Course Action Request Form

Initiator of this proposal: Name: Paul Heller Phone: x2245 Dept.: Geology

Requested Action (check one or more):
- [x] Add new course
- [ ] Cross or dual list
- [ ] Discontinue
- [ ] Other (specify) Seeking approval as a University Studies, Integrative Science (S) course.
- [ ] Change course description
- [ ] Change title
- [ ] Change credit hours
- [ ] Change prerequisites
- [ ] Change number
- [ ] Change grading system

Semester and year action requested to take effect: Spring 2008
(Please note: changes in credit hours, grading method, or course level cannot go into effect for a semester if early registration has begun. Changes will be effective the following semester.)

Existing Course?

<table>
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<tr>
<th>Prefix</th>
<th>Number</th>
<th>Title</th>
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Proposed Course:

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<tr>
<th>Prefix</th>
<th>Number</th>
<th>Title</th>
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</table>

Abbreviated title (18 character maximum including spaces):
Earth History

List any currently approved University Studies Program (USP) designation(s):

Request for University Studies Program (USP) Approval (check boxes for which you have attached criteria sheets. Contact Rollin Abernethy at 766-4287 with any questions on USP):

Integrated Cultural Context ............... C [ ]
Humanities .................................. CH [ ]
Social Sciences ............................. CS [ ]
Arts ............................................ CA [ ]
Cultural Diversity in the United States ... D [ ]
Global Awareness ............................. G [ ]
Intellectual Community ..................... I [ ]
Information Literacy ....................... L [ ]
Oral Communication ....................... O [ ]
Physical Activity and Health ............. P [ ]
Quantitative Reasoning I ................. QA [ ]
Quantitative Reasoning II ............... QB [ ]
Integrated Science ....................... S [ ]
Biological Science ....................... SB [ ]
Physical Science ......................... SP [ ]
Earth Science .............................. SE [ ]
U.S. and Wyoming Constitutions .......... V [ ]
Writing I .................................... WA [ ]
Writing II ................................... WB [ ]
Writing III .................................. WC [ ]

Rationale for the change or new course proposed:
Note: For 1000- and 2000-level courses, also address articulation with the Statewide Course Catalog (consult Janet Timmerman at 766-3152).

There is only one “S” course currently offered at the University of Wyoming, and the Department of Geology and Geophysics is eager to help contribute to this USP requirement. This proposed course fulfills the “S” designation in that it is integrated science lecture/lab course with elements of geology, chemistry, physics and biology (please see attached syllabi and cover letter).
Current Credit Per Semester: Fixed hours _____ Variable hours: _____ to _____; career max. _____

Proposed: Fixed hours 4 _____ Variable hours: _____ to _____; career max. _____

Current Grading System: A/F ☐ or S/U ☐

Proposed: A/F ☒ or S/U ☐

Current Prerequisites: ________________________________

Proposed: None

Current Course Description (limit of 50 words):

Proposed (limit of 50 words):
Reviews the evolution of the Earth including: the creation of the Universe, formation of a layered earth, development and history of continents, controls on climate change, and the origin and evolution of life. Class introduces basic geologic, chemical, physical and biologic concepts used to decipher Earth history.

Current Cross Listings with: ________________________________
Note: Cross listed courses have the same course number, title, description, and prerequisites, but different departmental prefixes, e.g. WMST 2420 and POLS 2420.

Proposed cross listings with: None

Current Dual Listings (grad/undergrad) with: ________________________________
Note: Dual listed courses have the same departmental prefix and the same last 3 digits of the course number, e.g. ZOO 4425 and ZOO 5425.

Proposed dual listings with: None

What courses does this new or modified course RESEMBLE or OVERLAP, in content or title, and how does it differ? (Attach statement of support from other program(s) if appropriate.)
The material presented in this course will overlap slightly with Historical Geology, but Historical Geology (SE) uses a geologic approach in discussing the sequence of events in the formation of the continents and the record of life, and it spends most of its effort on the details of how historical reconstruction is done. Earth History (S) will more broadly discuss the scientific method and the underpinnings of a variety of scientific disciplines while covering the evolution of the Earth.

Current Activity Type (Select only one major category):

☐ Lecture ☐ Independent Study ☐ Internship
☐ with separately scheduled Laboratory Section ☐ Practicum ☐ Seminar
☐ with separately scheduled Discussion Section ☐ Studio ☐ Research
☐ Clerkship ☐ Lesson

Proposed: Lecture with separately scheduled lab

September 2003 – Previous editions should not be used
Material Resources required:
Will additional teaching space (such as a networked computer classroom), equipment, travel, support budget, TV production, or library holdings be required? If so, please specify what resources are needed and the source or sources of the necessary funding for these resources.
No

Personnel Resources required:
Who will be available to teach this course and will this course affect the instructor’s teaching load?
Paul Heller already teaches the class under a different number, and he will continue to teach the course. Mark Clementz may begin to alternate years with Heller.

Impact on Other Courses:
What will be taught less often? What course or courses might be discontinued?
“None”, “Not Available” or similar responses are not acceptable and may result in the proposal being denied.
Historical Geology will be taught less often and/or alternate with this course on opposite years, pending teaching assignments for new faculty. Contacted Janet Timmerman for articulation issues. Had discussion with Doug Parrot (VP of Academic Affairs) at Sheridan College regarding impact on Historical Geology.

For modifications involving a change in credit hours, dual listing, and/or change in course description, attach both current and proposed syllabi.

<table>
<thead>
<tr>
<th>For Course Committee Use Only:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Course:</strong></td>
</tr>
<tr>
<td>Prefix</td>
</tr>
</tbody>
</table>

Record of Approval
Department/Program head(s): [Signature]
Date: 1/25/07

College(s) Approval:
[Signature]

Graduate School Dean:
(Required for all 4000- and 5000-level courses)

University Studies Committee:
Approved for: [Signature]
Disapproved for: [Signature]

Chair: [Signature]

Recommendation of University Course Review Committee:
Approve
Table
Disapprove

Chair: [Signature]
Secretary: [Signature]

Comments of Course Review Committee:

September 2003 – Previous editions should not be used
University Studies Program
Criteria Review Sheet
Integrated Science (S)

S courses include basic scientific principles and explore the interrelationships between or within the traditional fields of biological, physical, and earth sciences. While S courses may also explore the applications of science to broader societal issues, they must emphasize rigorous content, application, methodology, and scientific inquiry. These must be 4 credit (or more) courses with an appropriate laboratory component.

Course Prefix & Number: Geol 1005  Credit Hours: 4

Course Title: Earth History

Please attach a detailed course syllabus that includes the objectives or outcomes for the course and the means to assess the extent that students reach them.

List any prerequisites, including math placement level: None

1. **How does the laboratory experience integrate with the lecture material? How does the laboratory subject matter emphasize more than one science discipline or subdiscipline?**

   Although the class covers a wide range of topics, it is, at heart, a geology course and so the labs build on aspects of geologic principles. That said, topics do include fundamentals of life science (via paleontology) and chemistry (via mineralogy). Laboratories are designed to provide depth into several topics to correspond with, but augment, the breadth of lectures. In designing labs for the class we had several goals. One is to stress an understanding of how classification systems are built, whether they be geologic or taxonomic. The memorization of classification is secondary to having students understand the logic of such schemes and how they make apparent order out of large array of, at first blush, chaotic data (especially in the “Sweet Taxonomy” exercise). Secondly, we wanted to be sure that students learn how to read and interpret maps. This type of knowledge will be invaluable to them no matter what their major. Third, we want students to develop an appreciation of deep time and the temporal distribution of major events in earth history.

   Subjects treated in laboratory include chemistry (lab on radioactive decay and age dating), biology (taxonomy, paleontology and paleobiology, biologic basis for correlation of events globally) and geology (rock and mineral identification, and map reading). Lastly we end with a lab on putting together a representation of deep time events.

2. **Using information from the syllabus, please describe how this course meets the learning goals (outcomes) and criteria for the integrated S category.**
   A. **What are the interdisciplinary emphases of this course?** We cover topics ranging from geology, chemistry, biology and astronomy. Lectures are grouped under fundamental scientific disciplines as follows:
<table>
<thead>
<tr>
<th>Discipline</th>
<th>Lecture Name</th>
<th>Key Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>Hadean Earth, Rocks and Minerals, Geologic Time Scale, Stratigraphy, Plate Tectonics, Imaging the Earth, Surface Processes, Precambrian, Paleozoic, Mesozoic, Cenozoic earth, Pleistocene</td>
<td>Emphasize processes (i.e. how the Earth works including crystallization, mountain building, climate change and then summarize the history of the event. Crystallization processes</td>
</tr>
<tr>
<td>Astronomy/Physics</td>
<td>Origin of the Universe, Creation of the Solar System, Hadean Earth, Plate Tectonics</td>
<td>Heat transfer, Big Bang, Red Shift, fission/fusion, conservation of momentum, conservation of mass</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Rocks and Minerals, Radioactive Isotopes, Stable Isotopes and Climate</td>
<td>Isotopic decay processes and time scales, fractionation processes (esp. climate driven).</td>
</tr>
</tbody>
</table>

B. **How does this course examine how basic scientific concepts across disciplines or sub-disciplines evolve?** Throughout the course I emphasize, often by example, how the scientific method works, where ideas come from, and how societal factors influence scientific research. In each topic area I present not just the key aspects of that area but also take a historical view. That is, I begin with our early understanding of a topic and how, by a few key observations, or imaginative connections, we build a scientific framework that gets later filled in with more and more observations. I then concentrate on a few key discoveries/ideas that led to major breakthroughs in our understanding of how the earth works. One example is in cosmology where I stress how Edwin Hubble discovered his constant including the basic physics behind his discovery and how that observation led to the idea of a Big Bang. As another example, we discuss how Yugoslav astronomer Milutin Milankovic predicted the role of orbital
variability in climate change, and how decades later the Climap Project, using stable isotopes, substantiated those predictions.

C. How does this course introduce students to the scientific approach as practiced in several disciplines or sub-disciplines? Through out the course I stress not just what we think we know, but how we have come to know these things. In some cases, I try to talk about the people, the conflicts those people were dealing with in their lives politically, socially and scientifically. For example, the hospitalization of Alfred Wegner and how that led to his hypothesis of continental drift. How the increase in cold war spending led to the discovery of seafloor spreading. In other cases I explain what drove the discovery (e.g. the geologic time scale falls out of the economic need to predict where coal and useful ores can be found). Or how different scientific disciplines build on a basic scientific design (e.g. how biostratigraphy is linked to slow vs. punctuated evolution combined with the prejudice of the scientist doing the work (there are lumpers vs. splitters)).

D. How does this course address the scope and limitations of the scientific approach? Since this may be the only science class that some of the students ever have a main goal is to demystify the scientific method. Elements that lead to this include: 1. Within each topic of the course I attempt to find at least one example of how a key idea came to be known. Often this follows from serendipitous events (e.g. the iridium anomaly at the K/T boundary), connections to other allied sciences that either provide a conceptual breakthrough that trickles down or technological breakthroughs (the mass spectrometer), or the result of solving a specific, financially important, problem (e.g. finding the easiest way to dig irrigation ditches which led to geologic mapping). 2. We talk about discoveries that are either based on conceptual breakthroughs, technologic breakthroughs or data base explosions (i.e. so much data gathered that eventually examples that simply do not fit extant paradigms force rethinking). Examples are discussed of hidden assumptions, later exposed, that destroy a theory (e.g. the “lost” fossils of Dr. Berringer). 3. It is important to separate the concept from the facts and observations that led to that concept. As such I show how the combination of data sets and theories, many of them failed, lead slowly towards a consensus of what is likely true. This process of ‘strong inference’ in observational science stresses that while it may be impossible to prove something true, we can prove some things false. In this way we build an accepted (but often unproven) scientific theory. 4. In order to show how scientific theories are testable hypotheses, we discuss, briefly, how intelligent design is not a scientific theory.

E. How does this course address how the various disciplines or sub-disciplines influence and are influenced by contemporary society (e.g. ethical considerations, social issues)? Major breakthroughs are often tied to societal or political zeitgeist at the time. Examples used include (as mentioned above): how the geological time scale fell out of the need for finding ores and coal deposits in a predictive way, furthermore how class distinctions in England influenced the breakdown of the geologic time scale, and how the proof of plate tectonics fell out cold war spending. In addition we talk
about how geologic and climatic factors may have influenced the birth of civilizations (floodling of the Black Sea, volcanic ash and small scale climate variability).

3. Explain how the assessment method(s) used for this course demonstrate student achievement of the learning outcomes for the S category. Explain how this assessment might provide information that can be used to improve accomplishment of desired learning outcomes.
   
   A. Laboratories are the place where students get to exhibit a creative understanding of complex concepts, such as deep time, and how classification schemes are established. For example, one laboratory requires the students in small groups to develop a classification scheme for types of candies. This is analogous to taxonomic schemes used to track evolutionary changes preserved in the fossil record. In addition, the final project requires the student to come up with their own analog that captures the meaning of deep time and the relative scaling of time. In these examples there is no single correct answer but demonstrate that the student understands the concept and can translate that understanding into a consistent conceptual model.

   B. While many test questions center on their having a basic understanding of key concepts and terms, some test questions are designed so that there is no simple right or wrong answer, but that the student can succeed only by explaining the logic that led to their answer. Examples of this type of question might involve presenting a sketch of a geologic feature and having them explain the concept being shown. Although I am trying to lead them to a specific concept, the answer is considered correct as long as they can explain reasonably how they arrived at that conclusion.

4. Does this course include an embedded USP component? No

5. What other factors should the committee consider?
   
   The goal in designing this course is that, possibly being the only science course students may have in college, the students have 1. A basic understanding of how the scientific method works so they can understand the logic of this approach, 2. Not to be overwhelmed with science, but to have enough basic understanding to not be afraid of scientific results and have a healthy skepticism of results that don’t make sense; 3. Have a basic understanding of how the earth works so that they can appreciate landscapes, and the interactions among natural systems; and 4. To have enough knowledge to be a well informed citizen.
# GEOLOGY 1005 (Earth History) SYLLABUS

Paul Heller – Room 311A Geology, (heller@uwyo.edu) (office hrs: 10-11 MWF)

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Reading</th>
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<tbody>
<tr>
<td><strong>HOW THE EARTH WORKS</strong>&lt;br&gt; Lect 8-10: Rocks and Minerals</td>
<td>p. 27-47</td>
</tr>
<tr>
<td><strong>TEST #1</strong></td>
<td>p. 103-127&lt;br&gt; p. 129-145&lt;br&gt; “ “&lt;br&gt; p. 177-207</td>
</tr>
<tr>
<td><strong>TEST #2</strong></td>
<td>p. 469-502&lt;br&gt; p. 502-537</td>
</tr>
<tr>
<td><strong>CLIMATE &amp; MAN</strong>&lt;br&gt; Lect 38-39: Late Cenozoic Climate&lt;br&gt; Lect 40: Man-Earth Interactions</td>
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**FINAL TEST:** Wed., May 2, 10:15 a.m.-12:15 p.m.


**LAB:** Thursday either 1:10-3 p.m., 3:10-5 p.m. rm 311G, Geology Bldg.

**GRADING:** Attendance = 5%; In class tests = 10%, 15%, 20% (proportioned),<br> Final Test = 20%, Lab = 30%

**ACADEMIC HONESTY STATEMENT:** “The University of Wyoming is built upon a strong foundation of integrity, respects, and trust. All members of the university community have a responsibility to be honest and the right to expect honesty from others. Any form of academic dishonesty is unacceptable to our community and will not be tolerated.”
Appendix A: Earth History Course Outline

Course Objective: This course covers the fundamentals of (1) the origins of the solar systems and creation of the earth; (2) the essential physics/chemistry of how the earth system works; (3) the origin and sequence of evolution of life on earth; and (4) the interaction of man and his environment.

Earth History is taught from a systems point of view and is designed to introduce students to a broad array of earth science disciplines. We emphasize the synergism of a broad, integrated scientific approach to understand how the earth works and appreciate the interrelationship between the Earth and life.

Laboratory study is designed to reinforce conceptual topics broached in lecture. Basic earth science tools and approaches are learned including: map reading, rock/mineral identification, fossil identification and how they are used to establish a geologic time scale, an understanding of radiometric age dating, and an appreciation for deep time.

Extended course outline:

Lecture 1: Deep Space & Deep Time

1. Range of space and time
   A. electrons to Universe
   B. microseconds (1/1,000,000 sec.) to age of Universe (~15,000,000,000 years)

2. Units of measure
   A. metric system
   B. units of mass (M), length (L), time (T)
   C. converting english to metric
   D. prefixes (kilo, centi, milli, micro . . .)

3. Scientific notation
   A. short and simple
   B. orders of magnitude (handout)

4. How big is the universe?
   A. light year = 9.46 x 10^{12} km
   B. Milky Way
   C. Visible Universe
   D. 10^{11} stars per galaxy X 10^{11} galaxies = 10^{22} stars
   E. 15x10^9 light years away ➔ light emitted 15 Ga (billion years ago)
   F. ➔ Universe formed ~ 15 Ga
   G. diameter of universe
   H. Inflation hypothesis

5. Deep Time
Lecture 2: Origin of the Universe, the Solar System, and Everything

1. The Red Shift
   A. Doppler Effect - sound
   B. Doppler Shift – light
   C. Using light for elemental abundances
   D. Expanding universe – at uniform rate (Hubble Constant)
   E. Gravitational attraction within galaxy clusters
   F. Calculating the age of the Universe

2. The Big Bang
   A. Singularity c. 16 Ga
   B. Early Big Bang events (first million years)
      a. Formation of H & He
   C. Inflation Model – Visible Universe

3. Formation of the Solar System
   A. Big Bang ➔ lumpy universe of molecular clouds
   B. Period of Nucleosynthesis
   C. fusion starts 15-8 Ga
   D. by 4.56 Ga enough solid matter to make solar system
   E. ~0.1% of galaxy is heavier than He
   F. Star Formation
      a. Why form stars?
      b. A star is born
      c. balance of falling particles vs. outward explosion = stable star
   G. Formation of planets
      a. conservation of momentum
      b. angular momentum
      c. molecular cloud collapse
      d. distribution of elements across spinning disk
      e. erosion by solar wind
      f. heavy particles ➔ minerals, ice, rock, planetismals
      g. planet arrangement by density
Lecture 3: The Hadean Earth

1. Period from 4.56 Ga (formation of Earth) to \(\approx 4.0\) Ga (oldest dated rocks in existence.
   Time of many impacts to development of a layered Earth.

2. Accretion of the Earth
   A. The energy of impacts \(\Rightarrow\) heat

3. Early Differentiation
   A. Rock inside earth is heated up to molten
   B. Elements rearrange themselves
     1. Lithophile elements ("rock loving") - crust
     2. Siderophile elements ("iron loving") - sink towards core
     3. Chalcophile elements ("ore loving") - sulfide phases
   C. Differentiation based on element size

4. Radioactive heating
   A. Large elements tend to split apart (fission)
   B. Continental crust \(\sim 1/2\) of the heat of granite is produced in that rock.
   C. Ocean crust - only about 1/12 of the heat comes out of the basalt.

5. Formation of the Core
   A. about 1/3 of Earth’s mass is iron
   B. heat production by sinking Fe atoms
   C. conduction vs. convection
   D. Formation of convection cells and plumes
   E. formation of magnetic field
     1. a self-enhancing process . . . geomagnetic dynamo

6. Formation of the moon
   A. capture?
   B. Primitive meteorites = chondrites
   C. Impact theory

7. Origin of Earth’s Atmosphere, ocean and organic reservoir
   A. Primordial atmosphere
   B. Outgassing vs. seeding
   C. Comet collision, carbonaceous chondrites

8. The layered Earth –
   A. chemical layering: crust, mantle, core
   B. rheologic layering: lithosphere, asthenosphere, mantle, outer core, inner core
Lecture 4: Minerals and Rocks

1. Minerals
   A. Element abundances
      a. fusion
      b. elemental abundances
   B. Mineral – naturally occurring, solid crystalline substance, generally inorganic, with a specific chemical composition
      a. covalent vs. ionic bonds
      b. silicate tetrahedron
   C. Crystallization
      a. crystal size
   D. Rock forming minerals
      a. 8 groups of minerals
      b. 30 common rock-forming minerals
         - silicates
         - carbonates
         - oxides
         - others (including: sulfides, sulfates, halides)
   E. Physical properties of minerals
      a. hardness
      b. cleavage
      c. fracture
      d. luster
      e. color
      f. density
      g. crystal habit

2. Rocks
   A. 3 types - Igneous, Sedimentary, Metamorphic

3. Igneous rocks (>700° C)
   A. magma vs. lava; and cooling rate
   B. intrusive vs. extrusive
   C. common minerals (felsic and mafic)
   D. General rock types
   E. Forms of Igneous bodies
      a. sill vs. dike vs. vein vs. pegmatite
      b. dec. dissolved gases → inc. viscosity and explosiveness
      c. shield volcano, cinder cone, composite volcano

4. Sedimentary rocks
   A. Weathering
      a. chemical weathering
      b. physical weathering
   B. Erosion, deposition, burial
      a. transportation
      b. deposition
c. burial
d. diagenesis

C. Clastic rocks
   a. types are function of grain size
   b. sorting, rounding and composition

D. Chemical rocks
   a. limestone
   b. salts
   c. biologic agents

5. Metamorphic rocks
   A. changed, recrystallized
   B. causes of metamorphism – heat vs. pressure
   C. Pressure – Temperature diagram
   D. Foliation
   E. Mineral association
      a. paired metamorphic belt

Lecture 5: Sediments and Paleogeography

1. Sediment records Earth surface processes ➔ useful in paleogeographic reconstruction,
   assuming we can accurately interpret how they were deposited. Sedimentary record is the
   most continuous recorder of continental deformation and climate.

2. Key principles/observations to interpret sedimentary rocks:
   A. modern is the key to the past
   B. Principle of superposition (Steno’s first law)
   C. Principle of original horizontality (Steno’s second law)
   D. Principle of original lateral continuity (Steno’s third law)
   E. Walther’s law
   F. Unconformities
      a. nonconformity
      b. angular unconformity
      c. disconformity
   D. Compositional studies (Provenance)

3. Terminological mumbo-gumbo
   A. Depositional system
   B. Facies & facies associations: lithofacies, biofacies, etc.
   C. Facies model

4. Sediment Transport
   A. Source to Sink of a mountain, alluvial fan, river, delta, shelf, deep basin system

5. Used to reconstruct paleogeography
   A. example of Cretaceous rocks of the Western Interior Seaway
Lecture 6: Stratigraphy & Geologic Time

1. Origin of the geologic time scale

2. Construction of a time scale
   A. William Smith (b. 1769)
      a. The Geologic Map of England and Wales – 1815
      b. Principle of Faunal (and Floral) Succession
   B. Extinctions
   C. Charles Lyell (early 1800’s)
      a. Lyell’s percentages
   D. Role of Politics and class distinctions
      a. Sedgwick vs. Murchison
      b. led to a time scale based on organic evolution.
   E. Geologic Time Scale – LEARN IT, KNOW IT
      a. No absolute ages, yet
      b. Example of dating the time scale

3. Stratigraphic Correlation
   A. Lithostratigraphy – correlation by rock type
      a. Transgression vs. Regression
      b. Example of the Grand Canyon
   B. Biostratigraphy – correlation by fossil assemblage

Lecture 7: Geochronology

1. A neutral atom = no net charge (i.e. not an ion)
   A. Atomic number (# of protons) – define element name
   B. Atomic mass (# protons + neutrons)
   C. Isotope = same chemical element, but different number of neutrons
      e.g. \(^{38}\text{K},^{39}\text{K},^{40}\text{K}\)
   D. Of ~1700 different atoms we know of, only ~260 are ‘stable’

2. Unstable isotopes
   A. a ‘stochastic’ process – e.g. electron capture
   B. radioactive decay
   C. Example of K-Ar dating:
      1. \(^{40}\text{K} \rightarrow ^{40}\text{Ca} \text{ vs. } ^{40}\text{K} \rightarrow ^{40}\text{Ar}\)
      2. Minerals with K are needed
   D. “Half-life” - time it takes for 0.5 of ‘adult’ population to decay to ‘daughters’, and exponential decay
   E. Problems
   F. How it is done.
Lecture 8: Plate Tectonics

1. Historical Perspective
   A. 1800s – advent of accurate maps
   B. 1915 - Alfred Wegner
   C. WWII – military-based funding \(\rightarrow\) heydays of the 1950s
   D. First maps of the seafloor \(\rightarrow\) surface of Earth had bimodal elevations
   E. Seismicity and volcanoes found in belts
   F. Paleomagnetism, magnetic reversals
      a. shipboard magnetometers
      b. magnetic anomaly pattern – Vine and Matthews hypothesis
      c. midocean ridges = spreading centers
   G. Geologic record on land- 1960s
      a. Fossil distribution between continents
      b. ‘Polar wander’ curve
      c. Rock offsets in California (San Andreas Fault)
      d. Commonly seen rates of a few cm/year
   H. Earthquakes and Subduction Zones
      a. Earthquakes associated with trenches
         • subduction zones
      b. ‘Ring of Fire’ – volcanic arcs

2. Plate Tectonic Model
   A. Earth’s crust broken into small number of \(~\text{rigid plates}\)
   B. Driven by density differences, convection, gravity
   C. Lithosphere & Asthenosphere vs. crust & mantle
   D. Types of Plate Boundaries
      a. Divergent Boundaries (spreading centers)
      b. Transform Boundaries
      c. Convergent Boundaries (subduction zones)

3. Past Plate Motions
   A. Reconstructing plate motions
      a. via magnetic anomaly patterns
      b. polar wander paths
      c. geologic matching
      d. hotspot tracks
   B. Supercontinents – Rodinia and Pangea
   C. Forces moving plates
      a. slab pull, ridge push, viscous drag

4. Geologic Implications of Plate Tectonics
   A. Convergent margins – e.g. Andes today vs. California in Mesozoic
   B. Continental Collision – e.g. Himalayas today vs. Appalachians 300 Ma
   C. Divergent margins – e.g. Death Valley today vs. Atlantic margin 120 Ma
   D. Transform margins – e.g. San Andreas Fault today
Lecture 9: Earthquakes and Neotectonics

1. Earthquake locations and mechanisms
   A. subduction zones
   B. ridges
   C. transform faults

2. P-waves vs. S-waves

3. Determining epicenter and focus

4. Earthquake damage – primary and ancillary

5. GPS surveying and modern plate motions

Lecture 10 – Origin Of Life

1. End of Hadean Time
   A. Early atmosphere rich in CO₂ N NH₄ but little O₂
   B. By 3.5 definite evidence of life

2. Definition of life
   A. Is a virus life?

3. Essential elements for life
   A. organic molecules, water, energy, ±O₂
   B. small set of molecular units
      a. carbohydrates via photosynthesis
      b. proteins (chains of amino acids)
      c. nucleic acids (directs amino acids to reproduce proteins)
      d. lipids

4. Role of mutation

5. Cells
   A. prokaryotic (bacteria)
   B. eukaryotic (with a nucleus)

6. Metabolism
   A. fermentation vs. respiration vs. chemisynthesis

7. Extremophiles
   A. Deep ocean, deep earth, Mars?

8. The Miller-Urey Experiment

9. Chances of getting life

10. Origin of RNA
    A. vesicles vs. clays

11. How do you keep life alive?

12. Earliest Life
    A. Bacteria
       a. Prokaryotes vs. Eukaryotes
       b. Chlorophyll
    B. The O₂ problem
C. Kingdoms of Life
   a. Archeobacteria
   b. Eubacteria
   c. Protista
   d. Fungi
   e. Plantae
   f. Animalia
D. Hierarchy of Life
   a. Phylogeny – the tree of life
E. Green Algae
F. Early Glaciations – role in early life?
G. Vendian (Ediacaran) Fauna
H. Mass Extinction Events
   a. volcanism?
   b. climate change?
   c. germs?
   d. impacts?

\textit{Lecture 11: Phanerozoic Life}

1. Key Features:
   A. The Cambrian Revolution
      a. remarkable diversity, radiation of multicellular animals (metazoan)
      b. hard-part skeletons, therefore well preserved
      c. all within 10 million years or so of each other
      d. possible roles of supercontinent, sea level, chemical concentrations, the "Snowball Earth"?
   B. Ordovician Radiation of Life
      a. suspension feeders develop
      b. pelagic (includes planktonic vs. nektonic)
      c. benthic (includes infaunal vs. epifaunal)
      d. importance of 'tiering'
   C. Silurian-Devonian
      a. vascular land plants
      b. development of fish
   D. Permian - massive mass extinction
   E. Triassic
      a. coming of dinosaurs
      b. foraminifera
   F. Cretaceous
      a. key innovation - flowering plants
      b. end of Cretaceous extinction
   G. Age of mammals and insects

2. Invertebrates:
   A. Trilobites - dominate skeletal species of Cambrian
   B. Brachiopods (early bivalves)
   C. Bryozoan - colonial animals
D. Coral

3. Microfossils
   A. radiolaria (zooplankton)
   B. dinoflagellates (phytoplankton)
   C. diatoms (phytoplankton)
   D. coccolithophoroids (phytoplankton)
   E. foraminifera (zooplankton)

4. Vertebrates
   A. Amphibian "double life": b. Pennsylvanian
   B. Reptiles (amniote egg): b. Pennsylvanian, dominant in Mesozoic
      a. reptile phylogeny (i.e. study of ancestor-descendent relationships)
   C. Ichthyosaurs 'fish lizard': b. Triassic
   D. Dinosauria
      a. Saurischian (lizard hip)
         1. Theropods: carnivores
         2. Sauropods: herbivores
      b. Ornithischians (bird hip)
      c. warm vs. cold blooded?
      d. Mass Extinction c. 65 Ma

5. Birds
   A. Saurischian (theropod) lineage
   B. Archaeopteryx
   C. Evolution of flight

6. Mammals
   A. Synapsid lineage
   B. characteristics
   C. reproduction modes: monotremes, marsupials, placentals

7. Plantae
   A. How did they get on land?
   B. Key groups:
      a. Ferns (spore bearing)
      b. Sphenophyta (equisetum)
      c. Gymnosperms ('seed bearing')
      d. Angiosperms (wake up and smell the flowers): b - Late Cretaceous
      e. Cladoxylopsida: ancestors of ferns and horsetails?

8. Arthropoda: crustaceans and insects
   A. chitin: an amino-sugar exoskeleton
Lecture 12: Geologic History of North America

1. Archean (>2.5 Ga)
   A. Formation of crust into continents
      a. Craton vs. Shield
      b. Accretion around cratonic cores – mid-Precambrian time
      c. “orogeny” – mountain building

2. Late Precambrian – rifiting
   A. Belt-Purcell Supergroup c. 1.3 Ga
   B. Cordilleran Miogeoclone c. 600 Ma
   C. S.W.E.A.T. hypothesis – Eastern Antarctica/S.W. US
   D. Wilson cycle – South America off eastern North America

3. Early Paleozoic – Caledonian Orogeny
   A. Taconic Orogeny (Ordovician) – eastern U.S.
   B. Antler Orogeny (Mississippian) – western U.S.

4. Late Paleozoic – Hercynian Orogeny
   A. Formation of Pangea
   B. Appalachian Orogeny – Pennsylvanian continental collision
   C. Ancestral Rockies (Pennsylvanian-Permian)
      a. Continental escape due to S. America collision?
   D. Sonoman Orogeny (Permian- Triassic)

5. Mesozoic convergent margin of western U.S.
   A. Evolution of an “Andean-type” margin – starts in Triassic
   B. California – subduction to volcanic arc scenario (Jurassic-Cretaceous)

6. Jurassic – Cretaceous rifting of eastern North America
   A. Break up of Pangea

7. Sevier Orogeny (Cretaceous-Eocene)
   A. fold-thrust belt behind volcanic arc
      a. Wyoming, Utah, Montana sectors
      b. Columbian Orogeny in Canada

8. Laramide Orogeny (Cretaceous-Eocene)
   A. Style – basement-cored uplifts of Rocky Mountains
   B. Igneous activity – ‘Sweep’ of volcanic arc into Wyoming and back
   C. Origin – North America overruns Pacific basin plates
   D. Analog to modern Andean Belt of S. America

9. Displaced Terranes of W. Canada and Alaska
   A. Fault-bounded slivers of lithosphere
   B. Net northward drift by plate motions off W. North America

10. Cenozoic Extension of western North America
    A. Starting in late Eocene lots of evidence of normal faulting
    B. Develops after thickening by shortening and igneous sweep
    C. Rio Grande Rift – starts c. 30 Ma
    D. Basin and Range faulting – starts c. 5 Ma
    E. Wasatch Fault/Teton Range on eastern boarder
    F. Late Cenozoic uplift of the Rockies
    G. The San Andreas vs. the Cascades
Lecture 13: Climate and Man

1. The record of climate change
   A. Fossils
   B. Rock types
   C. Historical
   D. Chemical

2. Stable Isotopes
   A. do not naturally decay
      a. $^{16}\text{O}$, $^{17}\text{O}$, $^{18}\text{O}$, $^1\text{H}$, $^2\text{H}$
   B. fractionation
      b. evaporation
   C. Example for reconstructing past climate

3. Sea level changes
   A. Record through geologic time
   B. Pleistocene record
   C. Impacts on man
      a. Noachian Flood?

4. Causes of Ice ages
   A. Changes in orbital parameters – Milutin Milankovic
      a. The Climap Project
   B. Plate motions
   C. Oceanic conveyor belt

5. The next million years
Appendix B: Geology 1005: Earth History Laboratory

Purpose and Summary of Historical Geology laboratories

Lab #1: Mineral Identification
Purpose: To identify 16 common rock-forming minerals on the basis of their physical properties. Part 1: Chemistry review- atoms and their protons, neutrons and electrons; ions; molecules; chemical formulas for minerals, and types of bonds responsible for the physical properties of minerals (i.e. bond strength, hardness, mechanical properties, melting point, solubility, structure). Part 2: Identifying minerals in hand sample. Using the scientific method minerals are identified using the following criterion: luster, Mohs hardness scale, cleavage and fracture patterns, crystal form, streak color, specific gravity, striations, HCl reaction and taste. Part 2 ends with questions about the lab and a few unknown samples. The students work in groups of four and then the class discusses the questions and replies as a whole.

Lab #2: Igneous Rocks
Purpose: To learn how to recognize and identify igneous rocks based on their texture and mineral content. Classification is based upon textural and mineral composition, which requires an understanding of igneous terms (maphic/felsic), volcanoes, magma, viscosity, geothermal gradient, rates of thermal cooling and how it affects crystal structure, and Bowen’s Reaction Series. Part 1: Students review the minerals of the previous week, are introduced to igneous rock classification schemes and then apply this gained knowledge to ten (10) hand samples. Part 2: Students draw/explain geothermal gradient and Bowen’s reaction series. Part 3: Students are given a set of hypothetical questions about igneous rocks, i.e. if an igneous rock was composed mainly of quartz would it be mafic or felsic? Part 4: Students are given a diagram of an igneous environment with a list of terms (rock types) that they must put in the most appropriate igneous environment and then they answer questions pertaining to different type of volcanoes and the magma viscosity differences.

Lab #3: Sedimentary Rocks
Purpose: To learn how to recognize and identify sedimentary rocks, understand the physics behind sediment transport, and make basic interpretations about transport and depositional histories. Part 1: Students use microscopes to describe several non-lithified sediment samples from various sedimentary environments (i.e. beaches, sand dunes, river beds, lakes). The must describe the sediment by the grain size, sorting, shape, surface texture, and overall mineral composition of the sediment sample. Part 2: An important part of sediment transport is the settling, hence deposition, of individual sediment grains. The students calculate the settling velocities (m/s) for a variety of different sized particles; including clay, fine sand and very coarse sand. Then the students answer questions pertaining to how the diameter of a grain affect settling velocity and how grain size in return reflects the depositional environment. Part 3: The students identify twelve (12) sedimentary rocks in hand sample. Part 4: The students are asked to correlate particular sedimentary rock types to possible environments and predict the energy of the environment required in order for the particular sediment to be deposited, or settled out of suspension.

Lab #4: Metamorphic Rocks
Purpose: To learn how to identify metamorphic rocks and obtain information about protolith composition, type of metamorphism, and metamorphic grade. Part 1: The students learn
about certain minerals that are considered “metamorphic minerals” and give clues to the
degree of heat and pressure that the rock endured. Part 2: Metamorphic textures, foliated and
nonfoliated, are introduced and the students must divide the hand samples into the above-
mentioned categories of texture. Part 3: Identification of the metamorphic rock hand samples
and evaluating a possible protolith. Part 4: The students take this knowledge one step further
by evaluating the degree of metamorphic grade, the metamorphic mineral facies in specific
samples, and then use temperature/pressure charts to identify the type of metamorphism and
the metamorphic facies the sample belongs to. Part 5: The students are asked to interpret and
label a diagram of rocks that have undergone metamorphism. This requires that they
understand pressure/temperature gradients, protolith relationships and the basics of the
metamorphism process.

Lab #5: Time and Ordering of Geologic Events
Purpose: To learn the fundamental laws, or principles, of geology and use them as
interpretive tools for the ordering of sequential events and the role of unconformities in the
rock record. Part 1: The students are presented with several cross-sections depicting
deposition, erosion, unconformities, faulting, intrusions, etc. and they must order the events
in sequential order starting with the first event (or oldest) to the last event (or most recent).
This exercise requires all of their knowledge from the previous labs and truly reinforces the
knowledge that they have gained. Part 2: After doing the practice set they apply this skill to a
real geologic scenario that most are familiar with, the stratigraphic record of the Grand
Canyon.

Lab #6: Relative and Absolute Time
Purpose: The purpose of this lab is to become familiar with relative and absolute dating
methods and to use them to develop a geologic history. Part 1: Introduction to relative dating
methods and the advantages versus disadvantages. Part 2: Introduction to radioactive decay,
isotopes, half-life and the idea of a radiometric “clock”. They are given a story problem
involving a radioactive species with a certain half-life and weight measurement. They must
plot the decay of the parent element. Part 3: Field Study of the Colorado Plateau. A set of
story problems dealing with relative correlations, stratigraphic relationships and correlation,
calculations of sediment deposition rates and a zircon-based dating exercise for the granite
they examined in Lab #5 (part of the Grand Canyon sequence).

Lab #7: Introduction to Paleontology and Paleobiology
Purpose: Understand how living things become part of the rock record. Become familiar with
major Kingdoms and Phyla important to geologists. (Read Ch 3 in your textbook.) This lab is
designed as a self-discovery/research project where the student must use all available
resources (classroom textbook, Internet, geology museum located within the geology
building, library, teaching assistant) to complete the questions within the lab handout. Part 1:
Why do geologists care how living things become part of the rock record (Biostratigraphy)?
Biology plays a large part in this lab, as it starts with taxonomy as a classification system.
Part 2: The preservation of living things in the rock record. Examines soft-body versus hard-
body plans as living strategies, preservation biases and ideal environments to which they suit.
Body fossils and trace fossils are also examined. Part 3: The students are “re-introduced” to
the Kingdoms of life and the major phyla they need to become familiar with for future
laboratories.
Lab #8: Identifying Fossils
Purpose: Learn to identify several fossils important to the geologic record and become familiar with their geologic ranges and extinctions. Part 1: Basic hand specimen identification skills (similar to those learned during the “mineral/rock labs”) are used to recognize seventeen (17) fossils, their Kingdom, Phylum, Class, common or group name and the range and peak range for each fossil. The work is done in groups of four with the help of hand-outs, teaching assistant and the hand-out from Lab #7.

Lab #9: Biostratigraphic Correlations
Purpose: This exercise is designed to introduce the concepts and practical problems involved in the subject of biostratigraphy. The exercise combines the relationships of fossils, determined by radiometric dates and different rock types (paleo-environment). Solving various elements of the problem will lead to an understanding of basic concepts used by the stratigraphic paleontologist in relating fossil-types to their ancient environments and to time. The students create a lithofacies map delineating ancient environments by using fossils assemblages, radiometric dates and stratigraphy.

Lab #10: Sweet Taxonomy
Purpose: Learn to observe unidentified “fossil” organisms, understand how to generate and communicate taxonomic classifications of life forms. Part 1: The students work in groups of four (4) and each group is given a set of nine (9) different “fossil organisms”, which are really different types of candy. For each sample they sketch and describe the symmetry, body plan, size/shape, texture, taste, etc. Part 2: The students must, based on their above observations, determine, explain and justify how the “life form” may have lived. For example, did it move around? If so, how? Did it live on land, under water? What did it eat, how and what did it forage-chemosynthesis, photosynthesis? How did it protect itself from predators? Did it have and ecological relationship to any of the other “life form” samples? Part 3: Generation of a classification scheme for all nine (9) samples. How close or distant are the relations between any of the “life forms”? Using morphologic characteristic or traits they determine if there are any evolutionary significant traits, or examples of convergent evolution. Finally, each group creates a cladogram for the sample set. At the end of the lab session each group gets up and reports their findings to the rest of the class. Each member of the group has to handle one aspect of the group’s oral report to receive full credit. This is a very fun lab (candy!) and interesting to watch the findings of each group evolve through discussion and creative application of skills gained in the previous three (3) labs.

Lab #11: Introduction to Topographic Maps
Purpose: To introduce the wealth of information you can get from a topographic map. Concepts of the global reference system, public land survey system, map scales, direction (azimuth and bearing) and measuring distances are introduced and learned. The Laramie quadrangle map (for familiarity sake) is used to answer an array of questions pertaining to the concepts outlined above.

Final Project: Geologic Timeline
The final project is assigned mid-semester and due during the last schedules laboratory meeting when they individually present their final project to the teaching assistant and lab mates. Each student chooses something to represent the geologic timeline, anything from the length of the Appalachian Trail, a piece of classical music to a road trip from New York City....
to Los Angeles. Then the student must choose at least twelve (12) geologically significant events and perform conversions and appropriate scaling to apply this timeline to their chosen comparison (i.e. the length Appalachian Trail). The work must be presented on poster board that is presented on the lab meeting. The students must also turn in all their conversion calculations and a short write-up giving an explanation of the time scale with a list of the events used, their dates, the scale of representation, in addition to a few interesting observations. They are graded on accuracy, write-up, quality, creativity, presentation and timeliness.