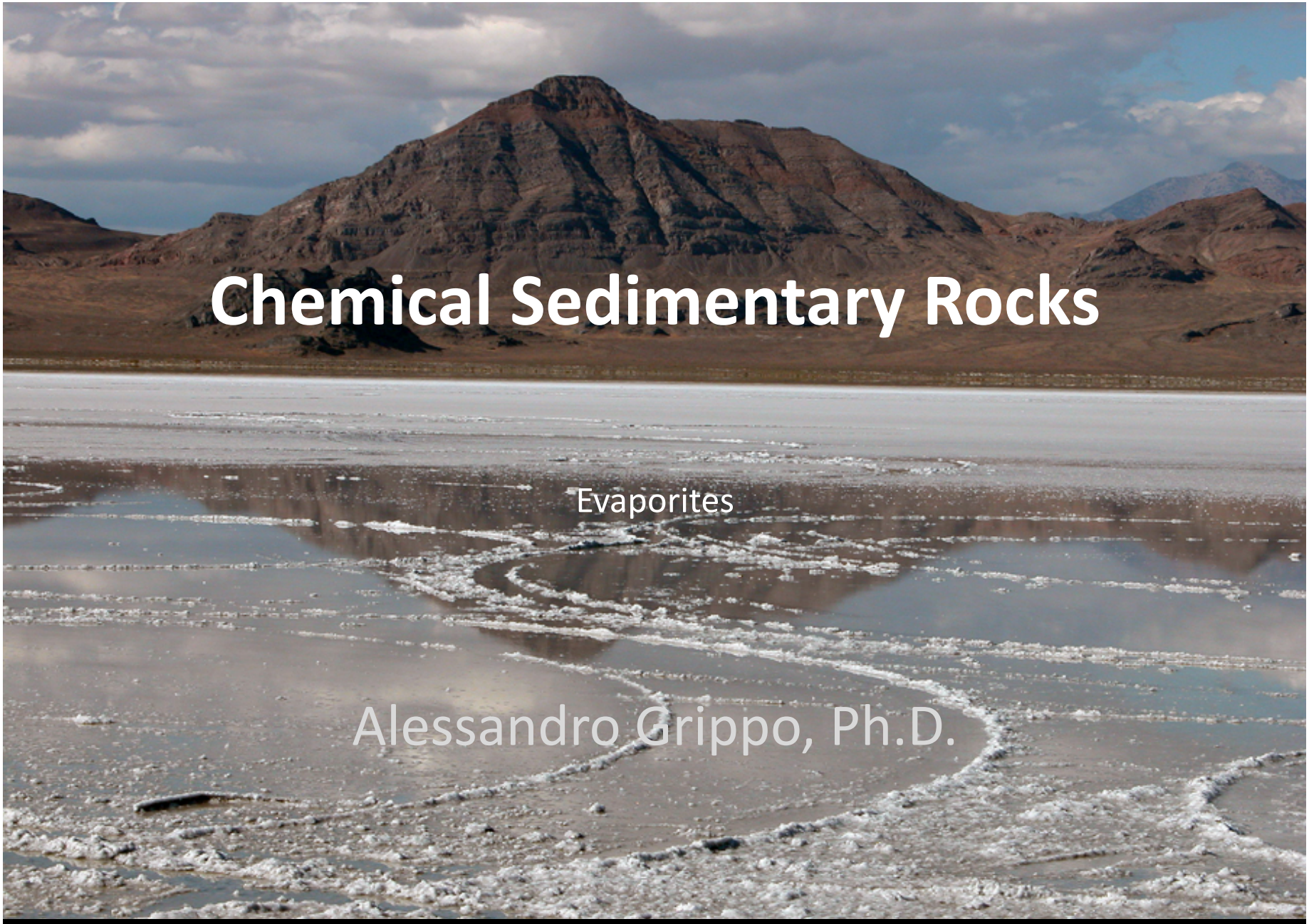

Chemical Sedimentary Rocks

Evaporites

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Bonneville Salt Flats, Wendover, Utah

What are Evaporites?

- Bedded sedimentary rocks that crystallize from hypersaline solutions known as brines

- Brines develop where the amount of water lost through evaporation exceeds freshwater influx from precipitation (rain), surface flow (rivers), groundwater flow

- High temperatures and lack of precipitation found in arid climates promote brine formation

- More than 100 evaporite minerals are known
  - Only few are abundant
  - Most consist of ions that are easily solved and that tend to stay in water for longer times
    - Na^+ and Cl^-
  - The most common evaporite minerals are:
    - Carbonates (calcite, aragonite, dolomite, magnesite)
    - Sulfates (gypsum and anhydrite)
    - Halides (halite, sylvite, carnallite)
    - Small amounts of Borates, Silicates, Nitrates, Sulfocarbonates

Common marine and non marine evaporite minerals

MARINE	EVAPORITES	NONMARINE	EVAPORITES
Halite	**NaCl**	**Halite, Gypsum, Anhydrite**	
Sylvite	KCl	Epsomite	$MgSO_4 * 7H_2O$
Carnallite	$KMgCl_3 * 6H_2O$	Trona*	$Na_2CO_3 * NaHCO_3 * 2H_2O$
Kainite	$KMgClSO_4 * 3H_2O$	Mirabilite	$Na_2SO_4 * 10H_2O$
Anhydrite	**$CaSO_4$**	Thenardite	$NaSO_4$
Gypsum	**$CaSO_4 * 2H_2O$**	Bloedite	$Na_2SO_4 * MgSO_4 * 4H_2O$
Polyhalite	$KMgCa_2(SO_4)_4 * 2H_2O$	Gaylussite	$NaCO_3 * CaCO_3 * 5H_2$
Kieserite	$MgSO_4 * H_2O$	Glauberite	$CaSO_4 * Na_2SO_4$

From: Prothero and Schwab, 2004. Sedimentary Geology, Freeman, New York

In Bold: minerals (and chemical compositions) you should know
*: Trona is not uncommon in the playa lakes of California.
As a matter of fact a village born for the mining of trona on the west bank of Searles Lake is aptly named Trona

Evaporites today and in the past

- Today's evaporites
  - uncommon
  - in areas with very high temperatures, extremely low rainfall
    - Playa lakes of California and Nevada
    - Sabkhas of the Persian Gulf

- Peaks of evaporites during Cambrian, Permian, and Triassic
  - widespread aridity must be coupled with tectonic setting that favors intermittent connections of coastal areas to the sea
  - other sediments (clastics, carbonates) must be scarce or absent

Playas of Basin and Range Desert

(California, Nevada, Utah)

Sabkhas of the Persian Gulf

Nonmarine Evaporites

- Deposited in closed lakes with interior drainage and no outlet
- Typical of arid and semiarid regions

- Scant precipitation brings sediment into lakes
  - Coarse clastics stop in alluvial fans
  - Muds and ions travel with water to basin bottom
  - Muds are deposited first, when water stands still
  - Evaporation eventually causes salts to crystallize


Bonneville Lake
Wendover, Utah
© Alessandro Grippo

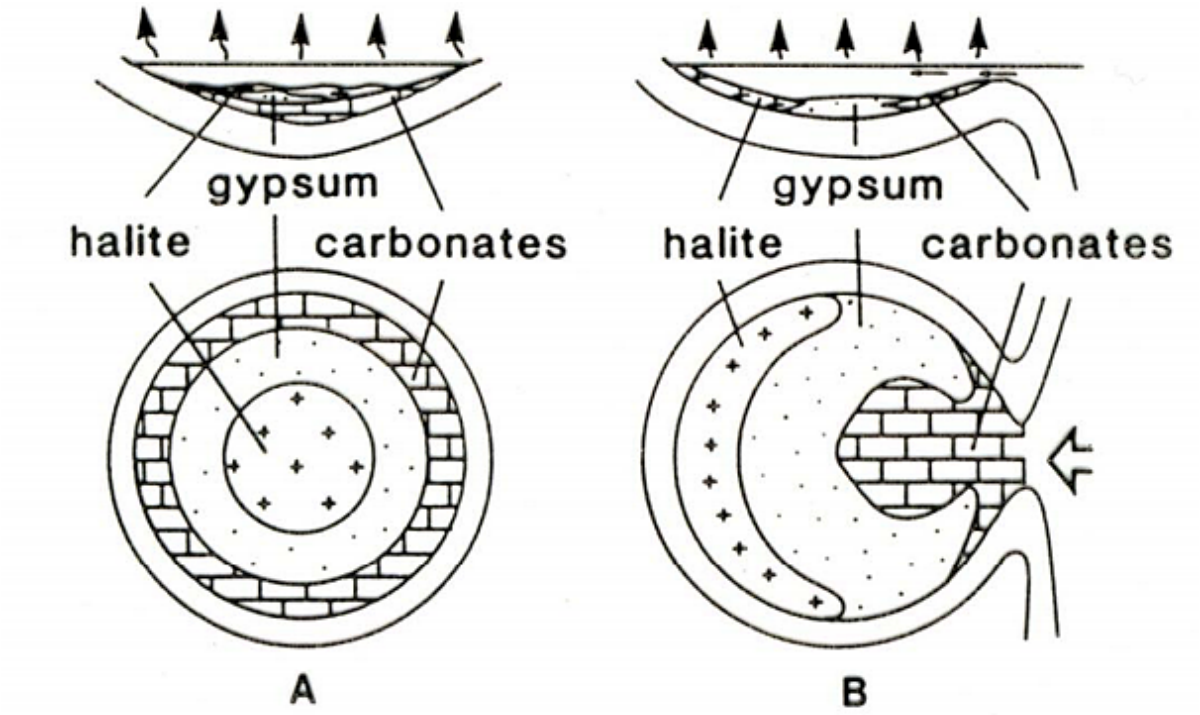
Halite crystals from the Bonneville Lake
Wendover, Utah

A playa lake: Searles Lake

Searles Lake is a playa lake west of Death Valley. In this picture you can see the salt-encrusted bottom of the valley and a few residual brine pools. Most salts here are halite and trona

Trona, California

evaporite depositional patterns

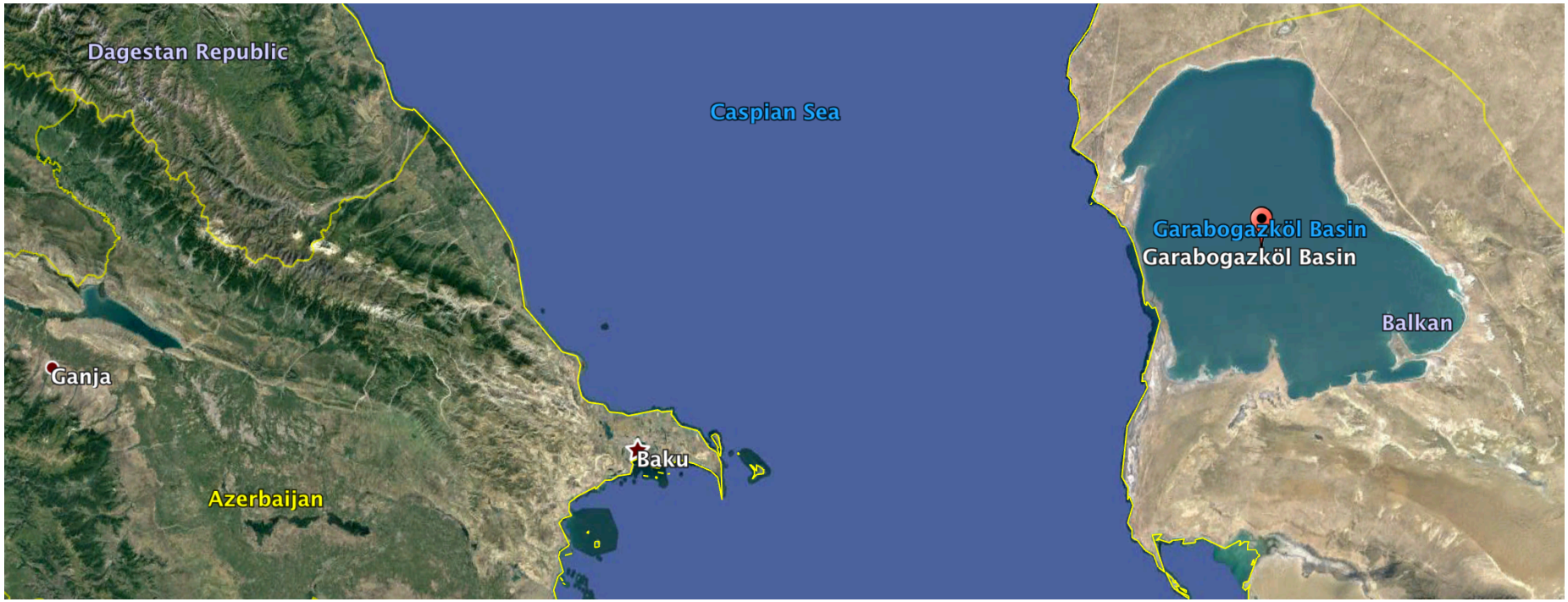


A - Bullseye pattern
most soluble salts in basin center.
Typical of completely enclosed basins

B - Tear-drop pattern
most soluble salts occur away from basin entrance. Typical of restricted basins with near-permanent connection to open ocean

Garabogazkol, Turkmenistan

an example of intermittently enclosed basin



Shallow Marine Evaporites

- Supratidal and intertidal (sabkha) deposits
  - Typical today of the Persian Gulf region

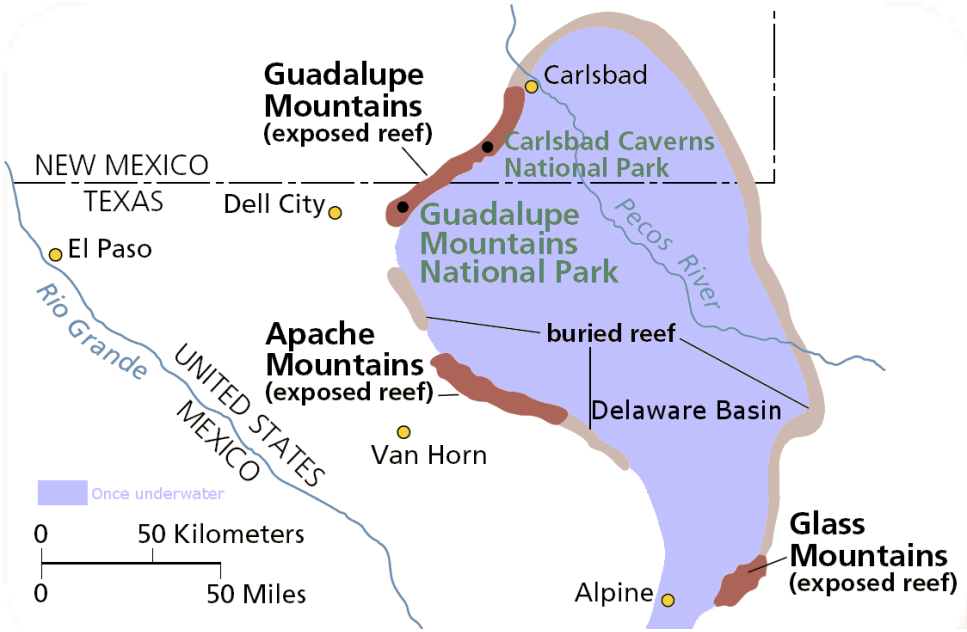
- Truly shallow marine ancient deposits
  - Marine shelf areas with depth less than 5 m
  - Very few modern analogs

Sabkha along the Persian Gulf coast of the Arabian peninsula

- Sabkha minerals include anhydrite, gypsum, dolomite
- Anhydrite occurs as lumps or nodules that replace original gypsum
- This creates a so-called chickenwire structure
- Sabkha evaporites have been recognized in the Permian of Texas and New Mexico

Chickenwire structure in anhydrite
Zechstein Salt, Germany

- Many ancient deposits come from shallow shelves and basins
- Typically finely laminated
- Today, these deposits are not common
- These sequences are very thick, which is not compatible with a shallow body of water
- Likely, there were several cycles of inundation and evaporation that stacked successive layers of salts on top of each other



Left: laminated gypsum from the Castile Formation of Delaware Basin, Texas
Right: map of the Permian Delaware Basin, Texas and New Mexico

Deep Marine Evaporites

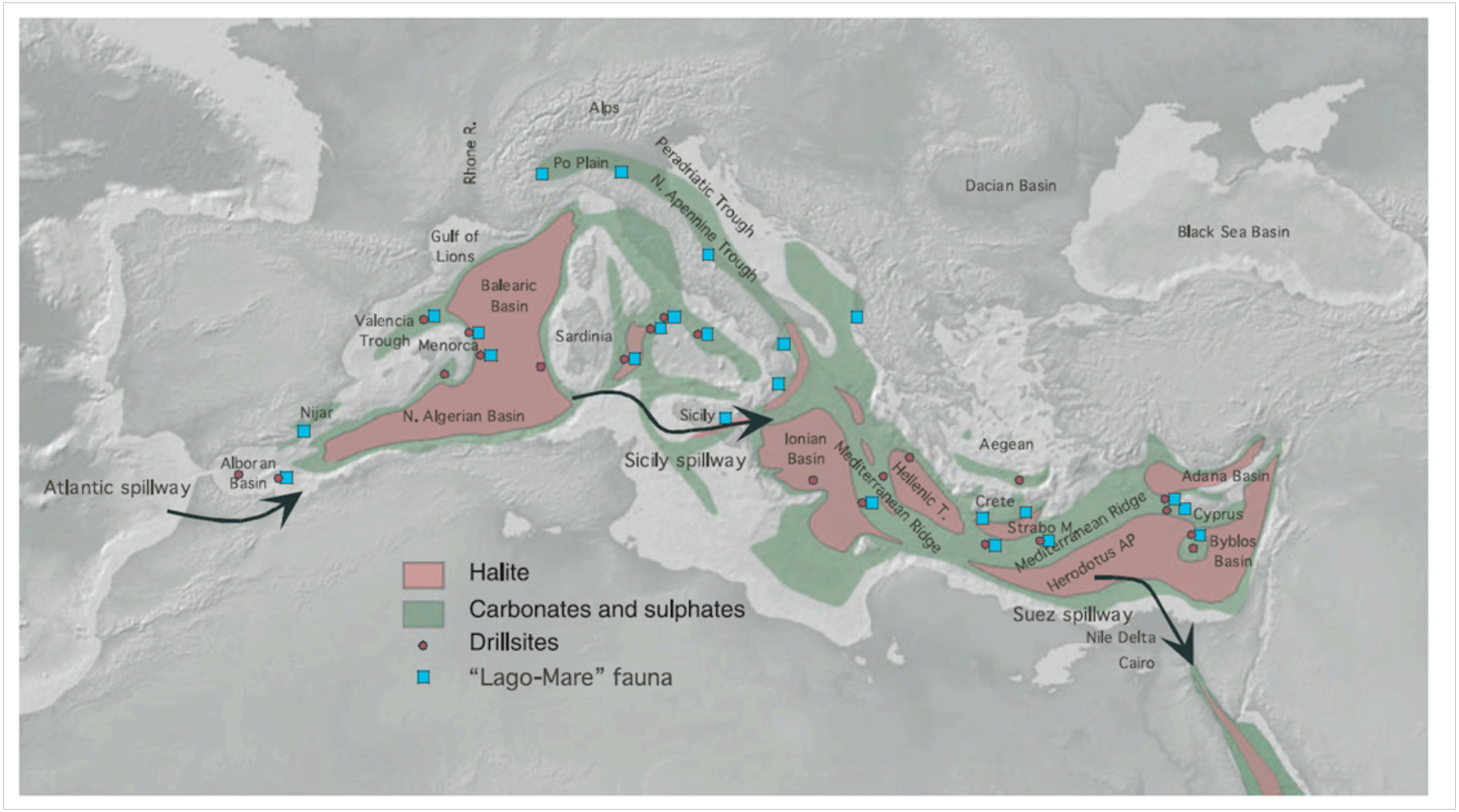
- Absence of laminations
- Presence of gravel-size block of evaporites
- Several cycles of sedimentation
  - That means that we have alternate flooding and desiccation

- Example: the Mediterranean Salinity Crisis

The Mediterranean Sea today

left over from the Tethys Ocean

The Mediterranean Sea during the Miocene



Thick layers of gypsum deposited during the Mediterranean Salinity crisis
Gypsum-Sulfur Formation, Santerno River, Borgo Tossignano, Bologna, Italy

Individual crystals of gypsum (with “swallow-tail” pattern) within the gypsum layers of the Gypsum-Sulfur Formation. This chaotic assemblage is evidence of erosion and re-deposition

Gypsum-Sulfur Formation, Borgo Tossignano, Bologna, Italy

Salt for human consumption

- Table salt is an essential ingredient in human diet
- Some salt is mined
  - Pink Salt from the Himalayas
  - Real Salt from Utah
- Most salt is harvested directly from the ocean
  - Many places around the world, including San Francisco Bay, California

A salt pond in Sicily: salt has been harvested and prepared for treatment before being put on sale
Trapani, Italy

Salt ponds in San Francisco Bay

The red colors of the water, sometimes veering to hues of magenta and sometimes towards tones of green, depend on algae that thrive in salt waters, that react to different levels of salinity in the water.

Conclusions

- Evaporites are chemical sedimentary rocks that form because of evaporation of water
- Upon evaporation, dissolved ions form crystals
- Typical of arid regions
- Can form:
  - inland in playa lakes
  - in shallow sea water
  - in deep sea water
- Most common minerals are
  - Gypsum **$CaSO_4 * 2H_2O$** and Anhydrite **$CaSO_4$**
  - Halite (table salt) **NaCl**