

College of the Environment, Forestry, and Natural Sciences

**AST 460 - Planetary Geomorphology**

**Department of Astronomy and Planetary Science**

**Fall, 2021:** M/W/F 9:10 – 10:00 am, 3 credit hours

**Location:** Physical Sciences (Bldg #19) Room 111

**Course Pre-Requisite(s):** none

**Mode of Instruction:** Face-to-face

**Instructor:** Prof. Devon Burr ([Devon.Burr@nau.edu](mailto:Devon.Burr@nau.edu))

**Office:** Physical Science (Bldg 19), Room 315, 523-7063

**Office hours:** Mondays, 2-3pm and by appointment. Feel free either to come to office hours or e-mail to make an appointment. Please come prepared with questions or concepts to discuss and keep any appointments that you make.

**GTA:** Tony Maue ([adm578@nau.edu](mailto:adm578@nau.edu))

Please check the course Bblearn website and your NAU email frequently for communications about this course.

**Course Purpose:**

Geophysical and geologic processes shape landscapes throughout our Solar System. Understanding how these processes shape landscapes and being able to interpret planetary landscapes give important insights into planetary evolution. Thus, an understanding of landscapes is a necessary foundation to understanding its past and present evolution, current state, and habitability potential of planetary bodies.

The purpose of this course is to introduce beginning graduate students to planetary landscapes. This course serves the graduate program in Astronomy and Planetary Science by developing the essential skill of scientific inquiry (SI) and also developing and practicing the essential skills of critical thinking (CT), quantitative reasoning (QR), and Effective Writing [EW].

The result will be the continued development of graduate students into stronger and more independent scientists and research professionals. Our ambition for each student in the course is the development of: i) a foundational understanding of planetary landscapes and the processes that shape them, and ii) enhanced skill in reading and understanding scientific literature, including a knowledge of the scientific methodology of hypothesis testing. These desiderata will be shaped both by independent work and in collaboration with other students.

**Prerequisites:** This course is a beginning graduate course for students in astronomy and planetary science, the Earth sciences, or a related field. A working knowledge of undergraduate physics and mathematics is expected, along with a familiarity with geologic and geophysical concepts, although students with other backgrounds are welcome with the consent of the instructor.

**Course Topics, Objectives, and Format:**

This course is a beginning graduate course in the surface geology of planetary bodies in the inner and outer Solar System. It serves as an elective in the Ph.D. program in Astronomy and Planetary Science and is co-convened with AST 460, and advance undergraduate elective. Course objectives are: 1) to learn to recognize the basic morphology created by various geologic processes, and 2) understand the associated physics that created the morphology.

The class activities will be a mixture of lecture presentations, literature discussion, lab exercises, and geologic mapping. The lectures will be led by the professor, guest lecturers, and/or students. Discussion by you is encouraged and expected with each lecture and will be integral to developing our individual and collective understanding of the science concepts, so please come prepared.

- Homework will be introduced by the course instructor during lecture and is due to them.
- Labs will be led by the GTA, Tony Maue, and is due to him.
- The mapping exercise will be led jointly by the instructor, GTA, and USGS colleagues, and is due to the instructor.

### **Course Student Learning Outcomes:**

Undergraduate Students who successfully complete AST 460 will:

- SLO 1. Understand and be able to explain in words, with diagrams, and/or with equations the common physical and chemical processes that shape planetary landscapes throughout the Solar System on both rocky and icy bodies (SI, CT, QR).
- SLO 2. Exercise the scientific method in interpreting planetary landscapes, including applying pre-existing knowledge to formulate hypotheses for their formation, develop tests for these hypotheses, collect data and analyze them in performing these tests, and drawing conclusions for the results of the hypothesis testing (SI, CT, QR).
- SLO 3. Understand, be able to explain, and apply the analytical methods and approaches used in planetary exploration (CT, QR)
- SLO 4. Understand and be able to explain the physical laws and technology used in planetary exploration (QR)
- SLO 5. Develop and exercise the discipline skill of planetary geologic mapping, culminating in the production of either a planetary geologic map or a series of mapping exercises (CT).

### **Assignments/Assessments of Course Student Learning Outcomes (with grading weights).**

Assignments / assessments are designed to support the accomplishment of Course Student Learning Outcomes and will be in the form of i) homework, ii) laboratory exercises, iii) two sequential mapping presentations, and iv) class participation.

- a. Homework (10%): [SLOs 1,2,3]  
There will be two homework assignments pertaining to aeolian, fluvial, and / or glacial processes. Both assignments will include explaining in words, with diagrams, and/or through use of equations to provide quantitative information about such processes to characterize the formation of landscapes on Earth and other planetary bodies.
- b. Lab exercises (35%): [SLOs 1,2,3]  
There will be five lab assignments that will provide experience with and understanding of: planetary science data, planetary geologic mapping, primary and secondary impact cratering, volcanism, and tectonism. The labs will involve computer-based hands-on activities to become skilled in handling and analyzing planetary data and include the formulation and testing of multiple working hypotheses for planetary landscape formation.
- c. Initial map presentation (10%): [SLOs 2,4,5]  
The initial planetary geologic map presentation will include explaining the source of data used to make the map, the technical approach used to make the map, and the inferred formation of each geologic map unit on the basis of physical and/or chemical laws. Evaluation by classmates will both provide feedback to the presenter and sensitize the class to the many aspects of effective geologic mapping.

d. Final map presentation (25%): [SLOs 2,4,5]

Like the initial map presentation, the final map presentation will include explaining the source of data used to make the map, the technical approach used to make the map, and the inferred formation of each geologic map unit on the basis of physical and/or chemical laws. Evaluation by classmates will both provide feedback to the presenter and continue to enable the class to develop their understanding of what makes a good geologic map and a good presentation.

e. class participation (5%) [SLOs 1-3]

In-class activities will include think-pair-share in the interpretation of planetary landscape data, filling out group worksheets in the development of hypotheses for formation of planetary landscapes, and / or work at the board in small groups to develop methods to test these hypotheses.

### **Class Outline or Tentative Schedule for a Spring semester**

1. **Attendance:** I *strongly* recommend you attend class. Research shows that in-person attendance enhances learning and activities in this course are built around in-person attendance including student interactions.

It's imperative of course that we look out for our group health and safety.  
*If according to CDC guidelines and NAU policy would be unsafe for others for you to attend any given class, please let me know as early as possible and I will be glad to provide a one-time link for your remote attendance.*

2. **Reading:** Reading assignments will be posted on the course Blackboard site and announced in class.

3. **Labs and Homework:** Due dates for both labs (portions of which will be performed in class) and homework are listed in the course schedule.

- Homework assignments are due (in hard copy, stapled together) to the course instructor.
- The labs are due (electronically) to the GTA

**Both labs and homework are due *five minutes before the start of class* on the due date.**

**Please note that late assignments will not be accepted.**

***It's better to hand in a partial lab on time for partial credit than a completed lab late for no credit.***

4. **Presentations:** Presentations will be of three types:

- a. Lectures / reading discussions given by the instructor or a guest lecturer,
- b. Mapping presentation – see Geologic Mapping Exercises / Projects below.

All student presentations must be provided to the professor *by 8am of the day on which they will be given*.

More information regarding these presentations will be provided.

5. **Geologic Mapping Exercises / Projects:** A major part of this course is individualized geologic activities / projects. This mapping work will entail exercises developed and provided by the USGS Astrogeology Planetary Geologic Mapping Group and presentation of a planetary geologic map of an area of Mars. More information on the mapping assignments will be provided during the course.

6. **Grades:** Coursework will be weighted as follows:

- |                                   |     |
|-----------------------------------|-----|
| a. Homework                       | 20% |
| b. Lab exercises                  | 35% |
| c. Mapping exercises / activities | 35% |
| d. class participation            | 10% |

Final course grades will be earned based on the standard scheme of: A = >90.0%, B = 80% to 89.9%, etc.

Minuses and pluses will be used within 3% of a letter grade break.

**8. Academic Standards of Conduct:**

**a) Honor code:** Do your own work and let others to do theirs.

**b) In-class conduct:** Be courteous, follow the Golden Rule...

*If you need course adaptations or accommodations, please contact the Office of Disability Resources at*

Room 2050 Building 25

Health and Learning Center

824 South San Francisco Street

Flagstaff, AZ 86011

*(telephone 928-523-8773)*

*e-mail [DR@nau.edu](mailto:DR@nau.edu))*

**Initial Course Schedule and Outline: May be adjusted NLT the class period prior.**

| <b>D</b> | <b>Date</b>      | <b>Subject</b>  | <b>Potential Readings / Assignment / Activities (elective / background)</b>                                    |
|----------|------------------|---|--|
| M<br>W   | Jan<br>10,12     | Introduction to course.<br>Structure of the SS.<br>Tour of terrestrial bodies.  | "The four hundred years of planetary science since Galileo and Kepler" (Burns, 2010)<br>Melosh 2011 (Ch. 1.1). |
| F        | Jan 14           | Planetary surfaces and histories. Types of geomorphic processes.  | Melosh 2011 (Ch. 1.3).   |
| W        | Jan 19           | Hypsometry of terrestrial bodies.<br><br>JMars introduction <a href="https://jmars.mars.asu.edu/">https://jmars.mars.asu.edu/</a> | Lorenz et al. 2011   |
| F        | Jan 21           | <b>LAB 1: Introduction to Planetary Surface Data</b>  | JMARS prep: i) create account, ii) review info under "Tour of JMars user interface"                            |
| M<br>W   | Jan<br>24,26     | Impact Crater morphologies.<br>Ejecta deposits.   | Melosh 2011 (Ch. 6.2).<br>Melosh 2011 (Ch. 6.4).   |
| F        | Jan 28           | <b>LAB 2: Impact Cratering morphology</b>   | <b>LAB 1 <u>due</u> to GTA</b>   |
| M<br>W   | Jan 31,<br>Feb 2 | Secondary Impact Craters and Age-dating   | McEwen and Bierhaus 2006<br>(Hartmann and Neukum 2001,<br>Hartmann et al. 2001)                                |
| F        | Feb 4            | <b>LAB 3: Secondary impact cratering / age dating</b>   | <b>LAB 2 <u>due</u> to GTA</b>   |
| M<br>W   | Feb 7, 9         | Tectonism: planetary diversity, lunar examples  | Watters and Schultz 2010 (Intro)<br>Watters et al. 2012,<br>(Kattenhorn and Prockter 2014)                     |
| F        | Feb 11           | <b>LAB 4: Planetary Tectonism</b>   | <b>LAB 3 <u>due</u> to GTA</b>   |
| M<br>W   | Feb 14,<br>16    | Volcanism: planetary geomorphology  | Lopes et al., 2010<br>(Wood 1984, Vaucher et al. 2009)   |
| F        | Feb 18           | <b>LAB 5: Planetary Volcanism</b>   | <b>LAB 4 <u>due</u> to GTA</b>   |
| M<br>W   | Feb<br>21,23     | Sediment Production and Diagenesis.<br>Martian sedimentology.   | Grotzinger and Milliken 2012,<br>Grotzinger et al. 2013  |
| F        | Feb 25           | Titan sedimentology.<br>Guest lecture by Tony Maue (GTA).   | <b>LAB 5 <u>due</u> to GTA</b>   |
| M<br>W   | Feb 28,<br>Mar 2 | Aeolian morphologies.<br>Aeolian landforms on Mars.   | Kok et al. 2012 (through 2.1.1)<br>McKee 1979 (figures), Bourke et al. 2010                                    |

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|          |              |   |   |
|----------|--------------|---|---|
| F        | Mar 4        | Other extraterrestrial aeolian landforms<br>Intro to <b>HW1: Aeolian morphologies</b>   | Bridges et al. 2007, Bridges et al. 2012 (N+V), Ewing et al. 2015 |
| M<br>W   | Mar 7, 9     | Fluvial morphologies.<br>Fluvial morphologies on Mars.  | Baker et al., 2015, Burr et al. 2013,<br>Jacobsen and Burr 2017   |
| F        | Mar 11       | Intro to <b>HW 2: Fluvial morphologies</b>  | <b>HW1 <u>due</u></b>   |
| M<br>W   | Mar 14,16    | <b>SPRING BREAK</b>   |   |
| F        | Mar 18       |   |   |
| M<br>W   | Mar 21,23    | Glaciation processes. Ice deposits.   | Head et al. 2003, Head et al. 2005                                |
| F        | Mar 25       | Periglacial processes   | <b>HW 2 <u>due</u></b>  |
| M<br>W   | Mar 28,30    | Landscape evolution and/or astrobiology   | TDB   |
| F        | Apr 1        | CATCH UP  | TDB   |
| M<br>W   | Apr 4,6      | Intro to planetary geologic mapping.<br>Guest lecture(s) by Jim Skinner (USGS<br>Planetary Geologic Mapping Group<br>Coordinator) | Wilhelms, 1990 (from Greeley and<br>Batson Planetary Mapping)     |
| F        | Apr 8        | Pen and paper mapping exercise by USGS<br>Planetary Geologic Mapping Group  | Introductory geologic mapping on<br>USGS photomosaics of Mars     |
| M<br>W   | Apr 11,13    | Scales, bodies, and map components.<br>Guest lecture(s) by Jim Skinner (USGS<br>Planetary Geologic Mapping Group<br>Coordinator)  | Readings TBD  |
| F        | Apr 15       | Planetary geologic mapping (individual)   | Geologic mapping on assigned<br>areas of Mars                     |
| M<br>W   | Apr 18,20    | Planetary geologic mapping (individual).  | Continued geologic mapping on<br>assigned areas.                  |
| F        | Apr 22       | Presentation of maps.   | Present individual maps to class.                                 |
| M<br>W   | Apr 25,27    | Planetary geologic mapping (group)  | Correlation among individual<br>regional maps to create group map |
| F        | Apr 29       | <b>Present individual and group maps to department.</b>   |   |
| <b>W</b> | <b>May 4</b> | <b>Map due at final exam time for this class.</b>   |   |

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## **COVID-19 REQUIREMENTS AND INFORMATION**

Additional information about the University's response to COVID-19 is available from the **Jacks are Back!** web page located at <https://nau.edu/jacks-are-back>.

### **SYLLABUS POLICY STATEMENTS**

#### **ACADEMIC INTEGRITY**

NAU expects every student to firmly adhere to a strong ethical code of academic integrity in all their scholarly pursuits. The primary attributes of academic integrity are honesty, trustworthiness, fairness, and responsibility. As a student, you are expected to submit original work while giving proper credit to other people's ideas or contributions. Acting with academic integrity means completing your assignments independently while truthfully acknowledging all sources of information, or collaboration with others when appropriate. When you submit your work, you are implicitly declaring that the work is your own. Academic integrity is expected not only during formal coursework, but in all your relationships or interactions that are connected to the educational enterprise. All forms of academic deceit such as plagiarism, cheating, collusion, falsification or fabrication of results or records, permitting your work to be submitted by another, or inappropriately recycling your own work from one class to another, constitute academic misconduct that may result in serious disciplinary consequences. All students and faculty members are responsible for reporting suspected instances of academic misconduct. All students are encouraged to complete NAU's online academic integrity workshop available in the E-Learning Center and should review the full *Academic Integrity* policy available at <https://policy.nau.edu/policy/policy.aspx?num=100601>.

#### **COURSE TIME COMMITMENT**

Pursuant to Arizona Board of Regents guidance (ABOR Policy 2-224, *Academic Credit*), each unit of credit requires a minimum of 45 hours of work by students, including but not limited to, class time, preparation, homework, and studying. For example, for a 3-credit course a student should expect to work at least 8.5 hours each week in a 16-week session and a minimum of 33 hours per week for a 3-credit course in a 4-week session.

#### **DISRUPTIVE BEHAVIOR**

Membership in NAU's academic community entails a special obligation to maintain class environments that are conducive to learning, whether instruction is taking place in the classroom, a laboratory or clinical setting, during course-related fieldwork, or online. Students have the obligation to engage in the educational process in a manner that does not interfere with normal class activities or violate the rights of others. Instructors have the authority and responsibility to address disruptive behavior that interferes with student learning, which can include the involuntary withdrawal of a student from a course with a grade of "W". For additional information, see NAU's *Disruptive Behavior in an Instructional Setting* policy at <https://nau.edu/university-policy-library/disruptive-behavior>.

#### **NONDISCRIMINATION AND ANTI-HARASSMENT**

NAU prohibits discrimination and harassment based on sex, gender, gender identity, race, color, age, national origin, religion, sexual orientation, disability, or veteran status. Due to potentially unethical consequences, certain consensual amorous or sexual relationships between faculty and students are also prohibited as set forth in the *Consensual Romantic and Sexual Relationships* policy. The Equity and Access Office (EAO) responds to complaints regarding discrimination and harassment that fall under NAU's *Nondiscrimination and Anti-Harassment* policy. EAO also assists with religious accommodations. For additional information about nondiscrimination or anti-harassment or to file a complaint, contact EAO located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011, or by phone at 928-523-3312 (TTY: 928-523-1006), fax at 928-523-9977, email at [equityandaccess@nau.edu](mailto:equityandaccess@nau.edu), or visit the EAO website at <https://nau.edu/equity-and-access>.



## **TITLE IX**

Title IX is the primary federal law that prohibits discrimination on the basis of sex or gender in educational programs or activities. Sex discrimination for this purpose includes sexual harassment, sexual assault or relationship violence, and stalking (including cyber-stalking). Title IX requires that universities appoint a “Title IX Coordinator” to monitor the institution’s compliance with this important civil rights law. NAU’s Title IX Coordinator is Elyce C. Morris. The Title IX Coordinator is available to meet with any student to discuss any Title IX issue or concern. You may contact the Title IX Coordinator by phone at 928-523-3515, by fax at 928-523-0640, or by email at [elyce.morris@nau.edu](mailto:elyce.morris@nau.edu). In furtherance of its Title IX obligations, NAU will promptly investigate and equitably resolve all reports of sex or gender-based discrimination, harassment, or sexual misconduct and will eliminate any hostile environment as defined by law. Additional important information about Title IX and related student resources, including how to request immediate help or confidential support following an act of sexual violence, is available at <https://in.nau.edu/title-ix>.

## **ACCESSIBILITY**

Professional disability specialists are available at Disability Resources to facilitate a range of academic support services and accommodations for students with disabilities. If you have a documented disability, you can request assistance by contacting Disability Resources at 928-523-8773 (voice), 928-523-6906 (TTY), 928-523-8747 (fax), or [dr@nau.edu](mailto:dr@nau.edu) (e-mail). Once eligibility has been determined, students register with Disability Resources every semester to activate their approved accommodations. Although a student may request an accommodation at any time, it is best to initiate the application process at least four weeks before a student wishes to receive an accommodation. Students may begin the accommodation process by submitting a self-identification form online at <https://nau.edu/disability-resources/student-eligibility-process> or by contacting Disability Resources. The Director of Disability Resources, Jamie Axelrod, serves as NAU’s Americans with Disabilities Act Coordinator and Section 504 Compliance Officer. He can be reached at [jamie.axelrod@nau.edu](mailto:jamie.axelrod@nau.edu).

## **RESPONSIBLE CONDUCT OF RESEARCH**

Students who engage in research at NAU must receive appropriate Responsible Conduct of Research (RCR) training. This instruction is designed to help ensure proper awareness and application of well-established professional norms and ethical principles related to the performance of all scientific research activities. More information regarding RCR training is available at <https://nau.edu/research/compliance/research-integrity>.

## **MISCONDUCT IN RESEARCH**

As noted, NAU expects every student to firmly adhere to a strong code of academic integrity in all their scholarly pursuits. This includes avoiding fabrication, falsification, or plagiarism when conducting research or reporting research results. Engaging in research misconduct may result in serious disciplinary consequences. Students must also report any suspected or actual instances of research misconduct of which they become aware. Allegations of research misconduct should be reported to your instructor or the University’s Research Integrity Officer, Dr. David Faguy, who can be reached at [david.faguy@nau.edu](mailto:david.faguy@nau.edu) or 928-523-6117. More information about misconduct in research is available at <https://nau.edu/university-policy-library/misconduct-in-research>.

## **SENSITIVE COURSE MATERIALS**

University education aims to expand student understanding and awareness. Thus, it necessarily involves engagement with a wide range of information, ideas, and creative representations. In their college studies, students can expect to encounter and to critically appraise materials that may differ from and perhaps challenge familiar understandings, ideas, and beliefs. Students are encouraged to discuss these matters with faculty.

*Last revised August 1, 2021*

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