- **General geology and tectonics of Jordan**

Geologically, Jordan is located in the northwestern part of the Arabian Plate, (Figure 1) separated from the African Plate along the Aqaba-Dead Sea-Jordan Valley-Rift. In its simplest form, the geology of the Jordan-Palestine area (Figure 2) consists of a sequence of mainly marine sediments, which surround a small area of Precambrian crystalline outcrop in the southwestern part of the area and thicken toward the north and east (Bender, 1974; Abed, 1982 and 1985).

In outcrop, close to the Precambrian core, the units are thin and separated by many unconformities. The oldest igneous and metamorphic rocks of the Nubo-Arabian Shield of more than 600 million years in age are exposed in the southern and southwestern parts of Jordan (Precambrian Basement Complex). Paleozoic sandstone and shale sediments attaining 1800 meters in thickness of marine and continental origins overlie unconformably the rocks of the Basement Complex. These rocks are exposed mainly in the southern, southwestern parts of Jordan, in addition to central parts of Wadi Araba.

The oldest Mesozoic marine sediments of Lower Triassic age crop out in the lower reaches of wadis draining the eastern Dead Sea Basin to the north of Wadi Zarqa Ma'in to the Zarqa River. Marine sedimentation during this epoch was restricted only in the northern and western parts of the country. At the end of the Triassic, the sea regressed and the whole area was subjected to erosion.

In the Middle Jurassic the sea transgressed again, marine sedimentation was restricted to the Jordan Valley side wadis in a region extending southwards about 20 km from Zarqa River.

At the beginning in the Late Cretaceous Epoch regional transgression started to spread over extensive areas of Jordan and Palestine depositing appreciable thickness of sediments accumulated in basins particularly along the Wadi Araba Jordan Rift Valley and in the Jafr and Azraq Wadi Sirhan Basins. The pattern of gentle swells characterized by phosphorites, oyster lumachelles, and chert layers, and of local euxenic basins characterized by thick bituminous limestones and marls, was pronounced during the Late Cretaceous and continued during the Paleocene and Early Eocene Epochs. In the Cenozoic Era, the Tertiary marine sediments of the Paleocene and the major part of the Eocene were deposited in a similar "Gentle Swells and Basins Systems". Along Wadi Araba - Jordan Rift coarse clastic weathering products from the bordering uplifted areas were deposited at the same time together with taphrogenic tectonism in the Oligocene Epoch.

Locally, in the central parts of the graben, thick rock salt was deposited in the Oligo-Miocene to Pliocene.

During the Cenozoic Era the Jordan Rift was either occupied by fresh water lakes draining west to the Tethys Sea, or formed in an inland depression with terrestrial or lacustrine sediments or was entered by marine waters. Miocene transgression from the north reached to Azraq-Wadi Sirhan Depression and to northeast Jordan beyond Jebel Ed-Druze basalt flows.

During the time in the Miocene–Pliocene, the Mediterranean Sea may have linked with the Red Sea through the Gulf of Aqaba and Wadi Araba Jordan Rift and through the Beisan Depression.

A major phase of taphrogenic movements took place in the Plio-Pleistocene. The major graben movements ended at the time of the Middle Pleistocene basalt volcanism. It is likely a fresh water lake (Samra Lake)

covered the northern part of the rift. This lake slowly changed to the brackish Lisan Lake, Lisan Marls extend from approximately 50 km south of the Dead Sea to the north almost as far as Lake Tiberias. The Lisan Lake did not change into the present Dead Sea before the Upper Pleistocene.

Throughout the Quaternary, detritus was transported into the Rift Valley, and the extension Azraq-Wadi Sirhan and Jafr depressions of East Jordan. These depressions were partly covered by fresh and brackish water lakes during fluvial periods of the Pleistocene, while fluviatile conglomerates of the same age spread over wide areas along the eastern slopes of the mountain ridges bordering the east side of the Wadi Araba-Jordan Rift. General geology of Jordan is shown in Figure (3).

Structurally, the geological structure of Jordan-Palestine area shows the effect of several phases of deformation since the Cambrian Period. The crustal movement that affected the area has resulted in gentle, regional tilting, uplift and subsidence and a combination of faulting and folding. Therefore, the area can be divided into a series of broad, plateau-lime arches and gentle desert-covered basins. The basic tectonic features, which developed at different times and rates, are intersected by long, essentially linear grabens and half grabens, along which significant strike-slip movement has occurred.

The most fundamental of these linear fault zones strike northwest, parallel to the Red Sea trend. They are cut off obliquely by the Dead Sea Rift trend, striking north-northeast. The Dead Sea Rift is a large transcurrent fault system extending from the Red Sea to Turkey. Movement along the Dead Sea rift, which is usually considered as a transform fault separating the African (or Sinai-Palestine) and the Arabian plate, started less than 20 M.A. ago (Steintz et. al., 1978; Garfunkel, 1981). Since the time of its formation, 107 Km of left-lateral displacement took place along the fault (Quennell, 1959 and Freund, 1970).

Similar to other strike-slip fault systems, several sedimentary basins of various sizes exist along its length. These basins, which form morphotectonic depressions, are, from north to south, the Hula, Sea of Galilee, Dead Sea and the Gulf of Aqaba. The basins are fault bound structures. Most of them are divided into several sedimentary basins which are in turn divided into smaller units by transverse faults.

Several transverse faults, extend beyond the boundaries of the basins into areas which are otherwise unaffected by the rifting activities (Ben-Avraham et. al., 1990; Ben Avraham and Lyakhovsky, 1992). In some cases the transverse faults are active at present as strike-slip faults. In the Dead Sea area where multi-channel seismic profiles are available across several transverse faults (Ginzburg et al., 1994), there are indications that some of these faults have changed their mode of activity from normal to strike-slip faults during the evolution of the basins.

Tectonic trends within the Late Paleozoic and Mesozoic basins were largely controlled by transgressive-regressive movements within the Tethys seaways entering from the north. The basalt plateau is covered by 11,415 km^2 of thin basalt over a basin which is known from regional considerations to contain a thick Mesozoic section, as well as unknown Paleozoic elements beneath it.

Tectonically, Jordan-Palestine area has been affected by three main phases of deformation (Figure 4), (Barazangi, 1983 and Barazangi et. al., 1992)). The first phase is the folding episode along the Syrian Arc System, which is a series of anticlines and synclines forming an S-shaped Fold Belt,

which extends from Central Syria (the Palmyra Fold Belt) in a southwest direction to Sinai (the Levantine Fold Belt). Three phases of folding, during this episode, affected the area, namely a Pre-Jurassic system, Late Mesozoic-Early Cenozoic system and a Late Eocene-Oligocene Folding System, which extended in most places into Neogene and Quaternary periods.

The second phase is the Erythrean Fault System, which consists of northwest-southeast and east-west oriented normal and strike-slip faults ranging from the Late Miocene-Early Pliocene in age. Many faults and rifts valleys, during this phase, were formed, such as Wadi Sirhan Graben and Karak-Fayha Fault.

The third phase is the Jordan-Dead Sea Transform Fault System, which was formed in the Miocene as a result of the breaking off of the Arabian plate from the African Plate (Adams and Barazangi, 1984, Rotstein and Kafka, 1982). The complete structure is extending about 1100 Km long and is thought to have formed principally by left-lateral shear motion with about 107 Km of horizontal displacement (Quennell, 1959; Freund, 1965; Girdler, 1985) and only a minor component of transverse extension (Garfunkel, 1981). The left lateral shear motion along the Jordan-Dead Sea Rift is also considered to be a response to the extensional opening of the Red Sea (Abou Karaki, 1987; Arkin, 1989; Girdler, 1990, and 991).

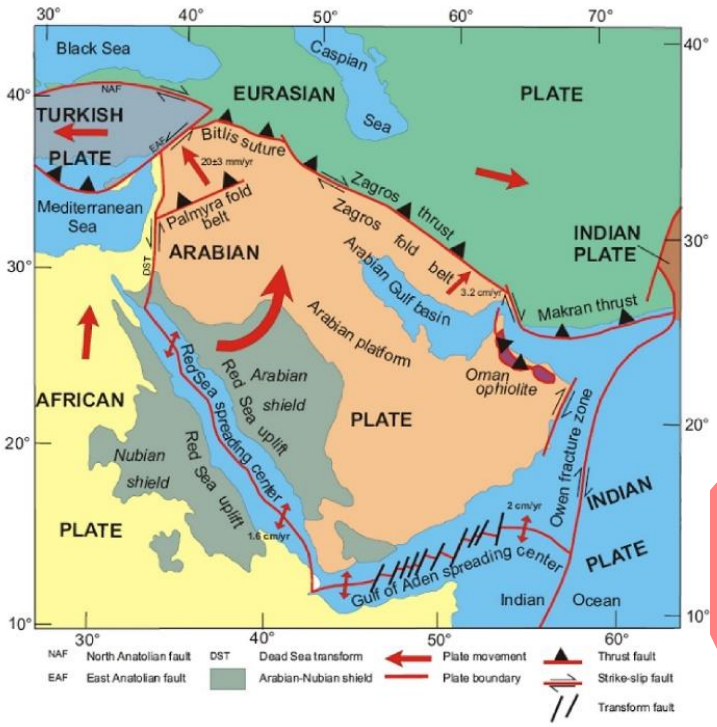

Figure (1)

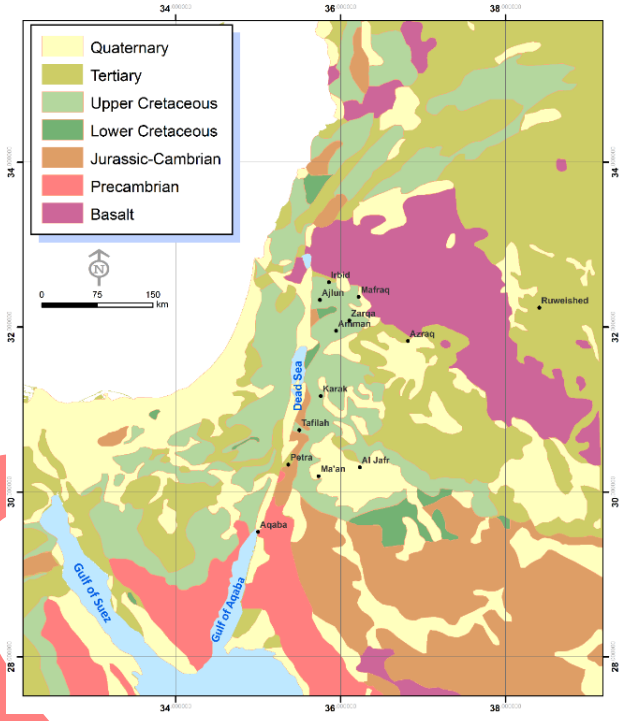

Figure (2)

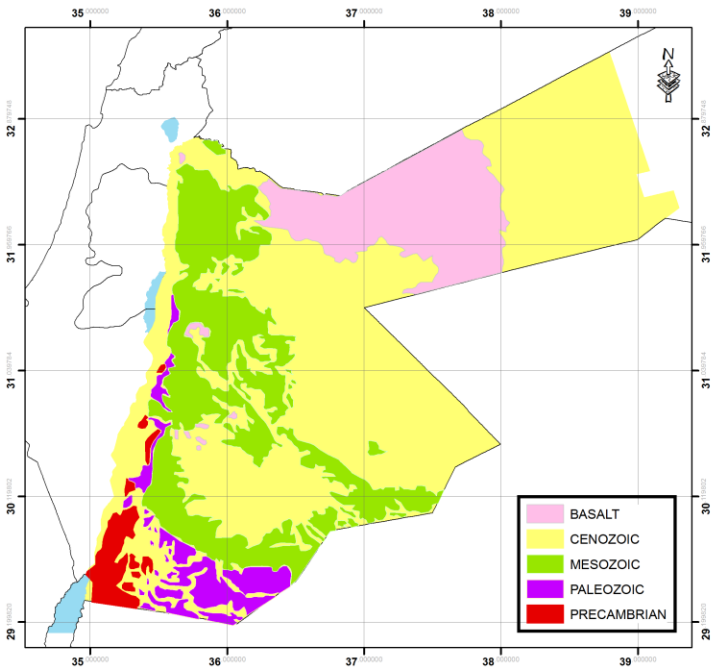

Figure (3)

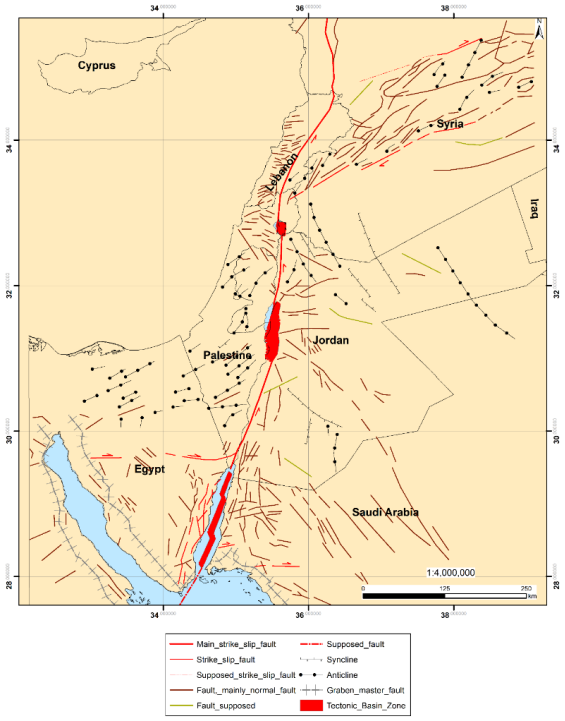

Figure (4)