

# Tectonic and Geologic Settings of Halul and Al-Alyia Off-shore Islands: Examples of Different Evolution Models, Within the Emergence Framework of the Arabian Gulf Geosyncline (A Review)



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The Arabian Gulf represents a significant water body and strategic pathway, which has pronounced regional and international benefits. This research investigated the evolution of the Arabian Gulf geosyncline. Furthermore, it explored the formation, geologic and tectonic settings of Halul and Al-Alyia offshore Islands, as examples of two different evolution models, within the emergence framework.

The Arabian Gulf geosyncline has been emerged during the Cenozoic Era (Late Miocene-Pliocene Epoch), situated in the northeastern collisional marginal part of the Arabian Plate, as a foredeep geosyncline or basin, squeezed or crammed between the stable Arabian Plate and the mobile Euro-Asian Plate, along the subduction zone, within Zagros Mountain Fold Thrust Belt Figure (1).

Halul Island is situated to the northeast of the Greater Doha City and has great national economic value. It has a unique shape, elongated domal structure, oriented from South-West to North-East. The tectonic setting of Halul Island was described as salt diapirism. The geology of this Island is dominated by carbonate rocks, mainly limestone and dolomitic limestone, and some igneous rock, such as basalt and Tholeiite

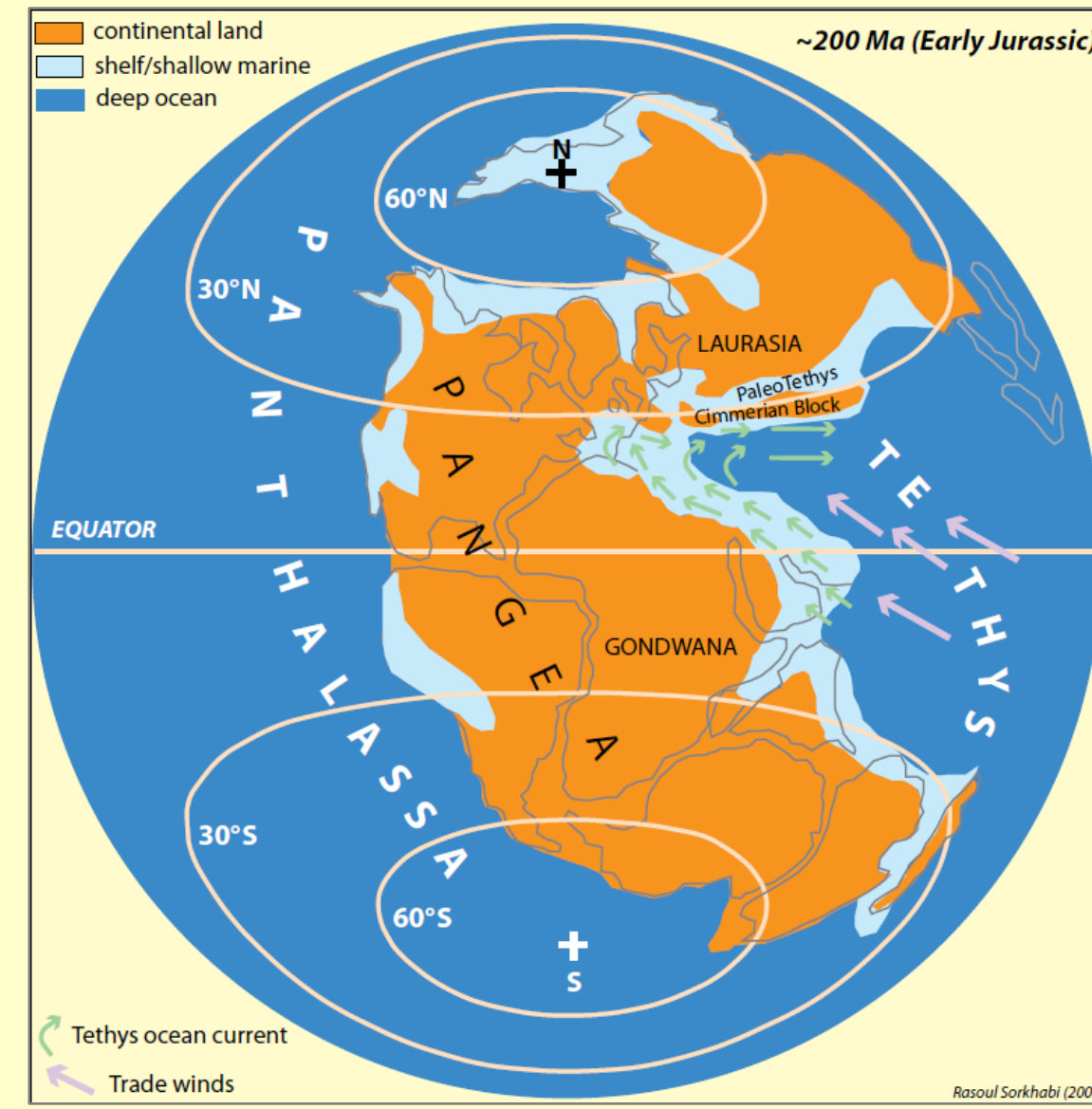


Figure (1): Paleogeography of the World during the Early Jurassic (200 Ma.). The Middle East was part of Gondwana at that time, submerged under Neo-Tethys. (after Keller 2012).

Al-Alyia Island is an integral part of the mainland. It is situated to the north-east, and in the Greater Doha City's vicinity, in the eastern coastal zone. The Island is oriented from south-east to north-west. It is characterized by a gentle slope and low relief topography. The main rocks forming the island is the limestone and dolomitic limestone of the Simsima /Umm Bab Member of the Upper Dammam Formation of Tertiary age. This fact suggests that the island has a similar geologic setting to the mainland.

This study revealed that the Halul Island evolution model is completely different from the evolution model of Al-Alyia Island, as Halul Island is a typical example model of salt dome Island and remnants of the infracambrian salt basin, while Al-Alyia Island represents a different sedimentation model island.

This research has been carried out as part of agenda of the Environmental Science Center (ESC), Qatar University.

## Evolution of the Arabian Gulf

### The Tertiary Principal Events (Cenozoic Era)

#### The Paleogene Main Tectonic Events:

- Basin isolation during the Paleocene.
- Complete emergence during the Eocene.
- Qatari Dome Uplift, by the end of the Eocene.

#### The Neogene Main Tectonic Events:

- First marine invasion during the lower Miocene.
- Orogenic movements in Western Arabia.
- Isolation of Qatar during the Pleistocene.

The geologic and tectonic settings and stratigraphic Summary of the Tertiary & Quaternary Rocks and the Principal Events during the Cenozoic Era on Qatar Peninsula and the Arabian Gulf region is summarized in Table (1) and Figure (2) .

Table (1): Stratigraphic Summary of the Tertiary & Quaternary Rocks and the Principal Events during the Cenozoic Era on Qatar Peninsula (Modified after Caveller 1970 and AlHajari 1990)

AGE	PERIODS	ROCKS	Principal Events
CENOZOIC	PALEOGENE	ABSENT	Basin isolation during the Paleocene.
	NEOGENE	Dammam Formation (Upper Eocene to Lower Miocene)	
	QUATERNARY		
PRE-CAMBRIAN	PROTEROZOIC	Hormuz Salt Series (Pre-Cambrian to Early Paleozoic)	Complete emergence during the Eocene.
PALEOZOIC	TRIASSIC		

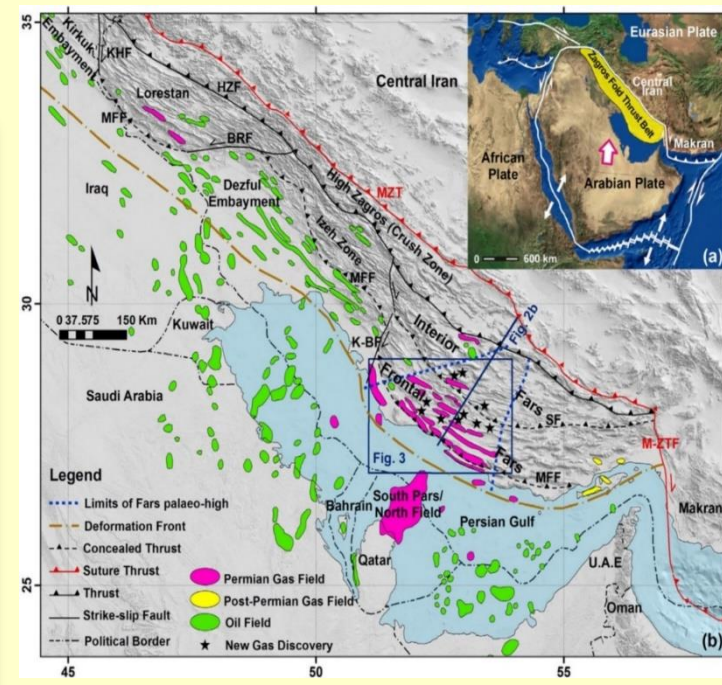


Figure (2): (a) Structure geologic settings of the Arabian Gulf. (b) The plate tectonic setting of the Arabian Gulf and its surroundings (After Keller 2018).

### Classification of the Qatari Islands:

The evolution and principal tectonic events of Qatar Peninsula and its offshore islands and Isles have started and finalized during the Tertiary, except Halul and Sherah Islands during the Paleozoic.

The Islands of Qatar are classified and categorized, based on the evolution and geomorphology, into three main types as follows:

- **The rocky islands.**
- **The salt dome islands.**
- **The sedimentation islands.**

Halul Island belongs to the salt dome islands, while Al-Alyia Island belongs to the sedimentation Islands.

### Structure and Tectonics of the Arabian Gulf Geosyncline

The regional tectonic activity include the evolution and formation of Red Sea Rift and the Gulf of Aden Rift within the frame of the collision between the Arabian Plate and the EuroAsian Plate, within Bitlis-Zagros Suture Line, through the active Zagros Mountain Thrust Belt.

This activity is illustrated in Figure (3a and 3b), as the major geologic and tectonic events during the Phanerozoic, the Zagros Orogeny and the collision of the Arabian-Asian Plate throughout the Cenozoic, with the sedimentation background of the Middle East.

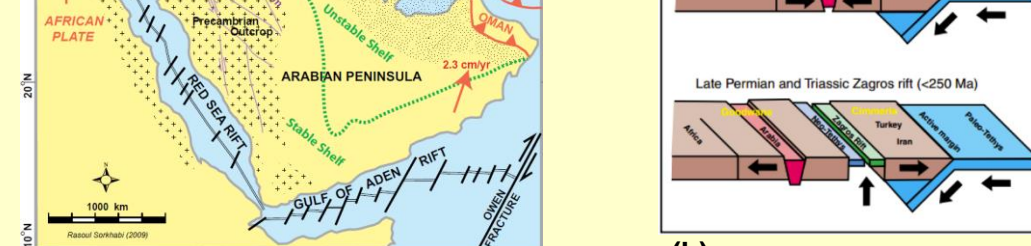


Figure (3): (a) The major geologic and tectonic events during the Phanerozoic, showing the Zagros Orogeny and the collision of the Arabian-Asian Plate throughout the Cenozoic, with the sedimentation background of the Middle East (b) Evolution of the Tectonics of the Arabian Plate since early Paleozoic to Permian and Tertiary, showing the tectonic mechanism of Zagros Mountains

### The pre-Cambrian Principal Events (Paleozoic Era)

#### Tectonics and Principal Events with Evolution of the Islands

-The Hormuz Salt Series:

This event is described as an emerging or piercing small surface domal structure, originated mainly from salty diapir or diapirism of deep source, belongs to Hormuz salt series plug type during the pre-Cambrian of the Paleozoic Era Figure (4 and 5).

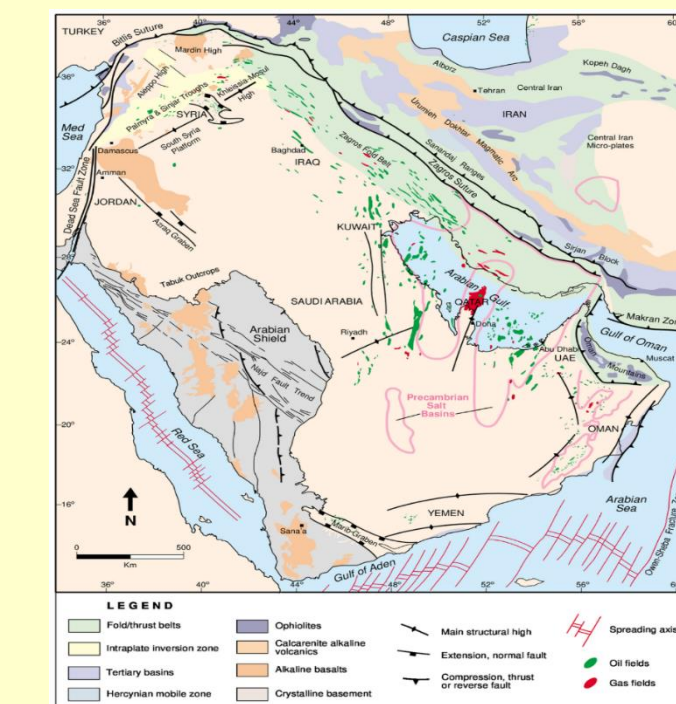


Figure (4): The major regional tectonic events and Structural high with the spreading axis.

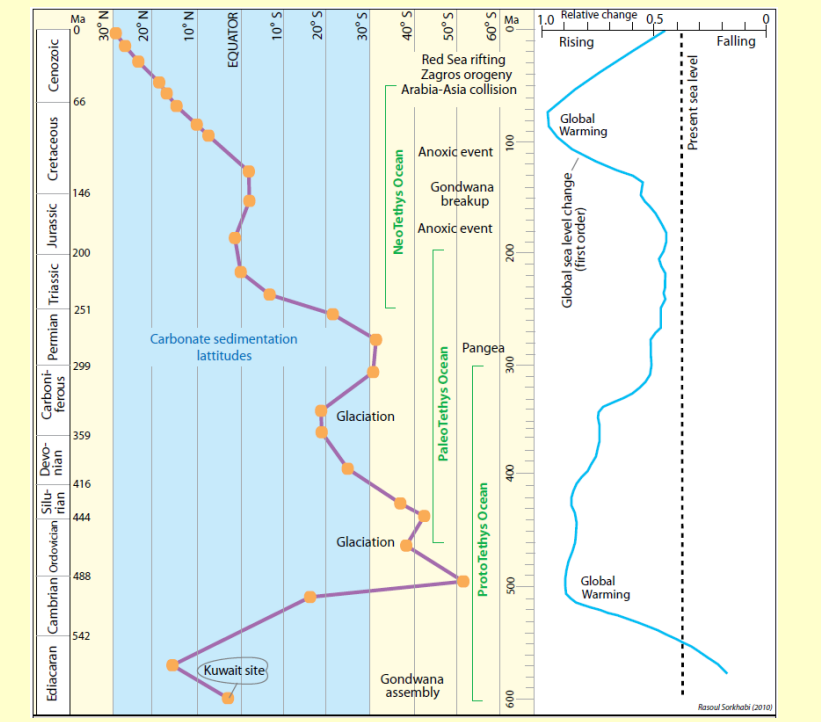


Figure (5): Movement of the Arabian Gulf during the Phanerozoic Eon, with the major geologic and tectonic events related to the depositional and sedimentation history of the area. (After Komst et al. 2001).

### Geology and tectonics of Halul Island

**Geological Description:** The Halul Island is situated about 90 km to the northeast of Doha. Halul Island has characteristic shape, elongated domal structure, oriented from South-West to North-East Figure (6). This Island occupies an area of about 1.5 km<sup>2</sup>.

The exposed surface of Halul is dominated by carbonate rocks, limestone and dolomitic limestone, in addition to some igneous rock, mainly basalt and Tholeiite, classified by geologist, as a salt diapirism, representing an emerging or piercing small surface domal structure. The age of the igneous rocks exposed in these two islands are estimated to be of infra-Cambrian Hormuz Salt Series. The main three rock types exposed on Halul Islands and the emergence in Figures (8 and 9) are as follows:

- Hard dolomitic limestone and dolomite.
- Igneous rocks of volcanic origin.
- Beach sand and deposits.
- Anhydrite and gypsum.

This island of great importance to the national economy. It is operated by Qatar Petroleum (QP) since the beginning of the oil era and serve as a gathering station, loading and export terminal for crude oil produced from the off-shore oil fields and pumped by subsea pipelines to the mega scale oil tanks in the island.

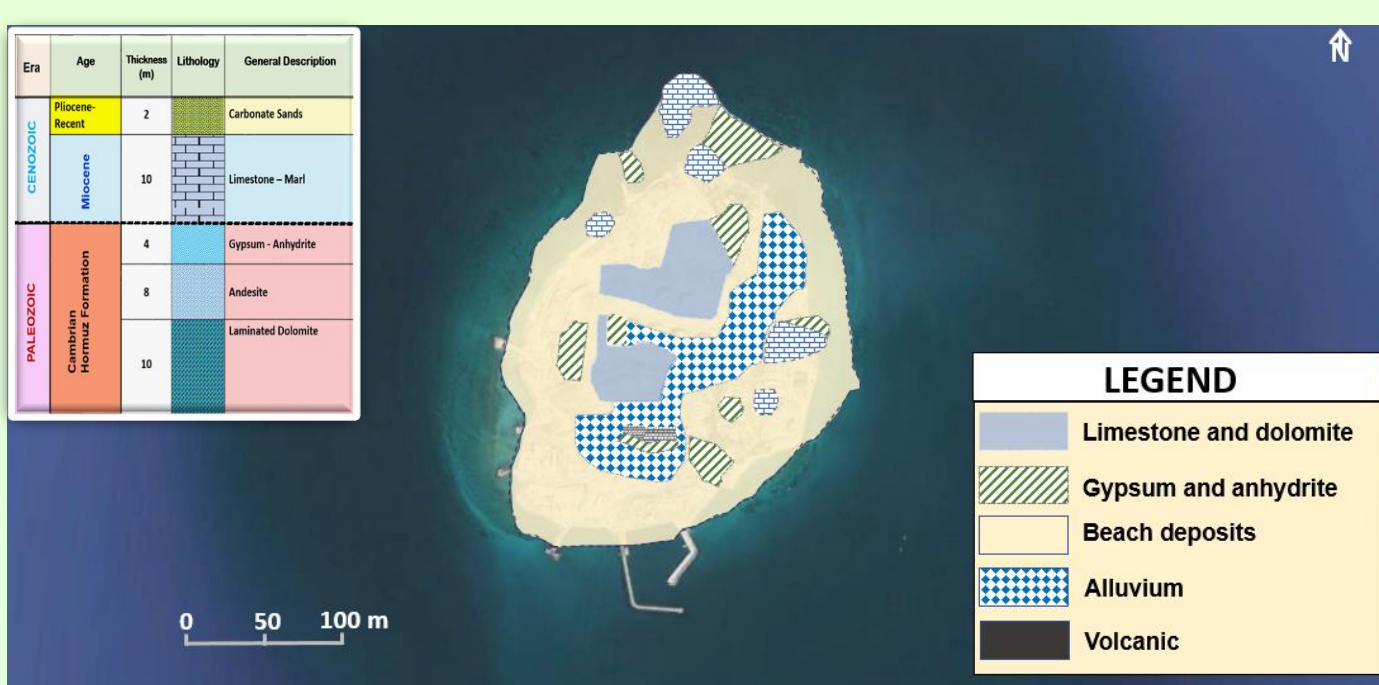


Figure (8): (Map of the surface geology of the Halul Island and Stratigraphic column of the geology of the Halul Island (Modified after: Meneisy et. al. 1988 and Sadooni et. al. 2004). (Courtesy: Google-Earth).

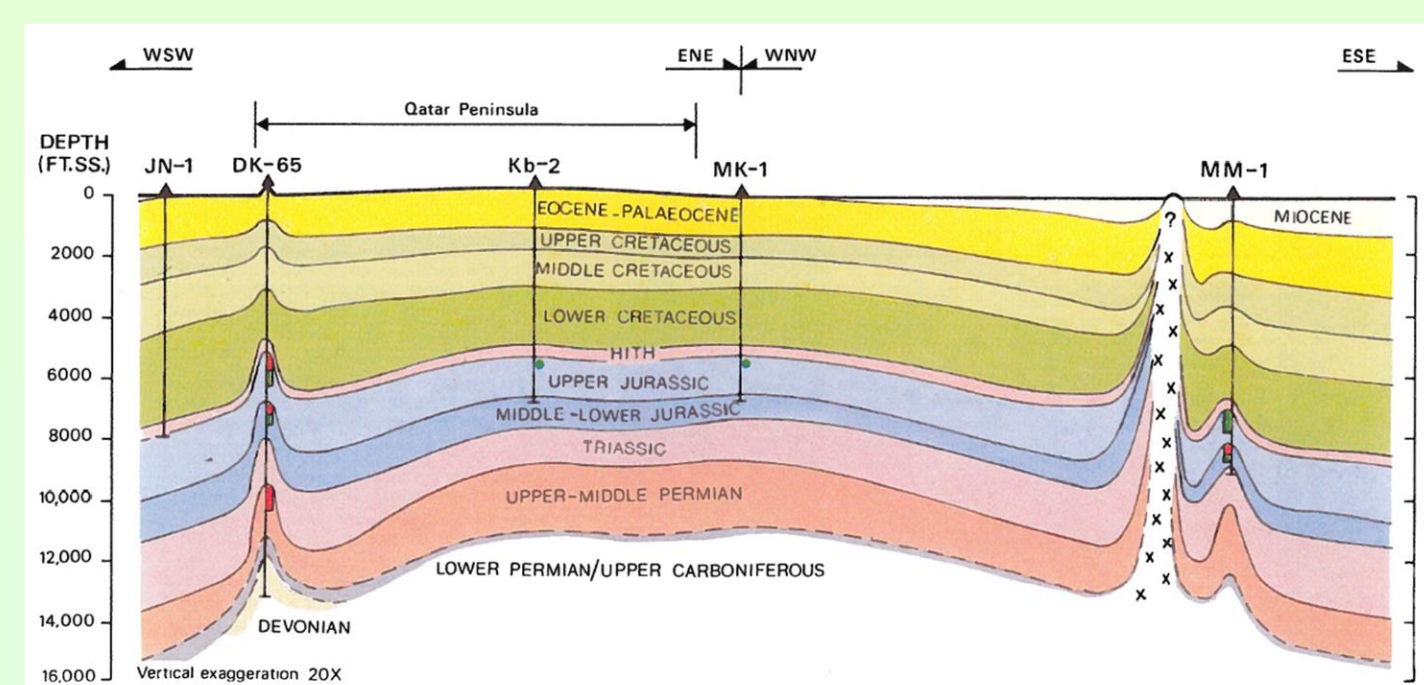


Figure (9): Subsurface cross-section across Qatar Arc showing the emergence of the Salt slab or diapirism, such as Halul salt dome Island, from deep the Paleozoic along the Quaternary and Tertiary Period.

### Evolution of the Islands



Figure (6): Locations of the Halul and Al Alyia Islands, Qatar Peninsula (Courtesy: Google-Earth).

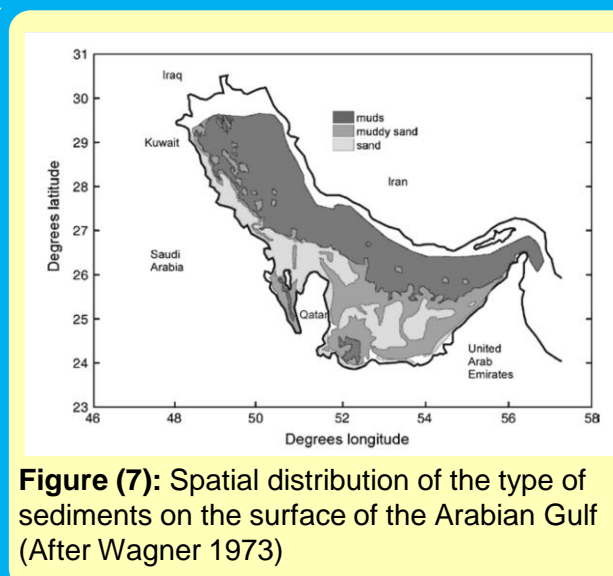


Figure (7): Spatial distribution of the type of sediments on the surface of the Arabian Gulf (After Wagner 1973).

### Geology and Topography of Al Alyia Island

**Geological Description:** The major rocks forming the island is the limestone and dolomitic limestone of the Simsima /Umm Bab Member of the Upper Dammam Formation (Eocene) Figure (10),

This suggests that the island has a similar geology to the mainland of the country at least up to the Eocene and probably formed by the same mechanism before being separated due to later tectonic movement. These Eocene carbonates are covered by surficial sediments of Quaternary age. These sediments are formed of calcareous pebbly sand probably derived from the underlying substratum. There a longitudinal, relatively thin sand bar extending south-west towards the shoreline. This may be a relatively recent feature generated by the hydrodynamic of the water system around the island or the sand accumulated on a rocky ridge that used to connect the island with the mainland.

**Topography:** This island is situated about 6 Km to the north-east of Doha. It is one of the biggest islands in the eastern coastal zone. The Island is oriented from the south-east to the north-west. It is characterized by a gentle slope and low relief topography, where the minimum elevation is about 1 m above sea level (absl), while the maximum elevation is about 7 m above sea level (absl), as shown in the digital elevation model (DEM) Figure (11). The Island is about 1.95 km long with a maximum width of about 0.75 km.

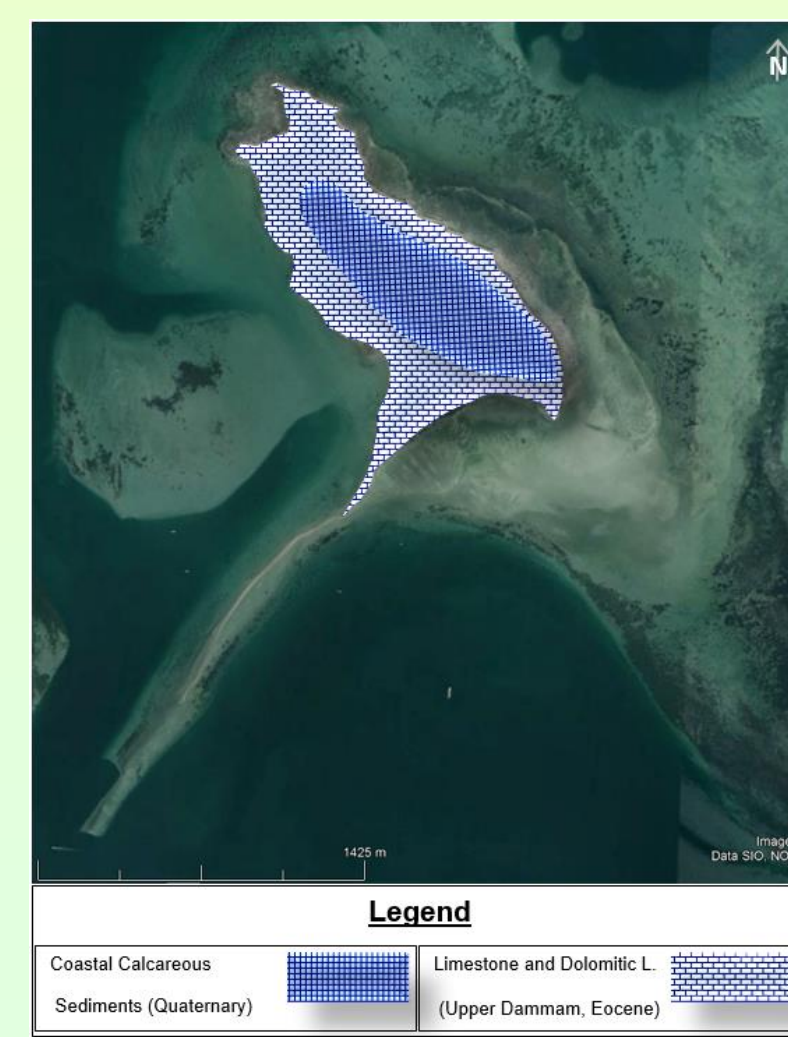


Figure (10): Map of the surface geology of the Al Alyia Island, Qatar Peninsula (Courtesy: Google-Earth).

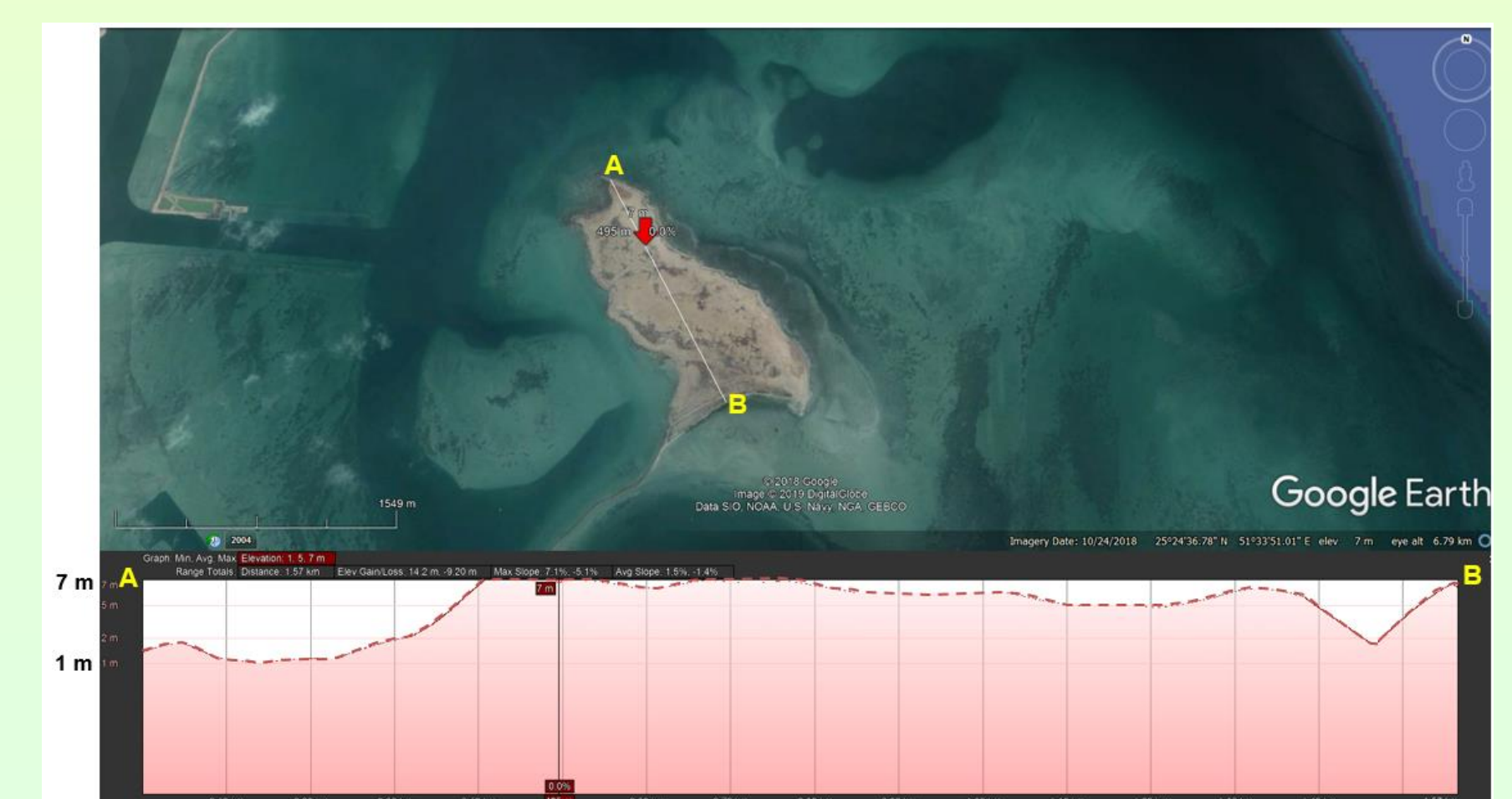


Figure (11): Digital elevation model (DEM) from point A to point B, of Al Alyia Island, Qatar Peninsula (Courtesy: Google-Earth).

OVERVIEW

DISCUSSION

and

RESULTS