

College of the Environment, Forestry, and Natural Sciences

AST 560 - Planetary Geomorphology

Department of Astronomy and Planetary Science

Spring, 2024: M/W/F 9:10 – 10:00 am, 3 credit hours

Location: Physical Sciences (Bldg #19) Room 321

Course Pre-Requisite(s): none

Mode of Instruction: Face-to-face

Instructor: Prof. Devon Burr (Devon.Burr@nau.edu)

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

Student support hours: I would be very glad to meet with you! Please talk to me after class or email to set up an appointment. In addition, I'll hold regular student support hours Mondays, 2-3pm. Please come prepared with questions or concepts to discuss and keep any appointments that you make.

Please check the course Canvas website and your NAU email ~daily for communications about this course.

Course Purpose:

Planetary landscapes are glorious things! Besides their sheer beauty, landscapes provide evidence for the past and present evolution, current state, and habitability potential of planetary bodies.

The purpose of this course is to introduce beginning graduate students to the geophysical and geologic processes shape planetary landscapes and their results. This course serves the graduate program in Astronomy and Planetary Science by developing the essential skills of scientific inquiry (**SI**), critical thinking (**CT**), quantitative reasoning (**QR**), and Effective Writing (**EW**). The result will be the continued development of students into stronger scientists and research professionals.

Prerequisites: Knowledge of undergraduate physics and mathematics is expected, along with a familiarity with geologic and geophysical concepts. Students with other backgrounds are welcome with instructor consent.

Course Topics, Objectives, and Format:

This course is a beginning graduate course in the study, analysis, and mapping of planetary landscapes. The ambition for each student is development of: i) a foundational understanding of planetary landscapes and processes that shape them, ii) enhanced skill in understanding scientific literature, including a knowledge of scientific hypothesis testing, and iii) initiation into the skill of planetary geologic mapping.

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. Please come prepared.

Each course assignment corresponds to Student Learning Outcomes and to Career-Ready Competencies:

Course Student Learning Outcomes:

Graduate Students who successfully complete AST 560 will:

- SLO 1. Understand and be able to explain with words, diagrams, equations, and images or other data 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 skill of planetary geologic mapping, culminating in the presentation of a planetary geologic map and writing an accompanying conference abstract (**CT**).

Another outcome for this and all NAU courses is enhanced career-readiness, a University-wide initiative at NAU. The following are **Career Ready Resources** available to NAU students:

LinkedIn:

CEFNS Career Development

www.linkedin.com/in/cefns-career-development-072715233

NAU Career Development

<https://www.linkedin.com/company/nau-career-development/>

Handshake:

<https://nau.joinhandshake.com/login>

Udemy: Online courses and career searching advice

<https://in.nau.edu/its/udemy/>

Log in with your NAU email account and search 'NAU Career Steps'

O*net Online: Occupation exploration reports

<https://www.onetonline.org/>

Career-Ready Competencies

In addition to these resources, each type of assignment in this course provides practice developing specific [Career Readiness Competencies](#), as defined by The National Association of Colleges and Employers (NACE). These competencies are transferable skills that promote successful entrance into the workforce and lifelong career management. They are

1. **Career & Self-Development:** Proactively develop oneself and one's career through continual personal and professional learning, awareness of one's strengths and weaknesses, navigation of career opportunities, and networking to build relationships within and without one's organization.
2. **Communication:** Clearly and effectively exchange information, ideas, facts, and perspectives with persons inside and outside of an organization.
3. **Critical Thinking:** Identify and respond to needs based upon an understanding of situational context and logical analysis of relevant information.
4. **Equity & Inclusion:** Demonstrate the awareness, attitude, knowledge, and skills required to equitably engage and include people from different local and global cultures. Engage in anti-racist practices that actively challenge the systems, structures, and policies of racism.
5. **Leadership:** Recognize and capitalize on personal and team strengths to achieve organizational goals.
6. **Professionalism:** Knowing work environments differ greatly, understand and demonstrate effective work habits, and act in the interest of the larger community and workplace.
7. **Teamwork:** Build and maintain collaborative relationships to work effectively toward common goals, while appreciating diverse viewpoints and shared responsibilities.
8. **Technology:** Understand and leverage technologies ethically to enhance efficiencies, complete tasks, and accomplish goals.

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

Assignments / assessments in support of a) Student Learning Outcomes and b) Career-Readiness will be in the form of i) laboratory exercises, ii) two sequential mapping presentations, and iii) (u/g) class participation.

- a. Lab exercises (42%): [SLOs 1,2,3] [*Communication, Critical Thinking, Technology*]
These exercises will provide experience with analyzing landscapes formed by various planetary surface processes. 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. Of the seven lab assignments, the last has two parts for a total of eight equally weighted lab exercises. The lowest of the eight lab grades will be dropped.
- b. Peer-assessment of lab exercises (8%): [SLOs 1,2,3] [*Communication, Critical Thinking*]
Assessing other students' lab exercises will reinforce knowledge gained from the lab and develop transferable skills. We will review an example of a lab assessment in the second week of class.
- c. Initial map presentation (10%): [SLOs 2,4,5] [*Career and Self-Dev, Communication, Critical Thinking, Professionalism*]
The initial planetary geologic map presentation will include explaining aspects of the map and the inferred formation of each geologic map unit. Feedback from classmates and community experts will support the presenter in their subsequent development of their final map package.
- d. Final map package (20%): [SLOs 2,4,5] [*Career and Self-Dev, Communication, Critical Thinking, Professionalism*]
The final map package will include a colored-and-inked map, a colored Correlation of Map Units (CMU) and a Description of Map Units (DMU).
- e. Major conference abstract (20%) [SLO 5] [*Career and Self-Dev, Communication, Critical Thinking*]
Graduate students will write a mapping abstract to explain their planetary geologic map using template from the Lunar and Planetary Science Conference (LSPC).

Class Components

1. **Attendance:** Class attendance is *strongly* recommended. In-person attendance enhances learning and activities in this course are built around in-person class participation, discussions and interactions.
2. **Reading:** Reading assignments will be posted on the course Canvas site by module / week.
3. **Labs:** Due dates for labs (the initial portion of which will be performed in class) are listed in the course schedule and in the labs themselves. *The labs are due via Canvas before 9:00 on the due date.*

**As 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.
Lowest lab grade will be dropped.**

4. **Peer-assessment of lab exercises:** Students will provide constructive feedback to each other on lab write-ups by noting: three positive aspects, two points for potential improvement, and one question per assignment. This feedback will have no effect on the (other student's) lab grade. *Assessments are due via Canvas NLT 9:00 on the due date.* We will do a practice assessment in class during the second week of the course.
5. **Presentations:**
 - a. Lectures / reading discussions given by the instructor or a guest lecturer,
 - b. Initial map presentation – see Geologic Mapping 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.

6. **Geologic Mapping Exercises / Projects:** A major part of this course is individualized geologic mapping. This mapping will entail a) exercises developed and provided by the USGS Astrogeology Planetary Geologic Mapping Group and b) presenting one's own planetary geologic map of an area of Mars. More information on the mapping assignments will be provided during the course.

- For graduate students, the mapping assignment will include an LPSC-style abstract summarizing the project and findings. LPSC templates are available at the course BB site or at http://www.hou.usra.edu/meetings/templates/abstract_templates.shtml.

Typos, spelling errors, bad grammar, incorrect word choice, etc., throw me off-track! Please spell correctly, double-check your grammar, use correct terminology. More information including examples of planetary mapping abstracts and guidance on abstract writing will be provided.

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

- | | |
|--|----------------------------|
| a. (8) Lab exercises | 42% [lowest grade dropped] |
| b. (8) Peer-assessments of lab exercises | 8% |
| c. Initial map presentation | 10% |
| d. Final map package | 20% |
| e. LPSC-style abstract | 20% |

Please note that there is no final exam for this course.

Instead, the final map package is due before the end of the final exam period for this course.

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. Please see the NAU **ACADEMIC INTEGRITY** policies at <https://www9.nau.edu/policies/Client/Details/1443?wholsLooking=Students&pertainsTo=All> for more information. Infractions of academic integrity may result in loss of points for a specific answer, loss of credit for an assignment, or loss of credit for the course.

Statement about use of Artificial Intelligence (AI): This course expects that any work submitted by students that contributes toward the course grade will be generated entirely by the students themselves. Thus, use of generative AI tools, such as ChatGPT, would constitute an academic integrity violation.

b) In-class conduct: Please be courteous to everyone in this class, treating them as you would like to be treated. If you feel that the behavior of any class member – instructor or student – is discriminatory, harassing, or otherwise impedes your learning, please bring it to my attention (if appropriate) so that we may together refer to the resources below and/or on the following pages for help in addressing this behavior.

- Equal Opportunity Office: <https://nau.edu/equity-and-access> or equityandaccess@nau.edu
- Title IX: <http://nau.edu/equity-and-access/title-ix> or pamela.heinonen@nau.edu
- Student Counseling Services: <https://in.nau.edu/campus-health-services/nau-counseling-services/>
- Office of the University Ombuds: <https://in.nau.edu/university-ombuds-program/>

Feedback: Feedback on this course is welcome, either something you like about the course and/or something I (or the USGS instructors) could do to enhance your learning. Any one of us would be glad to receive information through: (1) speaking in-person, (2) sending an email, and/or (3) noting it in the reflection section of the lab assignments. Any feedback you provide, whether praiseworthy or critical, will not affect your grade. You're always free to join with other students in the class in communicating with us.

For 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

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

W	D	Date	Subject	Readings / Assignment / Activities (supplemental / optional reading)
1	M	Jan 15	Holiday in honor of the Rev. Dr. Martin Luther King, Jr. > please note that there are readings due for Wednesday <	
	W	Jan 17	Introduction to course / syllabus. Tour of the Solar System	The syllabus, Melosh 2011 (Ch. 1). ("The four hundred years of planetary science . ." Burns, 2010)
	F	Jan 19	LAB 1: Introduction to Planetary Surface Data	i) create JMARS account, ii) review "Tour of JMARS user interface" iii) read over LAB 1 https://jmars.mars.asu.edu/
2	M	Jan 22,	Types of geomorphic processes / landscapes. Hypsometry of terrestrial bodies.	Introduction to Geomorphology: Ch. 23, Lorenz et al. 2011
	W	24		
	F	Jan 26	Peer assessment introduction w/example	
3	M	Jan	Impact Crater Morphologies, Impact Crater Ejecta.	Melosh 2011 (Ch. 6.2) Melosh 2011 (Ch. 6.4)
	W	29,31		
	F	Feb 2	LAB 2: Impact Crater Morphologies	LAB 1 due Read over LAB 2
4	M	Feb 5,7	Secondary Impact Craters and Age-dating with Crater Counts	Peer-assessment Lab 1 due (W 9am) McEwen and Bierhaus 2006 (<i>Hartmann and Neukum 2001</i>)
	W			
	F	Feb 9	LAB 3: Crater counting for Age-dating (revisit Tanaka+ 2014)	LAB 2 due Read over LAB 3
5	M	Feb 12,	Tectonism: planetary diversity, examples Review of fault morphologies prior to lab	Peer-assessment Lab 2 due (W 9am) Watters and Schultz 2010 (Intro), Kattenhorn and Prockter 2014, (<i>Byrne et al., 2021</i>)
	W	14		
	F	Feb 16	LAB 4: Planetary Tectonic Landforms	LAB 3 due Read over LAB 4
6	M	Feb 19,	Volcanism: planetary geomorphology	Peer-assessment Lab 3 due (W 9am) Lopes et al., 2010 (<i>Wood 1984, Vaucher et al. 2009</i>)
	W	21		
	F	Feb 23	LAB 5: Planetary Volcanic Landforms	LAB 4 due Read over LAB 5
7	M	Feb 26,	Aeolian morphologies on Mars and elsewhere	Peer-assessment Lab 4 due (W 9am) Kok et al. 2012 (through 2.1.1) McKee 1979 (figures), (<i>Bourke et al. 2010</i>)
	W	28		
	F	Mar 1	LAB 6: Aeolian morphologies	LAB 5 due Read over LAB 6
8	M	Mar 4,6	Fluvial morphologies. Fluvial morphologies on Mars.	Peer-assessment Lab 5 due (W 9am) Baker et al., 2015, Jacobsen and Burr 2017 (<i>Burr et al. 2013</i>)
	W			
	F	Mar 8	LAB 7: Fluvial morphologies (Part 1)	LAB 6 due Read over LAB 7 (Part 1)

	M W F	Mar 11, 13, 15	SPRING BREAK	
9	M W	Mar 18, 20	Glaciation processes and morphologies	Peer-assessment Lab 6 due (W 9am) Head et al. 2005
	F	Mar 22	LAB 7: Fluvial morphologies (Part 2)	LAB 7 (Part 1) due Read over LAB 7 (Part 2)
1 0	M W	Mar 25, 27	Periglacial processes (M / W) Sedimentary units (Mars) (W / F)	Peer-assessment Lab 7(1) due (W 9a) Burr et al., 2009 (sections 1,2,3.2, and 4) Grotzinger and Milliken 2012 (selections)
	F	Mar 29	Sedimentary units (Mars)	LAB 7 (Part 2) due
1 1	M W	Apr 1, 3	Introduction to planetary geologic maps Introduction to mapping exercise	Peer-assessment Lab 7 (2) due (W 9a) Tanaka et al., 2014, other Mars maps
	F	Apr 5	USGS personnel discuss careers	Work on mapping exercise
1 2	M W	Apr 8,10	Intro to planetary geologic mapping by the USGS Planetary Geologic Mapping Group	Review completed mapping homework exercise, Wilhelms, 1990
	F	Apr 12	Pen and paper mapping exercise by USGS Planetary Geologic Mapping Group	Wilhelms, 1990 (from Greeley and Batson Planetary Mapping)
1 3	M W	Apr 15,17	Scales, bodies, and map components by the USGS Planetary Geologic Mapping Group	Readings TBD
	F	Apr 19	Planetary geologic mapping (individual)	Geologic mapping on assigned areas of Mars
1 4	M W F	Apr 22, 24	Planetary geologic mapping (individual).	Continue geologic mapping on assigned areas.
1 5	M W	Apr 29, May 1	Initial presentation of individual maps	
	F	May 3	<i>Either Correlate geologic mapping (group) or Present individual maps to the department.</i>	
	W	May 8	Final map package – map, CMU, DMU, abstract – due during class final exam time (NLT 9:30 am)	

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>.

ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) technologies bring both opportunities and challenges. Ensuring honesty in academic work creates a culture of integrity and expectations of ethical behavior. The use of these technologies can depend on the instructional setting, varying by faculty member, program, course, and assignment. Please refer to course policies, any additional course-specific guidelines in the syllabus, or communicate with the instructor to understand expectations. NAU recognizes the role that these technologies will play in the current and future careers of our graduates and expects students to practice responsible and ethical use of AI technologies to assist with learning within the confines of course policies.

COPYRIGHT INFRINGEMENT

All lectures and course materials, including but not limited to exams, quizzes, study outlines, and similar materials are protected by copyright. These materials may not be shared, uploaded, distributed, reproduced, or publicly displayed without the express written permission of NAU. Sharing materials on websites such as Course Hero, Chegg, or related websites is considered copyright infringement subject to United States Copyright Law and a violation of NAU Student Code of Conduct. For additional information on ABOR policies relating to course materials, please refer to [ABOR Policy 6-908 A\(2\)\(5\)](#).

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, veteran status and genetic information. 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, or visit the EAO website at <https://nau.edu/equity-and-access>.

TITLE IX

Title IX of the Education Amendments of 1972, as amended, protects individuals from discrimination based on sex in any educational program or activity operated by recipients of federal financial assistance. In accordance with Title IX, Northern Arizona University prohibits discrimination based on sex or gender in all its programs or activities. Sex discrimination includes sexual harassment, sexual assault, relationship violence, and stalking. NAU does not discriminate on the basis of sex in the education programs or activities that it operates, including in admission and employment. NAU is committed to providing an environment free from discrimination based on sex or gender and provides a number of supportive measures that assist students, faculty, and staff.

One may direct inquiries concerning the application of Title IX to either or both the Title IX Coordinator or the U.S. Department of Education, Assistant Secretary, Office of Civil Rights. You may contact the Title IX Coordinator in the Office for the Resolution of Sexual Misconduct by phone at 928-523-5434, by fax at 928-523-0640, or by email at titleix@nau.edu. In furtherance of its Title IX obligations, NAU promptly will investigate or equitably resolve all reports of sex or gender-based discrimination, harassment, or sexual misconduct and will eliminate any hostile environment as defined by law. The Office for the Resolution of Sexual Misconduct (ORSM): Title IX Institutional Compliance, Prevention & Response addresses matters that fall under the university's Sexual Misconduct policy. Additional important information and related 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), 928-523-8747 (fax), or 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.

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 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 November 28, 2023