Dolomitization & Anhydrite Precipitation by Highly Evaporated Seawater formed during Late Permian Salt Deposition, Permian Basin, Texas & New Mexico

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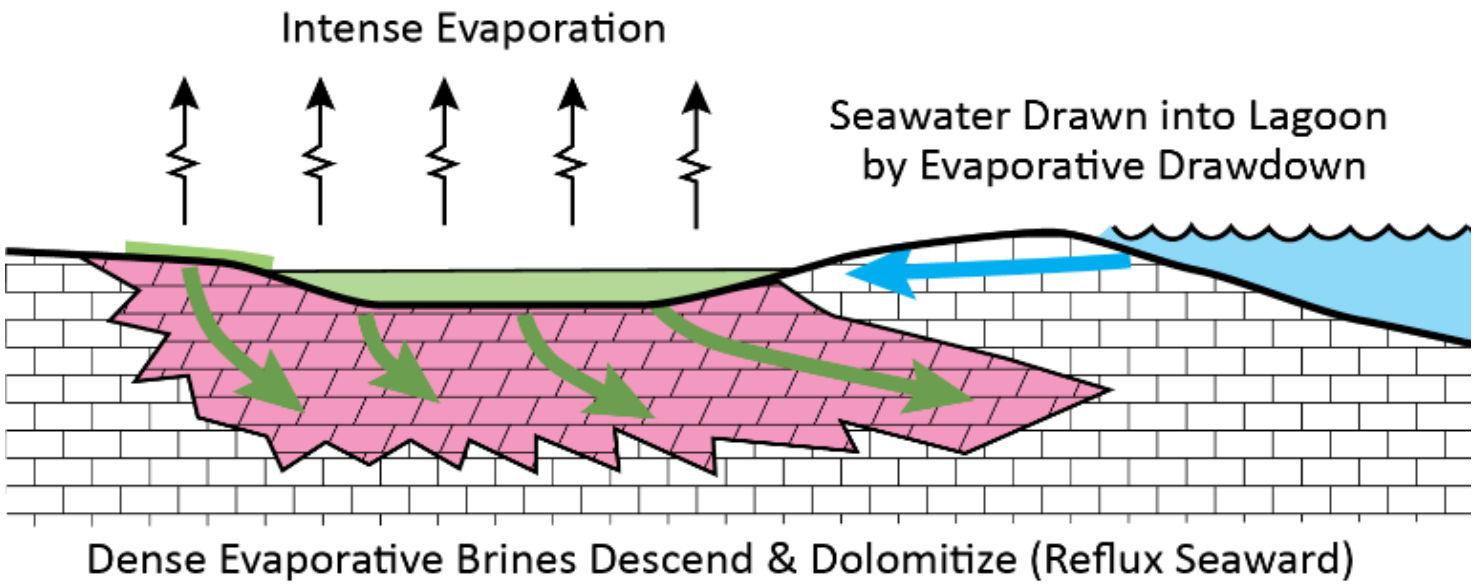
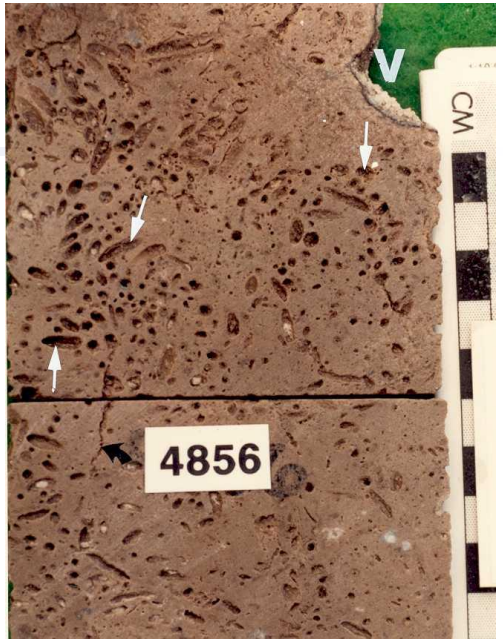
Dolomitization
along fractures

Dolomite in the Permian Basin

- Dolomitization is important for reservoir quality in many conventional reservoirs in the Permian Basin
- Most dolomitization in the Permian of the Permian Basin occurred shortly after deposition by evaporated seawater (reflux dolomitization)
- Later stage dolomites are also present including some derived from highly evaporated seawater the precipitated Salado salt





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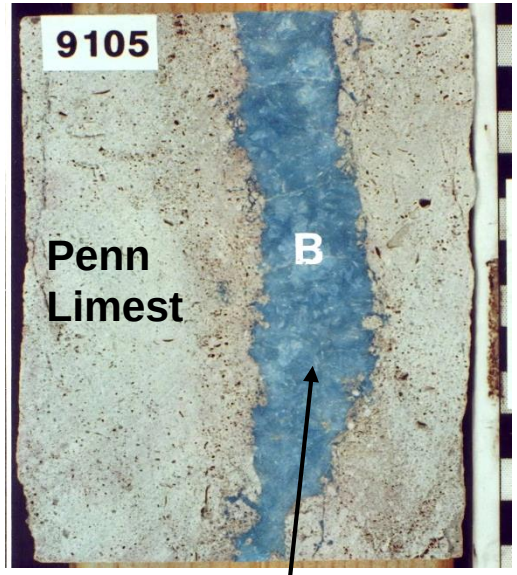
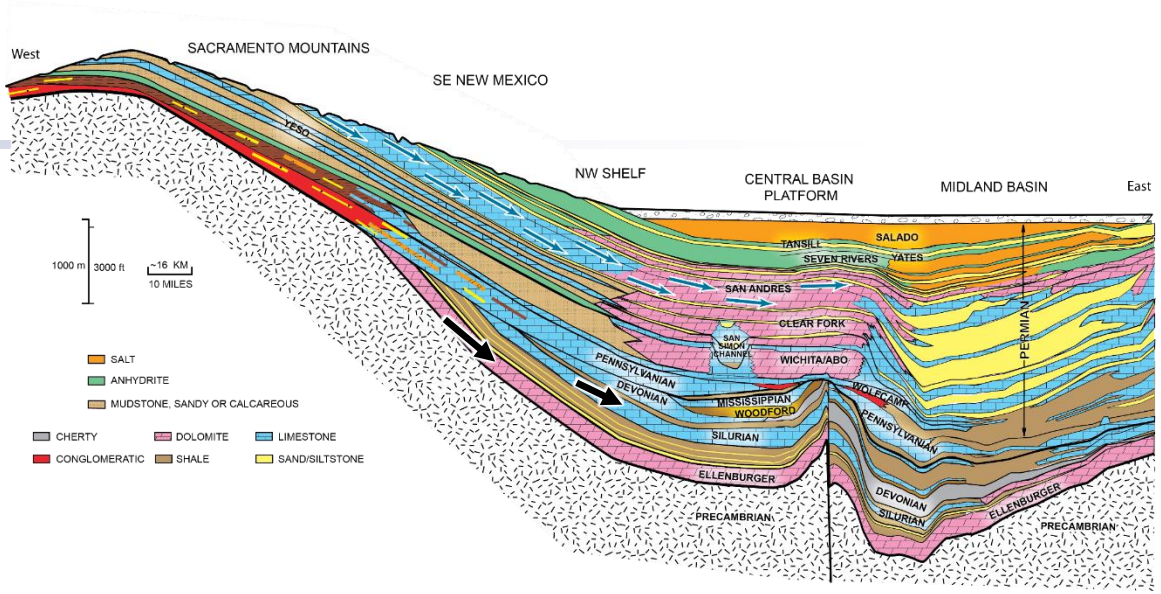


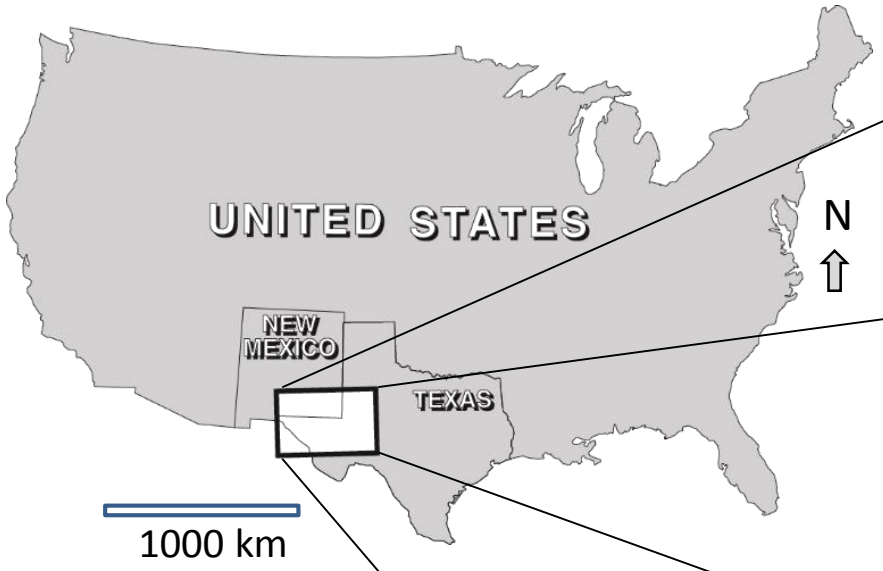
Late Fe dolomite

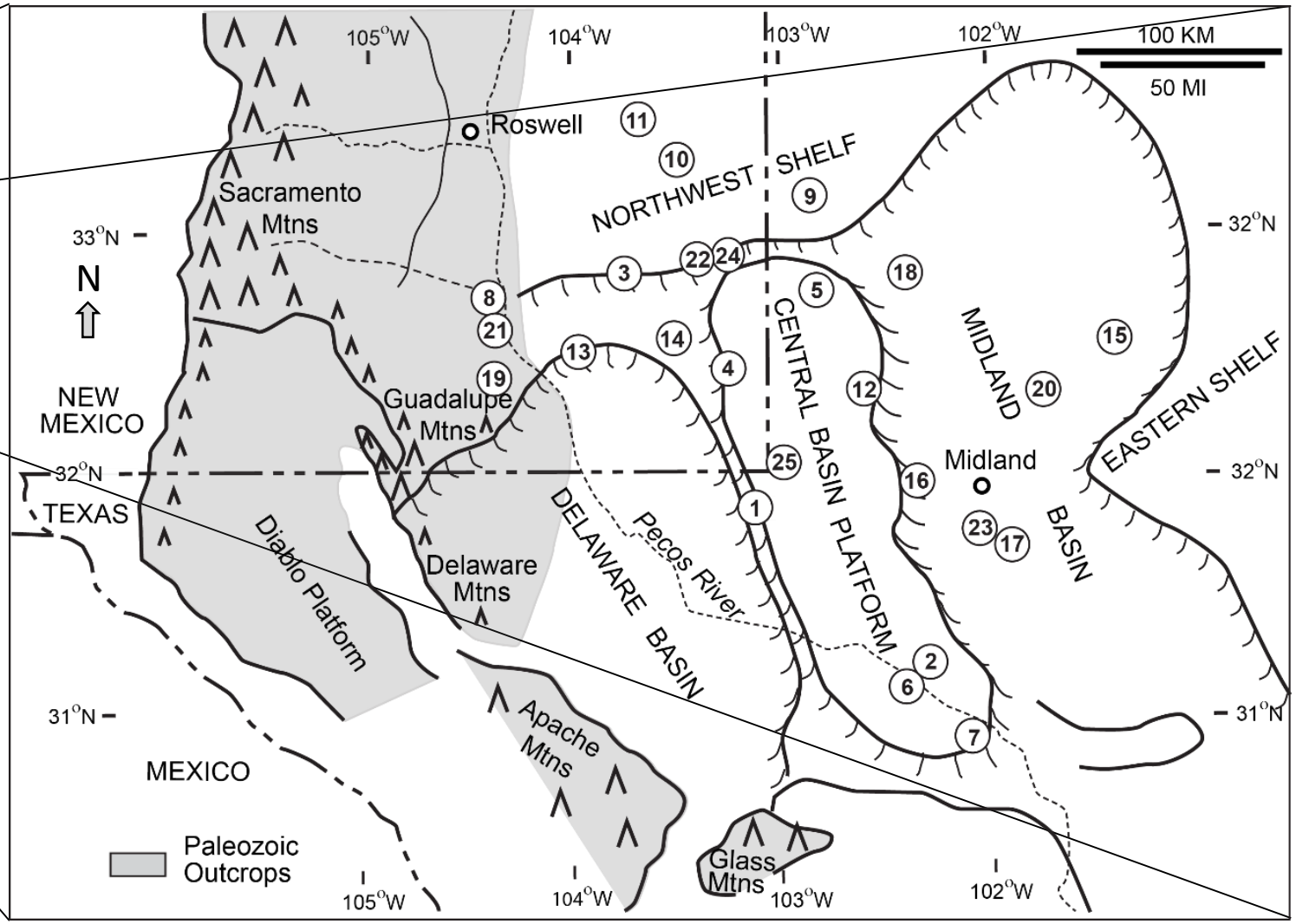
Dolomitization & Anhydrite Precipitation by Highly Evaporated Seawater in Moderately Deep Subsurface



- **Two main Permian Basin formation waters**
  - **Neogene meteoric water from SE New Mexico**
  - **Late Permian highly evaporated seawater**
- **Evaporating seawater to halite saturation results in large amounts of dissolved Mg (McCaffrey et al, 1987)**
- **Formation water chemistry of the late Permian highly evaporated seawater supports dolomitization by those waters as they descended into the basin**
- **Volumetrics of late Permian seawater evaporating to form Salado salt indicate substantial volumes of Mg & dolomite could form**
- **Highly evaporated seawater has abundant SO_4 causing $CaSO_4$ precipitation when Ca is liberated during dolomitization**
- **Moderately late dolomite and anhydrite are common in the Permian Basin**
- **Similar formation water chemistries in other evaporitic basins suggest similar processes in other basins**

Formation waters were sampled & analyzed across the Permian Basin by Alan Stueber



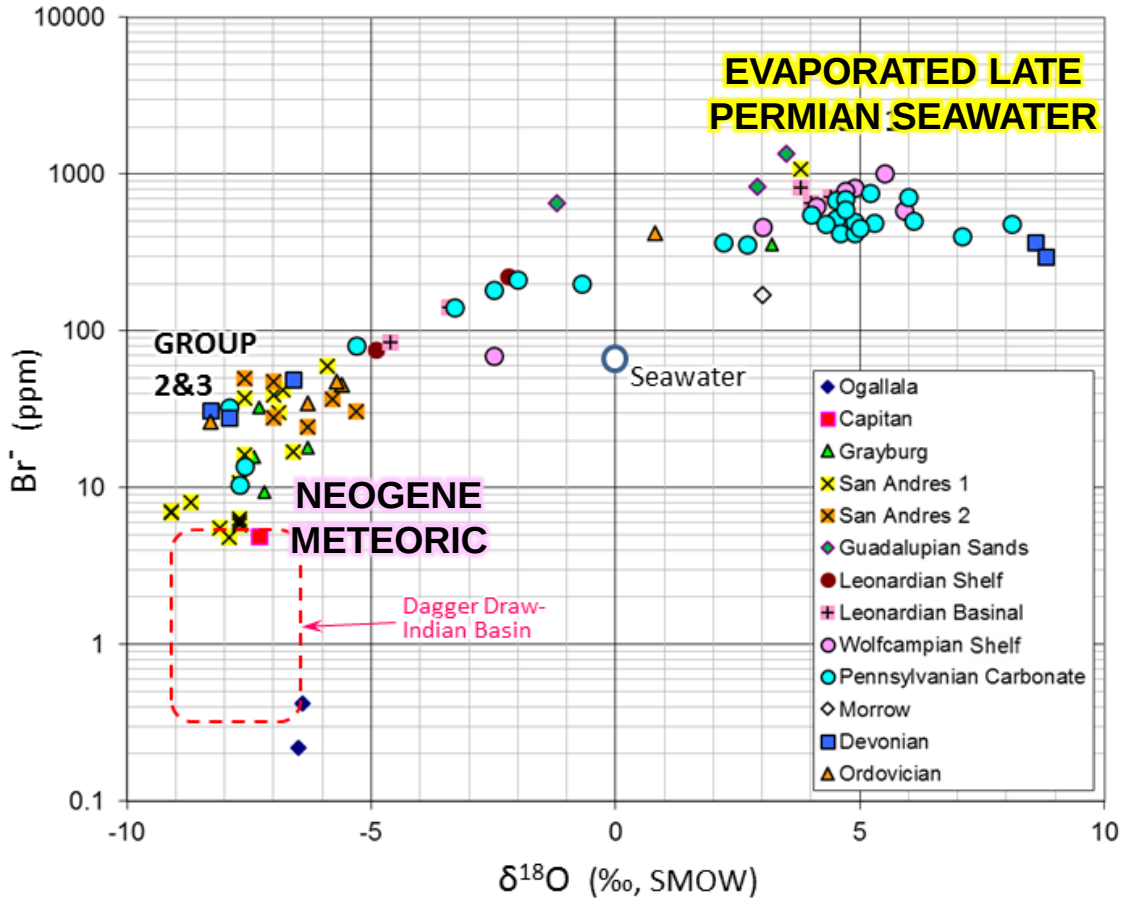


From Stueber et al 1998 & Saller & Stueber (2018)

Two Types of Permian Basin Formation Waters

- **(1) Neogene water identified by low (meteoric) δD-H & $\delta^{18}O$**
- **(2) Late Permian Highly Saline water**
  - **High Br, High $\delta^{18}O$, Cl>Na, Ca>SO4**

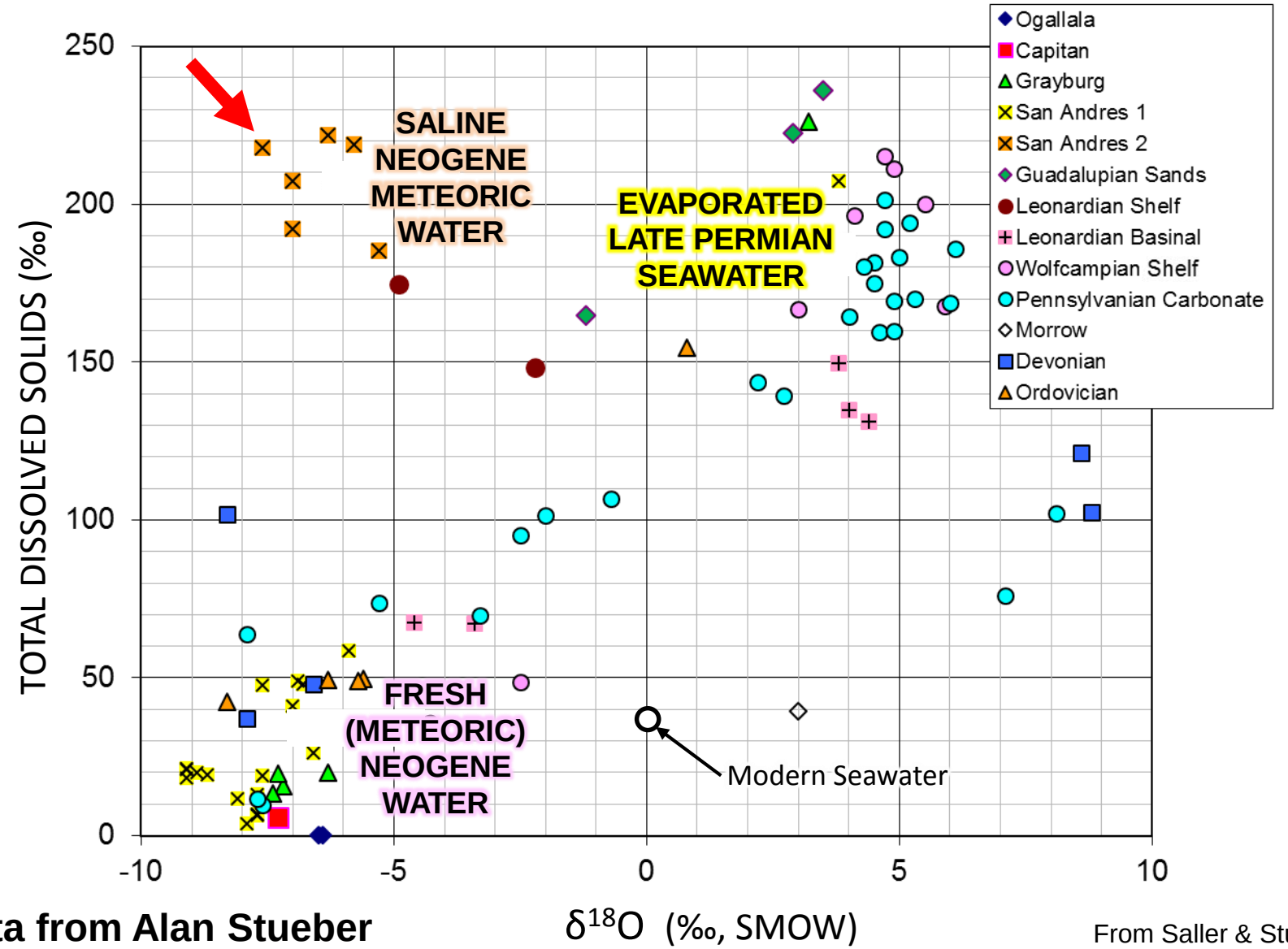
Highly saline Permian waters are still present where Neogene meteoric waters have not displaced them



Data from Alan Stueber

From Saller & Stueber (2018)

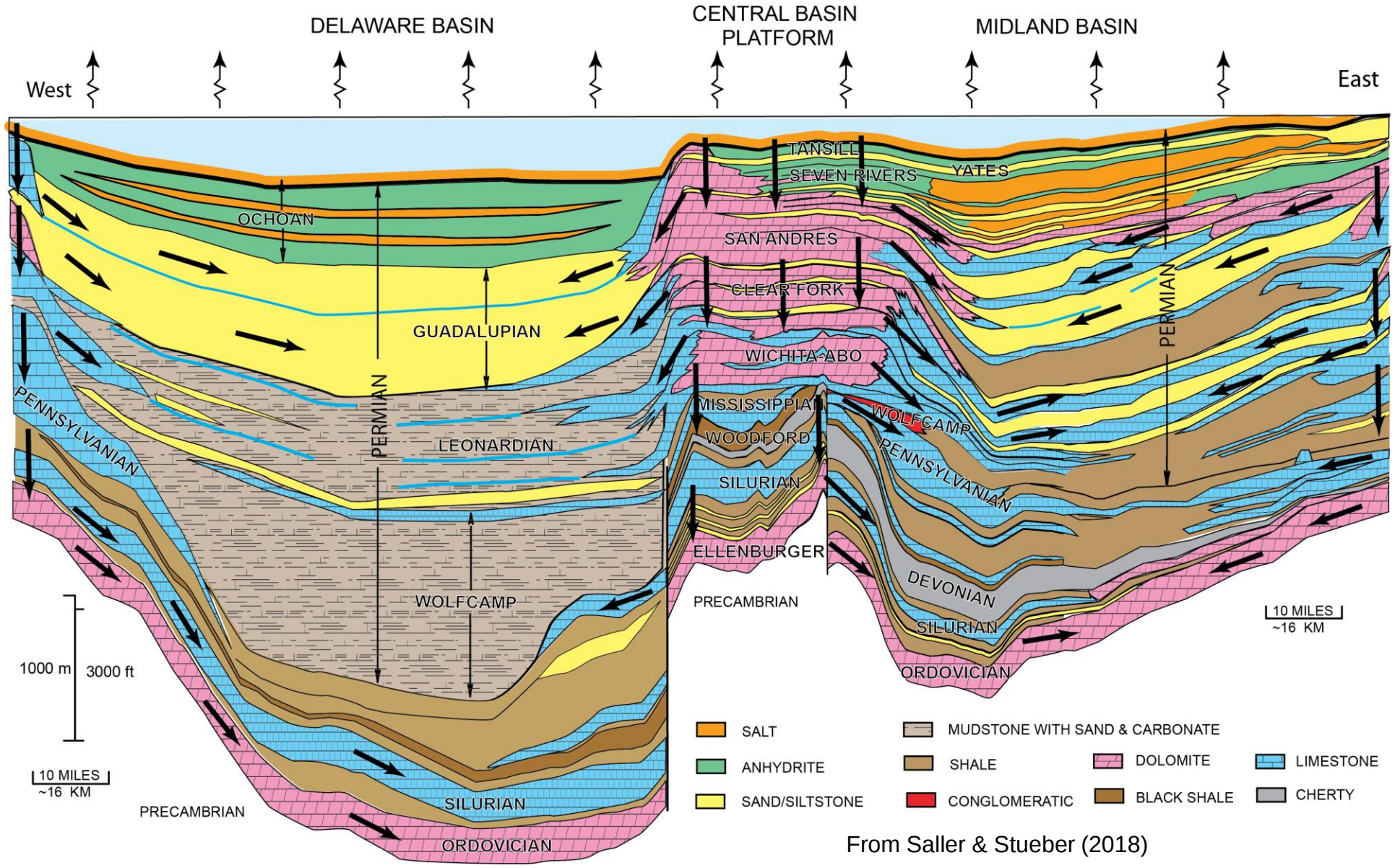
Some Neogene Meteoric Formation Waters Have High Salinities Because they Dissolved Nearsurface Salts as they Descended into the Basin



Data from Alan Stueber

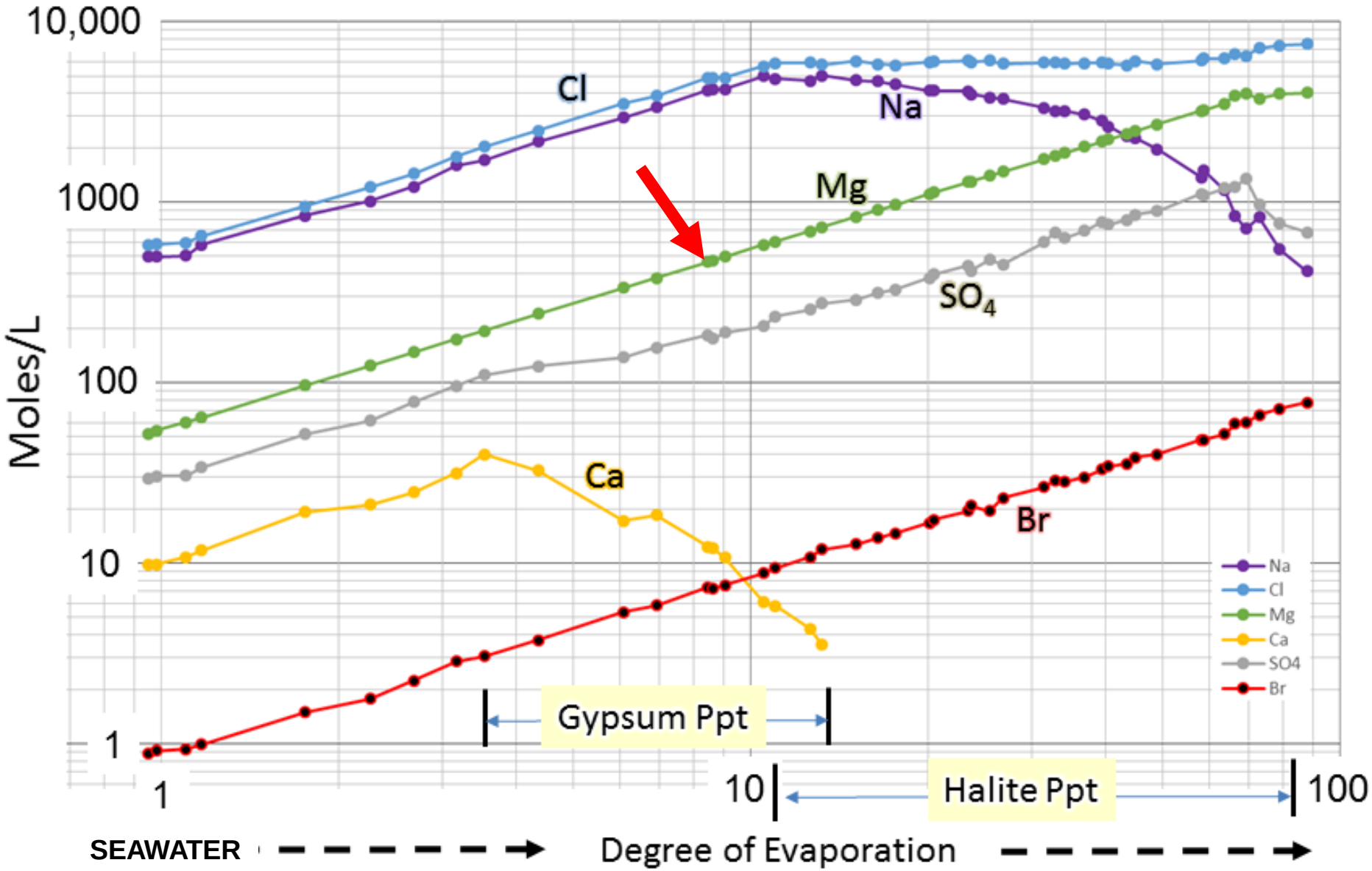
From Saller & Stueber (2018)

Highly Saline Waters Formed & Descended during Deposition of Late Permian Salado Salt



From Saller & Stueber (2018)

Evaporating seawater produces large amounts of dissolved Mg (data from McCaffrey et al, 1987)

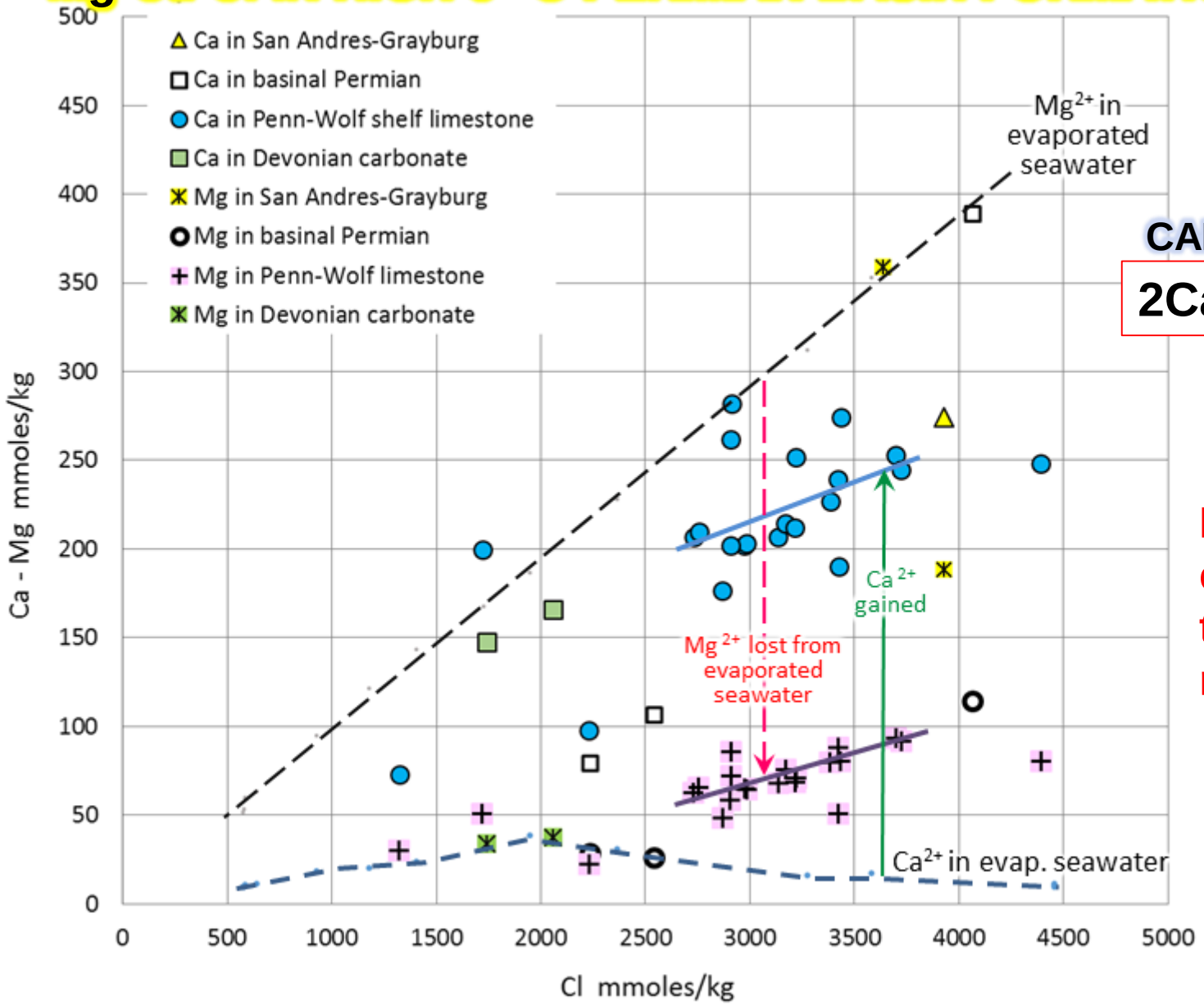


Dolomitization & Anhydrite Precipitation by Highly Evaporated Seawater in Moderately Deep Subsurface

- Two main Permian Basin formation waters
  - Late Permian highly evaporated seawater
  - Neogene meteoric water from SE New Mexico
- Evaporating seawater to halite saturation results in large amounts of dissolved Mg (McCaffrey et al, 1987)
- Formation water chemistry indicates dolomitization by the late Permian highly evaporated seawater that descended into the basin
- Volumetrics of late Permian seawater evaporating to form Salado salt indicate substantial volumes of Mg & dolomite could form
- Highly evaporated seawater has abundant SO_4 causing $CaSO_4$ precipitation when Ca is liberated during dolomitization
- Moderately late dolomitization and anhydrite precipitation are common in the Permian Basin
- Similar formation water chemistries in other evaporitic basins suggest similar processes in other basins

Formation water chemistry indicates dolomitization by late Permian evaporated seawater that descended into the basin

Mg-Ca-Cl IN HIGH $\delta^{18}O$ PERMIAN BASIN FORMATION WATERS



CALCITE **DOLOMITE**

$$2CaCO_3 + Mg^{2+} \rightarrow CaMg(CO_3)_2 + Ca^{2+}$$

Moles of Mg lost from evaporated seawater is similar to, but commonly slightly more than moles of Ca gained

From Saller & Stueber (2018)

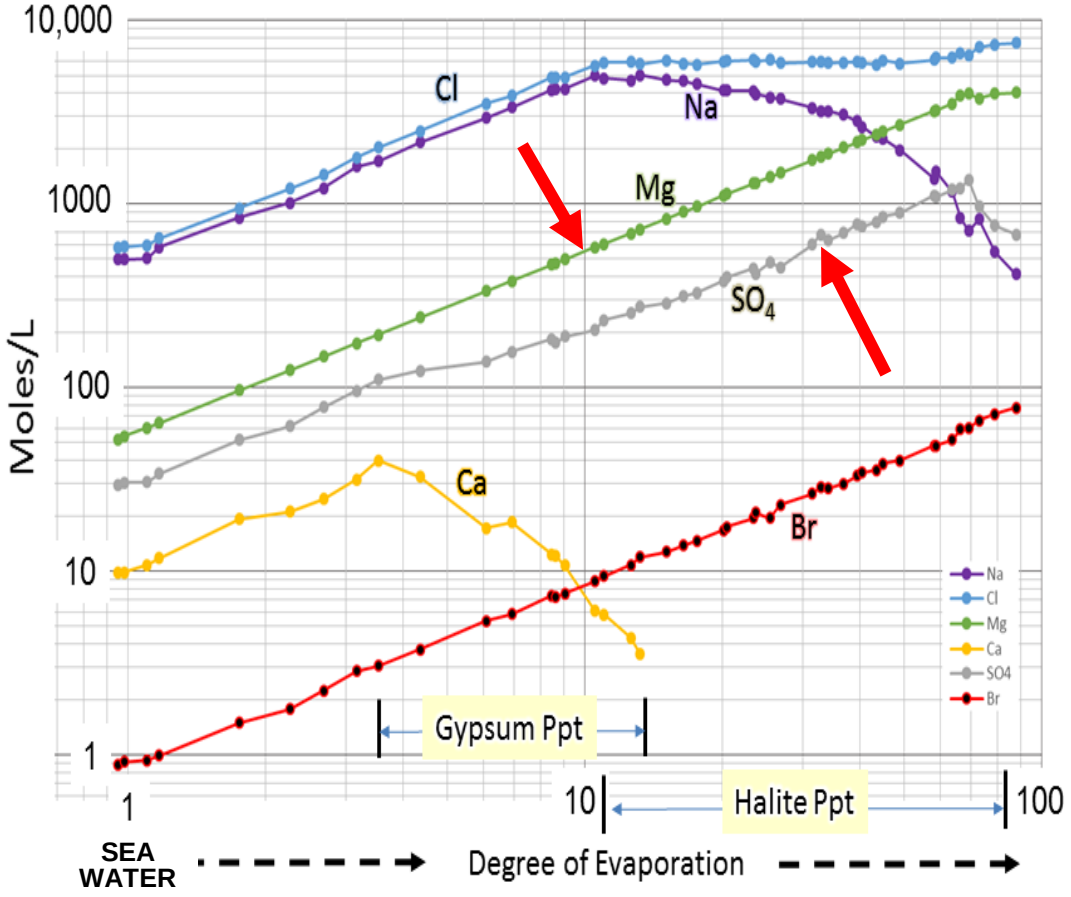
Volumetrics of late Permian seawater evaporating to form Salado salt indicate substantial volumes of dolomitization

- 1500 feet (~500 m) of Upper Permian Salado Fm (dominantly salt)
- 1 m of salt require ~70 m of evaporated seawater
- 500 m of Salado salt requires ~35,000 m of seawater
- 50 mmoles of Mg/liter: 1 m^3 of SW has 50 mole
- 35,000 cubic m of seawater contains 1,750,000 moles of Mg
- Dolomitize 3,500,000 moles of $CaCO_3$
- 3,500,000 moles of $CaCO_3$ * 100 g/mole = 350,000,000 g
- 350,000,000 g/ 2.7 g/cc = 130,000,000 cc of $CaCO_3$
- 130,000,000 cc of $CaCO_3$ = 130 cubic m
- **Mg from Salado depositional brine could dolomitize 130 m of limestone across the basin**

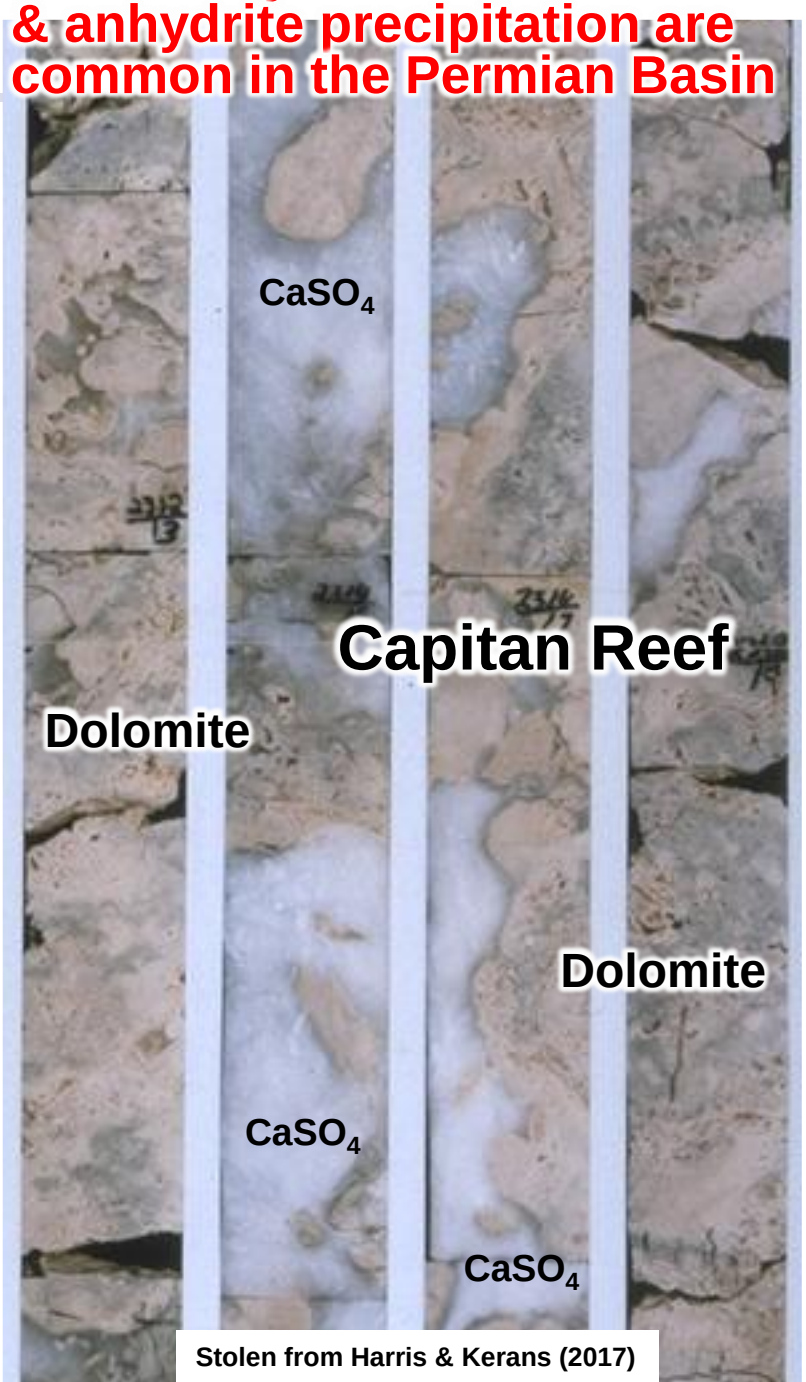
Highly evaporated seawater has abundant SO_4 & little Ca causing $CaSO_4$ precipitation when Ca is liberated during dolomitization

$$2CaCO_3 + Mg^{2+} \rightarrow CaMg(CO_3)_2 + Ca^{2+}$$

$$Ca^{2+} + SO_4 \rightarrow CaSO_4$$



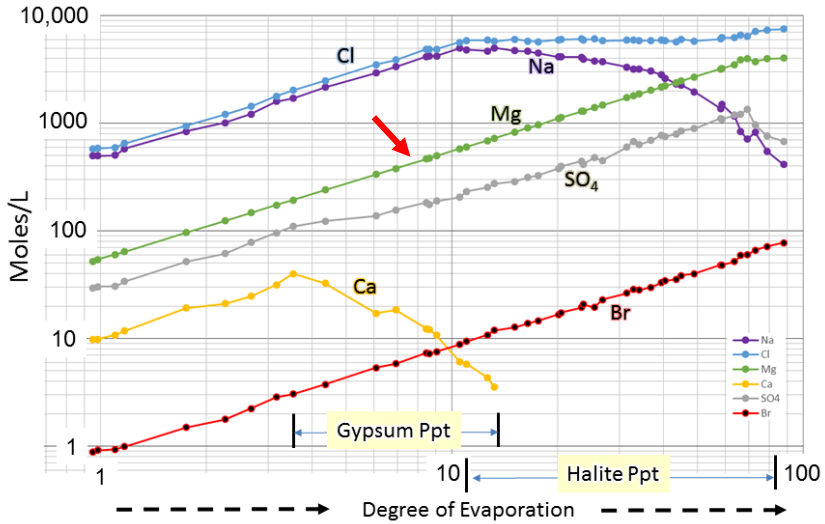
Moderately late dolomitization & anhydrite precipitation are common in the Permian Basin

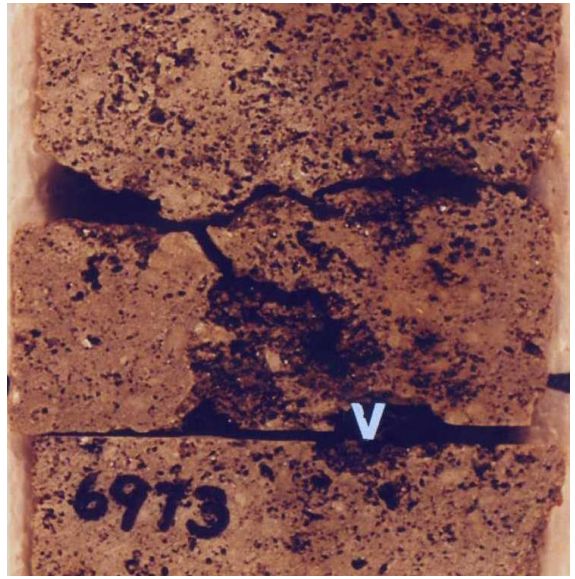


Stolen from Harris & Kerans (2017)

Summary: Dolomitization & Anhydrite Precipitation by Highly Evaporated Seawater in Moderately Deep Subsurface

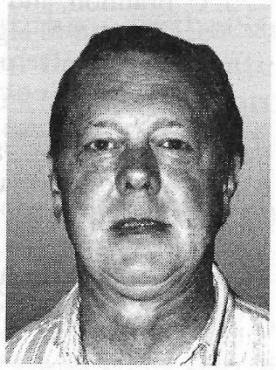
- Late Permian highly evaporated seawater displaced formation waters in the Permian Basin
- Evaporating seawater to halite saturation resulted in large amounts of dissolved Mg
- Current formation water chemistry indicates dolomitization by the late Permian highly evaporated seawater that descended into the basin
- Volumetrics indicate late Permian seawater evaporating to form Salado salt could form substantial volumes of Mg & hence dolomite
- Highly evaporated seawater has abundant SO_4 causing $CaSO_4$ precipitation when Ca is liberated during dolomitization
- Moderately late dolomitization and anhydrite precipitation are common in the Permian Basin
- Similar formation water chemistries in other evaporitic basins suggest similar processes in other basins
- Maybe the source for waters causing hydrothermal dolomite





Late, Hydrothermal Dolomite, Penn, Horseshoe Atoll

Alan Stueber



Alan Stueber received B.S. and M.A. degrees from Washington University (St. Louis) and a Ph.D. from the University of California at San Diego. He has held academic positions at Miami University (Ohio) and Louisiana State University, and currently teaches geology and hydrology courses at Southern Illinois University (Edwardsville). His present research interests involve geochemical studies of groundwaters and saline formation waters.

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