

Understanding Hydrocarbons in an Evaporite Context*

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Abstract

Some, but not all, types of evaporite deposits can be related to likely occurrences of substantial hydrocarbon accumulations hosted by carbonate or siliciclastic reservoirs in suprasalt, intersalt, or subsalt positions. These ties and associations can be used to build predictive region-scale exploration models, but only when age-appropriate, tectonic-appropriate, and hydrology-appropriate scaling parameters are chosen. Yet, for the past 50 years, inappropriate Quaternary-based sabkha-salina coastal-edge deposit models have been used to build interpretations of ancient marine evaporite systems. Many such Quaternary-biased comparisons do not recognise their inherently time-limited and eustatic-limited nature. Nor can they account for scaling and tectonic errors created when using Quaternary analogs in an attempt to create a predictive understanding of hydrocarbon accumulations within regional ancient evaporite paradigms. Predictive understanding is only achieved when the comparison paradigm is built on an appreciation of the greater depositional breadth and diversity inherent to ancient evaporite systems.

Ancient mega-evaporite deposits (platform and/or basinwide deposits) require conditions epeiric seaways (greenhouse climate) and/or continent-continent proximity at the plate-tectonic scale. Basinwide evaporite deposition is facilitated by continent-continent proximity at tectonic plate margins (Late stage E through stage B in the Wilson cycle). This creates an isostatic response where, in an appropriate arid climate belt, large portions of the collision suture belt or the incipient opening rift can be subsealevel, hydrographically isolated (a marine evaporite drawdown basin) and yet fed seawater by a combination of ongoing seepage and occasional marine overflow (Aptian Salt Basins of southern Atlantic vs Miocene Zagros collision belt). Basinwide evaporite deposits can be classified by tectonic setting into: convergent (collision basin), divergent (rift basin; prerift, synrift, and postrift), and intracratonic settings. Ancient platform evaporites can be a subset of basinwide deposits, especially in intracratonic sag basins, or part of a widespread epeiric marine platform fill. The latter tend to be mega-sulphates and are associated with hydrographically isolated

marine fed saltern and evaporitic mudflat systems in a greenhouse climatic setting (e.g. Ghawar, Saudi Arabia vs. San Andres, West Texas).

Selected References

Gomes, P.O., B. Kilsdonk, J. Minken, T. Grow, and R. Barragan, 2009, The Outer High of the Santos Basin, Southern Sao Paulo Plateau, Brazil; Pre-Salt Exploration Outbreak, Paleogeographic Setting, and Evolution of the Syn-Rift Structures: Search and Discovery Article #10193. Web accessed 24 January 2012.

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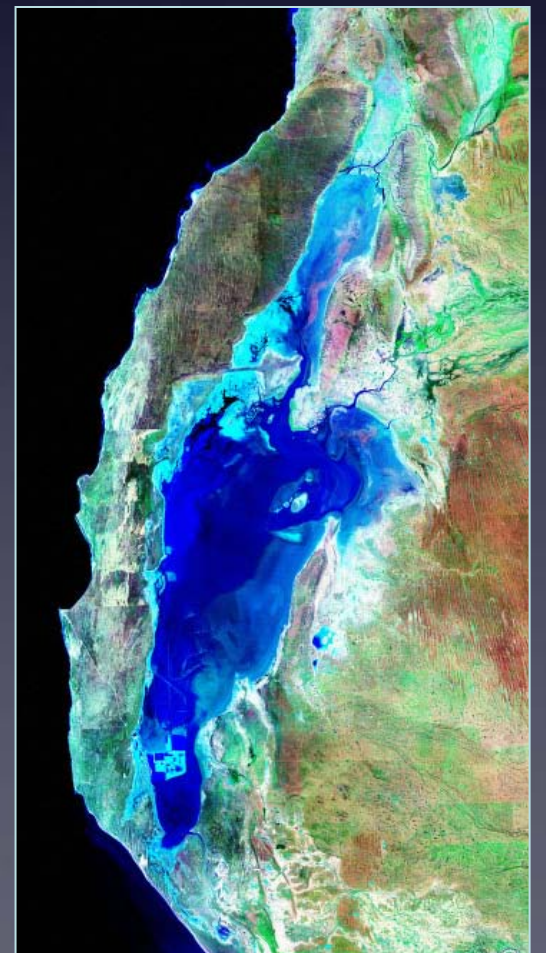
Evaporites

“One size fits all”

- Sabkhas and salinas
- Modern = Ancient



Abu Dhabi



Macleod

Is the Present is the Key to the Past?

The “now of then” or the “then
of now”

Archean nahcolite versus
Phanerozoic halite

Sylvite versus carnallite
oceans?



Strictly Quaternary

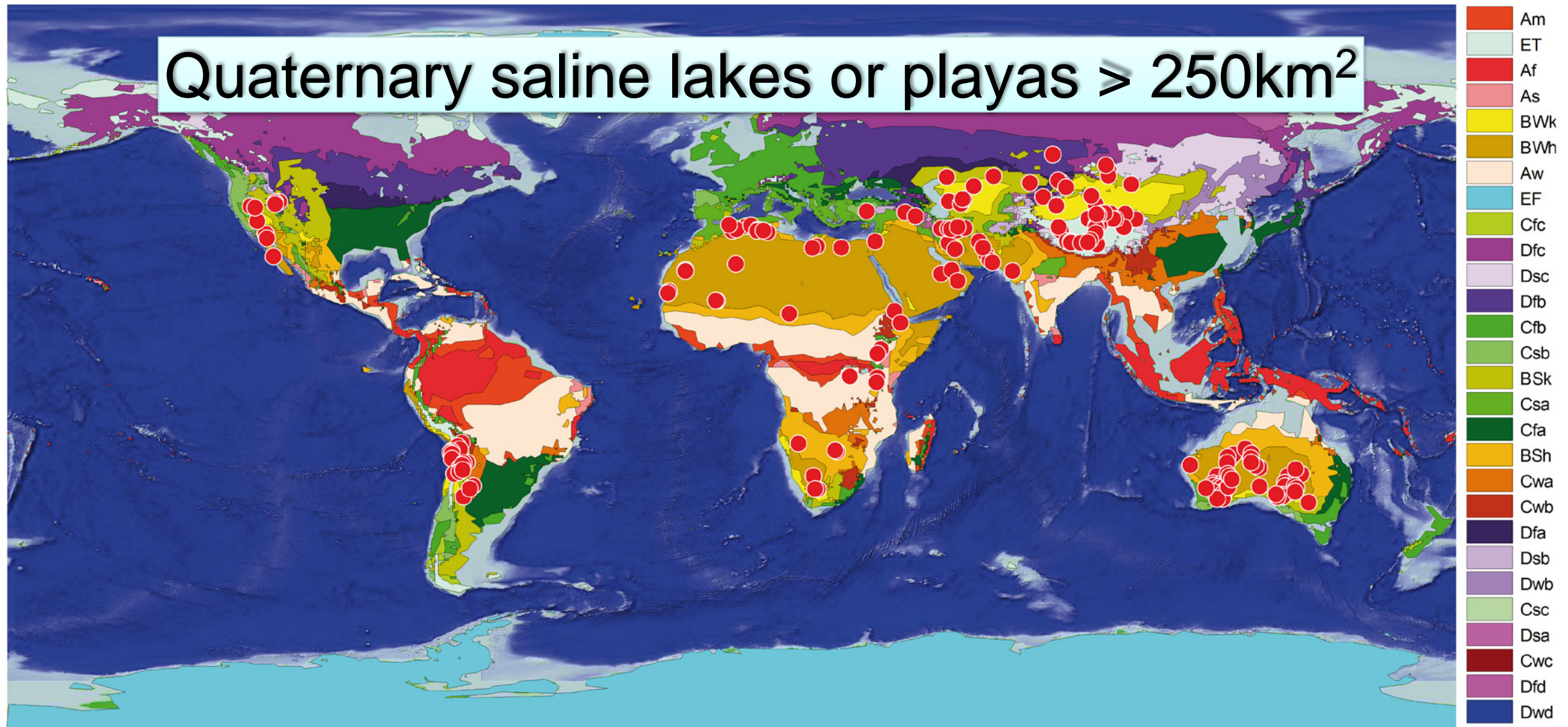
Where are the largest and thickest natural halites forming today?

Quaternary Koeppen climates

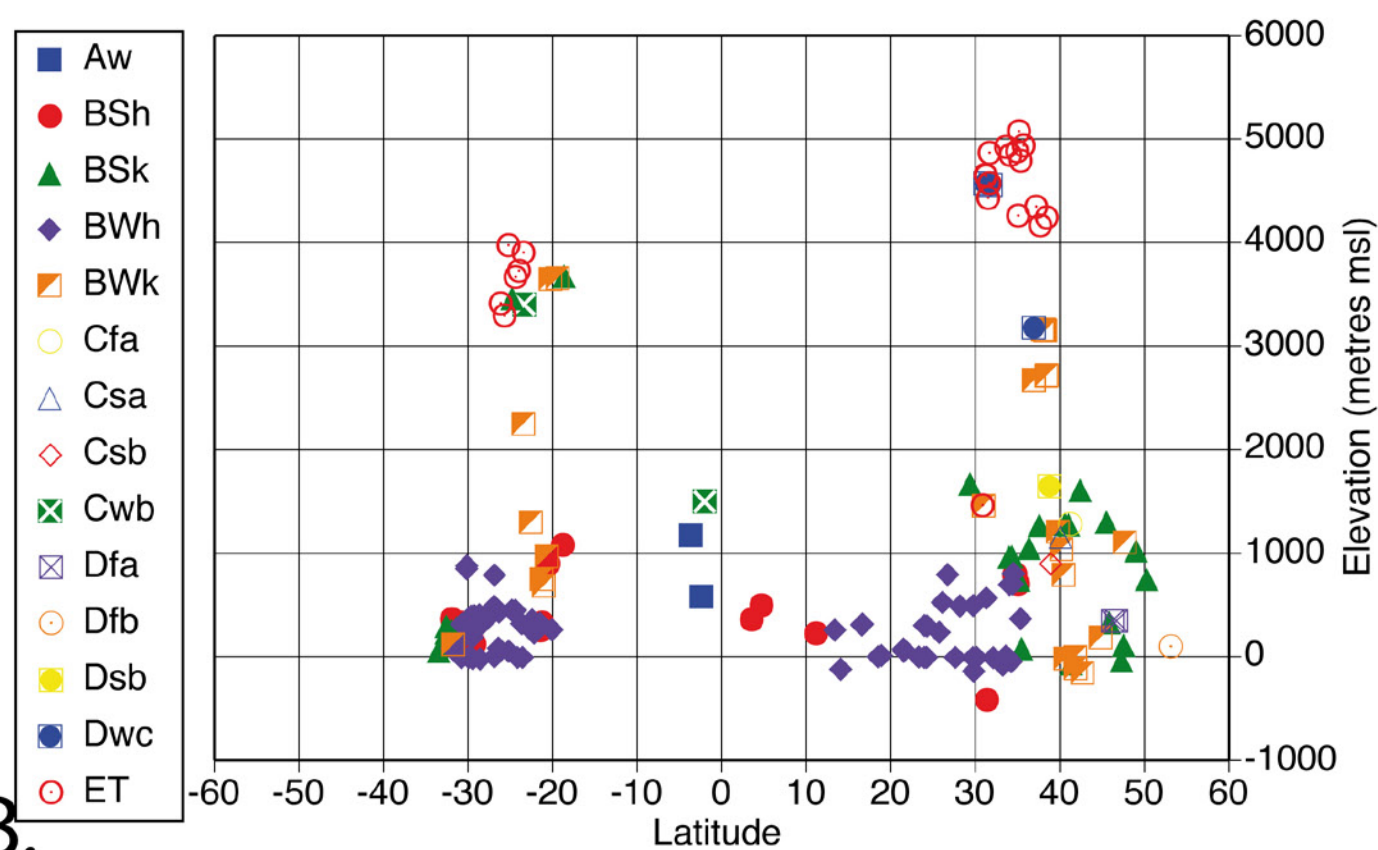
- B: arid
- W: desert
- S: steppe
- h: hot arid
- k: cold arid
- ET: polar tundra
- A: tropical



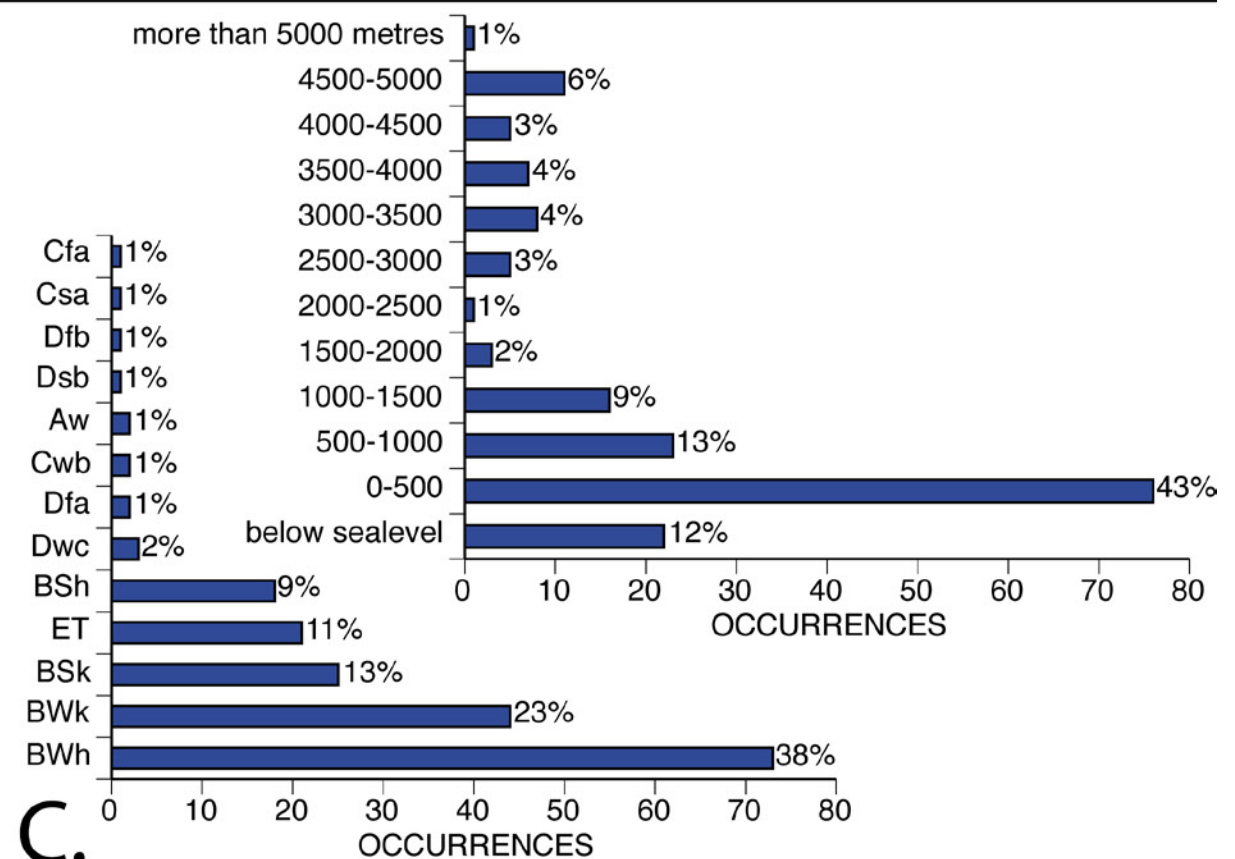
Quaternary saline lakes or playas $\geq 250\text{km}^2$



A.

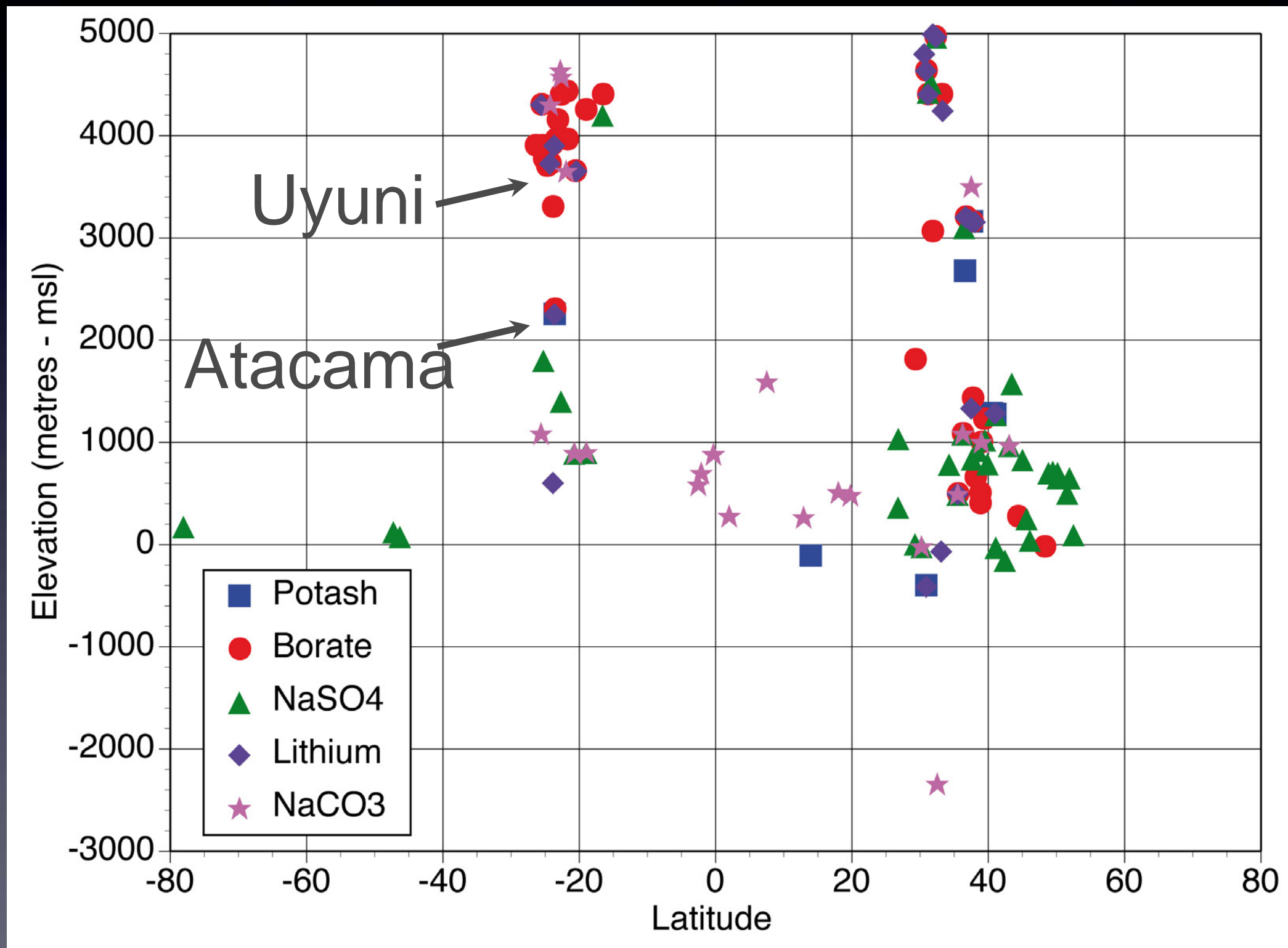


B.



C.

Quaternary non-marine



Larger Quaternary halites are
high altitude & diapir-fed.

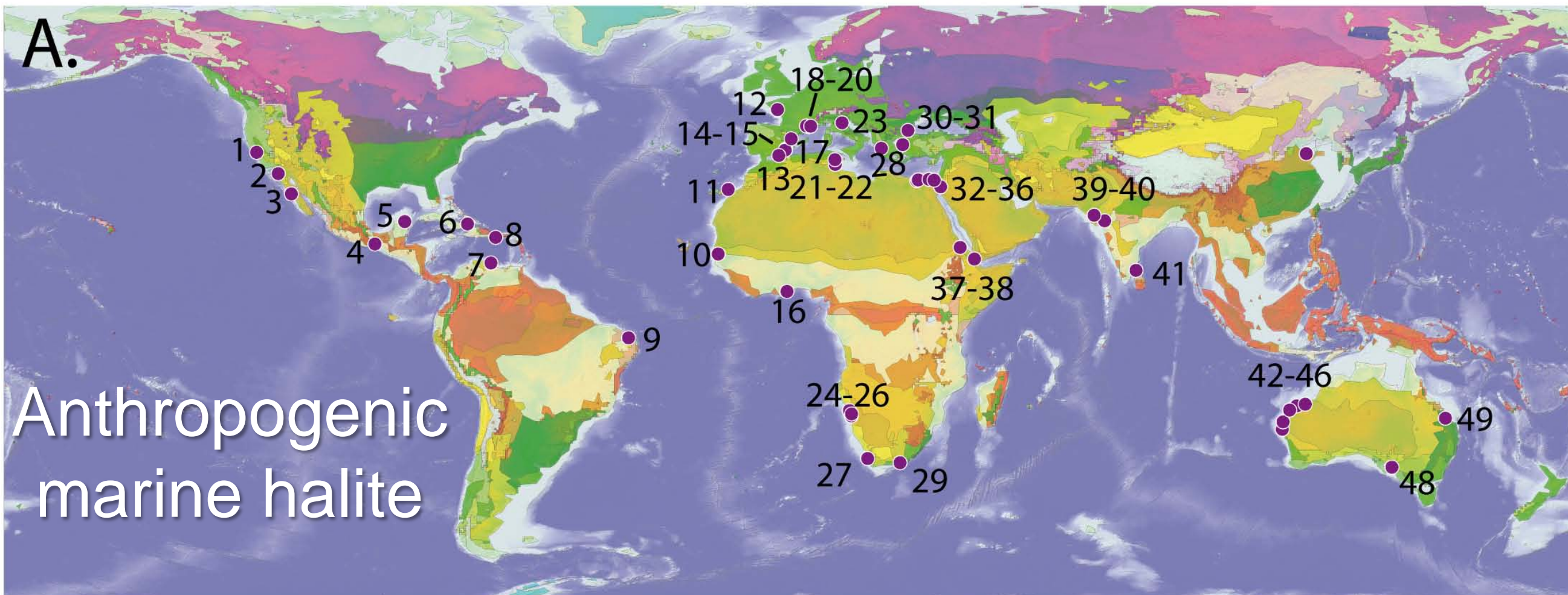


Salar di Uyuni
($\approx 10,000 \text{ km}^2$)

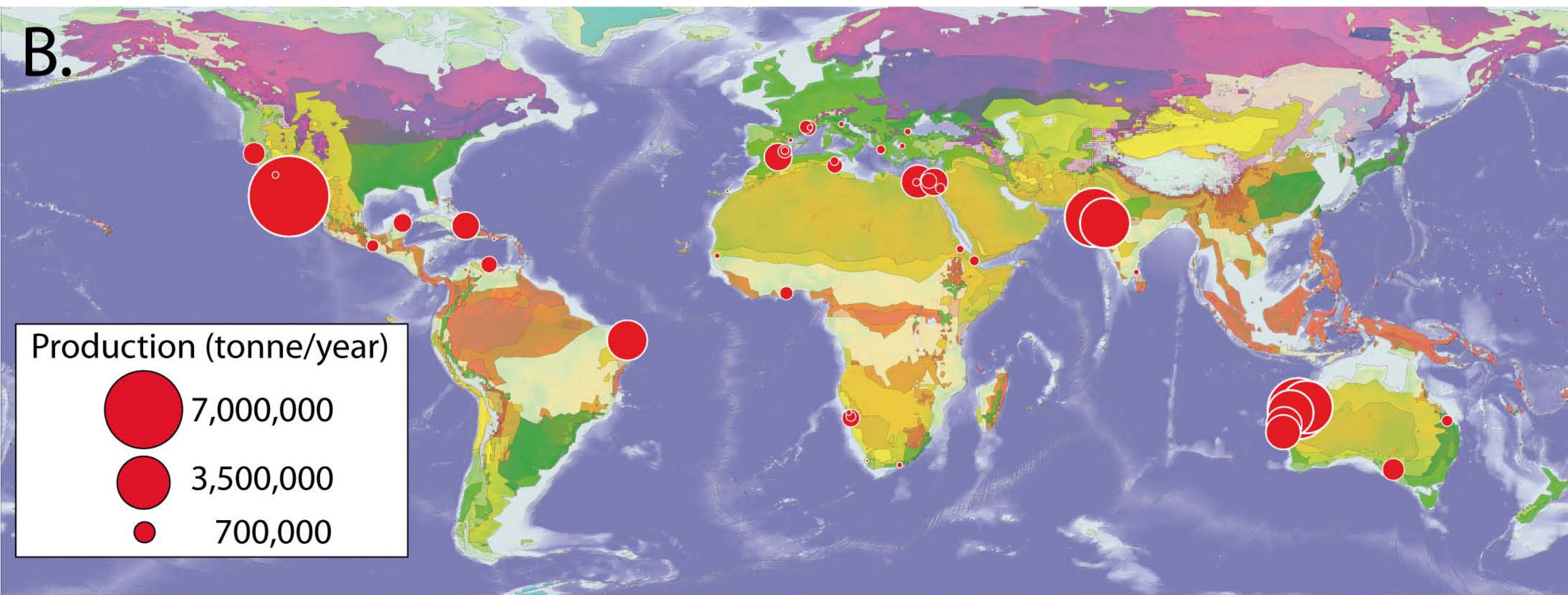
Strictly Quaternary

Where are the greatest volumes of marine-fed
halite forming today?

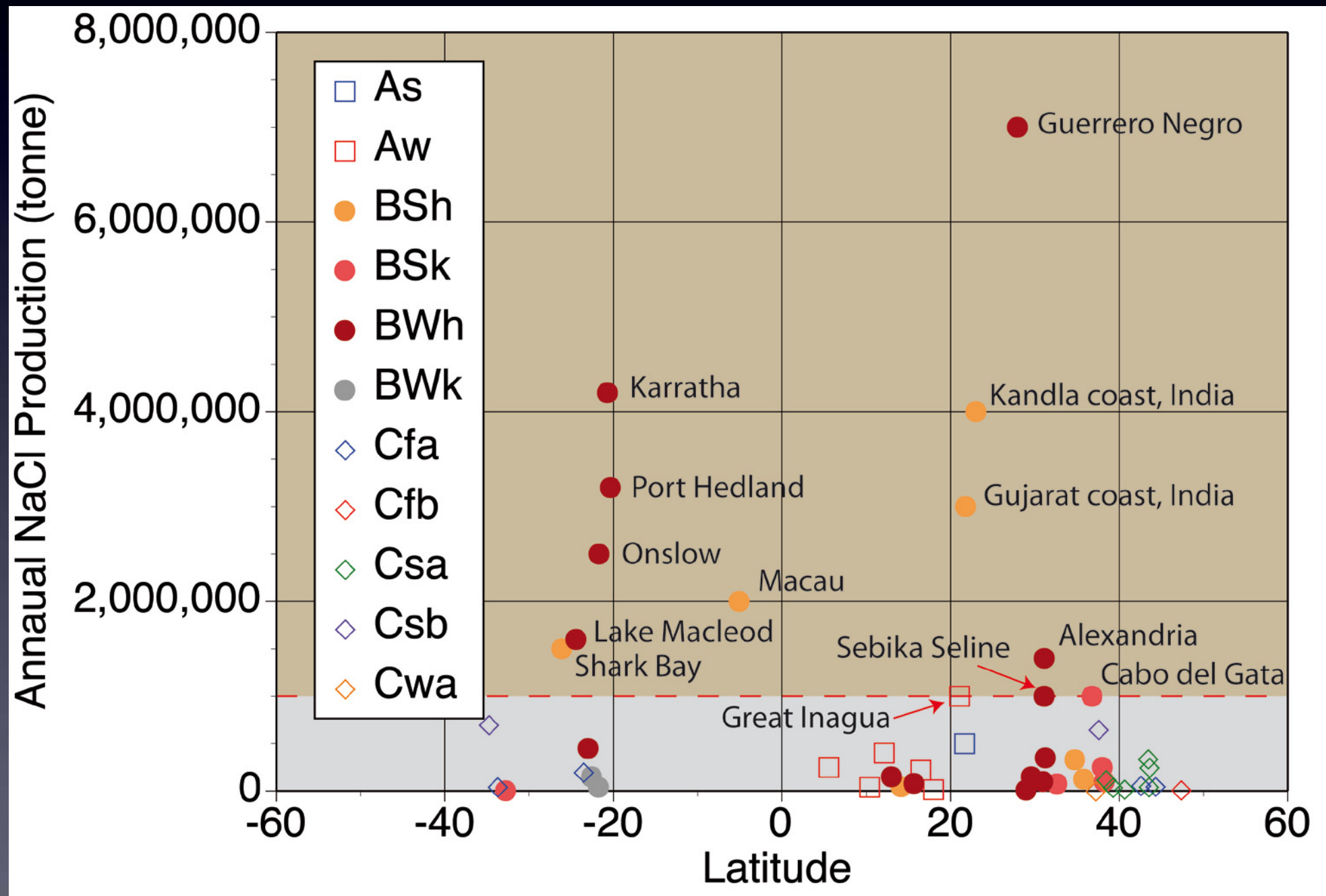
A.



B.

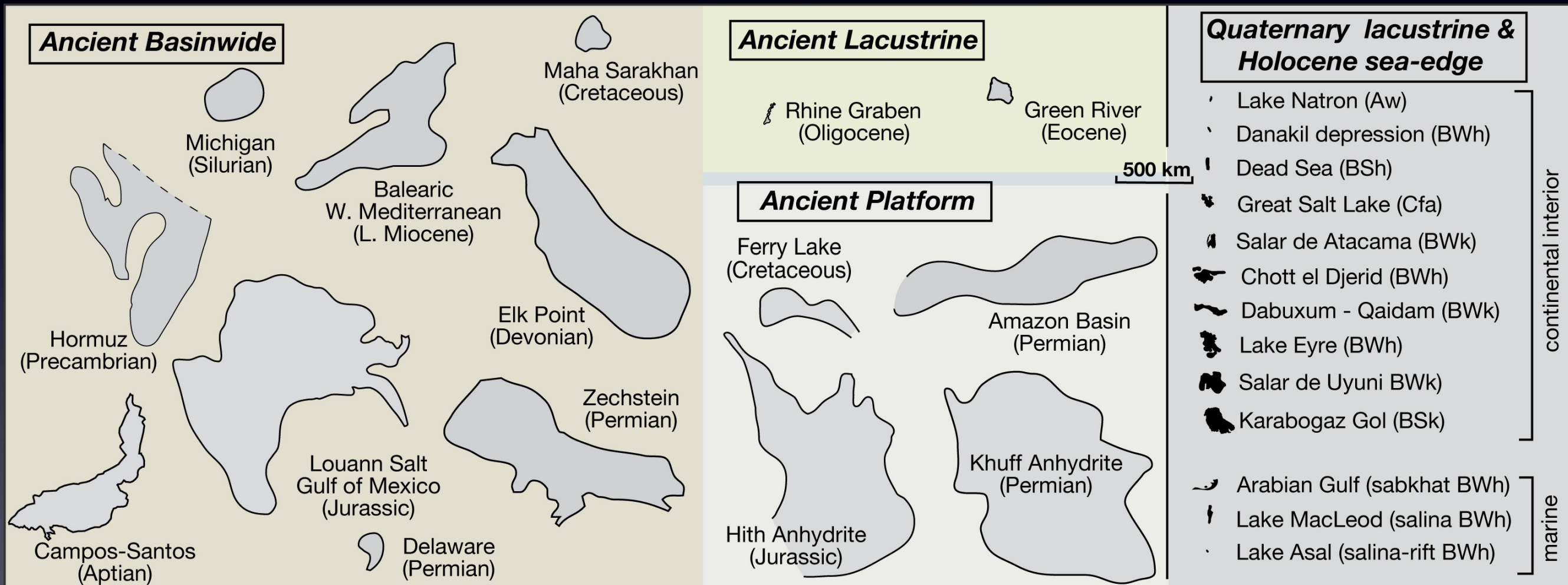


Holocene marine halite is anthropogenic (BWh & BSh)



Basin scales

“The then of now”



Quaternary evaporite depositional settings offer same-scale analogs only for ancient lacustrine reservoir systems

Quaternary depositional spectrum

Does not capture ancient marine evaporite
diversity

Marine platform evaporites
&
Basinwide evaporites

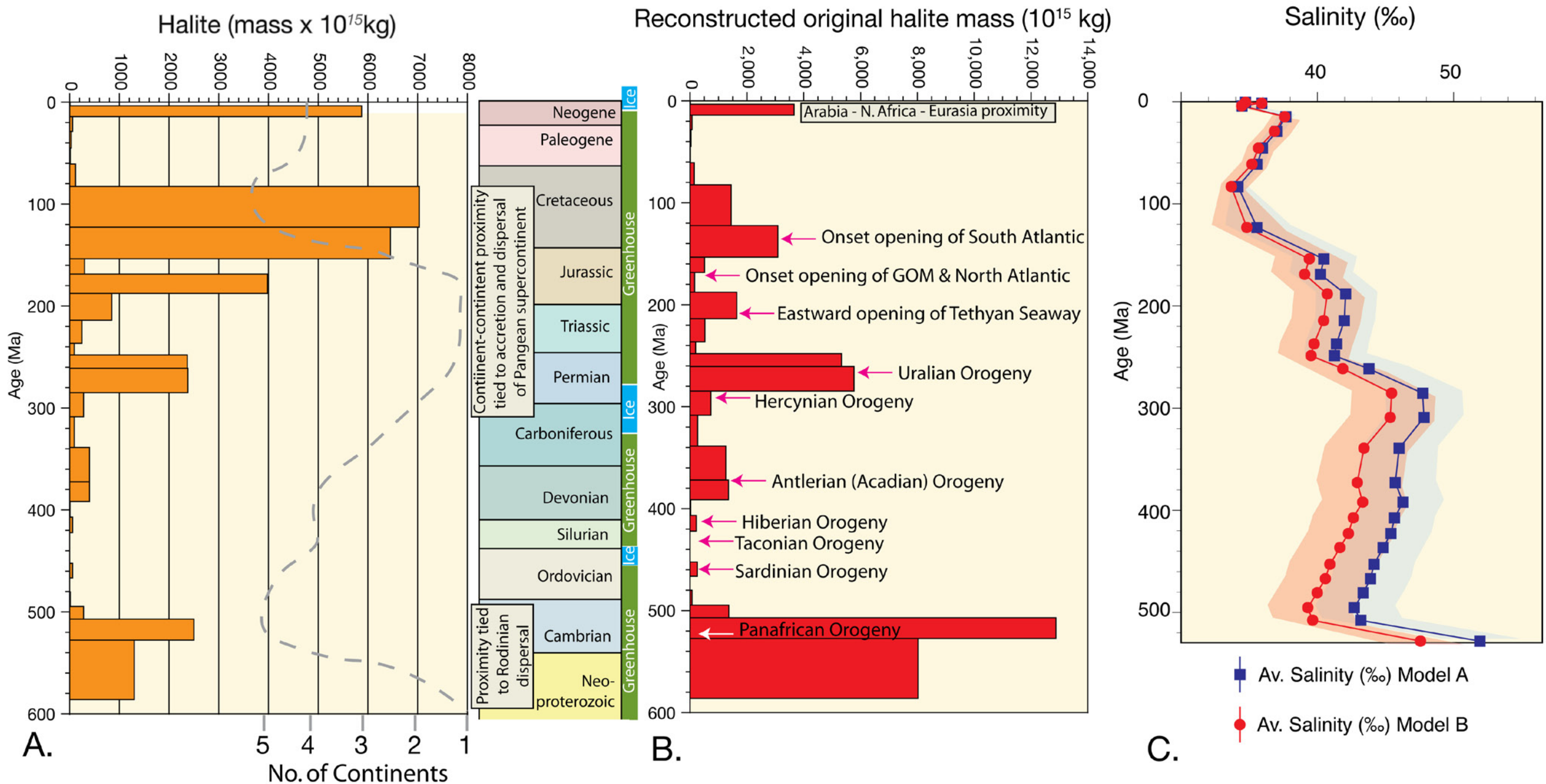
What about ancient evaporite deposits?

No modern examples of platform evaporites or basinwide evaporites.

We live in an icehouse world, whereas ancient epeiric platform evaporites are favoured by greenhouse eustacy.

The continent-continent plate proximities and drawdown hydrographies needed to deposit basinwides are not currently present on the world's surface. They were in the Miocene and will be again.

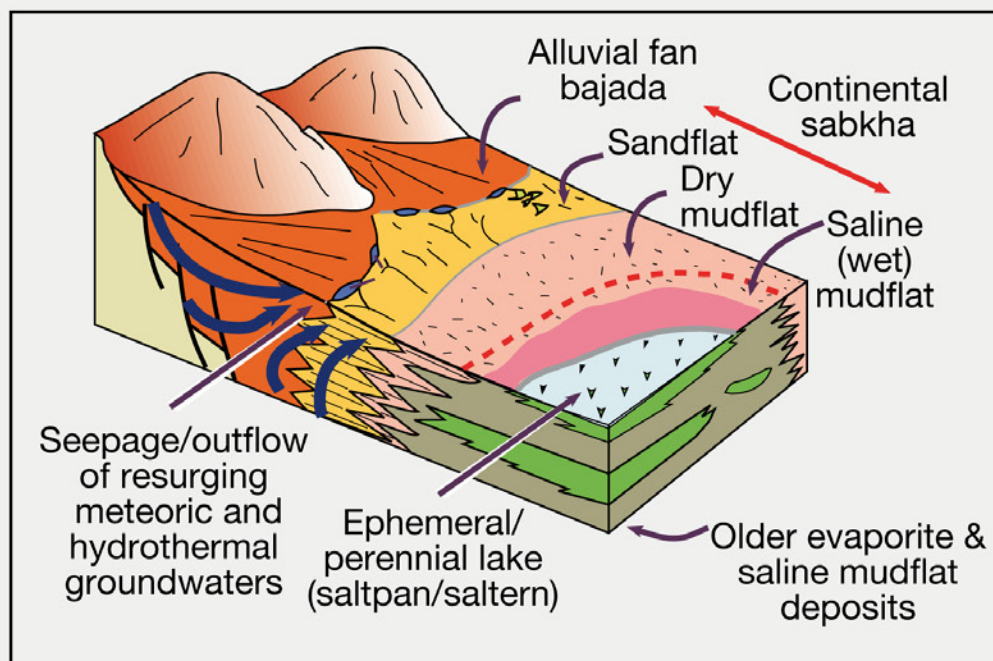
Marine evaporite volumes across deep time



Depositional Styles

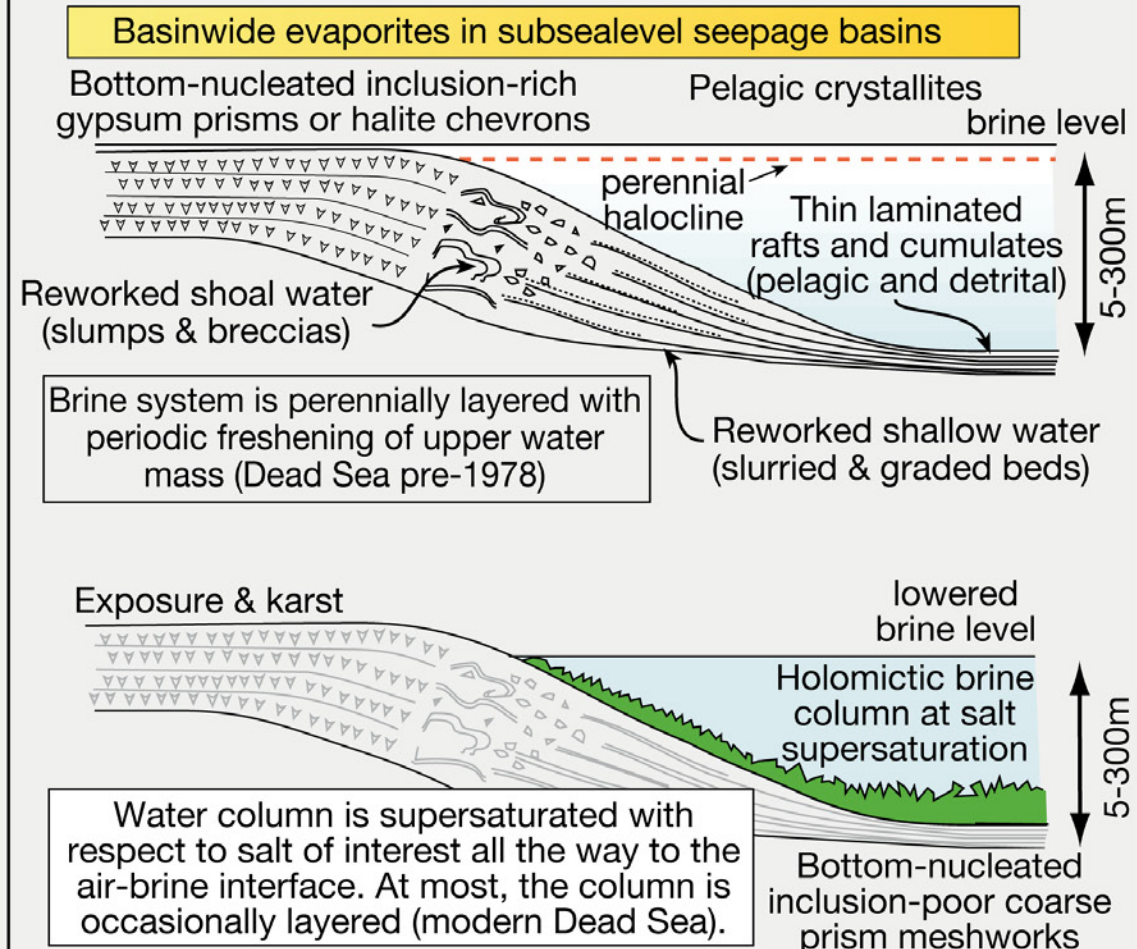
“Now and then”

Depositional spectrum of ancient evaporite systems across deep time



CONTINENTAL (NONMARINE-BRINE FEED)
sabkhas, saline pans, salt lakes

Quaternary lacustrine analogues in texture, scale and hydrology (borates, salt cake, soda ash with halite and variable CaSO_4)



MARINE FEED
platform

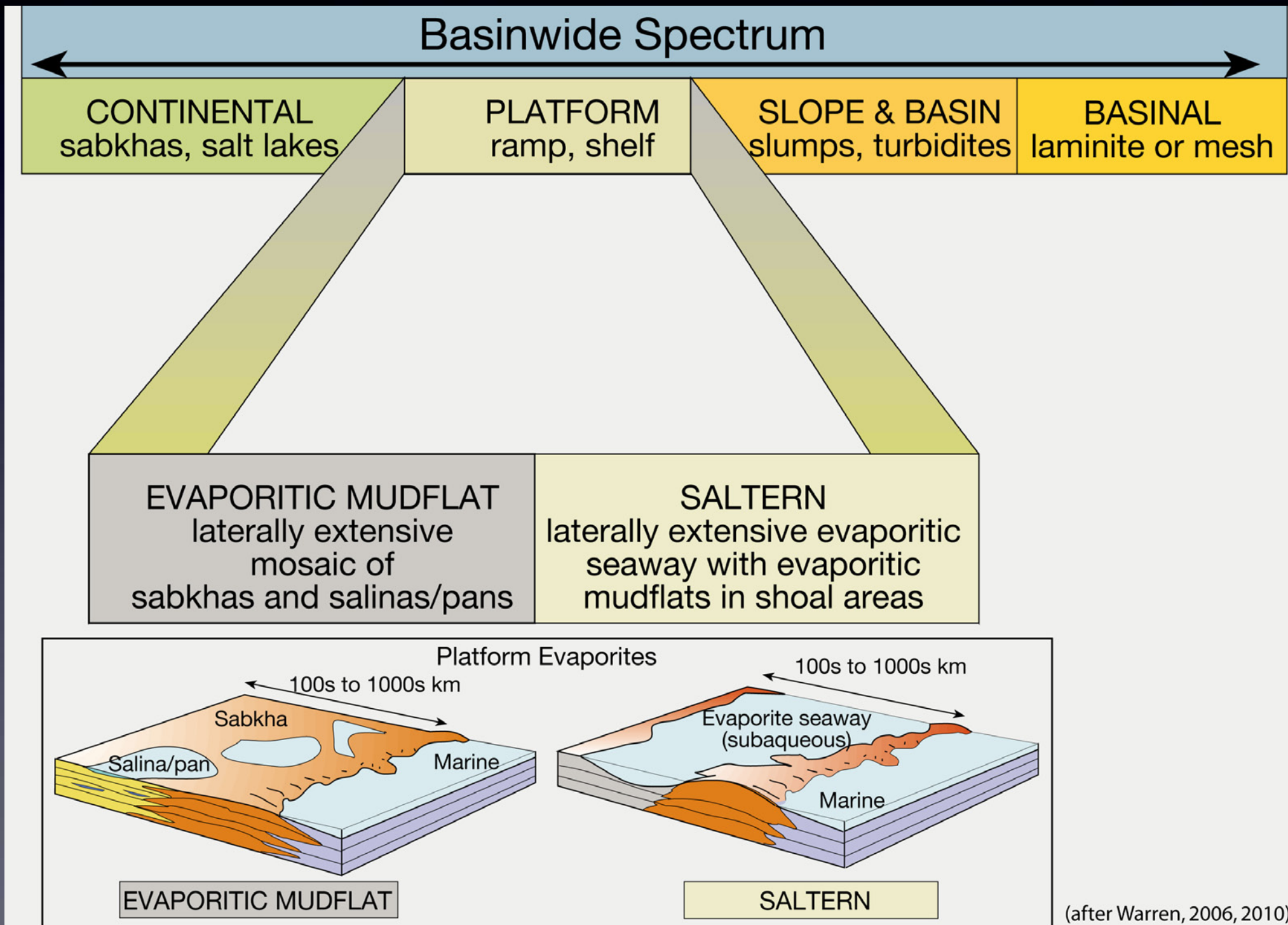
MARINE-BRINE FEED
slope basin

Partial textural analogues in modern lakes and salinas but no marine Quaternary analogues in scale or tectonic setting (extensive ancient potash, halite anhydrite basins)

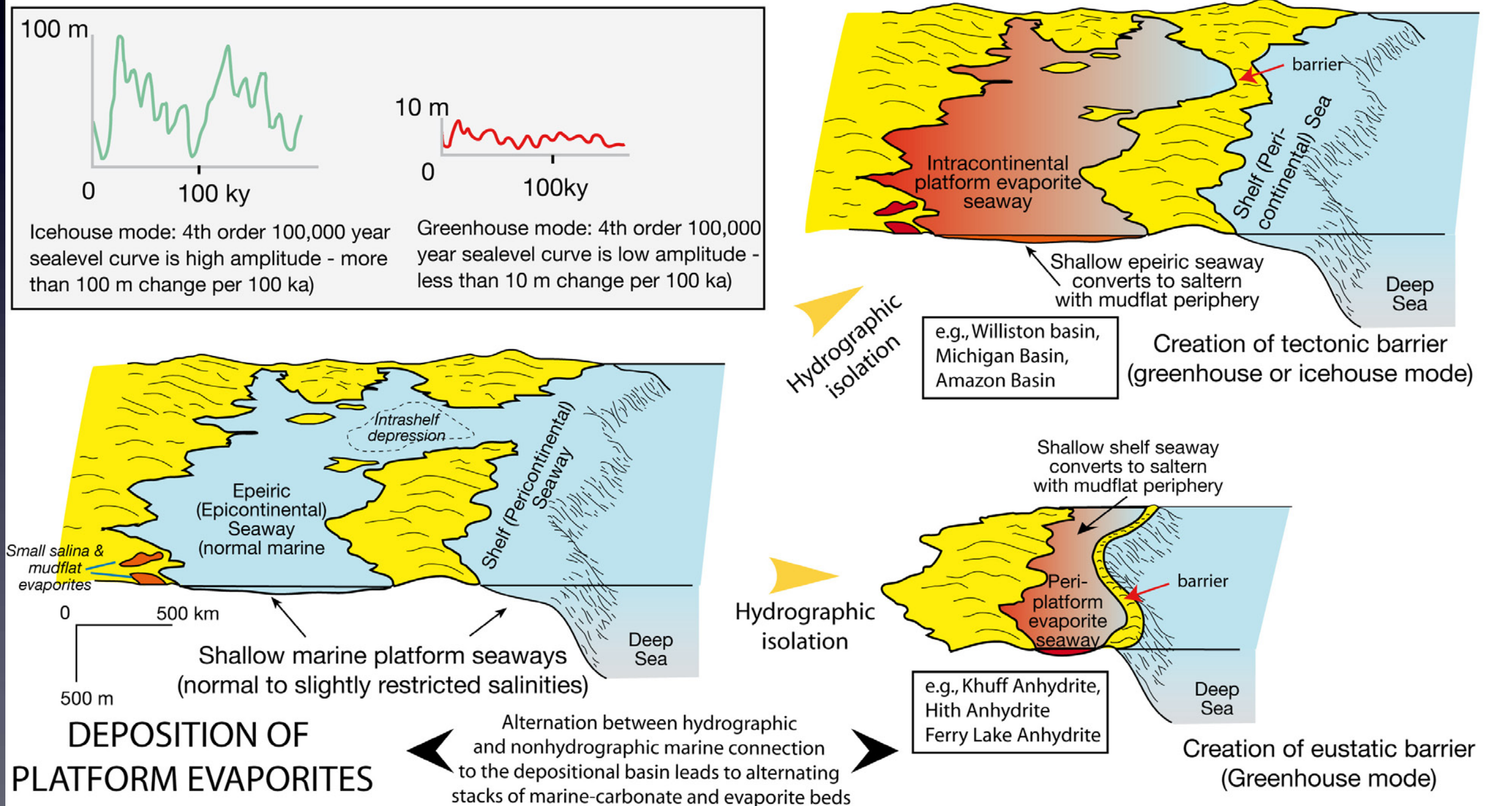
Basinwide Spectrum

Depositional styles

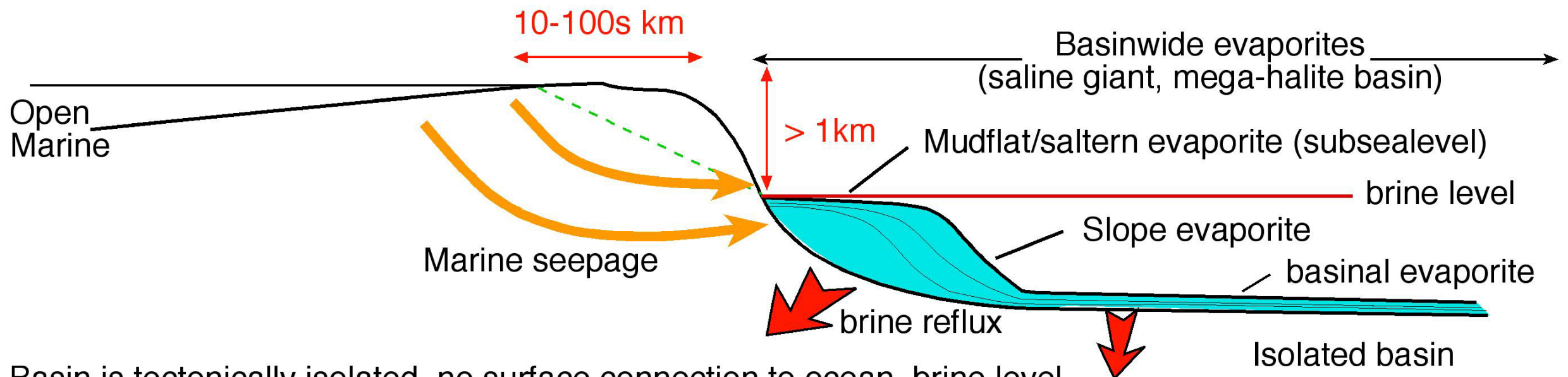
“Now and then”



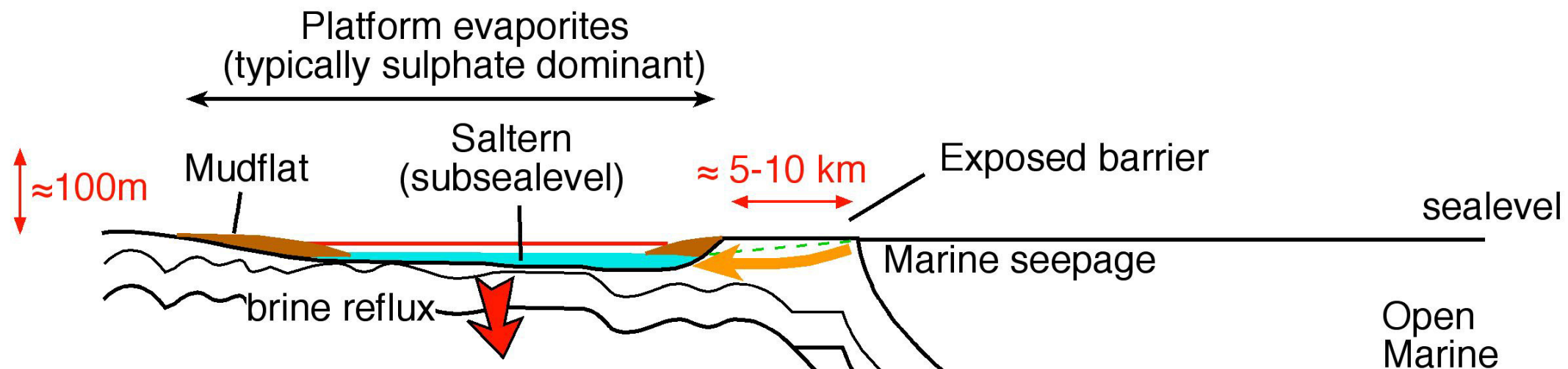
Platform salts, intracratonic and/or megasulphate



Platform vs basinwide

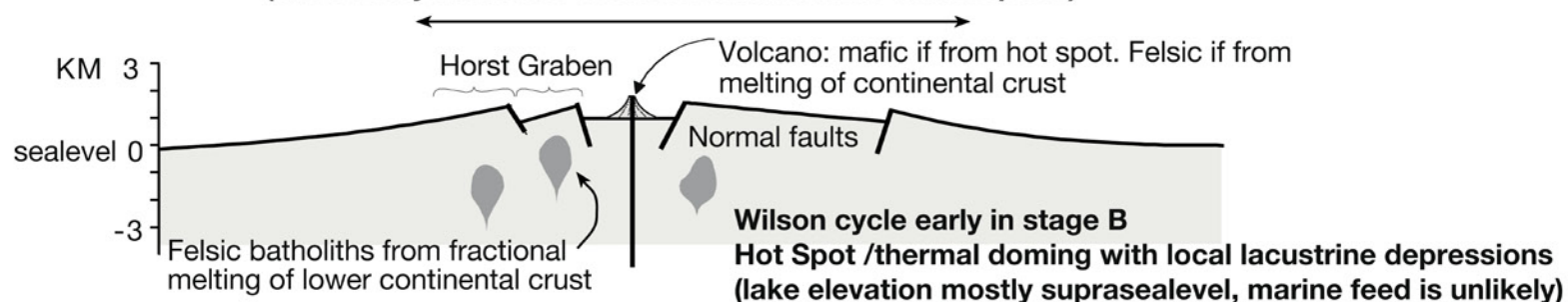


Basin is tectonically isolated, no surface connection to ocean, brine level in basin is drawn down to where seepage inflow equals outflow. Drawdown in basin centre may be $\approx 1000\text{m}$ or more - a noneustatic response (basin subject to later halokinesis)

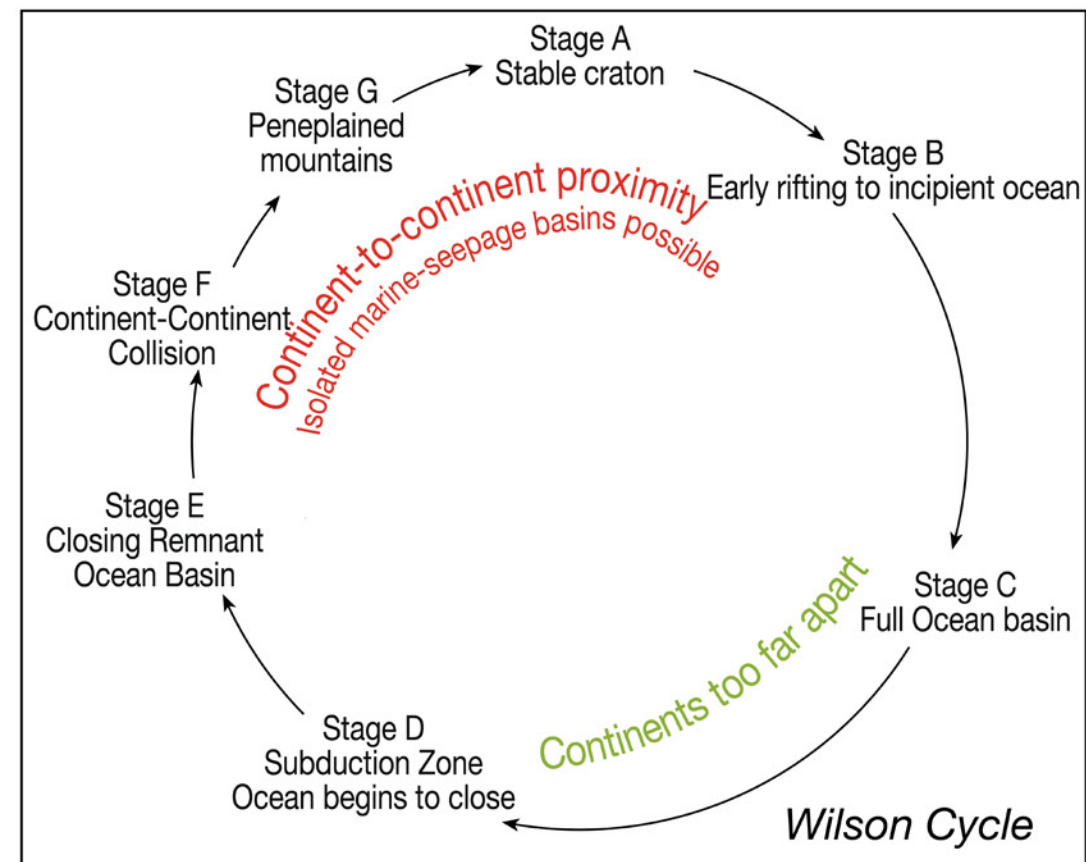
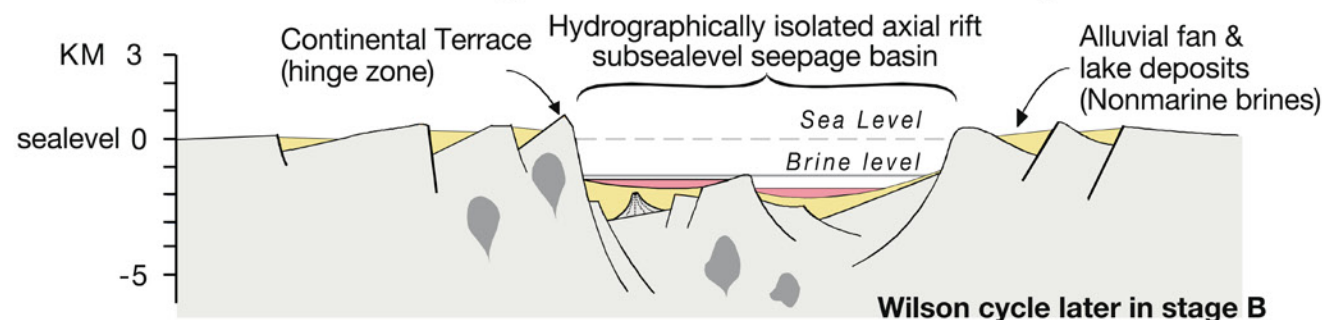


Slight relative fall in sealevel isolates back barrier (e.g. 4th-order fall superimposed on 3rd-order rise) - a eustatic response with saltern evaporites interlayered with marine platform carbonates (non-halokinetic)

**Continental endoheic lacustrine, mostly suprased level
evaporites (Type 1, 2 & 3 nonmarine brines)
(Quaternary dominant with ancient lacustrine counterparts)**

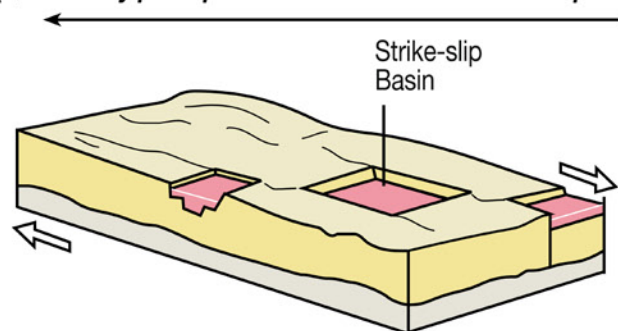


**Marine-margin subsealevel endoheic rifts,
aulocogen and intracratonic sags
(dominantly marine brine feed)
(No same-scale Quaternary counterparts)**



**Basinwide evaporite settings
in a plate tectonic context**

**Continental lacustrine evaporites
(Quaternary pull-apart basins with ancient counterparts)**

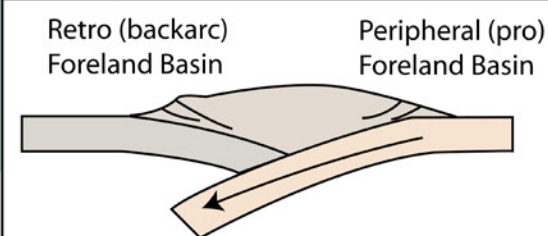
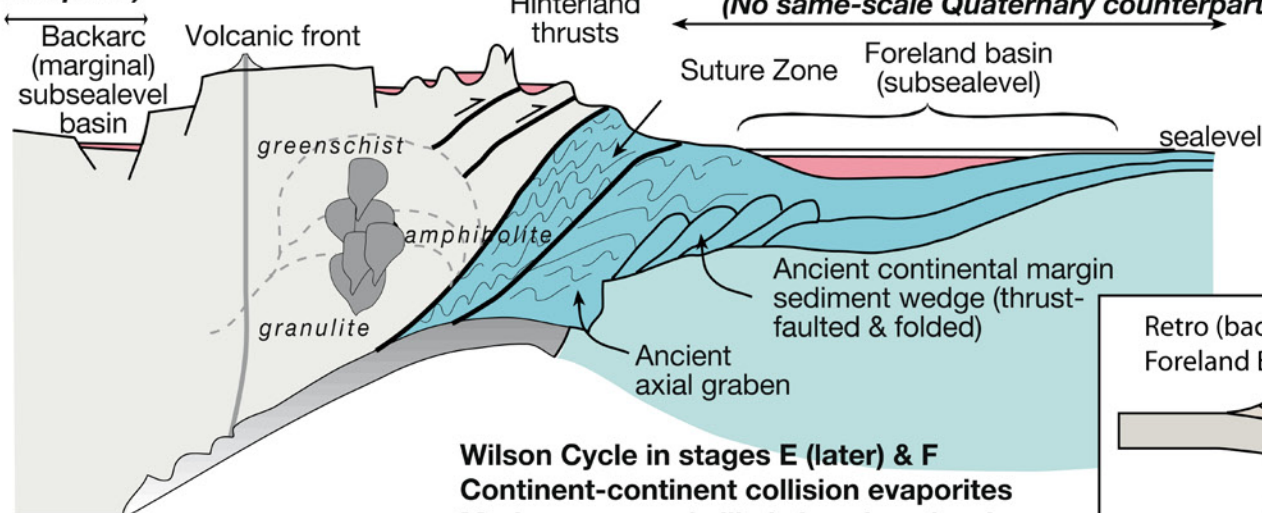


Transtensional or transpressional evaporites typically form in Wilson stage F (marine seepage possible, but rare)

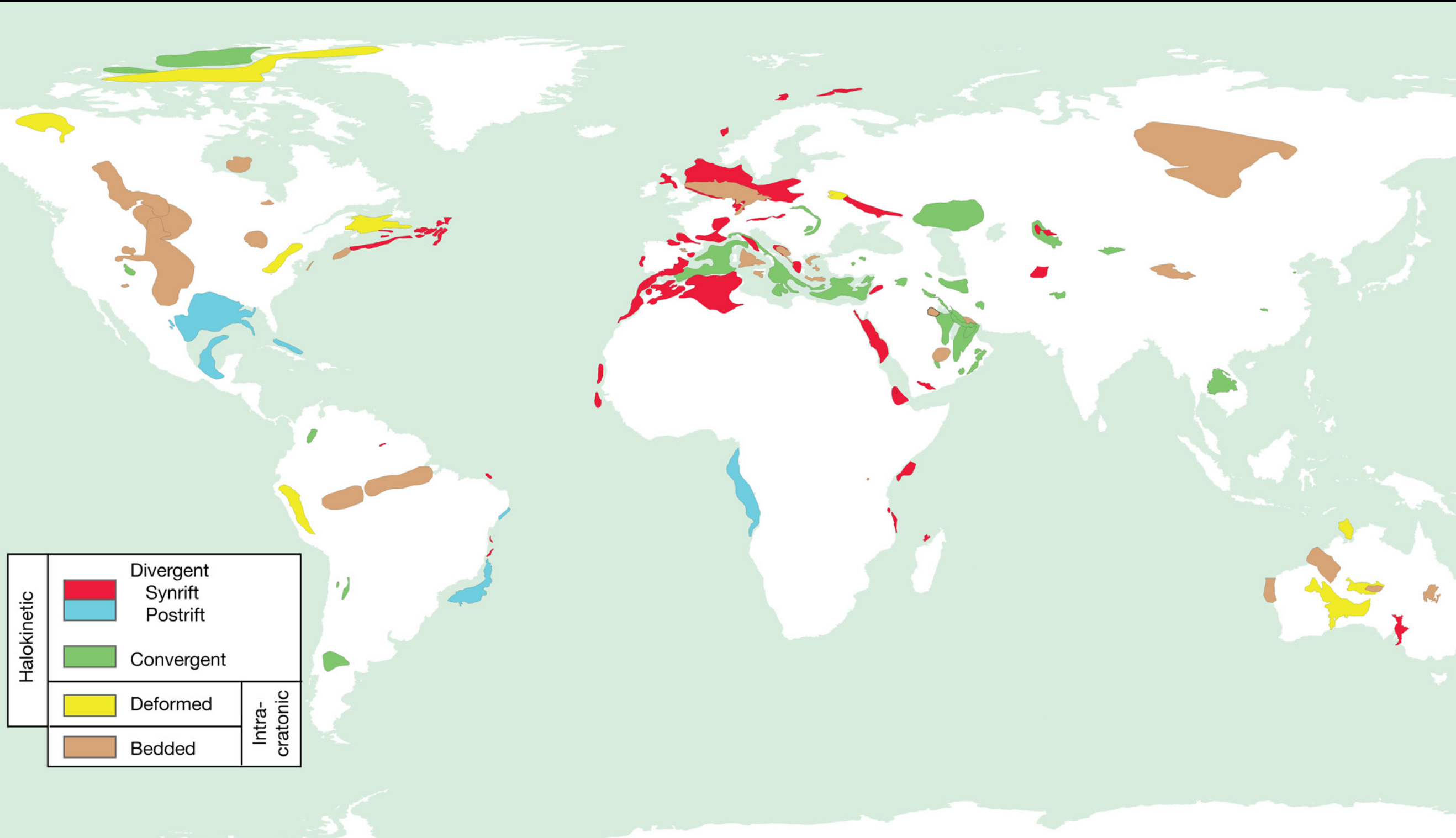
**Collision belt marine evaporites
(No same-scale Quaternary counterparts)**

**Continental high-altitude lacustrine evaporites
Quaternary with same-scale ancient counterparts (nonmarine brines)**

**Collision belt subsealevel marine evaporites
(No same-scale Quaternary counterparts)**



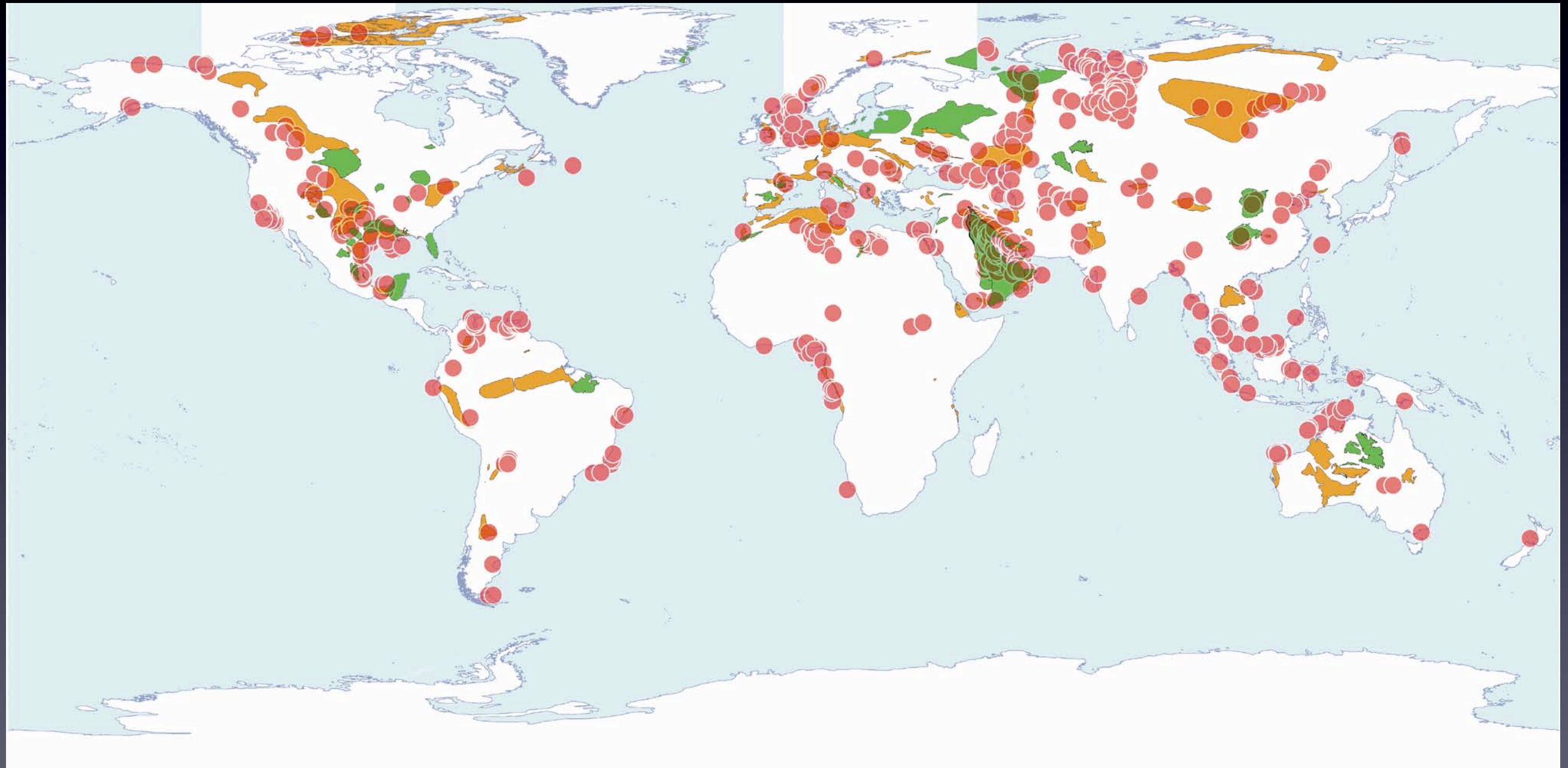
Basinwide Tectonic Styles



So What?

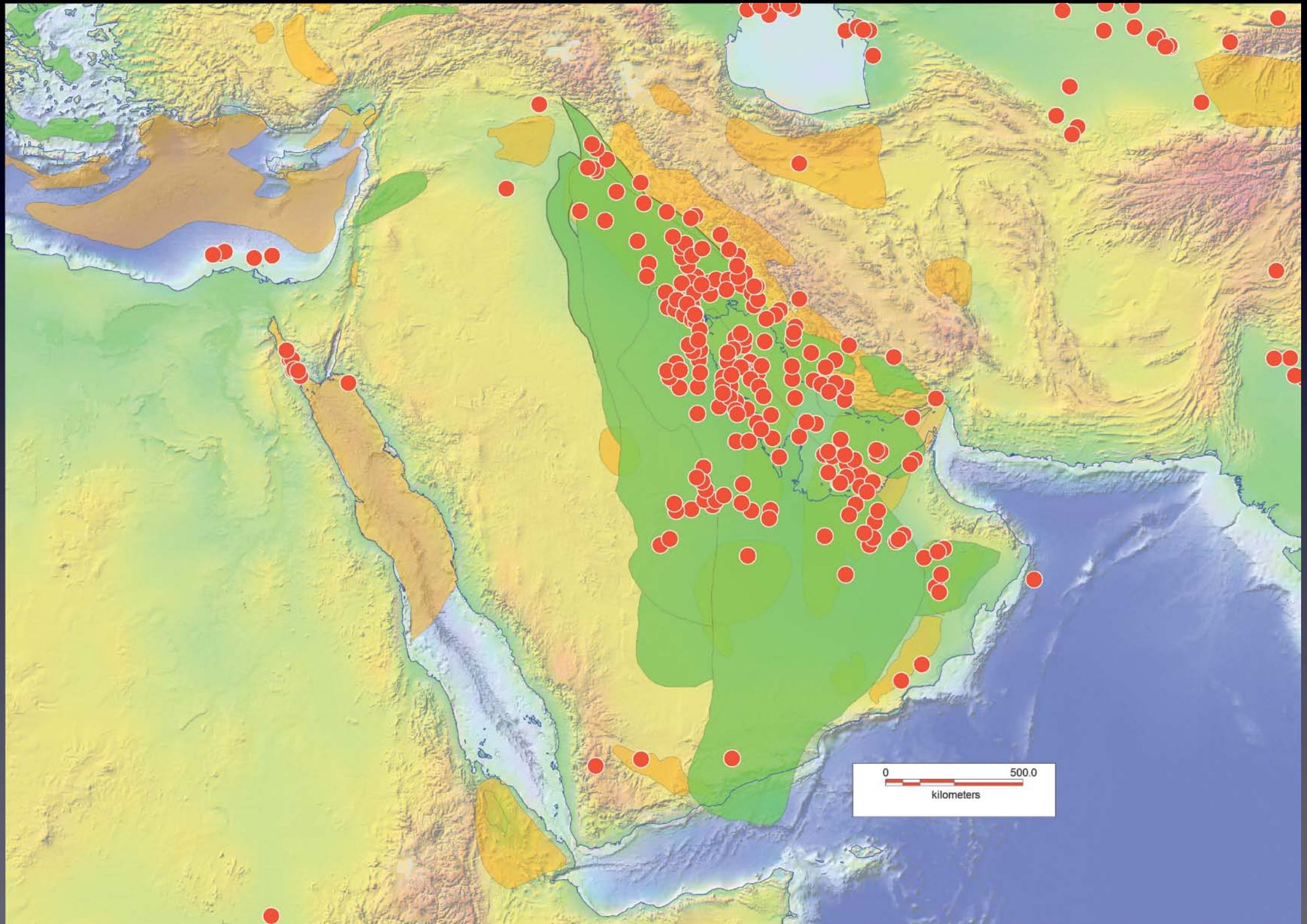
Does an enhanced understanding of ancient evaporite depositional setting improve our ability to predict trapping styles and occurrences?

Giant oil fields

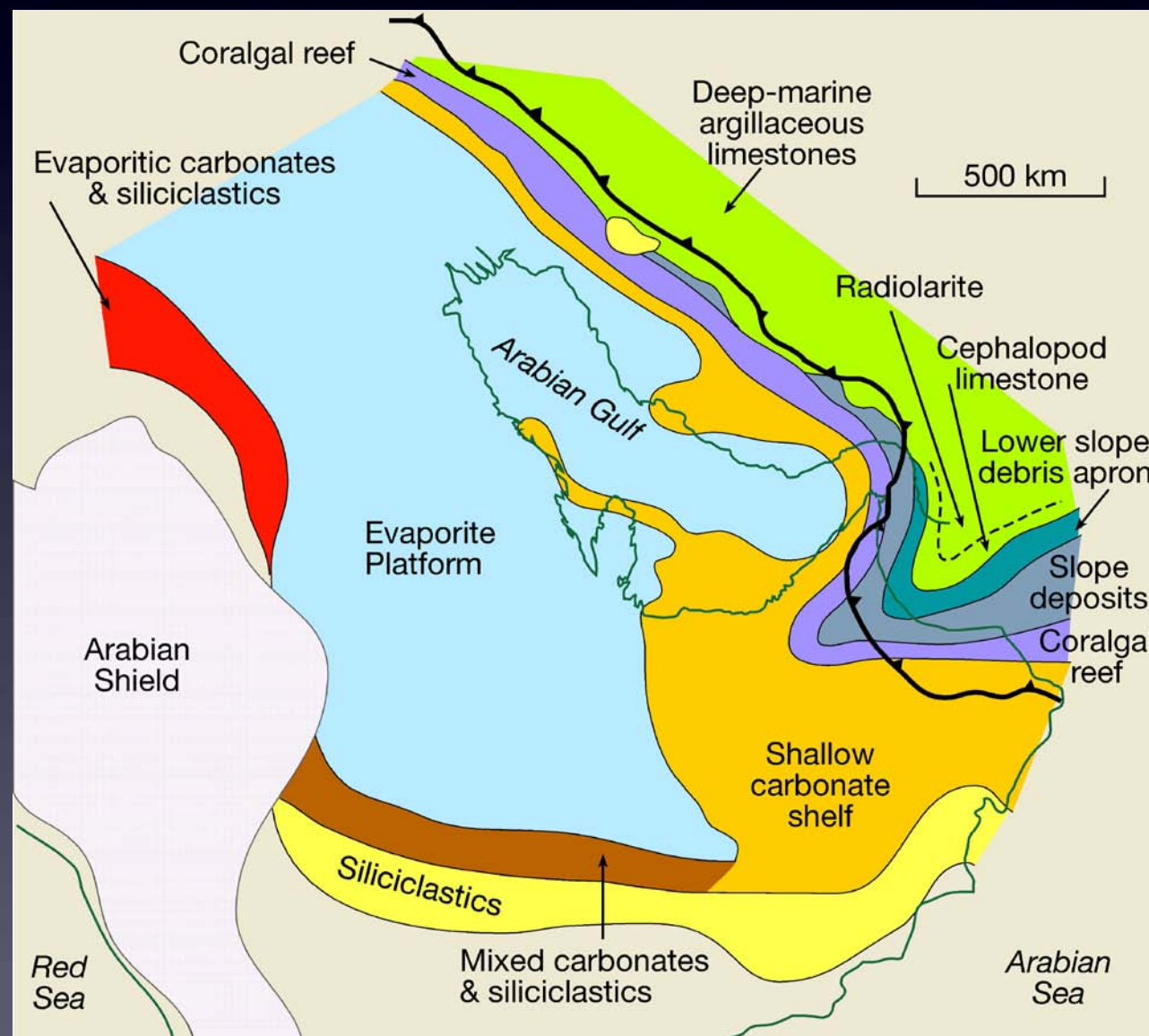


Saltworks & Mann, 2005

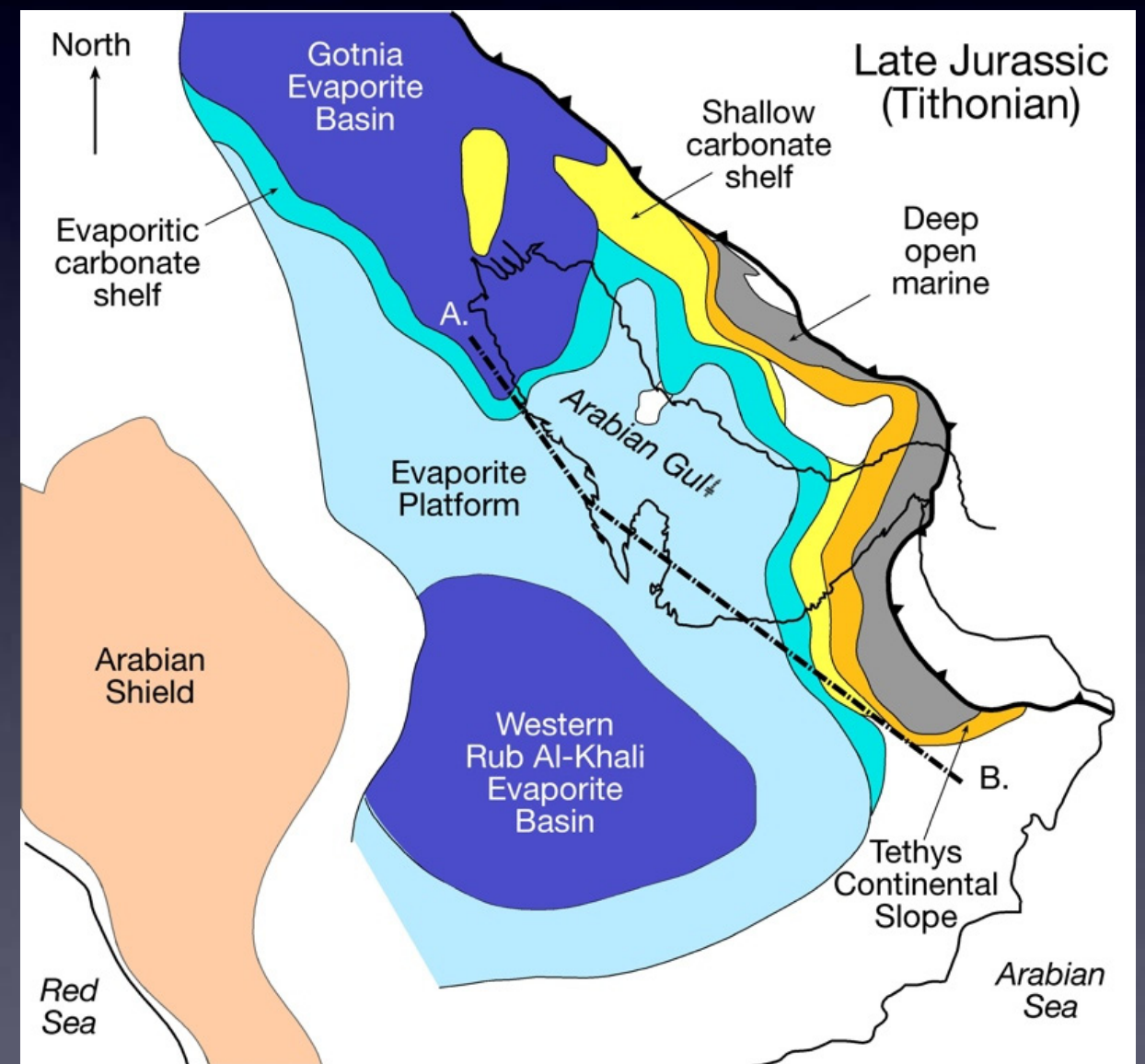
Megasulphates and giants



Megasulphate seals in Middle East

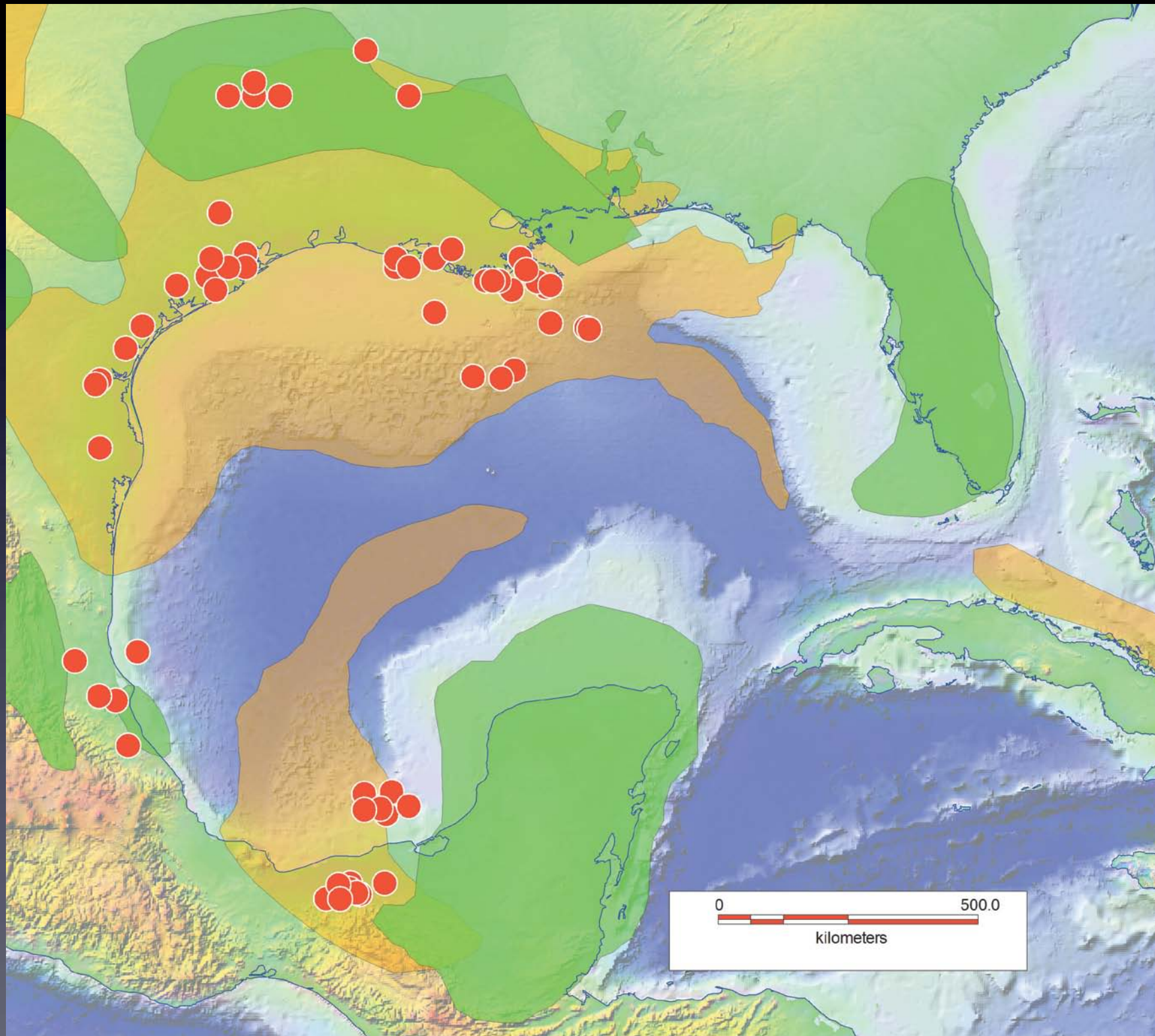


Permian Khuff Fm

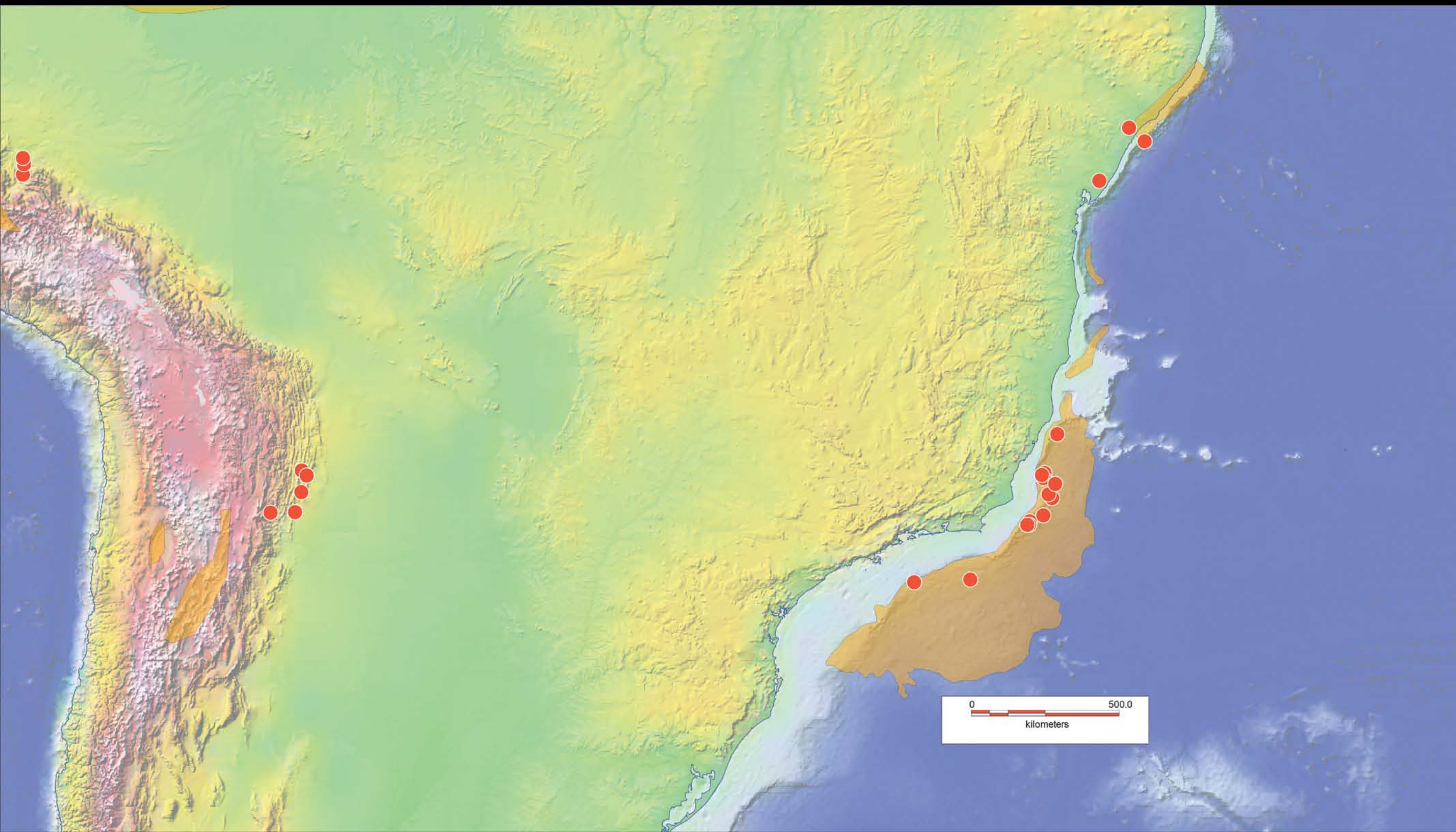


Jurassic Arab Fm

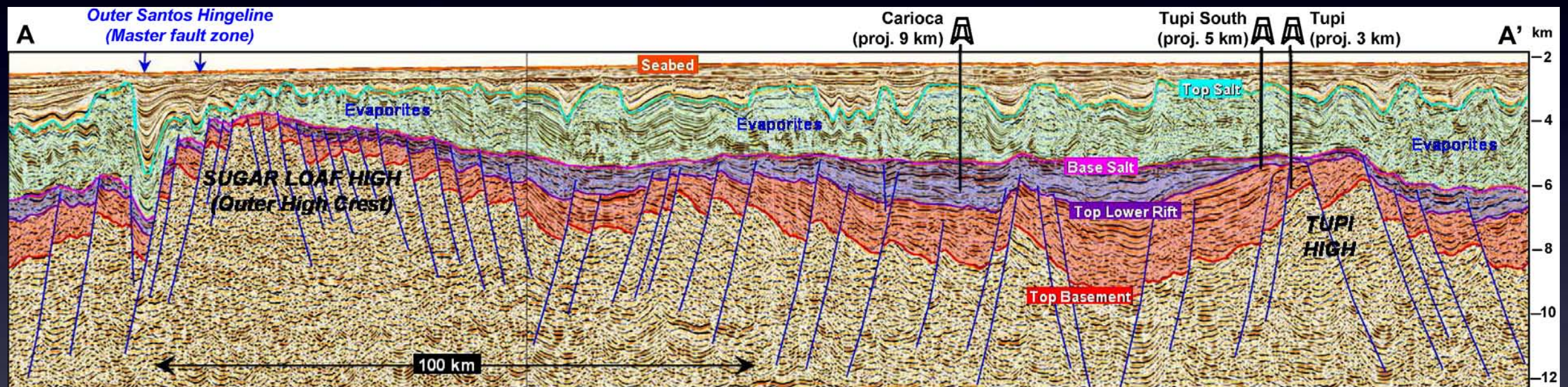
Gulf of Mexico



Brazil, South America



Tupi (Subsalt)



Gomes et al., 2009

Salty truths

- Quaternary depositional settings do not capture the diversity of ancient marine evaporite systems
- No modern analogs to megasulphate seals of the Middle East and elsewhere – seal style favored giant fields with interlayering of reservoir and seal
- No modern analogs to megahalite seals and associated structuration system (extensional and compressional halokinesis) – seal style favored giant fields that are subsalt or suprasalt (minor intrasalt)

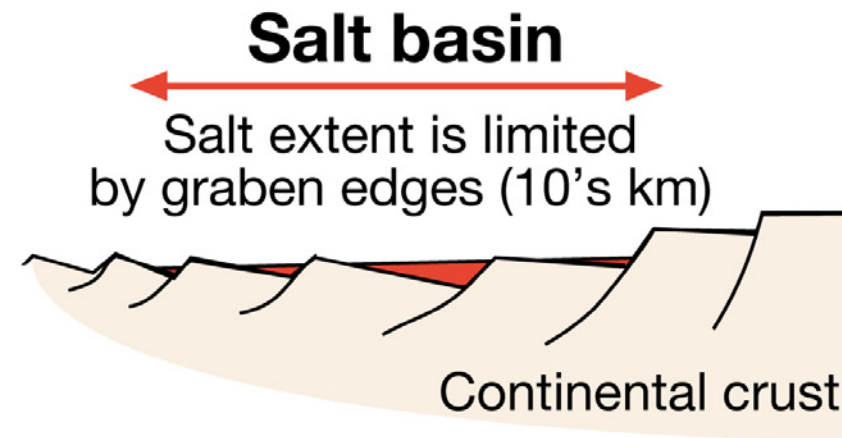
One size does not fit all

- Exploration in salt basins should be done in a framework that uses the diversity of evaporite depositional analogs, both past (majority) and present (minority).
- Classify the likely seal association with targeted reservoir potential in any basin in terms of actualistic salt models, which are defined by the relevant tectonic setting and/or eustacy and the age of the salt seal in the basin.

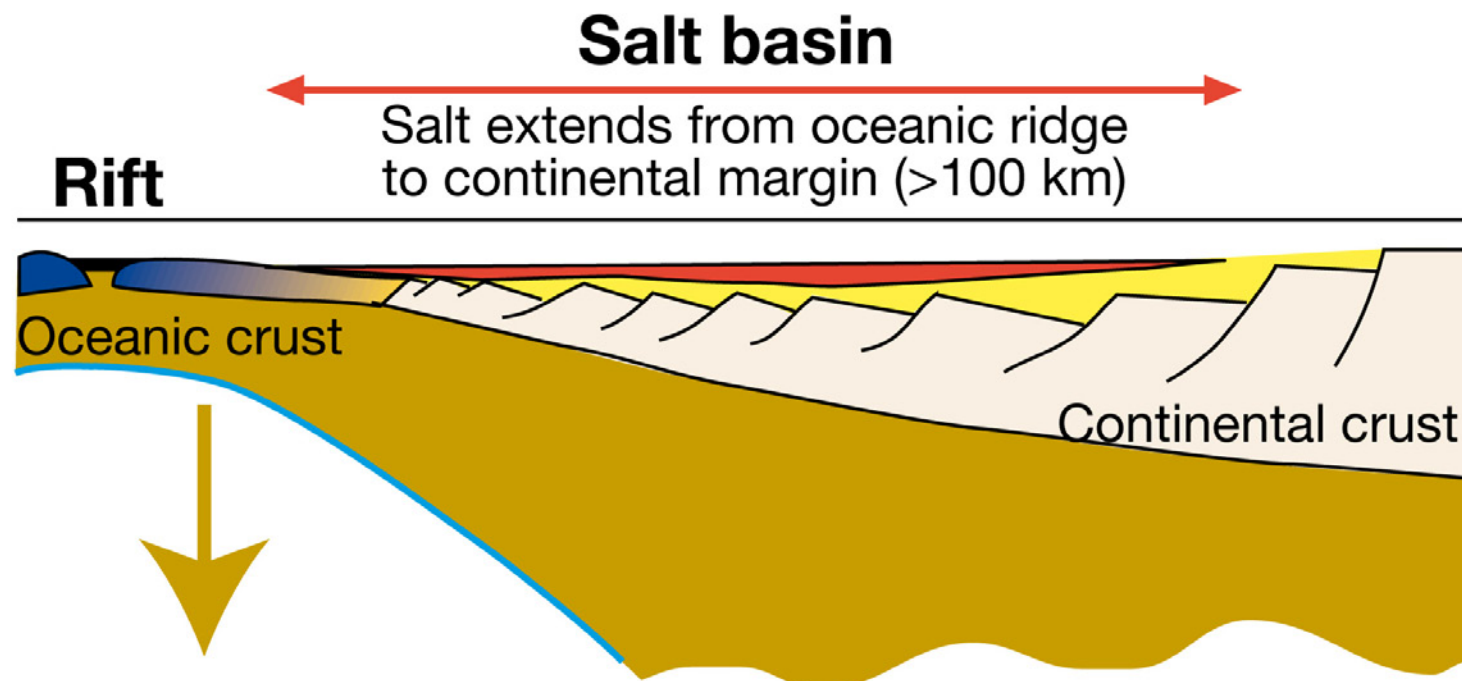


Synrift versus post-rift

Different lateral extents of bedded synrift and postrift salt at time of hydrographic isolation



Synrift megahalite



more rapid subsidence due to cooling of newly formed oceanic crust

Postrift megahalite