NUCLEAR POWER PLANT SITE SELECTION

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I. Introduction

The aim of this article is to present the requirements and characteristics for the nuclear power plant site selection.

It will focus on the treatments of the main geologic and tectonic features and the nature of the site.

Sitting factors and criteria are important in assuring that radiological doses from normal operation and postulated accidents will be acceptably low.

Factors to be considered when evaluating sites

(a) Characteristics of reactor design and proposed operation including:

(1) Intended use of the reactor including the proposed maximum power level and the nature and inventory of contained radioactive materials;

(2) The extent to which generally accepted engineering standards are applied to the design of the reactor;

(3) The extent to which the reactor incorporates unique or unusual features having a significant bearing on the probability or consequences of accidental release of radioactive materials;

(4) The safety features that are to be engineered into the facility and those barriers that must be breached as a result of an accident before a release of radioactive material to the environment can occur.

(b) Population density and use characteristics of the site environs, including the exclusion area, low population zone, and population center distance.

Exclusion area

Area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area

Low population zone

Area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident.

Population center distance

The distance from the reactor to the nearest boundary of a densely populated center ($\geq$ 25,000 residents).

(c) Physical characteristics for site; seismology, meteorology, geology & hydrology

(1) Seismic and Geologic Sitting Criteria for Nuclear Power Plants," describes the nature of investigations required to obtain the geologic and seismic data necessary to determine site suitability and to provide reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public.

It describes procedures for determining the quantitative vibratory ground motion design basis at a site due to earthquakes and describes information needed to determine whether and to what extent a nuclear power plant need be designed to withstand the effects of surface faulting.

(2) Meteorological conditions at the site and in the surrounding area should be considered.

(3) Geological and hydrological characteristics of the proposed site may have a bearing on the consequences of an escape of radioactive material from the facility. Special precautions should be planned if a reactor is to be located at a site where a significant quantity of radioactive effluent might accidentally flow into nearby streams or rivers or might find ready

(d) Where unfavorable physical characteristics of the site exist, the proposed site may nevertheless be found to be acceptable if the design of the facility includes appropriate and adequate compensating engineering safeguards.

Geologic and seismic sitting criteria.

(c) *Geological, seismological, and engineering characteristics*

The geological, seismological, and engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, to provide sufficient information to support evaluations performed to arrive at estimates of the Safe Shutdown Earthquake Ground Motion, and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site

The following points should be studied;

*vibratory ground motion,

*tectonic surface deformation,

*non-tectonic deformation,

*earthquake recurrence rates,

*fault geometry and slip rates,

*site foundation materials, and

*seismically induced floods and water waves

(d) *Geologic and seismic sitting factors.*

The geologic and seismic sitting factors considered for design must include a determination of the Safe Shutdown Earthquake Ground Motion for the site, the potential for surface tectonic and non-tectonic deformations, the design bases for seismically induced floods and water waves.

(1) Determination of the Safe Shutdown Earthquake Ground Motion.

The Safe Shutdown Earthquake Ground Motion for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface. Uncertainties are inherent in such estimates. These uncertainties must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis or suitable sensitivity analyses.

(2) Determination of the potential for surface tectonic and nontectonic deformations.

Sufficient geological, seismological, and geophysical data must be provided to clearly establish whether there is a potential for surface deformation.

(3) Determination of design bases for seismically induced floods and water waves.

The size of seismically induced floods and water waves that could affect a site from either locally or distantly generated seismic activity must be determined.

(4) Determination of siting factors for other design conditions.

Siting factors for other design conditions that must be evaluated include: soil and rock stability, liquefaction potential, natural and artificial slope stability, cooling water supply, and remote safety-related structure siting.

Each applicant shall evaluate all siting factors and potential causes of failure, such as, the physical properties of the materials underlying the site, ground disruption, and the effects of vibratory ground motion that may affect the design and operation of the proposed nuclear power plant.

IV. Required Investigations

(a) Required Investigation for Vibratory Ground Motion.

The investigations required here provide an adequate basis for selection of an Operating Basis Earthquake:

(1) Determination of the lithologic, stratigraphic, hydrologic, and structural geologic conditions of the site and the region surrounding the site, including its geologic history;

(2) Identification and evaluation of tectonic structures underlying the site and the region surrounding the site, whether buried or expressed at the surface.

(3) Evaluation of physical evidence concerning the behavior during prior earthquakes of the surficial geologic materials and the substrata underlying the site from the lithologic, stratigraphic, and structural geologic studies;

(4) Determination of the static and dynamic engineering properties of the materials underlying the site. Included should be properties needed to determine the behavior of the underlying material during earthquakes and the characteristics of the underlying material in transmitting earthquake-induced motions to the foundations of the plant, such as seismic wave velocities, density, water content, porosity, and strength;

(5) Listing of all historically reported earthquakes which have affected or which could reasonably be expected to have affected the site, including the date of occurrence and the following measured or estimated data: magnitude or highest intensity, and a plot of the epicenter or location of highest intensity.

(6) Correlation of epicenters or locations of highest intensity of historically reported earthquakes, where possible, with tectonic structures any part of which is located within 200 miles of the site. Epicenters or locations of highest intensity which cannot be reasonably correlated with tectonic structures shall be identified with tectonic provinces any part of which is located within 200 miles of the site;

(7) For faults, any part of which is within 200 miles^2 of the site and which may be of significance in establishing the Safe Shutdown Earthquake, determination of whether these faults are to be considered as capable faults.

This determination is required in order to permit appropriate consideration of the geologic history of such faults in establishing the Safe Shutdown Earthquake.

Table 1: The minimum length of fault to be considered versus distance from site. Capable faults of lesser length than those indicated in table 1 and faults which are not capable faults need not be considered in determining the Safe Shutdown Earthquake, such consideration is appropriate;

Distance from the site (miles):	Minimum length
0 to 20	1
Greater than 20 to 50	5
Greater than 50 to 100	10
Greater than 100 to 150	20
Greater than 150 to 200	40

(8) For capable faults, any part of which is within 200 miles^2 of the site and which may be of significance in establishing the Safe Shutdown Earthquake, determination of:

(i) The length of the fault;

(ii) The relationship of the fault to regional tectonic structures; and

(iii) The nature, amount, and geologic history of displacements along the fault, including particularly the estimated amount of the maximum Quaternary displacement related to any one earthquake along the fault.

(b) *Required Investigation for Surface Faulting*

(1) Determination of the lithologic, stratigraphic, hydrologic, and structural geologic conditions of the site and the area surrounding the site, including its geologic history;

(2) Evaluation of tectonic structures underlying the site, whether buried or expressed at the surface, with regard to their potential for causing surface displacement at or near the site. The evaluation shall consider the possible effects caused by man's activities such as withdrawal of fluid from or addition of fluid to the subsurface, extraction of minerals, or the loading effects of dams or reservoirs;

(3) Determination of geologic evidence of fault offset at or near the ground surface at or near the site;

(4) For faults greater than 1000 feet long, any part of which is within 5 miles of the site, determination of whether these faults are to be considered as capable faults

(5) Listing of all historically reported earthquakes which can reasonably be associated with capable faults greater than 1000 feet long, any part of which is within 5 miles of the site, including the date of occurrence and the following measured or estimated data: magnitude or highest intensity, and a plot of the epicenter or region of highest intensity;

(6) Correlation of epicenters or locations of highest intensity of historically reported earthquakes with capable faults greater than 1000 feet long, any part of which is located within 5 miles of the site;

(7) For capable faults greater than 1000 feet long, any part of which is within 5 miles of the site, determination of:

(i) The length of the fault;

(ii) The relationship of the fault to regional tectonic structures;

(iii) The nature, amount, and geologic history of displacements along the fault, including particularly the estimated amount of the maximum Quaternary displacement related to any one earthquake along the fault; and

(iv) The outer limits of the fault established by mapping Quaternary fault traces for 10 miles along its trend in both directions from the point of its nearest approach to the site.

Surface faults (Salman, 1995) and their relation to the recent tectonics:

A. Searching for evidences of recent faulting in elevated terraces and beaches for distance of 25 km around NPP site.

B. Inspecting stream notches in terrace fronts at intersects with linear trends for profile evidence of faults that offset terrace materials and faults that offset terrace caps.

C. Searching for evidences 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 mage features, distorted by faulting should be identified.

(c) *Required Investigation for Seismically Induced Floods and Water Waves.*

(1) For coastal sites, the investigations shall include the determination of:

(i) Information regarding distantly and locally generated waves or tsunami which have affected or could have affected the site. Available evidence regarding the runup and drawdown associated with historic tsunami in the same coastal region as the site shall also be included;

(ii) Local features of coastal topography which might tend to modify tsunami runup or drawdown. Appropriate available evidence regarding historic local modifications in tsunami runup or drawndown at coastal locations having topography similar to that of the site shall also be obtained; and

(iii) Appropriate geologic and seismic evidence to provide information for establishing the design basis for seismically induced floods or water waves from a local offshore earthquake, from local offshore effects of an onshore earthquake, or from coastal subsidence.

The probable slip characteristics of offshore faults shall also be considered as well as the potential for offshore slides in submarine material.

(2) For sites located near lakes and rivers.

This is important to determine the potential for the nuclear power plant to be exposed to seismically induced floods and water waves as, for example, from the failure during an earthquake of an upstream dam or from slides of earth or debris into a nearby lake.

V. Seismic and Geologic Design Bases

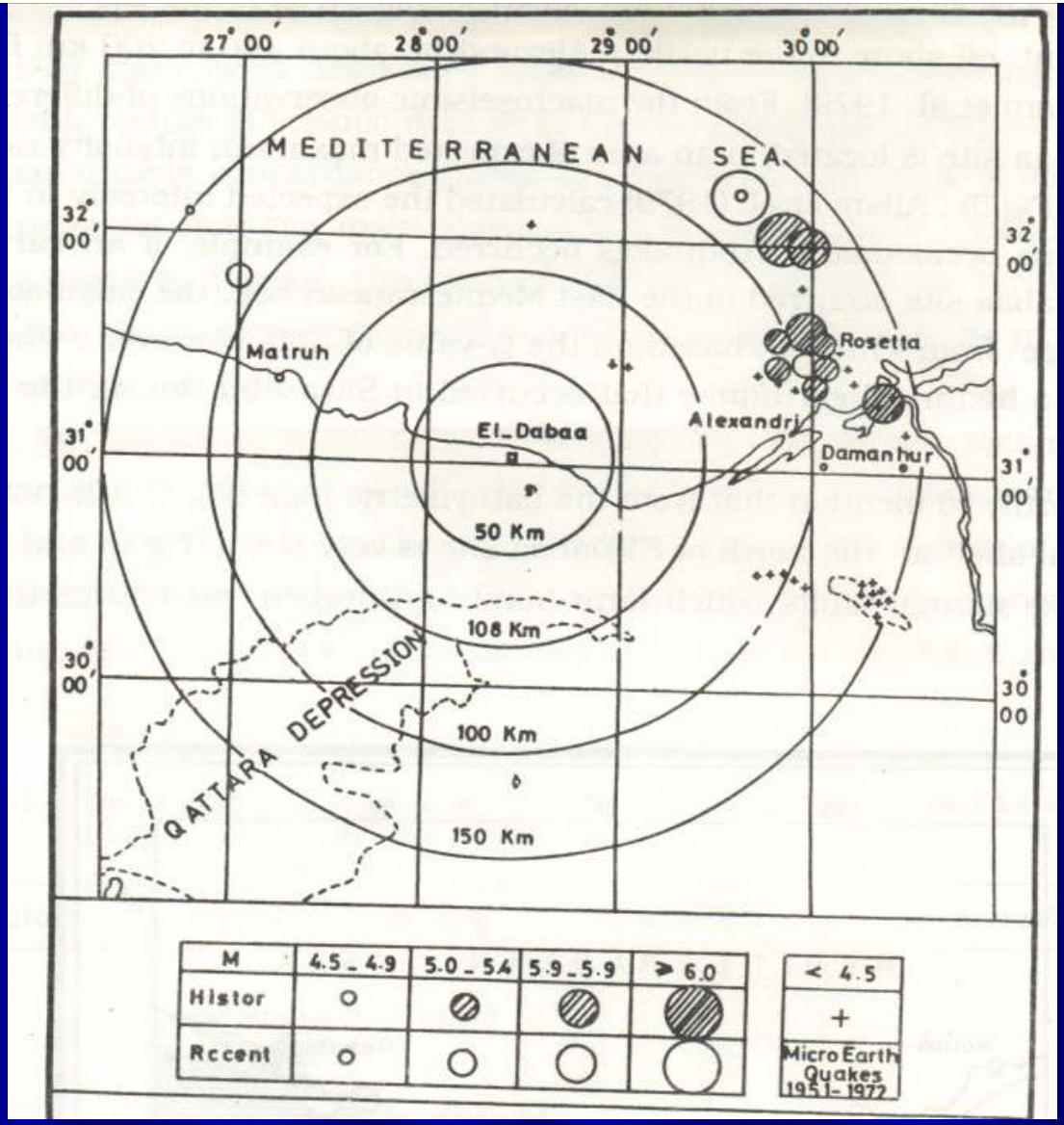
(a) ***Determination of Design Basis for Vibratory Ground Motion.***

The design of each nuclear power plant shall take into account the potential effects of vibratory ground motion caused by earthquakes. The design basis for the maximum vibratory ground motion and the expected vibratory ground motion should be determined through evaluation of the seismology, geology, and the seismic and geologic history of the site and the surrounding region.

(1) Determination of Safe Shutdown Earthquake.

The Safe Shutdown Earthquake shall be identified through evaluation of seismic and geologic information developed pursuant to the requirements of paragraph IV(a), as follows:

(i) The historic earthquakes of greatest magnitude or intensity which have been correlated with tectonic structures. In addition, for capable faults, shall also be taken into account in determining the earthquakes of greatest magnitude related to the faults.



Earthquakes magnitude in East Mediterranean Region

(ii) Where epicenters or locations of highest intensity of historically reported earthquakes cannot be reasonably related to tectonic structures, but are identified with tectonic provinces in which the site is located, the accelerations at the site shall be determined assuming that these earthquakes occur at the site;

(iii) Where epicenters or locations of the highest intensity of historically reported earthquakes cannot be reasonably related to tectonic structures, but are identified with tectonic provinces in which the site is not located, the accelerations at the site shall be determined assuming that the epicenters or locations of highest intensity of these earthquakes are at the closest point to the site on the boundary of the tectonic province;

(iv) The earthquake producing the maximum vibratory acceleration at the site shall be designated the Safe Shutdown Earthquake for vibratory ground motion.

(v) Where the maximum vibratory accelerations of the Safe Shutdown Earthquake at the foundations of the nuclear power plant structures are determined to be less than one-tenth the acceleration of gravity (0.1 g) as a result of the steps required in paragraphs (a)(1)(i) through (iv) of this section, it shall be assumed that the maximum vibratory accelerations of the Safe Shutdown Earthquake at these foundations are at least 0.1 g.

(2) *Determination of Operating Basis Earthquake.*

The Operating Basis Earthquake shall be specified by the applicant after considering the seismology and geology of the region surrounding the site. If vibratory ground motion exceeding that of the Operating Basis Earthquake occurs, shutdown of the nuclear power plant will be required. Prior to resuming operations, the licensee will be required to demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public. The maximum vibratory ground acceleration of the Operating Basis Earthquake shall be at least one-half the maximum vibratory ground acceleration of the Safe Shutdown Earthquake.

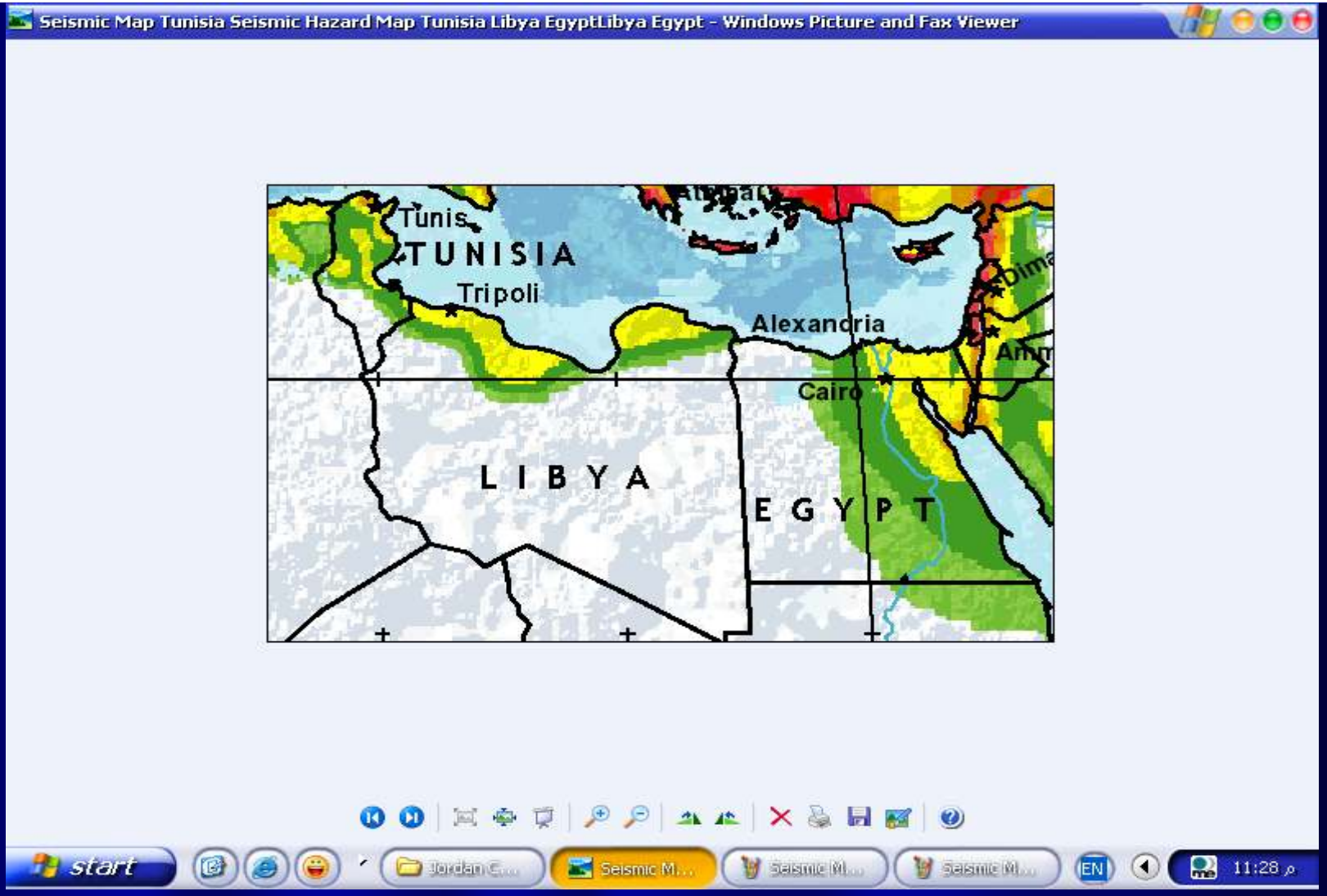


Fig. Sciesmisity magnitude map for SE Mediterranean Sea

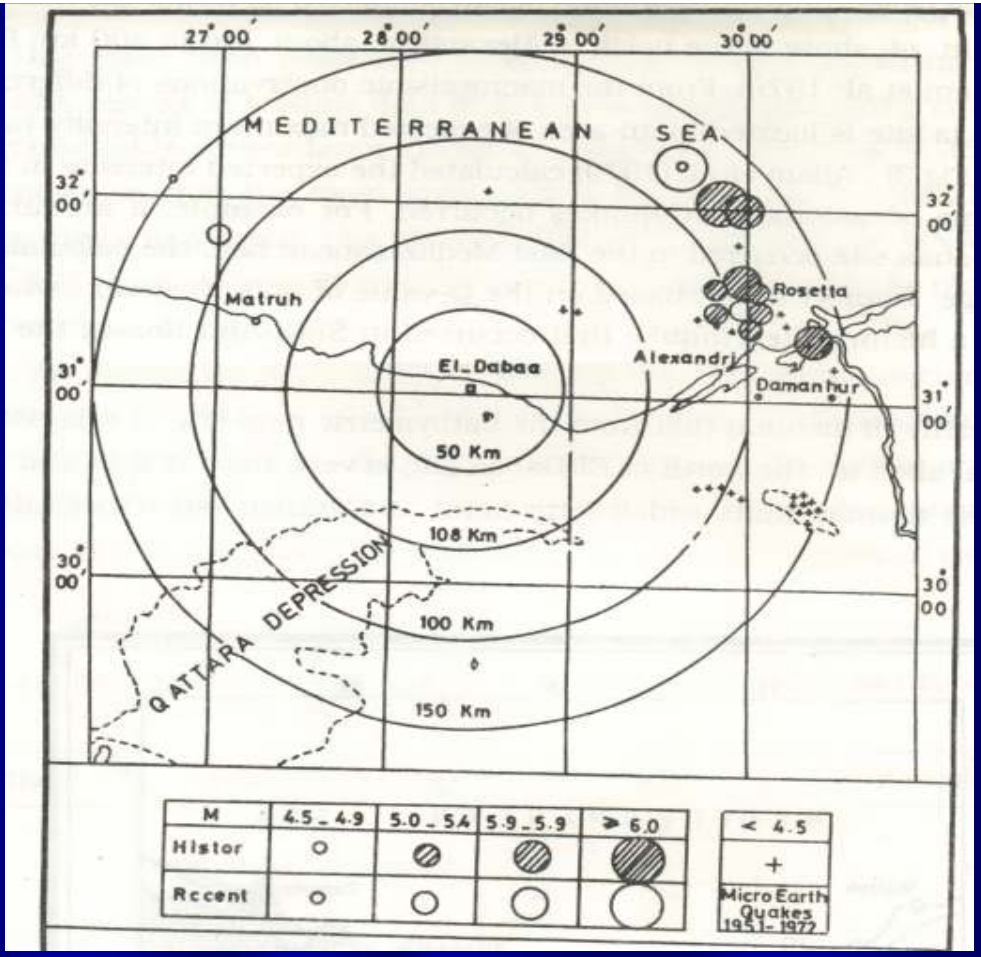


Fig. Geographic distribution of earthquakes (after Allam, et.al, 1979) for

El Dabaa region (in Salman 1995)

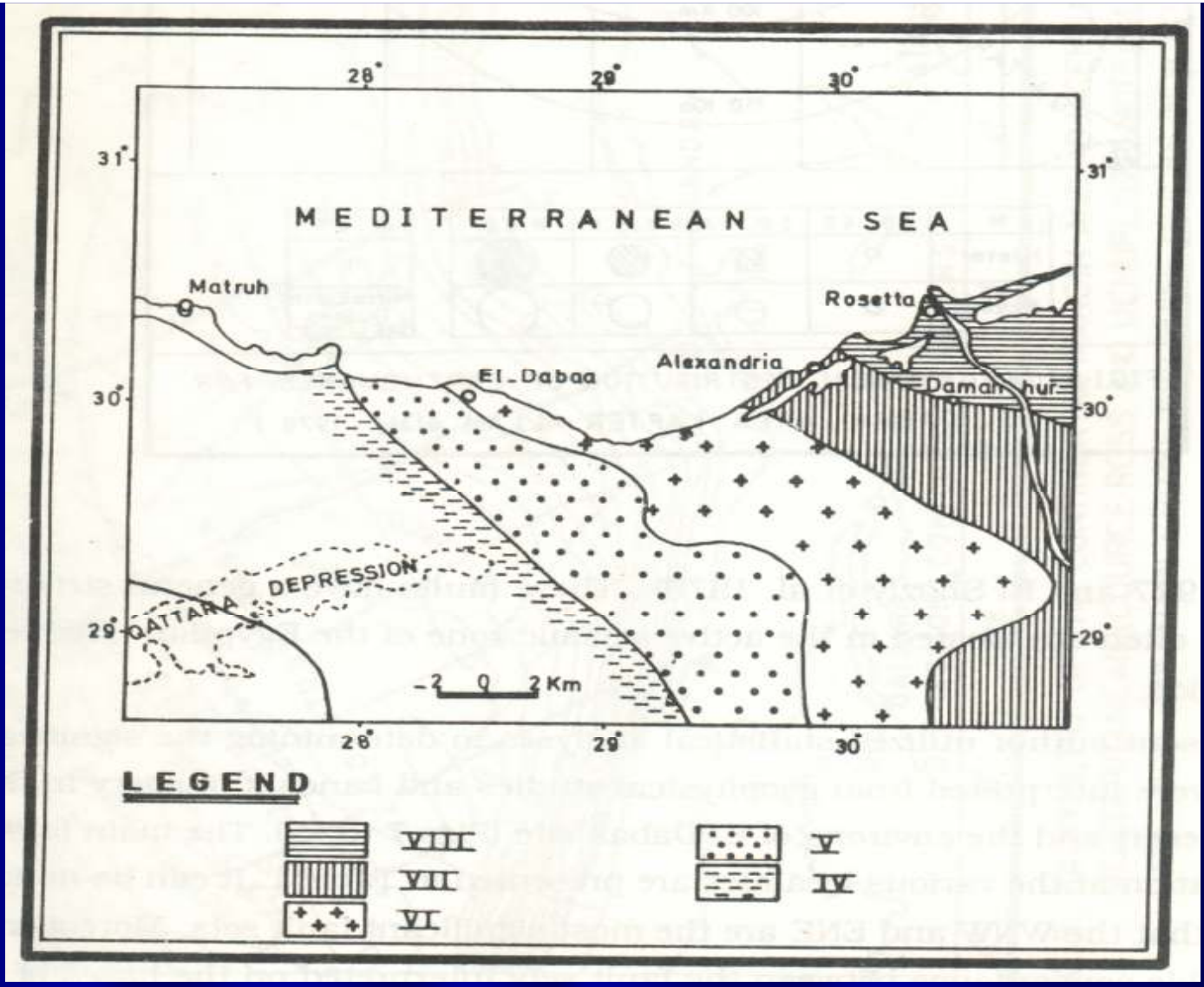


Fig. Intensity map for El Dabaa region (in Salman 1995), based on maximum intensity (after Allam, et.al., 1979)

(b) *Determination of Need to Design for Surface Faulting*

In order to determine whether a nuclear power plant is required to be designed to withstand the effects of surface faulting, the location of the nuclear power plant with respect to capable faults shall be considered.

The area over which each of these faults has caused surface faulting in the past is identified by mapping its fault traces in the vicinity of the site. The fault traces are mapped along the trend of the fault for 10 miles in both directions from the point of its nearest approach to the nuclear power plant because, for example, traces may be obscured along portions of the fault.

* The maximum width of the mapped fault traces, called the control width, is then determined from this map. Because surface faulting has sometimes occurred beyond the limit of mapped fault traces or where fault traces have not been previously recognized.

* The control width of the fault is increased by a factor which is dependent upon the largest potential earthquake related to the fault. This larger width delineates a zone, called the zone requiring detailed faulting investigation, in which the possibility of surface faulting is to be determined.

*The following paragraphs outline the specific procedures for determining the zone requiring detailed faulting investigation for a capable fault.

(1) *Determination of Zone Requiring Detailed Faulting Investigation.*

The zone requiring detailed faulting investigation for a capable fault (Fig.1) as in the following table 2:

Magnitude of earthquake	Width of zone requiring detailed faulting investigation
Less than 5.5	1 x control width.
5.5-6.4	2 x control width.
6.5-7.5	3 x control width.
Greater than 7.5	4 x control width

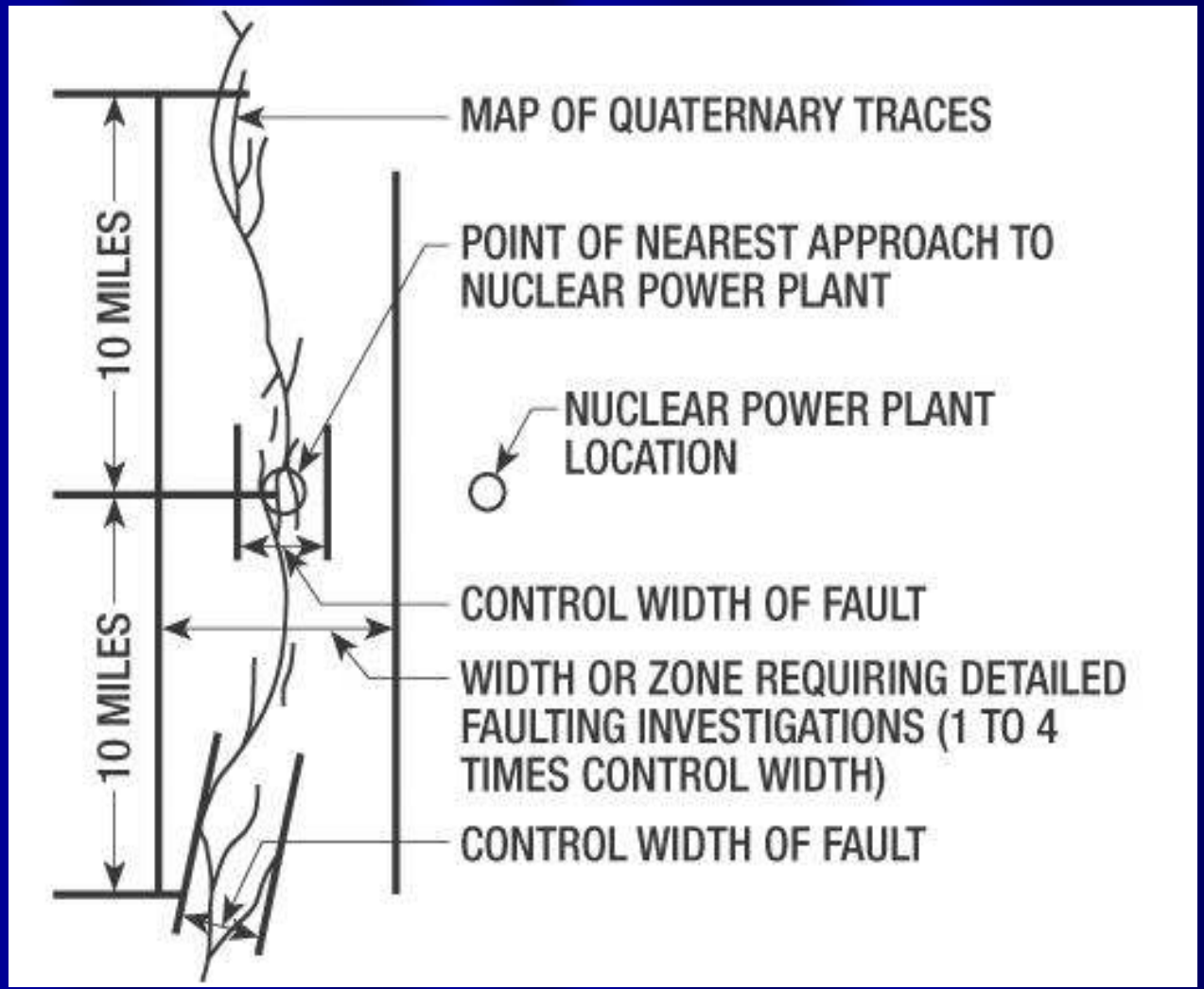


Fig.1. Fault - power plant site relation

The zone requiring detailed faulting investigation, as determined from table 2, shall be used for the fault except where:

(i) The zone requiring detailed faulting investigation from table 2 is less than one-half mile in width. In this case the zone shall be at least one-half mile in width; or

(ii) Definitive evidence concerning the regional and local characteristics of the fault justifies use of a different value. For example, thrust or bedding-plane faults may require an increase in width of the zone to account for the projected dip of the fault plane; or

(iii) More detailed three-dimensional information, such as that obtained from precise investigative techniques, may justify the use of a narrower zone. Possible examples of such techniques are the use of accurate records from closely spaced drill holes or from closely spaced, high-resolution offshore geophysical surveys.

In delineating the zone requiring detailed faulting investigation for a fault, the center of the zone shall coincide with the center of the fault at the point of nearest approach of the fault to the nuclear power plant as illustrated in figure 1.

(c) *Determination of Design Bases for Seismically Induced Floods and Water Waves.*

*** The size of seismically induced floods and water waves which could affect a site from either locally or distantly generated seismic activity shall be determined.**

*** Local topographic characteristics which might tend to modify the possible runup and drawdown at the site shall be considered. Adverse tide conditions shall also be taken into account in determining the effect of the floods and waves on the site.**

*** The characteristics of the earthquake to be used in evaluating the offshore effects of local earthquakes must be determined.**

d) *Determination of Other Design Conditions*

(1) Soil Stability

Vibratory ground motion associated with the Safe Shutdown Earthquake can cause soil instability due to ground disruption such as fissuring, differential consolidation, liquefaction, and cratering which is not directly related to surface faulting. The following geologic features which could affect the foundations of the proposed nuclear power plant structures shall be evaluated, taking into account the information concerning the physical properties of materials underlying the site:

(i) Areas of actual or potential surface or subsurface subsidence, uplift, or collapse resulting from:

(a) Natural features such as tectonic depressions and cavernous or karst terrains, particularly those underlain by calcareous or other soluble deposits;

(b) Man's activities such as withdrawal of fluid from or addition of fluid to the subsurface, extraction of minerals, or the loading effects of dams or reservoirs; and

(c) Regional deformation.

(ii) Deformational zones such as shears, joints, fractures, folds, or combinations of these features.

(iii) Zones of alteration or irregular weathering profiles and zones of structural weakness composed of crushed or disturbed materials.

(iv) Unrelieved residual stresses in bedrock.

(v) Rocks or soils that might be unstable because of their mineralogy, lack of consolidation, water content, or potentially undesirable response to seismic or other events. Seismic response characteristics to be considered shall include liquefaction, thixotropy, differential consolidation, cratering, and fissuring.

(2) *Slope stability*

Stability of all slopes, both natural and artificial, the failure of which could adversely affect the nuclear power plant, shall be considered.

An assessment shall be made of the potential effects of erosion or deposition and of combinations of erosion or deposition with seismic activity, taking into account information concerning the physical property of the materials underlying the site and the effects of the Safe Shutdown Earthquake.

(3) *Cooling water supply*

Assurance of adequate cooling water supply for emergency and long-term shutdown decay heat removal shall be considered in the design of the nuclear power plant, taking in to account information concerning the physical properties of the materials underlying the site and the effects of the Safe Shutdown Earthquake and the design basis for surface faulting.

Consideration of river blockage or diversion or other failures which may block the flow of cooling water, coastal uplift or subsidence, or tsunami runup and drawdown, and failure of dams and intake structures shall be included in the evaluation, where appropriate.

(4) *Distant structures*

Those structures which are not located in the immediate vicinity of the site but which are safety related shall be designed to withstand the effect of the Safe Shutdown Earthquake and the design basis for surface faulting determined on a comparable basis to that of the nuclear power plant, taking into account the material underlying the structures and the different location with respect to that of the site.

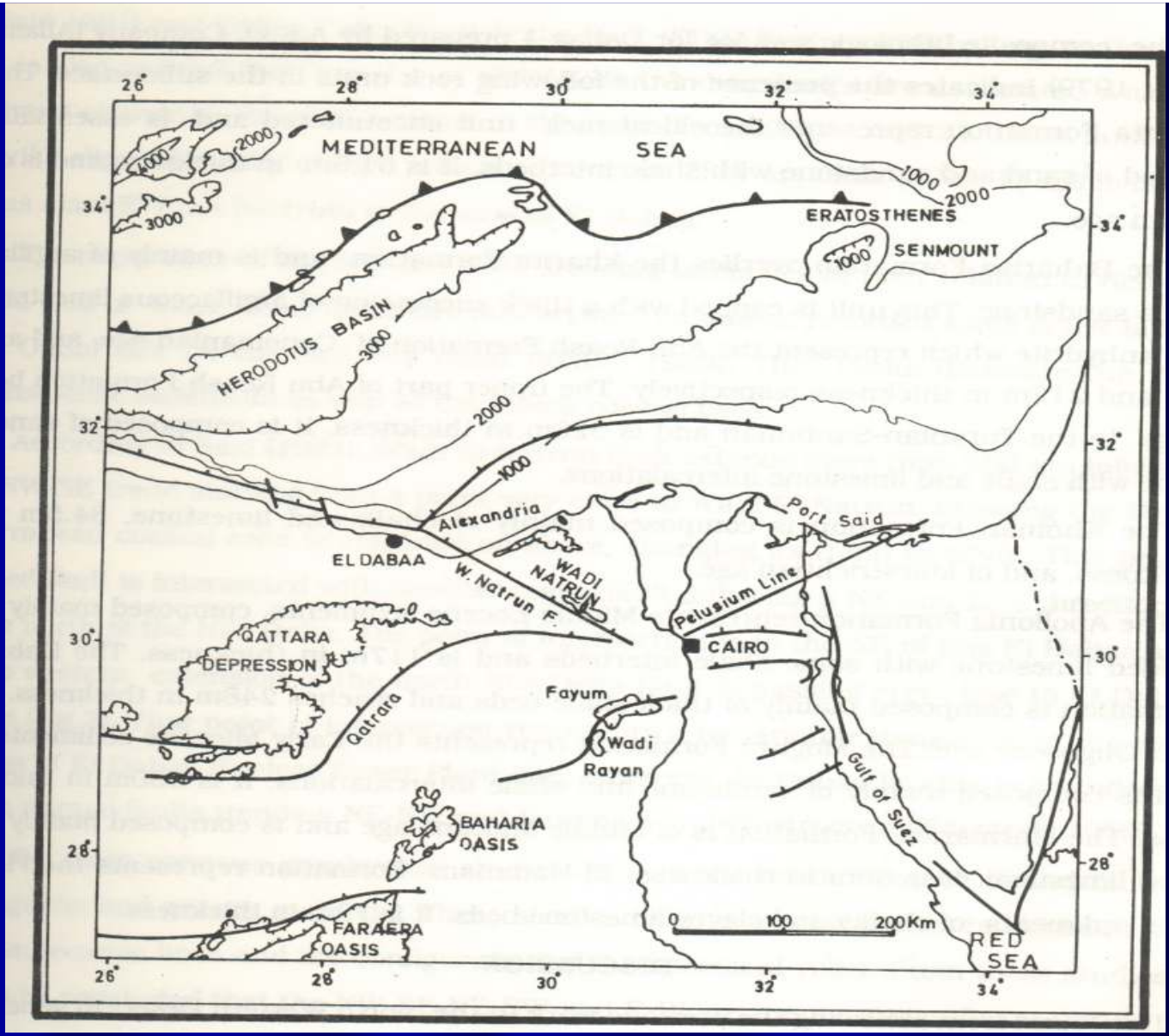
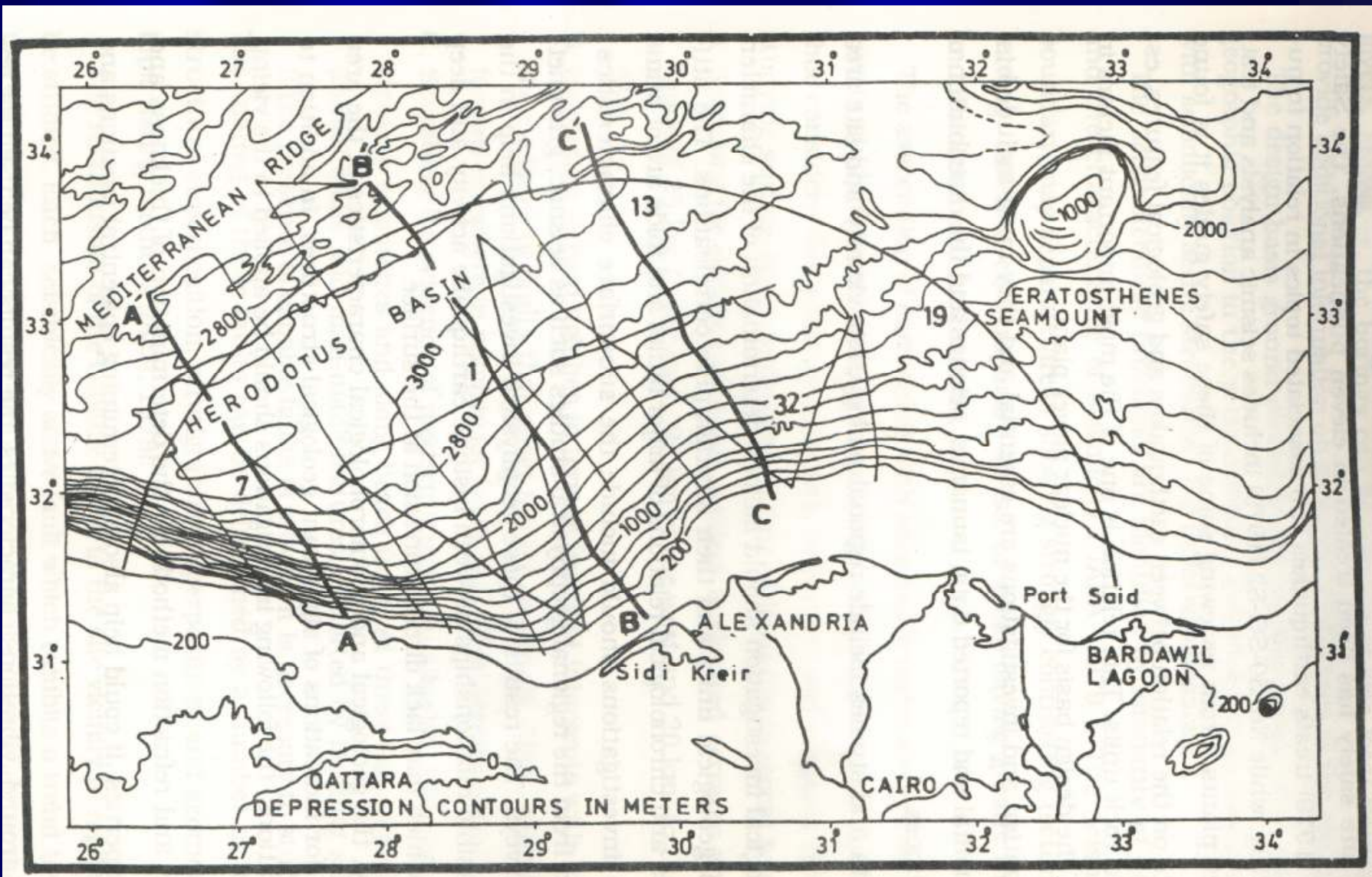


Fig. Schematic map showing major tectonic elements (Said, 1981) of north Egypt showing El Dabaa NPP proposed site (in Salman 1995)



Bathymetry of the continental margin & adjacent deep sea in Eastern Mediterranean, contours in meters corrected for sound velocity (in Salman, 1995)

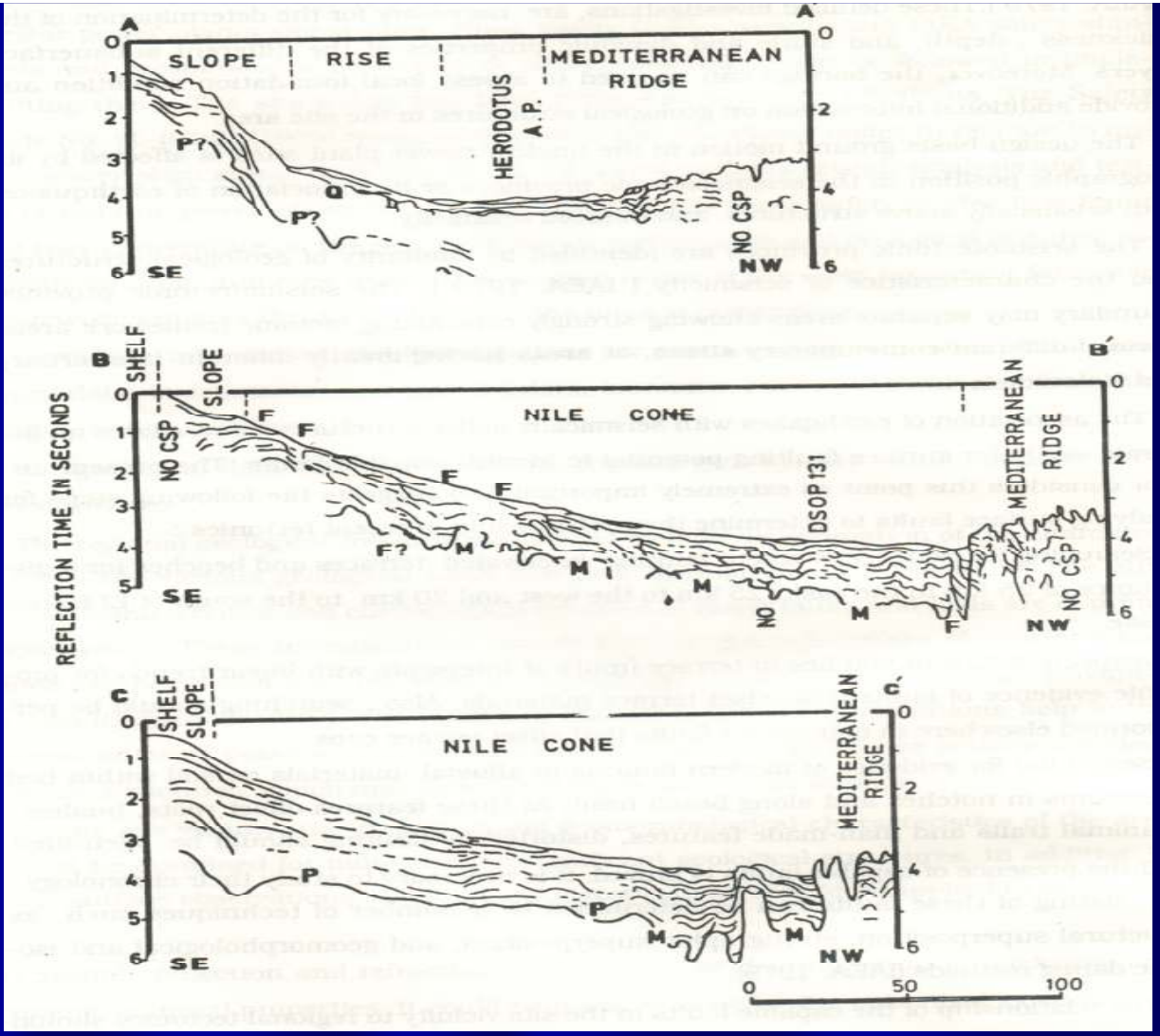


Fig. Seismic reflection profiles of the continental margin, north Egypt **(in Salman, 1995)**

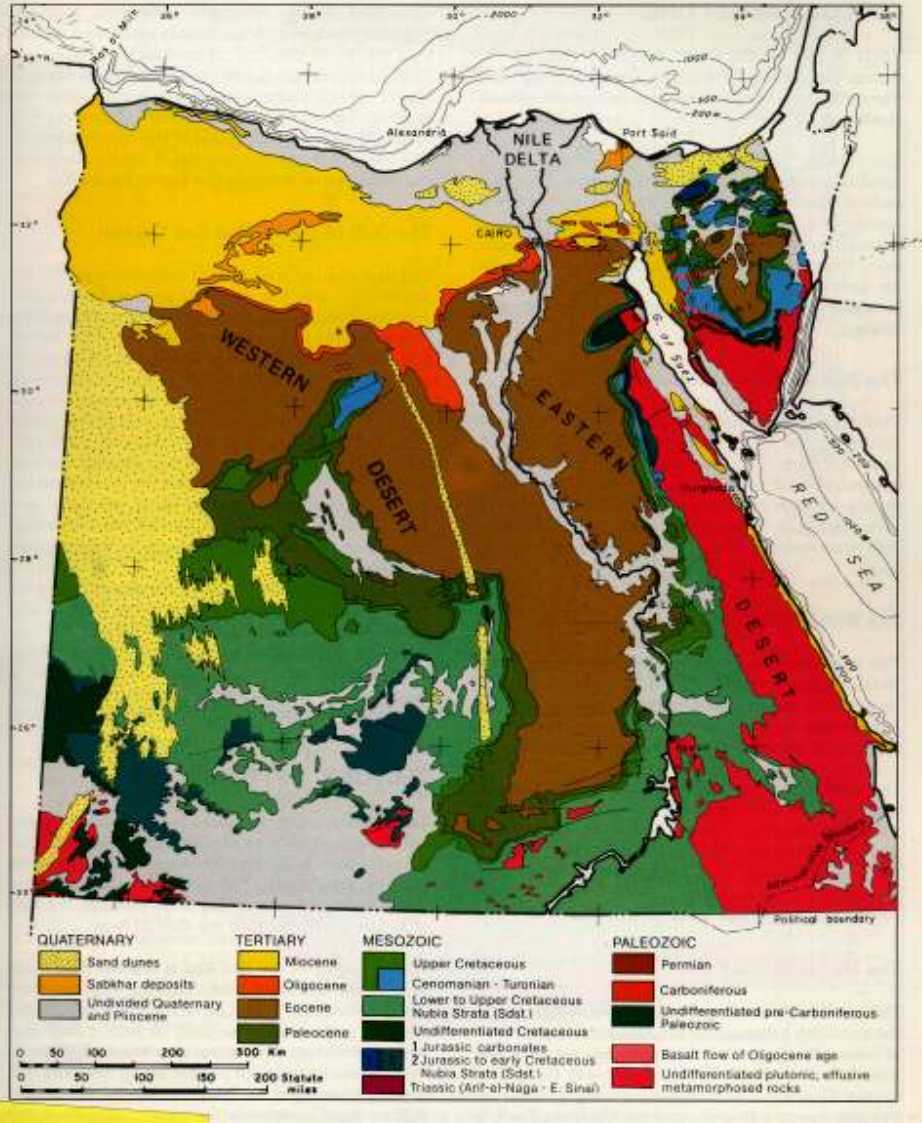


Fig. 1-1. Geological map of Egypt.

Fig. 1.1

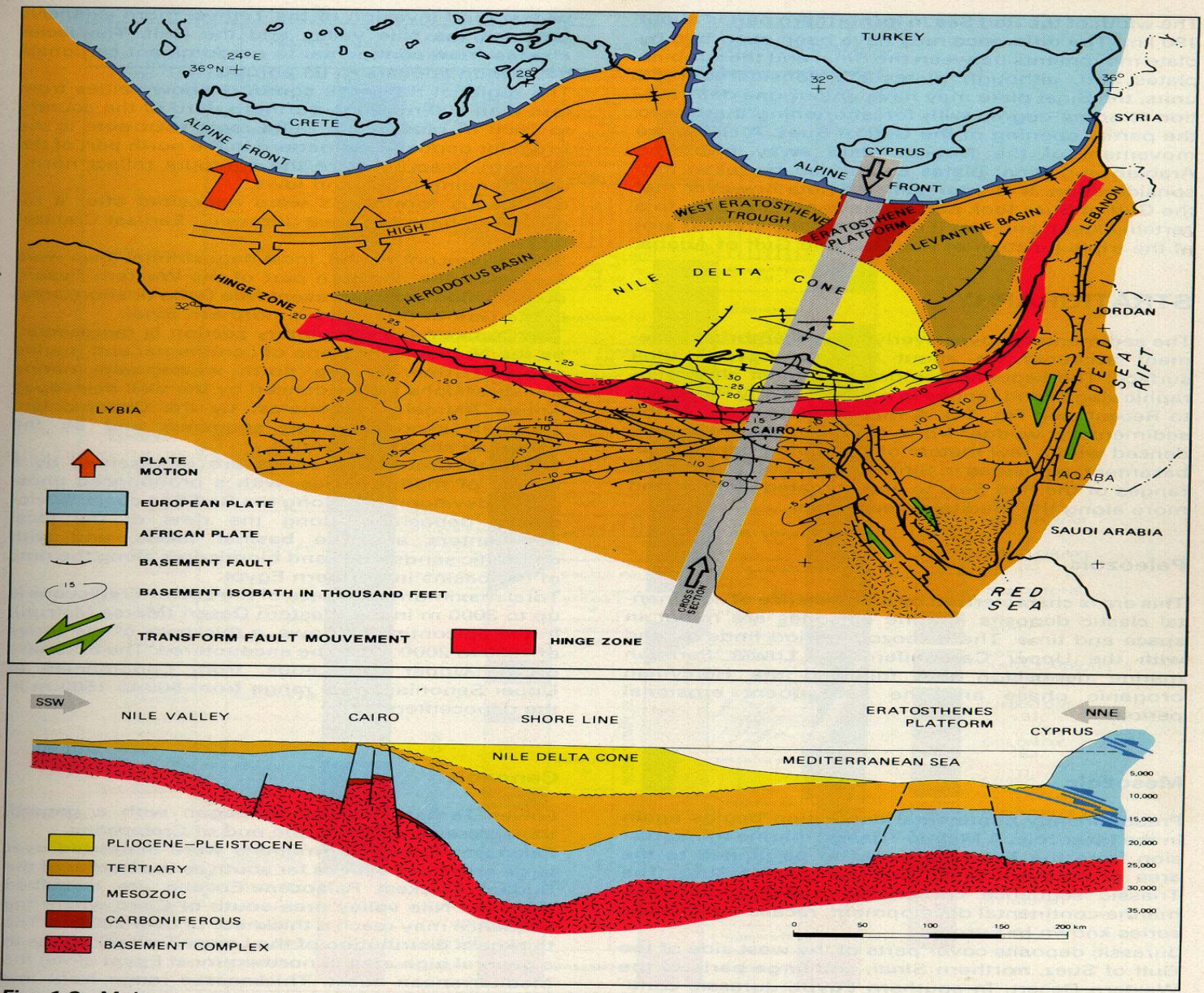


Fig. 1-2. *Main structural features of Northern Egypt and the East Mediterranean Sea. The lower diagram shows a schematic cross-section along the line indicated in the upper part.*

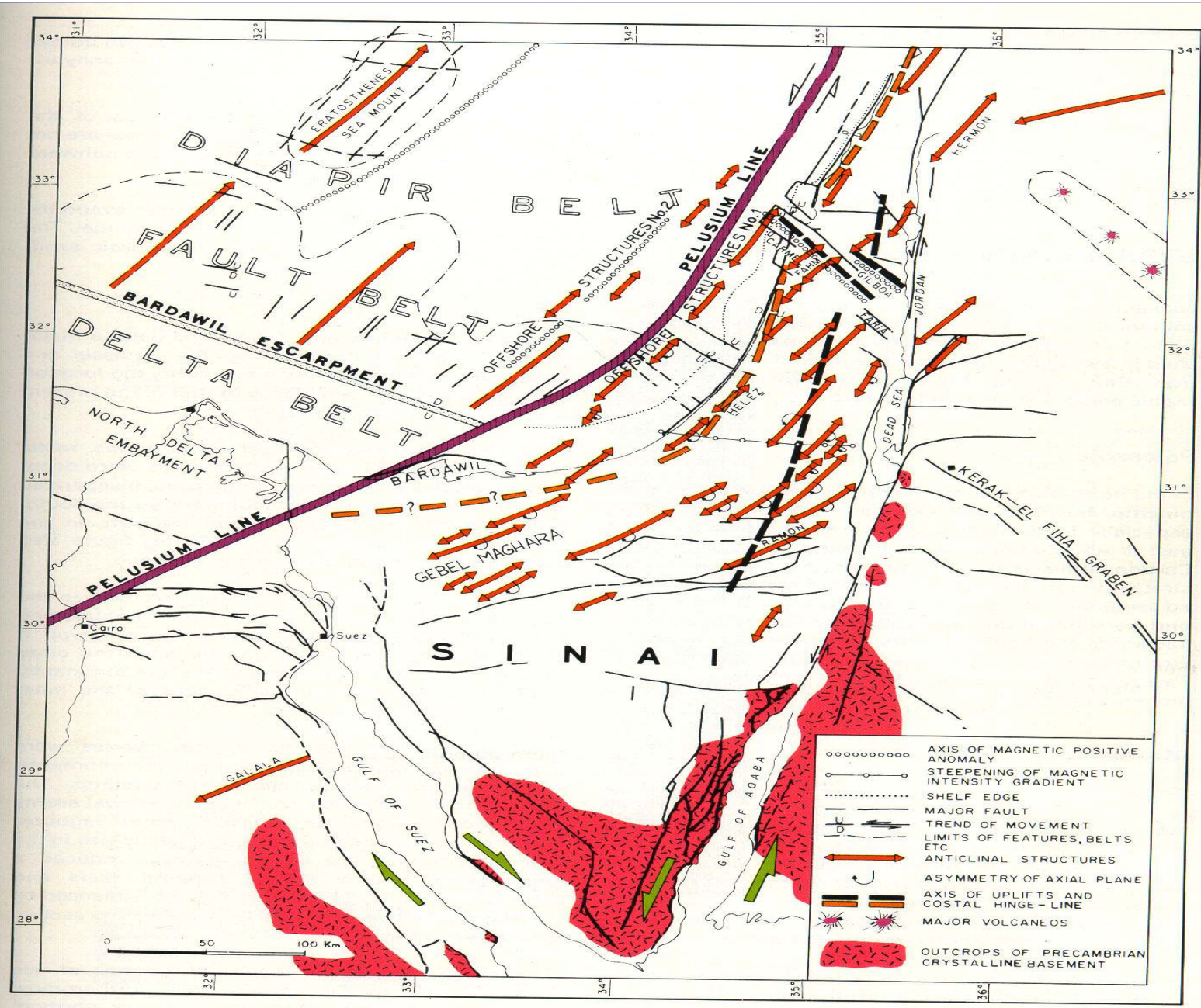


Fig. 1-33. *Sketch of major regional tectonic elements of Sinai area.*

(c) *Seismically Induced Floods and Water Waves and Other Design Conditions.*

- The size of seismically induced floods and water waves which could affect a site from either locally or distantly generated seismic activity shall be determined.
- Local topographic characteristics which might tend to modify the possible runup and drawdown at the site shall be considered. Adverse tide conditions shall also be taken into account in determining the effect of the floods and waves on the site.
- The characteristics of the earthquake to be used in evaluating the offshore effects of local earthquakes must be determined.