Relative Sea-Level Changes During the Late Pleistocene to Holocene of Qatar: Implications for Eustasy and Tectonics*

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Abstract

The Arabian Gulf initially formed during the Tertiary as a foreland basin due to the uplift of the Zagros Mountains. It separates two geological provinces, the stable Arabian Platform and the unstable Iranian Fold Belt. Basin bathymetry is asymmetric with maximum depths and depth gradients along the northern, Iranian side of the basin. The southern margin of the Arabian Gulf dips gently northward towards the axis of the basin. Widespread areas of shallow water along the southern margin are the sites for deposition of continuous facies belts, like barrier beaches, broad lagoons, and sabkhas. Detailed mapping of coastal deposits of Qatar and published data throughout the region suggests that tectonic uplift may be a significant factor influencing these coastal sedimentation patterns.

Age dating from Qatar coastal sediments provides evidence for a rapid rise in sea level from the Last Glacial Maximum (LGM) approximately 20,000 years before present (yr BP) until approximately 7000 yr BP. Most coastal deposits are relicts of a Holocene sea-level highstand, dating from 7000-3000 yr BP. Stranded Holocene beaches at 2-4 meter elevations and up to 15 km inland are relicts of the highstand. Similar beaches are found in Abu Dhabi and the Kingdom of Saudi Arabia. During this period coral reefs formed a nearly continuous fringe around the windward and oblique Qatar coastlines. Reef sedimentation characterizes the highstand in areas devoid of high clastic sediment input. A drop of sea level approximately 2000 yr BP may account for the demise of these fringing reef platforms. Seaward stepping strandlines indicate a falling sea level to its present day position.

Unaltered, calcitic organisms from strandlines up to 13 km inland of the present day coastline and 4-6 meters above present day sea level, have radiocarbon ages between approximately 30,000 to 40,000 yr BP. These ages coincide with well documented glacio-eustatic sea-level lowstands before the LGM. Published data from various locations along the southern margin show similar ages. Late Pleistocene to Miocene fluvial gravel deposits occur 20 to 40 meters above sea level; an additional indication of tectonic uplift. Thus, data from Late Pleistocene and

Early Holocene suggest rapid rates of tectonic uplift may account for sediment distribution patterns during a relatively recent period of human history.

References

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Relative Sea-Level Changes during the Late Pleistocene to Holocene of Qatar: Implications for Eustasy and Tectonics

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Goals of Presentation

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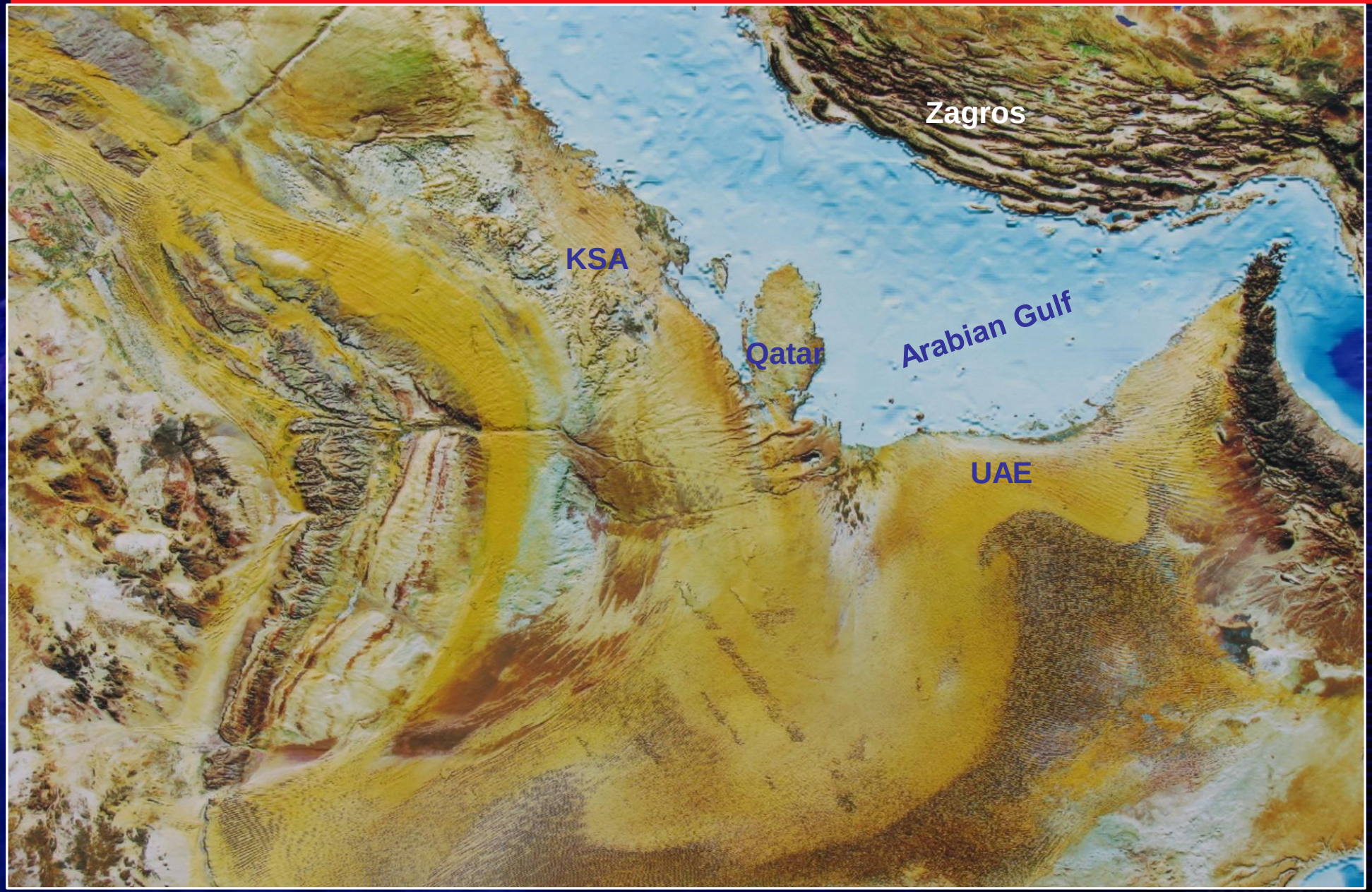
1. Present evidence of a highstand of sea level during Holocene of ~ 2m above present day; 7500-4000 ybp

2. Why?
   - High-frequency cyclicity is a primary depositional and diagenetic feature of the Holocene of Qatar and southern Arabian Gulf
   - High frequency cyclicity occurs on a scale that should be incorporated into any geological model- Holocene highstand is 3-10 m thick and 5-15 km wide.
   - Cultural history of coastal inhabitation equally affected by sea level changes
   - Evaporite models are based on the Holocene high stand

3. Illustrate some of the uncertainties in building a sea level curve for the Holocene from available data

4. What's up with Qatar? Separating eustasy from tectonics

Location



Creating a sea level curve

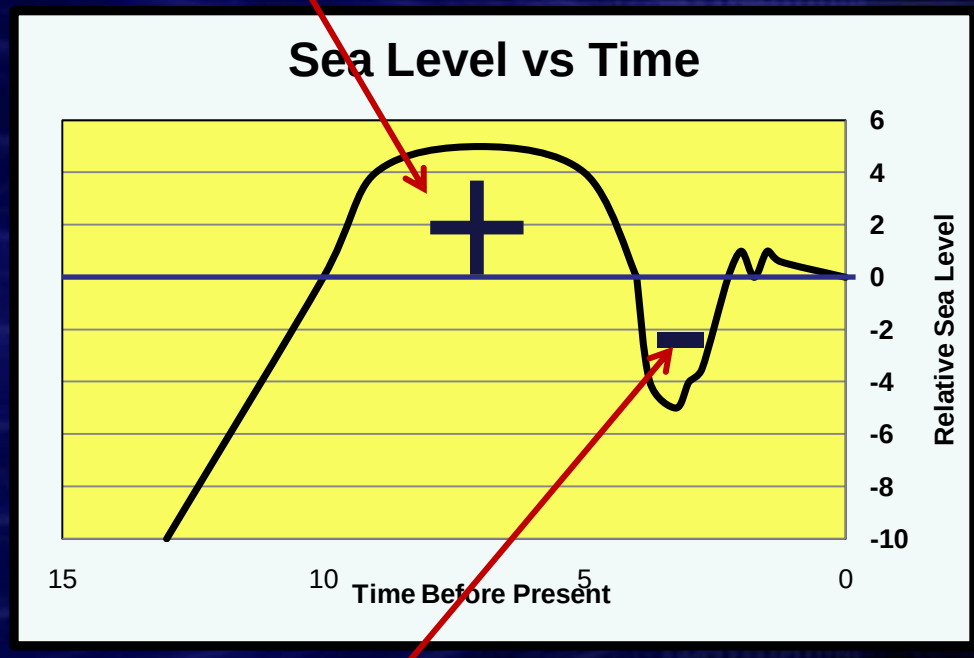
Creating a sea level curve relies on:

1. Accurate elevation data
   - Variable accuracy countrywide DEM- +/- 1 m
   - Comparison to control points .25 - 1m range
   - Geoid corrected GPS surveys +/- 0.05 m

2. Reliable ages- stromatolites most reliable, short lived biota (cerithids) nearly equally accurate, calcitic organisms (barnacles) for older Pleistocene
   - 'Lag" effect- modern carbonate facies are made up of 500- 800 year old grains

3. Bathymetry and elevation estimates from sedimentary structures +/- .2 – 2.0 m
   - Stromatolites + fenestrae have precise bathymetric interpretations
   - Beach ridge data more problematic; stranded beaches tend to be eroded

High stands above s.l.are easily mapped



Events below s.l. mapped erosional surfaces and seaward shifts in facies

Holocene Pleistocene History

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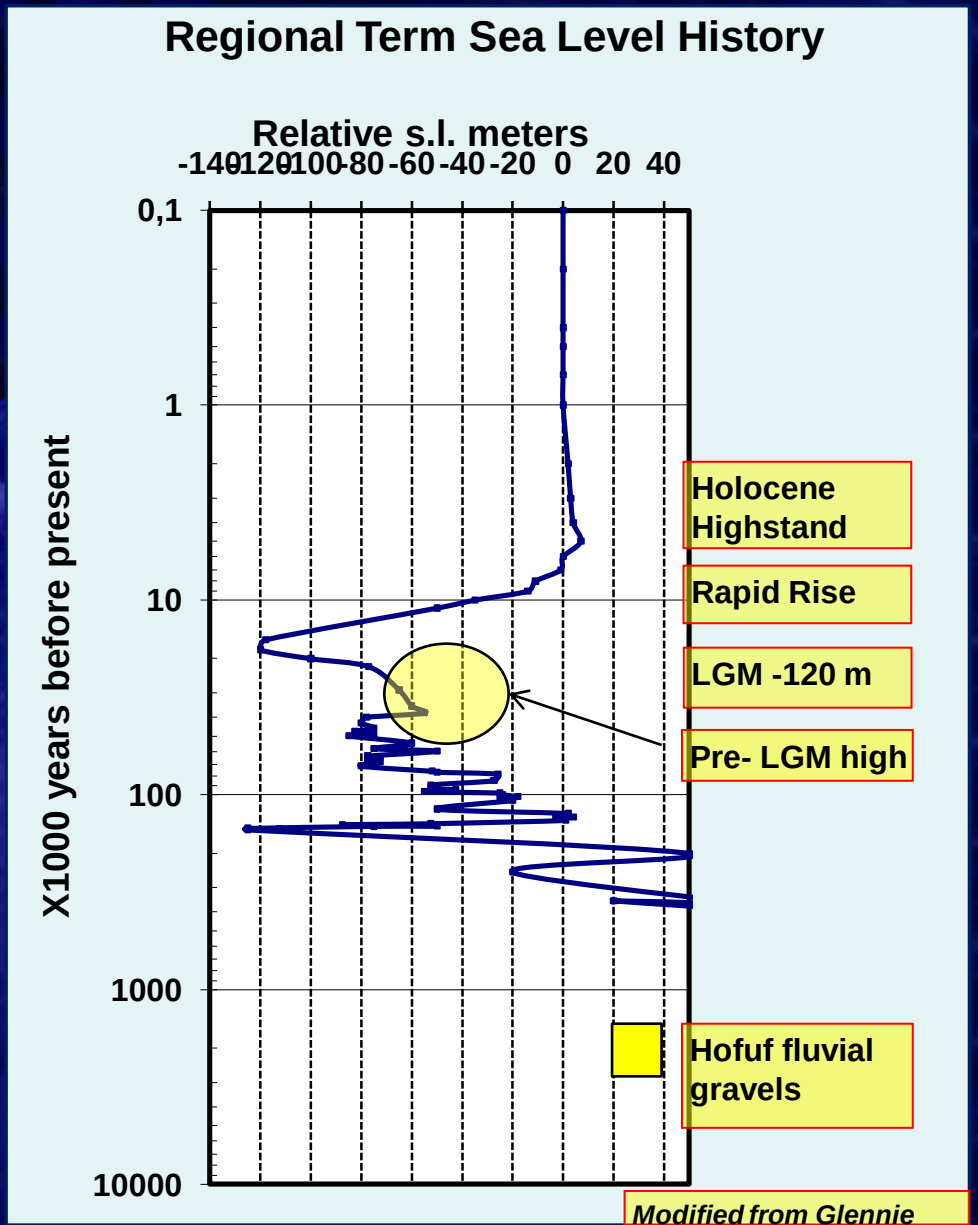

- General agreement between authors (Haq, Chappell, Glennie)

Major Events:

- 1-3 ma- deposition Hofuf fluvial-outwash clastics
- Pre LGM high 30-40 kbp- Sea level -50+ m
- -18 kbp Last Glacial Maximum (low)
- Followed by rapid rise ~ 1 meter/ 100 years
- Holocene highstand

Holocene High Stand

Stranded beaches 5-15 km from present shore provide evidence for Holocene High stand

Oldest settlement in Qatar, Shagra (7000y bp) is 10 km from present coast

Eocene

Pleistocene beach + dune
+4-6 m
38,000 ypb

Holocene Beach
+2.3m 4550 ybp surface
+ 0.60 cm below surface 5500 ybp pit

Example of Pleistocene beach

Holocene High stand in KSA and UAE

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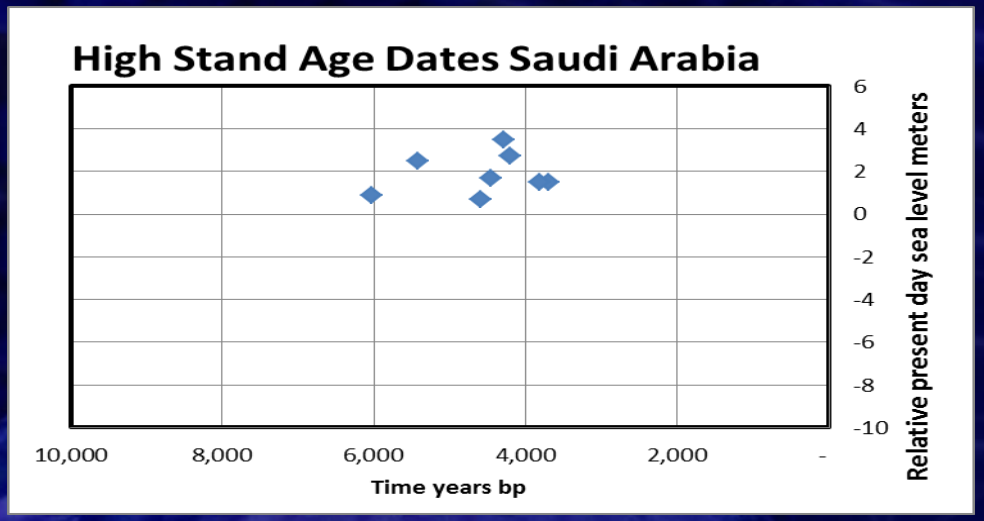

Vita-Finzi 1982
McClure et al 1982
McClure et al 1982
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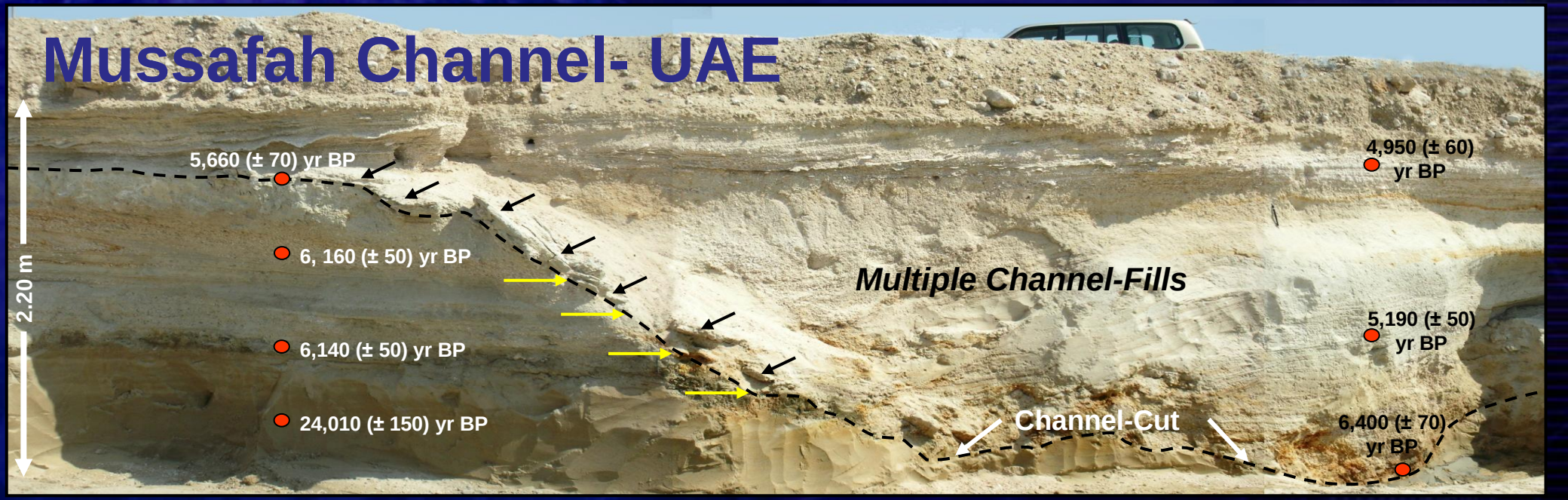
McClure et al 1982
Ridley et al 1979
Vita-Finzi 1982



Examples of Holocene High Stand

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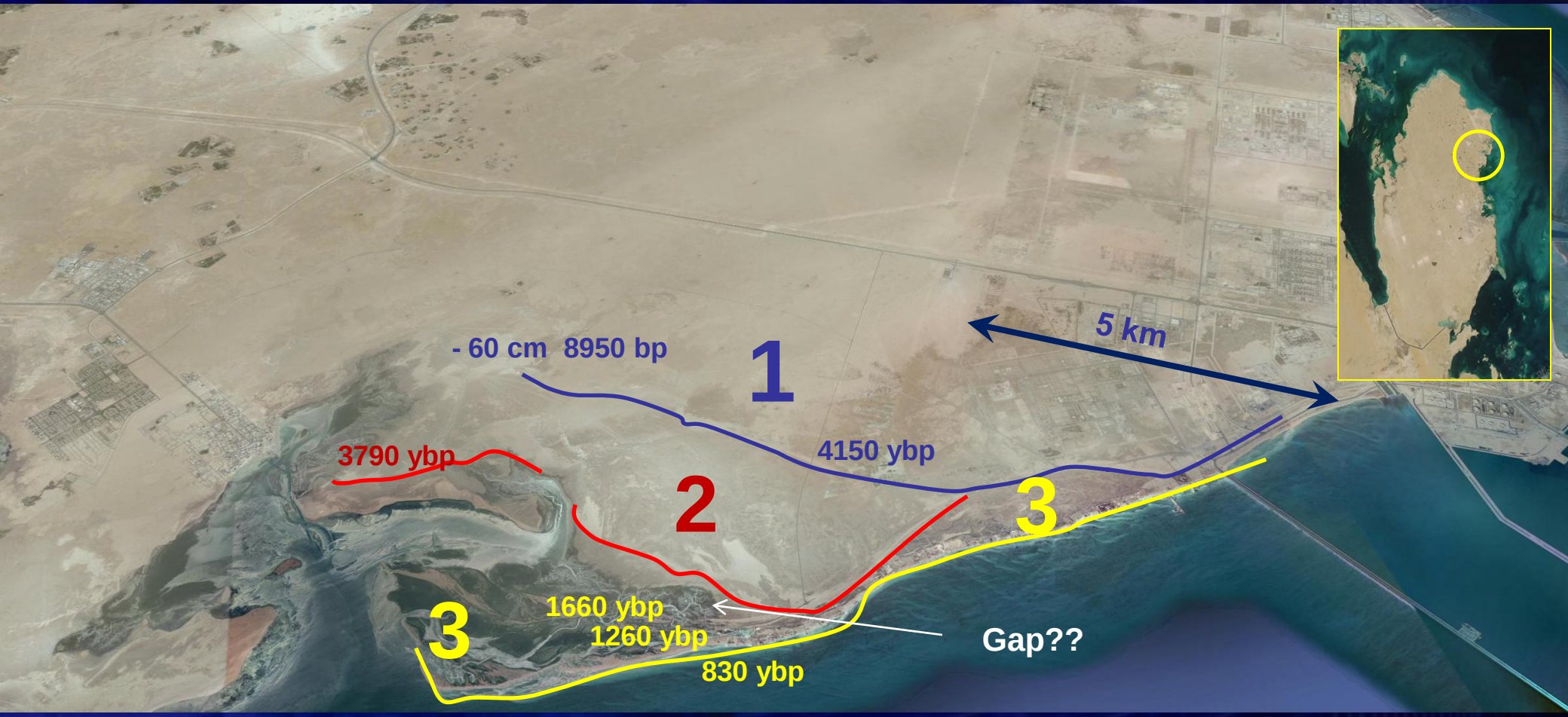

3 major time slices in coastal plain
Surface sediments young towards shoreline
Marked by seaward jumps in facies tracts related to sea level changes

Holocene High Stand

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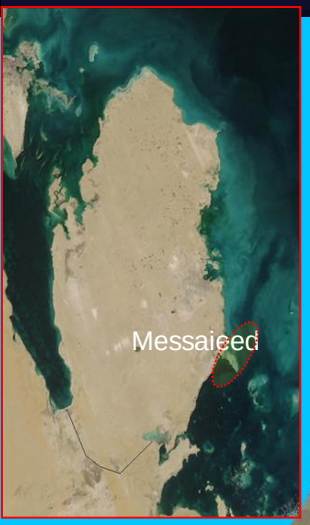

Perspective view of Messaieed with Holocene High stand time slices

Eocene bedrock

2000-3000 ybp

3000-6000 ypb

< 1600 ybp

Holocene spit systems in lee of headland

Imagery used with permission CGIS

The Holocene High Stand

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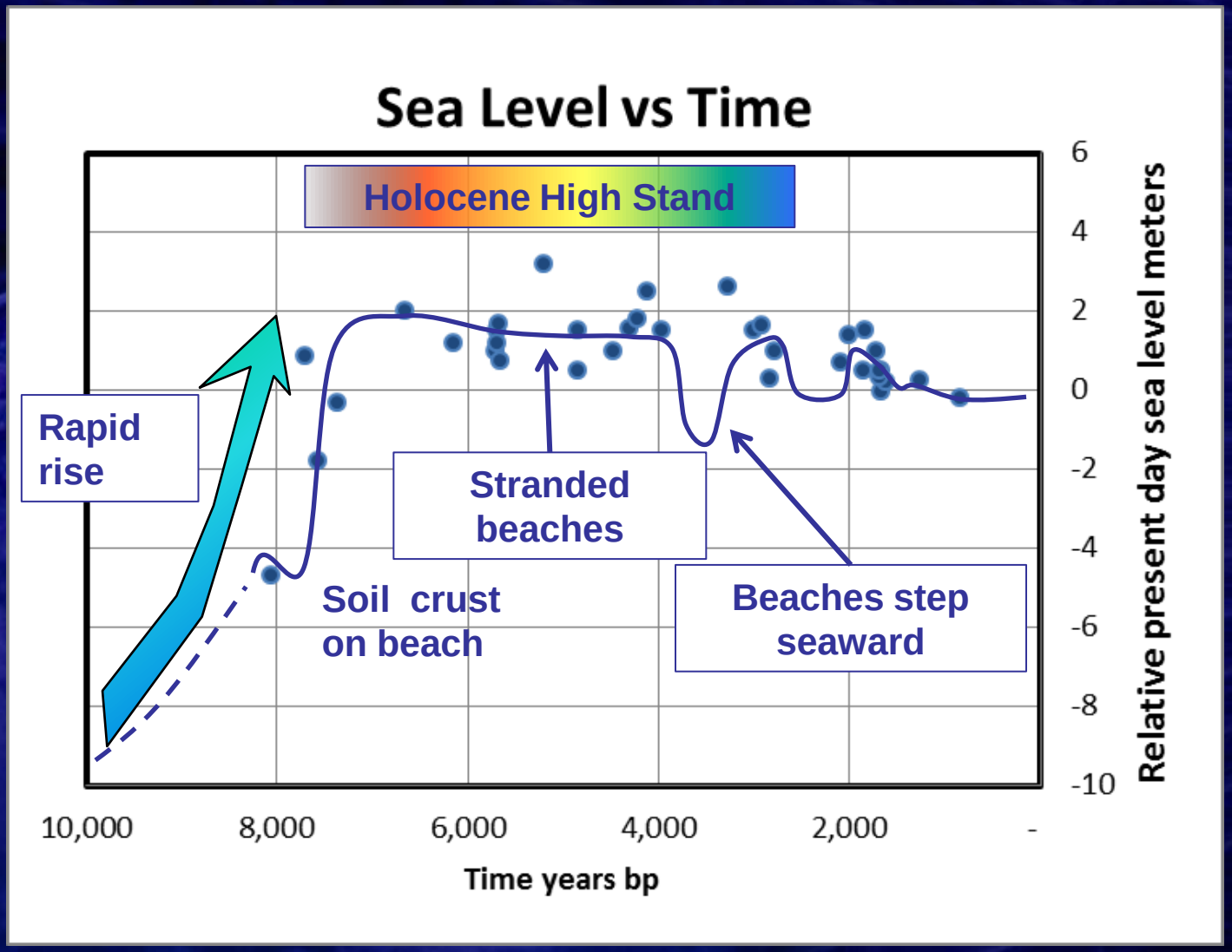

Main Events

- 10 – 8 ka Rapid rise 1m / 100 years
- Holocene High stand- +2 m above present
- Seaward Facies offsets

Most of Coastal Plain is Holocene High Stand

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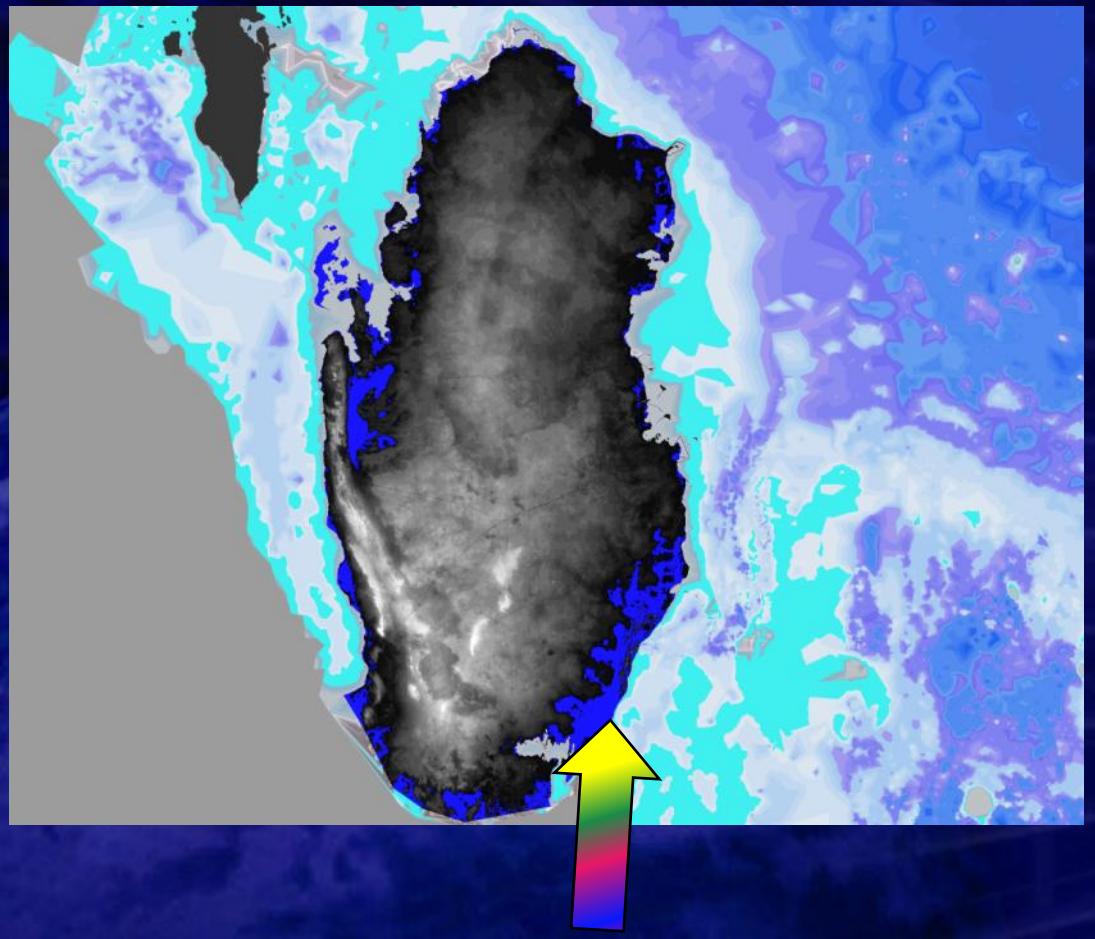

Grey shaded Digital Elevation Model of Qatar- Blue area shows coastal plain +2m above sea level

~ 20 % land surface Qatar is Holocene

Most of the Holocene of Qatar was formed during Holocene high stand

Highstand volume and size occurs on a scale that should be captured in a geological model

Do sea level falls = gaps in age data?

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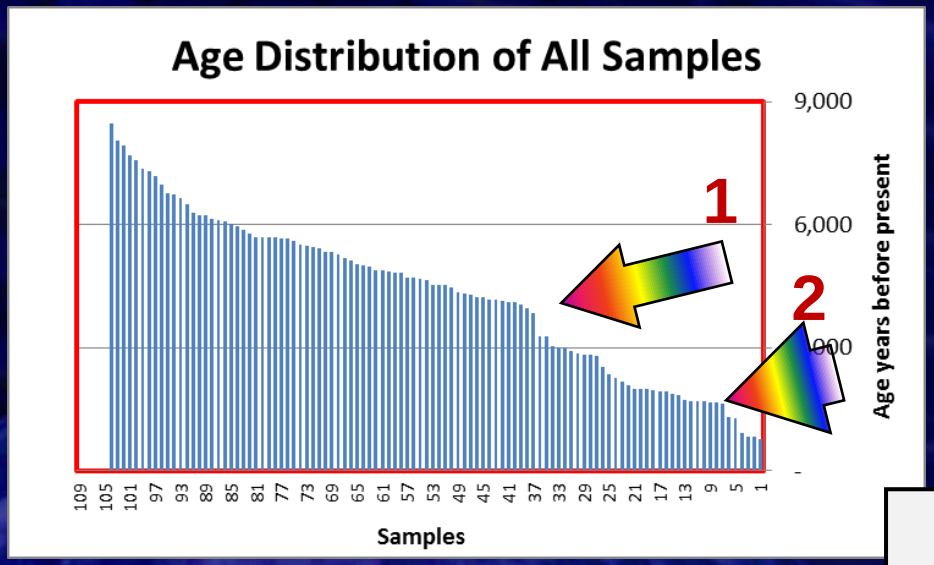
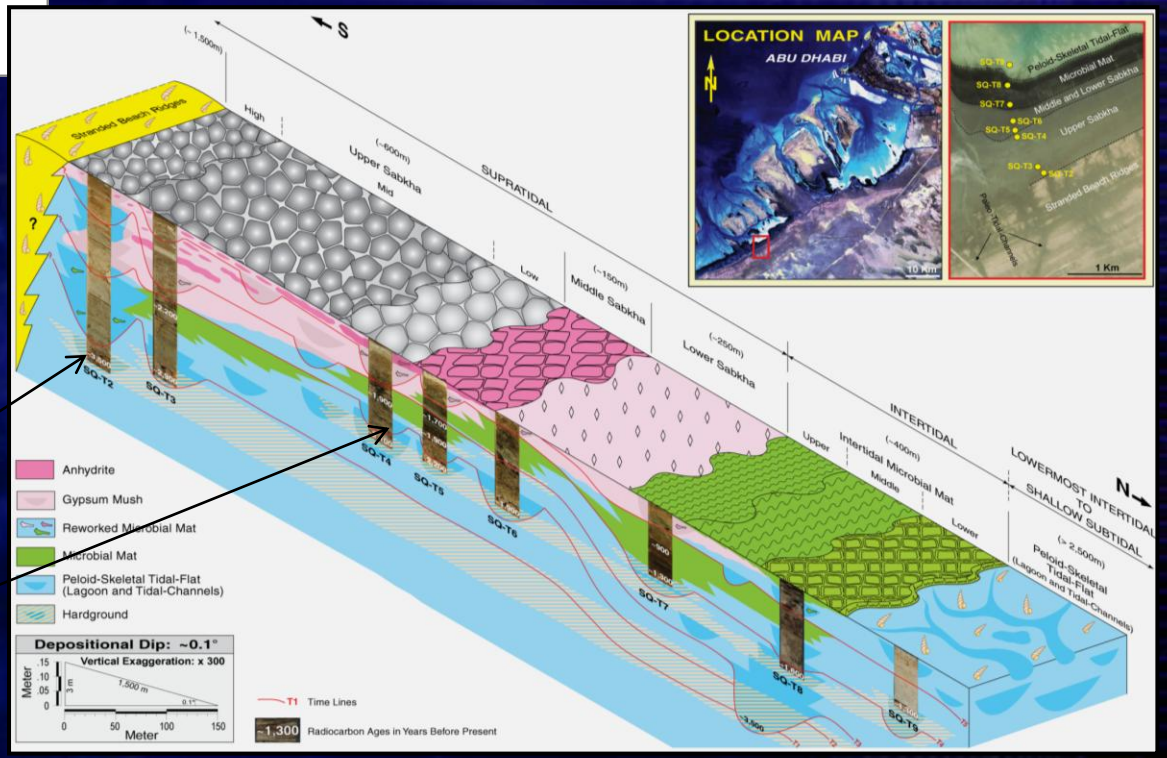


- Plot of all 104 age elevation pairs reveals two gaps in distribution
- 1- 3800 ypb 560 year gap = 7% of all time
  = First cycle seaward of beaches in UAE
- 2. 1800 ybp 350 year gap
  = Coastal shift microbial mats UAE

Time gaps in sample distribution approximately coincide with seaward shifts in coastal systems

1

2



Whats up with Qatar? Sea level or Tectonics?

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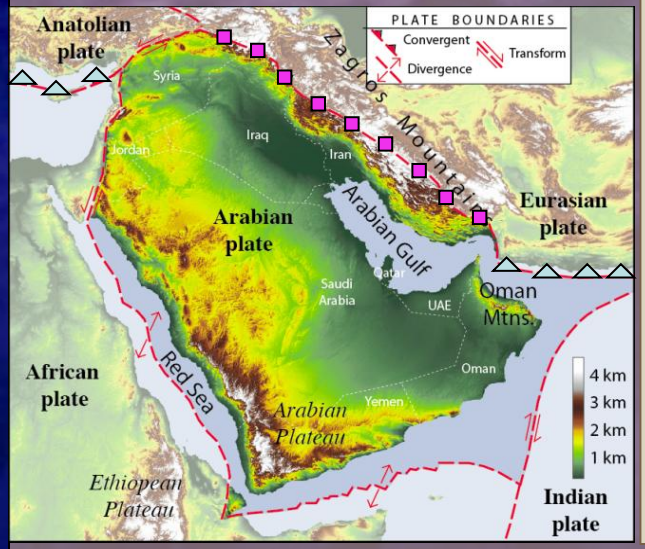
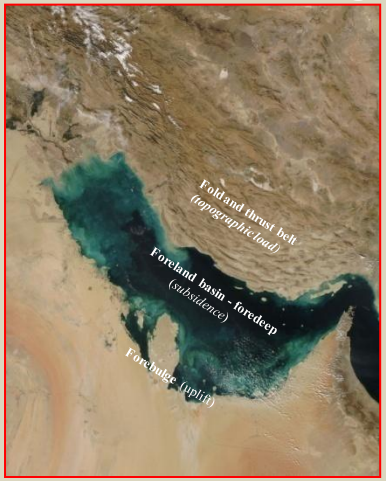
Al Naksh Hill- Miocene Pliocene river gravels on a hilltop 240 feet (75m) above sea level.

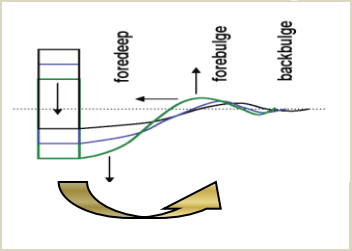
Neogene uplift along the northern coast of the Gulf is consistent with back-bulge migration from Zagros foredeep and tilting of Arabian plate due to Red Sea rifting.

Rift Related North Tilt



Southward Migration Fore Bulge

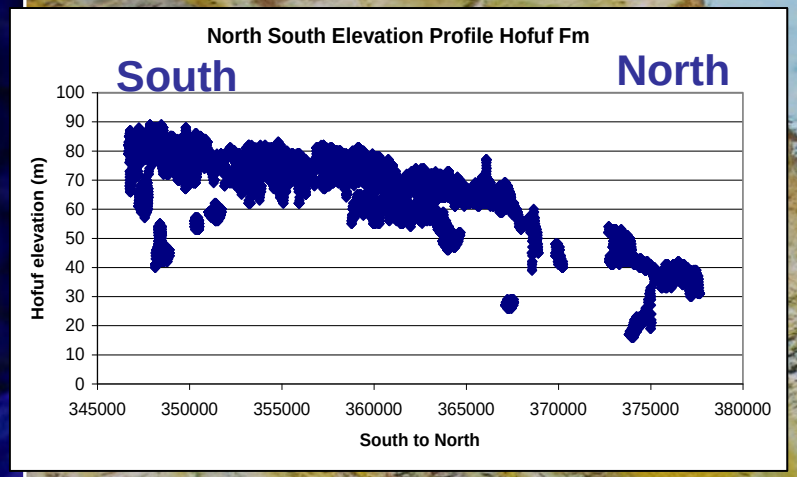




Flexure of the lithosphere through topographic loading (Zagros Mts.) drives subsidence in the adjacent foreland basin (Arabian Gulf) and uplift in the forebulge region (UAE - Qatar) of the Arabian plate.

Stranded Beaches in Abu Dhabi

Signs of Uplift



Conclusions

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- Stranded beach and sabkha deposits provide evidence for a high stand of sea level of approximately +2 m above present day

- The Highstand is the most significant event in the Holocene affecting sediment distribution patterns in coastal sediments measuring 3-5 meters in thickness over a width of 5-15 km.

- The accuracy of a sea level curve relies on:
  1) accurate elevation data
  2) reliable age dates
  3) interpretation of paleobathymetry/elevation

- Drops in sea level are marked by seaward shifts in coastal systems

- Holocene sedimentation patterns are superimposed on a long-term cycles of tectonic uplift

BACKUP

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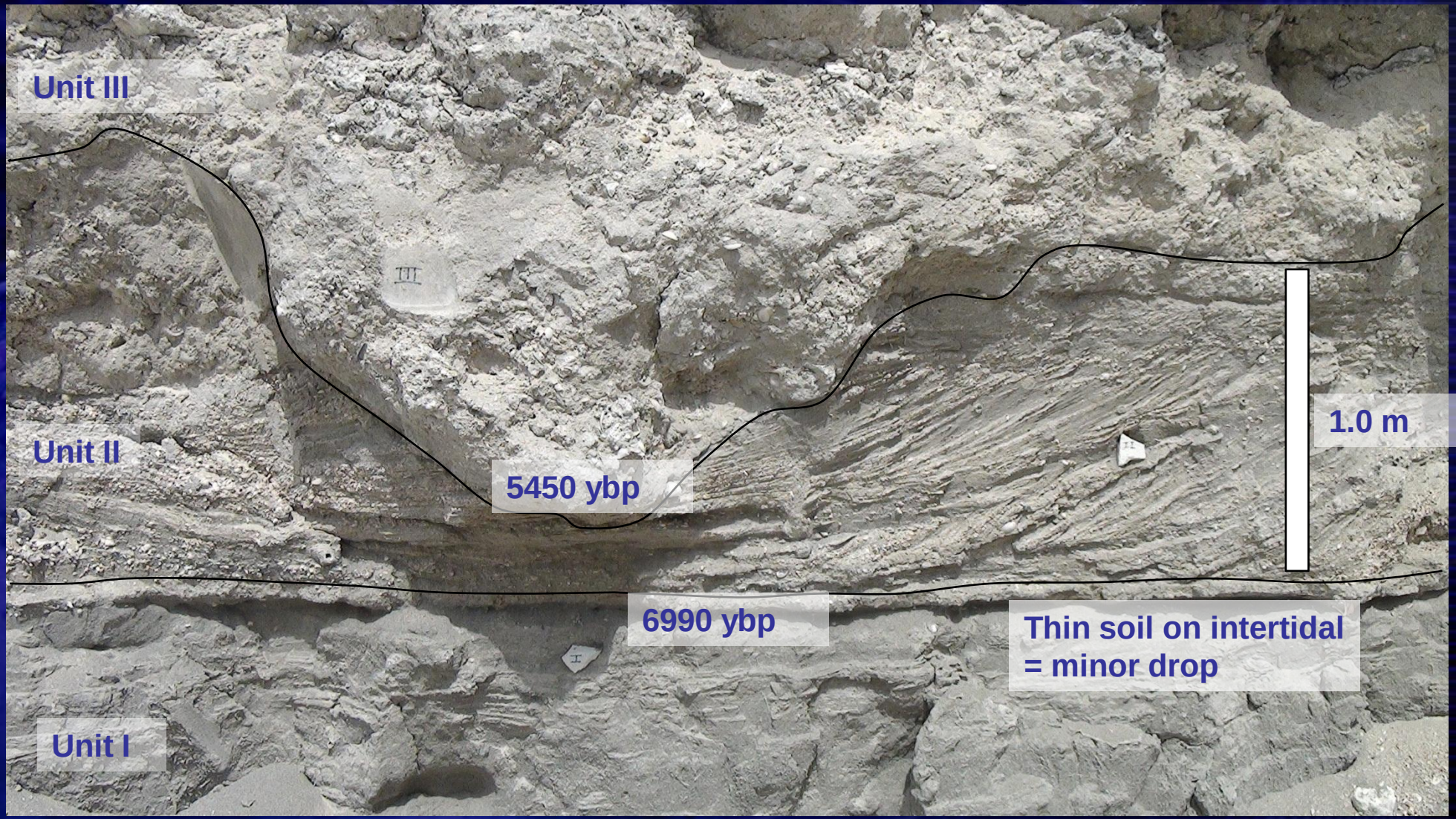
Measuring sea level drops by erosional events



Eastern Australia is rising too

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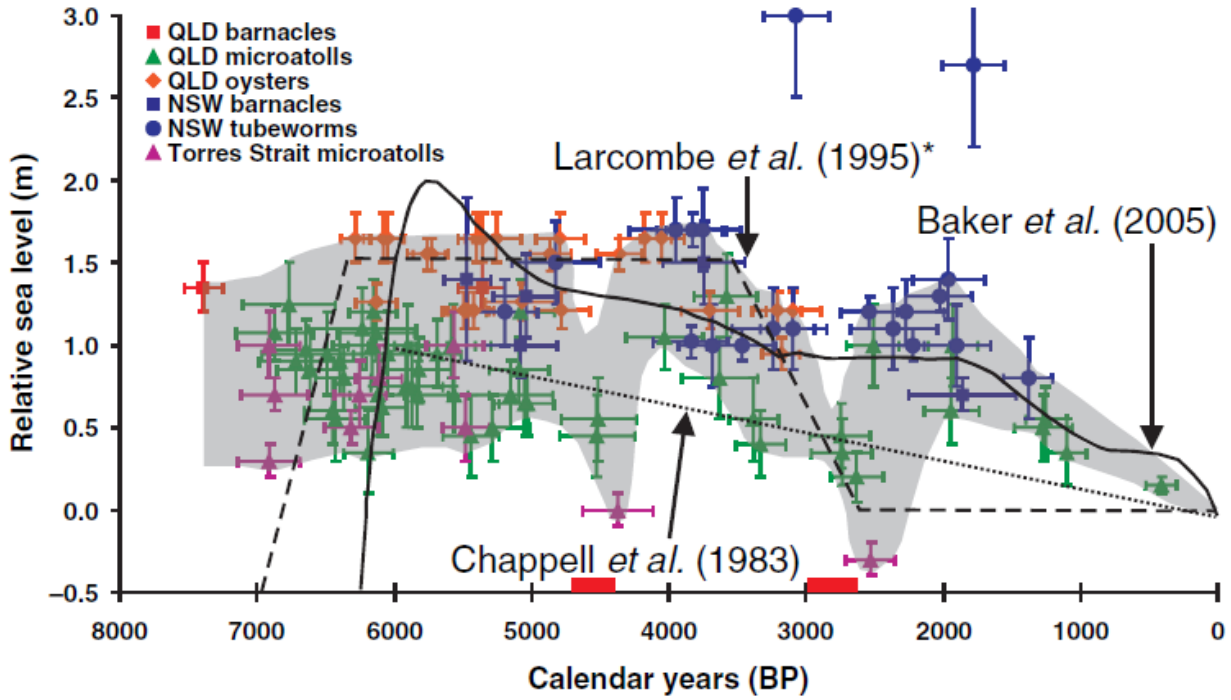

Fig. 4 Sea level data with superimposed past sea-level interpretations of Chappell *et al.* (1983), Larcombe *et al.* (1995) and Baker *et al.* (2005) for eastern Australia. The red bars show the growth hiatuses in oyster bed and tubeworm colonies. *The Larcombe *et al.* (1995) sea-level curve has been recalibrated.

Sea-Level History

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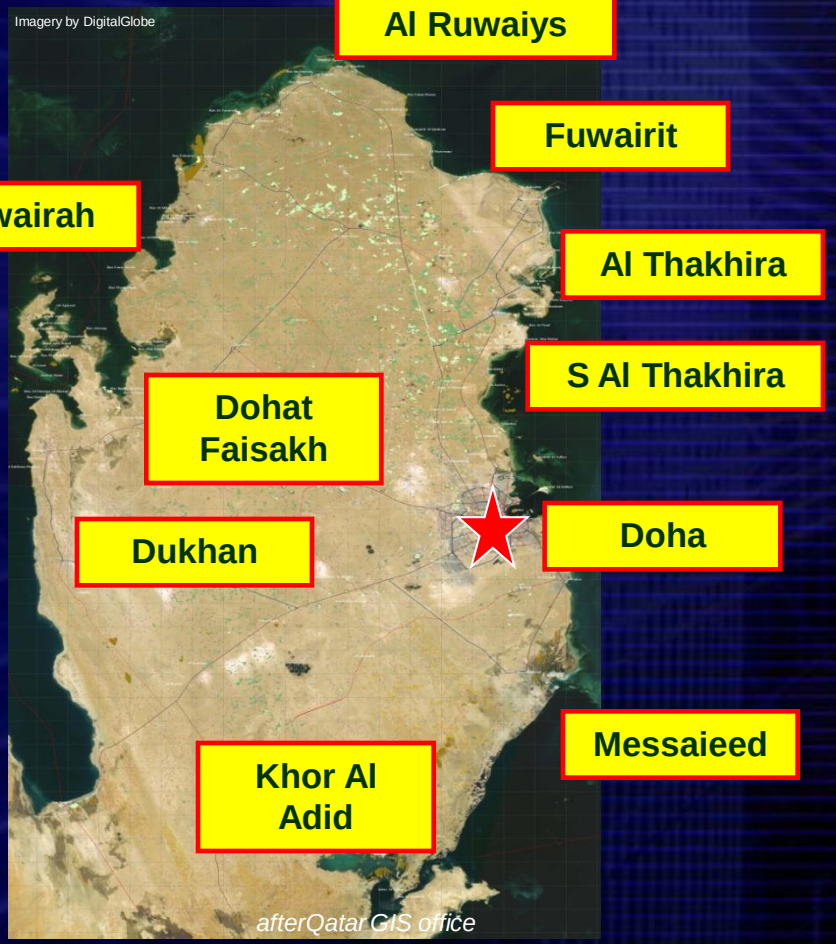
Qatar Sabkha studies

- 10 years of co-operative field research between ExxonMobil and QP in Qatar
- 3 years work sabkha research in Abu Dhabi
- Comparison to published studies in Kuwait and Abu Dhabi
-

Map of Dukha sabkha by Robb Ross QP Centre for GIS (UPDA) used with permission



Gypsum precipitation- surface and water table

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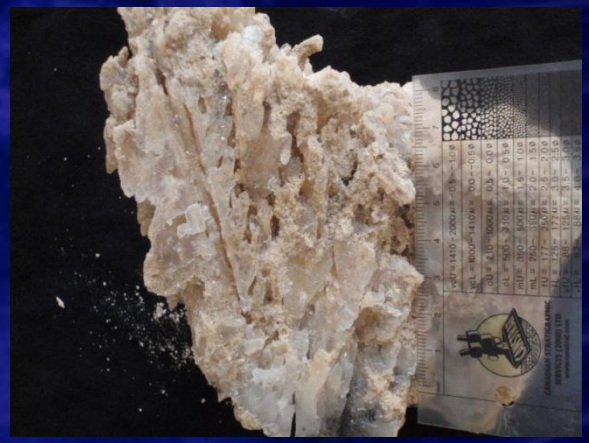


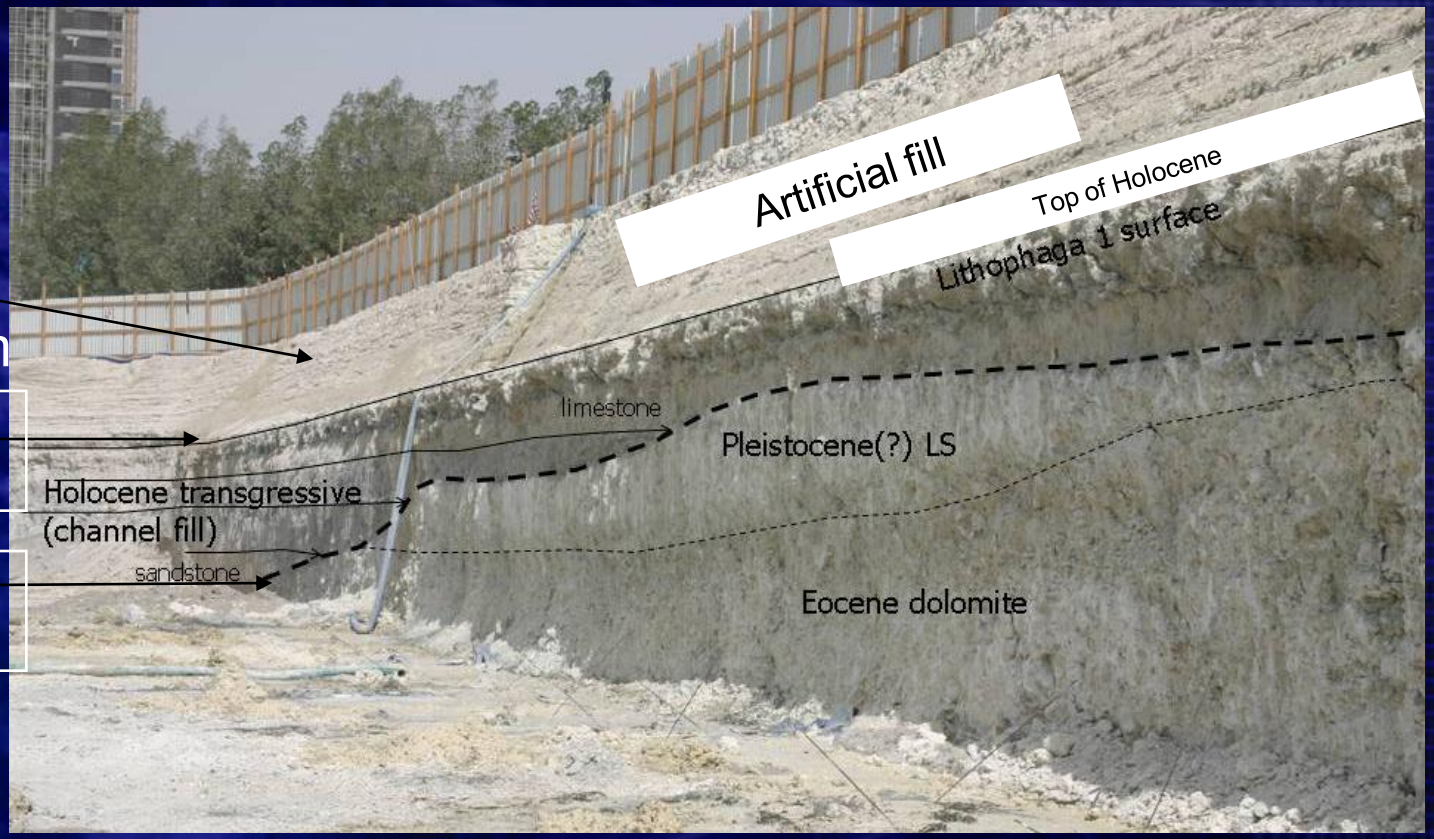
Unique Database

Geotechnical data (from buildings, ports, aiports etc) are being used for mapping holocene in 3-D

Doha Corniche Reclamation

Open Marine Coralgal sands 2300 bp

Transgressive Stromatolite 8000 bp



Evidence of Holocene High Stand

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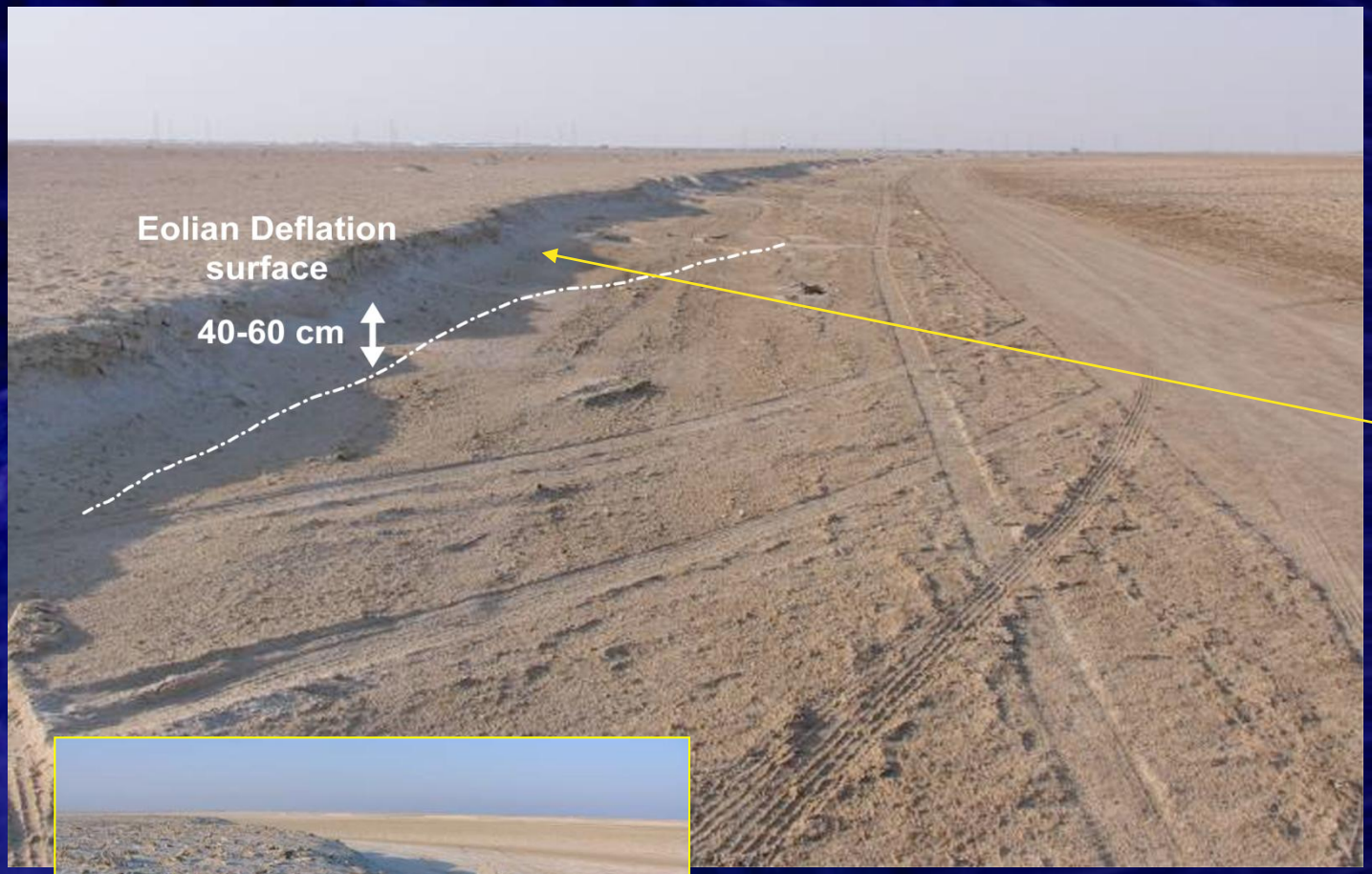
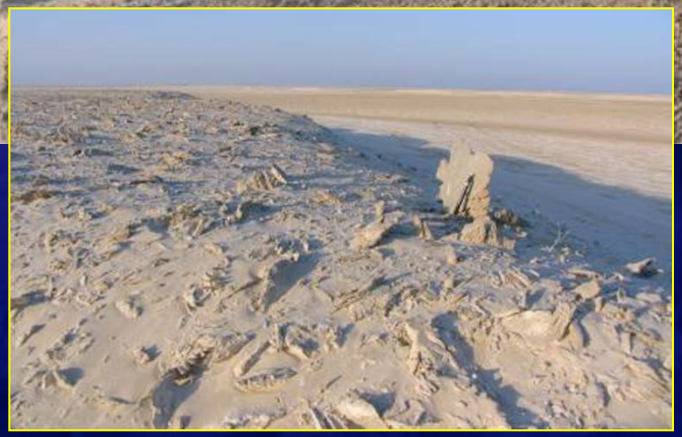
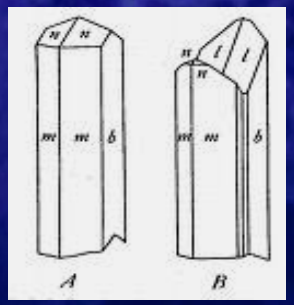


Marcia flammea 3990 bp



Decimeter plates of gypsum originally formed above water table at top of erosional remnant indicate ~ 50-100 cm erosion

Estimates of erosion



Decimeter plates of gypsum originally formed above water table at top of erosional remnant indicate ~ 50-100 cm erosion

Evidence for Sea level history

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QP Centre GIS (UPDA)

Regional Hardgrounds

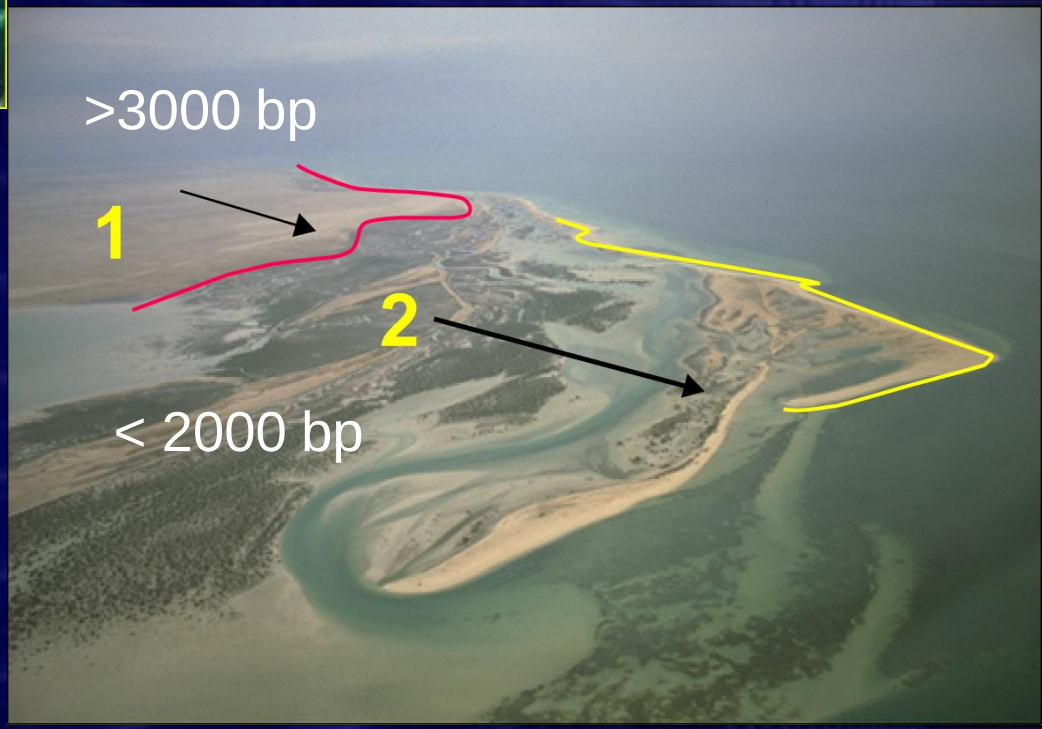
Lithophaga bored hardground

Borer: 4310 bp

1430 yr hiatus

Rock: 5650 bp

Facies Offsets of Coastal Spits



Al Thakhira view from south, showing facies offsets coincident with sea level changes

Features of the Windward Margin

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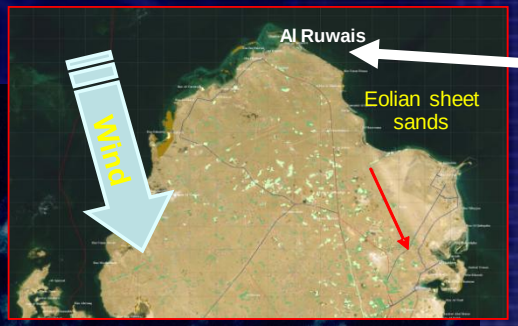

After Qatar GIS

Limit of platform

Subtidal

Ras Ra Kha

5 km

Intertidal

Limit of platform

Subtidal

Umm Taiys

Sabkha with inliers of Holo High Stand and Eocene

Shoreline

Sabkha with inliers

Broad intertidal, shifting sand platform with

Beachrock stabilized islands

Built on early Holocene fringing reef

Features of the Windward Margin

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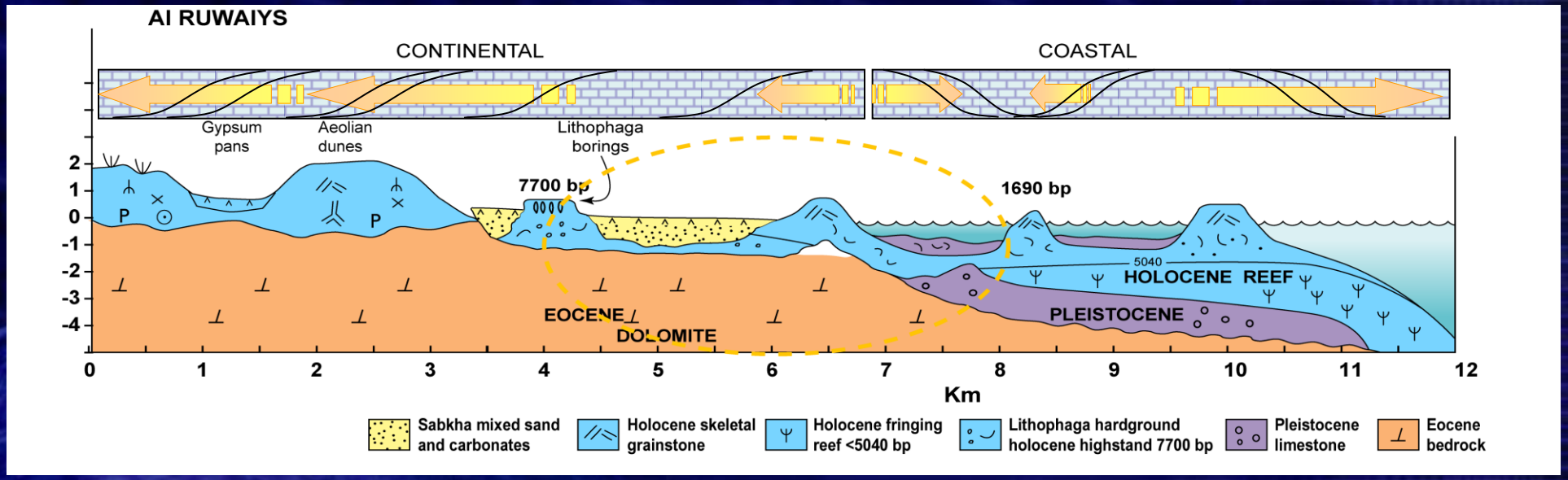
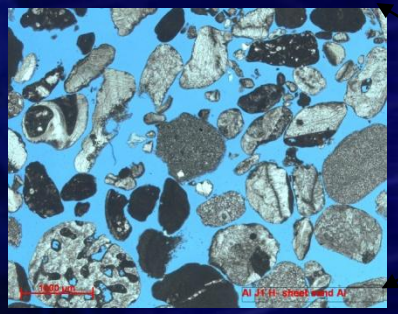
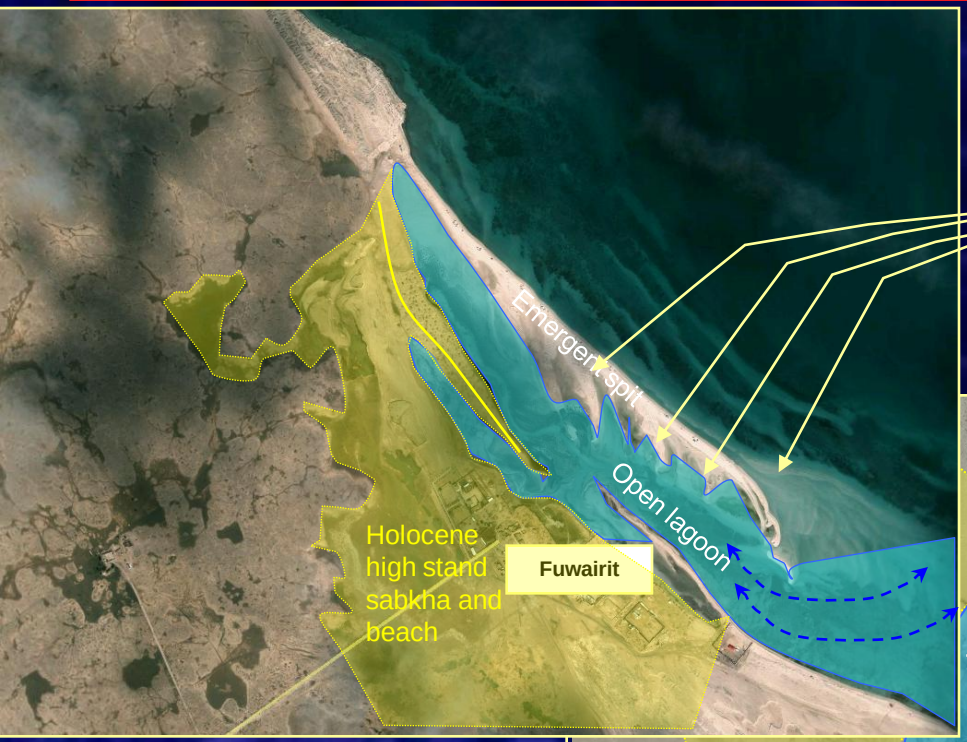


- Little or no sabkha
- Broad coarse, mollusc-red algal intertidal sands
- Broad eolian sheet sands
- Marked facies offsets
- Early Holocene fringing reef platform



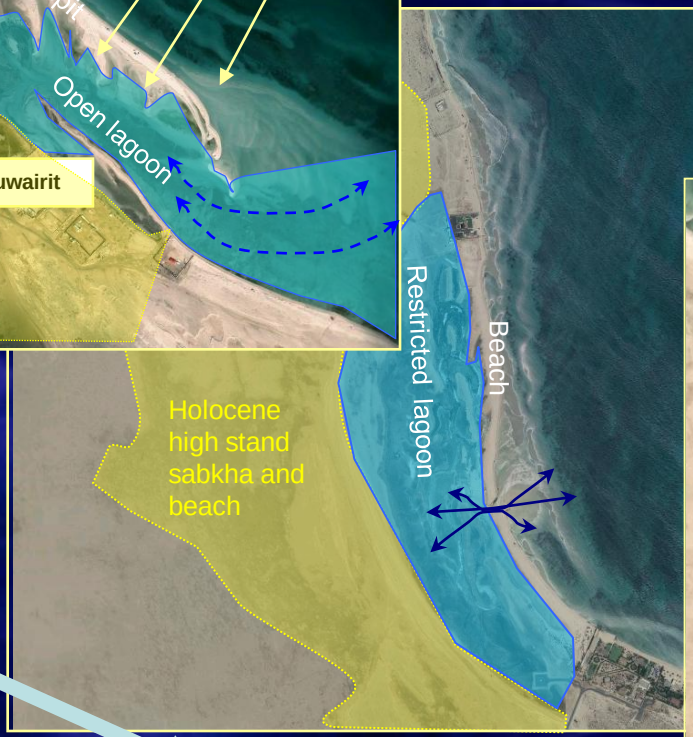
Back-barrier carbonate sheet sands
100 km^2

Spit evolution- oblique coast



Refraction tips on spit

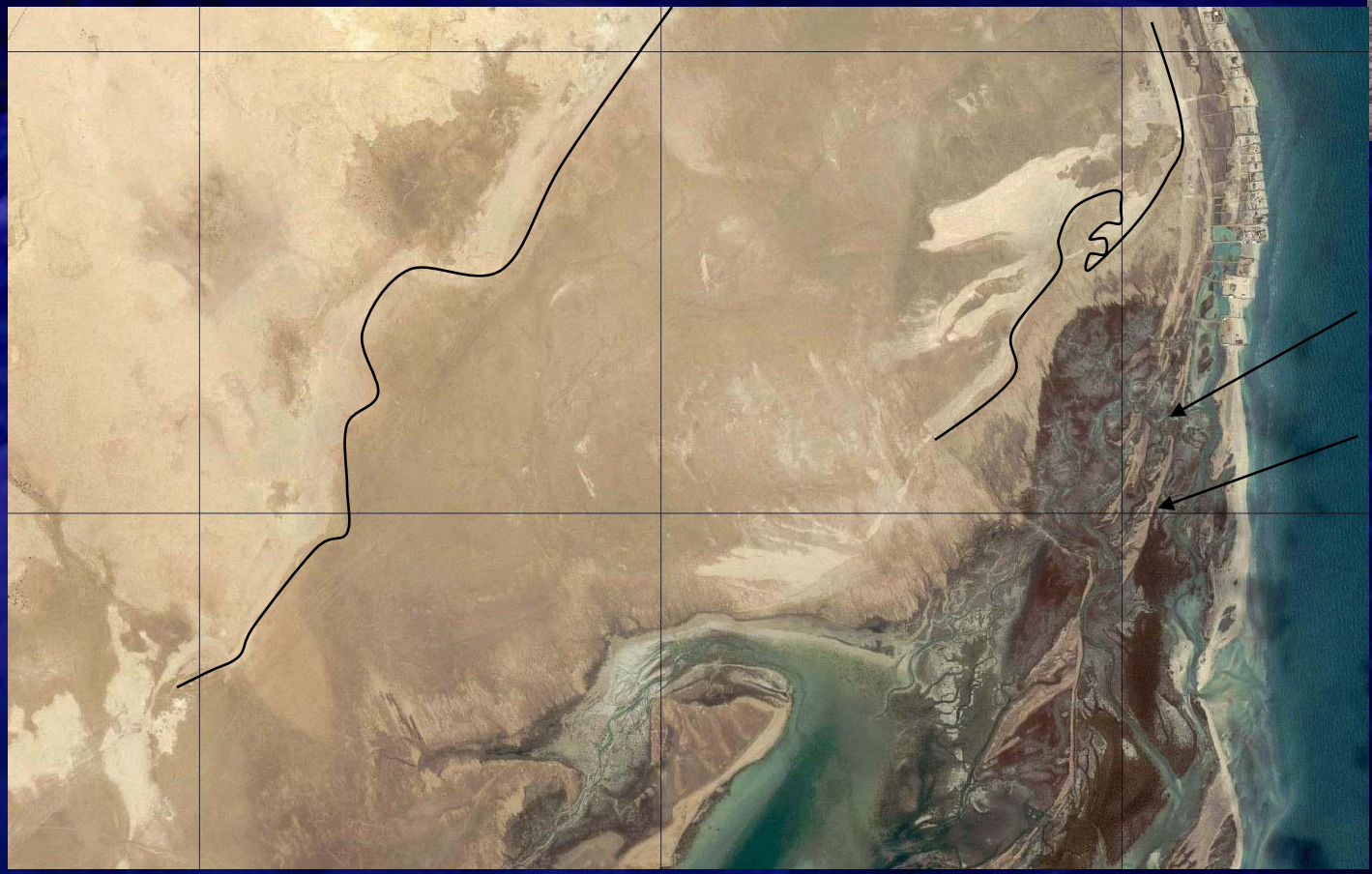
Open Lagoon



Restricted Lagoon

Closed Back Barrier

Back barrier erosion



Tidal drainage redistribution of beach ridges

Summary: coastal systems

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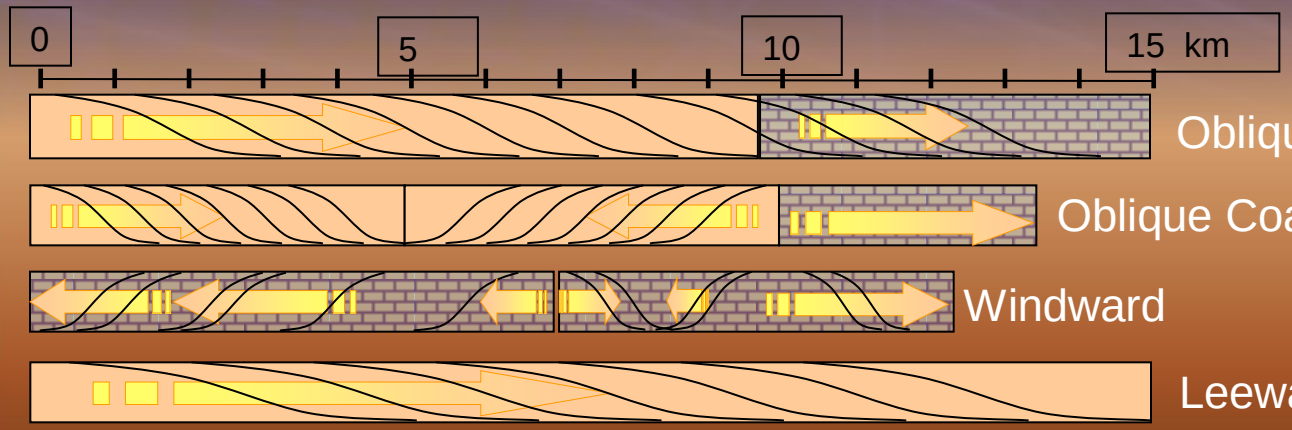
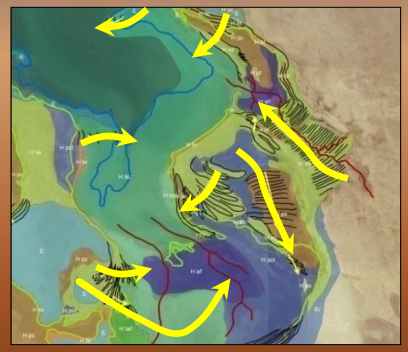


Protected Coast



Variable progradation patterns- in normal coastal sediments

Sea-Level History

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Sea-Level History

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