

# Petrologic Systems - 316L

## Spring, 2023

### Instructors:

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Teaching assistant: Naomi Rodgers, ZHS-129; [nrodgers@usc.edu](mailto:nrodgers@usc.edu).

### Time and Place

Lecture: Tuesdays, Thursdays 1:00 – 2:20 pm in ZHS118.

Lab: Friday, 9.00 – 10.50 am, ZHS B65.

### Textbook:

*Principles of Igneous and Metamorphic Petrology (2<sup>nd</sup> edition)* John Winter. Prentice Hall, 2009.

### Exams:

Exam 1 (Igneous) – Friday March 3, 9.00 – 10.50 am

Exam 2 (Metamorphic) – Wednesday May 10, 2.00-4:00 pm

### Field Trip:

April 10-12, Santa Catalina Island.

### Basis of Grade:

Lecture midterms: (total 50%):

    Igneous Midterm 25 %

    Metamorphic Midterm 25 %

Lab (total 50%):

    Lab assignments 30%

    Field trip projects (total 20%):

        Igneous paper on arcs 10%

        Metamorphic paper on Catalina 10%

## Schedule of Lectures

Jan. 10: Class Intro (Reading: Chapter 1)

    Go over course and syllabus.

    Differentiation of solar system + earth, crustal growth, heat sources, and plate tectonics

### Igneous Petrology Module

Jan. 12: Introduction to Igneous Petrology (Chapter 1)

What is igneous petrology and what techniques are used to study igneous rocks?

What is Earth made of, and what are major subdivision of the Earth's interior?

How do the conditions of pressure and temperature vary within the Earth?

Jan. 17: Classification and Nomenclature of Igneous Rocks (Chapter 2)

On what basis are igneous rocks classified?

What are general terms used to describe textural and compositional classification of igneous rocks?

What is the generally accepted classification scheme?

Jan. 19: Textures of Igneous Rocks (Chapters 3)

What textures may be produced as magma cools and crystallizes to form igneous rocks?

What physical variables control the development of igneous textures?

What recrystallization textures may result as high-temperature igneous minerals?

Jan. 24: Igneous Structures and Field Relationships (Chapter 4)

In what field settings can you find volcanic and plutonic rocks?

How do magmatic properties affect the style of eruption?

What are types of volcanic landforms?

What are typical pluton shapes and how are they related to intrusion style?

Jan 26: Introduction to Thermodynamics (Chapter 5)

How can we determine the stability range of mineral assemblages?

How can we evaluate the effects of temperature, pressure, or changing geochemistry on a geologic system?

How can we qualitatively evaluate phase diagrams?

Jan 31: Phase Rule and One- and Two- Component Systems (Chapter 6)

How do crystallizing and melting of complex igneous systems differ from simple systems like water-ice?

How can we use simple laboratory experiments to understand complex natural systems?

How do liquids and associated minerals vary in composition during crystallization or melting?

Feb. 2: Mantle Melting and Basaltic Magma (Chapter 10)

What is required to initiate partial melting in the mantle?

When the mantle melts, what governs the nature of the partial melts?

What are the implications of the observed magma diversity on the nature of the mantle?

Feb 7: Magma Diversity (Chapter 11)

How can compositional diversity be developed in magmatic systems?

How does a parental magma evolve in composition?

What methods do we use to evaluate these processes?

Feb 9: No class (Emily at UCSB) <Make up lab day>

Feb. 14: Mid-Ocean Ridge Volcanism (Chapter 13)

What igneous processes occur at divergent plate boundaries?

How does mantle melting occur beneath mid-ocean ridges?

What is the variation of igneous rocks at mid-ocean ridges?

Feb. 16: Subduction-Related Island Arcs (Chapter 16)

Why does subduction lead to magmatism?  
Why are island-arc magmas so much more diverse?  
What is the source of island-arc magmas?

Feb 21: Subduction Related Continental Arcs (Chapter 17)

In what ways do continental arcs differ from island arcs?  
What influences does thick continental crust have on the composition and physical nature of continental arc rocks now exposed?  
What role does subcontinental lithospheric mantle play in arc magmatism?  
How are major batholith belts formed?

Feb 23: Granitoid Rocks (Chapter 18)

What variety of granitoids do we find and how are they classified?  
What controls the occurrence and distribution of various granitoid rocks?  
What is the nature of crustal and mantle inputs to granitoid petrogenesis?

Feb 28: Continental Alkaline Magmatism (Chapter 19)

What alkaline rock types occur in non-subduction continental settings and how does it differ from those other settings?  
Why are continental alkaline rocks so geochemically diverse?  
Why are continental rift zones, carbonatites, lamproites, lamprophyres, and kimberlites and what do they all tell us about the nature of the continental lithosphere?

March 2: Review

March 3: 9.00 – 10.50 am (Lab time) Igneous Petrology exam.

### **Metamorphic Petrology Module.**

*Introduction to metamorphic petrology*

Tuesday March 7

Metamorphism and the concept of metamorphic facies  
Controls on metamorphic mineral assemblages by facies and rock composition  
An outline of the principle metamorphic facies  
Geologic settings of metamorphism and metamorphic facies sequences  
Phase changes and metamorphic reactions  
*Reading:* Ch 21, p. 446-458; Ch 22; Ch 25, p. 537-542

*Progressive metamorphism in pelites*

Thursday March 9

The onset of greenschist facies metamorphism  
The chlorite isograd  
Breakdown of pyrophyllite  
The biotite isograd  
The garnet isograd  
AKF and AFM composition diagrams  
*Reading:* Ch 24, p.522-535; Ch 28, p. 607-614

## Spring Break March 12-19

*Progressive metamorphism in pelites continued* Tuesday March 21

The staurolite isograd and the onset of amphibolite facies metamorphism

The kyanite isograd and the breakdown of staurolite

Breakdown of muscovite and biotite

The first and second sillimanite isograds

*Reading:* Ch 28, sections 28.2.4, and 28.2.6 through 8.

*Progressive metamorphism in metamafic rocks* Thursday March 23

The greenschist - amphibolite transition in metamafic rocks

Comparison of assemblages among different rock types at different grades

ACF composition diagrams

*Reading:* Ch 25, p. 542-6

*Melting, migmatites and granulites* Tuesday March 28

Fluid-absent and fluid-present melting

Crustal melting and the generation of migmatites

Granulite facies assemblages in metapelitic rocks

Granulite facies assemblages in metamafic rocks

Fluid composition during granulite facies metamorphism

Distribution of granulite facies rocks in space and time.

*Reading:* Ch 28, sections 28.4 and 28.5

*Contact metamorphism; metamorphism of carbonates* Thursday March 30

Contact aureoles around plutons

Model of conductive heat transfer

Metamorphic grades / facies during contact metamorphism

Metamorphic reactions in carbonate rocks

T-X diagrams

Critical reactions in quartz-calcite-dolomite assemblages

*Reading:* Ch 6, section 26.4; Ch 29, p. 635-641; Ch 21, sections 21.3.1 and 21.6.5

*Subduction zone metamorphism* Tuesday April 4

Thermal conditions in subduction zone environments

Very low-grade metamorphism in subduction zone environments

Blueschist-facies metamorphism

Eclogite-facies metamorphism

Ultra-high pressure metamorphism

*Reading:* Ch 25, sections 25.3.4

*Metamorphic processes and textures* Thursday April 6  
Controls on metamorphism  
Neomineralization, metasomatism, and grain-growth  
Metamorphic textures  
Deformational processes during metamorphism  
Effect of fluids on metamorphic reactions, rates, and textures

*Thermodynamic concepts in metamorphic petrology* Tuesday April 11  
Definitions of phase equilibria and thermodynamic variables  
Examples of unstable, metastable, and stable conditions  
The phase rule and its applications  
*Reading:* Ch 24, p. 518-522 (see also p. 95-98)

*Thermobarometry* Thursday April 13  
Motivation for geothermobarometry  
Review of thermodynamic principles  
    Distribution coefficient  
    Clausius-Clapeyron equation  
Geothermometry  
    Exchange reactions  
    Solvus thermometry  
Geobarometry  
Net transfer reactions  
Gibbs method  
*Reading:* Ch 27, p. 579-595.

*Field trip to Santa Catalina Island, April 14-16*  
Students will be expected to write a full report on the field trip and the accompanying lab project.

*Application of thermobarometry to a tectonic problem:  
the Snake Range metamorphic core complex, Nevada.* Tuesday April 18

*P-T paths during metamorphism* Thursday April 20  
The Franciscan Complex  
The Alps  
The Himalayas  
The Betic Cordillera

*Exhumation of high-pressure metamorphic rocks* Tuesday April 25

*Review Session* Thursday April 27

Exam 2 (Metamorphic) – Wednesday May 10, 2.00-4:00 pm.

## Student Support Services:

*Disability Services and Programs (DSP):* Students requesting academic accommodations based on a disability are required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP when adequate documentation is filed. Please be sure the letter is delivered to me as early in the semester as possible. All DSP students are expected to remind me in advance regarding special arrangements needed for midterm exams. DSP is open Monday-Friday, 8:30-5:00. The office is in 3601 Watt Way, Grace Ford Salvatori Hall, 120, the phone number is (213) 740-0776, and email is [ability@usc.edu](mailto:ability@usc.edu).

*Academic Conduct:* Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, “Behavior Violating University Standards” [policy.usc.edu/scampus-part-b](http://policy.usc.edu/scampus-part-b). Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct>.

*Support Systems:* Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call  
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. [engemannshc.usc.edu/counseling](http://engemannshc.usc.edu/counseling)

*National Suicide Prevention Lifeline* – 1 (800) 273-8255: Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. [www.suicidepreventionlifeline.org](http://www.suicidepreventionlifeline.org)

*Relationship and Sexual Violence Prevention Services (RSVP)* – (213) 740-4900 – 24/7 on call. Free and confidential therapy services, workshops, and training for situations related to gender-based harm. [engemannshc.usc.edu/rsvp](http://engemannshc.usc.edu/rsvp)

*Sexual Assault Resource Center:* For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: [sarc.usc.edu](http://sarc.usc.edu)

*Office of Equity and Diversity (OED)/Title IX Compliance* – (213) 740-5086: Works with faculty, staff, visitors, applicants, and students around issues of protected class. [equity.usc.edu](http://equity.usc.edu)

*Bias Assessment Response and Support:* Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. [studentaffairs.usc.edu/bias-assessment-response-support](http://studentaffairs.usc.edu/bias-assessment-response-support)

*The Office of Disability Services and Programs:* Provides certification for students with disabilities and helps arrange relevant accommodations. [dsp.usc.edu](http://dsp.usc.edu)

*Student Support and Advocacy* – (213) 821-4710: Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. [studentaffairs.usc.edu/ssu](http://studentaffairs.usc.edu/ssu)

*Diversity at USC*: Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. [diversity.usc.edu](http://diversity.usc.edu)

*USC Emergency Information*: Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. [emergency.usc.edu](http://emergency.usc.edu)

*USC Department of Public Safety* – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime. Provides overall safety to USC community. [dps.usc.edu](http://dps.usc.edu)