Sediments Mineralogy in Soda Lake and Responses to Paleoenvironmental Change

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DEPARTMENT OF GEOSCIENCES

CALIFORNIA STATE UNIVERSITY - BAKERSFIELD

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ACKNOWLEDEMENTS

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- Dr. Dallas Rhodes, Dr. Rob Negrini
- Mr. Alex Rodriguez, CSUB staff and students
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CSUB Geology Faculty Research

Chandranath Basak: Isotope geochemistry, chemical oceanography, geochemical modeling, environmental geochemistry, paleoclimatology, marine geology

Jan Gillespie: Petroleum geology, GIS

Adam Guo: marine sedimentation, clay mineralogy, paleoclimatology, geomechanics and natural hazards, subduction zone earthquakes, oil reservoir/source rock diagenesis

William Chris Krugh: basin analysis, structural geology, thermochronology, tectonic geomorphology, Earth surface processes

David Miller: Basin Analysis, Sedimentology/Stratigraphy, Quaternary Tectonics, Stratigraphy, and Climate Change, Cordilleran Orogenesis, Hazard Assessment

Katie O'Sullivan Volcanology, Igneous Petrology, Planetary Geology

Anthony Rathburn: Micropaleontology, biogeochemistry, marine geology, methane hydrate geochemistry, proxies for organic-rich/oxygen-poor paleoenvironments

Liaosha Song: Petroleum Geology; Petrophysics

NSF CREST Center
$10.5 Million over 10 years

Plus over $2.5 Million in other external grants

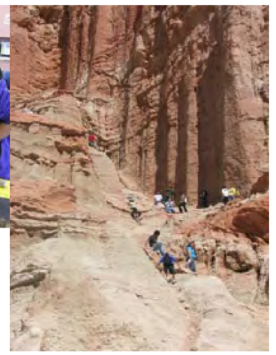
Department of Geological Sciences

- **6 Tenure-Track faculty**
- **2 full-time Lecturers**

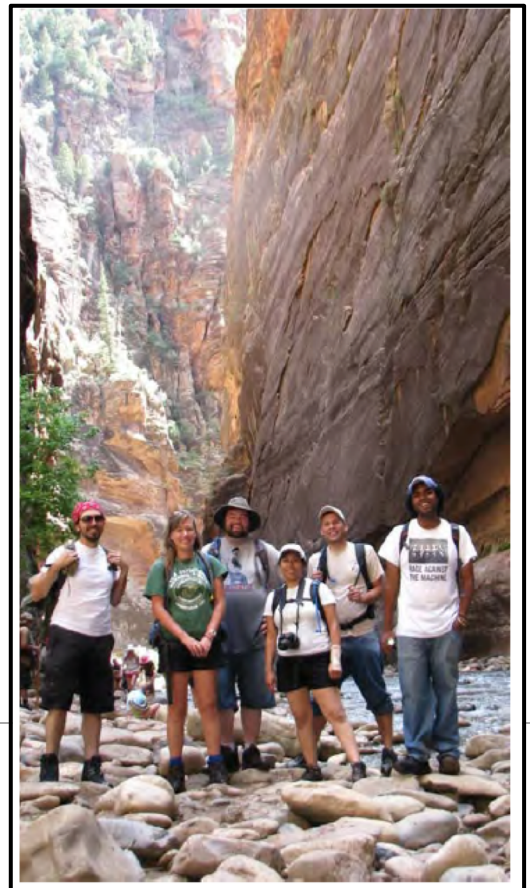
- **~85 undergraduate majors**
- **~35 graduate students**

CSUB Geosciences: Past, Present, and Future

Pam and Jan at the 2009 GSA Meeting in Portland where they presented their experience with their dual enrollment Physical Geology class.

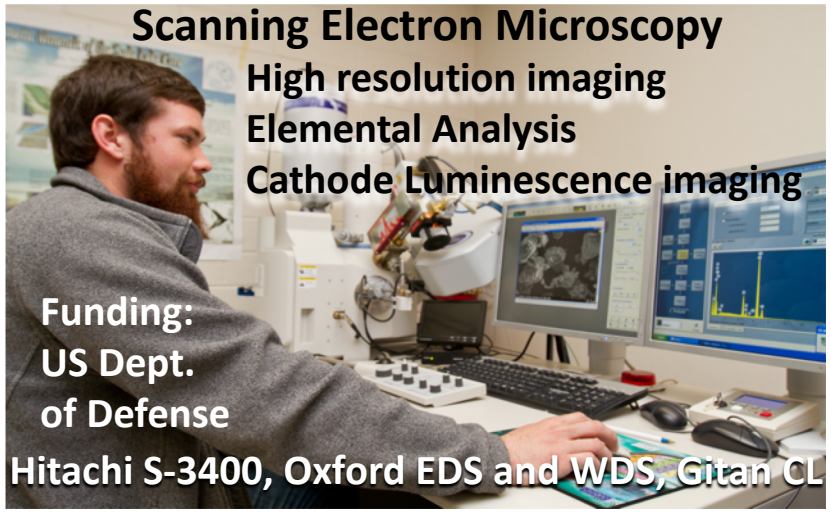


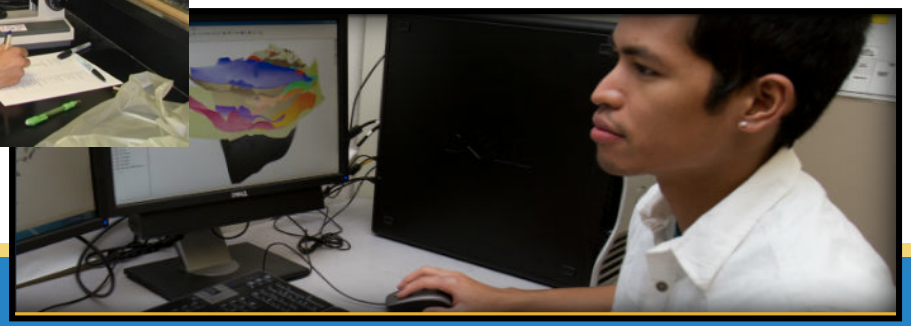
6th Graders examining sediment cores and on a field trip to Red Rock Canyon



Geology Seniors exploring Zion National Park on a well-deserved day off from Southern Utah University's 2009 summer field camp. Summer field camp for these and almost all previous graduating students was supported through CE Strange Scholarships.

CSUB Geology Research Labs





Sediment analysis lab
Micropaleontology lab

Located on the CSUB campus, the California Well Sample Repository offers unique access to a wide array of core samples (over 8000 wells and samples, well logs (over 200,000 well logs and files), plus other reports, surveys, and samples. These materials are used by industry, government and academia for research, teaching and other applications.

California Well Sample Repository

INFORMATION:

The California Well Sample Repository is California's only facility for the permanent storage and public use of cores, sidewall samples, drill cuttings, outcrop samples, micro faunal slides, foundation borings, and mineral suites. The repository, founded in 1975, is located on the campus of California State University at Bakersfield.

STUDENT USAGE:

- Classes taught on sedimentation, stratigraphy, core analysis, and petroleum related topics
- Seminars
- Field Trips
- Research storage and thesis use
- Rock Cutting room
- The Repository is eager to cooperate and support any legitimate request for free student use

PROFESSIONAL USAGE:

- Over 8000 wells of cores, ditch samples, and sidewall samples - onshore and offshore wells
- Collection of over 200,000 well logs and files
  - Including Mount Diablo, San Bernardino, Humboldt, and offshore wells
- Paleontological Reports
- Seismic Velocity Surveys
- Thin samples and slides

Staff:

- Project Director
  Anthony Rathburn
  CSUB Dept. of Geological Sciences
- Chairman:
  Larry Knauer
- Curator:
  Charles James

VISITING HOURS FOR AAPG:

- Open House
- Tuesday and Wednesday:
  - 9am to 2pm
- Contact Info: (661) -654-2324

LOCATION:

- Located across from Chevron
- On campus at CSU Bakersfield
- Take Camino Media to Roadrunner Drive
- CWSR is the first building on the west side

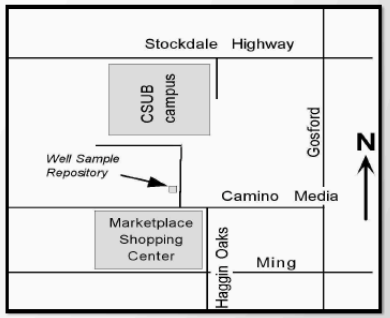
- Well histories, core descriptions, photos, analyses, and electric logs for wells
- Foundation boring samples, ocean bottom sediments, and rock sample suites from mining districts and geothermal areas

Donations:

- All items have been donated with support from companies, organizations, and independent individuals.
- Thank you to those companies and individuals for your continued support

Graphic by Matthew Van Grinsven

Catalog and Contact information Available at http://www.wellsample.com

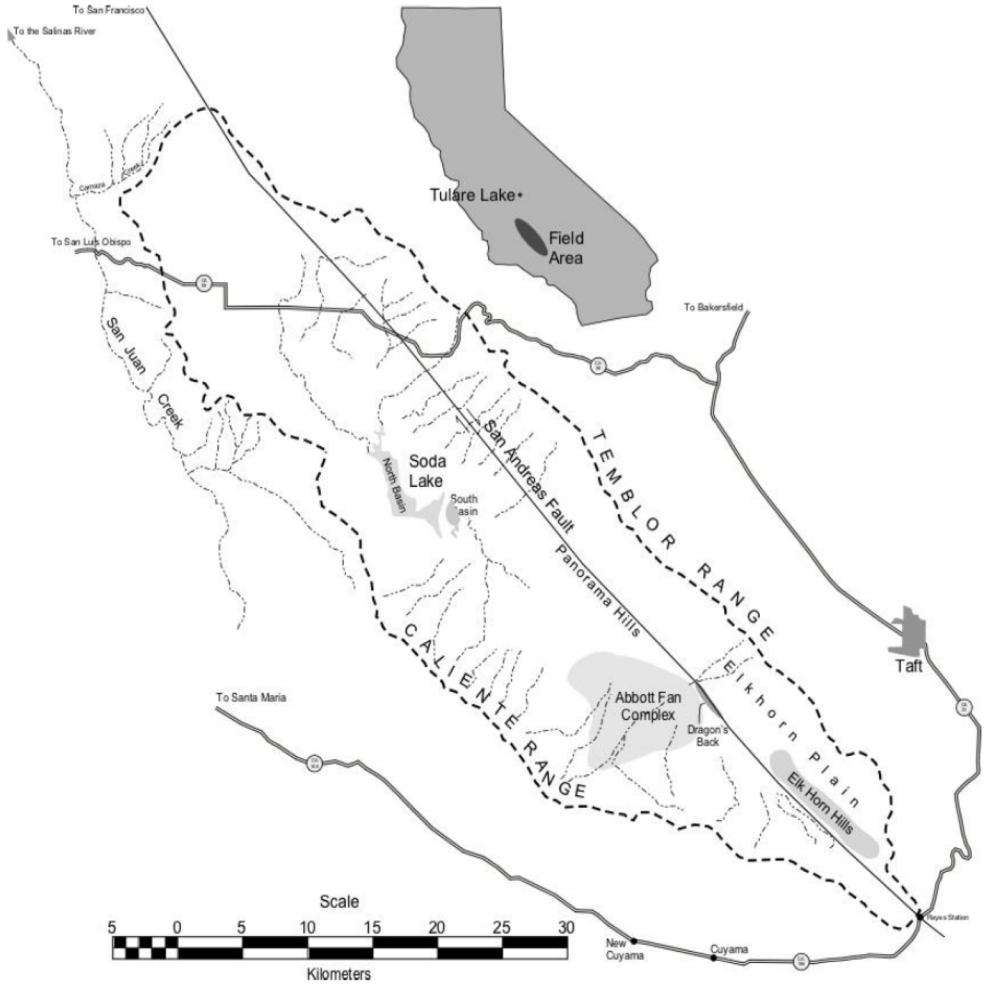


Created By Eric Heaton
Assistant Curator CWSR


JOHN DEERE

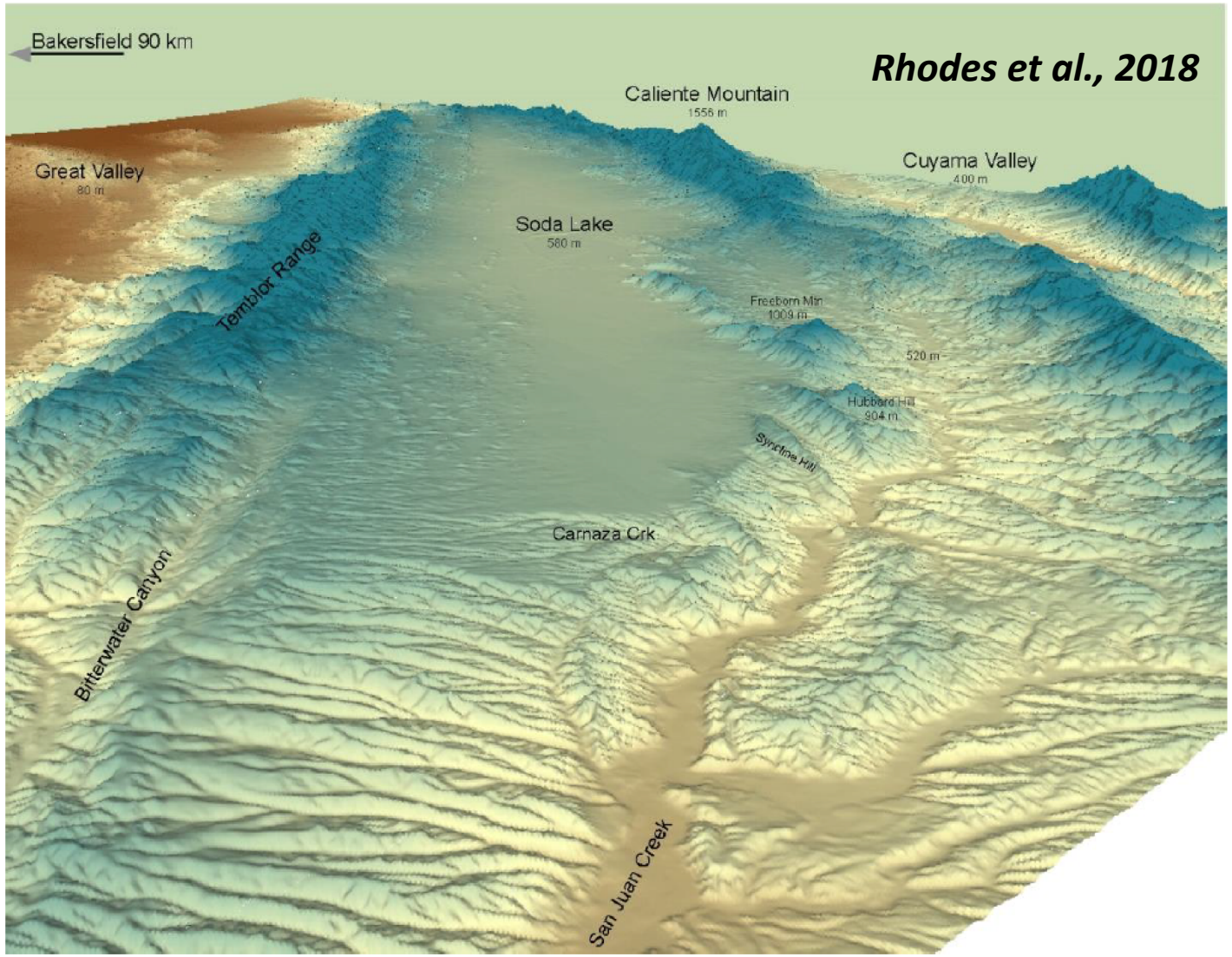
REGIONAL SETTINGS

- Soda Lake is a pluvial lake and located in the northwestcorner of the Carrizo Plain.
- Carrizo Plain is the only closed basin inCalifornia's Southern Coast Ranges.
- Carrizo Plain has the largest accumulated post-early Miocene offset of the San Andreas Fault.



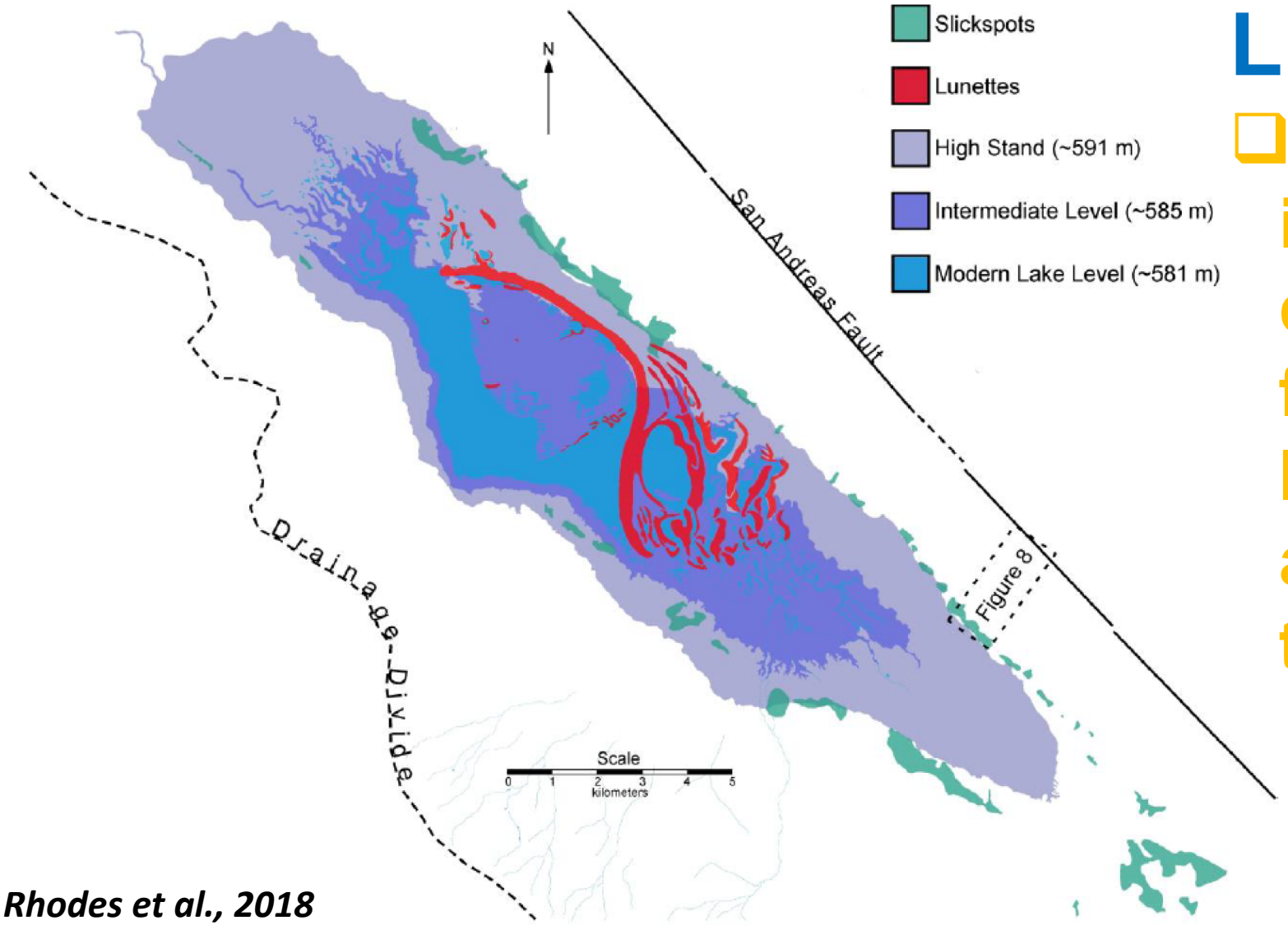
Modified from USGS by Rhodes et al. (2018)

Carrizo Plain and surrounding region



Tectonic warping

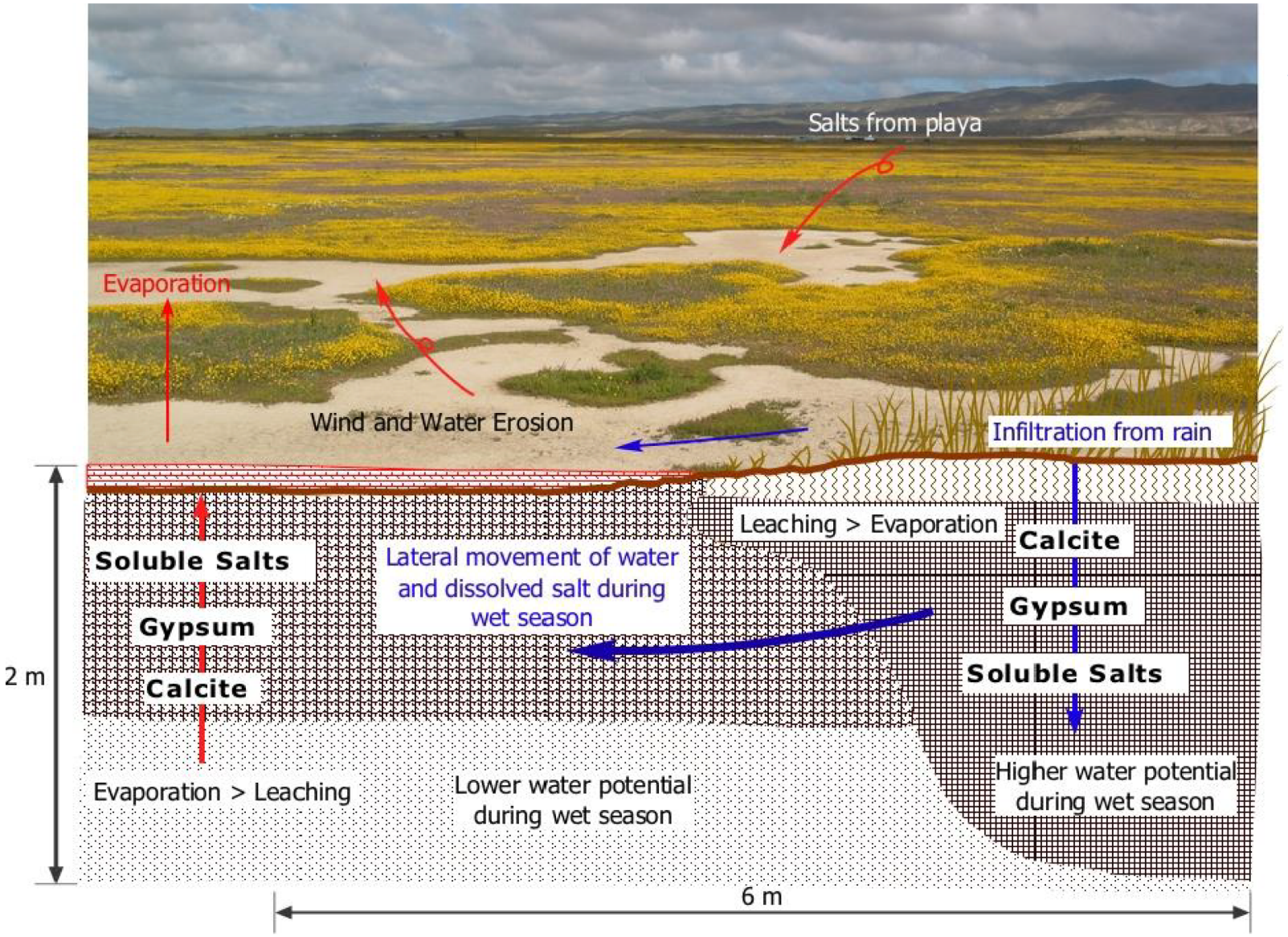
- several lines of evidence suggest a roughly 0.001 (1 m change in height over 1 km) southwestward tilt over the time of the development of the lake



Lunette

- Clay dunes indicate sufficient drying of the lake floor to produce the lcay and silt aggregates to build the dune

Rhodes et al., 2018

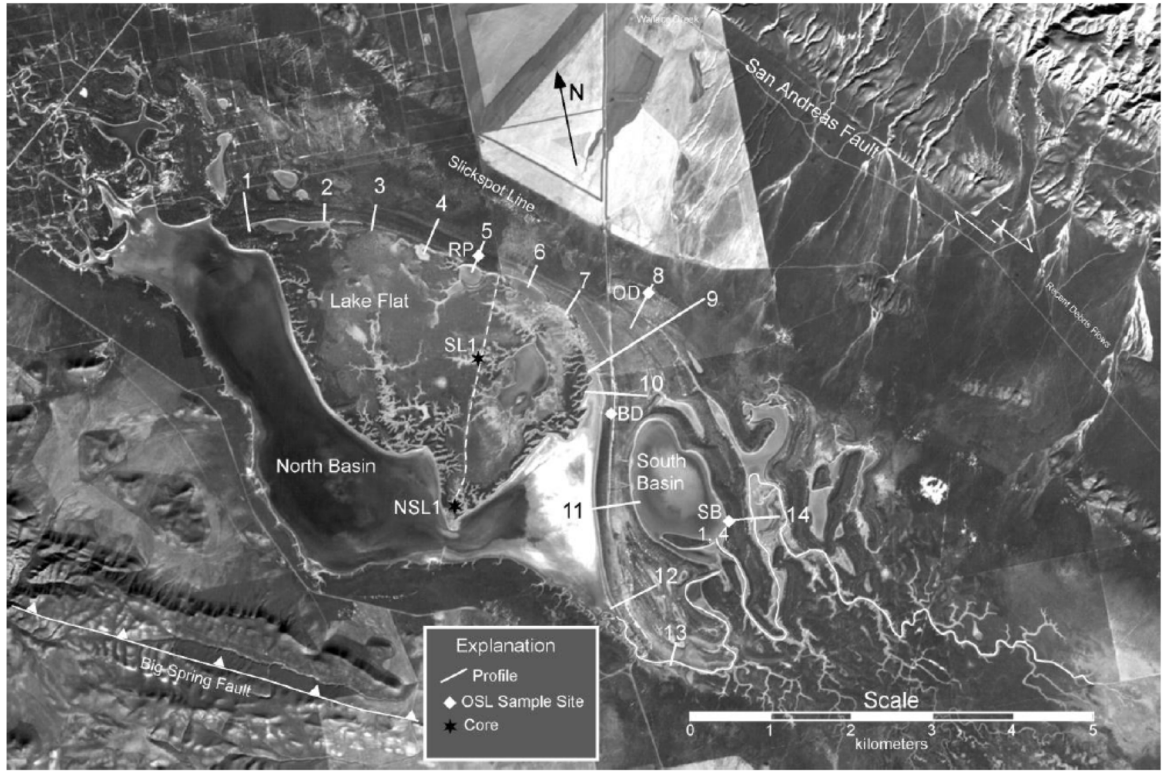


Slickspots

- patches of barren soils, capped by a thin evaporate crust
- Enrichement of sodium in soils

Coring

❑ NSL1 and SL1



Reduced Lithology

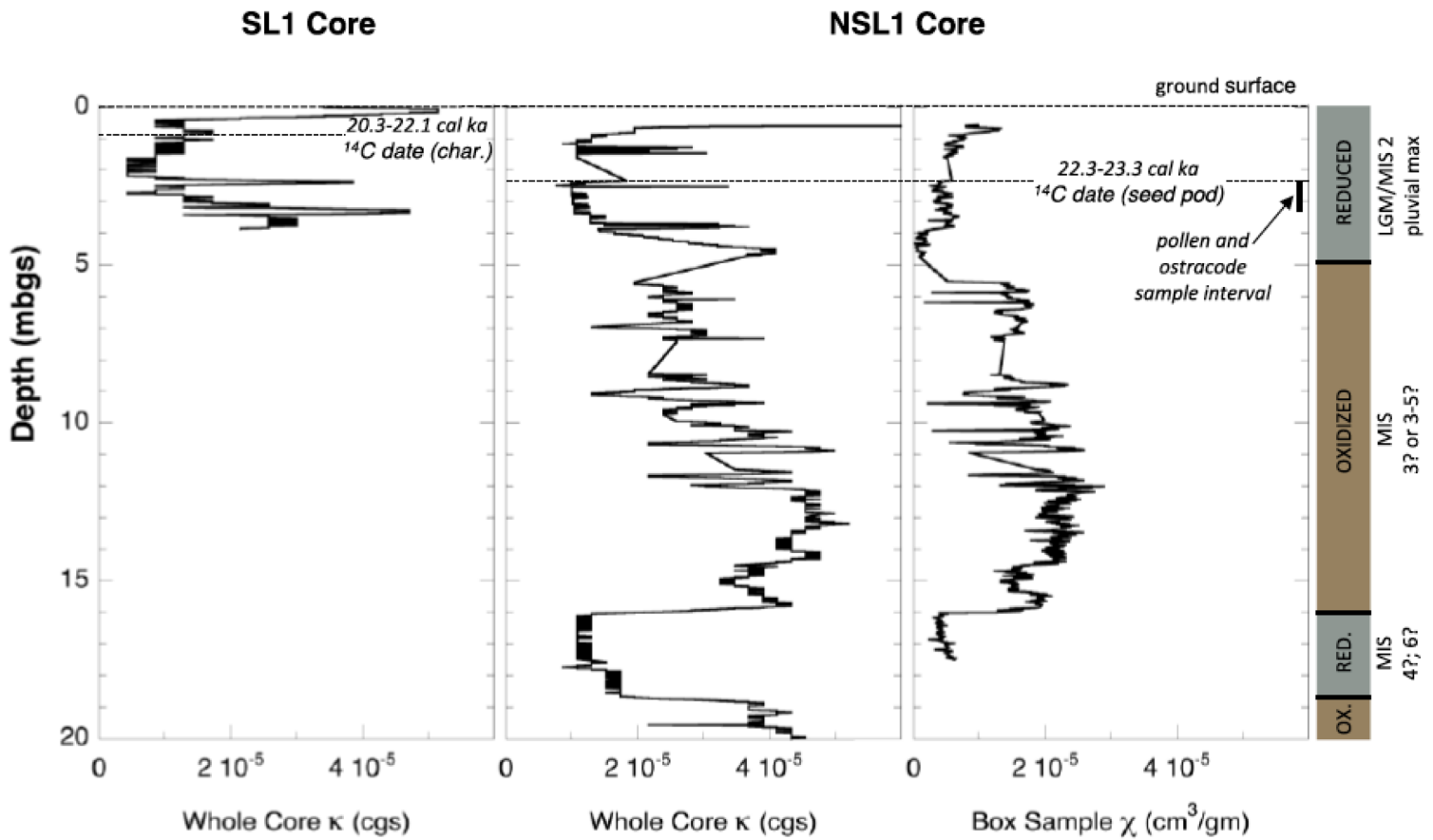
- *dark gray (5Y 4/1); greenish gray (10Y or 10GY 5/1)*
- *1-10 mm, euhedral, evaporite xtals uncommon*
- microscopic gypsum xtals in clay matrix
- *very low magnetic susceptibility*
- massive
- Pollen, charcoal and ostracodes preserved

Oxidized Lithology

- light olive-brown (5Y 6/4)
- 1-10 mm, euhedral, evaporite xtals common
- microscopic evaporite xtals in clay matrix
- relatively high magnetic susceptibility
- massive
- microfossil preservation very poor

Analyses

- ❑ Luminescence dates
- ❑ Magnetic susceptibility
- ❑ Pollen
- ❑ Ostracods
- ❑ SEM and EDS



- A ^{14}C date on charcoal from the upper reduced zone places the top of this zone at no older than *20.24-22.00* cal ka. This date is consistent with the OSL date on geomorphic features associated with *a high stand* above ~591 masl.
- Assuming that reducing conditions correspond to deep water, the new ^{14}C date suggests that the upper *reduced zone* represents a *Stage 2 pluvial maximum* lake in the Carrizo Plain.

- *Pollen and ostracods* from the reduced sediments indicate of a *wetter and cooler climate* relative to modern conditions capable of sustaining a lake with waters *much less saline* than that of the modern lake.
- The timing of the high stand (~20 ka) is consistent with the modified jet stream migration model of Oster et al. (2014) and not consistent with the tropical incursion model of Lyle et al. (2012).
- Northeast to southwest asymmetry across the lake floor may be consistent with southwestward tilting driven by Coast Range shortening normal to the orientation of the San Andreas Fault as is seen throughout the region.

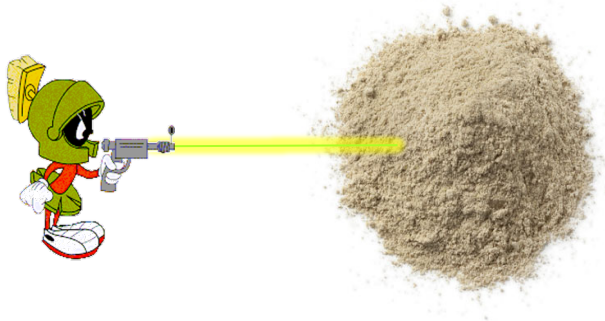
PURPOSE OF STUDY

- Improve the understanding of the paleoclimatic record found within the sediments in the Carrizo Plain.
- Evaluate the strength and weaknesses of minerals as a paleoclimate proxy.
- Further investigating the paleoclimate changes in Western America since the Last Glacial Maxim (LGM).

MATERIALS AND METHODS

- BULK MINERALS

- CLAY-SIZE MINERALS

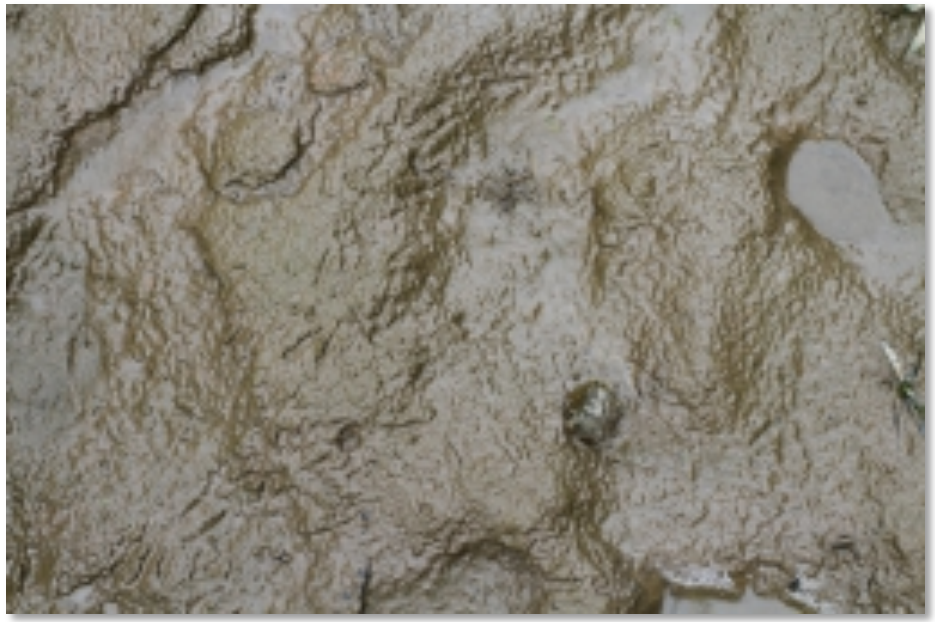


BULK MINERALS

- Composite clay

HIGH QUANTITIES IMPLY:

- Low depositional energy
- Deeper lake (high-stand)
- Possible change in lake morphology

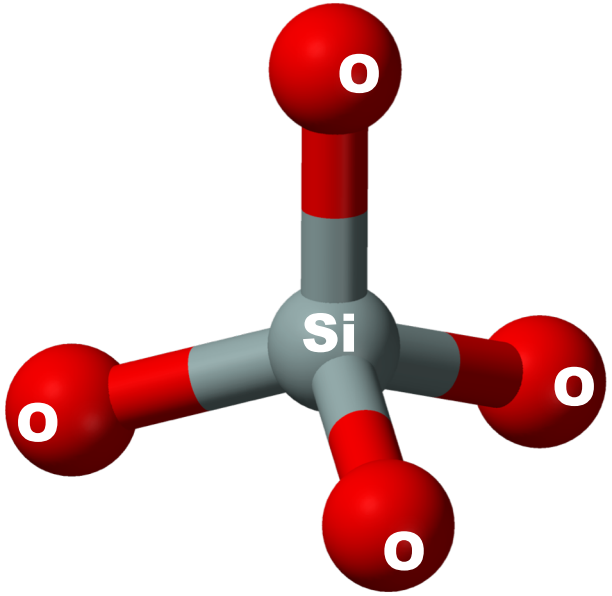


BULK MINERALS

- Quartz

HIGH QUANTITIES IMPLY:

- Increased transport of source area sediments (wet period)
- Near-shore depositional environment
- Shallower lake level (low-stand)

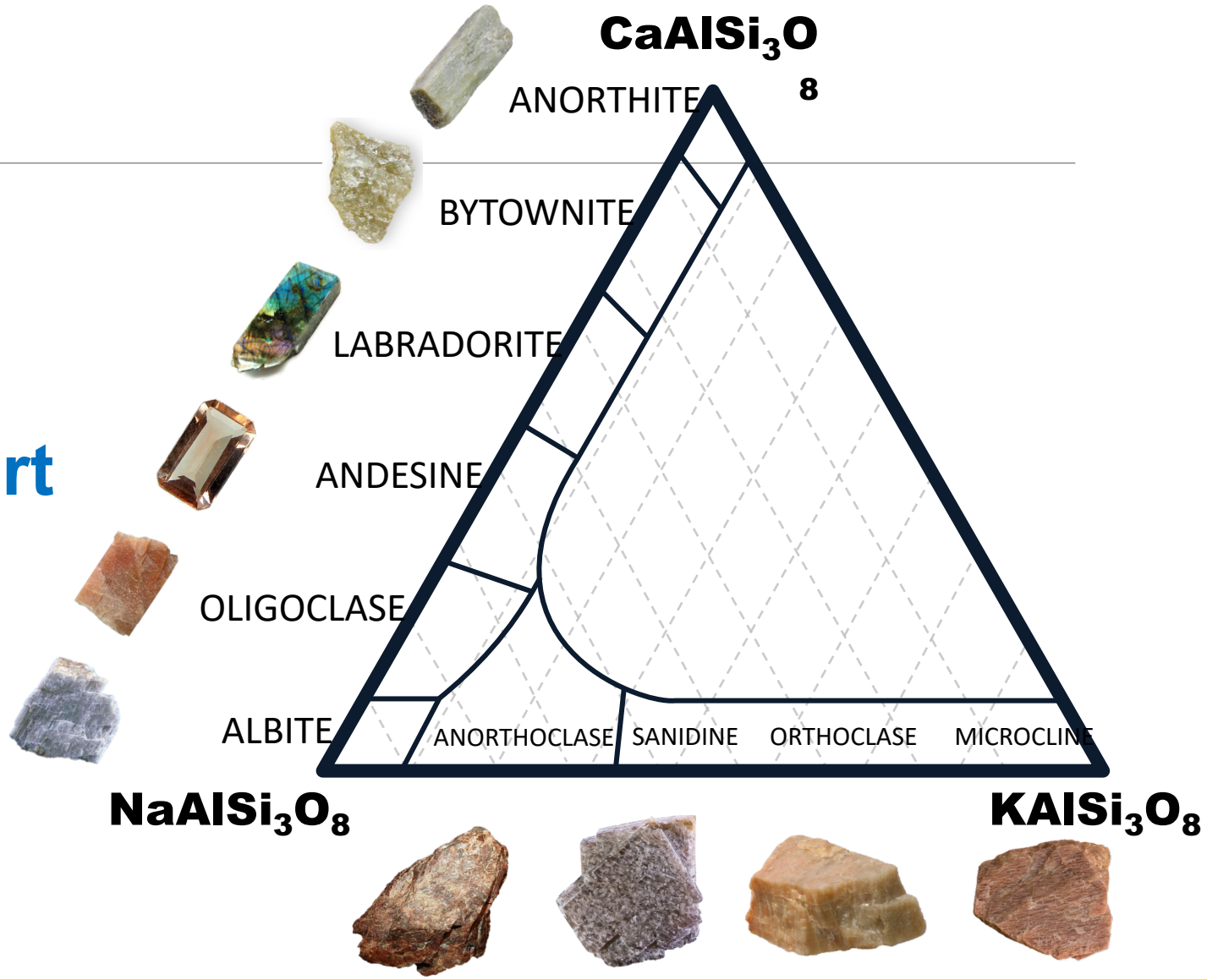


BULK MINERALS

- Feldspar

HIGH QUANTITIES IMPLY:

- Increased transport of source area sediments



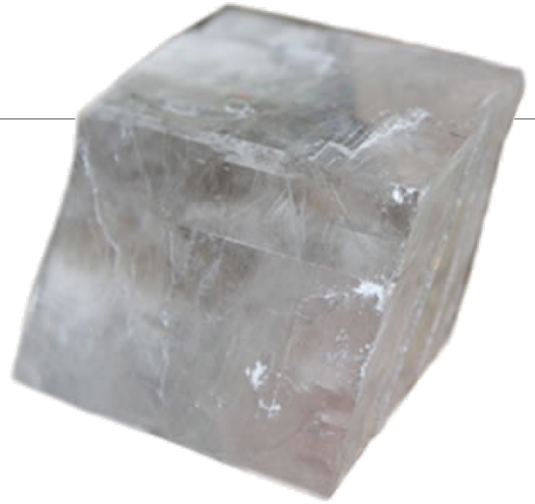
BULK MINERALS

- Calcite

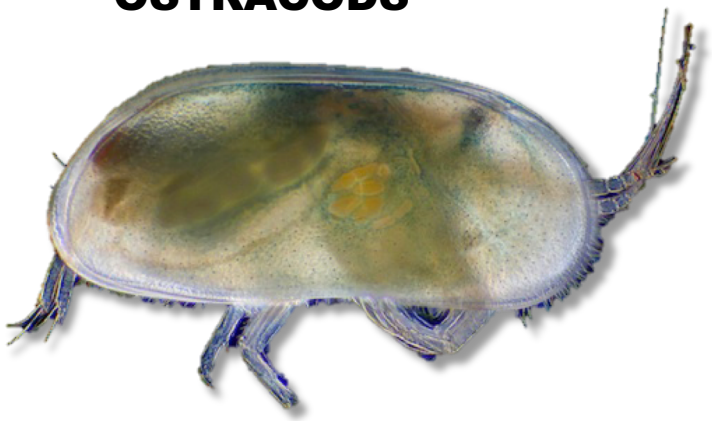
HIGH QUANTITIES IMPLY:

- Increased lake productivity
- Possible evaporation
- Possible change in lake morphology

RHOMBOHEDRAL CRYSTAL FORM



OSTRACODS



BULK MINERALS

- **Evaporite**

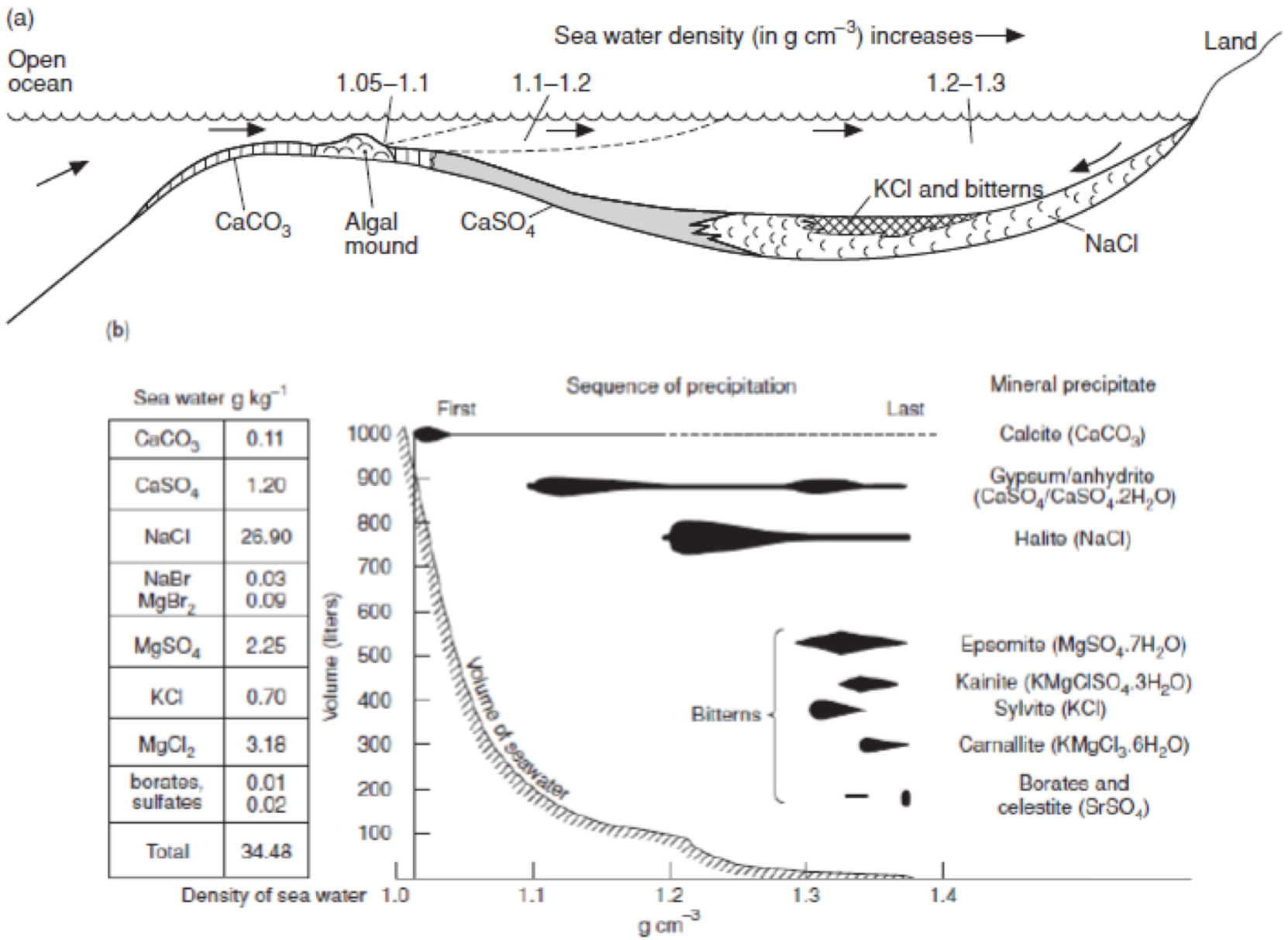
- Calcite
- Gypsum
- Halite
- Potassium salts

Volume of water remaining	Evaporite Precipitated	
50%	➢At this point, ***minor carbonates*** begin to form. ➢**A little iron oxide** and some **aragonite** are precipitated. ➢Minor quantities of carbonate minerals (Calcite and dolomite) form.	**a) Calcite**($CaCO_3$)**:** ✓ Precipitates if < 50% of seawater is removed. ✓ Only accounts for a small % of the total solids
20%	Gypsum precipitates: Gypsum (<42°C) or Anhydrite (>42°C).	**b) Gypsum:** ✓ Precipitates if 80-90% of seawater has been removed ✓ Solution is denser
10%	Rock salt (halite) precipitates	**c) Halite:** ✓ Precipitates if 86-94% of original seawater has been removed ✓ Brine (solution) is very dense ✓ The deposition of salt beds provides the source for about three-fourths of all salt used.
5%	➢Mg & K salts precipitate ➢Precipitation of various *magnesium sulfates and chlorides*, and finally to *NaBr and KCl.* ➢Potassium and magnesium salts (kainite, carnallite, sylvite)	**d) Potassic salts:** ✓ Precipitate if > 94 % of original seawater has been removed ✓ So: ionic strength (potential) of evaporating seawater has a strong control over minerals that form. ✓ After the deposition of common salt, chlorides and sulfates of magnesium and potassium are the other chief salts deposited. The potassium minerals result from evaporation carried almost to completion and, therefore, only rarely are they deposited.

Decreasing order of solubility

The first phase

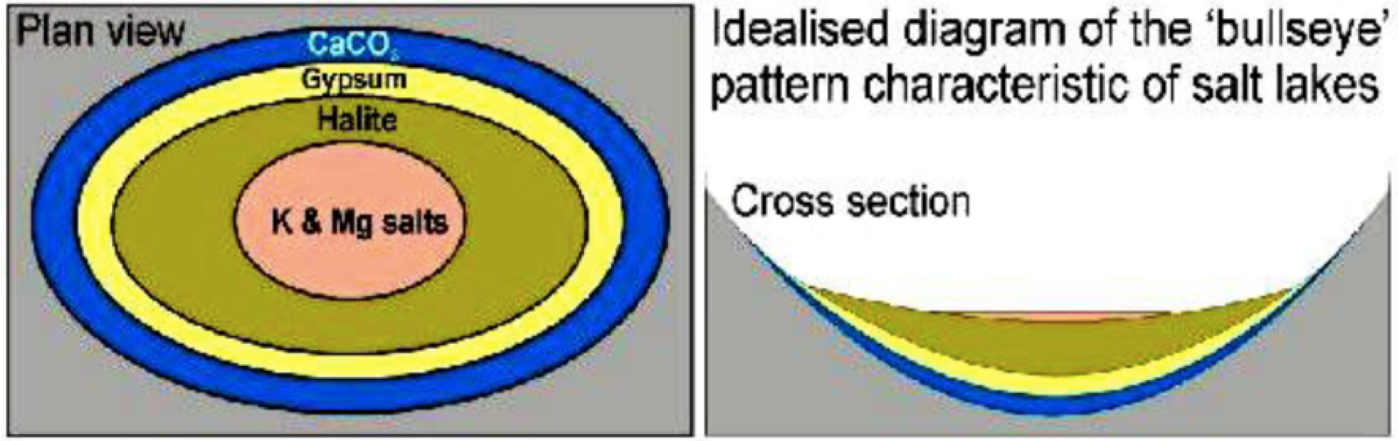
Increasing Evaporation Rates



- **Guilbert and Park, 1986**

Deposition Model

- Dry mudflats –crusts
- Saline mudflats -saltpan deposits
- Evaporites form when lake dries up – usually forming '*Bulls Eye*' pattern of deposits
  - least soluble ppt first
  - most soluble last

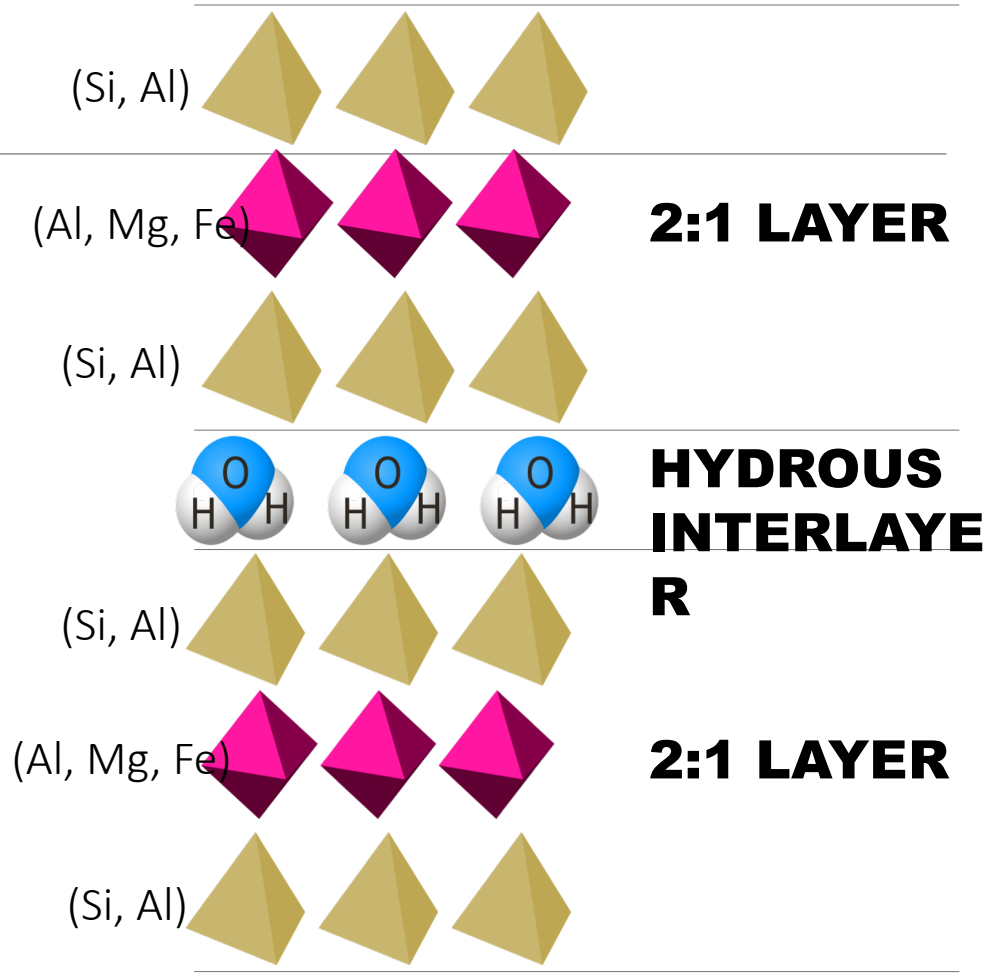


CLAY-SIZE MINERALS

- **Smectite**

HIGH QUANTITIES IMPLY:

- Wet and confined source environment
- Enriched in fine-size particle indicating increased sediment transport distance

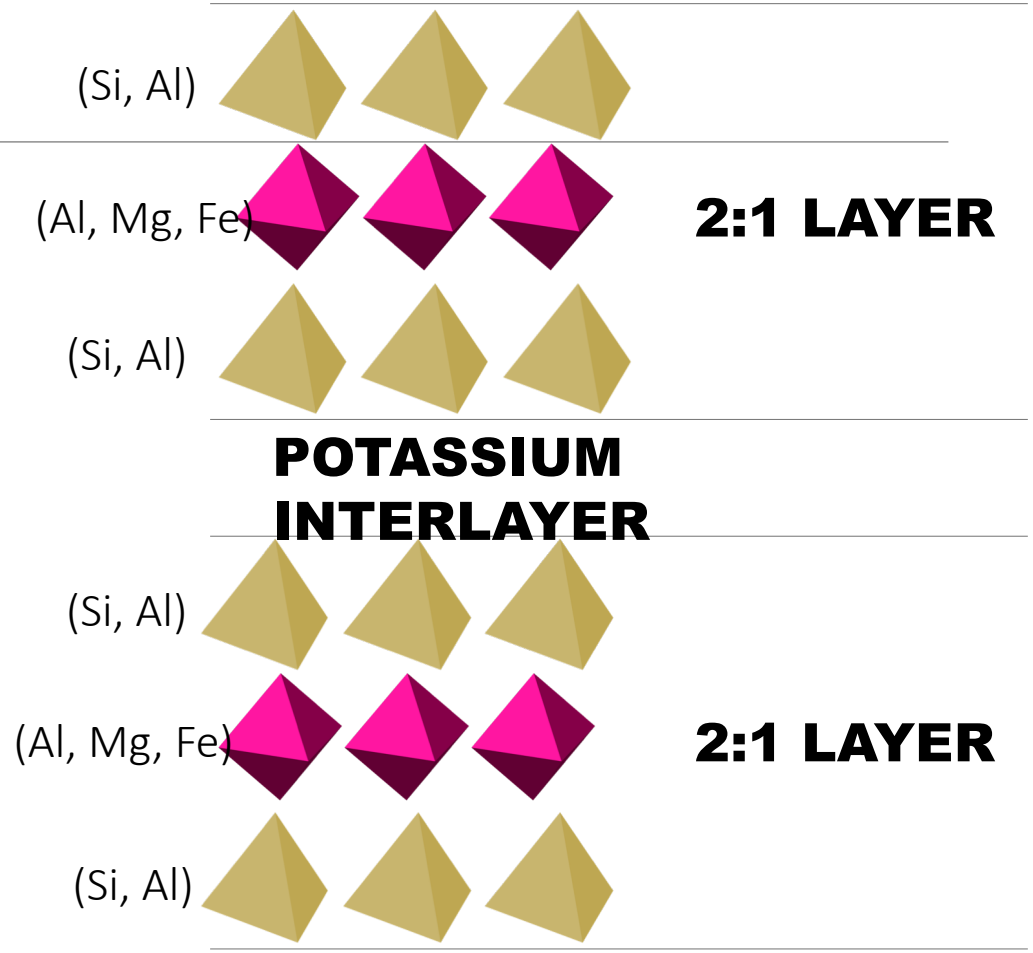


CLAY-SIZE MINERALS

- **Illite**

HIGH QUANTITIES IMPLY:

- Physical weathering of source environment
- Enriched in relatively coarse fraction indicating relatively short transport distance



CLAY-SIZE MINERALS

- Kaolinite & Chlorite

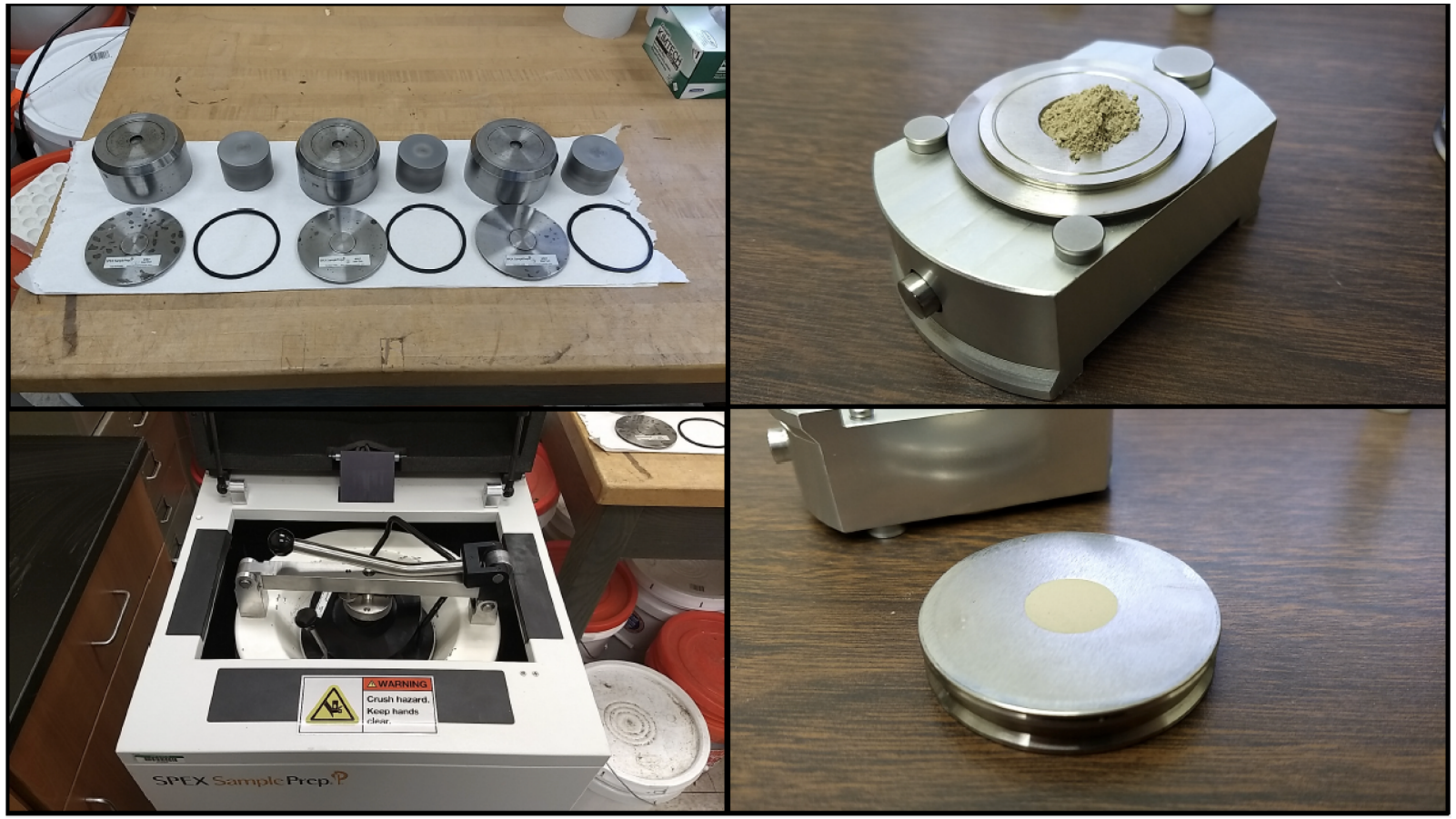
HIGH QUANTITIES IMPLY:

- Kaolinite - chemical weathering, temperate, and leaching source environment
- Chlorite - physical weathering of metamorphic parent rocks (chlorite) indicating cold physical weathering source environment.

CHLORITE

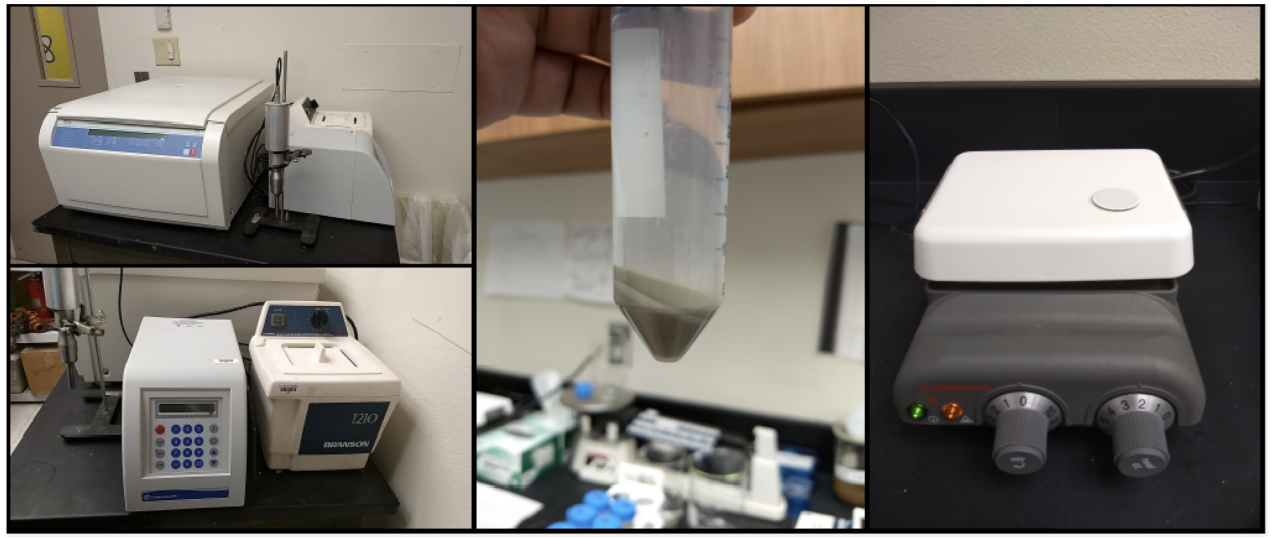
KAOLINITE

BULK SAMPLE PREPARATION

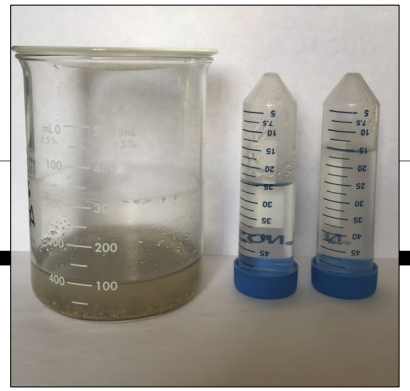


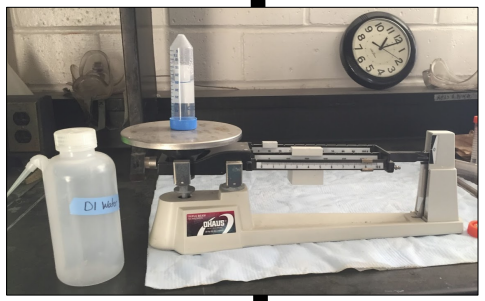
CLAY-SIZE PREPARATION

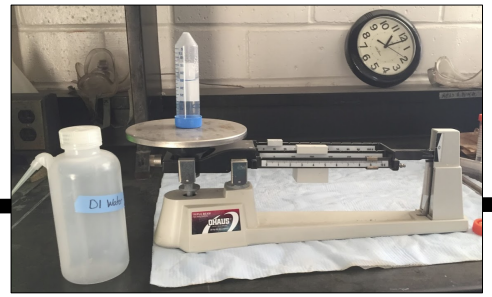
- Removal of organics using hydrogen peroxide.
- Deflocculating sample using sodium metaphosphate solution.
- Moore and Reynolds filter peel method



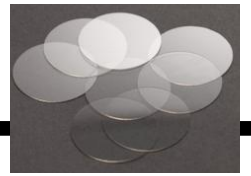
CLAY-SIZE PREPARATION



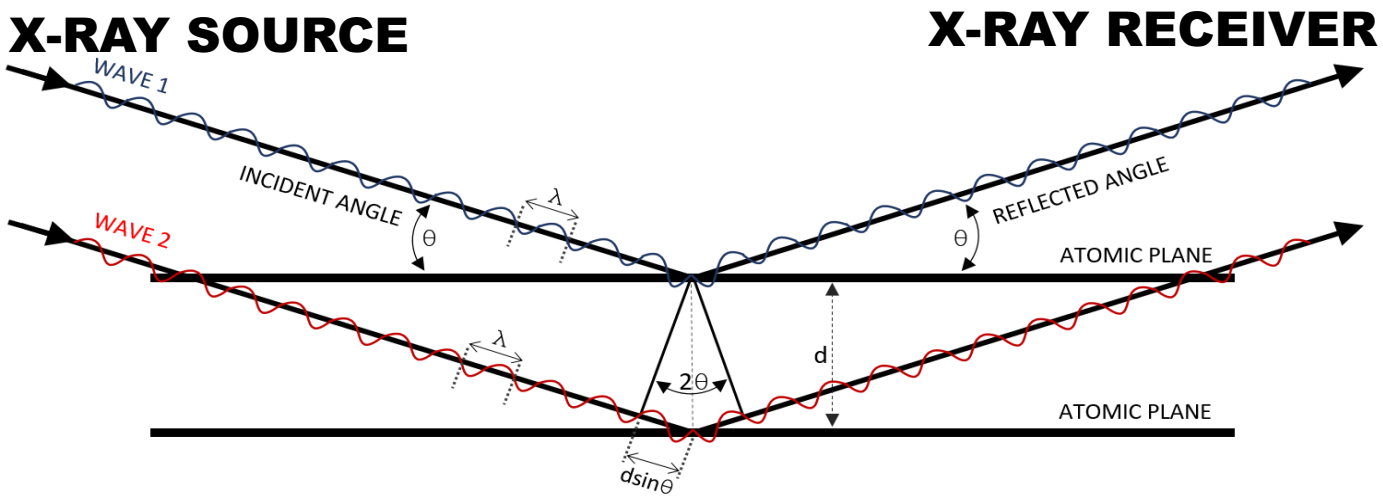


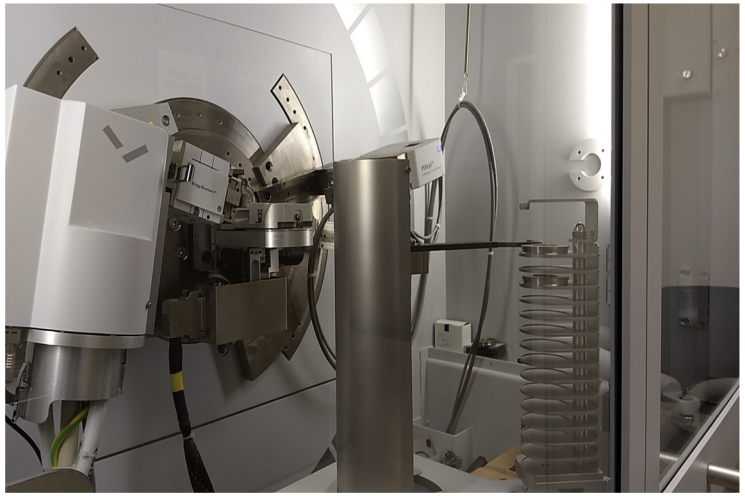


WASHED
BULK
58 cm



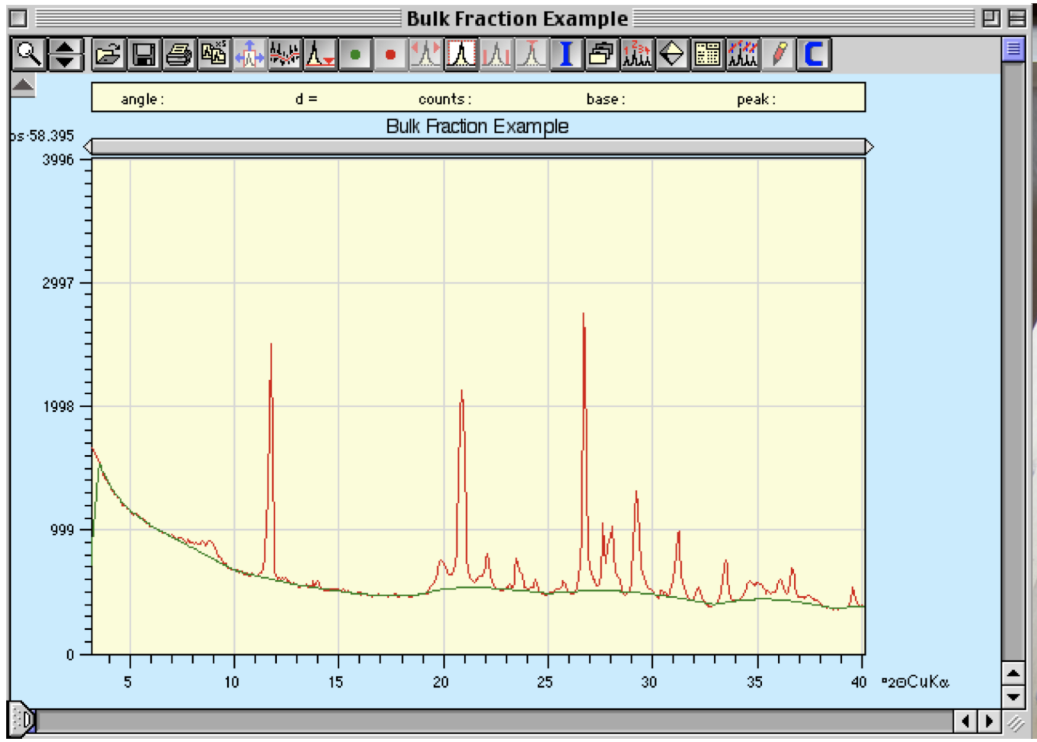
BRAGG'S LAW: (nλ = 2dsinθ)



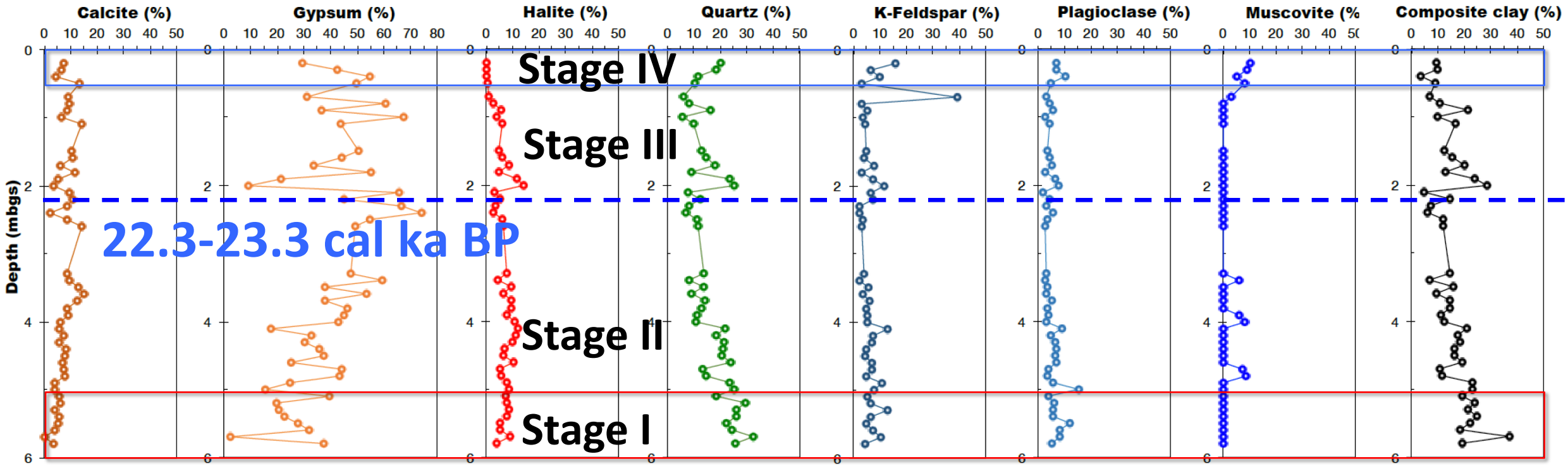


DATA REDUCTION

- **Software MacDiff**



RESULTS AND INTERPRETATION



SUMMARY

- Mineralogy assemblages contain large portion of evaporites, including calcite, gypsum, and halite.
- Mineralogy assemblages indicate four different climate intervals.
- At Stage I, sediments oxidation suggests an ephemeral and shallow-water lake bed.
- Since Stage II, the lake level increased and reached the maximum at then end of Stage II and the beginning of State III

SUMMARY

- The lake level remained relatively stable at Stage III.
- High muscovite content at Stage IV indicates sediments supply from a new source region.

Thank you for your time and attention…

Questions???