Geology OF JORDAN

Ministry of Energy and Mineral Resources

Jordan is a geological paradise. It is distinguished by the existence of many naturally
outstanding geological sites. This is clear through the diversity of geological features and rocks for most of the geological periods from the Late Proterozoic basement rocks to the present-day sediments including a thick sequence of Phanerozoic rocks. Jordan is located along the western border of the Arabian Plate and includes part of the African Rift Valley that encloses the Dead Sea “the lowest point on the Earth”. The geological structures in Jordan are influenced by the NNE movement of the Arabian Plate.

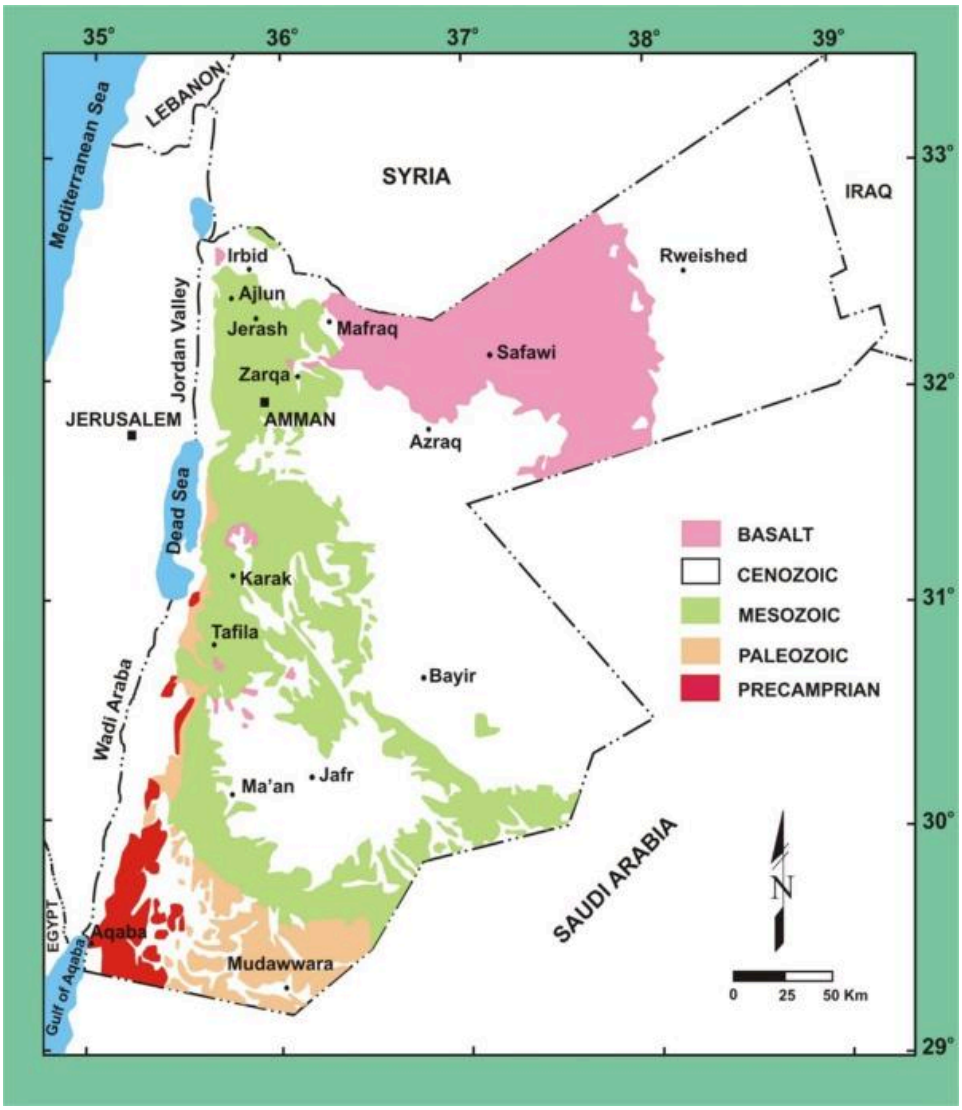


Figure 1:
Simplified Geological Map of Jordan.

Era	Period	Group	Formation		
Cenozoic	Neogene		Lake sediments (i.e. Lisan), alluvial fans, dune sands, wadi sediments, mudflats, travertines.	**Volcanics** (i.e., Harrat Ash Sham)	
	Paleogene		Dana Conglomerate		
		Belqa	Wadi Shallala Chalk		
			Umm Rijam Chert Limestone		
			Muwaqqar Chalk Marl		
			Al Hisa Phosphorite		
			Amman Silicified Limestone		
			Wadi Umm Ghudran		**Batn Al Ghul Group** (SE Jordan)/Siliciclastics
Mesozoic	*Cretaceous*	*Ajlun*	Khuraij Limestone		
			Wadi As Sir Limestone		
			Shua'yb	F/H/S (Undifferentiated)	
			Hummar		
			Fuhays		
			Na'ur Limestone		
		Kurnub Sandstone Group			
	Jurassic	*Azab*	Sandstone alternating with limestone.		
	Triassic	*Zarqa-Main*	Gypsum		
			Sandstone		
			Carbonates		
			Sandstone		
Palaeozoic	*Permian*		Umm Irna Sandstone		
	Devonian and Carboniferous (No Records in Jordan)				
	Silurian	*Khrayim*	Khushsha Sandstone		
			Mudawwara Sandstone / (Glacials)		
	Ordovician		Dubaydib Sandstone		
			Hiswah Sandstone		
	Cambrian	*Ram*	Umm Sahm Sandstone		
			Disi Sandstone		
			Umm Ishrin Sandstone	Burj Dolomite /Abu Khushayba Sst.	
			Salib Arkosic Sandstone		
Precambrian		**Aqaba and Araba complexes** Metamorphics, granites, volcanics, conglomerates, dykes.			

Table 1:
Stratigraphic nomenclature of Jordan.

Stratigraphy

The crystalline Precambrian basement in southwest Jordan is Neoproterozoic in age (900-541 Ma) and represent the northern rim of the Arabian Nubian Shield.

It is exposed at the eastern margin of the rift valley from Aqaba in the south to the southeastern part of the Dead Sea in the north. East of the rift, Precambrian rocks are dipping north-eastwards underneath thick Phanerozoic sediments.

The basement rocks are subdivided into Aqaba and Araba complexes. Its lithologies include metamorphics, granitoids, volcanics and conglomerates. These rocks are intruded by numerous dykes of different types. Copper, gold, feldspar, precious metal (i.e garnet) and decoration stones are the main mineral resources of these rocks.

Figure 2:
Peneplanation of the Precambrian basement near Aqaba, where early Cambrian sandstones of Ram Group unconformably

overlying the late Neoproterozoic Aqaba Complex granitoids with cross-cutting dykes

A thick sequence of fluvial and marine sediments of Palaeozoic age
unconformably overlie the basement rocks and represented by two main groups :

1) **Ram Group** (Cambrian-Ordovician) is predominantly continental sandstones with restricted marine sandstones and carbonates.

2) **Khrayim Group** (Ordovician-Silurian) is predominantly marine and contains alternating sandstones, siltstones and clays.

This group is marked by the presence of glacial deposits at the end of Ordovician period. The Cambrian-Silurian rocks are of high economic value for Jordan considering the presence of silica sand, copper, manganese, rare earth elements, zirconium, clay and hot
shale.

Meanwhile, these sediments are potential water reservoirs and possible targets in oil exploration.

Figure 3:
Cambrian sandstones (Abu Khushayba) unconformably overlying the immature
palaeotopography of the Ahaymir volcanics of Araba Complex in the central part
of Wadi Araba. View is several hundreds of metres wide

Figure 4:
Typical succession of the Ordovician Umm Sahm Sandstone Formation (dark brown) of the Ram Group unconformably overlained by the Darriwilian marine silicickastics of Hiswah Formation of the Khrayim Group, south Jordan

There are no records of Devonian and Carboniferous periods in Jordan. Permian rocks are represented by restricted exposures of Umm Irna Formation; to the east of the Dead Sea.

This formation comprises siliciclastics that deposited in a terrestrial environment.

Triassic rocks in Jordan are represented by Zarqa Main Group and exposed to the east of the Dead Sea and locally in the western part of River Zarqa, north of Salt area.

The marginal marine sandstones and siltstones are dominant in the lower part.
Open marine carbonate sediments represent the middle part, whereas evaporites are present in the upper part.

The Triassic rocks are of high economic value considering the presence of thick gypsum (80m), which is used as a raw material for cement industry.

Figure 5:
Exposure of Lower Triassic siliciclastics of Zarqa Main Group, east of the DeadSea

Jurassic sediments in Jordan are restricted to the east of Jordan Valley side wadis in a region extending for 20km southwards of River Zarqa in the northwestern part of Jordan.

Jurassic rocks are presented by the Azab Group, which comprises alternating sandstones, siltstones and limestones that were deposited in a marginal to open marine environments.

Figure 6:
*Siliciclastics and carbonates of Jurassic sediments (lower half) unconformably overlained by Cretaceous sediments, east of Jordan Valley south of River Zarqa,*Salt area

The Cretaceous rocks cover broad areas in Jordan (60 %). It is conventially divided into four lithostratigraphic groups bounded by regional unconformities.

These are Kurnub, Ajlun, Belqa and Batn Al Ghul groups. Clastic sediments of early Cretaceous (KurnubGroup) overlie the Palaeozoic, Triassic and/or Jurassic strata with a regional angular unconformity.

The Kurnub Group is dominated by continenta siliciclastics deposited by braided rivers with periods of marine deposition in northwest Jordan.

Throughout most of Jordan, a major transgression of the Tethys Ocean covering most of the country and deposited carbonate facies of the Ajlun Group on a broad platform.

Carbonate deposition was dominant throughout Cenomanian to Coniacian, influenced by a regional early Coniacian regression. An extensive marine transgression occurred around the Coniacian-Santonian boundary, on which predominantly pelagic sediments of Belqa Group were deposited in shallow to deep marine environment. Marine lithofacies dominating this period include. The Belqa Group comprises alternating beds of chalk, marl, limestone, chert and phosphate.

Lateral and vertical facies variations across Ajlun Group and the lower part of Belqa Group determine that these units integrated, laterally eastwards in southeast Jordan to a coeval terrestrial and marine mixed carbonates and siliciclactics of Batn Al Ghul Group.

The Cretaceous sediments are of high economic value for Jordan considering the presence of phosphates, uranium, oil shale, pure calcium carbonates, building stones, dolomite, marble, tar sand, sandstones, gypsum, kaolin, clay and chalk. For oil exploration, parts of Jordan are considered of interest for oil exploration including Cretaceous sediments as possible targets.

Figure 7:
Typical succession of Cretaceous sediments, in ascending order; varicoloured sandstones Kurnub Group overlained by carbonates of Ajlun Group and followed by
the Belqa Group sediments in the upper part, Wadi Karak

Figure 8:
Upper Cretaceous carbonate platform sediments of the Ajlun Group unconformably
overlained by chalk, limestone, marl, chert and phosphate of the Belqa group sediments, which capped by late Neogene volcanics, Wadi Mujib area

Figure 9:
Terrestrial and marine siliciclactics dominates the Upper Cretaceous (Cenomanian-Coniacian) Batn Al Ghul Group in southeast Jordan

Oligocene sediments are composed of conglomerates associated to the formation of the Rift Valley and exposed in the Dead Sea area and at the rift margins represented by Dana Conglomerate.

Locally, in the central part of the Jordan Rift Valley, a thick rock salt was deposited in the Neogene. Quaternary sediments are widespread in Jordan and show a great diversity.

The most impressive of these is the laminites of the Lake Lisan (63-16 ka). The recent sediments are represented by wadi sediments, mudflats, alluvial fans, dune sands and travertine.

The Dead Sea (DS) is one of the most spectacular natural and spiritual landscapes of the world. The DS attraction is due to its unique high salinity, black mud, adjacent fresh water and thermal mineral springs. The DS water is rich in minerals; mainly Potash and bromine. Meanwhile, lithium is potential.

Volcanics

Jordan hosts extensive Neogene basaltic plateau referred to as Harrat Ash Shaam (HAS) that spans 11000 km^2 in Jordan as pyroclastic cones, shield volcanoes and hydromagmatic craters.

HAS is also part of a huge basaltic territory extends from Syria to Saudi Arabia through Jordan.

The rocks of this group belong to mafic alkali basalt and basanites, and have been divided into five groups that were developed through three volcanic stages during the Neogene-late Pleistocene.

Volcanic rocks also exist as irregular small volcanic centers along the eastern side of the Dead Sea plate boundary; in northwestern and central parts of Jordan. Basalts and pyroclastics are of high economic

value for Jordan and can be used
in many industrial applications.

Figure 10:
Late Neogene basalt columns in a volcanic cliff running along Wadi Hidan, west central Jordan.

Structures and Tectonic Setting

Jordan is located in the northwestern part of the Arabian Plate to the east of the Dead Sea Rift.

Three tectonic phases have affected Jordan during its tectonic history. The first phase (E-W tensional stress field) was active during early Cambrian through Ordovician.

The second phase was expressed by an extensional tectonic regime (WNW-ESE direction) during late Triassic.

The third phase is associated with NNW-SSE compression was started in the late Turonian and produced the folds of the Syrian Arc. The compressional stresses were reactivated

during the Oligocene-Miocene, examples include sinistral movement on the N-S faults; dextral movement on the E-W faults; tension on the NW-SE faults and compression on the NE-SW faults.

Faults are the main structural elements in Jordan (Fig. 2). The N-S faults are the most
important mainly the Dead Sea Transform Fault that borders the Arabian Plate in the west and experienced 107km of sinistral movement
since early Neogene. Dextral E-W faults are represented by Salwan, Dana, Siwaqa, and Zarqa-Ma'in faults. NW-SE faults form horsts and grabens in Jordan Plateau such as Sirhan Fault, Mudawwara Fault and Karak-Al Fayha Fault. NE-SW faults form complex structures, folds and reverse faults; the most important of
these is Amman-Hallabat Fault (80km in length) that crosses Amman city.

Figure 11:
The N-S Quwayra Fault Zone encountered Cretaceous-Paleogene sediments (middle)
bounded by Cambrian Sediments (dark brown) to the right and Precambrian rock to
*the lef*t.

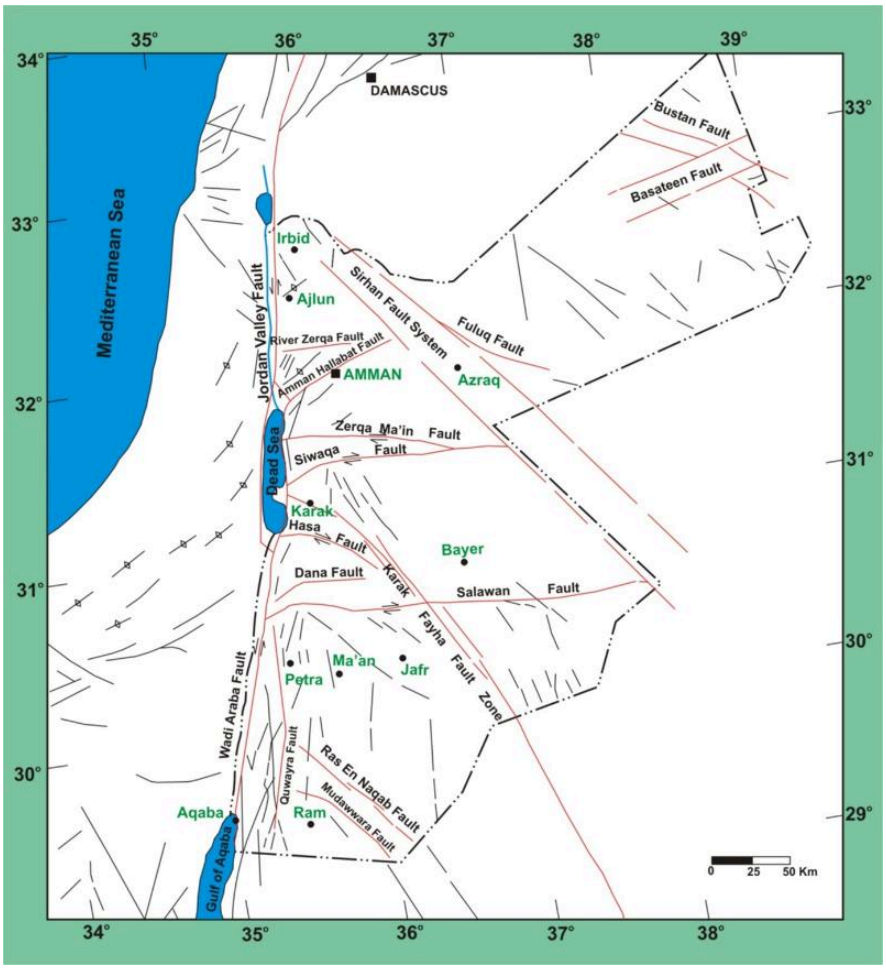
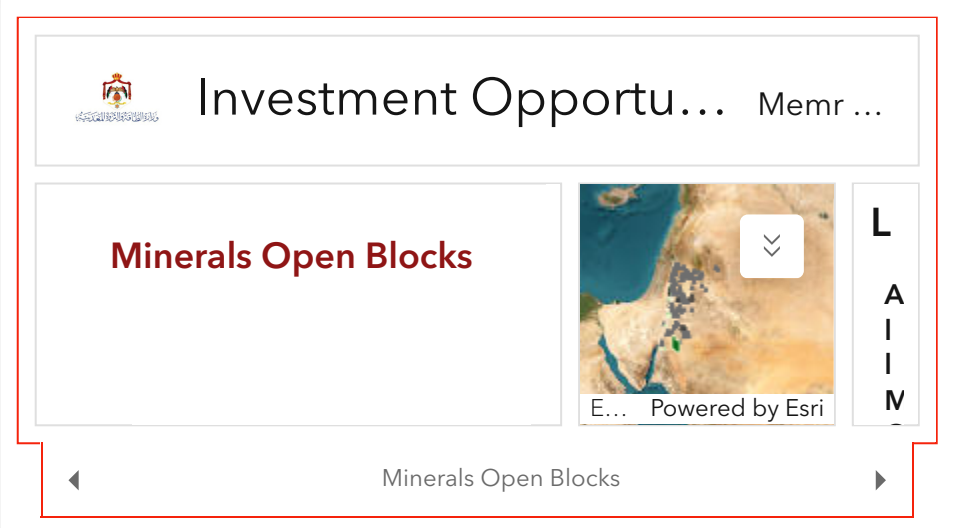
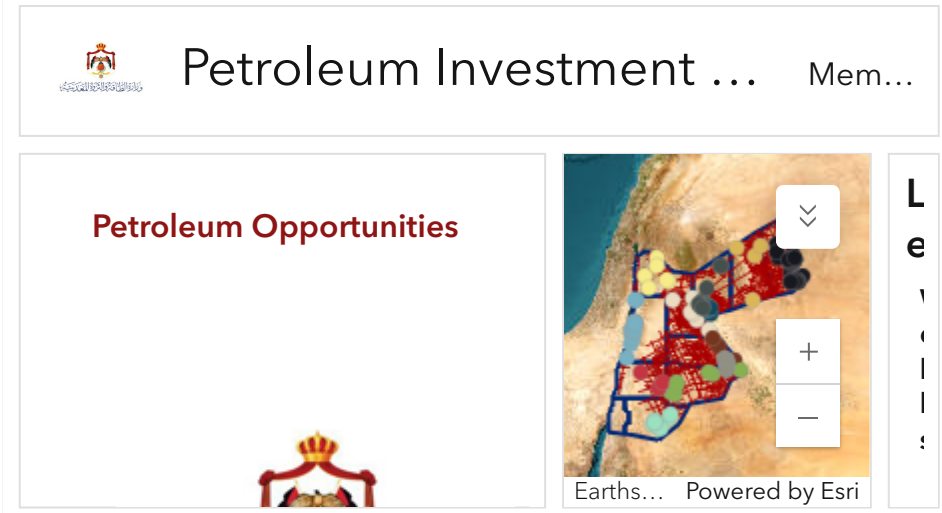


Figure 12
Structural elements of Jordan (compiled from various sources).

Investment Opportunities



Petroleum Investment Opportunists



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