA FORMATION, ABU GHARADIG FIELD, NORTH WESTERN DESERT, EGYPT.

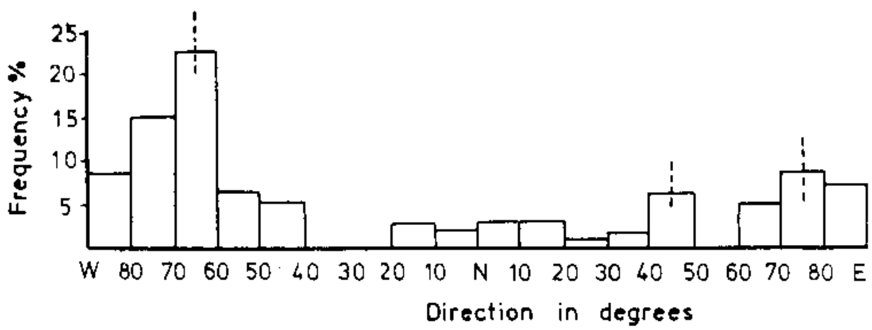

FIG.11. FREQUENCY DISTRIBUTION HISTOGRAM FOR FAULTS, ABU ROASH (C) MEMBER, ABU GHARADIG FIELD, NORTH WESTERN DESERT, EGYPT.

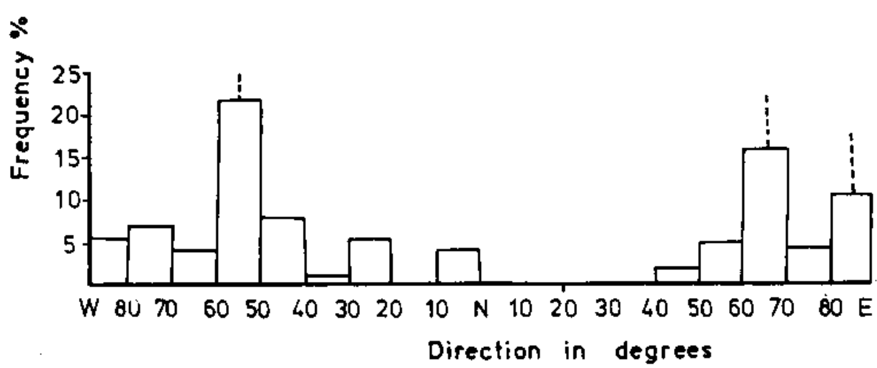

FIG. 12. FREQUENCY DISTRIBUTION HISTOGRAM FOR PHOTOLINEAMENTS BASED ON LANDSAT IMAGERY INTERPRETATION, NORTH WESTERN DESERT, EGYPT.

It is also important to correlate faults with seismicity. The scope and detail of this study will depend on the availability of earthquake data and on the neotectonic activity of the region. Minimum requirements should include evaluation of the earthqueke history for both pre-instrumental and instrumental periods, mapping of earthquake epicentres togerther with the tectonic features of the region . In areas of known neotectonism and usually complex fault structure , microearthquake monitoring may be useful for locating faults in the site vicinity and determining their geometry (IAEA, 1979).

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the previous review of available geological, geophysical and seismicity data with respect to the safety consideration for El Dabaa nuclear power plant, the following points are concluded :

The northern Western Desert in general and El Dabaa site vicinity in particular contain several faults of various dimensions. The most significant fault sets follow WNW and ENE directions . These faults have been identified by remote sensing techniques and geophysical methods. This result proves the effectiveness of the application of remote sensing in regional tectonic studies for nuclear power plant sites. However, both regional and local faults must be checked carefully in the field to determine the presence or absence of active faults in the site vicinity of El Dabaa environs. The results of a thorough field check will be of extreme importance for the safety consideration in the project area. Moreover, microearthquake monitoring often helps in identifying active faults in the project area.

The regional seismicity studies indicate the presence of three active seismic zones. The first follows the Egyptian Mediterranean coastal zone, while the second and the third are represented by Bahariya Fayum Abu Rowash Cairo and Geghbub-Siwa local seismic zones. The Egyptian Mediterranean coastal seismic zone is often controlled by a series of step-like normal faults which follow the same trend and is responsible for the steep inclination in the continental margin to the north of El Dabaa site. This steepness is rather clear in the constructed bathymetric maps.

The geographical distribution of earthquakes indicates that the main seismic center is off shore to the north of Alexandria; about 150 to 200 km ENE of El Babaa site. Moreover, in El Dabaa locality the expected maximum intensity range is VI on NSK scale. Accordingly , seismotectonic provinces within a region of about 300 km radius should be identified carefully. The boundaries of the site seismotectonic province should be established on the basis of extensive investigations.

The bed rock in the site area is mainly soft to medium hard detrital oolitic limestone which is easily soluble and forms cavities. Moreover, the presence of gypsum beds in the subsurface horizons in the site vicinity may be subject to solutioning and consequent deformation. So, the extension of the soft carbonate rocks and gypsum-bearing horizons should be carefully determined . Moreover, the studies of petrophysical characters, microstructures and joint patterns in these rocks are essential in the project area.

The IAEA Safety Guide No. 50-SG-SI is very suitable to be applied in nuclear power plant siting investigations in Egypt. This Safety Guide gave an integrated treatments for earthquakes and associated topics in relation to nuclear power plant siting .

REFERENCES

Abdallah, A.M., 1966 : Stratigraphy and structure of Sidi Barrani area in the north Western Desert of Egypt : U.A.R. Geol. Surv., Cairo (internal report)..

Abdel Baki, S.H., W.M. Meshref and M.A. Azoni, 1982 : A study of the northern Western Desert using the analysis of gravity and aeromagnetic data : Annals of G.S.E., Cairo , V. XII , pp. 193-206.

Albert, R.N.H. and R.M. Kebeasy, 1986 : Seismicity survey at El Dabaa area, Northern Western Desert. Egypt : Proc. 1st Sc. Gen Meetings, NARIG, Egypt, Vol. B, pp.1-23 .

Allam , A. and H. El Khashab , 1978 : Estimation of seismic intensities of Shedwan and Nile Delta earthquakes, Egypt : Helwan Institute of Astronomy and Geophysics (HIAG) Cairo , Egypt , Bull . 174 , pp. 1-8 .

Allam , A., H. El Khashab, M. Maamoun, E. Ibrahim and A. Abuel Ata. 1979 : Studies on seismicity in the area of El Dabaa, Zaafarana and south Safaga Nuclear Power Plant Sites : HIAG, Cairo , Egypt , Bull . 186, pp. 1-83.

Bayoumi, A. , M. Fahim , F. Ahmed and H. Deebes , 1979 : Major structural features of the basement complex in Egypt : HIAG , Cairo , Egypt. Bull .181, pp. 1-13.

EGCO , 1983 : Earthquake Risk Survey, Gabal Zeit area, Red Sea, Egypt : A study prepared by the Egyptian Geological Consulting office "EGCO" Cairo , Egypt, to ESSO EGYPT INC . pp. 1-20 .

Eggenberger , A.J., D. Rowlands and P.C. Rizzo , 1975 : The utilization of Landsat imagery in Nuclear Power Plant Siting : NASA Earth Resources Survey Symposium, Houston , Texas ,V. I-B , pp. 799-832.

El Etr , H.A., A..M. Abdallah and M.A. Yehia , 1973 : Structural analysis of the area southeast of Sidi Barrani, North-western Mediterranean Coast : Egypt. J. Geol., V. 17.No . 2,pp. 125-145.

El Ghawaby, M. 1979 : The tectonic development of north eastern Africa : First Geological Congress of the Middle East (GEOCOME -1) , 4-7 September 1979, Ankara, Turkey p. 20-42.

El Hefnawey , M. et al. , 1984 : Analysis of seismic data in El Dabaa area, Western Desert, Egypt : In press (Bull . Fac. Sci., Ain Shams Univ., Cairo) , 11 p.

El Shamy, I. , 1968 : The geology of water and soil resources in El Dabaa area, western Mediterranean Coastal zone , UAR : M.Sc. thesis, Cairo University, Cairo, Egypt .

El Shazly , E.M., M.A. Abdel Hady, M.A. El Ghaeaby, I.A. El Kassas, S.M. Khawasic, M.M. El Shazly and S. Sanad, 1975 : Geologic interpretation of Landsat satellite images for west Nile Delta area, Egypt : Remote Sensing Project, Cairo , Egypt. pp. 1-38 .

El Shazly, E.M. , A.B. Salman, M.M. Someida, M.A. Morsy and I.E. El Aassy , 1976 : Report on the evaluation of gypsum and clay, Deer El Biraqat- El Hagf. North Western Desert, Egypt : Internal report, Atomic Energy Establishment. Geology and Raw Materials Dept. Cairo , Egypt. p. 1-49.

El Shazly , E.M., M.A. Abdel Hady, M.M. El Shazly, W. Makram S. Sanad, S. Abdel Mogeith, M.A. Tamer and S.H. Attia, 1978 : Local geological and groundwater investigations of Sidi Kreir Nuclar Power Plant Site, Egypt : Remote. Sensing Center, Cairo, Egypt. p. 1-251 .

El Shazly , E.M., M.A. Abdel Hady, M.M. El Shazly , 1979 : Mediterranean Sea, regional geology and tectonics, Sidi Kreir Nuclear Power Plant Site, Egypt : Remote Sensing Center, Cairo, Egypt. p. 1-38 .

El Shazly , E.M., M.A. Abdel Hady, M.M. El Shazly and S.M. Khawasike, 1979 : Regional geological and hydrological investigations of Sidi Kreir Nuclear Power Plant Site, Egypt : Remote Sensing Center, Cairo , Egypt, p. 1-201.

El Shazly , E.M., M.A. Abdel Hady, M.A. El Ghawaby , A.B. Salman , I.A. El Kassas , S.M. Khawasik, H. El Amin, M.M. El Rakaiby, I.E. El Aassy , A.A. Abdel Megeed and S.I. Mansour, 1981 : New Geological , Structural Lineaments and Drainage Maps of Egypt, Based on Landsat Imagery Interpretation and field Investigations : International Symposium on Remote Sensing of Environments, 3-9 Nov., 1981 , Cairo , Egypt.

Ezzat , M.R. and M. Dia El Din, 1974 : Oil and gas discoveries in the Western Desert, Egypt : 4th Exploration Seminar, EGPC , Cairo , Egypt . 16 p.

Ghanem, M. S. Gabra and S.H. Ahmed, 1971 : El -Omayid gypsum deposit : Ann. G.S.E., V. 1,pp. 111-116.

Gergawi , A. and H.M.A. El Khashab , 1968 : Seismicity of UAR : HIAG , CAiro, Egypt , Bull . 76, p. 1-27.

IAEA , 1979 : Safety Series no. 50-SGSI : Earthquakes and Associated topics in relation to nuclear power plant siting : A Safety Guid , IAEA , Vienna, 60p.

Ibrahim, E.M. and I. Marzouk , 1979 : Seismotectonic study of Egypt : HIAG, Cairo, Egypt, Bull .191 , pp. 1-7 .

Jones, B.L. and P.W. Taylor , 1984 : Late Cretaceous Early Tertiary relationships in north central Egypt : Abstract, EGPC 7th Exploration Seminar, Cairo, Egypt. 1p .

Kebeasy, R. M. 1990 : Seismicity : In Geology of Egypt edited by R. Said, publisher A.A. Balkema/Rotterdam/Brookfield. pp. 51-60.

Maamoun , M.E. and E.M. Ibrahim 1978 : Tectonic activity in Egypt as indicated by earthquakes : HIAG , Cairo , Eygpt , Bull . 170 , pp. 1-21.

Maamoun , M.E. , 1979 a : Macroseismic observations of principal earthquakes in Egypt : HIAG , Cairo , Egypt , Bull . 183 , p. 1-11.

Maamoun , M.E. , 1979 b : Observed intensity-epicentral distance relations in Egyptian earthquakes : HIAG, Cairo, Egypt. Bull. 184 ,pp. 1-7.

Meshref, W.M. and M.M. El Sheikh, 1973 : Magnetic tectonic trend analysis in northern Egypt : Egypt. J. Geol. , V. 17, N0. 2 , pp. 179-184 .

Meshref, W.M. , E.M. Refai, H.S. Sadek , S.H. Abdel Baki, A.M.H.El Sirafe, E.M.I. El Kattan,M.A.M. El Meliegy and M.M. El Sheikh, 1980 : Structural geophysical interpretation of basement rocks of the north Western Desert of Egypt : Annals of the Geological Survey of Egypt, V. X, pp. 923-937.

Meshref, W.M., 1982 : Regional structural setting of northern Egypt : 6 Th EGPC Exploration Seminar, Cairo, Egypt, 10 p.

Nakhla, A.F. and E.A. podelove , 1973 : Qualitative and quantitative analyses of the aeromagnetic survey over the western part of the Western Desert, Egypt : Egypt .J. Geol., V , 17, No. 2,pp. 185-191

Riad , S., 1977 : Shear Zones in north Egypt, interpreted from gravity Data : Geophysics, V. 42, No . 6, pp. 1207-1214 .

Raid , S.M. Shaaban and A. Tealeb, 1979 : Tectonic trends and basement relief in the area of Minya, Egypt : HIAG, Cairo, Egypt, Bull. 209 , pp. 1-15.

Ross, D.A. and E. Uchupi, 1977 : The structure and sedimentary history of the southeastern Mediterranean Sea-Nile Cone area : AAPG Bull., V. 61, pp. 872-902.

Ross, D.A., E. Uchupi , C.P. Summerhays, D.E. Koelsch and E.M. El Shazly, 1978 : Sedimentation and structure of the Nile Cone and Levant Platform area : in Sedimentation in Submarine Canyons, Fans and Trenches, eds. D.J. Stanley and G.Kelling . Dowden, Hatchnson & Ross, Inc., Strounsburg, Pennsylvania, U.S.A., p. 261 - 275.

Ross, D.A. and E. Uchupi, 1979 : Shallow structure and Sedimentation in the South-eastern Mediterranea Sea : Sediment . Geol., V. 23, pp. 1-18.

Said , R., 1981 : The geological evolution of the River Nile: Springer Verlage New York , Heidelberg Berlin. P. 1-104 .

Said , R., 1990 : Geology of Egypt : Published by A.A. Balkema/ Rotterdam/Brookfield. 774 pp.

Salman, A.B., 1982 : Application of Landsat imagery to structural interpretations and exploration for petroleum in the Gulf of Suez environs, Egypt : American University in Cairo Press, Cairo, Egypt . 27 p .

Siagaev, N.A., 1959 : The main tectonic features of Egypt . An explanatory note to tectonic map of Egypt, Scale 1 : 2000,000 : Geol Surv. Dept., Cairo, Paper No . 39 , pp. 1-26.

Tealeb , A., 1979 a : Deep crustal studies in north Egypt based on the spectral analysis of the Bouguer anomly : HIAG , Cairo , Egypt , Bull , 176, pp. 1-21 .

Tealeb, A., 1979 b : Predominant tectonic trends in north Egypt : HIAG, Cairo , Egypt , Bull . V.189, pp. 1-22.