

Abstract

This chapter presents the main geological aspects of Egypt, which are relevant to its geomorphology. It depends on data collected from previous geological work, the interpretation of Geological Maps (scales 1:2,000,000 and 1:500,000 and 1:250,000), Landsat-TM and Google Earth images, and aerial photographs of different scales for parts of the various regions. Geologic aspects of Egypt are divided into two sections. The first section deals with rock formations, whereas the second deals with the tectonic framework.

Keywords

Egypt • Basement rocks • Sedimentary cover • Tectonic framework

2.1 Rock Formations

Rock formations are classified into two groups according to their mode of development. The first group is the **Crystalline Basement Complex rocks**, composed of igneous and metamorphic rocks and developed during Precambrian times. The second group comprises all the sedimentary rocks which developed during the Phanerozoic period and cover the basement complex.

2.1.1 The Basement Complex (Precambrian)

The crystalline basement is primarily Precambrian in age. It covers about one-tenth of the total land surface of Egypt. It is exposed in the Red Sea Mountains of the Eastern Desert, the southern part of Sinai and Gabal Uweinat area (Fig. 2.1). Small exposures also occur in the southern part of the Western Desert and the Cataract region of Aswan and Nubia. Basement rocks are also found in the depths as they extend below the sedimentary cover throughout Egypt. The basement complex of Egypt, Ethiopia, and Somalia together shape the Nubian Shield that had formed as a contiguous part of the Arabian Shield prior to the opening of the Red Sea (Hermina et al. 1989).

The oldest dated basement rocks are found in **Uweinat Mountains** in the southwest corner of Egypt and which belong to the Late Archean period, about 2.7 Ga (List et al. 1989). These rocks are known as the **Karkur Murr Series** and consist of charnockitic gneisses metamorphosed to granulite facies. Newly obtained ages from **Gabal Kamil** and **Gabal Al-Asr** areas range from 2300 to 1900 Ma. An age of about 1800 Ma is recorded in Ain Daw Series, indicating the formation of a new crust in the Early-to-Middle Proterozoic period and adds new evidence to the proposal of Harris et al. in (1984) that the Late Archean nucleus of Gabal Uweinat is rimmed by a Middle Proterozoic fold belt. This nucleus was named by Gass (1977) the Nile Craton (Morgan 1990). A wide range of younger ages of basement rocks have also been determined for other areas ranging from about 1200 to about 500 Ma.

2.1.2 The Sedimentary Cover (Palaeozoic, Mesozoic, Cenozoic)

The sedimentary cover, which overlies the basement complex, is composed of three major lithological divisions (Fig. 2.1): a **Lower Clastic Division** (Palaeozoic to Late Cretaceous), a **Middle Calcareous Division** (Cenomanian to

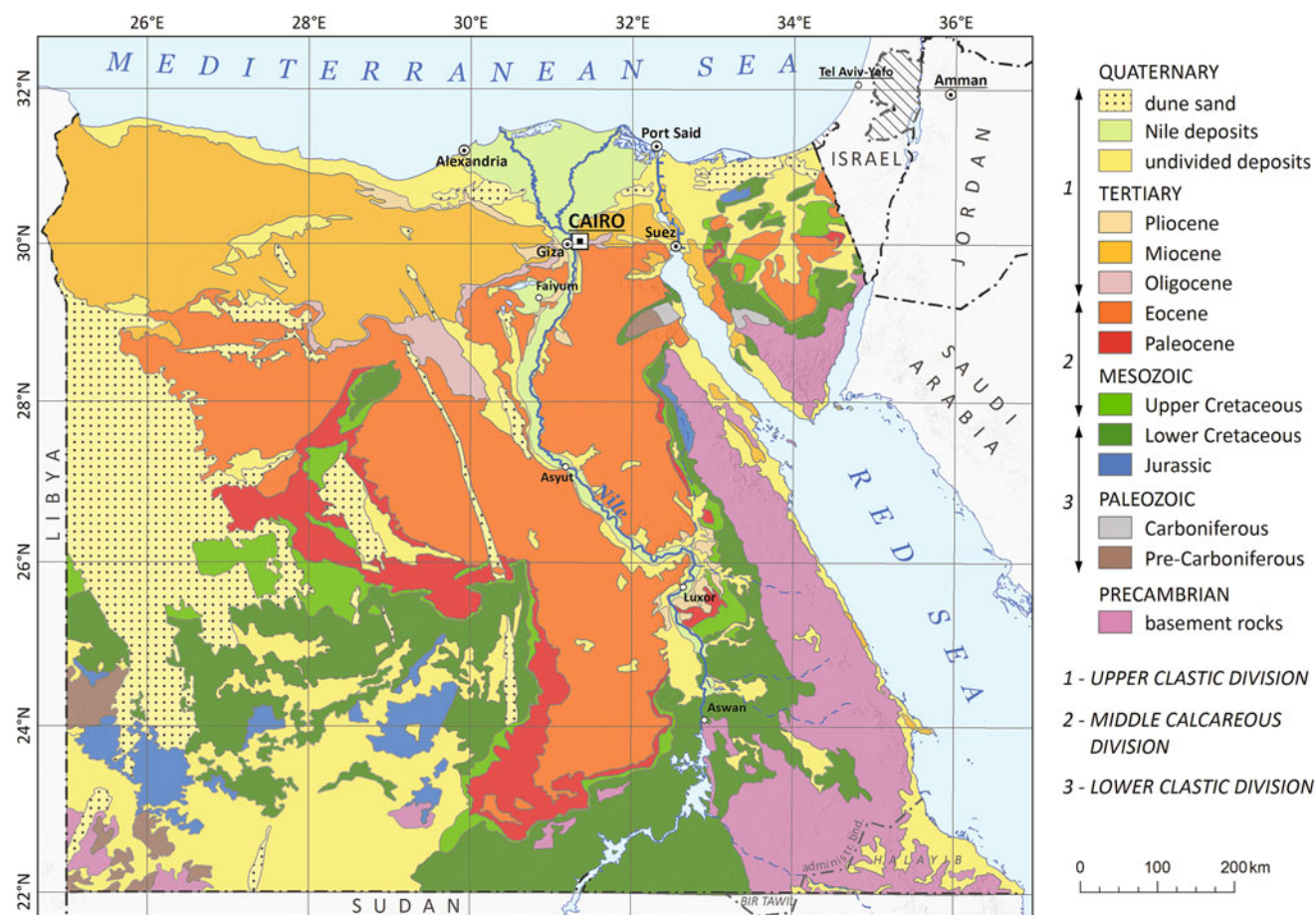


Fig. 2.1 Simplified Geological Map of Egypt. (Source The Geological Map of Egypt, scale 1: 2,000,000)

the end of Eocene), and an **Upper Clastic Division** from Oligocene to Holocene (Said 1962; Morgan 1990).

2.1.2.1 The Lower Clastic Division

The strata of the **Lower Clastic Division** are primarily clastic with a few calcareous beds. Although Said (1962) excluded the group of beds, which are known as Nubia formations from this division, it is preferable to include them, since this formation is all clastics. In this case, the age of this division will be from Palaeozoic to Upper Cretaceous. According to the area covered by exposures, the strata of this division can be divided into two groups: Pre-Jurassic, and Jurassic to Upper Cretaceous.

The **Pre-Jurassic strata** cover small areas in the south-west corner of Egypt around Uweinat and Gilf Kebir, **Wadi Araba** between **El-Galalah El-Bahariyah** and **El-Galalah El-Qibliyah** to the west of the Gulf of Suez, in various parts of Sinai at the eastern side of this Gulf, and in Arif El-Naga in northern Sinai. Until recently, Pre-Carboniferous clastics were undifferentiated (Geological Map of Egypt 1981); however, recent work made it possible to classify them

according to their age and environment of deposition (Klitzsch 1989, 1990). In the northern part of the Western Desert, Cambrian to Permian strata of up to several 1000 m in thickness have been identified in the subsurface. Palaeozoic beds are missing over most of the remaining parts of Egypt. Areas free of Palaeozoic beds today were probably covered by some of these formations, but due to intensive erosion following a regional up-arching of southern and central Egypt during a Late Palaeozoic–Early Mesozoic event, pre-Carboniferous strata were stripped from large parts of Egypt.

Strata of this subdivision are composed mainly of sandstone of fluvial, marine, and beach origin with a few shale and calcareous beds. However, the most interesting units are the chaotic glacial deposits of **Wadi Abd El-Malik (Abu Ras Plateau)** and Uweinat. These beds are composed of unsorted tillite of irregular boulders and blocks that can reach the size of a house placed in a clay sandy and conglomerate matrix intertwined with fluvial conglomerate and sandstone of the Middle and/or Late Carboniferous period (Klitzsch 1983, 1989). They are described by Klitzsch as

Northern Wadi Malik Formation. Their maximum thickness is 50–60 m near the northern end of Wadi Abdel-Malik, which cuts through the Abu Ras Plateau (Klitzsch 1989).

During the period from Jurassic to Upper Cretaceous, clastic sediments with over a kilometer thickness were deposited in the southern and eastern parts of Egypt. Their deposition was controlled primarily by marine transgressions and regressions. They are known collectively in the geological literature as **Nubia /Nubian Sandstone** since they are mainly composed of sandstone strata (Said 1962, 1990a). This sandstone was deposited during various cycles of sedimentation under different environments such as fluvial, deltaic, and lacustrine. Due to these cycles of deposition, the strata were divided into different formations (Klitzsch 1989). Examples of these formations are the **Gilf Kebir Formation**, the **Six Hills Formation**, and the **Sabaya Formation**. However, the Nubia Sandstone Formation will continue to be used as a regional facies term and is recommended to be used to these Late Jurassic to Upper Cretaceous sediments of similar origin. Strata of this formation are well exposed in the southern part of Egypt to the south of Kharga-Dakhla Depression and further south into the Sudan, in Nubia around **Lake Nasser** and Aswan, and in Bahariya Depression. They are also exposed in Wadi Qena, central and northern Sinai such as Gabal Maghara and other folded hills, and Wadi Araba between the two Galalah plateaus (Fig. 2.1).

Volcanics are inter-bedded at the base of the Nubia strata in southern Egypt. These, together with a group of intrusions cutting the basement rocks, represent a period of volcanic activity during the Upper Cretaceous period (Said 1962). There is another type of intrusions that characterize the Nubian strata. This type is represented by the sedimentary **sandstone ferruginous dykes**, which cut the Nubian strata and extend for several kilometers. These dykes appear on the surface of the ground as micro-ridges rising several tens of centimeters in the southern plain of the Western Desert (Fig. 2.2).

2.1.2.2 The Middle Calcareous Division

From Upper Cretaceous (Senonian) to the end of the Eocene, a series of beds, which are dominantly calcareous, was deposited and covered wide areas in the central parts of the Western and Eastern Deserts on both sides of the Nile Valley and central and northern parts of Sinai. They also extend to the southernmost parts of the Western Desert and along the Red Sea coast. The Upper Cretaceous strata show considerable variations in lithology. In the southern parts of Egypt, they are represented by **phosphate rocks** (Duwi Formation), which are best seen at the escarpment of the Abu Tartur Plateau, the Nile Valley sides, and along the Red Sea coastal zone, and overlie the Nubia Series. These in turn are overlain by a unit of grayish-green shales, which are best developed along the escarpments of Dakhla Depression (Dakhla Formation).

The **Dakhla Formation** is separated from the overlying **Esna Shale** by a chalky limestone unit known as **Tarawan Formation**. The age of these three formations dates back to the Late Cretaceous/Paleocene period. Toward the top, the Esna Shale becomes more calcareous and is replaced by Eocene rock units made up of carbonates and clastics, which form the cap rock of the wide plateaus of the Western and Eastern Deserts and central Sinai. The Eocene succession is divided into several groups of formations, since they were deposited in variable sedimentary sub-environments. Lower Eocene carbonates are known as **Thebes Group**, whereas those of Middle Eocene strata are known as the **Mokattam Group**, and the Upper Eocene formations, which are more clastics, are classified into various formations such as Maadi, and Qasr El-Sagha Formations (Hermine and Lindenberg 1989). Lower Eocene limestone (Thebes Group) is characterized by the presence of silica bands and concretions. Exposed concretions reach large sizes and frequently occur lying in crowds on the surface of the plateaus in the Western Desert recalling melon fields. This Lower Eocene limestone is

Fig. 2.2 Sandstone dyke in the southern plain of the Western Desert



also characterized by the presence of fossil remains of the earliest, and extinct, suborder of whales, Archaeoceti. This fossil was found in Wadi El-Rayan to the west of Fayum Depression. Due the concentration of the skeletons of the whales in a small area in the north of Wadi El-Rayan, this area is locally named **Wadi El-Hitan**, i.e., Valley of the Whales. Because of its scientific and international value, Wadi El-Hitan was recognized as a UNESCO World Heritage Site in 2005.

2.1.2.3 The Upper Clastic Division

The sedimentary rocks of the **Upper Clastic Division** are divided into two subdivisions: the Tertiary (Oligocene–Pliocene) rocks and the Quaternary deposits. Oligocene to Pliocene units occupy vast areas in the northern part of the Western Desert, small areas in the northern parts of the Eastern Desert, along the Red Sea coast, both sides of the Gulf of Suez, and several patches along the Nile Valley.

Oligocene Sediments are of fluvial origin and are composed of sand and gravel. They cover a small narrow belt from the Cairo-Suez region to northern Fayum and Bahariya Depression, with quite a wide area extending southward between Bahariya and the Nile Valley. Due to geyser activity, the Oligocene sands and gravel of the **Gabal El-Ahmar Formation** are known for their distinguished red color and silicified tree trunks (Said 1962; Hermina and Lindenberg 1989). The Oligocene fluvial sediments were connected according to some previous studies with a river system that flowed consequent to the uplift of North Africa at the end of the Eocene period and was called by Blankenhorn the **Ur-Nil** (Said 1962). In some other studies, the Oligocene gravel was correlated with another regional drainage system draining northward (Said 1990b), or draining southwestward and westward and then northward after being connected with tributaries from the Gilf highlands. This system is called the **Gilf System** (Issawi and McCauley 1993). Volcanic activity during the Mid-Tertiary period resulted in the development of a broad belt of basaltic intrusions to the north of Fayum, which extends to the Nile Valley in Cairo and continues eastward along the Cairo-Suez road. Similar volcanic outcrops of the same age are present in various parts in the Western and Eastern Deserts, Sinai, and the Gulf of Suez.

The **Miocene rocks** exhibit local variations due to their deposition in various environments. However, the Lower Miocene deltaic to estuarine sand and gravel clastics, which are exposed at the southern margins of Qattara Depression, are known as **Moghra Formation**. The top of this formation intertwines with the **Marmarica carbonates** toward Siwa in the west, carrying a mixed fluvio-marine fauna (Hermina and Lindenberg 1989; Said 1990b). These sediments seem to have been deposited under one regime belonging to a river system, which must have flowed into the sea from the north of Fayum (Said 1990b). Along with other evidence, it was postulated that

during the Early and Middle Miocene period, a drainage system developed in Egypt, of which the main river was called the **Qena River** (Issawi and McCauley 1993). In some other studies, however, this drainage system is considered to be a continuation of the **Ur-Nil system** (Salem 1976). The Middle Miocene reefal limestone, **Marmarica Formation**, is the most extensive exposure, covering the entire Marmarica (El-Diffa) Plateau of the northern Western Desert, and Cairo-Suez stretch (Said 1962; Hermina et al. 1989). Other Miocene sediments occupy small areas in the Western and Eastern Deserts, the Red Sea coast, and Sinai. Upper Miocene marine strata are not exposed in any part of Egypt.

The **Pliocene sediments** are scattered as relatively small outcrops along the margins of the Mediterranean coastal plain, in and around Wadi El-Natrun in the northern part of the Western Desert, and in the Nile Valley from Aswan to Cairo. They also occur in the lower sections of some Nile tributaries in the Eastern and Western Deserts, along the western coast of the Gulf of Suez and along the Red Sea coastal belt. Alongside the Nile Valley and its tributaries, there are two main facies: marine limestone, marls and coquina beds of Kom El-Shelul Formation on the surface in the north, and in the subsurface in the south (Hermina and Lindenberg, 1989). The second is conglomerate sandy facies in the south and in the mouths of several large wadis that debouch at the Nile Valley (Said 1962). The marine facies along the Nile valley and its tributaries are taken as an indication of the rise of the Mediterranean Sea level forming a Marine Gulf that submerged the Nile Valley and the mouths of the tributaries. This Marine Gulf is known as the Pliocene Gulf of the Nile Valley (Said 1993).-

The **Quaternary deposits** are spread all over Egypt and lie unconformably over the Pliocene or older rocks. These deposits are closely connected with climatic changes and sea level fluctuations that occurred during the Pleistocene period. They are classified according to their mode of origin into eolian, fluvial, and marine sediments.

Eolian sands are the most widespread and most recent, covering more than 20% of the total area of Egypt (Embabi 1998). They occupy vast areas in the south and west of the Western Desert and North Sinai, and small areas in the north and east of the Western Desert, and the north and south of the Eastern Desert. They are formed as dunes of different types sand sheets shaped as sand seas and dune fields.

Fluvial deposits include the following types:

- (a) Nile sediments (silt, clay, gravel) on the sides and floor of the Nile Valley, the surface and margins of the Delta, and the floor of Fayum Depression.
- (b) Wadi gravel in the form of fills, terraces, fans, bajadas, and sheets in various localities in the Western and Eastern Deserts and Sinai.

- (c) Playa silt, sand, and gravel clastics in the form of low-lying plains occupying the floors of internal basins or different sections of some wadis in the Western and Eastern Deserts, and Sinai.
- (d) Calcareous tufa and travertine developed in the form of thin laminae terraces or sheets on the faces of the escarpments of the plateaus in the southern part of the Western Desert.
- (c) Shelly-coralline sandy and silty sediments along the Red Sea coast, which indicate a shallow reefal marine environment during the Pleistocene epoch.

Marine and coastal deposits include the following types:

- (a) The Mediterranean coastal oolitic limestone in the form of parallel linear ridges separated by longitudinal Depressions covered by evaporites, marl, and gypsum. These ridges were formed as offshore bars in the receding Mediterranean Sea during the Pleistocene (Shukri et al. 1956; Selim 1974).
- (b) Sabkha deposits along the Mediterranean coasts of the Nile Delta, various stretches to the west of Alexandria, Sinai and in Siwa, Qattara, Wadi El-Natron and small patches in other Depressions and along the Red Sea coast.

2.2 Tectonic Framework

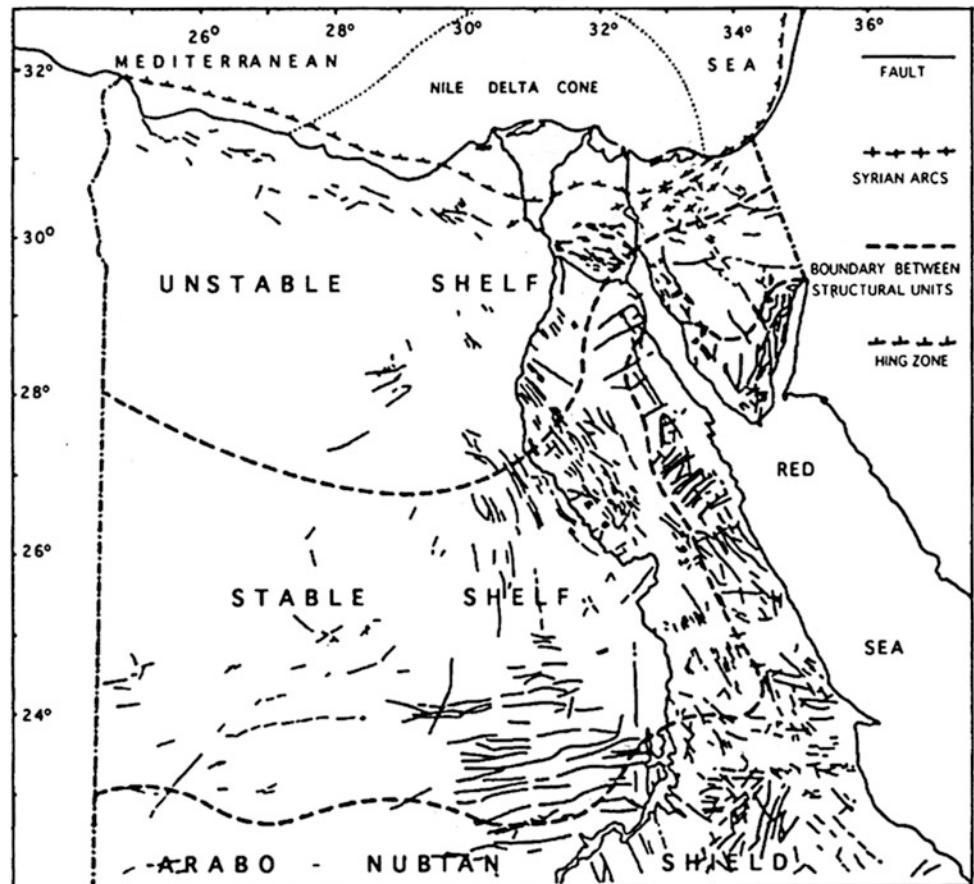
Studies of Said (1962) have divided Egypt tectonically into four units as follows (Fig. 2.3).

- (1) The Arabo-Nubian Shield
- (2) The Stable Shelf
- (3) The Unstable Shelf
- (4) The Gulf of Suez-Red Sea Graben

2.2.1 The Arabo-Nubian Shield

The rocks of the Arabo-Nubian unit (the basement rocks) are exposed, as previously mentioned, over large areas in the Eastern Desert and Sinai and small patches in the extreme

Fig. 2.3 Main structural features of Egypt (Compiled from various geological sources)



southwestern part of the Western Desert and along both sides of the Nile Valley in the Aswan environs. Also, evidence indicates that these rocks extend northward beneath the sedimentary cover of the Stable and Unstable Shelves. It is now well established that this shield was developed during several stages around an Archean Continental Nucleus (The Uweinat Massif) onto which a more recent crust was accreted (Morgan 1990). The shield was peneplained, and an extensive peneplain forms the base of the clastic sedimentary cover of the Nubia rocks. The **Arabo-Nubian Shield** remnants of this peneplain can be seen in central Sinai and is called by Awad (1951) "Pre-Nubian Erosion Surface." It is also found in the southwest corner of the Western Desert to the north of the famous hills of Peter and Paul, and in the central part of the Red Sea Mountains (Philobos and Hassan 1975). Due to this peneplanation, the **Arabo-Nubian Shield** has been the source of clastics of the sedimentary cover.

At the end of the Precambrian (520 Ma), the eastern Mediterranean had not yet been formed and the Nubian plate was not separated from the Arabian plate. Therefore, Egypt, the Arabian Peninsula, and Turkey were a continental mass on the southwest corner of the Gondwanaland. At the beginning of the Palaeozoic period, Egypt was drifting south and had probably reached its most southerly latitude with the location of Cairo at almost 70° south during the Ordovician period (Morgan 1990). This location explains the presence of the Carboniferous glacial deposits in southwest Egypt that was mentioned in the previous section.

Since basement rocks are the oldest formations, it is expected that they record all the tectonic events that have affected Egypt from the Precambrian period to the present. Furthermore, it was found that the greater density of faults lies in areas where the basement rocks are exposed or in areas where sedimentary cover is relatively thin.

2.2.2 The Stable Shelf

The **Stable Shelf** covers the area north and west of the **Nubian Shield** (Fig. 2.3). It looks like a belt of ill-defined boundaries and is characterized by the relatively thin sedimentary sequence of continental and epicontinental deposits such as the Mesozoic Nubian sandstone. Thickness of the sedimentary succession increases northward. It is about 400 m near the Shield nucleus, 1100 m in Dakhla and Kharga, and 2500 m in Bahariya in the Western Desert near the Stable–Unstable Shelf contact. The sedimentary column is composed of clastics in the lower section (Lower Clastic Division) and carbonates in the upper section (Middle Calcareous Division).

Crustal deformation of the Stable Shelf is expressed in faulting and folding on a large scale (Said 1962). It seems that

folding played a minor role in the structure of this Shelf. Some of these folds are mainly flexured blocks of which Ataq and the two limestone plateaus of El-Galalah El-Bahariya and El-Qiblia are examples. Several of these folds (anticlines and synclines) are noted in different areas, such as those present along the Nile Valley banks (Sandford 1934), Wadi Qena in the Eastern Desert (The Geological Map of Wadi Qena Quadrangle NG 36-6), and El-Egma Plateau in central Sinai (Awad 1952). Many of the small folds are bounded partially or completely by faults, such as those in the northern part of Kharga Depression which extends along a north–south line. According to orientation, the faults of the Stable Shelf were classified by Said (1962) into four groups: north–south (East African) faults, northwest (African) faults, east–west (Tethyan) faults, and northeast–southwest faults. The effect of these tectonic lines on local and regional features will be discussed in the following sections.

2.2.3 The Unstable Shelf

The **Unstable Shelf** occupies most of northern Egypt between the transition line that separates the two Stable and Unstable Shelves and the Hinge Zone along the Mediterranean geosyncline (Fig. 2.3). The sedimentary column of the Unstable Shelf is thick. Thickness is estimated to be more than 7000 m along the Mediterranean coast (Schlumberger 1984). The sedimentary column is composed of clastics in the lower part, calcareous series in the middle, and an upper clastic cover topped with carbonates (Said 1962).

The Unstable Shelf shows signs of tectonic disturbances. This structural deformation is related to the **Laramide Phase** of the **Alpine Orogeny** which began by the end of the Lower Cretaceous period (Schlumberger 1984). The result of this deformation can be seen in the numerous anticlines that distinguish the northern parts of Egypt. These folds are known as the **Syrian Arcs**. The tectonic disturbances also resulted in faulting parallel to the lines of folding. The anticlines of these folds are all asymmetrical, double plunging and are organized into numerous parallel lines with northeast and east-northeast orientation. They were classified into three groups according to size (Mostafa and Khalil 1990). Large folds include **Gabal El-Maghara**, **Gabal Yelleq**, and **Gabal El-Halal**. Medium folds comprise **Gabal El-Minsherah**, **Gabal Kherim**, **Gabal Arif El-Naga**, and some others. Small folds are many and are less than 2 km long. The largest two anticlines are Gabal El-Maghara and Gabal Yelleq. Gabal El-Maghara is 40 km long and 24 km wide and has a height of 735 m asl. Gabal Yelleq is 45 km long and 20 km wide and has a height of 1090 m asl. Most of these structures form a distinctive tectonic province in northern Sinai. However, they extend along an arcuate trend from North Sinai and

north of the Gulf of Suez across the southern part of the Nile Delta to the Western Desert to include **Gabal Abu Rawash** and the **Bahariya** and **Farafra** swells (Shata 1953; Shukri 1954). They also extend eastward toward the Negev Desert and the Mediterranean Basin to the north of Sinai. The geomorphologic characteristics of these structural hills and mountains will be discussed in Chap. 23 on **Geoparks**.

The **Unstable Shelf** is separated from the Mio-geosyncline of the Mediterranean Basin by a **Hinge Zone**, which practically coincides with the present coastal area of the Mediterranean. According to Sigaev (1959) and Schlumberger (1984), the Nile Delta occupies a large trough in the Hinge Zone. This trough which is called by Said (1981) the **North Delta Embayment** is present within the continental slope of the Mediterranean. It is limited in the south by a fault running along the northern boundary of the Cairo-Suez horst and in the north by structures consisting of parallel, elongated tilted blocks. This embayment has been filled with the sediments of the **Nile Delta Cone** since the Upper Miocene times. This sedimentary cone extends below the Mediterranean and covers an area which equals three times that of the present Nile Delta.

2.2.4 The Gulf of Suez—Red Sea Graben

The Gulf of Suez and the Red Sea are structurally and genetically closely related. They form the northern section of the **East African Rift System**. According to Said (1962), the **Gulf of Suez**, though situated within the Stable Shelf, has been an area of subsidence and a site of immense accumulation of sediments. It was formed during the Early Palaeozoic era as a narrow embayment of the Tethys and rejuvenated during the rifting phase of the Great East African Rift system in Oligocene–Miocene times. The Gulf is bordered by, and made up of, a large number of faulted blocks. Its connection with the Mediterranean in the north and with the Red Sea to the south was established during the Early Miocene period (Schlumberger 1984).

The **Red Sea** and the **Gulf of Aqaba** originated during the Oligocene period after the arching and crustal thinning in the area of the Nubian-Arabian Shield and subsequent collapse as a part of the East African Rifting. The spreading of the Red Sea was due to the northeastward motion of the **Arabian Plate**. The left lateral displacement of the Arabian Plate along the Gulf of Aqaba was also established then (Schlumberger 1984). In Egypt, it is likely that the resulting topography from the rising margins of the Red Sea controlled the development of the ancestral rivers of the Nile which have their origin at about the same time as the initiation of the Red Sea Rifting (Said 1981).

2.2.5 Volcanicity

Different volcanic activities took place during the Phanerozoic period in Egypt. Such tectonic activity was mainly controlled by the fracture system, which originated in the Late Precambrian. This relationship is clear in Fig. 2.3, which shows the main tectonic features of Egypt. **Volcanic rocks** of the Palaeozoic and Mesozoic eras are diversified in terms of their chemical characteristics, size, and mode of eruption, whereas Cainozoic eruptions produced basalt volcanites (Meneisy 1990).

The earliest Palaeozoic igneous activity resulted in the emplacement of minor alkaline intrusions, granite and what is known as “**Dyke swarms**,” which is common within basement rocks (Meneisy 1990). The oldest known alkaline intrusions in the Eastern Desert and Sinai have an average age of 550 Ma. A number of intrusions and extrusions yielded Ordovician–Devonian ages (Meneisy 1990). Dykes are a characteristic feature of the basement rocks of the Eastern Desert and Sinai, and they are among the most intensely dyke-intruded regions known. The dykes are narrow, steeply dipping bodies, a few meters thick, and several kilometers long (Fig. 2.4). Dykes north of the Qena-Safaga highway in the Eastern Desert are estimated to be 530–480 Ma old (Meneisy 1990). Because they vary greatly in composition from acidic to basic and alkaline, dykes respond differentially to erosion so they form positive or negative landforms relative to the host basement rocks.

Age determination revealed three main volcanic episodes in the Late Palaeozoic era: Late Carboniferous, Permian, and Permo-Triassic. The rocks are widely intruded as ring complexes, sills, dykes, plugs, sheets, and flows into the basement of the Eastern Desert and the sedimentary cover in the Western Desert (Meneisy 1990).

The Mesozoic volcanics include basaltic rocks, alkaline ring complexes, and minor granite intrusions. Basaltic dykes, sills, fills, and plugs scattered in the Eastern and Western Deserts, and Sinai were intruded or extruded in the Mesozoic, of which those of Wadi Natash in the southern part of the Eastern Desert (Late Cretaceous) are the largest (600 km²) Phanerozoic volcanic associations in Egypt. Early Cretaceous volcanics occur in the Wadi Araba and Wadi Darag areas in the northern part of the Eastern Desert.

The Cainozoic era witnessed several episodes of volcanic activity. The earliest started in Late Eocene, and the latest occurred in Lower-Middle Miocene. However, Mid-Tertiary (Oligocene–Miocene) volcanism was the most widespread and was related to the opening of the Red Sea. Quaternary volcanism is limited to Zabargad Island in the Red Sea and to Uweinat, Kamil peneplain, and Bir Safsaf in the south of the Western Desert.

Fig. 2.4 Two dykes projecting in Sinai Mountains



Tertiary volcanics are mainly basaltic, and most of them are distributed north of latitude 28° N. They take the form of sheets, dykes, sills, cinder cones, or small ridges. Significant outcrops occur in the Fayum (Gabal Qatrani)-Abu Rawash area, Cairo-Suez stretch, El-Bahnasa environs to the west of the Nile valley and Bahariya Depression. Minor exposures are present in the southern parts of the Western and Eastern Deserts, Red Sea coast, and Sinai. Tertiary basaltic rocks are also present beneath the Nile Delta and adjacent areas of the Western Desert (Said 1981).

Hydrothermal activities accompanied volcanic eruptions in Egypt. The most widespread and pronounced are those connected with Tertiary volcanism. The mineralization effects include ubiquitous ferrugination, silicification, and dolomitization. These activities affected several localities, of which El-Gabal El-Ahmar to the east of Cairo is a classical example with the red coloration of its sandstone. Silicified tree trunks are another classical example for silicification during hydrothermal activity.

2.3 Conclusion

In Egypt, it can be said that nearly all types of rocks and structures are well-represented and exposed on the surface of the ground. Also, ages extend from the Precambrian to Holocene indicating a long geological history. Geomorphic regions vary greatly in the distribution of rock formations, in that the Western Desert is dominated by sedimentary rocks, while the basement rocks are concentrated in the Eastern Desert and southern Sinai. In general, rock formations get younger from south to north. Thickness of the sedimentary cover increases on the

whole northward, since the basement rocks get deeper in the same direction. This is why strata are on the whole-dipping northward. Two of the sedimentary formations are of relative significance, which are the carbonates and Nubian sandstone. These two types of rocks cover wide areas in the Western Desert, the Eastern Desert, and central Sinai. They form all the plateaus in these regions except for the small peneplained plateau in SW Western Desert. Of the Quaternary sediments—eolian sands are the most widespread, especially in the Western Desert.

Faults represent the most dominant type of structure, especially the eastern part of the Eastern Desert and the southern part of Sinai Peninsula. These mountainous are the most affected areas in Egypt by tectonics that accompanied the opening of the Red Sea. Another region which is tectonically significant is that one which is dominated by fold that lies in northern Sinai and is known as the Syrian Arcs. Other folds are present in several other localities in other regions as separate ones and not clustered as those of Sinai. Volcanic activities occurred in all regions and in all periods of the geological history of Egypt. Their materials take several forms, such as volcanic cones, lava sheets, dykes, and ring complexes.

References

- Awad H (1951) La Montagne du Sinai Central. Étude Morphologique. Société Royale de Géographie d'Égypte, Le Caire
- Awad H (1952) A new type of desert cuesta in central Sinai. In: Proceedings Of The XVII International Geographical Congress, Washington

- Embabi NS (1998) Sand seas of the Western Desert of Egypt. In: Alsharhan AS, Glennie KW, Whittle GL, St. C. Kendall CG (eds) Quaternary Deserts & Climatic Change, Proceedings of International Conference on Quaternary Deserts and Climatic Change, Al-Ain, United Arab Emirates, 9-11 Dec. 1995, Balkema, Rotterdam, pp 495–509
- Gass I (1977) The evolution of the Pan-African crystalline basement in NE Africa and Arabia. *J Geol Soc London* 134:129–138
- Harris NBW, Hawkesworth CJ, Ries AC (1984) Crustal evolution in northeast and east Africa from model Nd ages. *Nature* 309:773–776
- Hermine M, Lindenberg HG (1989) The tertiary. In: Hermine M, Klitzsch E, List F (eds) Stratigraphic lexicon and explanatory notes to the geological map of Egypt, scale 1:500,000. Conoco Inc, Cairo, pp 141–218
- Hermine M, Klitzsch E, List F (eds) (1989) Stratigraphic Lexicon and explanatory notes to the geological map of Egypt, Scale 1:500,000. Conoco Inc, Cairo
- Issawi B, McCauley J (1993) The Cenozoic landscape of Egypt and its river systems. *Ann Geol Sur Egypt* 19:357–384
- Klitzsch E (1983) Paleozoic Formations and a Carboniferous Glaciation from Gilf Kebir-Abu Ras area in southwestern Egypt. *J Afr Earth Sci* 1:17–19
- Klitzsch E (1989) The Paleozoic. In: Hermine M, Klitzsch E, List F (eds) Stratigraphic lexicon and explanatory notes to the geological map of Egypt, scale 1:500,000. Conoco Inc, Cairo, pp 57–76
- Klitzsch E (1990) Paleozoic. In: Said (ed) The Geology of Egypt, Balkema, Rotterdam, pp 393–406
- List F, El-Gaby K, Tehrani R (1989) The basement rocks in the Eastern and Western Deserts and Sinai. In: Hermine M, Klitzsch E, List F (eds) Stratigraphic Lexicon and explanatory notes to the geological map of Egypt 1:500,000. Conoco Inc, Cairo, pp 33–56
- Meneisy M (1990) Volcanicity. In: Said (ed) The Geology of Egypt, Balkema, Rotterdam, pp 157–172
- Morgan P (1990) Egypt in the framework of global tectonics. In: Said (ed) The Geology of Egypt, Balkema, Rotterdam, pp 91–111
- Mostafa AR, Khalil MH (1990) Structural characteristics and tectonic evolution of north Sinai fold belts. In: Said R (ed) The geology of Egypt. Balkema, Rotterdam, pp 381–389
- Philobos ER, Hassan KK (1975) The contribution of palaeosol to Egyptian lithostratigraphy. *Nature* 253:33
- Said R (1962) The geology of Egypt. Elsevier Publishing Co, Amsterdam
- Said R (1981) The geological evolution of the River Nile. Springer-Verlag, New York
- Said R (1990a) Red Sea coastal plain. In: Said R (ed) The geology of Egypt. Balkema, Rotterdam, pp 345–359
- Said R (1990b) Cenozoic. In: Said R (ed) The geology of Egypt. Balkema, Rotterdam, pp 451–486
- Said R (1993) The River Nile: Geology, Hydrology and Utilization. Pergamon Press, Oxford
- Salem R (1976) Evolution of Eocene-Miocene sedimentation patterns in parts of northern Egypt. *Amer Assoc Petrol Geol Bull* 60:34–64
- Sandford K (1934) Paleolithic man and the Nile valley in upper and middle Egypt: a study of the region during Pliocene and Pleistocene times. Oriental Institute Publication No 3, Chicago, Illinois
- Schlumberger (1984) Well Evaluation Conference. Egypt, Cairo
- Selim A (1974) Origin and lithification of the Pleistocene carbonates of the Sallum Area, western coastal plain of Egypt. *J Sedimentary Petrology* 44:70–78
- Shata A (1953) New light on the structural development of the Western Desert of Egypt. *Bull Institut du Desert d'Égypte* 3:101–106
- Shukri NM (1954) Remarks on the geological structure of Egypt. *Bull. Soc. Géogr. d'Égypte*, 27: 65–82
- Shukri NM, Philip G, Said R (1956) The geology of the Mediterranean coast between Rosetta and Bardia, II Pleistocene sediments: geomorphology and microfacies. *Bull Institute d'Égypte* 37:395–427
- Sigae N (1959) The main tectonic features of Egypt: an explanatory note to the tectonic map of Egypt, scale 1:2,000,000. Geological Survey of Egypt, Cairo, Paper, p 39

Landscapes and Landforms of Egypt

Landforms and Evolution

Embabi, N.S.

2018, XXII, 336 p. 181 illus., 122 illus. in color.,

Hardcover

ISBN: 978-3-319-65659-5