NORTHERN ARIZONA UNIVERSITY

College of the Environment, Forestry, and Natural Sciences

AST 560 - 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)
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)

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:

Graduate Students who successfully complete AST 560 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).
- SLO 6. Develop and exercise the skill of communicating results through writing, culminating in the production of a major conference abstract to accompany their planetary geologic map [EW]

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. Major conference abstract (15%) [SLO 6]
Students will write a mapping abstract to explain their planetary geologic map in the formation of the Lunar and Planetary Science Conference (LSPC), a premier conference in this discipline. Examples of planetary mapping abstracts and guidance on abstract writing will be provided by the instructor, and the abstract writing will include review by classmates and revision as desired by the author before submission for this class. In previous classes, students have submitted their abstracts to the conference and presented a poster of their map, and this practice will again be encouraged.

f. 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. Thus, activities in this course are built around in-person attendance including student interactions.

Likewise, it's imperative that we look out for our group health and safety.
If according to CDC guidelines and NAU policy, it would be unsafe for others for you to attend a given class, please let me know 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 lab 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 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 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.

- Part of the mapping assignment will be 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.

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

a.	Homework	10%
b.	Lab exercises	35%
c.	Mapping exercises / activities	35%
d.	LPSC-style abstract	15%
e.	class participation	5%

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…

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.**

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

To all faculty submitters and committee members: please be sure to proofread and edit all response submissions.
Form Effective Fall 2019

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

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POLICY STATEMENTS FOR COURSE SYLLABI
https://nau.edu/university-policy-library/wp-content/uploads/sites/26/Syllabus-Policy-Statements.pdf

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.

UNIVERSITY 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 (Academic Credit Policy 2-224), for every unit of credit, a student should expect, on average, to do a minimum of three hours of work per week, including but not limited to class time, preparation, homework, and studying.

DISRUPTIVE BEHAVIOR
Membership in NAU's academic community entails a special obligation to maintain class environments that are conductive 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 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. The Equity and Access Office (EAO) responds to complaints regarding discrimination and harassment that fall under NAU's Safe Working and Learning Environment (SWALE) policy. EAO also assists with religious accommodations. For additional information about SWALE 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 via 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 Pamela Heinonen, Director of the Equity and Access Office located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011. 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-

3312 (TTY: 928-523-1006), by fax at 928-523-9977, or by email at pamela.heinonen@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 http://nau.edu/equity-and-access/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 (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.