

Geology 5315/6332
Carbonate Geochemistry, Petrography, and Depositional Systems

Lecture: Monday & Wednesday: 12:30 -1:20pm; GS 404

Lab: Monday: 1:30 - 3:20pm; GS 320

Instructors: Drs. Kate Giles and Ben Brunner

Office: Geological Science 201

E-mail: Kate- kagiles@utep.edu and Ben- bbrunner@utep.edu

Office Hours: By email appointment.

Assignments and Grading

Grades will be based on performance on the following:

Weekly Quiz, Group Exercise / Discussion (7 at 10pts each)	70 pts
Weekly Lab (10 labs at 10pts each)	100 pts
Practical Lab Exam CO ₃ Grain Types (Week of October 20)	50 pts
Field Trip 1 Exercise: Shelf margin facies, Sacramento Mountains (Nov. 7)	30 pts
Field Trip 2 Exercise: Permian Reef Complex (Nov. 14 &15)	50 pts

Total: 300 pts

Readings

There is no required textbook for this course. However, I strongly suggest purchasing Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, 474 p. Referenced readings for Lecture are found in a purple folder on Blackboard marked "Carbonate Readings". Please do the reading assignment prior to class for best success.

Weekly Quiz/Group Assignments/Discussion

Quizzes and assignments will be made available to you either via Blackboard or direct email. We will set deadlines after consulting with you, so that everybody can submit their assignment on time. Late submissions will not be accepted (i.e. 0 points). The group assignment will be graded for the entire group, unless group members raise concerns about the performance of the peers. Grading of your contribution and activity in discussions will be done by both instructors, and averaged. The recipe to obtain a good grade in such discussion is to be prepared.

Weekly Lab Assignments

To be worked on in GS 320 during scheduled Lab time. After hours can use either yourscope in GS 320 when the room is open or in GS 201. microscope time slot and turned in via email the following Thursday before the end of lab time. Kate will leave a box with thin sections and hand samples on the table next to the microscope in 201 for each weeks lab. Email Kate with any questions about the lab.

Practical Lab Exam

A suite of 20 thin sections will be housed in GS 201. You will schedule a 3 hour time slot to come into 201 and use the microscope to take the exam. We will email you the exam (Word document) in the morning of the day prior to your exam timeslot. You will fill in the answers on the word document and email completed exam to Kate. The exam will be focused on determination of common carbonate grain types in thin section.

Fieldtrip Exercises

This will be a handout with questions and observations made at a series of stops on the fieldtrip. To be completed and turned in at the end of each fieldtrip.

Required Field Trips

Two field trips are required for this course. The field trips will be graded based on participation in discussions and quality of your field notes/exercises. Field notes and exercises will be handed in at the end of each field trip.

Fieldtrip 1: Saturday & Sunday Nov. 12 & 13 (Overnight) Required

Permian Reef Complex, Guadalupe Mountains, and Carlsbad Caverns. Depart Geological Sciences at 8:00am and return by 5:00pm each day.]

Field Trip 2: Saturday Nov. 19 Topic: TBD Required

Shelf margin facies Sacramento Mountains or similar. Depart Geological Sciences at 8:00am and return by 5:00pm.

Fall 2022 Tentative Class Schedule

Geol. 5315/6332

Carbonate Geochemistry, Petrography, and Depositional Systems

Lecture: M & W 12:30 - 1:20pm GS 404

Lab: M 1:30 - 3:20pm GS 320

August 22 Monday

Lec 1: Brunner & Giles Introduction of participants. Overview of class organization & introduction to topics for TBD lectures & updates on Giles, Brunner et al. paper "The salty heritage of Neoproterozoic dolostones" writing process & Grades. Intro. to CO₃ sedimentation. Carbonates are born, not made! Carbonate classification. Carbonate marine depositional profile/environments.

Lecture Reading 01:

Wilson, J. L., 1975, Carbonate Facies in Geologic Time: Springer-Verlag, p.1-7.
Tucker, M. E. and Wright, V. Paul, 1990, Chapter 1-Limestone classification: *in* Carbonate Sedimentology: London, Blackwell Scientific Publications, p. 18-22.

Lab 0: Assign microscopes. Review basics of microscope.

[Basic chemistry I: Elementary, my dear Watson!](#)

[Atoms, isotopes, elements, oxidation state](#)

[Lab Reference Reading: Periodic table \(made available on blackboard\)](#)

August 24 Wednesday

Lec. 2: Giles Carbonate mineralogy

Lecture Reading 02:

Tucker, M. E. and Wright, V. P., 1990, Chapter 6- Carbonate mineralogy and chemistry: *in* Carbonate Sedimentology: London, Blackwell Scientific Pubs, p. 284-294.

Milliman, J. D., 1974, Chapter 1- Carbonates and the ocean: *In* Marine Carbonates: New York, Springer-Verlag, p. 3-12.

August 29 Monday Giles out

Lec. 3 Brunner [Basic chemistry II: Opposites attract](#)

[Ionic and covalent bonds, salts *sensu lato*, cations and anions, charge, aqueous solutions, oxyanions](#)

Quiz 1 (individual)

Lab 1: Determination of carbonate and commonly associated minerals in thin section and hand sample.

Lab Reference Reading:

Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, p. 372-407, 417-425.

Dickson, J. a. D., 1966. Carbonate identification and genesis as revealed by staining. J. Sediment. Res. 36, 491-505.

<https://doi.org/10.1306/74D714F6-2B21-11D7-8648000102C1865D>

August 31 Wednesday

Lec. 4 Giles: Tidal flat carbonate rocks - Non-skeletal grains (ooids and pisoids; peloids and intraclasts)

Lecture Reading 05:

Chafetz, H. S., 1986, Marine peloids: A product of bacterially induced precipitation of calcite: *Jour. Sed. Pet.*, V. 56, (6), p. 812-817.

Diaz, M. and Eberli, G., (2019) Decoding the mechanism of formation in marine ooids: *Earth Science Reviews*, V. 190, p. 536-556.

Shinn, E. A., 1983, Chapt. 4-Tidal Flat Environment: *in* Scholle, P. A., Bebout, D. G., and Moore, C. H., eds., *Carbonate Depositional Environments: A.A.P.G. Memoir 33*, p. 172-210

September 5 Monday – No Class Labor Day

September 7 Wednesday

Lec. 5: Giles Tidal flat carbonate rocks - Skeletal grains (cyanobacteria, oncolites and stromatolites; ostracods.

Lecture Reading 03:

Chafetz, H.S., Buczynski, C., 1992. Bacterially induced lithification of microbial mats. *PALAIOS* 7, 277–293.

Kaźmierczak, J., Fenchel, T., Kühl, M., Kempe, S., Kremer, B., Łacka, B., et al. (2015). CaCO₃ precipitation in multilayered cyanobacterial mats: clues to explain the alternation of micrite and sparite layers in calcareous stromatolites. *Life* 5, 744–769. doi: 10.3390/life5010744

*Popall RM, Bolhuis H, Muyzer G and Sánchez-Román M (2020) Stromatolites as Biosignatures of Atmospheric Oxygenation: Carbonate Biomineralization and UV-C Resilience in a *Geitlerinema* sp. - Dominated Culture. *Front. Microbiol.* 11:948. doi: 10.3389/fmicb.2020.00948

September 12 Monday Giles gone

Lec. 6 Brunner [Basic chemistry III: Into the mud](#)

Redox reactions (photosynthesis, respiration), redox tower in sediments, balancing of chemical equations.

Lecture Reading 04:

Canfield, D.E., and Thamdrup, B., 2009, Towards a consistent classification scheme for geochemical environments, or, why we wish the term 'suboxic' would go away: *Geobiology*, v. 7, p. 385–392, doi:10.1111/j.1472-4669.2009.00214.x.

Quiz 2 (teamwork is allowed)

Lab 2: Non-skeletal grains (ooids, pisoids, peloids, & intraclasts)

Lab Reference Reading:

Scholle, P. A. and Ulmer-Scholle, D. S, 2003, *A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77*, p. 227-245, 245-259.

Bathurst, R., 1976, Chapt. 2- Petrography of carbonate grains and Chapt. 7- Growth of ooids, pisolites, and grapestone: *in* *Carbonate Sediments and Their Diagenesis*: New York, Elsevier, p. 77-84; 84-87. p. 295-319

Skeletal grains – cyanobacteria, oncolites and stromatolites; ostracods.

Lab Reference Reading:

- Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, p. 1-28, 60-63.
- Bathurst, R., 1976, Chapt 1- Petrography of carbonate grains: *in* Carbonate Sediments and Their Diagenesis: New York, Elsevier, p. 58-70. Chapt. 5 - Recent carbonate algal stromatolites: *in* Carbonate Sediments and Their Diagenesis: New York, Elsevier, p. 90-91; 217-230.

September 14 Wednesday

Lec. 7 Giles Shallow shelf, normal marine carbonate rocks - Skeletal grains I (invertebrates-molluscs, brachiopods, echinoderms, trilobites)

September 19 Monday

Lec. 8: Shallow shelf, normal marine carbonate rocks - Skeletal grains II (invertebrates-corals & sponges, bryozoans, forams, worm tubes, misc.)

Lab 3: Normal marine skeletal grains (invertebrates-molluscs, brachiopods, echinoderms, trilobites, corals, sponges, stromatoporoids, bryozoans, forams, worm tubes, misc.)

Lab Reference Reading:

- Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, p. 33-48, 75-80, 83-121, 123-205.
- Bathurst, R., 1976, Chapt 1- Petrography of carbonate grains: *in* Carbonate Sediments and Their Diagenesis: New York, Elsevier, p. 2-57: p. 70-75.

September 21 Wednesday

Lec. 9 Brunner [Basic chemistry IV: Thermodynamics and Kinetics – two sides of a coin](#)
Knowing where the journey is supposed to go does not mean getting on the road, catalysts (life), what the hell is activity, why does complexation equal distraction, and how is it possible that the pH could sneak in so casually?

Quiz 3 (teamwork is allowed)

September 26 Monday

Lec. 10 Giles: Constituents of carbonate rocks - Carbonate mud (matrix) and the origin(s) of mud and identification of cement versus replacement spar

Lecture Reading 06:

- Trower, E. J., Lamb, M. P., & Fischer, W. W. (2019). The Origin of Carbonate Mud. *Geophysical Research Letters*, 46, 2696–2703.
<https://doi.org/10.1029/2018GL081620>

Lab 4: Matrix mud versus neomorphic and replacement spar.

Lab Reference Reading

- Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, p. 265-273, 305 -309, and p. 313-371

Bathurst, R., 1976, Chapt 2- Petrography of carbonate grains and Chapt. 6- Origin of Bahamian aragonite mud and Chapt. 10: *in* Carbonate Sediments and Their Diagenesis: New York, Elsevier, p. 87-89; p. 276-291, p. 415-457.

September 28 Wednesday

Lec. 11 Brunner Carbonate chemistry I: The carbonic acid system

Why is this so damn complicated? Or are they just messing with us? Since when is ACD & CCD not a rock band?

Lecture Reading 07:

Bosellini, A., Winterer, E.L., 1975. Pelagic limestone and radiolarite of the Tethyan Mesozoic: A genetic model. *Geology* 3, 279–282.

[https://doi.org/10.1130/0091-7613\(1975\)3<279:PLAROT>2.0.CO;2](https://doi.org/10.1130/0091-7613(1975)3<279:PLAROT>2.0.CO;2)

Milliman, J.D., 1975. Dissolution of aragonite, Mg-calcite, and calcite in the North Atlantic Ocean. *Geology* 3, 461–462. [https://doi.org/10.1130/0091-7613\(1975\)3<461:DOAMAC>2.0.CO;2](https://doi.org/10.1130/0091-7613(1975)3<461:DOAMAC>2.0.CO;2)

Quiz 4 (teamwork is allowed)

October 3 Monday

Lec. 12 Giles: Porosity types & their generation. Cement types and precipitation setting.

Lab 5: Classification of CO₃ rock porosity and cements

Lab Reference Reading

Moore, C. H., 1989, Chapt. 2- The classification and nature of carbonate porosity: *in* Carbonate Diagenesis and Porosity: Amsterdam, Elsevier, p. 21-40.

October 5 Wednesday Giles gone

Lec. 13 Brunner Carbonate chemistry II: The silicic acid system

The hidden beauty of geochemistry

Quiz 5 (teamwork is allowed)

October 10 Monday Giles gone

Lec. 14 Brunner Carbonate Diagenesis

Lecture Reading 08:

Tucker, M. E. and Wright, V. Paul, 1990, Chapter 7- Diagenetic processes, products and environments: *in* Carbonate Sedimentology: London, Blackwell Scientific Publications, p. 314-364.

Lab 6 Diagenesis & paragenetic sequences

Lab Reference Reading

Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, p. 340-370; 371-392

October 12 Wednesday Giles gone

Lec. 15 Brunner Carbonate chemistry III: Redox and fatal attraction – wild love affairs in carbonate rocks

The fate of Ca^{2+} , Mg^{2+} , $\text{Fe}^{2+}/\text{Fe}^{3+}$, $\text{Mn}^{2+}/\text{Mn}^{3+}$, CO_3^{2-} , SO_4^{2-} , and H_2S recorded in thin section

Lecture Reading 10:

Dickson, J. a. D., 1966. Carbonate identification and genesis as revealed by staining. *J. Sediment. Res.* 36, 491–505.
<https://doi.org/10.1306/74D714F6-2B21-11D7-8648000102C1865D>

Quiz 7/Discussion: Geochemical meaning of content, morphology, and colors of fossils and minerals in rocks, thin sections, and stained thin sections (**active participation mandated**)

October 17 Monday Giles gone

Lec. 16 Brunner: Dolomite and dolomitization models.

Lecture Reading 09:

Tucker, M. E. and Wright, V. Paul, 1990, Chapter 8-Dolomites & dolomitization models: *in* Carbonate Sedimentology: London, Blackwell Scientific Publications, p. 365-400.

Quiz 6/Discussion: the dolomite problem – a thermodynamic or kinetic issue? (**active participation mandated**)

Lab 7 Dolomite

Lab Reference Reading:

Scholle, P. A. and Ulmer-Scholle, D. S, 2003, A Color Guide to the Petrography of Carbonate Rocks: AAPG Memoir 77, p.

October 19 Wednesday

Lec. 17 Giles: Bank margin and shelf margin reef environment.

Lecture Reading 12:

Halley, R. B., Harris, P. M., and Hine, A.C., 1983, Chapt. 9-Bank Margin Environment: *in* Scholle, P. A., Bebout, D. G., and Moore, C. H., eds., Carbonate Depositional Environments: A.A.P.G. Memoir 33, p. 264-506.

James, N. P., 1983, Chapt. 8-Reef Environment: *in* Scholle, P. A., Bebout, D. G., and Moore, C. H., eds., Carbonate Depositional Environments: A.A.P.G. Memoir 33, p. 346-462.

Enos, P. and Moore, C. H., 1983, Chapt. 10- Fore-reef Slope Environment: *in* Scholle, P. A., Bebout, D. G., and Moore, C. H., eds., Carbonate Depositional Environments: A.A.P.G. Memoir 33, p. 508-537.

October 24 Monday ***This week Lab Practical Exam Carbonate Grain Types: Sign up for microscope & sample time slot***

Lec. 18 Giles: Slope, basin margin or toe-of slope, basinal environment in the Permian Delaware Basin.

Reading 24:

Cook, H. E. and Mullins, H. T., 1983, Chapt. 11- Basin Margin Environment: *in* Scholle, P. A., Bebout, D. G., and Moore, C. H., eds., Carbonate Depositional Environments: A.A.P.G. Memoir 33, p. 540-617.

Scholle, P. A., Arthur, M. A., and Eckdale, A.A., 1983, Chapt. 12- Pelagic Environment: *in* Scholle, P. A., Bebout, D. G., and Moore, C. H., eds., Carbonate Depositional Environments: A.A.P.G. Memoir 33, p. 620-691.

Lab 8 Tidal flat to basinal facies of the Permian reef complex Guadalupe Mountains, west Texas

October 26 Wednesday

Lec. 19 Giles: Controls on platform slopes.

October 31 Monday

Lec. 20 Giles: Sequence stratigraphy of carbonate platforms & the Permian Reef Complex.

Lecture Reading 25:

Sarg, J. F., 1988, Carbonate sequence stratigraphy: *in* Wilgus, C. K., Hastings, B. S., Kendall, C., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., Sea-level Changes: An Integrated Approach, S.E.P.M. Spec Pub. No. 42, p. 155-181.

Lab 9 Sequence Stratigraphy of the Guadalupe Mountains Permian Reef complex

November 2 Wednesday

Lec. 21 Giles: Carbonate karst systems

Nov. 5 & 6 Saturday & Sunday

Field trip 1: Permian Reef Complex, Guadalupe Mtns/ Carlsbad Caverns. Examine depositional facies of Permian Reef complex. Study diagenetic alteration of reef system at Carlsbad Caverns.

November 7 Monday

Lec. 22 : Class debate - do carbonate platforms really drown?

Lecture reading

Schlager, W., 1981, The paradox of drowned reefs and carbonate platforms: GSA Bulletin, v. 92, p. 197-211.

Lab 10 Cool water carbonates. Heterozoan versus Photozoan biofacies associations

Lab Reference Reading:

James, N. P., 2010, The cool water depositional realm: *In*: James N. P. and Clarke J. (eds) Cool-Water Carbonates Edited by Noel P. James and Jonathan A. D. Clarke. v.56, p.1-20.

Mutti, M. and Hallock, P. 2003, Carbonate systems along nutrient and temperature gradients: some sedimentological and geochemical constraints: International Journal of Earth Science (Geol. Rundsch), v. 92, p. 465-475.

November 14 Monday

Lec. 23 Lacustrine Carbonates, Brazilian and Angolan Pre-salt Alkaline Lacustrine Systems

Lecture Reading:

Wright, V.P., 2022, The mantle, CO₂ and the giant Aptian chemogenic lacustrine carbonate factory of the South Atlantic: Some carbonates are made, not born: *Sedimentology*, v. 69, p. 47–73, <https://doi.org/10.1111/sed.12835>.

Lab Cretaceous lacustrine carbonates Indios Mountains, West Texas

November 16 Wednesday [Ben out NMSU giving talk “The many flavors of carbonates associated with salt diapirs”](#)

Lec. TBD

November 19 Saturday

Fieldtrip 2: TBD El Paso Area

Depart Geology Department parking lot at 8:00am and return by 5:00pm.

November 21 Monday

Lec. 29 : TBD

November 23 Wednesday ***No Class Thanksgiving Break***

November 28 Monday

Lec. 30 : TBD

November 30 Wednesday

Lec. 31 : TBD