Marine Evaporites

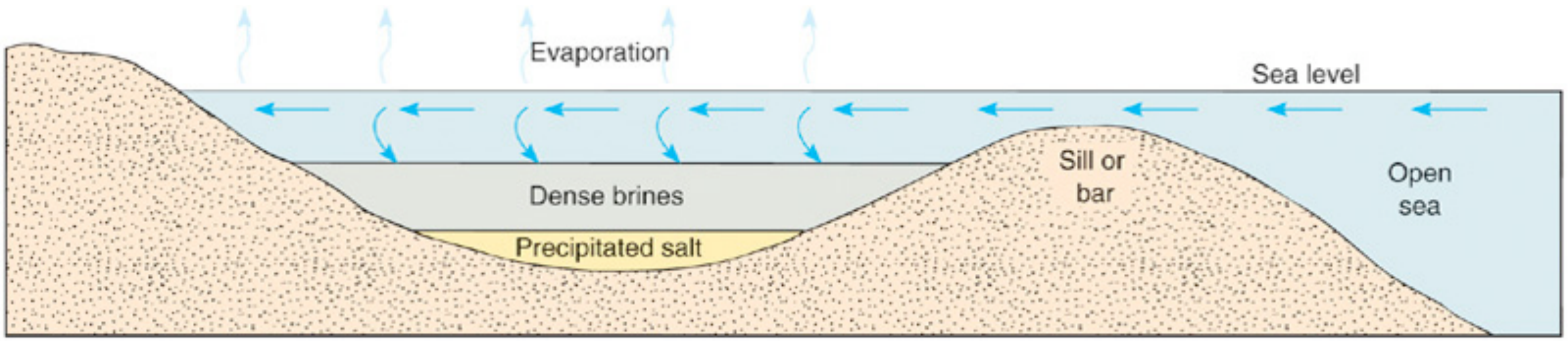
Composition

TABLE 8.3 Classification of marine evaporites on the basis of mineral composition

Mineral class	Mineral name	Chemical composition	Rock name
Chlorides	Halite	$NaCl$	Halite; rock salt
	Sylvite Carnallite	KCl $KMgCl_3 \cdot 6H_2O$	Potash salts
Sulfates	Langbeinite Polyhalite Kainite	$K_2Mg_2(SO_4)_3$ $K_2Ca_2Mg(SO_4)_6 \cdot H_2O$ $KMg(SO_4)Cl \cdot 3H_2O$	
	Anhydrite Gypsum Kieserite	$CaSO_4$ $CaSO_4 \cdot 2H_2O$ $MgSO_4 \cdot H_2O$	Anhydrite; anhydrock Gypsum; gyprock —
Carbonates	Calcite Magnesite Dolomite	$CaCO_3$ $MgCO_3$ $CaMg(CO_3)_2$	Limestone — Dolomite; dolostone

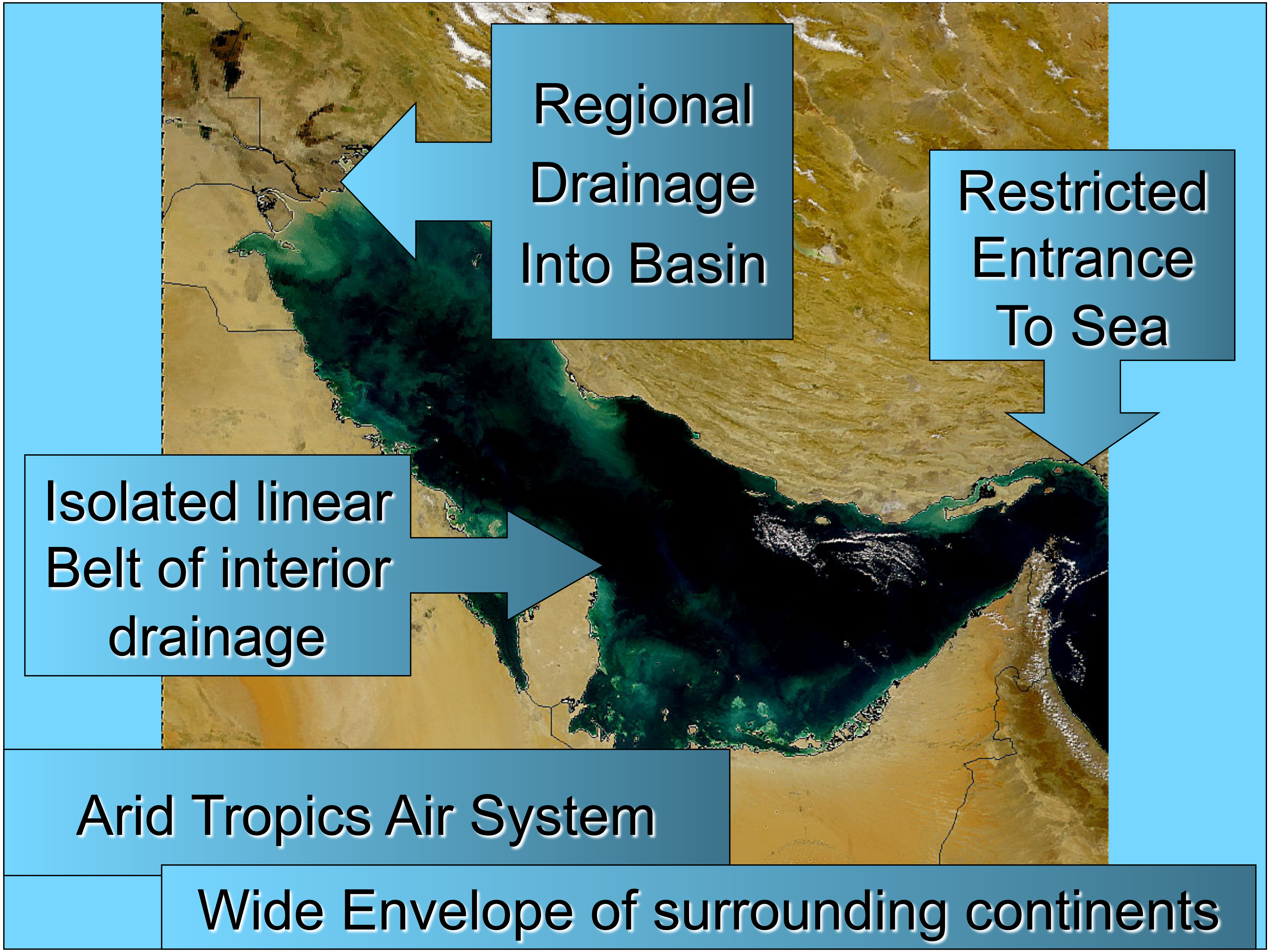
Source: Data from Stewart, F. H., 1963, Marine evaporites, *in* M. Fleischer (ed.), Data of geochemistry: U.S. Geol. Survey Prof. Paper 440-Y; Borchert, H., and R. O. Muir, 1964, Salt deposits: The origin, metamorphism, and deformation of evaporites: Van Nostrand, London.

Barred/silled basin



Examples of Evaporites at Collision Margins

- Current Arabian Gulf & underlying Late Mesozoic to Tertiary
- Silurian of Michigan Basin & Western New York State
- Devonian of Western Canada & NW USA
- Permian of New Mexico & West Texas
- Permian of Zechstein Basin
- Mesozoic to Tertiary of southern South America
- Tertiary of Mediterranean
- Mesozoic & Tertiary in final phases of Tethys Sea


Regional Drainage Into Basin
Restricted Entrance To Sea
Isolated linear Belt of interior drainage
Arid Tropics Air System
Wide Envelope of surrounding continents

Evaporite Generation Behind Barriers

- Isolated linear belts of interior drainage.
- Linear belts connected by restricted entrance to the sea.
- Regional drainage tends to flow into basin
- Air system of the arid tropics
- Wide envelope of surrounding continents.

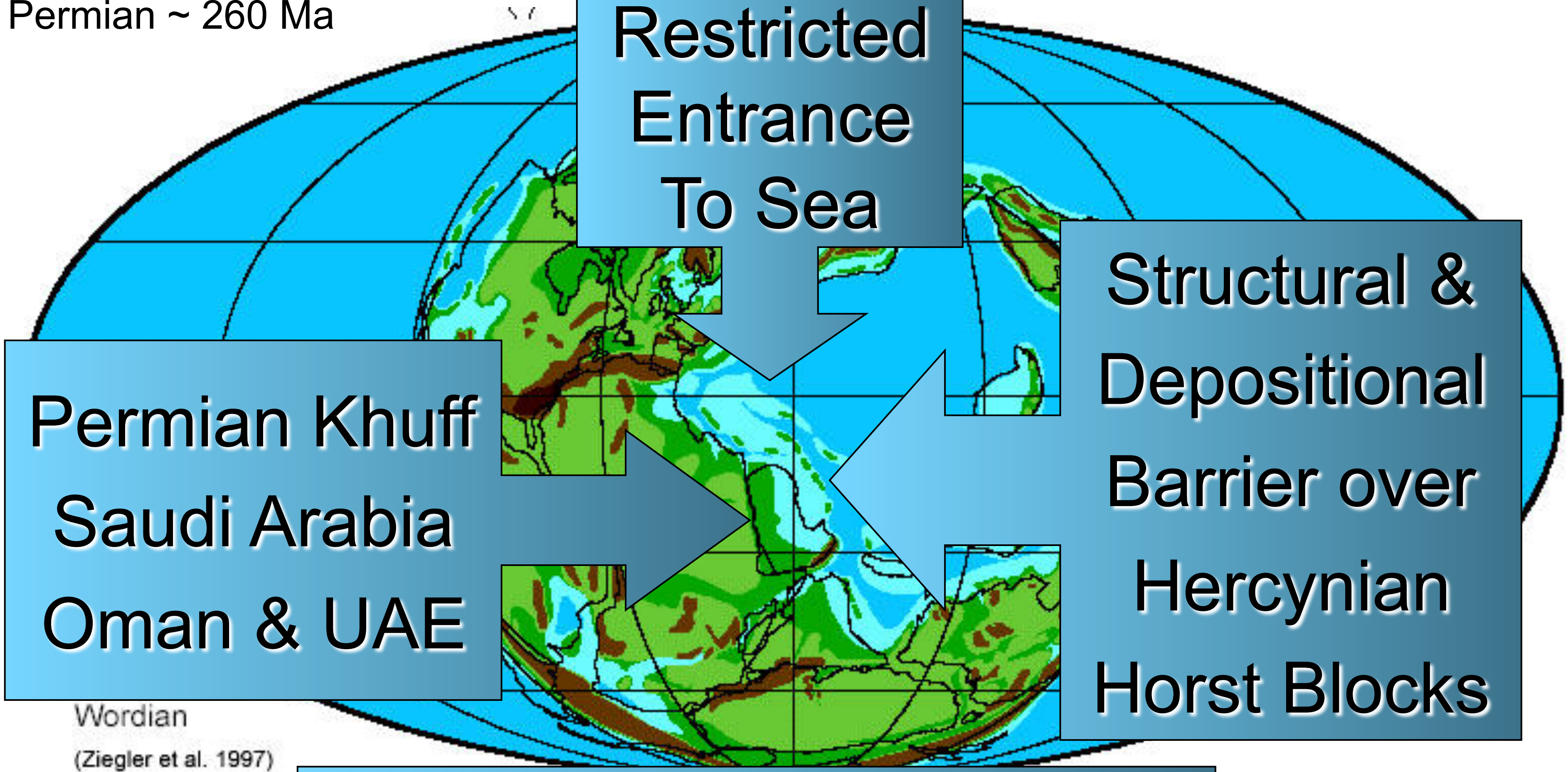
Examples of Evaporites Behind Structural & Depositional Barriers

Late Paleozoic to Early Mesozoic beneath Arabian Gulf

- Permian Khuff of Saudi Arabia, UAE & Oman
- Upper Jurassic Hith Anhydrite of western UAE, eastern Saudi Arabia, southern Kuwait and western Iran

Evaporites trapped by original Hercynian horst & block terrain at southern shore of Tethys Ocean. Punctuated by limited access to sea & repeated arid climatic events.

Permian ~ 260 Ma



Wordian

(Ziegler et al. 1997)

Restricted Entrance To Sea

Permian Khuff Saudi Arabia Oman & UAE

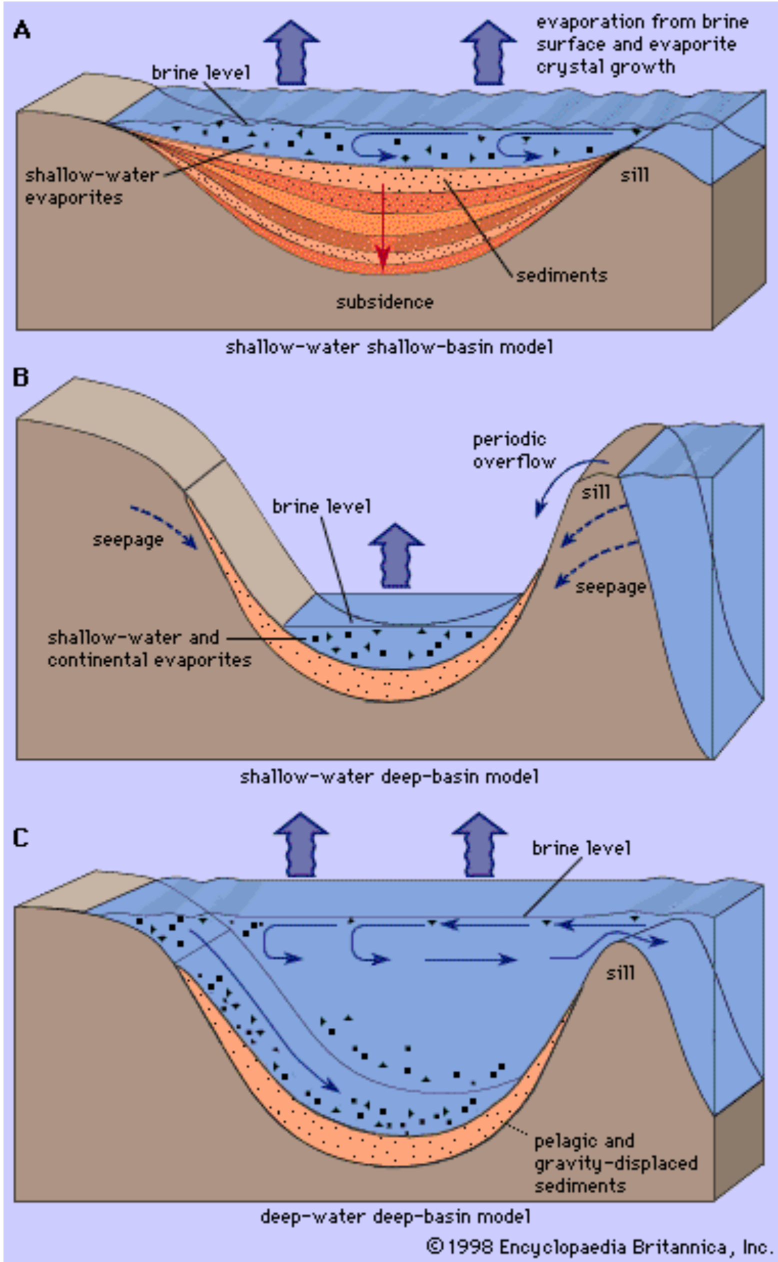
Structural & Depositional Barrier over Hercynian Horst Blocks

Arid Tropics Air System

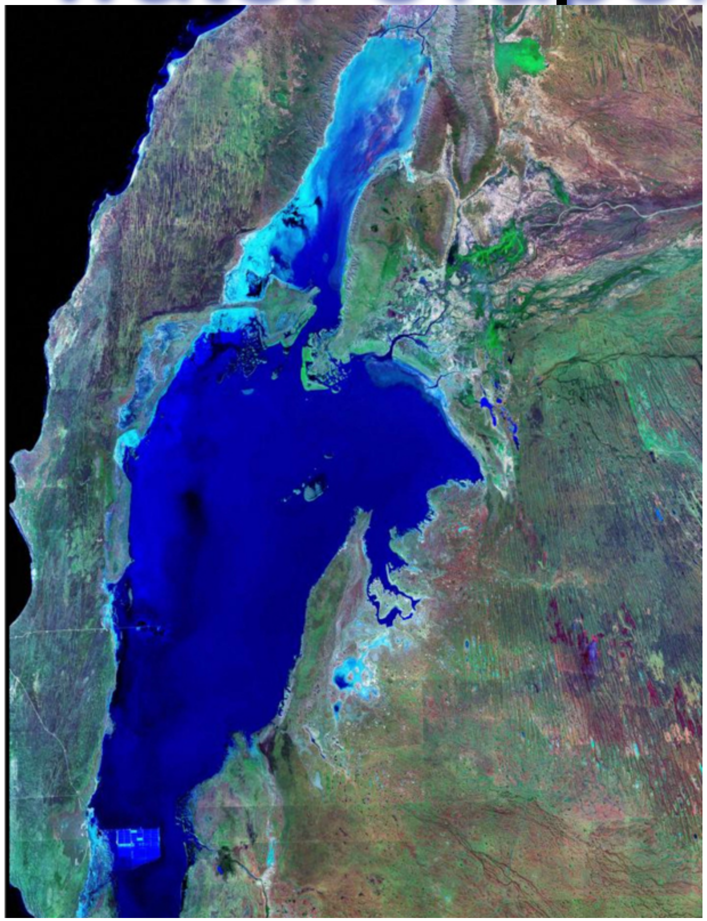
Wide Shadow from Adjacent Continents

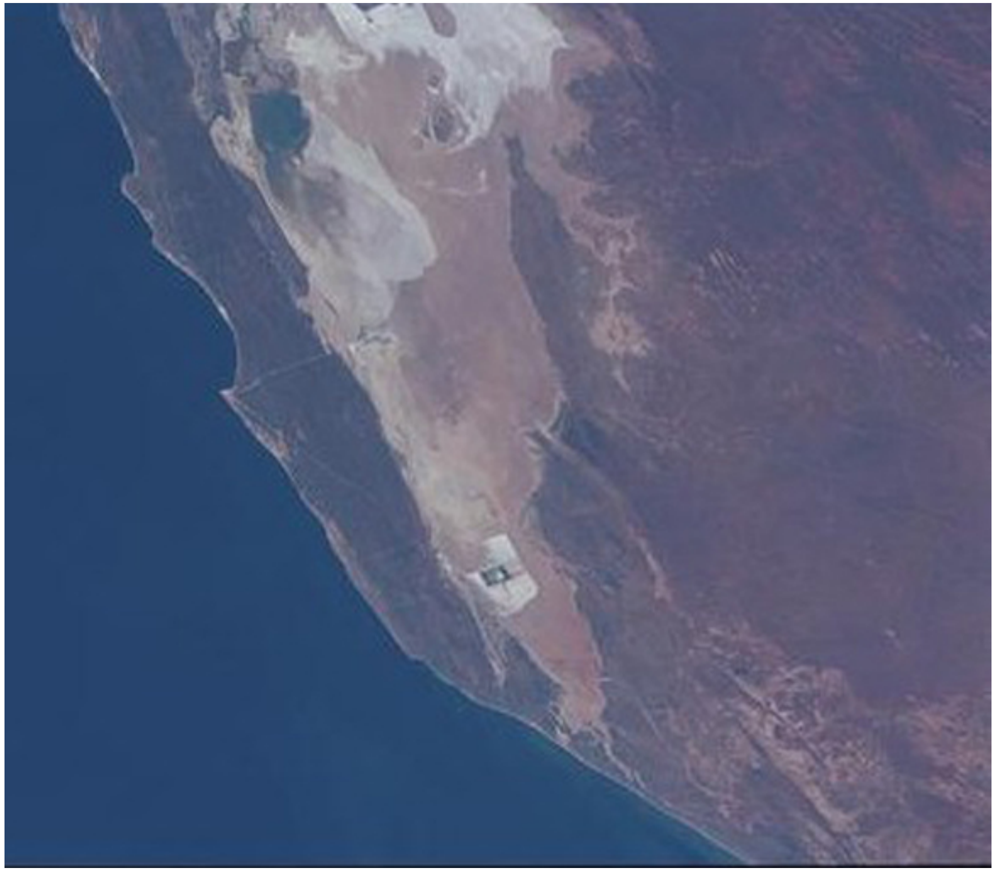
Basin-central evaporites

- Shallow basins most favourable
- Basin-central evaporites form during sea-level falls
- Deep-water basin - concentrated brine results in formation of laminated deposits



Modern Example - Shallow water evaporites





Lake McLeod, Western Australia (100 x 50 km, 9 m of Holocene evaporites)

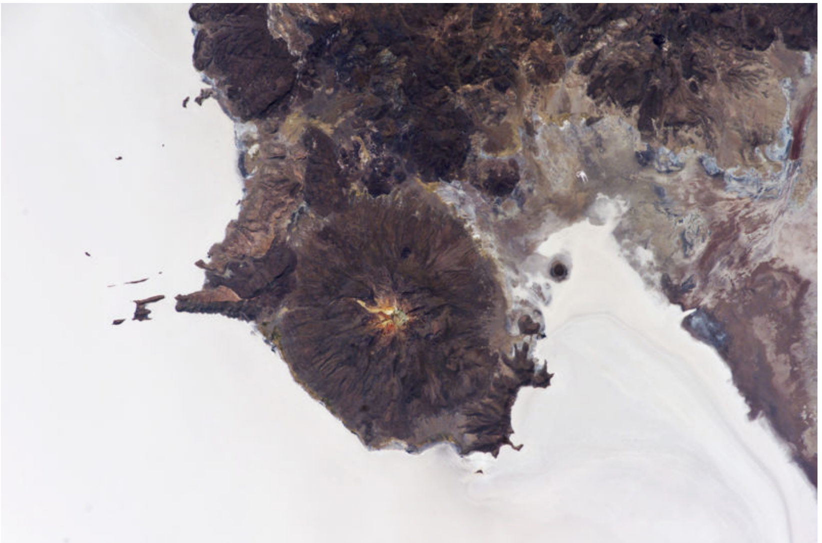
Messinian Mediterranean basins evaporite fills up to 2 km

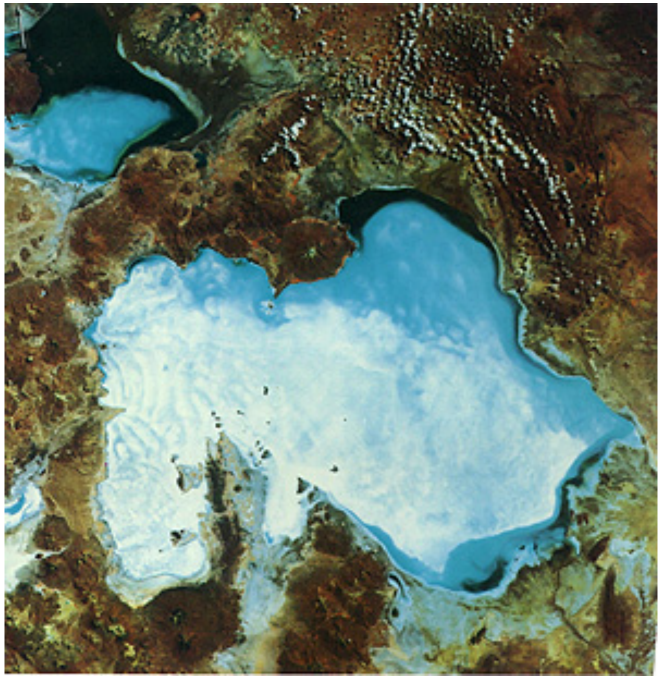
Lake McLeod cont.

Lake McLeod cont.

Salar de Uyuni, Bolivia

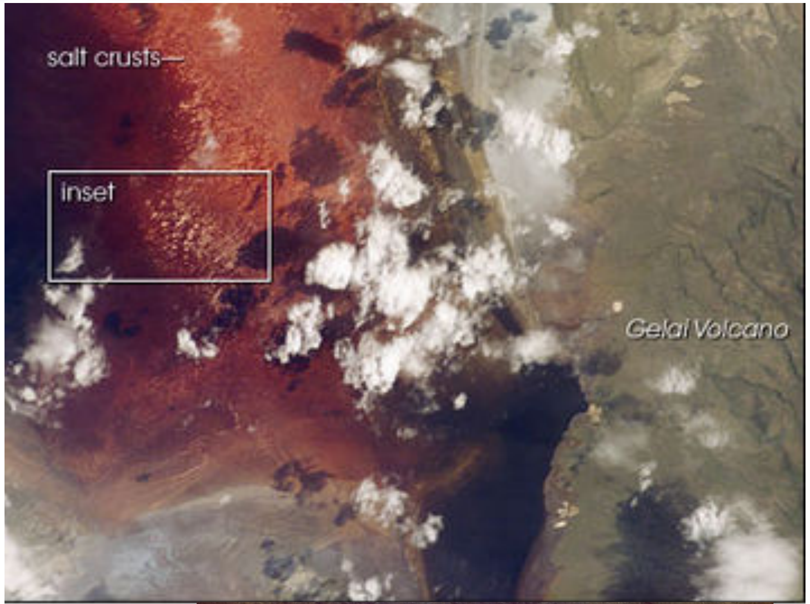
- World's largest salt flat (playa) (10.5 km^2)
- Contains ~ 10 billion tonnes of salt (halite and gypsum)
- Calibration of remote sensing instruments on satellites





Lake Natron, Tanzania

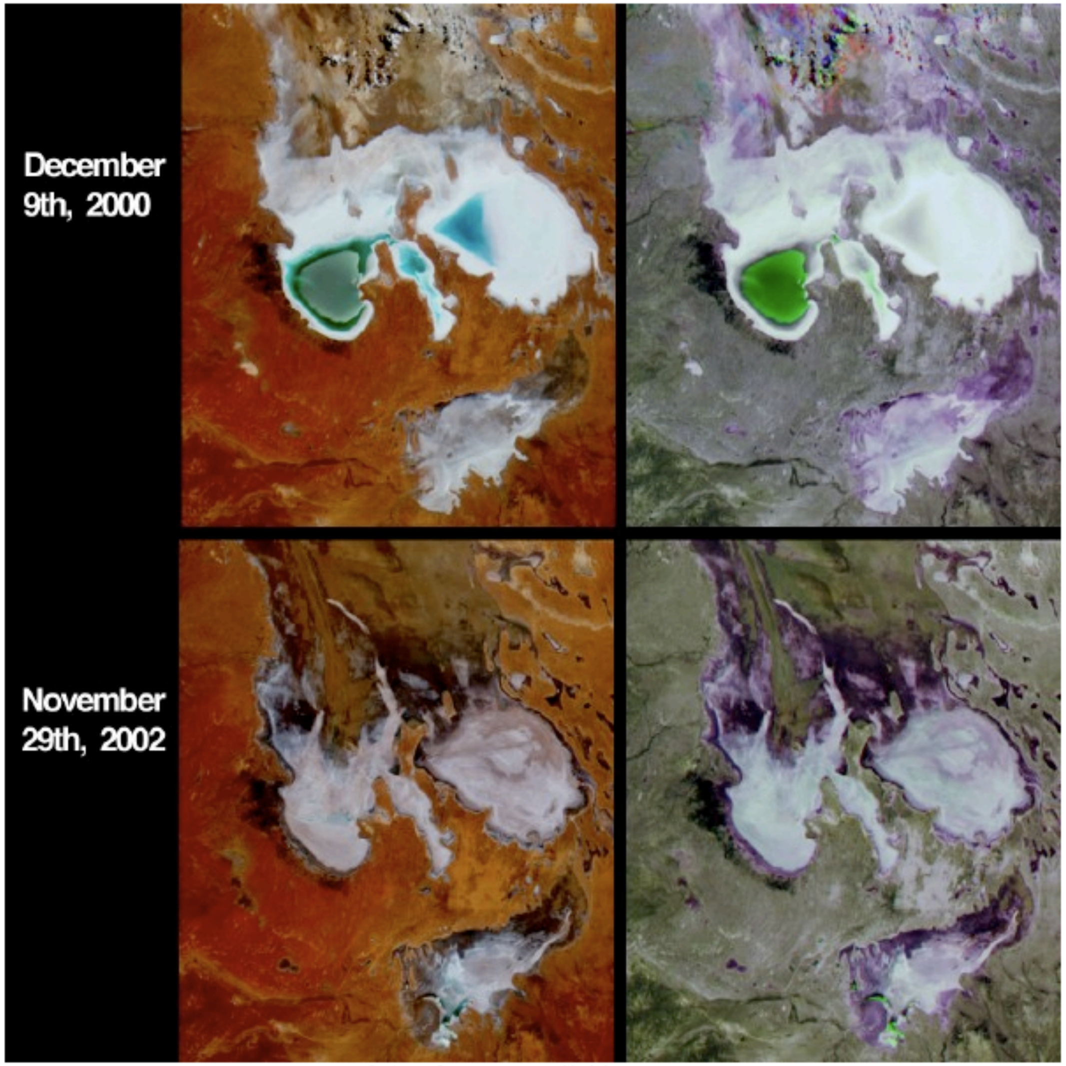
- Most caustic lake in the world (pH up to 10.5) rich in sodium carbonate
- Shallow lake (50 cm water)
- Red colour due to the algae *Spiricum* and halophilic bacteria
- $Na_2CO_3 10H_2O$ (soda ash with ~ 17% sodium bicarbonate)



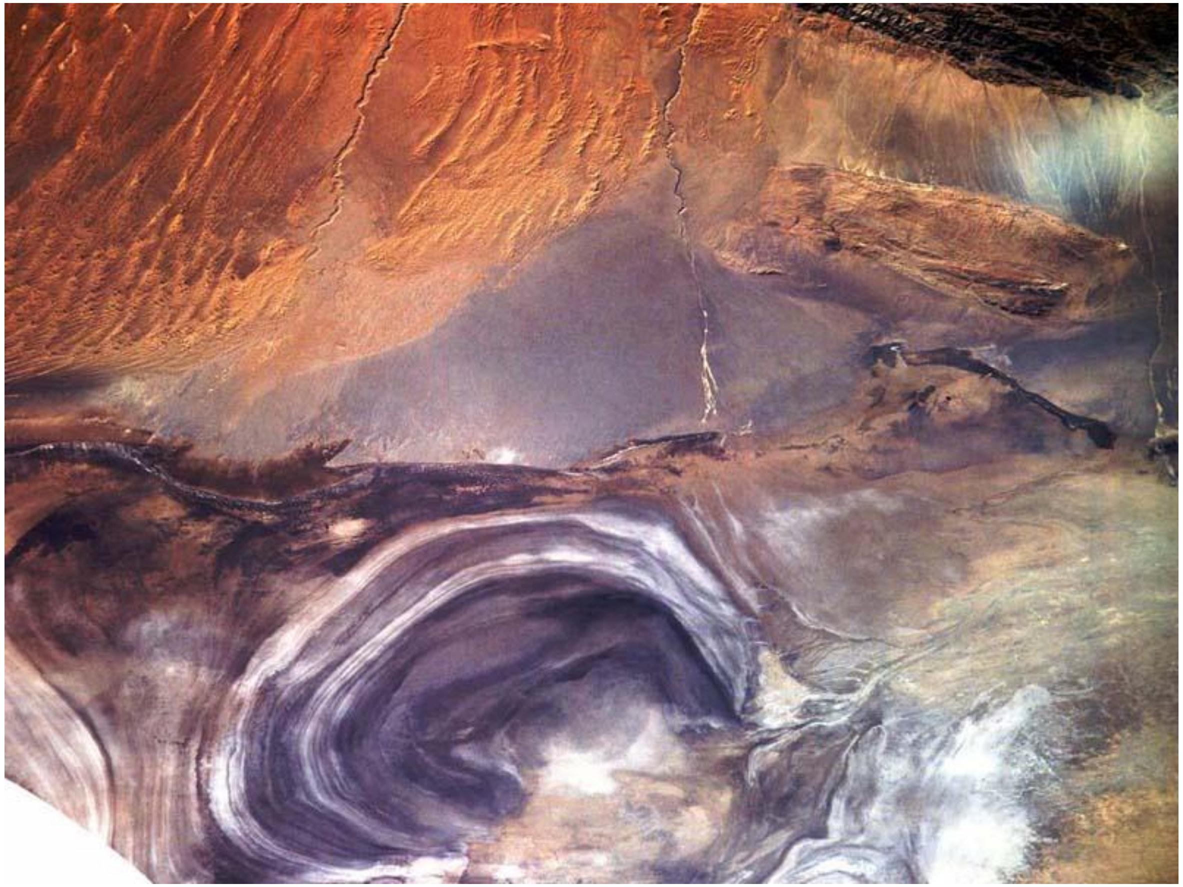
Lake Carnegie, W.A.

Lake Eyre, S.A.

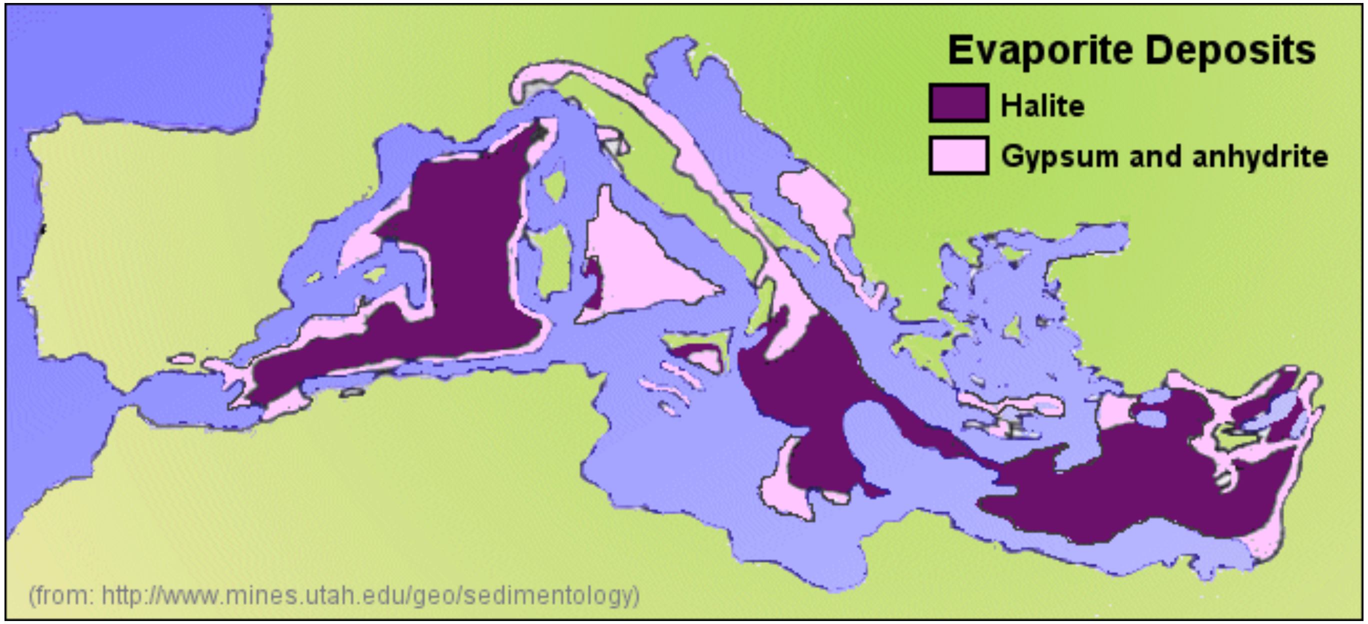
- low-lying lake attracts run-off from one of the largest inland drainage systems in the world



Lop Nur, China

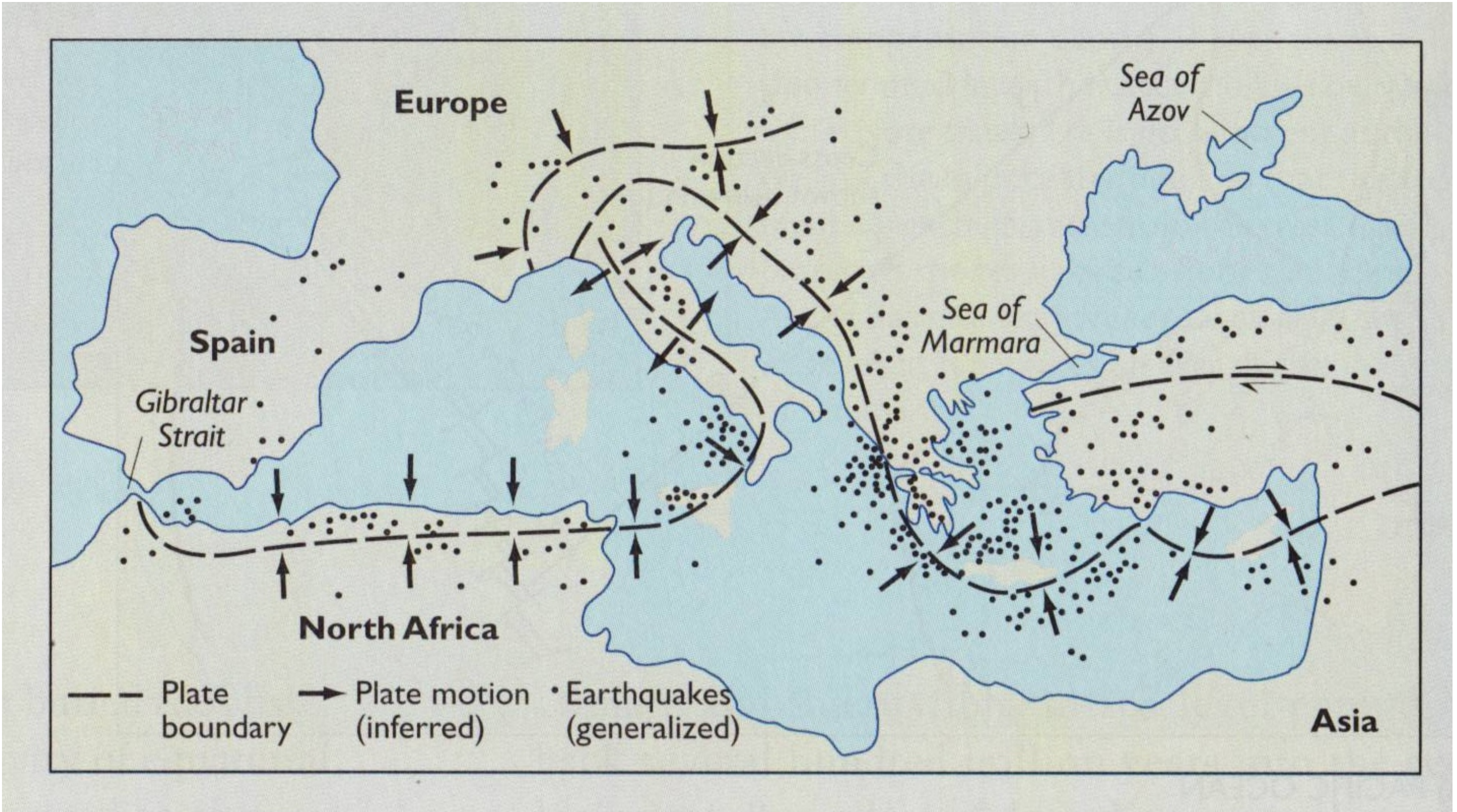


Messinian Salinity Crisis (7-5 Ma)



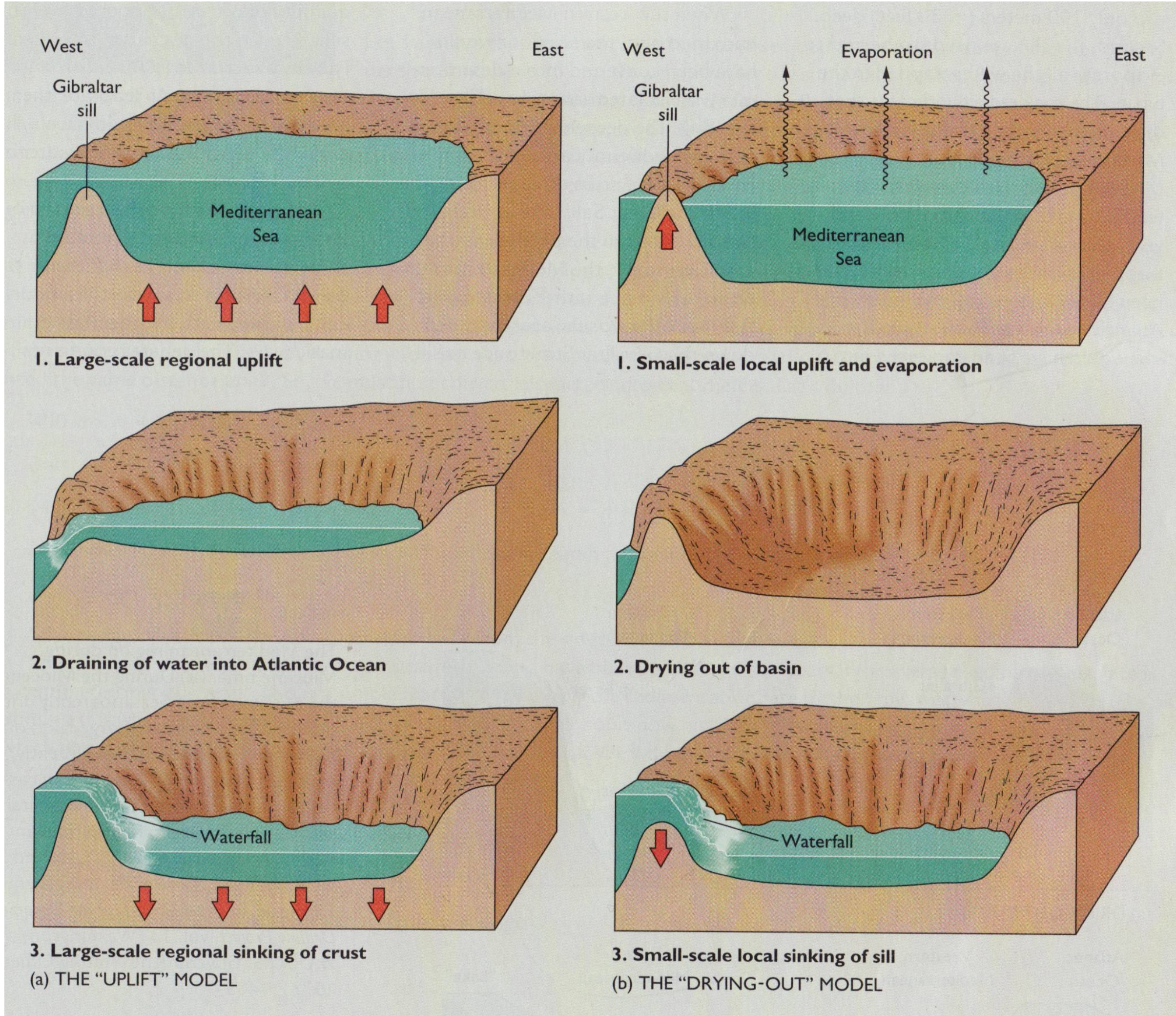
- Closure of marine passage (SL drop due to glaciation, uplift)
- Some evaporites formed in shallow water and others in deep water

Plate tectonics in the Mediterranean Region



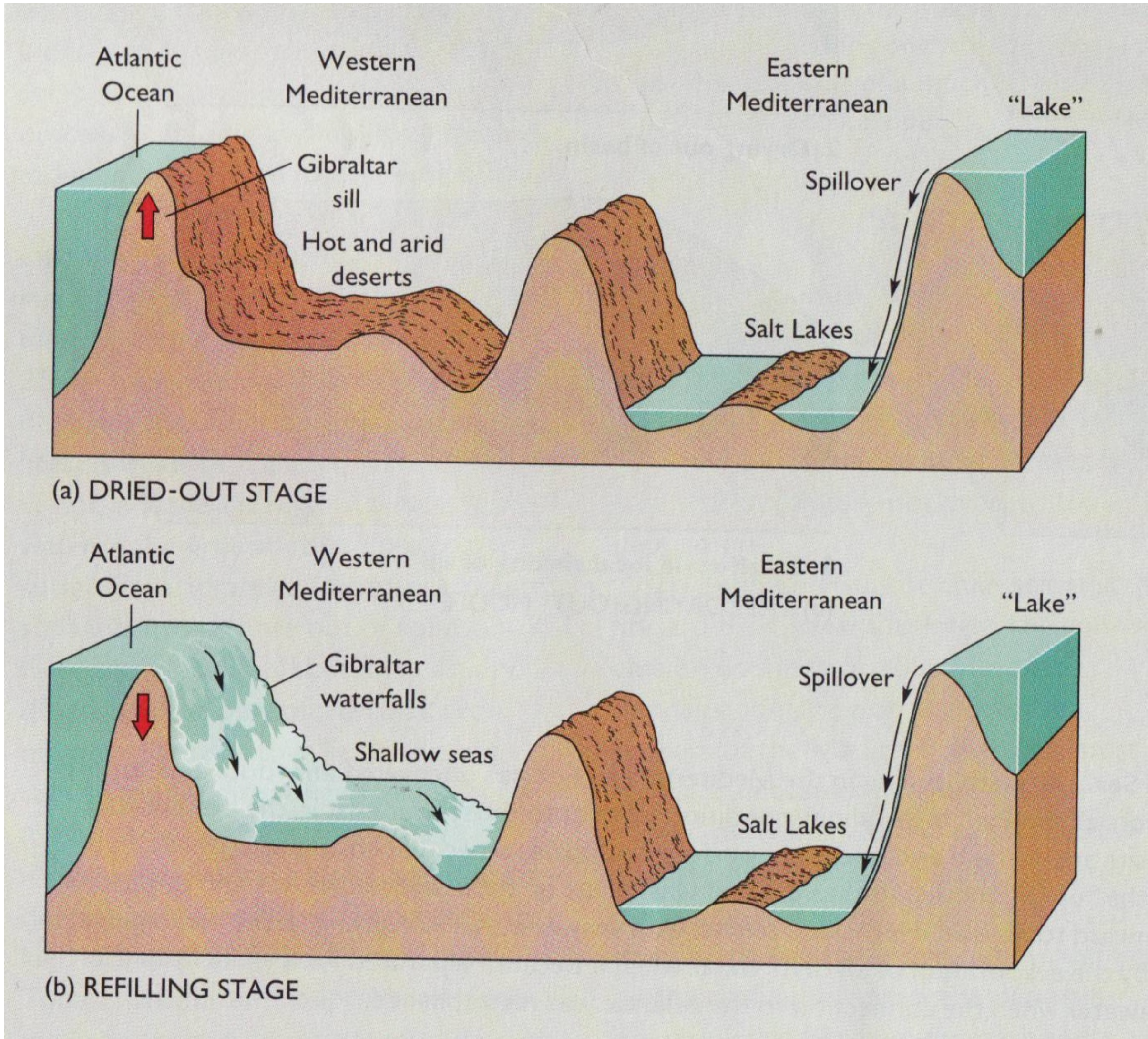
From Pinet (2003)

Models for emptying of the Mediterranean Sea



From Pinet (2003)

One of the models for the Miocene



From Pinet (2003)

Size comparison

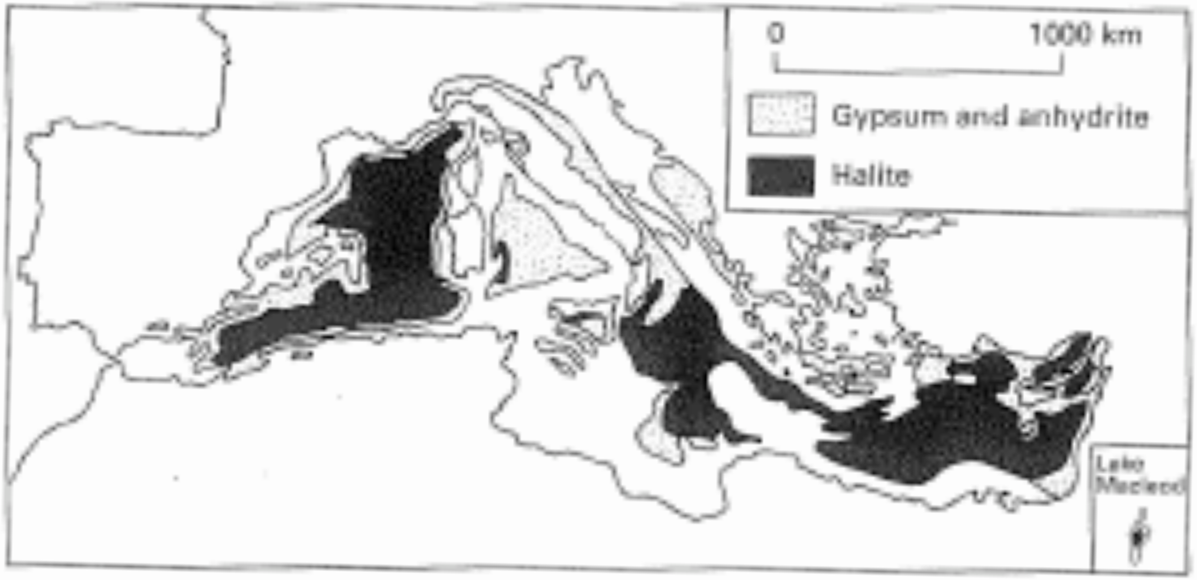


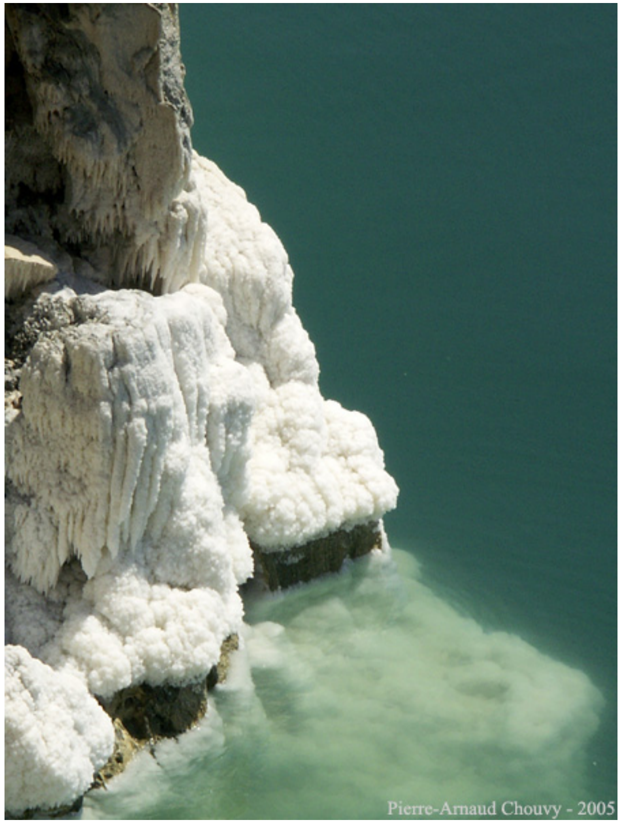
Figure 8.1 Size comparison between ancient and modern evaporites. Messinian of the Mediterranean (after Rouchy, 1980) and Holocene of Lake Macleod, Western Australia.

Dead Sea - deep water evaps

- Lowest body of water on Earth (~ 400 m below SL
- Rift valley
- Pleistocene-Holocene evaporites 11 km thick
- Only modern analogue of deep-water evaporites

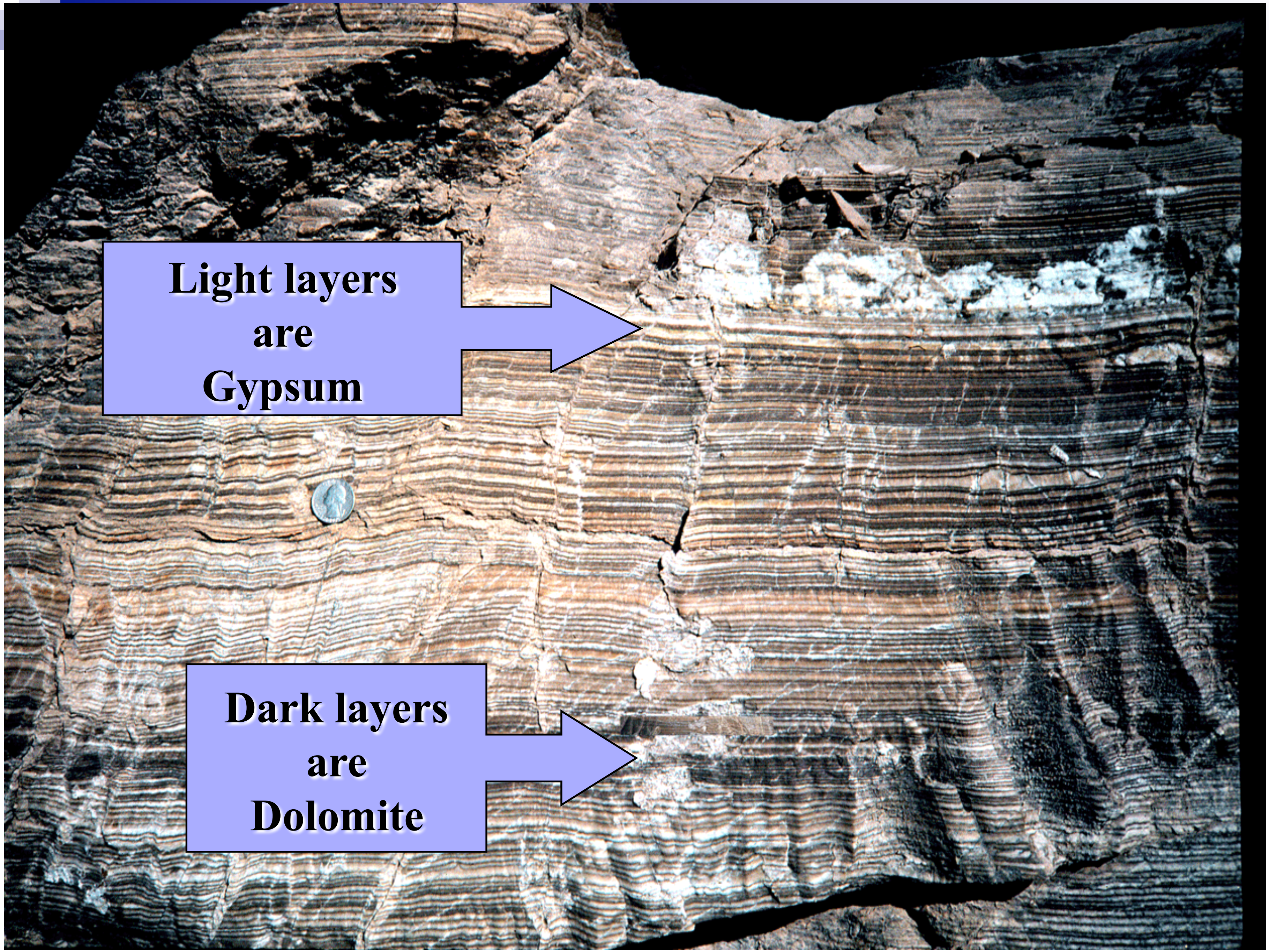
(COURTESY NEIL FOLBERG, COURTESY ABBEVILLE PRESS)

Dead Sea Evaporites

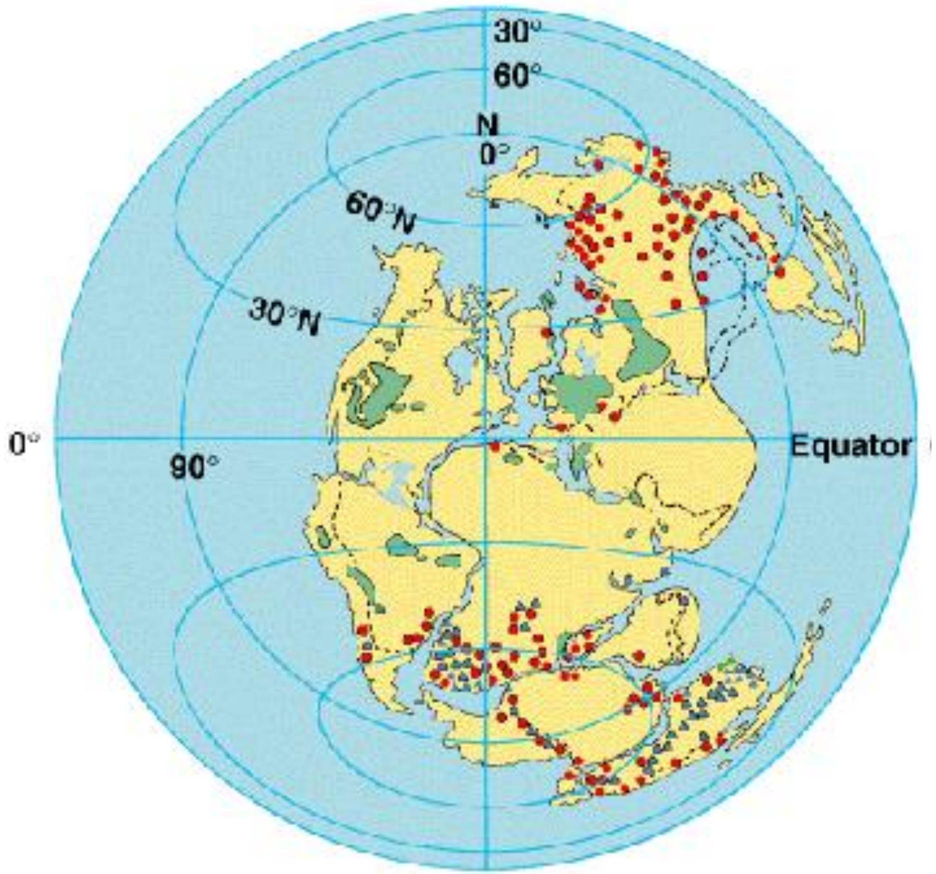


Deep-water evaporites

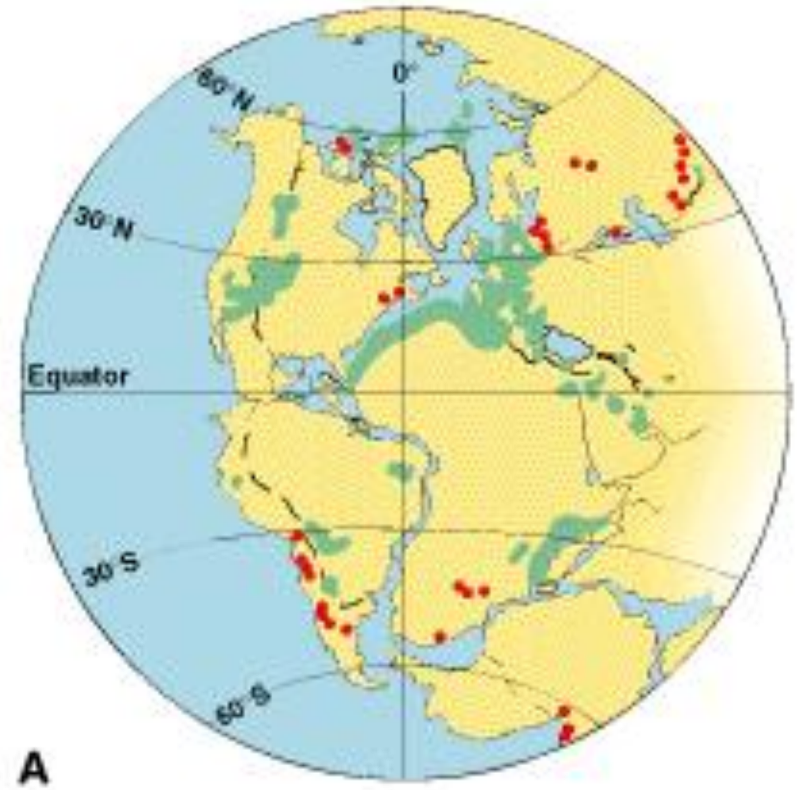
- Laminated carbonates, sulphates and halite
- Lateral and vertical continuity suggests a deep body of brine
- Growth and nucleation of crystals at brine surface followed by settling


Light layers are Gypsum
Dark layers are Dolomite

Evaporites through time



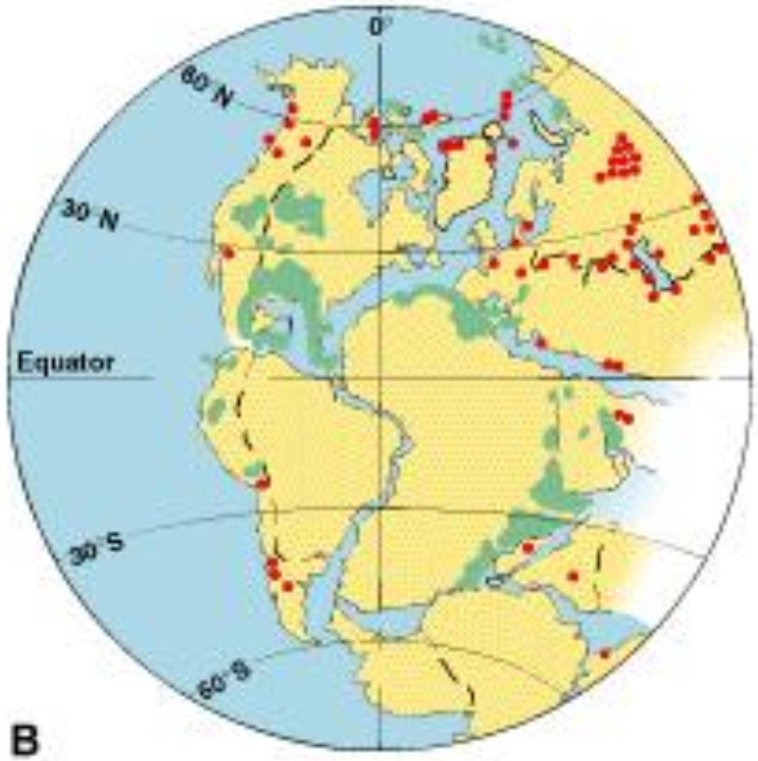
Permian

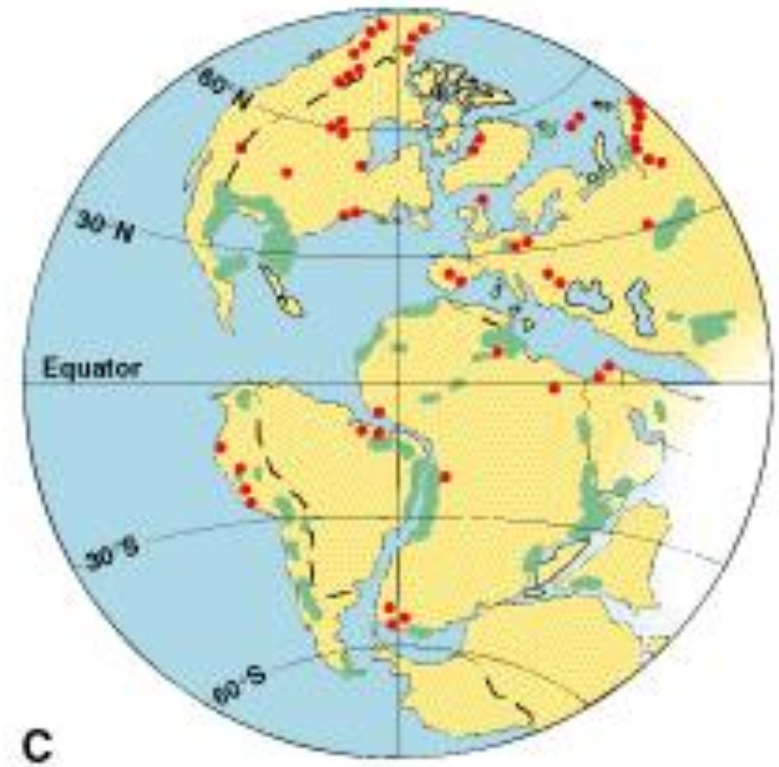


Triassic

Tillites - blue triangles, Coal - red circles, Evaporites - green areas

Evaporites through time





Jurassic

Early Cretaceous

Subaqueous evaporite facies

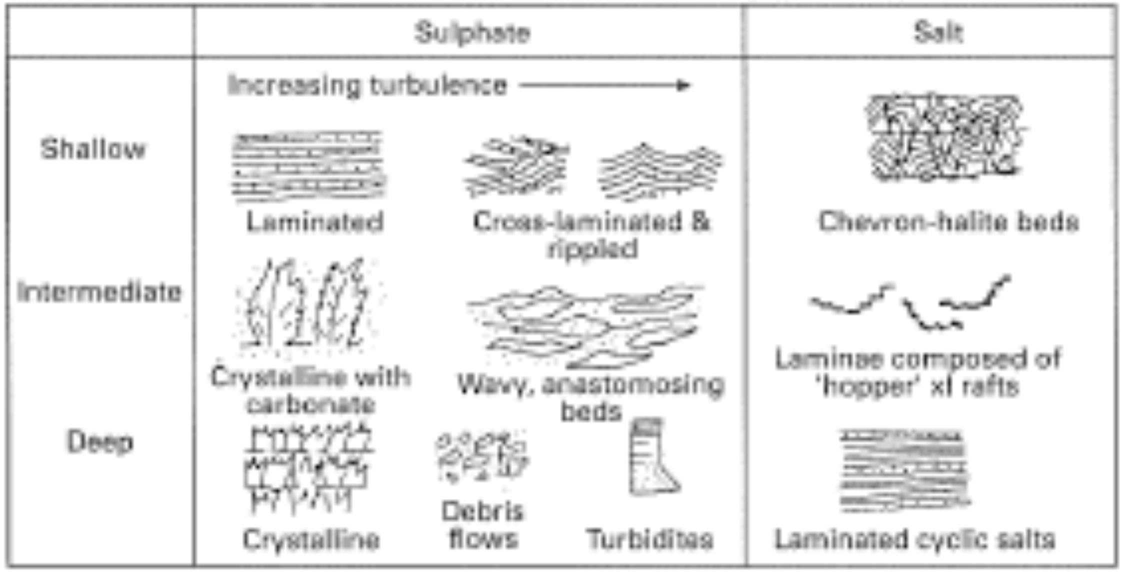


Figure 8.11 Environmental interpretation of subaqueous evaporite facies (after Schreiber, Friedman *et al.*, 1976).

Sabkha Evaporites

- stromatolites
- nodular gypsum
- Anhydrite
- planar and ripple cross-lamination
- flat pebble conglomerates
- polygonal shrinkage cracks

***Examples*:** **Modern - UAE**
Ancient - Permian Basins

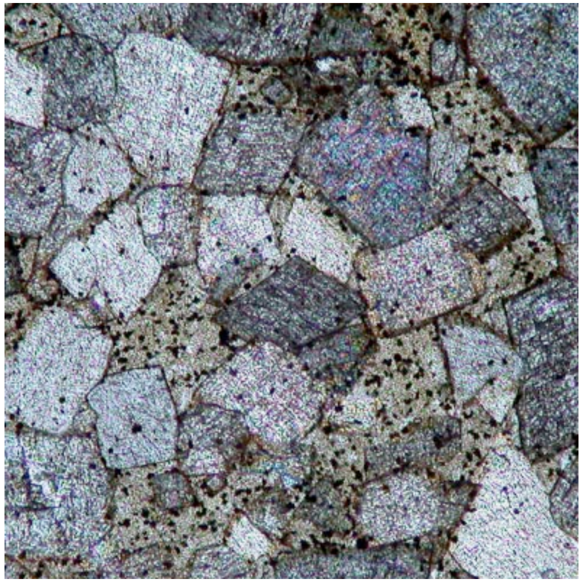

5 CM 10 15

Evaporites and Climate

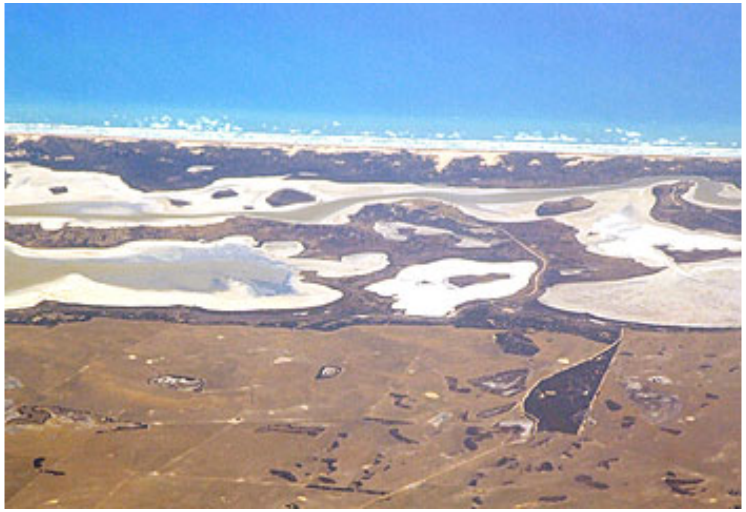
- Arid climates common through earth history
- Arid climates signaled by thick sections of evaporites in marine & lacustrine settings adjacent to margins of recently pulled apart continental plates &/or in compressional terrains of colliding margins
- Arid climates punctuate geologic column & so provide time markers
- Evaporites form stratigraphic marker horizons

Dolomite

- Calcium carbonate rocks with > 50% dolomite ($CaMg(CO_3)_2$)
- Most dolomites are diagenetic replacements of limestone
- Associated with evaporites
- Precambrian to Holocene but mostly Palaeozoic
- "Dolomite Problem"
- Dolomite as primary precipitate?
- Dolomite formed through dolomitization?
- Waters require high Mg:Ca



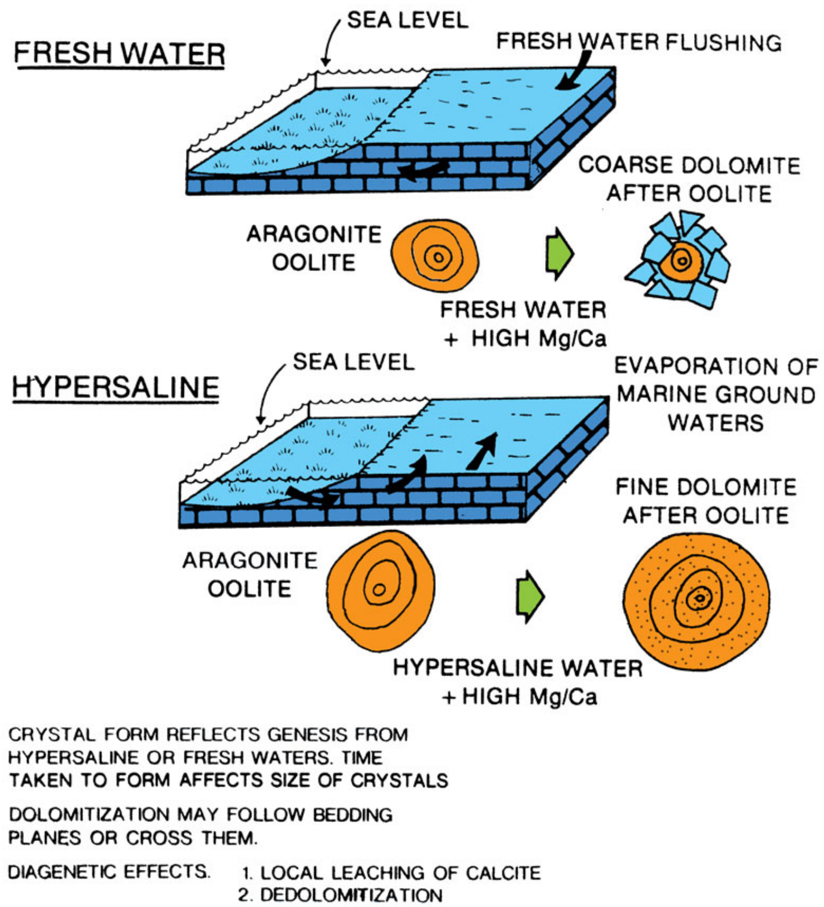
Ordovician dolomite



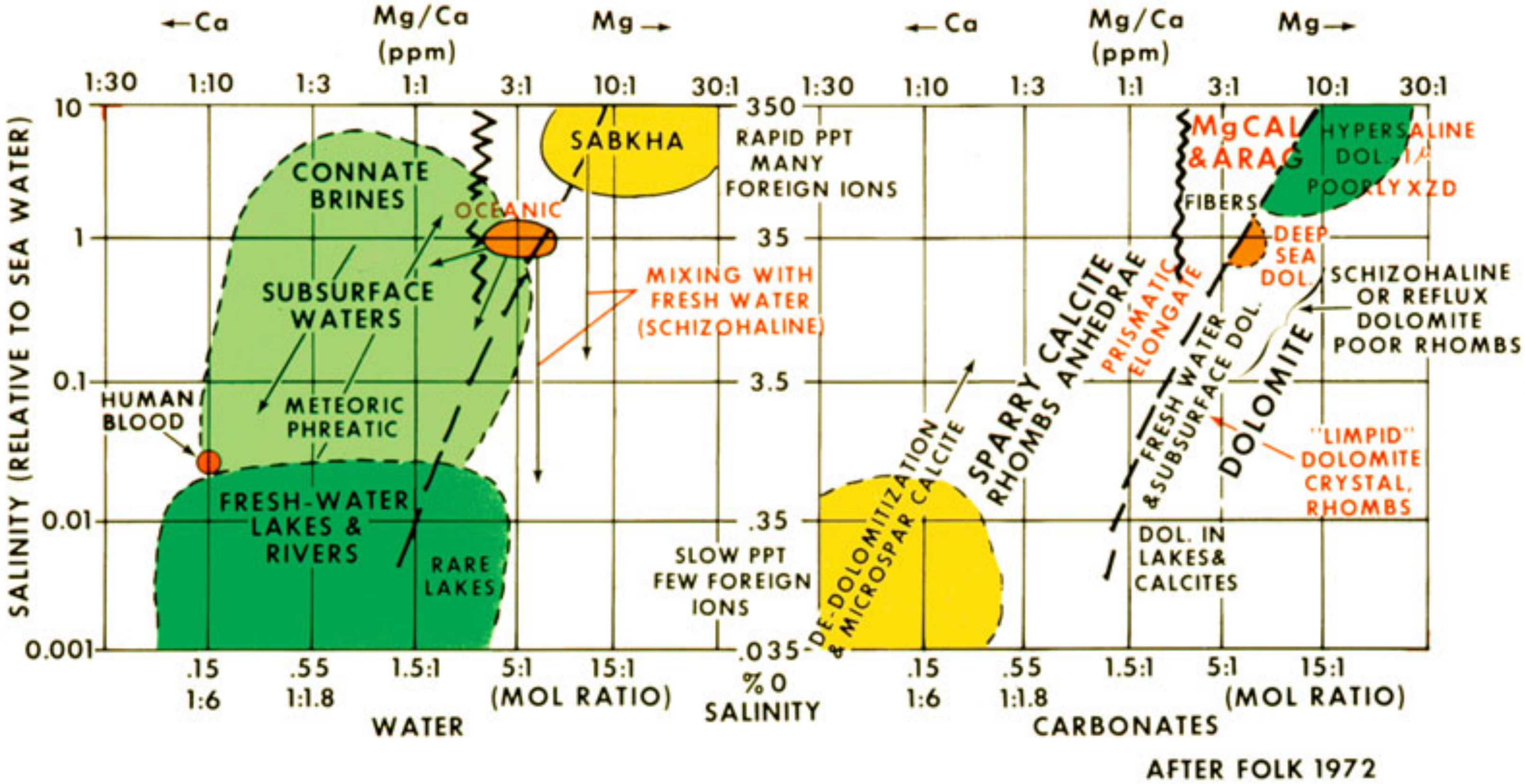
The Coorong

Dolomitization

- Arid supratidal salt flats
- Capillary crusts in the up slope portions of tidal and supratidal flats
- Near surface submarine sediments of the margins of carbonate banks
- Flanks and interior of carbonate banks with circulating marine waters
- Near surface mixing zone with magnesium remobilization
- Late diagenesis by late movement of subsurface waters

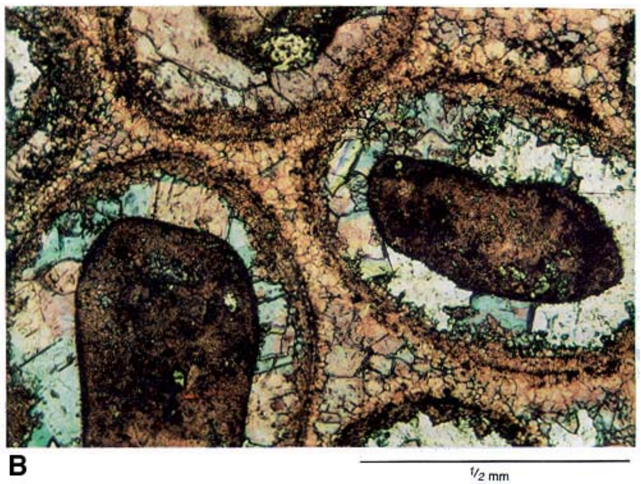


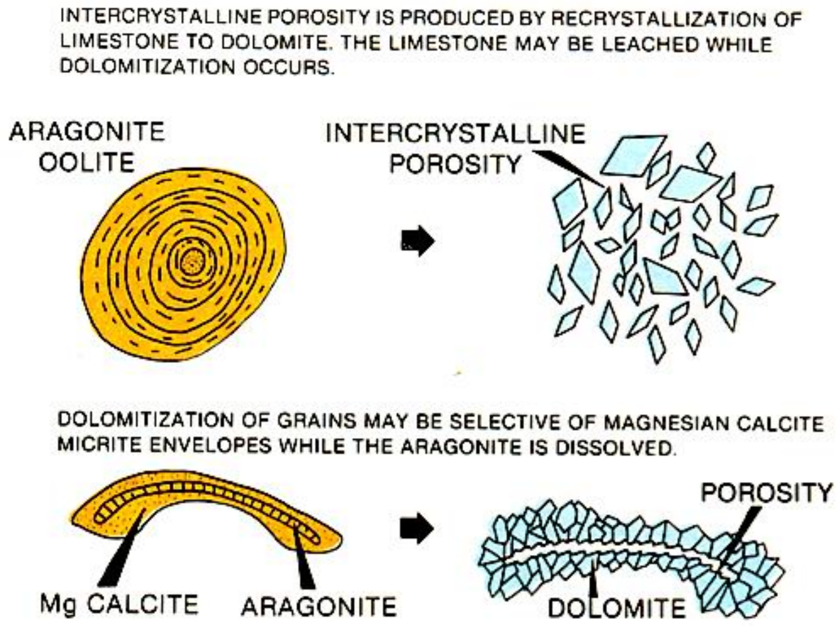
Mg++/Ca++ VERSUS SALINITY-A FRAME OF REFERENCE FOR DIAGENESIS OF ARAGONITE, CALCITE, & DOLOMITE

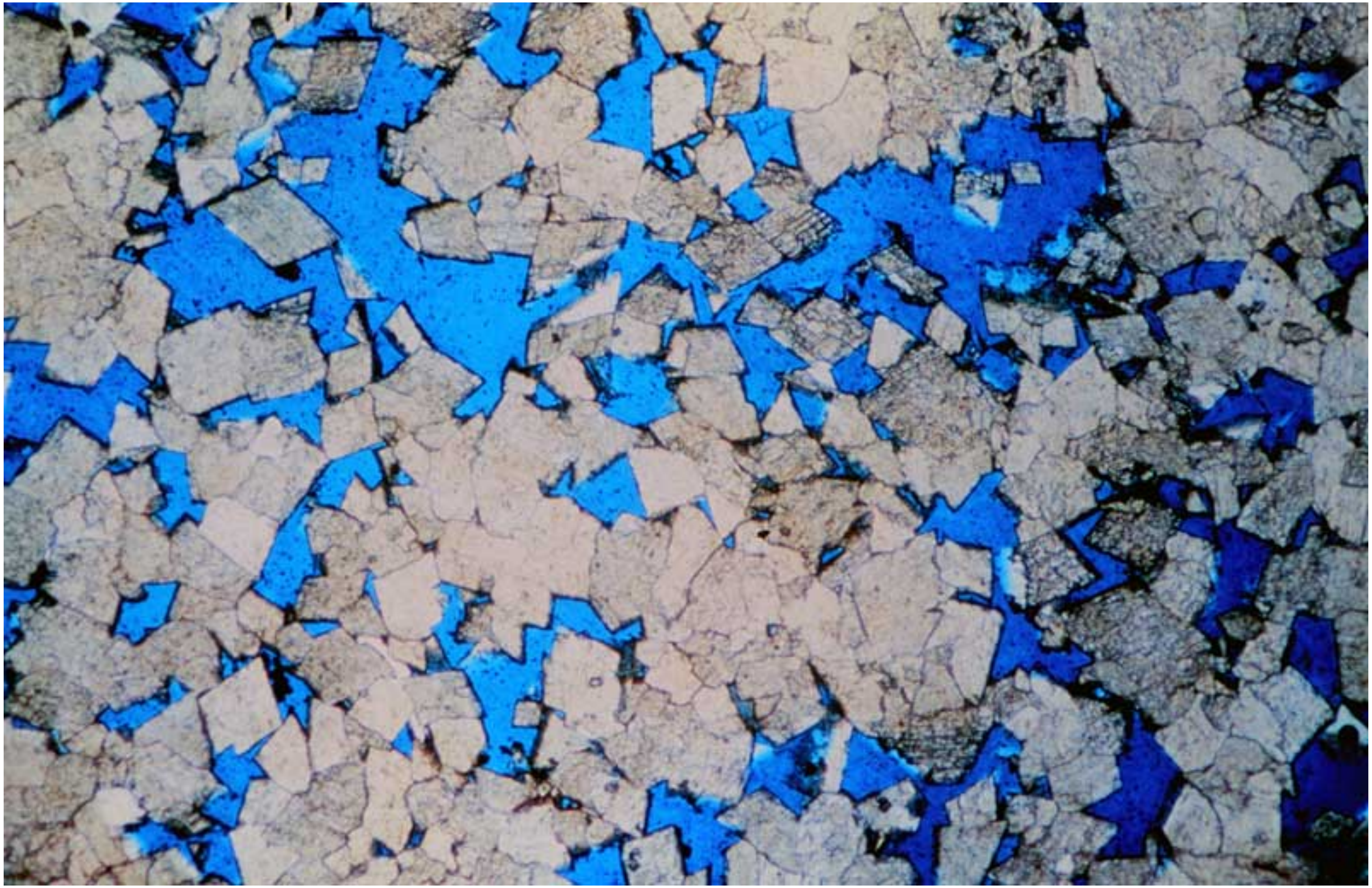


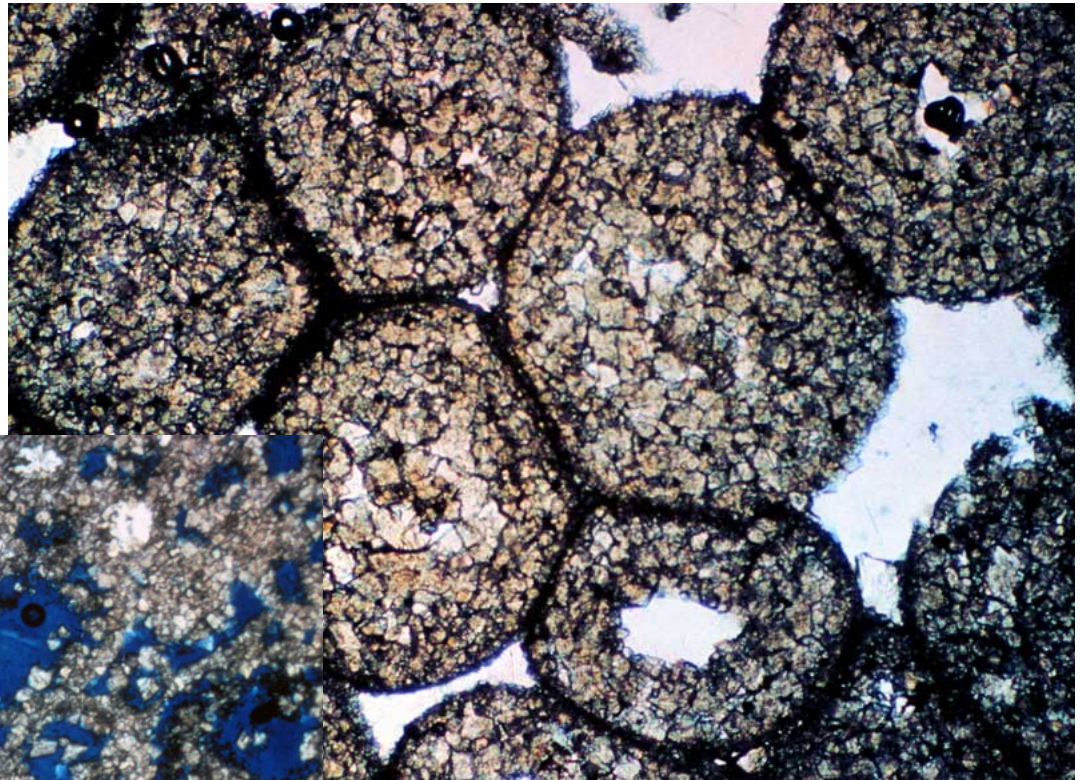
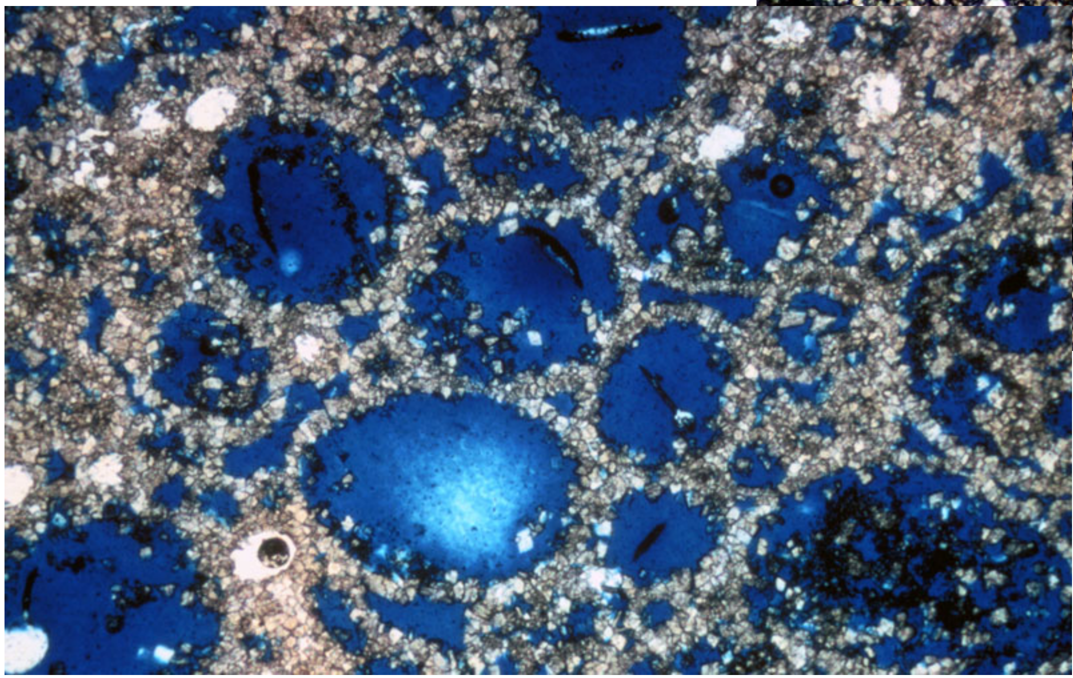
Late Dolomitization Associated with the Late Movement of Subsurface Waters

- Burial flow model (high T, Mg-brines, long time scales)
- Seepage reflux model (evap of sw and mixing with fresher water)







Marine Carbonates

PROPORTIONS OF SEDIMENTARY

ROCK TYPES IN EARTH'S SEDIMENTARY CRUST

CARBONATES	19-22%
SANDSTONES	22-37%

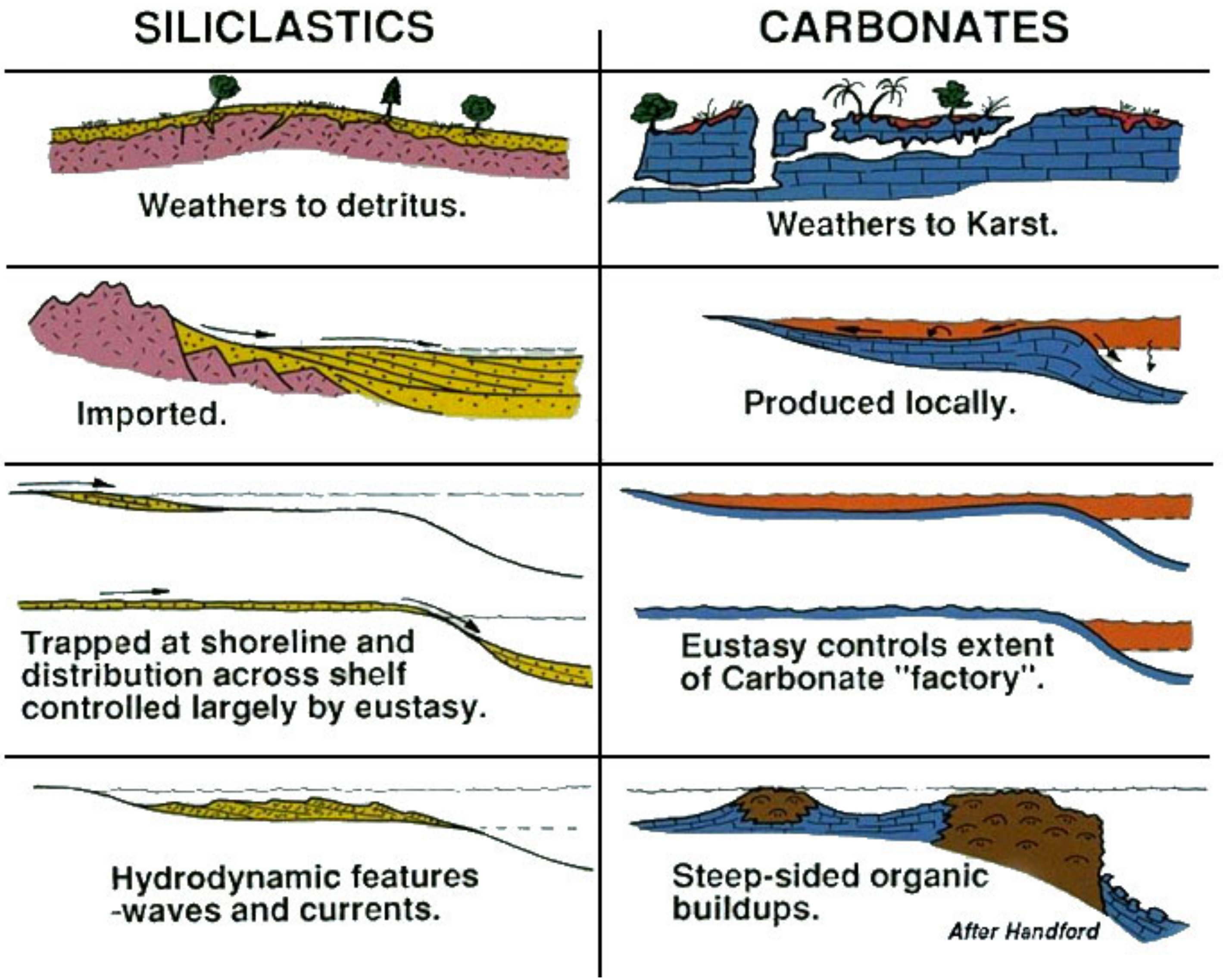
Mineralogy

TABLE 8.1 Chemical composition and crystal structure of the common carbonate minerals

Mineral	Chemical formula	Crystal system
Aragonite	$CaCO_3$	Orthorhombic
Calcite	$CaCO_3$	Hexagonal (rhombohedral)
Magnesite	$MgCO_3$	Hexagonal (rhombohedral)
Dolomite	$CaMg(CO_3)_2$	Hexagonal (rhombohedral)
Ankerite (ferroan dolomite)	$Ca(Fe,Mg)(CO_3)_2$	Hexagonal (rhombohedral)
Siderite	$FeCO_3$	Hexagonal (rhombohedral)

Limestones Form - Where?

- Shallow Marine –*Late Proterozoic to Modern*
- Deep Marine – *Rare in Ancient & more common in Modern*
- Cave Travertine and Spring Tufa – *both Ancient & Modern*
- Lakes – *Ancient to Modern*


SILICLASTICS
CARBONATES
Weathers to detritus.
Weathers to Karst.
Imported.
Produced locally.
Trapped at shoreline and distribution across shelf controlled largely by eustasy.
Eustasy controls extent of Carbonate "factory".
Hydrodynamic features -waves and currents.
Steep-sided organic buildups.
After Handford

Carbonate sediments	Siliciclastic sediments
The majority of sediments occur in shallow, tropical environments.	Climate is no constraint, sediments occur worldwide and at all depths.
The majority of sediments are marine.	Sediments are both terrestrial and marine.
The grain size of sediments generally reflects the size of organism skeletons and calcified hard parts.	The grain size of sediments reflects the hydraulic energy in the environment.
The presence of lime mud often indicates the prolific growth of organisms whose calcified portions are mud-size crystallites.	The presence of mud indicates settling out from suspension.
Shallow-water lime-sand bodies result primarily from localized physicochemical or biological fixation of carbonate.	Shallow-water sand bodies result from the interaction of currents and waves.
Localized buildups of sediments without accompanying change in hydraulic regimen alter the character of surrounding sedimentary environments.	Changes in the sedimentary environments are generally brought about by widespread changes in the hydraulic regimen.
Sediments are commonly cemented on the seafloor.	Sediments remain unconsolidated in the environment of deposition and on the seafloor.
Periodic exposure of sediments during deposition results in intensive diagenesis, especially cementation and recrystallization.	Periodic exposure of sediments during deposition leaves deposits relatively unaffected.
The signature of different sedimentary facies is obliterated during low-grade metamorphism.	The signature of sedimentary facies survives low-grade metamorphism.

carbonate v siliciclastic sediments