Geol 1030-1

Introduction to Earth science

Spring 2017

Mark Abolins, Ph.D.

-Document 1-

This document includes large contributions from NSF InTeGrate:
http://serc.carleton.edu/integrate/index.html *.*

Sustain humanity. Sustain the Earth.

[First of two documents. Document 2 *will be available in late February. Most (but not all) of what you need for the first two exams is in this document. (You will receive the rest in class, by e-mail, and through D2L.) Some content from this document will be used after Spring Break. No content from* Doc 2 *will be used before Spring Break.]*

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SCHEDULE FOR GEOL 1030-1 THROUGH SPRING BREAK

PRE-CLASS ASSIGNMENT. COMPLETE *PRIOR* TO CLASS ON INDICATED DAY.	IN CLASS/AFTER CLASS.	OPTIONAL READING (TLT, 14th ed.)
None.	1. First day of class W 1/18. (Yes, you should be there.)	
None.	2. Second day of class F 1/20. (Yes, you should be there.)	
M 1/23. Complete MasteringGeology assignment(s). Hardcopy Doc1 and bring to every class starting today.	3. Minerals 1.2 M 1/23	Chapter 2, p. 33-37; p. 46-52 (mineral groups). Chapter 3, p. 60-62 (rock cycle).
W 1/25. Complete MasteringGeology Assignment(s). Bring clicker (or device with clicker app) to every class starting today.	4. Minerals 1.3 split between W 1/25 and F 1/27.	
M 1/30. Complete MasteringGeology Assignment(s).	5. Minerals 2.1 split between M 1/30 and W 2/1.	
F 2/3	Guest Speaker Day. (Yes, you should be there.)	
M 2/6. Complete MasteringGeology Assignment(s).	6. Minerals 5.1 split between M 2/6 and W 2/8.	Chapter 7, p. 209-229.
None.	7. In-class review F 2/10.	
None.	8. Facebook review Su 2/12 7p-8p.	
None.	**9. Exam 1 M 2/13.**	

Continued on next page.

PRE-CLASS ASSIGNMENT. COMPLETE *PRIOR* TO CLASS ON INDICATED DAY.	IN CLASS/AFTER CLASS.	OPTIONAL READING (TLT, 14th ed.)
W 2/15. Complete MasteringGeology Assignment(s).	1. Edge 1.1 split between W 2/15 and F 2/17.	Chapter 8, *all.*
None.	2. Edge 2.2 M 2/20	
W 2/22. Complete MasteringGeology Asssignment(s).	3. Minerals 4.2 split between W 2/22 and F 2/24.	Chapter 11, *all;* Chapter 12, *p. 12.2-12.4, 12.6-12.9.*
M 2/27. Complete MasteringGeology Assignment(s).	4. In-class review M 2/27.	
	5. Facebook review Tu 2/28. 7p-8p.	
None.	6. **Exam 2 W 3/1**.	
None.	**7.** Guest speaker. F 3/3.	
None.	(Spring Break 3/6-3/11.)	

What do I do before coming to every class?

- Complete pre-class assignment, reading, etc. (if any) listed on course calendar.
- Check your @mtmail.mtsu.edu e-mail address for course announcements. Do this every day of the semester. Set up forwarding to another e-mail address if you don't want to check your MTSU e-mail address.
- Read related takeaways. For example, if the pre-class assignment was about plate tectonics, read the plate tectonics takeaways.

How do I prepare for the exam?

Higher priority (my recommendation – the way you need to study may be different)

- Memorize the takeaways.
- Answer the study questions and study your answers.
- Participate in the facebook study session (or log in to facebook after the study session is over and examine the questions and answers). Ten questions posted to facebook will appear on the exam, and the other ten facebook questions will be similar to exam questions. You receive an invitation to join the facebook group early in the semester. The study session will happen a day or two before the exam.
- Study the ten commonly-missed pre-class assignment questions. You will receive these questions by e-mail a few days before the exam. The answers to these questions are in MasteringGeology. These questions will be on the exam.

Lower priority (my recommendation – the way you need to study may be different)

- Rework past-due pre-class assignments.
- Study optional reading in Tarbuck, Lutgens, and Tasa 14^{th} edition.

COURSE INFORMATION **Spring 2017**

GEOL 1030-1 INTRO TO EARTH SCIENCE-LECTURE

--- BASIC INFO ---

LECTURE TIMES AND LOCATION: MWF 9:10a-10:05a in 100 DSB.

LEARNING OUTCOMES (based on Earth Science Literacy Initiative "Big Ideas"):

1. Students use repeatable observations and testable ideas to understand and explain our planet.
2. Students demonstrate knowledge that the Earth is 4.6 billion years old.
3. Students describe the Earth as a complex system of interacting rock, water, air, and life.
4. Students describe the Earth as continuously changing.
5. Students describe the pervasive role of water in Earth processes.
6. Students describe the evolution of life on Earth and the impact of life on the Earth.
7. Students demonstrate knowledge of Earth resources.
8. Students demonstrate knowledge of natural hazards.
9. Students describe human-induced changes to the Earth.
10. Students are aware of opportunities for career development and further study in the Earth Sciences – both at MTSU and in the world at large.

INSTRUCTOR: Mark Abolins, Ph.D. **Office:** DSB (Davis Science Bldg) 217.

Office hours: Office hours: MWF 10:20a-11:50a. (When not instructing a scheduled class, I am available by appointment at other times on every week day.)

Contacting me:

- Call my cell (615-594-4210). Do not call my MTSU landline.
- E-mail address: Mark.Abolins@mtsu.edu. *E-mail is the best way to contact me.* If I don't respond to your e-mail within 24 hours, call 615-594-4210 (because I didn't receive your e-mail or you didn't receive my reply).
- *I communicate extensively through mass e-mails. Check your campus e-mail daily.*
- *Course e-mails will NOT appear in D2L, and I will not send messages through MasteringGeology. Do not attempt to communicate with me through D2L because I will not receive your message.*

"REQUIRED" TEXT: Earth Science by Tarbuck, Lutgens, and Tasa, 14th ed., Prentice Hall. The 14th edition of Tarbuck, Lutgens, and Tasa "Earth science" is officially required department-wide. However, nothing in my section requires that you actually have the textbook. Note, though, that many students likely find that the textbook helps them perform well. Note also that you can obtain access to the e-text when purchasing MasteringGeology (see below).

REQUIRED MATERIALS (BRING TO EVERY CLASS MTNG):

- i>clicker app, i>clicker2, or another i>clicker product (e.g., i>clicker+).
- All course materials (notes, etc.) obtained during lecture and through D2L and e-mail.
- Paper (that you can turn in) and a pen or pencil.

FREE TUTORING!

Learn how to study, get help with understanding difficult course material, receive better test grades, or simply improve your grade point average. Take advantage of our FREE tutoring that is available to you as an MTSU student. Tutoring is available in study skills and learning strategies, and over 180 courses including biology, history, computer information systems, physics, math, psychology, chemistry, economics, recording industry, and many more. The central location for tutoring is the Tutoring Spot, located in Walker Library. Tutoring is also conducted at various other campus sites. For available tutoring opportunities, visit http://mtsu.edu/studentsuccess/tutoring.php#on. For questions, call the Tutoring Spot at 615-904-8014.

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Getting started

- **Obtain access to MasteringGeology. For many students, the preferred option is to simply go to the website (http://www.masteringgeology.com/) and purchase access. You will need (1) the MTSU zipcode (37132), (2) the course ID (SPRING17GEOL1030), and (3) your MTSU e-mail address (e.g., abc1d@mtmail.mtsu.edu).**
- **Complete the first assignment in MasteringGeology. It's the introductory assignment due on 1/23 at 9:10am.**
- **Acquire the i>clicker app (https://www1.iclicker.com/products/reef-polling/), an i>clicker2, or another i>clicker product (e.g., i>clicker+).**
- **Go to https://www1.iclicker.com/register-clicker/ and register your clicker if you are using a physical clicker. To register, you will need (a) your MTSU e-mail address and (b) the clicker itself. (Use your MTSU e-mail address as your student id number.)**
- **During 1/12-1/23, go to http://capone.mtsu.edu/mabolins/Doc1.pdf , download course materials, and hardcopy the materials. Punch holes in these materials, place these materials in a 3-ring binder, and bring the materials to every class meeting starting with class on 1/23.**
- **Beginning on 1/25, bring your clicker (i.e., a physical remote or a device that has the app) to every class meeting.**

Questions?
Dr. Mark Abolins:
Mark.Abolins@mtsu.edu
or 615-594-4210

NO USE OF GEOSCIENCES PHOTOCOPIER: Geol 1030 students cannot use the Geosciences photocopier.

WHEN IS MY FIRST LAB? *Labs meet during the first week of classes (beginning on 1/17).*

LAB AND LECTURE GRADES: *Lab and lecture are separate courses. Grades are not combined and I don't generally know what's happening in lab or have any influence over what happens. Contact your lab instructor with all lab questions.*

HOW OFTEN DOES GEOL 1030 MEET AND FOR HOW LONG? If at all possible, I use every day of the semester and every minute of every lecture period to prepare you for the exams and final.

FIELD TRIPS: There will be required field trips on 3 days during March some time after Spring Break. On one of those days, you will be required to travel on your own to Evergreen Cemetery (to examine different kinds of rocks and the way they weather) during the regularly scheduled class time. Evergreen Cemetery is on Greenland Drive a relatively short distance from campus. On the other two days, you will be on campus picking up litter while also pondering environmental policies, regulations, and solutions. (You'll see how this works when you do it.)

TWO PAGE PAPER: A required two-page mock sustainability grant proposal, mock undergraduate research assistantship proposal, or water education brochure will be due on 4/14. You will receive more information about this at a later date.

FINAL EXAM: W 5/3 10a-noon in 100 DSB. You must take the Final exam with the rest of the class on that day and at that time, and the score cannot "drop."

--- POLICIES ---

WITHDRAWALS AND INCOMPLETES*: I almost never assign I's, and they will not be given to students who have performed poorly and are suspected of seeking an I solely to avoid a F. Extensive medical documentation is required for an I. Students can drop without a grade through 1/30. The last day to drop with a grade of "W" is 3/26. After 3/26, the only way out (without a F or an I) is to withdraw from the university (withdraw from all classes). The last day you can withdraw from the university is 4/26. BEFORE YOU DROP OR WITHDRAW, CAREFULLY CONSIDER THE IMPACT OF YOUR DECISION ON YOUR ACADEMIC SITUATION INCLUDING FINANCIAL AID.*

PARTICIPATION: *Lecture participation is mandatory and you must be present for the entire lecture period (even on exam days). Participation will be monitored through clicker use. Work-related absences, weather-related absences, weddings, funerals, and other personal/family absences are expressly not excused but note that you get to drop one exam and two homework assignmenst, and you can be absent from six clicker sessions without penalty. If you miss a lecture, obtain notes and/or handouts from a student who was there. Absences for university sponsored events (e.g., athletics and forensics), medical reasons, court dates, immigration appointments, and military commitments (e.g., National Guard drills) are excused but only if I receive documentation (e.g., a doctor's note) which I can* keep.

TAKE THE EXAM ANYWAY: If you miss an exam and your absence is *NOT* excused, you should still complete the exam although you will not receive any credit. You should still complete the exam, so you can check your knowledge and also become better-acquainted with course assessments.

ARRIVE ON TIME: You MUST arrive on time for exams. Your score on the exam may not "count" if you arrive after some students have left the room.

GRADING: *Course grade – <u>Your course grade is based on your percentage in the course as a whole.</u>* Generally, students who earn a course grade of A have percentages exceeding 89% and students earning a course grade of B have percentages between 79% and 89%. I use +/- grading. It is possible to earn a D or F and approx. 8% of students generally do.

HOW THIS COURSE WORKS:

I will go to extraordinary lengths to help students learn Earth Science, and I will spend large amounts of time with students who need help. If you don't understand something, send e-mail or call, and we'll get to the bottom of the problem.

*<u>However, I do not adjust grades on an individual basis or accommodate individual needs (except for disabilities or in very extreme/unusual situations). For example, if you need to earn a certain grade in this course to keep a scholarship, then you will have to earn that grade through your performance. * Your work schedule is not an excuse for poor course performance. * No makeup exams or quizzes will be given unless the absence was excused (see ATTENDANCE above). Simply missing an exam or quiz is not an adequate reason for a makeup. *</u>*

LOTTERY STATEMENT: Do you have a lottery scholarship? To retain the Tennessee Education Lottery Scholarship eligibility, you must earn a cumulative TELS GPA of 2.75 after 24 and 48 attempted hours and a cumulative TELS GPA of 3.0 thereafter. A grade of C, D, F, FA, or I in this class may negatively impact TELS eligibility. If you drop this class, withdraw, or if you stop attending this class you may lose eligibility for your lottery scholarship, and you will not be able to regain eligibility at a later time. For additional Lottery rules, please refer to your Lottery Statement of Understanding form (http://www.mtsu.edu/financial-aid/forms/LOTFEV.pdf) or contact your MT One Stop Enrollment Coordinator (http://www.mtsu.edu/one-stop/counselor.php).

Reasonable Accommodations for Students with Disabilities: Middle Tennessee State University is committed to campus access in accordance with Title II of the Americans with Disabilities Act and Section 504 of the Vocational Rehabilitation Act of 1973. Any student interested in reasonable accommodations can consult the Disability & Access Center (DAC) website and/or contact the DAC for assistance at 615-898-2783 or dacemail@mtsu.edu.

******I TRY VERY HARD TO STICK TO THIS OUTLINE BUT EVERYTHING IS SUBJECT TO CHANGE.******

WHAT YOU ACTUALLY DO IN THIS COURSE

- THREE EXAMS (see "LECTURE SCHEDULE").
    - Description
        - Collectively 50% of course grade;
        - Lowest exam score drops;
        - 35-50 questions each;
        - Largely or entirely multiple choice and true/false;
        - Highly restrictive make up policy (see **ATTENDANCE**).
    - Content
        - Everything that came out of my mouth during lecture;
        - Lecture notes (available in D2L or mass e-mailed to you);
        - Additional notes taken by you and based on videos, etc.;
        - Commonly-missed pre-class assignment questions;
        - Content derives solely from lectures post-dating the previous exam.
- FINAL (see "LECTURE SCHEDULE").
    - Description
        - 25% of course grade;
        - 100 questions total;
            - approx. 40 questions related to content post-dating Exam 3;
            - approx. 10 questions drawing on content from throughout the course;
            - approx. 50 commonly-missed pre-class assignment questions and exam questions.
        - Largely multiple choice and true/false.
        - You cannot drop your final exam score.
- CLICKER QUESTIONS (ANSWERED DURING LECTURE PERIOD)
    - Description
        - Collectively 15% of course grade;
        - You can be absent from six clicker sessions without penalty.
    - Content
        - Pre-class reading. (See reading schedule.)
        - Lecture.
- PRE-CLASS ASSIGNMENTS (PROBLEMS) AND HOMEWORK
    - Description
        - Collectively 10% of course grade;
        - Complete in MasteringGeology;
        - No credit for completion after the due date;
        - See additional info about grading policy in MasteringGeology;
        - Lowest two scores drop.
    - Content
        - See "CALENDAR."
- EXTRA CREDIT AND TUTORING
    - Good for the addition of up to 5 percentage points to your course grade.
    - For a few students who are performing extremely poorly, a final course grade of "C-" or better can be earned through a combination of improved exam performance and successful completion of a large amount of closely-monitored regular coursework, extra credit, and tutoring. This is NOT the easy way to earn a "C-." Students become one of the aforementioned "few students" at my discretion.

Takeaways for Exam 1

Earth science, Earth Science, 14e, Chapter 1

1. Events in the distant past (tens of thousands, millions, or billions of years ago) are responsible for the form and distribution of the living things around us.
2. Scientific knowledge falls into three categories: observation, hypothesis, and theory.
3. Most scientists think there is little or no connection between science and religion.
4. The interior of the Earth has four fundamental subdivisions: crust (outermost), mantle, outer core, and inner core (innermost).

Earth science, Earth's Place in the Universe, 14e, Unit 7

1. The universe is immense, but the Earth is able to support human life because it is a very special place.
2. Planets within our solar system fall into two categories: terrestrial (inner) and Jovian (outer).
3. Asteroids and comets both strike the Earth from time to time, but they differ compositionally and they originated in different parts of the solar system.

Earth science, Matter and Minerals, 14e, Chapter 2

1. In Earth science, the definition of mineral has five parts and is more restrictive than definitions common in other fields and in everyday life.
2. The most abundant elements in Earth's crust are oxygen (47% by weight) and silicon (28% by weight).
3. The silicate minerals are the most common mineral group, and, within this group, feldspars are the most common mineral.
4. Most rocks in central Tennessee consist of non-silicate minerals (specifically, the carbonate minerals calcite and dolomite).

Earth science, Rocks, 14e, Chapter 3

1. Rocks are *igneous, sedimentary,* or *metamorphic.*
2. Rock cycle: igneous, sedimentary, and metamorphic rocks change from one into another through processes including *weathering, erosion, transport, deposition, lithification, metamorphism, melting, and crystallization.* These changes require a long amount of time (e.g., millions of years).
3. Globally, about 75% of rock outcrops are sedimentary, and shale, a kind of detrital sedimentary rock, is the most abundant sedimentary rock.
4. Carbonates (e.g., limestone and dolostone) are the most abundant chemical sedimentary rocks globally, and carbonates are (by far) the most abundant rocks in central Tennessee.

Plate Tectonics I: A Scientific Revolution Unfolds, Earth Science, 14e, Chapter 7

1. Thanks to GPS and other technologies, plates and plate motion are now observational (facts), but some aspects of plate tectonics may always remain theoretical.
2. Plate tectonics explains the origin of Earth's features as well as most contemporary earthquake and volcanic activity.

Takeaways for Exam 2

Earthquakes and Earth's Interior

1. Scientists use scientific observations to identify the geographic areas where strong shaking is most likely to happen, but scientists cannot presently predict individual large earthquakes on the kind of timescale which would make evacuation practical. In many areas where strong shaking is likely to happen, people prepare by strengthening buildings and preparing for the aftermath.
2. Strong earthquake shaking (surface wave) is preceded by a much weaker trembling (P wave) which provides a few seconds of warning that stronger shaking is on the way.
3. Aftershocks impact humans, but real time seismology can help first responders deal with them.
4. Historically, structural collapse and tsunamis have killed the largest numbers of people.
5. Scientists have used the study of seismic waves and other phenomena to discover the core and mantle, even though humans have drilled through less than half of the crust.
6. Parts of the Southeast will be shaken by major earthquakes in the future but scientists don't know exactly when. Hazard is highest in West TN (e.g., Memphis), East TN (e.g., Knoxville), Charleston, SC, and nearby areas.
7. Middle Tennessee is not at great risk from earthquake shaking.

Geologic Time I, Earth Science, 14e, Chapter 11

1. Uniformitarianism: most large changes in the Earth happen over immense amounts of time through the slow operation of processes like those observed in the world today. Catastrophism: however, the geologic record suggests that catastrophic change has also had a large impact on the planet.
2. The study of unconformities provided key evidence for the great antiquity of the Earth long before reliable radioisotope dating became possible.
3. The geologic timescale was largely developed through (a) the study of fossils and (b) the application of relative dating before reliable radioisotope dating became possible. Later, radioisotope dating confirmed key parts of the geologic timescale.
4. The Earth's climate is changing rapidly, and past climates may provide clues to the future of climate.

Geologic Time II, Earth Science, 14e, Chapter 12

1. Single-celled life originated early in Earth history, but animals did not appear until relatively recently.
2. The Earth's atmosphere originally lacked oxygen and became breathable (by you and me) over (a large amount of) time through the action of photosynthetic (green) life.

3. The Earth should be around for a few billion additional years, and then the Sun will change, destroying the Earth.
4. The oldest fossils of many kinds (phyla) of invertebrates are found in sedimentary rocks deposited during the Cambrian period of the Paleozoic era around 540 m.y. ago.
5. The oldest fish, land plant, insect, amphibian, and reptile fossils are found in rocks of the Paleozoic Era.
6. The oldest and youngest dinosaur fossils and the oldest bird, mammal, and flowering plant fossils are found in rocks of the Mesozoic Era.
7. We live in the Holocene epoch of the Quaternary period of the Cenozoic era of the Phanerozoic eon. Human (Homo sapiens sapiens) fossils are only found in Quaternary deposits.
8. Contemporary Earth science has its origins in the late Renaissance (17th Century) and grew into a science during the Enlightenment (18th Century) and Industrial Revolution (19th Century).

EXAM 1 *ADDITIONAL* STUDY QUESTIONS – ANSWER PRIOR TO EXAM 1

INTRODUCTION TO COURSE

•1. Why do most scientists think thorn (honey locust) trees have thorns?

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INTERIOR OF EARTH (Ch 1 and 8 in TLT)

• 2. Sketch the interior of the Earth, labeling the inner and outer core, mantle, and crust.
• 3. Indicate layers made of iron-nickel alloy and layers which are mostly (or entirely) liquid.

EARTH'S PLACE IN SPACE AND DEEP TIME (Unit 7 in TLT)

Earth is special

• 4. What are some of the "special" characteristics of the Earth that make it able to support life?
• 5. Name the planets of the solar system in order of distance from the Sun.
• 6. Which planets are inner (terrestrial) planets and which planets are outer (Jovian) planets?
• 7. In what ways do the inner planets differ from the outer planets?

Space hazards

• 8. Where are the asteroid belt, Kuiper belt, scattered disk, and Oort cloud?
• 9. Are all asteroids in the asteroid belt?
• 10. Where do comets "come from?"
• 11. What is a "coronal mass ejection" and what are some problems that one might cause?

The universe has been here for a while

• 12. How old is the universe according to most scientists?
• 13. How old is the Earth according to most scientists?
•

MINERALS AND ROCKS (Ch 2 and 3 in TLT)

- What happened to world population between 1960 and 2010? What happened to the gap between the richest and poorest between 1960 and 2010? What does Rosling think world population will be in 2050? What has happened to child survival and family size over time? Which population is likely to grow: less developed or more developed? What does Rosling think will limit population growth?
  https://www.ted.com/talks/hans_rosling_on_global_population_growth?language=en

EXAM 2 *ADDITIONAL* STUDY QUESTIONS – ANSWER PRIOR TO EXAM 2

EARTHQUAKES

Prompt #1. Most of California's population is concentrated in large cities near the plate boundary. The statewide probability map suggests that overall, there is a 99% chance of a damaging M=(6.7 or greater) earthquake occurring somewhere in the state in the next 30 years. Should resources for earthquake preparedness be spread evenly across the state? Explain your reasoning using a set of 2-3 sentences or bullet points, supported with information from this unit.

For full credit:
Response describes contributions of regional differences in both earthquake probability and population as important factors in deciding how to allocate earthquake preparedness resources. As part of the answer, the student explains the difference between hazard and risk.

Prompt #2. Based on your risk assessment of the two schools in this activity, make the case for funding upgrades to buildings at one school. Also, describe the upgrades. Prepare a set of bullet points to be presented to the City of San Francisco that uses data from your analysis to support your recommendations.

Criterion	***For full credit***
The student explains how specific geological characteristics of the school site (strong shaking potential, which includes rock/soil type and distance from potentially active faults; liquefaction potential; landslide potential) contribute to seismic hazard. (Aligned with unit goal 1)	*The response correctly identifies the degree to which the school sites are exposed to seismic hazard, and explains the factors contributing to the seismic hazard at each specific site. Complete explanations include a discussion of proximity to active faults; rock/soil type and consolidation (liquefaction potential); proximity to steep slope*
The student explains how construction at each school site could be upgraded to enhance seismic safety. (Aligned with unit goal 2)	*The response correctly identifies specific seismic hazard mitigation options and explains why they would be useful at the two chosen school sites. The mitigation options are relevant to the hazards outlined in the response. These may include: To mitigate loose soil/ liquefaction effects: add deep piles to foundation, dewater or densify sediment* *To mitigate effects of shaking: reinforce soft stories, add devices to resist vibration*
The student appropriately calculates risk as a combination of hazard, vulnerability, and value, with value in this case referring to the potential number of lives saved. (Aligned with unit goal 3)	*The response takes into account all risk factors when prioritizing seismic retrofits*

GEOLOGIC TIME (Ch 11 and 12)

- Where is the Gray fossil site, what animals have been unearthed there, and what is its significance to climate both past and future?
- Distinguish between uniformitarianism and catastrophism.
-
- Name any eons, eras, periods, and epochs mentioned in class and in the notes.
- Describe major events (e.g., Cambrian Explosion), animals (e.g., first amphibians), and plants (e.g., “Age of Flowering Plants”) associated with each.
- Place the eons and eras in correct order from oldest to youngest.
- In what eon, era, period, and epoch are we living?

Activity 1.1 - Minerals and Products

Prajukti (juk) Bhattacharyya (University of Wisconsin, Whitewater)
Joy Branlund (Southwestern Illinois College)
Author Profiles
This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

In the minerals and products activity, students match physical products with actual mineral samples, using observable properties as well as the minerals' chemical formulas and some products' ingredient lists.

Learning Goals

Upon completion of this segment, students should be able to:

- Cite examples of mineral resources, the products that contain them, and the mineral properties that cause these resources to be used in these products.
- Describe how elemental abundance relates to mineral abundance and hence resource availability.

Humans' Dependence on Earth's Mineral Resources
Unit 1
People, Products, and Minerals
Part I: Minerals and Products

Here is a list of the minerals, and their chemical formulas, that we have in class today. Use this, and other properties of the minerals (such as hardness, color, etc.), to match them to the products listed on the back of this sheet (one mineral per product).

Mineral Name	**Chemical Formula**
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$
Bauxite	$Al(OH)_3$ - $AlO \cdot OH$
Barite	$BaSO_4$
Calcite	$CaCO_3$
Chalcopyrite	$CuFeS_2$
Galena	PbS
Graphite	C
Gypsum	$CaSO_4 \cdot 2(H_2O)$
Halite	$NaCl$
Hematite (red)	Fe_2O_3
Hematite (specularite)	Fe_2O_3
Kaolinite	$Al_2Si_2O_5(OH)_4$
Muscovite	$KAl_2(AlSi_3)O_{10}(OH,F)_2$
Quartz	SiO_2
Talc	$Mg_3Si_4O_{10}(OH)_2$

Which mineral is in each product? (Choose 1 mineral per product)

Product #	Products	Associated Mineral Name
	Toothpaste, Cheerios & Antacid	
	Glass & Sandpaper	
	Table Salt & Road Salt	
	Jewelry	
	Baby Powder & Makeup	
	Pencils	
	Drywall & Plaster	
	Sparkly Eye Shadow	
	Blush	
	Car Battery	
	Porcelain	
	Copper Wire, Pennies & Matches	
	Aluminum Foil	
	Fertilizer	
	Mud Flap of Truck	

Activity 1.2 - Review of Minerals and Rocks

Prajukti (juk) Bhattacharyya (University of Wisconsin, Whitewater)
Joy Branlund (Southwestern Illinois College)
Author Profiles
This material was developed and reviewed through the InTeGrate curricular materials development process.

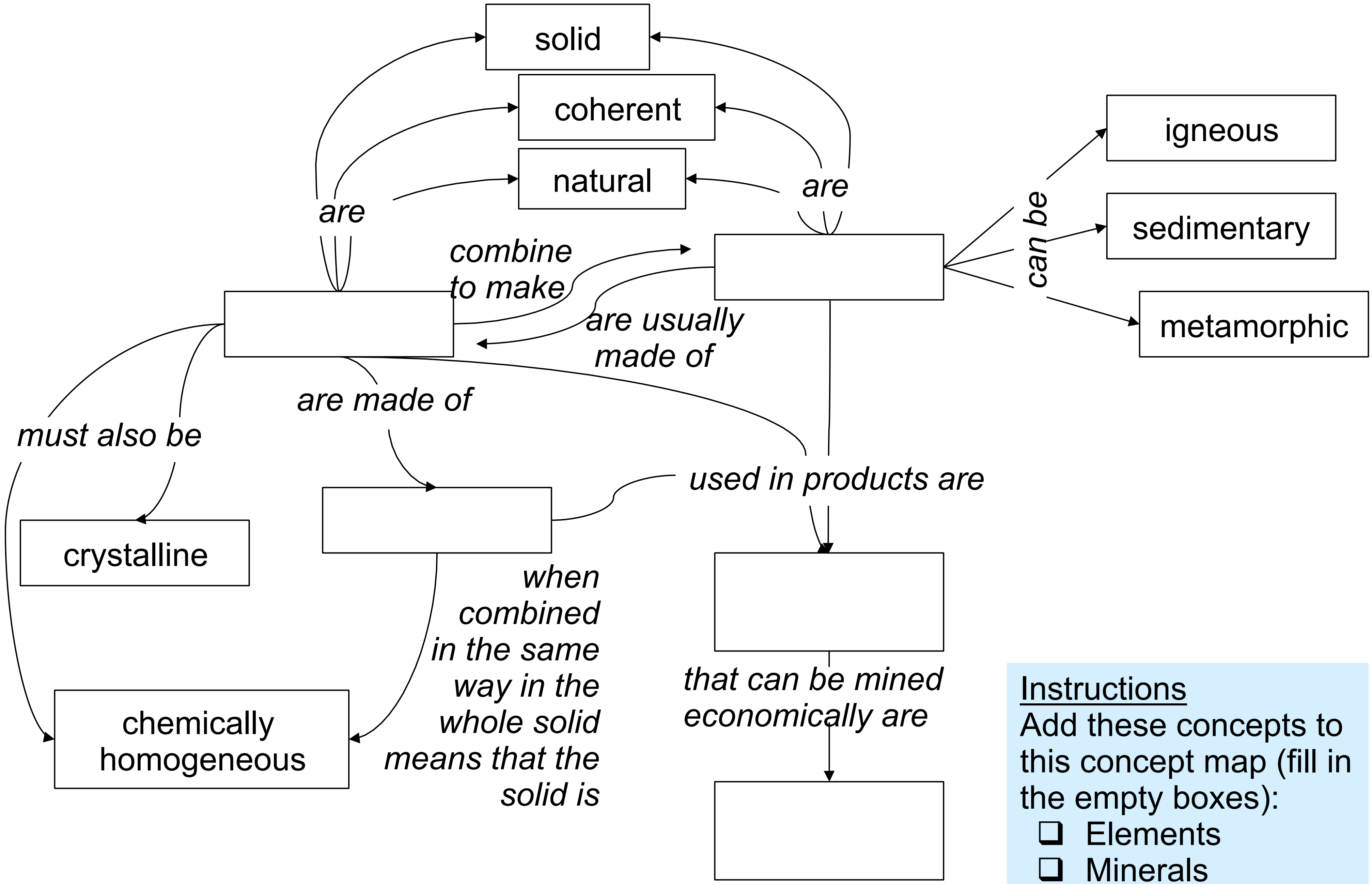
Summary

The discussion presented here is meant to augment, not replace, the pre-class reading, as well as to provide an introduction to concept maps.

Learning Goals

Upon completion of this segment, students should be able to:

- Differentiate between rocks and minerals, including rock-forming processes and rock families
- Draw concept maps to organize material learned.



Instructions

Add these concepts to this concept map (fill in the empty boxes):

- ❑ Elements
- ❑ Minerals
- ❑ Mineral resources
- ❑ Mineral reserves
- ❑ Rocks

Activity 1.3 - Economic Development and Resource Use

Leah Joseph (Ursinus College) with significant input from Joy Branlund (Southwestern Illinois College)

Author Profiles

This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

This short activity (10–15 minutes) for Unit 1 introduces students to the general relationship between economic development and resource use, and, particularly with the follow-up homework, the relationship among growing populations, increasing economic development, and natural resource extraction. The activity is intended to be completed by individuals or small groups but could also be used for a guided class discussion. This activity serves as a transition to Unit 2.

Learning Goals

Upon completion of this segment, students should be able to:

- Infer the relationships between sustainability, resource availability, and economic development

People, Products, and Minerals
Unit 1/Activity 3

Economic Development and Resource Use

Learning Outcomes

- Infer the relationships among sustainability, resource availability, population growth, and economic development

Economic Development and Resource Use

The gross domestic product (GDP) of a country is frequently used as an indicator of a country's economic performance and its level of development. A per capita GDP is the overall GDP divided by the number of people in that country and can be used to more easily compare the economic performance of countries with different population sizes.

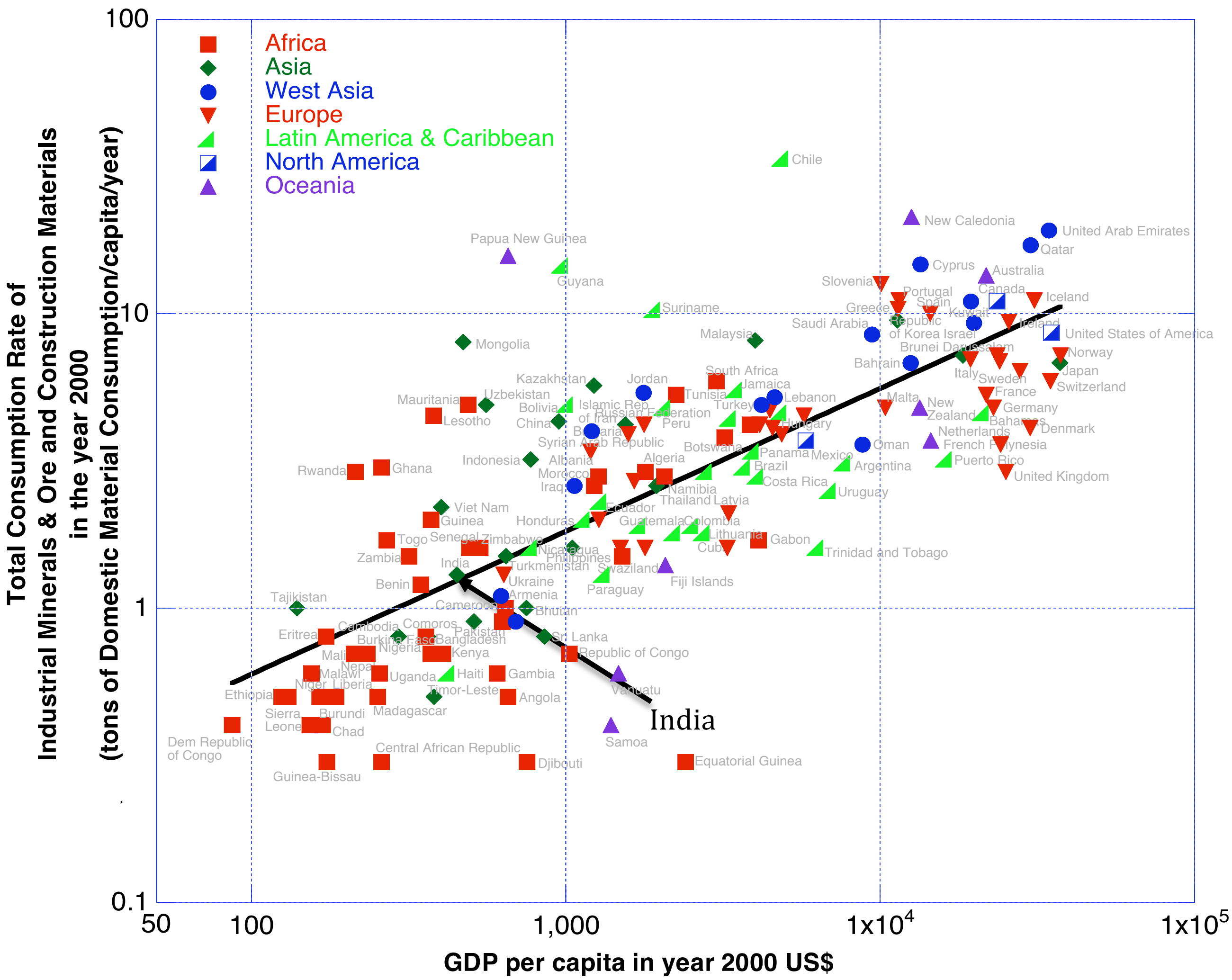


Figure 1. ***The relationship between gross domestic product (GDP) per capita and the total domestic consumption rate of industrial minerals & ore and construction material in tons per capita for ~150 different countries in the year 2000*** (Modified from UNEP Decoupling Report, 2011; Consumption (metabolic) rate data from Steinberger et al., 2010; GDP data from http://data.worldbank.org/indicator/ NY.GDP.PCAP.KD); Country region from http://unstats.un.org/unsd/methods/m49/m49regin.htm with the exception of considering Mexico as part of North America). Not all the countries plotted are labeled above due to space restrictions.

The plot above shows the per capita GDP of many countries versus a measure of their natural resource *consumption rate*. In this case, *consumption rate* is the domestic extraction of a material plus its imports minus its exports of those same materials (in tons per capita per year). In this case, the natural resources measured are Industrial Minerals & Ore and Construction Materials. As the legend denotes, different regions of the world are indicated by markers of different colors and shapes.

<u>**Questions**</u>

1) Provide the names of two countries that consume approximately the same amount of resources but have widely varying per capita GDP's.

2) Provide the names of two countries that have approximately the same per capita GDP but have widely varying total consumption rates.

3) Despite the pairs noted above, use the trend line in Figure 1 to describe the overall relationship between a country's wealth, as defined by its per capita GDP, and the amount of natural resources used (per capita), as defined by its total consumption rate.

4) Is India more or less developed (as determined by per capita GDP) than most of the Latin American and Caribbean countries (which includes South America)?

5) Using this trend (from #3) predict what will happen as India's economy grows.

Figure 2 (*below*) shows consumption and extraction trends for various types of products in three different regions (North America, South America, and India) since around 1970.

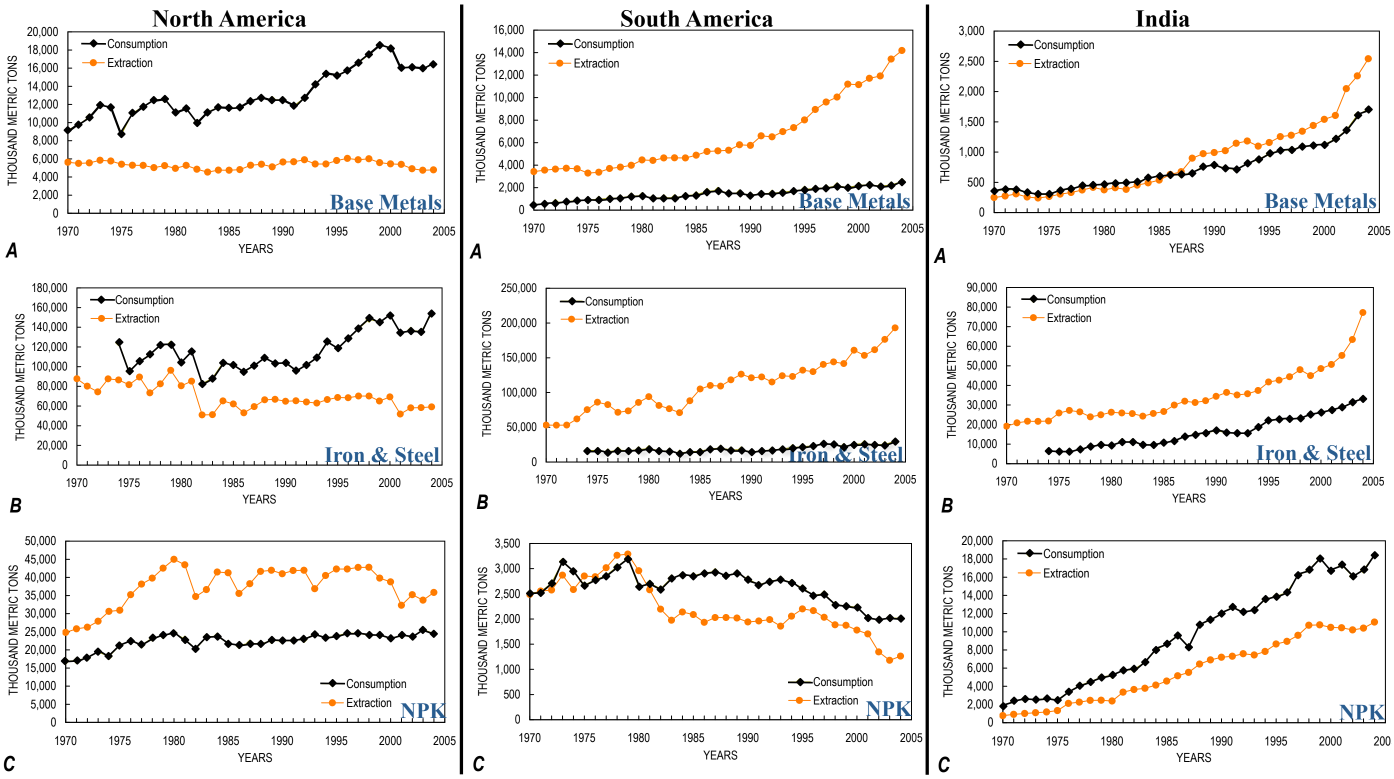


Figure 2: ***Consumption and extraction of various specific commodities in thousand metric tons for North America (left), South America (middle) and India (right).*** **A. Base metals (Aluminum, copper, lead, and zinc); B. Iron and steel; C. NPR (Nitrogen, phosphorus, and potassium), components often used in the production of fertilizer. From Rogich and Matos, 2008. North America includes the Canada, the United States, and Mexico.**

6) Describe the trends in consumption (toward more recent times) for all three regions.

7) Give a possible explanation for the trends in consumption in India. In North America?

8) India currently uses more NKP than South America, even though India is less developed. Why might that be the case?

Source Information for Figures:

Figure 1 Consumption (Metabolic) Rate data:

Steinberger, J., Krausmann, F., and Eisenmenger, N. (2010). "The Global Patterns of Materials Use: A Socioeconomic and Geophysical Analysis." *Ecological Economics* 69, no. 5: 1148–58. Data downloaded for plotting from: http://www.uni-klu.ac.at/socec/inhalt/3812.htm (see "Get data" link).

Figure 1 GDP per capita for constant 2000 US$ data for the year 2000:

Downloaded from http://data.worldbank.org/indicator/NY.GDP.PCAP.KD.

Figure 1 Country Classification:

From the United Nations Statistics Division at http://unstats.un.org/unsd/methods/m49/m49regin.htm. Exception is that Mexico is considered on the plot to be part of North America, rather than Latin America/Central America.

Figure 1 concept (and general source of information):

Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E. U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., and Sewerin, S. (2011). *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth.* A Report of the Working Group on Decoupling to the International Resource Panel. United Nations Environment Programme. Downloaded from http://www.unep.org/resourcepanel/decoupling/files/pdf/decoupling_report_english.pdf on November 15, 2012 (Figure 2.6 on page 14).

Figure 2: Data and concept

Rogich, D. G., and Matos, G. R. (2008). "The Global Flows of Metals and Minerals." U.S. Geological Survey Open-File Report 2008-1355. 11 pg., available only online at http://pubs.usgs.gov/of/2008/1355/.

Other Information:

Fridolin, K., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H., and Rishcer-Kowalski, M. (2009). "Growth in Global Materials Use, GDP and Population During the 20th Century." *Ecological Economics,* 68, no. 10: 2696–705.

Gross Domestic Product. *Encyclopedia Britannica* http://www.briannica.com/EBchecked/topic/246647/gross-domestic-product-GDP) (accessed November 15, 2012).

SERI, 2011. Global Resource Extraction by Material Category 1980–2008. . http://www.materialflows.net/trends/analyses-1980-2008/global-resource-extraction-by-material-category-1980-2008/ (accessed September 12, 2012).

Activity Option 2 Learning Goals

Upon completion of this segment, students should be able to:

- Identify mineral resources (REE) used in common electronic goods and clean energy technologies.
- Describe overall trends illustrated in REE production and value (price) graphs; identify changes in trends and/or anomalous features in the graphs; and explain trends, changes over time, and anomalies in terms of mine production, demand, recycling, changes in technology, regulation, and/or population growth.
- Apply geoscientific habits of mind to interpret the complex relationships among consumers, producers, regulating agencies, and the environment in a global context by means of concept maps.
- Examine their own consumer behavior and judge the impacts of this behavior on sustainability.

Rare Earth Elements: Supply, demand, consumption, price

Rare Earth Elements (REE) are extensively used every day in batteries, electronics, ceramics, and high-powered magnets, and they are vital for clean energy technologies as well. In this activity we will look at REE supply, and consumption and price data, and discuss possible future strategies for balancing REE supply and demand.

China supplies the majority of the world's REE. The Chinese government sets the maximum amount of REE that can be legally exported out of the country (i.e., **export quota**) each year. The following table shows the amount of the export quota each year for the years 2000–2010 (except for 2002, for which we have no data), and the price per ton of REE adjusted for inflation with respect to the value of U.S. dollars (USD) during 1998 (shown as 98$/t, which means 1998 dollars per ton).

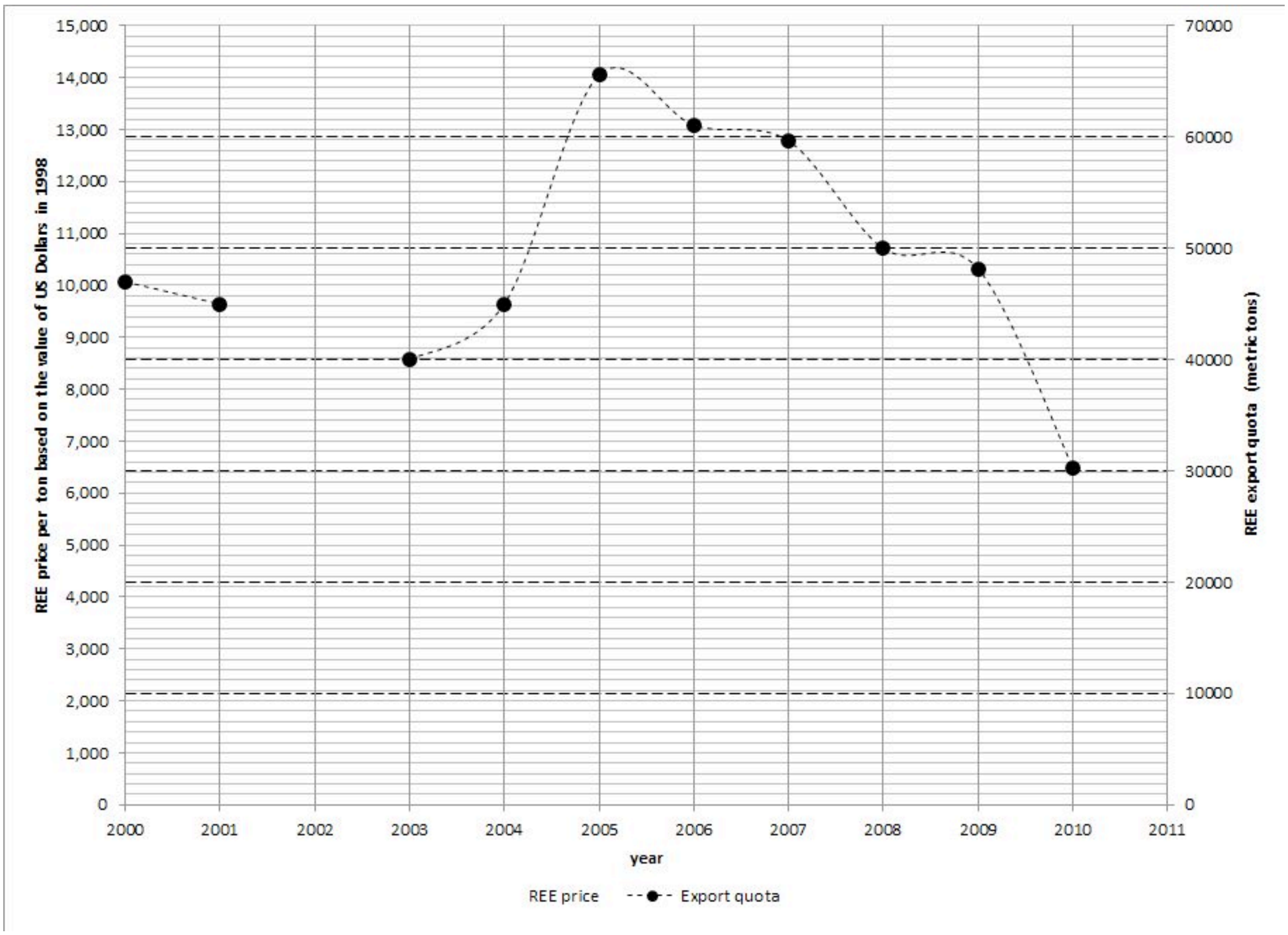
Year	**Total export quota (metric tons)***	**REE price per ton** in USD during 1998, expressed as (98$/t)**
2000	47,000	6,110
2001	45,000	5,330
2002	N/A	6,800
2003	40,000	5,450
2004	45,000	7,410
2005	65,580	5,500
2006	61,070	3,150
2007	59,643	4,160
2008	49,990	10,300
2009	48,155	7,100
2010	30,258	14,500

* Quota data from "China's Rare-Earth Production, Consumption, and Export Quotas for 2000 through 2011." (Tse, Pui-Kwan, 2011, China's Rare-Earth Industry: U.S. Geological Survey Open-File Report 2011–1042, 11 p.) Data from 2005 onward show total export quota for domestic producers and traders, plus Sino–foreign joint ventures.

** Price data from: "U.S. Geological Survey, 2011, REE statistics," in Kelly, T. D., and Matos, G. R., comps., "Historical Statistics for Mineral and Material Commodities in the United States," U.S. Geological Survey Data Series 140, at http://pubs.usgs.gov/ds/2005/140/.

1. The amount of REE allowed to be exported out of China is plotted on the graph below. Plot the REE price from the above table (the third column) on the same graph, using connected symbols. Please use a different symbol (not a filled circle) for your plot, and indicate your symbol on the legend below the graph.

   Note: This graph has TWO vertical axes. The vertical axis on the left indicates the price of REE expressed in terms of dollars per ton adjusted for inflation (98$/t). Use this axis for the data you need to plot. The vertical axis on the right shows the amount of REE export quota from China for the years listed. This data is already plotted for you.

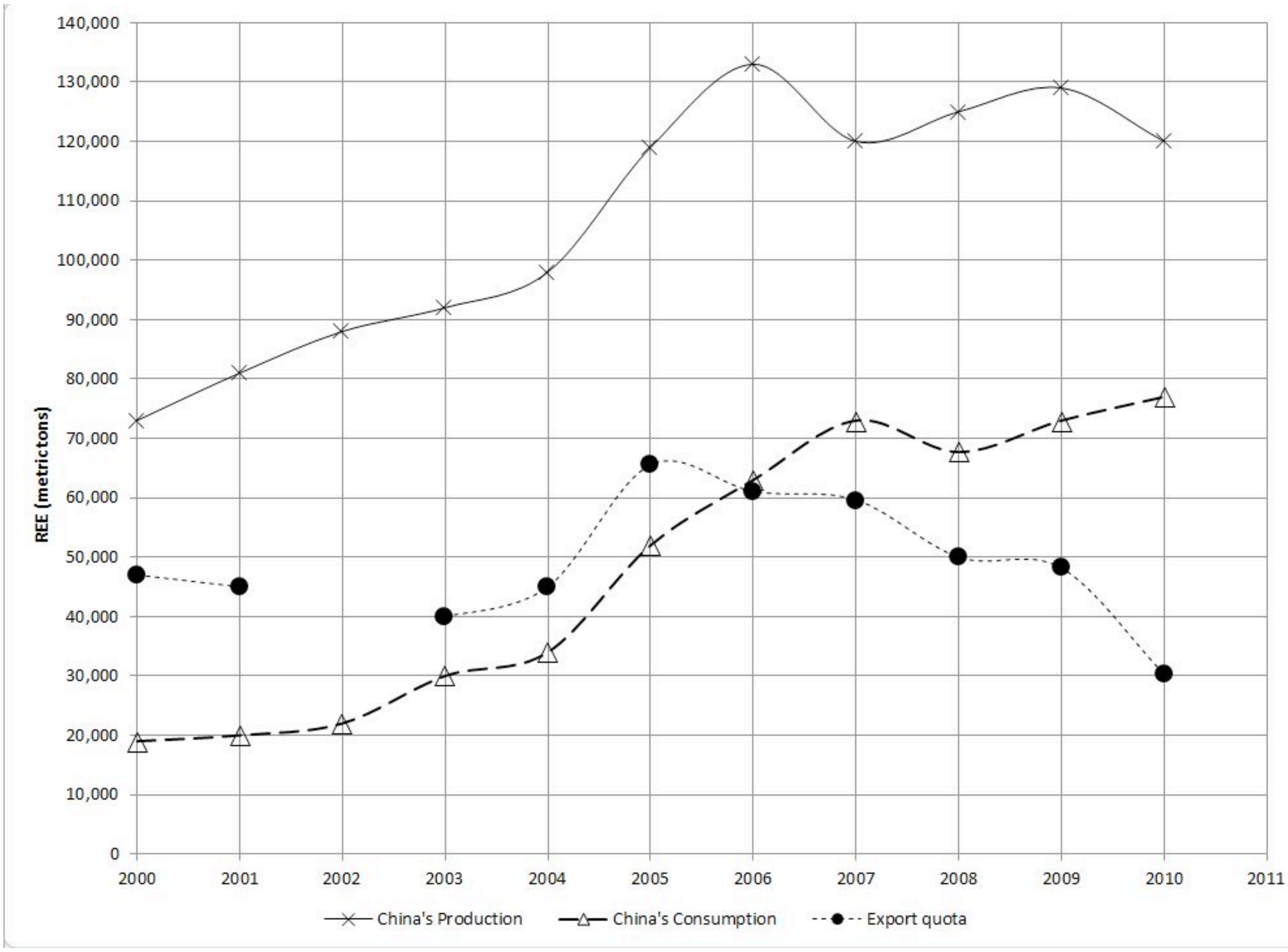


Answer the following questions based on the plot shown above:

2. The trend of the REE export quota is shown by black dots and the dotted line. By how much was the REE export quota reduced between 2005 and 2010?

3. When did the price of REE reach its lowest value? What was the approximate lowest value for REE?

4. Based on this graph, what can you say about the relationship between the REE export quota out of China (supply) and the price of REE?



5. China's REE production (Xs), consumption (open triangles), and export quota (filled circles) for 2000–2011 are shown in the above chart. Why do you think China is currently reducing its export quota? Give two reasons.

Rare Earth Element	Partial list of uses in clean energy technology fields				Demand* (Tons)	Supply* (Tons)
	Magnets (to generate electricity, in wind turbines, hybrid cars, etc.)	NiMH batteries in some hybrid cars	Phosphors in energy-efficient light bulbs (CFL)	Catalysts in cars (catalytic converters, to reduce pollutants)		
Lanthanum		**X**	**X**	**X**	41,200	30,500
Cerium		**X**	**X**	**X**	43,900	38,400
Praseodymium	**X**	**X**		**X**	9,800	7,000
Neodymium	**X**	**X**			27,000	24,400
Europium			**X**		400	390

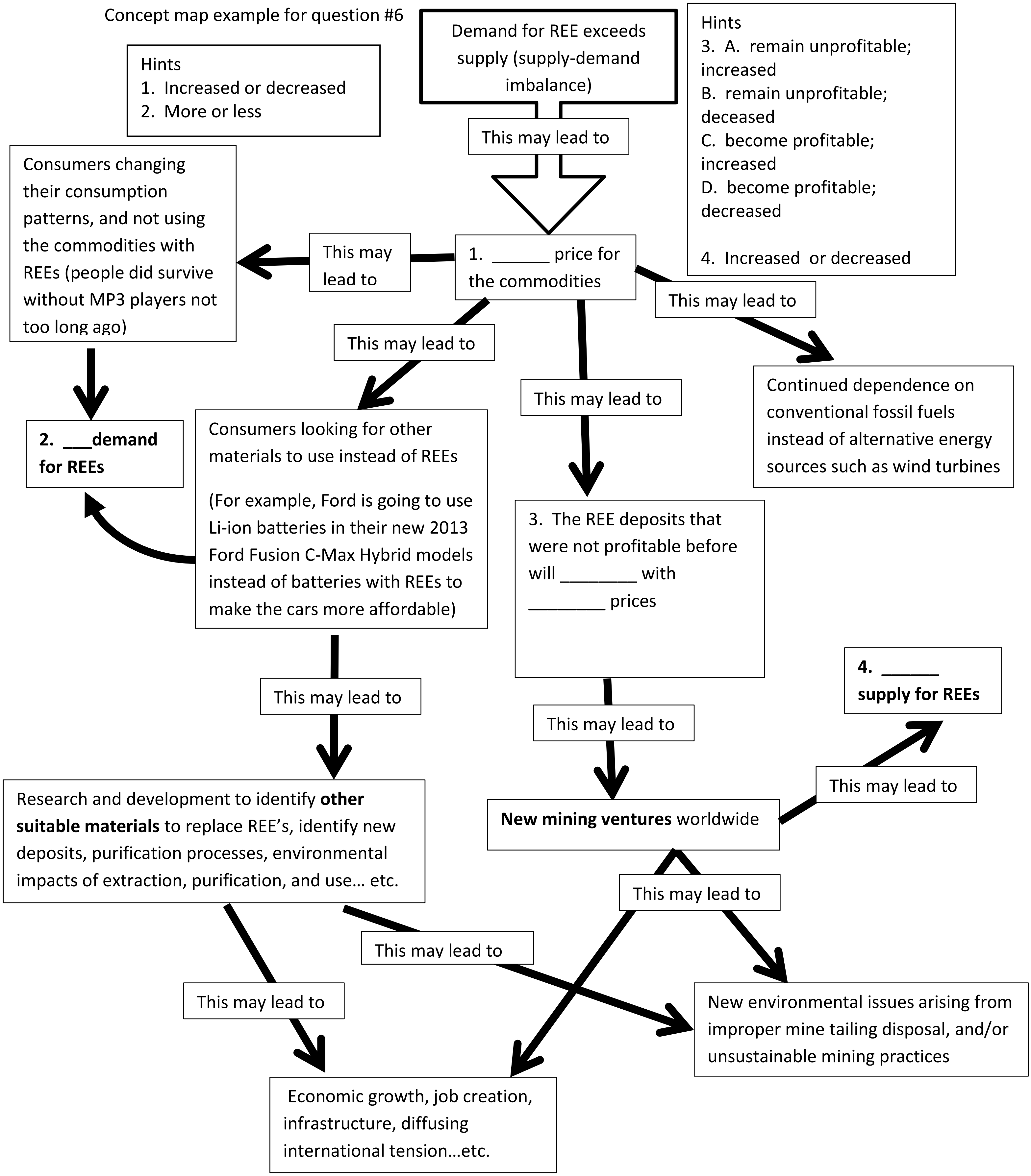
*Data from Roger Bade (2010), "Rare Earth Review: Is the Hype Justified?"
http://www.slideshare.net/RareEarthsRareMetals/libertas-rareearthreview

6. Some common uses, demand, and supply, for five of the rare earth elements are shown in the above table. You'll notice that supply and demand are out of balance. What can consumers, REE producers (e.g., mining companies), and technology manufacturers do to reduce the imbalance, and how will these actions affect the adoption and use of clean-energy technologies? Create a concept map to illustrate your answers.

Optional end-of-unit reflection question (this can also be used as a post-unit homework assignment or can be used as a unit-based question for an exam)

7. Describe two measures that you can personally take to reduce the supply/demand imbalance of REEs. Explain how those measures could either increase REE supply or reduce REE demand or both.

Concept map example for question #6



Unit 4: Mineral Resources Created by Sedimentary Processes

Joy Branlund (Southwestern Illinois College)
Author Profile
This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

In this unit, students will learn about sedimentary processes and the rocks they form. Activities are specifically designed to address topics such as clastic sedimentary processes, chemical weathering, and how such processes form heavy mineral sand deposits. This unit will also explore the chemical sedimentary processes that form salt deposits.

Learning Goals

Upon completion of this unit, students should be able to:

- Describe the processes that act to make sedimentary rocks with specific reference to how sedimentary processes redistribute and concentrate mineral resources.
- Diagram how the processes link together to form mineral resources, specifically with regards to placer (heavy mineral sands) and evaporite (salt) deposits.
- Apply knowledge of sedimentary environment, climate, and sedimentary processes to infer potential types and locations of mineral resources.
- Give examples and uses of mineral resources that are formed by sedimentary processes.

Activity 4.2 - Mining Sand

Joy Branlund (Southwestern Illinois College)
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▶ **This material was developed and reviewed through the InTeGrate curricular materials development process.**

Summary

Students will analyze data and answer questions regarding the weathering, erosion, and deposition responsible for concentrating shoreline titanium placer deposits in Florida.

Learning Goals

Upon completion of this segment, students should be able to:

- Describe the processes that act to make sedimentary rocks with specific reference to how sedimentary processes redistribute and concentrate mineral resources. This activity specifically addresses erosion, deposition, and chemical weathering.
- Diagram how the processes link together to form placer deposits that are mineral resources.
- Apply knowledge of sedimentary environment, climate, and sedimentary processes to infer potential types and locations of mineral resources.
- Give examples and uses of mineral resources that are formed by sedimentary processes. Specifically, students will see that titanium dioxide (from the mineral illmenite) is derived from sedimentary processes, and should be able to list its use in paints, papers, and plastics.

Mining minerals from sand

Learning objectives

By completing this activity, you will:

- Use ilmenite (a mineral which contains the element titanium), which is mined by DuPont to use as a white pigment, as an example of a mineral resource formed by sedimentary processes.
- Summarize the processes that act to make clastic sedimentary rocks.
- Diagram how sedimentary processes link together to form placer deposits (the heavy mineral sands).
- Explain how the sedimentary processes of mechanical weathering, erosion, and deposition, redistribute and concentrate mineral resources.
- Analyze graphs to interpret erosion and deposition processes that create heavy mineral sand deposits.
- Apply knowledge of sedimentary environment and processes to infer potential types and locations of heavy mineral sand.
- Explain how climate influences chemical weathering and how chemical weathering concentrates certain mineral resources.

Brief background

Figure 1. Map showing the location of the Trail Ridge heavy mineral sand deposit in Florida. The southern portion of the deposit is being actively mined by the DuPont Corporation. Map created using Google Maps; deposit located with Google Earth imagery and sketch map in Force, 1991.

Layers of dark sand, rich in heavy minerals, can be mined for the heavy minerals they contain. For example, the DuPont Corporation mines heavy mineral sand from the Trail Ridge sand deposit in northern Florida. The mineral ilmenite is used as a source of titanium dioxide (TiO_2), which is used to make white plastic and paints more opaque. Other minerals, like zircon and staurolite, are mined to be used as abrasives (to use in sandblasting and to etch tombstones, for example).

The right combination of factors existed in central Florida to make these heavy mineral sand deposits, and incorporate aspects of the geosphere, hydrosphere, and atmosphere. By studying these processes, geoscientists can predict other places that might have heavy mineral deposits, and thus guide exploration.

Part 1. How the sand at the Trail Ridge deposit came to be

> Quartz is found in many rocks, but some of the heavy minerals like sillimanite and kyanite only form in metamorphic rocks that make up the cores of mountains. These rocks broke apart into sand. The sand was carried to the ocean by streams and deposited. Waves picked up the sand from offshore and deposited it on the beach. Winds picked up some of the sand and deposited it in dunes behind the beach.

1. In the description of how the sand deposit formed, circle examples of weathering.
2. In the description of how the sand deposit formed, draw rectangles around examples of erosion.
3. Draw a diagram of how the sand deposit formed.

4. Although its exact age is not known, the Trail Ridge deposit formed in the Pliocene or Pleistocene (sometime between 12 thousand and 5.33 million years ago). Based on today's location of the Trail Ridge deposit, what happened to sea level between the time this sand was deposited and today. Explain how you came up with your answer.

Part 2. Characteristics of the heavy mineral sands, and how sedimentary processes led to their formation

Heavy minerals	**Formula**	**Specific gravity**
ilmenite	$FeTiO_3$	4.7–4.79
zircon	$ZrSiO_4$	4.6–4.7
staurolite	$(Fe,Mg)_2(Al,Fe)_9O_6(SiO_4)_4(O,OH)_2$	3.74–3.83
sillimanite	Al_2SiO_5	3.23–3.27
kyanite	Al_2SiO_5	3.53–3.65
Other minerals	**Formula**	**Specific gravity**
quartz	SiO_2	2.65

Table 1. Some minerals found in the Trail Ridge sands. Recall, specific gravity is a mineral property akin to density. Except for quartz, all the minerals listed are considered "heavy minerals."

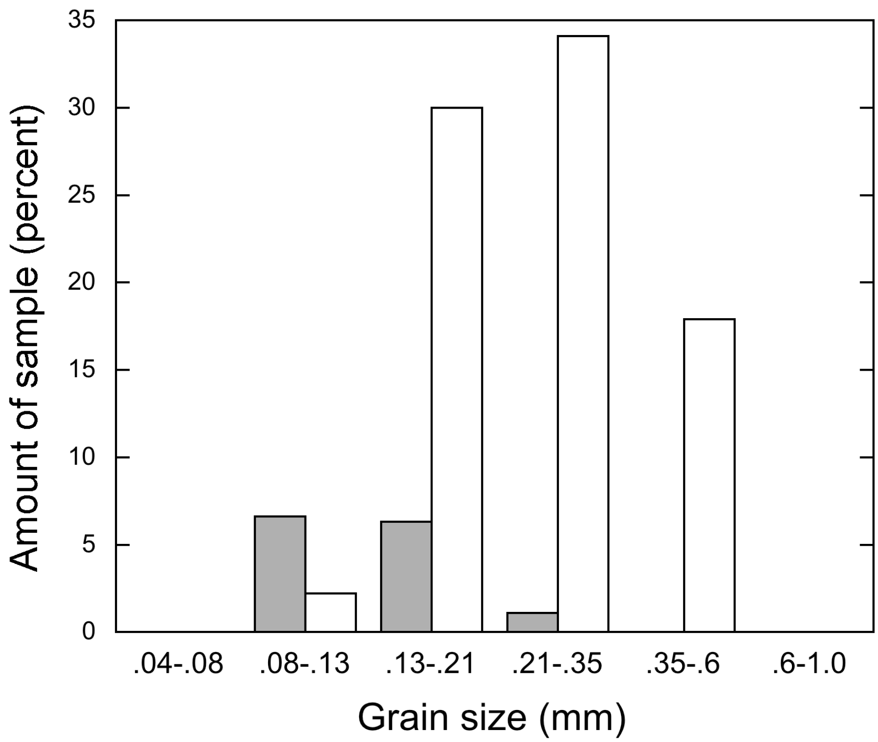

Figure 2. The graph shows size of heavy mineral sand grains (gray bars) and normal quartz sand grains (white bars) from the Trail Ridge deposit (after Force and Rich, 1989).

5. Describe the Trail Ridge sand deposit as shown in the graph.

6. Explain why the sand deposit has the characteristics that it does. Your answer should specifically explain how erosion and deposition has sorted the sand (sorting means the grains are separated by weight, so that particles that weigh the same are deposited together).

7. Draw a graph similar to the one shown in Figure 2, showing the characteristics of a similar deposit formed on the beach instead of a sand dune. Think about how waves might erode and deposit differently than the wind, or, think about what might be left on the beach after the wind eroded sand from there.

8. Do you think the beach deposit would contain more or less heavy minerals? (Would it be more or less desirable to mine the beach deposit?)

Part 3. Concentration of titanium in the mineral ilmenite

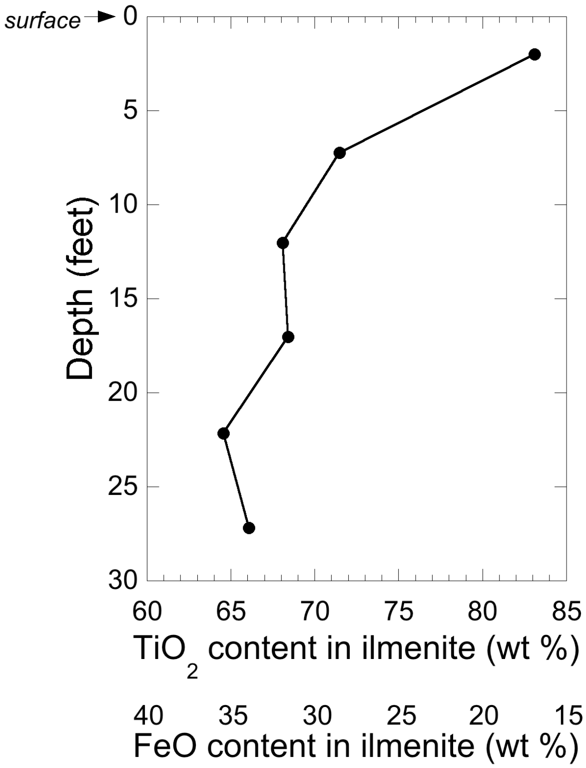

Figure 3. The Trail Ridge sand deposit consists of different layers of sand, which contains ilmenite and other minerals listed in Table 1. The composition of the ilmentite changes with depth (sand analyzed at the surface has a different composition than sand found deeper), and this is shown in the graph. Ilmenite has an average composition of $FeTiO_3$ but the relative amounts of iron (Fe) and titanium (Ti) can vary. "Wt %" means *weight percent*, the weight of TiO_2 in a given weight of the mineral. Two equivalent labels for the x-axis are given, one showing the amount of titanium (Ti) and one showing iron (Fe). So, ilmenite with 83 weight % TiO_2 means that 83% of that ilmenite's mass is TiO_2 , and 17% of the mass is FeO. After Force, 1991.

9. Describe how the composition of the ilmenite changes with depth.

10. What process do you think caused the ilmenite to change?

11. Explain why the ilmenite composition changes with depth, and specifically why this is expected in Florida.

Part 4. Summary

12. What do you think might be the advantage of mining sand as opposed to mining Ti-bearing minerals from metamorphic or igneous rocks?

13. The heavy mineral sand is a mix of minerals (see Table 1). In general, how do you think the mine processing (beneficiation) plant could separate the ilmenite from the other minerals?

14. Imagine that you work for an exploration company hired by DuPont to find new deposits of heavy mineral sands. Describe the type of place you would choose to explore. (Your answer should include the ideal characteristics of a place in which these sands would form.)

References

Force, Eric R. 1991. "Geology of Titanium-Mineral Deposits." GSA Special Paper 259.

Force, Eric R., and Rich, Fredrick J. 1989. "Geologic Evolution of Trail Ridge Eolian Heavy-Mineral Sand and Underlying Peat, Northern Florida." U. S. Geological Survey Professional Paper 1499.

Activity 4.3 - Mining Salt

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Author Profile

▶ **This material was developed and reviewed through the InTeGrate curricular materials development process.**

Summary

Students will research two types of salt deposits: solar salt (e.g., facilities in Bahamas) and rock salt (e.g., Heber City, Utah). Students will be able to compare and contrast the two types of salt deposits by creating a concept map.

Learning Goals

Upon completion of this segment, students should be able to:

- Describe the processes that act to make sedimentary rocks, with specific reference to how sedimentary processes (especially crystallization and deposition) redistribute and concentrate mineral resources.
- Diagram how the processes link together to form mineral resources, specifically with regards to evaporite (salt) deposits.
- Apply knowledge of sedimentary environment and operational processes to infer potential types and locations of mineral resources.

Mining Minerals from Salt

Learning objectives

By completing this activity, you will:

- Summarize the processes that act to make chemical sedimentary rocks.
- Diagram how the processes link together to form mineral resources, specifically with regards to evaporite (salt) deposits.
- Apply knowledge of sedimentary environment and operational processes to infer potential types and locations of mineral resources.

Step 1: Research how (a) salt is produced and mined in solar salt facilities in the Bahamas, and (b) how salt is mined from underground rock salt deposits, in places like Redmond, Utah.

Step 2: In your own words, write down the definitions of the italic words from the table on the right.

Evaporation	*Erosion*
Deposition (or deposit)	Minerals
Chemical *Weathering*	Rocks on Land Surface
Crystallization	Oceans
Lithified	Ion

Step 3: Create a concept map about how the solar salt is produced and how rock salt deposits form.

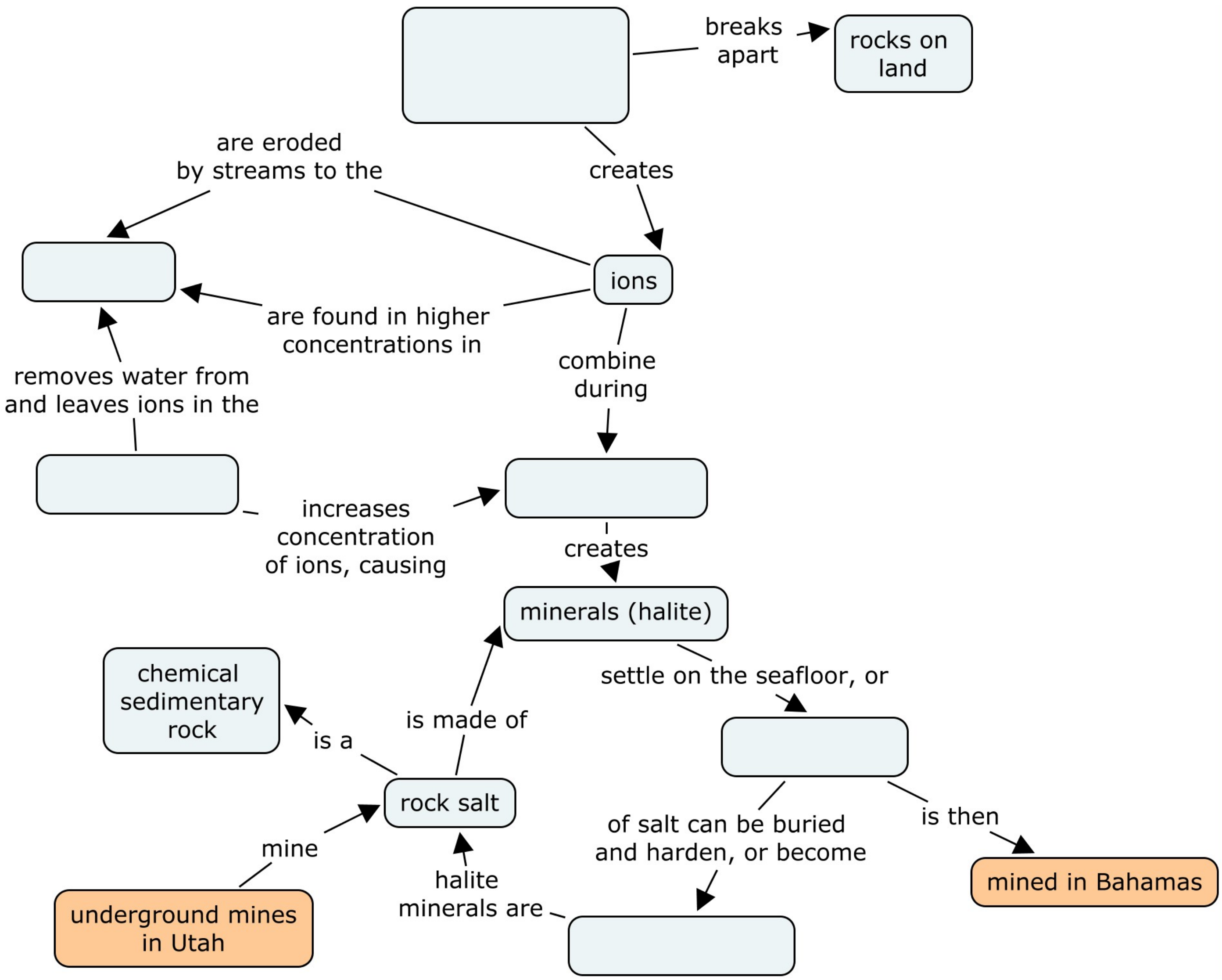
Alternate Step 3: Complete the concept map (on the following page) about how solar salt is produced and how rock salt deposits form.

Step 4: Answer the following questions:

A. In what sorts of places do you think salt deposits are forming today? (Think about: what are the characteristics of places in which salt deposits can be found)?

B. Use the completed concept map to help answer this question: Is "sea salt" really any different from normal (rock) salt? Explain your answer.

C. What are the pros and cons of mining salt in each of the two locations?


breaks apart
rocks on land
are eroded by streams to the
creates
ions
are found in higher concentrations in
removes water from and leaves ions in the
combine during
increases concentration of ions, causing
creates
minerals (halite)
settle on the seafloor, or
chemical sedimentary rock
is a
is made of
rock salt
of salt can be buried and harden, or become
is then
mined in Bahamas
mine
underground mines in Utah
halite minerals are

Unit 5: Mineral Resources Created by Igneous & Metamorphic Processes

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This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

This unit introduces the concepts of igneous and metamorphic processes and how these processes create mineral deposits. The background material provides an overview of the formation and distribution of mineral resources created due to hydrothermal activities, their tectonic association, and acid mine drainage (a major environmental concern for sulfide mining). The activity, in which students analyze a simplified geologic map and use the information for mineral exploration, addresses economic mineral resources created by mostly igneous processes, specifically metallic sulfide deposits. Students also weigh the pros and cons of mining near Yellowstone National Park and on the shores of Lake Superior.

Learning Goals

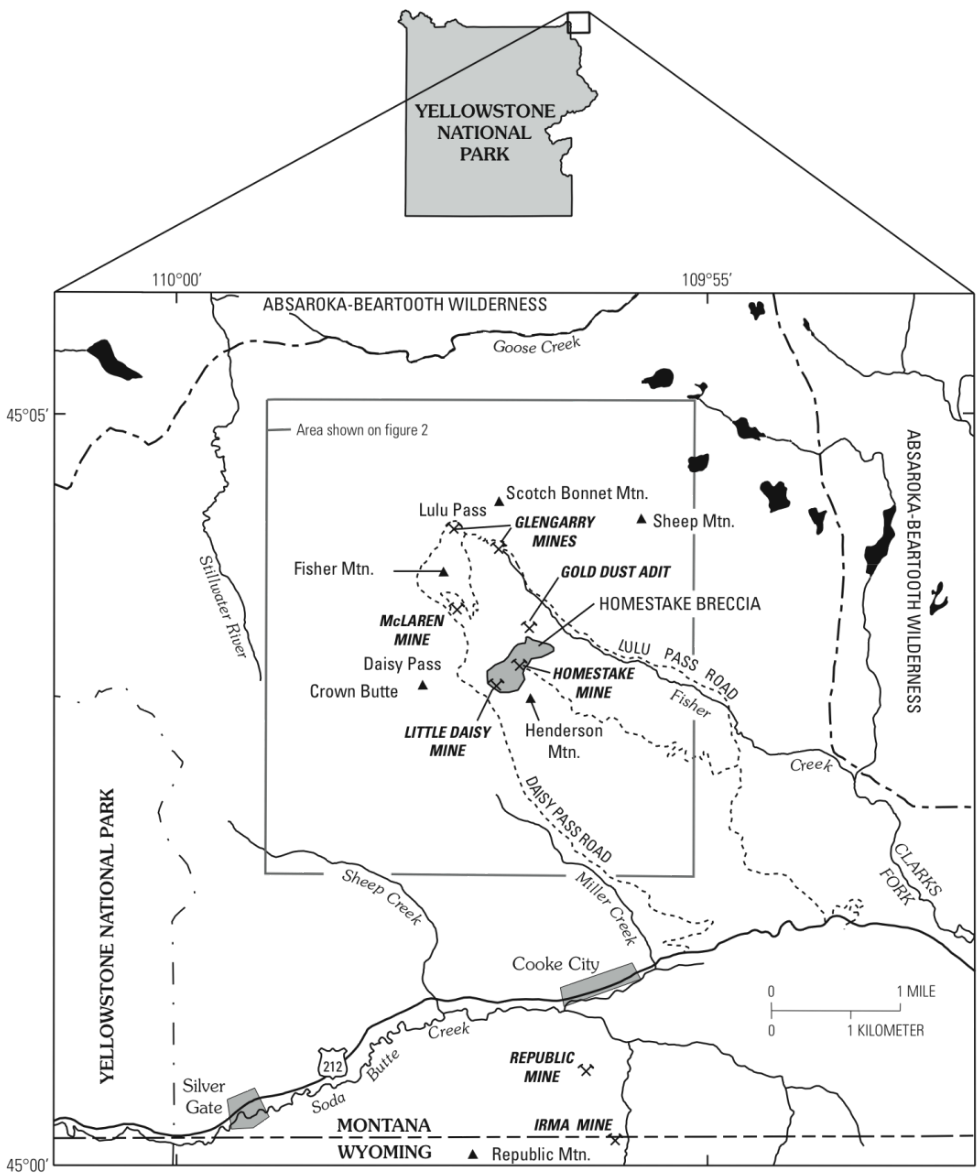
Upon completion of this unit, students should be able to:

- Explain how mineral resources are concentrated by hydrothermal activity, and how this links to intrusions, volcanism, and plate tectonics.
- Identify the potential environmental impacts of sulfide mining and associated activities.
- Identify stakeholders, and weigh their diverse views in determining if, how, and where to mine.
- Practice geoscientific habits of mind by identifying geologic features and infer spatial distribution patterns on a geologic map for mineral exploration.

Igneous Processes, Hydrothermal Fluids, and Gold! A tale of two deposits

In this activity, you will analyze a geologic map of the Homestake Mine near Yellowstone National Park, and weigh the pros and cons of developing a gold-silver-copper mine at that location. You will also compare the potential environmental impacts of sulfide mining activities near Lake Superior with those near Yellowstone National Park. **Please read the document titled "Student Reading on Yellowstone National Park and Lake Superior" before completing this activity.**

An introduction to the gold-silver-copper deposits near Yellowstone National Park



Map modified from USGS Special paper 1717, Chapter M: "The Life Cycle of Gold Deposits Near the Northeast Corner of Yellowstone National Park—Geology, Mining History, and Fate," by Bradley S. Van Gosen (http://pubs.usgs.gov/pp/1717/downloads/pdf/p1717M.pdf).

The generalized map on the previous page shows the location of the Homestake Mine, Montana, near Yellowstone National Park. The region around the Homestake Mine hosts identified resources of at least 2.3 million ounces of gold, 8.9 million ounces of silver, and 130 million pounds of copper (USGS Special paper, 1717). The mineral deposits were deposited by hydrothermal fluids during volcanic activities in that region about 40–50 million years ago.

Reading and interpreting geologic map

Handout 1 is a geologic map showing different types of bedrock with different types of shading. *Bedrock* is unbroken, solid rock, which may in some places be covered by soil, dirt, and broken rock pieces. The map also shows the locations of metal sulfide (such as copper sulfide) and gold deposits. Answer the following questions using the map:

1. Use the legends at the bottom of the map to find the locations where metallic sulfide and gold deposits have been identified. Which mountain is closest to the deposits?

2. The hydrothermal fluids carrying the metallic minerals came from igneous rocks, but did they deposit those minerals within igneous rocks? From the map, identify the rock type (igneous or sedimentary) where most of the ore minerals are deposited. Why do you think the ore deposits formed within that rock type?

3. Now look at the high-angle faults shown in the map. Faults often provide pathways for fluids bearing metallic minerals. Do you think those faults played any role in the way the metallic minerals were deposited? Explain your answer.

4. Based on this geologic map and your answer to the question above, would you recommend that a mining company should explore the area around Scotch Bonnet Mountain for potential gold, silver, and copper reserves? Why or why not?

   Base your answer on whether the rocks that might house those deposits and/or faults that might carry the mineral-bearing fluids are present near Scotch Bonnet Mountain. Also see where the known deposits are located with respect to Scotch Bonnet Mountain, and whether it makes sense to look for more such deposits near Scotch Bonnet.

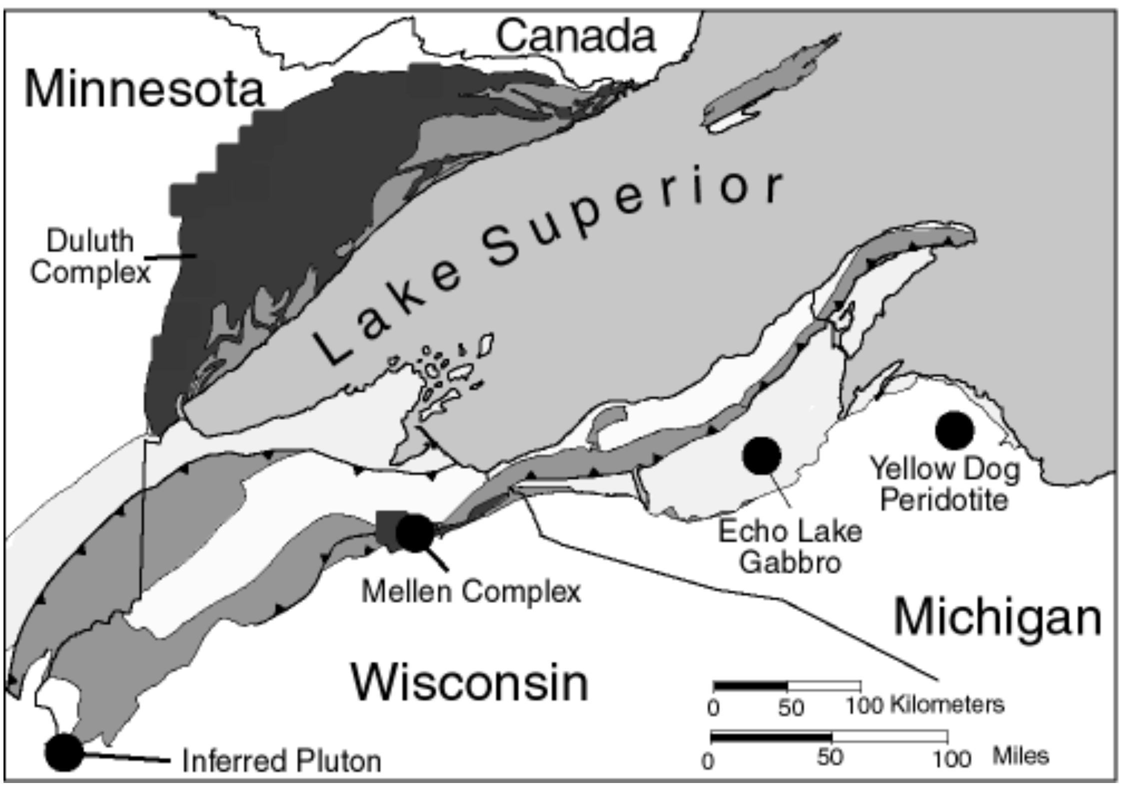
5. The area around Homestake Mine, Montana, is currently under a "no-mining" rule until 2017. After that, there is a high probability that this region will see active mining.

   There is a high likelihood of earthquakes in this region due to the igneous activity under Yellowstone National Park, and while most of the earthquakes are small, there have been some large earthquakes (such as a magnitude 7.3 in 1959) in the region. What type(s) of environmental concern(s) arising specifically from earthquake risk should be addressed before a mine is established in this region? Explain your answer.

Comparison with Lake Superior deposits (refer to the background reading for these questions as needed)

6. Some of the world's largest sulfide deposits are around the Lake Superior region, which happens to contain almost 10% of world's entire supply of freshwater. Yellow Dog Peridotite, and Echo Lake Gabbro in Michigan, as well as the Mellen Complex in Wisconsin are potential locations for sulfide mines (see the map below for locations with respect to Lake Superior).

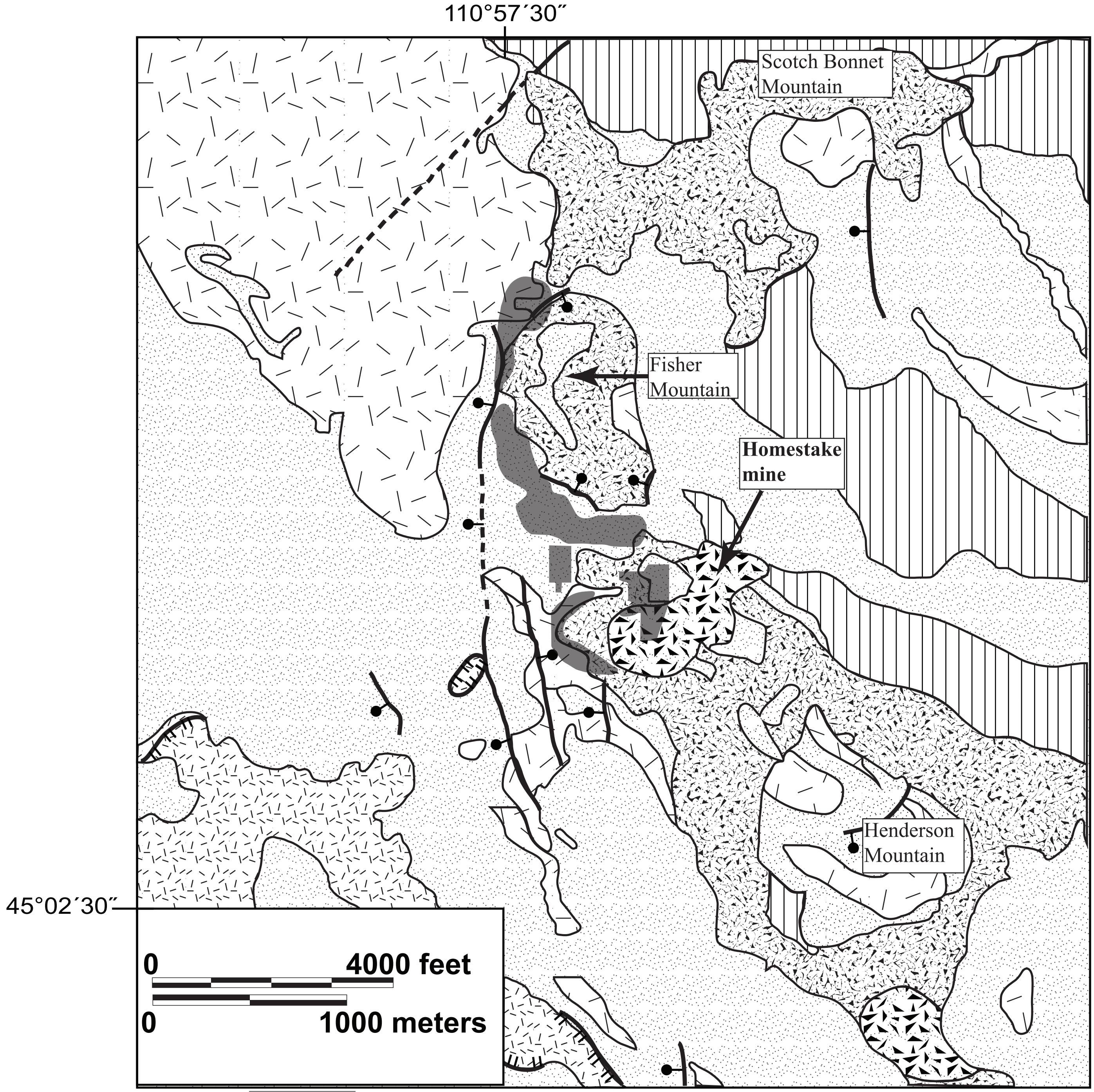
Assume that mining has to happen either near Yellowstone National Park or near Lake Superior. What factors (for example, land disturbance from mining as well as from infrastructure development, potential for pollution, increased job creation/economic development, etc.) would influence whether you decide to mine in Yellowstone or Lake Superior? Or would you prefer *not* to mine any more metallic sulfides in either location, but have an alternate proposal to meet the rising demand for those metals? Discuss the issue in your group, and write a one-minute position paper (Position 1: support mining near Yellowstone; Position 2: support mining near Lake Superior; or, Position 3: a viable alternative to mining for meeting demands) based on your discussion.



Map modified after USGS publication "Potential for New Nickel-Copper Sulfide Deposits in the Lake Superior Region" http://pubs.usgs.gov/info/mwni_cu/.

Handout 1: Generalized Geologic Map of the Area around Homestake Mine

Map modified after Figure 2 of USGS Special Paper 1717, Chapter M: Van Gosen, Bradley S. "The Life Cycle of Gold Deposits Near the Northeast Corner of Yellowstone National Park—Geology, Mining History, and Fate." (2007). (http://pubs.usgs.gov/pp/1717/downloads/pdf/p1717M.pdf)



High-angle faults*

Detachment faults*

Contacts

*Faults=a break in rock layers. Fluids bearing minerals often travel along faults

Metalic sulfide and gold deposits

50-40 Million Year old extrusive rocks and lava flows

50-40 Million Year old intrusive rock formations

50-40 Million Year old volcanic rock formations

50-40 Million Year old volcanic pipes shattered during eruption

Sedimentary rocks and unconsolidated surface deposits

>2,500 million years old igneous and metamorphic rocks

Activity Option 6.1 –

Phosphorus Mining and Impacts

Joy Branlund (Southwestern Illinois College)
Author Profile
This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

Mined phosphorus is considered essential for agriculture, especially with the need to feed the ever growing population. However, there are consequences of phosphate mining and use, including pollution at mine sites and fertilizer processing plants, heavy metal accumulation in soil where fertilizers are used, national security issues intertwined with Morocco's dominance of the world supply, and eutrophication that comes with alteration of the phosphorus cycle. Students will consider these issues, their own roles in the problem, and possible solutions in this jigsaw activity.

Learning Goals

- Describe how different stages of phosphate extraction and use (mining, beneficiation, production, consumption, and/or disposal) affect land use, pollute land, air, and/or water, and create wastes, and discuss how waste products are/can be managed.
- Describe the phosphate cycle and how the use of chemical phosphate fertilizer alters this cycle.
- Identify stakeholders, explain their viewpoints, and weigh their diverse views in determining if, how, and where to mine and use phosphate resources.
- Make informed predictions of future supply, demand, and impacts of phosphate, based on (a) population change, (b) technology change, and (c) people's choices, specifically addressing how personal choices impact resource sustainability.

Who Cares about Phosphate? Final group activity

Instructions – Step 1 (15 minutes)

As a group, list all of the stakeholders involved in extraction and use of phosphorus (mainly as phosphorus fertilizer). These are the stakeholders that you listed with your first group. For example, even though they are not human, the *organisms in Tampa Bay* are a stakeholder.

Pick five of these stakeholders that you would like to explore in more detail. Write these in the first column of the attached worksheet. All other stakeholders can be listed at the end of the worksheet.

Next, if you assume that phosphorus fertilizer is applied liberally on all farm fields and lawns in the United States, how does the extraction and use of phosphate fertilizer affect the five individual stakeholders you listed? Some stakeholders will benefit, some may be harmed, and some may experience both benefit and harm. Write your answers in the second column on the worksheet.

Your answers should be specific and use the information from the activity you did in your first groups. A specific answer will include the following: *What happens that is harmful or beneficial? Why does this happen? Under what conditions does this happen? In what part of the fertilizer lifecycle does this happen?*

Instructions - Step 2 (15 minutes)

As a group, suggest an alternative: What could be done to reduce phosphate fertilizer use or otherwise minimize harm (and maximize benefit) to the stakeholders? You can pick from the list below or write your own. Write a paragraph describing your plan and a brief explanation of why you picked it.

Pick one (or a combination of two) alternative(s) from this list:

- Stop mining/processing phosphorus in the United States and import fertilizer instead.
- Use manure and composted plant material as fertilizer instead of using chemical fertilizer.
- Capture phosphorus from (human) wastewater and use this as a fertilizer.
- Require (or strongly recommend) that fertilizer users test the phosphorus levels in the soil and only apply the amount of fertilizer (if any) needed.
- Change farming so that a variety of crops are grown and animals are raised in the same area.
- Change farming to use no-till agriculture, where fields are not plowed; instead, seeds are grown amid the previous years' dead plants.
- Other. Suggest your own.

Instructions - Step 3 (10 minutes)

Finally, fill out the third column of the table on the worksheet to summarize how the stakeholders will benefit or be harmed by the adoption of the alternative solution your group proposed in Step 2.

Group Worksheet: Who Cares about Phosphate?

Stakeholder – STEP 1	Explain the benefits or harm to this stakeholder based on current phosphorus extraction and use (see instructions) – STEP 1	Explain how and why adopting your alternative plan might change how phosphate extraction and use impacts each stakeholder – STEP 3

Stakeholder – STEP 1	Explain the benefits or harm to this stakeholder based on current phosphorus extraction and use (see instructions) – STEP 1	Explain how and why adopting your alternative plan might change how phosphate extraction and use impacts each stakeholder – STEP 3
List all other stakeholders here. (You only need to give specifics for five of the stakeholders.)		

Unit 1 Hazards at Transform Plate Boundaries

Laurel Goodell (Princeton University)
Peter Selkin (University of Washington, Tacoma)
Rachel Teasdale (California State University, Chico)
Author Profiles

This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

This unit uses scientific data to quantify the geologic hazard that earthquakes represent along transform plate boundaries. Students will document the characteristics of the Pacific/North American plate boundary in California, analyze information about historic earthquakes, calculate probabilities for earthquakes in the Los Angeles and San Francisco areas, and assess the regional earthquake probability map.

Learning Goals

This unit addresses several overarching goals of the InTeGrate program including analyzing geoscience-related grand challenges facing society (impact of natural hazards), developing students' ability to address interdisciplinary problems and use authentic geoscience data, and improving students' geoscientific thinking skills (interpretation of multiple data sets).

Unit 1 Learning Objectives

1. Students will be able to describe characteristics of transform boundaries.
2. historic earthquakes along the North American/Pacific transform plate boundary in California and the risks of those earthquakes to population centers.
3. Students will be able to use data to determine the conditional probabilities of earthquakes of various magnitudes in the San Francisco and Los Angeles areas over the next year, and over the next 30 years.
4. Students will compare their results to the regional earthquake probability map for California and assess the regional earthquake hazard along this plate boundary.

Name ______________________________

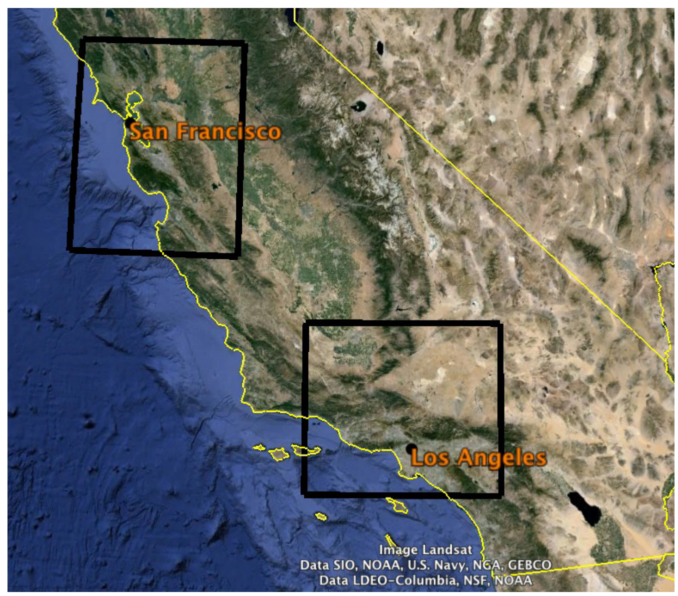
Determining Earthquake Probabilities

A magnitude 7.0 or greater earthquake has not occurred in either the San Francisco or the Los Angeles area for over 100 years. But we know they do occur (e.g. 1906). Are such events worth worrying about? How do scientists determine the probability of such events occurring in the next year? In the next 30 years?

Learning objectives for this activity:

- *To use data to determine the probabilities of earthquakes of various magnitudes in the San Francisco area and the Los Angeles area (optional).*
- *To compare your results to the regional earthquake probability map for California and assess the regional earthquake hazard along this plate boundary.*

You will use the history of earthquakes in the San Francisco (and Los Angeles) areas[1] to determine the probability of occurrence of earthquakes of various magnitudes over various time periods. The areas are delineated in the black boxes at right.



The data come from two searchable databases. For each search, the investigator enters the area, the time period, the magnitude range, and the depth-to-hypocenter range to be searched. The parameters used here are listed below:

	San Francisco area	**Los Angeles area**
Latitude range	36.25 - 38.75°N	33.5-35.5°N
Longitude range	120.75 - 123.25°W	116.75-119.75°W
Date range	01/01/1983 – 12/31/2012	01/01/1983 – 12/31/2012
Magnitude ranges	2.0-2.9, 3.0-3.9, up to 9.0-9.9	1.0-1.9, 3.0-3.9, up to 9.0-9.9
Depth range	All	All
Data source	United States Geologic Survey	Southern California Earthquake Center
Searchable database	http://neic.usgs.gov/neis/epic/epic_rect.html	http://www.data.scec.org/eq-catalogs/date_mag_loc.php

On the spreadsheet for the San Francisco area (which you will complete with the class), the number of earthquakes in each magnitude range (**Column A**) has been entered in **Column B**.

[1] Google Earth Imagery with data from SIO, NOAA, U.S. Navy, NGA, GEBCO, LDEO-

In **Column C**, calculate the average number of earthquakes per year that occurred in each magnitude range. Some rows have been completed for you.

In **Column D**, calculate the mean recurrence interval (MRI) for each magnitude range for up through magnitude 6.0-6.9. The MRI is defined as the average time between earthquakes, and it is calculated by taking the reciprocal of the average number of earthquakes per year:

$$\text{MRI} = \frac{1}{\text{average number of earthquakes}}$$

> Example: The database records an average of 57.2 earthquakes of magnitude 2.0-2.9 each year in the San Francisco area. The MRI (1/57.2) is 0.017 years, which is equivalent to an average of one earthquake every 6 days.
>
> Your turn: What is the approximate MRI in days for earthquakes in the San Francisco area with magnitudes of 4.0-4.9?
> a) Less than 1 day b) 68 days c) 113 days d) 256 days e) 340 days

But what about MRIs for earthquakes of magnitudes 7.0 and greater? Earthquakes of this size have not occurred over the 30-year study period, and thus we do not have enough data to determine the MRI by taking the reciprocal of the average number of earthquakes. However, it is possible to extrapolate MRIs for these large earthquakes by using data for the lower-magnitude earthquakes as follows:

- On the graph, plot the MRI (**Column D**) for each magnitude range for which you have data. Note that the vertical scale is logarithmic, and the MRI increases by about a factor of 10 for each increase in magnitude size. Some have been plotted for you.
- Sketch in a best-fit line to the data and extend it to cover the magnitude ranges for which you do not have data.
- Read off extrapolated MRIs for those magnitude ranges and enter them to complete Column D. One has been entered for you.

In **Column E**, determine the probability of earthquakes of each magnitude range occurring in one year. Probability can be expressed as either a fractional probability between 0 and 1.0, or as a percentage from 0 - 100% (by multiplying the fractional probability by 100). In the worksheet you will record both.

- For earthquakes with MRIs of one year or less: The probability of these earthquakes occurring in any one year is 1/1 = 1.0 or 100%. Record these values for the appropriate magnitude ranges in Column E. The first row has been done for you.
- For earthquakes with MRIs greater than one year: Fractional probability = 1/ MRI and then multiply by 100 to get % probability. *Note that this is equal to the average # of earthquakes per year. But using the 1/ MRI method allows calculation of probabilities for earthquakes that have not occurred over the study period because we have extrapolated MRIs.*

Use the 1/MRI method to complete Column E.

We have just calculated *annual* probabilities of earthquakes.

But what about longer time periods?

The probability of an earthquake occurring over any time period is 1 (or 100%) minus the probability of the earthquake not occurring over that time period (either it happens or it does not).

So consider a two-year time period. For an earthquake to not occur over two years, two conditions must be met:

1) The earthquake must not occur in the 1^{st} year, *and*
2) The earthquake must not occur in the 2^{nd} year.

To get the combined probability, we multiply the individual probabilities of the two events.

Thus we need to determine the probability of an earthquake not occurring in one year.

In **Column F,** determine the probability of each earthquake magnitude *not* occurring in a year. This is simply 1.0 (or 100%) minus the probability of that event occurring in a year (Column E). That is, either it occurs or it does not! Some have been completed for you.

Now we have the information we need in order to determine earthquake probabilities for any time period. For example:

What is the probability of a 6.0-6.9 earthquake occurring in the San Francisco area in the next **thirty** years? To determine this:

- Determine the annual probability of such an earthquake not occurring (0.90 from Column F). Then,

- The probability of it not occurring in **two** years is
  $0.90 \times 0.90 = 0.90^2 = 0.81$ or 81%, and

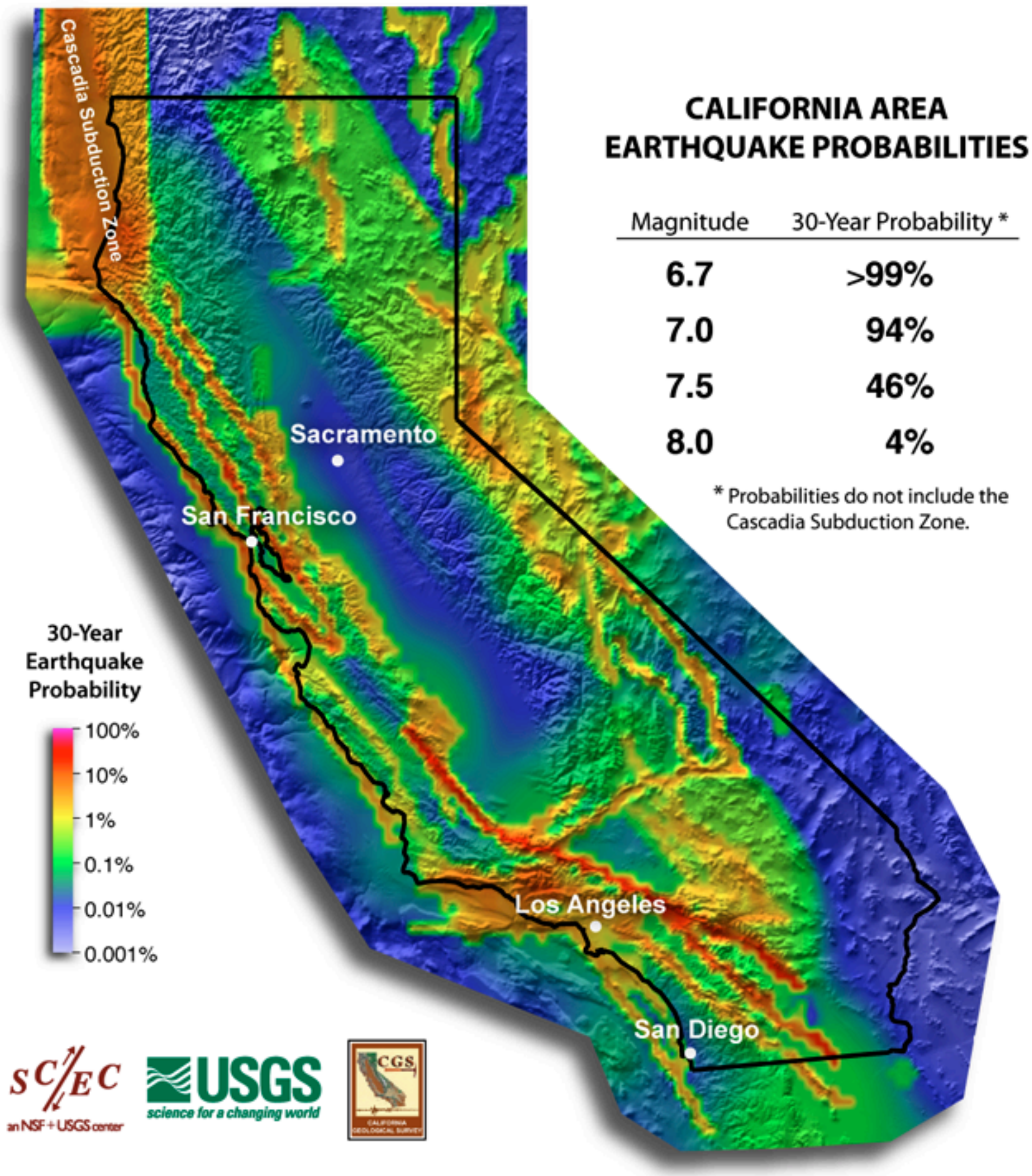
- The probability of it not occurring in **three** years is
  $0.90 \times 0.90 \times 0.90 = 0.90^3 = 0.729$ or ~73%, and

- The probability of it not occurring in **thirty** years is
  $0.90^{30} = 0.042$ or ~4%, and

- The probability of a 6.0-6.9 earthquake occurring in the San Francisco area in **thirty** years is

  1 – 0.042 = 0.958 or ~ 96%

This is how scientists calculate earthquake probabilities (see figure below[2]) – and thus quantify the hazard.



QUESTIONS

[2] CA Earthquake Probability Map
Credit: USGS, California Geological Survey, Southern California Earthquake Center
Source: http://www.scec.org/core/public/sceccontext.php/3935/13661/
Accessed December 2013

1. No earthquake with magnitude 7.0-7.9 has occurred in the San Francisco area over the 30-year study period.

a. What is the probability of an earthquake of magnitude 7.0-7.9 occurring in the San Francisco in the next 30 years? Show your work.

b. Do you think this probability is high enough to warrant concern? Why or why not?

2. Suppose that a particular area has a MRI of 30 years for earthquakes of M = 6.0-6.9. Suppose a M=6.7 earthquake occurs in that area this year. How does this affect the probability of such an earthquake occurring next year?

3. The statewide probability map suggests that overall, there is a 99% chance of a damaging M=(6.7 or greater) earthquake occurring somewhere in the state in the next 30 years. Should resources for earthquake preparedness be spread evenly across the state? Support your position with information from this unit.

Further applications (optional)

4. Use the provided spreadsheet and graph to repeat the analysis for the Los Angeles area (33.5-35.5°N / 116.75-119.75°W). Again, numbers of earthquakes for each magnitude range are filled in for you.

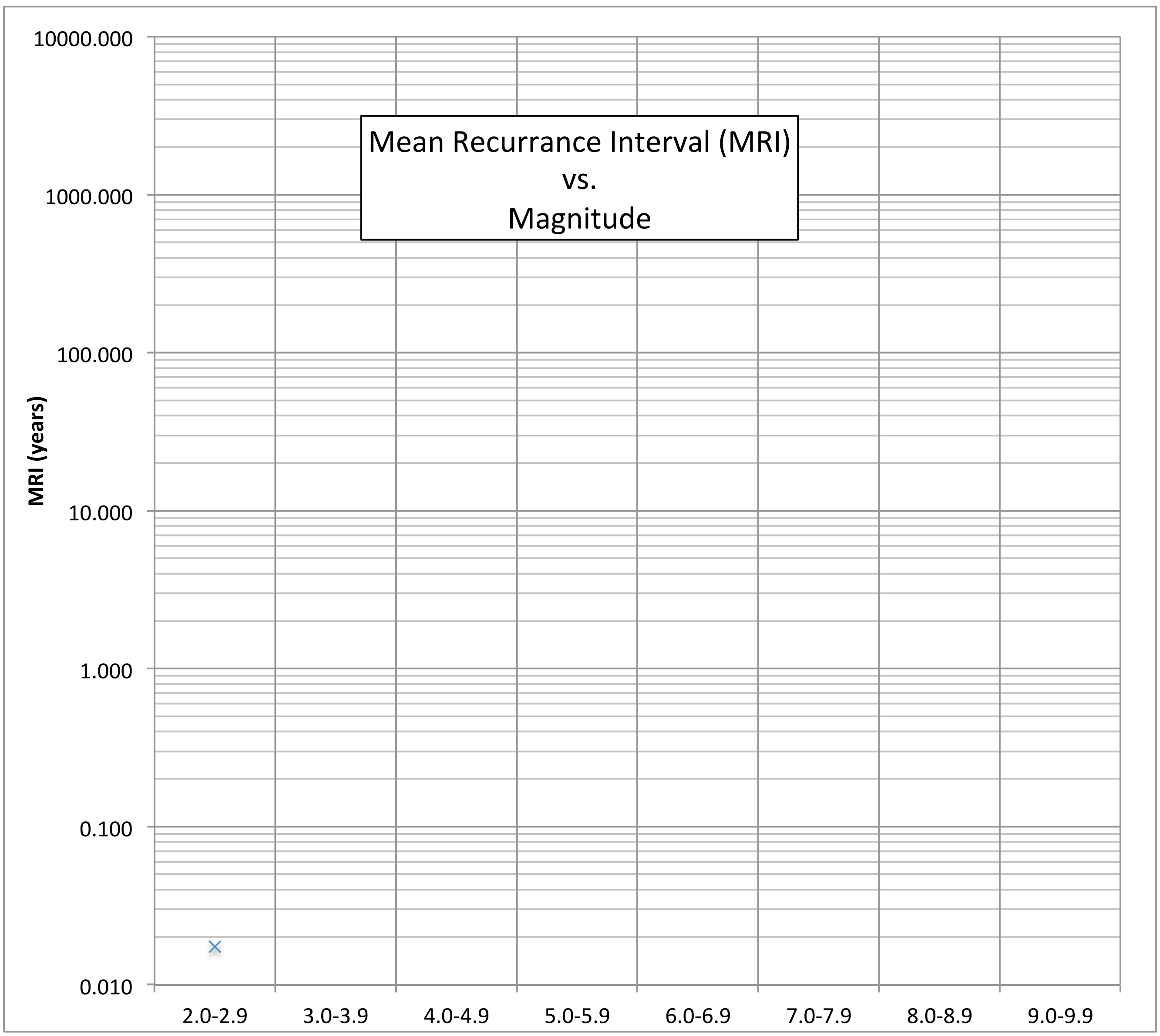
5. What is the probability of a magnitude 7.0-7.9 earthquake in the Los Angeles area in the next 30 years? How does this compare to what you calculated for a magnitude 7.0-7.9 earthquake in the San Francisco area?

San Francisco area probabilities

36.25 - 38.75 N latitude/120.75 - 123.25 W longitude

data from http://earthquake.usgs.gov/earthquakes/search/

A	B	C	D	E		F	
magnitude range	# of earthquakes 1983-2012 (30 years; from data base)	average # of earthquakes per year	MRI (mean recurrance interval) in years	one year probability			
				of earthquake occurring		of earthquake not occuring	
				fractional	*%*	*fractional*	*%*
2.0-2.9	1716	57.20	0.017	1.000	100%	0	0%
3.0-3.9	1326						
4.0-4.9	161						
5.0-5.9	13						
6.0-6.9	3	0.10	10.000	0.100	10%	0.900	90%
7.0-7.9	0	0.00	50.000				
8.0-8.9	0						
9.0-9.9	0						



Name ________________

How often do earthquakes happen?

The graph on the next page shows the frequency of earthquakes between 1974 and 1998 in the New Madrid Seismic Zone. Note that the vertical axis is logarithmic and also note that there are two vertical axes (one indicating earthquakes/year and the other indicating years between earthquakes).

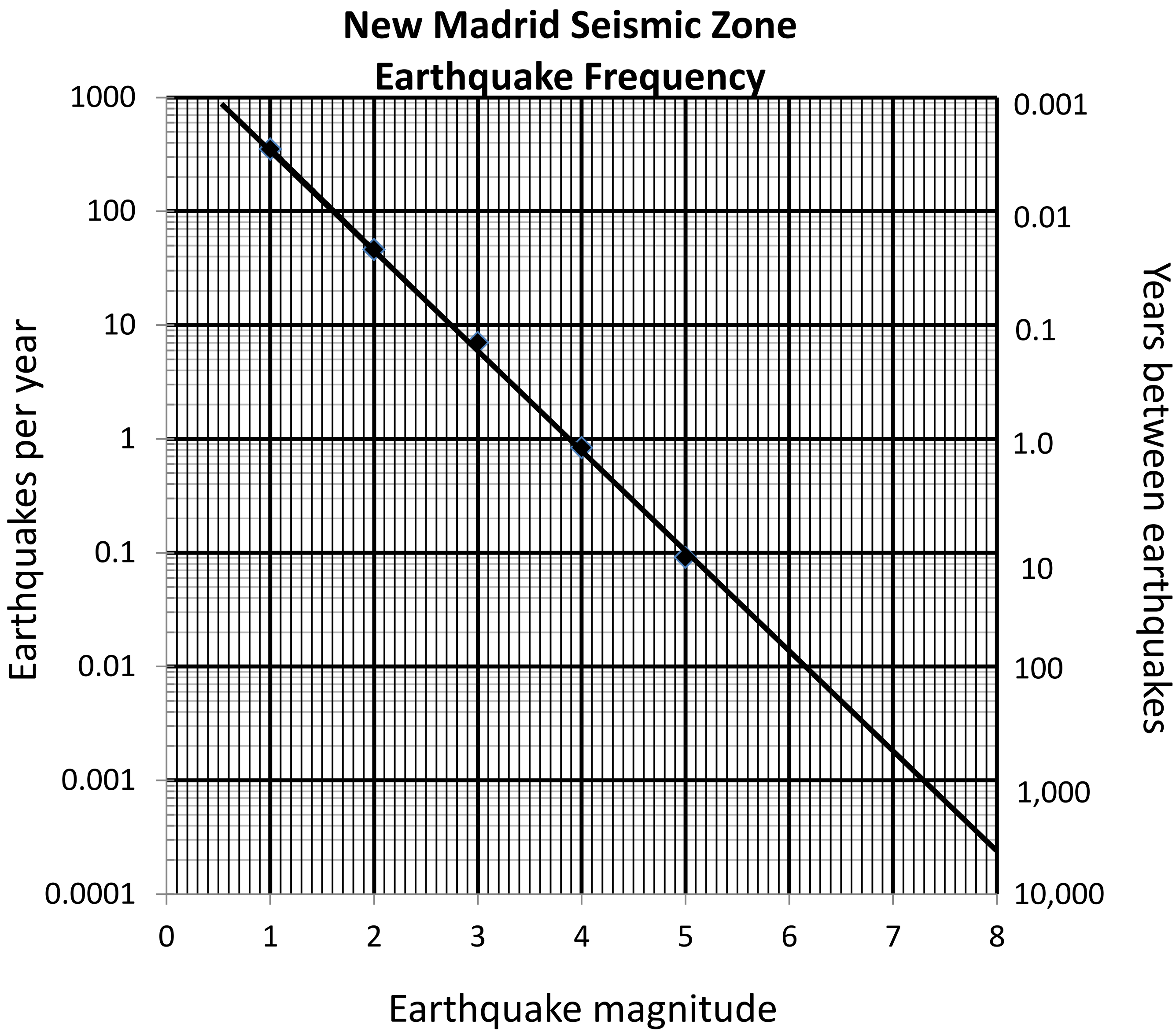
1. Approximately how many M2 or greater earthquakes happened each year in the New Madrid Seismic Zone?

2. On average, about how many years pass between M5 or greater earthquakes?

3. No earthquakes of M6 or greater happened in the New Madrid Seismic Zone during this time interval. Nonetheless, scientists can use the graph to form a hypothesis about the frequency of M7 or greater earthquakes. Based on the graph, approximately how often would you expect M7 or greater earthquakes to happen?

4. Geologists have investigated and dated geologic features formed during M7 or greater earthquakes in the New Madrid Seismic Zone. Based on the dating of these features, many geologists think M7 or greater earthquakes happen approximately once every 500 years on average in the New Madrid Seismic Zone. Does this number (500 years) agree with your answer to question #3?

5. Briefly discuss the similarity or dissimilarity of your answers to #3 and #4. Feel free to speculate. Write complete sentences on the back of this sheet. Limit your answer to one paragraph or less.



New Madrid Seismic Zone
Earthquake Frequency
Earthquakes per year
1000
100
10
1
0.1
0.01
0.001
0.0001
Years between earthquakes
0.001
0.01
0.1
1.0
10
100
1,000
10,000
0
1
2
3
4
5
6
7
8
Earthquake magnitude

2.

School	Grades	Enrollment	Staff	Percent Attendance	Data Source / Additional Information
Francisco Middle School	6-8	699	39	95.90%	www.sfusd.edu/assets/sfusd-staff/rpa/profile/prfl-546.htm
Garfield Elementary School	K-5	224	15	97.10%	www.sfusd.edu/assets/sfusd-staff/rpa/profile/prfl-562.htm
Guadalupe Elementary School	K-5	434	24	94.40%	www.sfusd.edu/assets/sfusd-staff/rpa/profile/prfl-593.htm
Herbert Hoover Middle School	6-8	1206	65	97.50%	www.sfusd.edu/assets/sfusd-staff/rpa/profile/prfl-607.htm
Marina Middle School	6-8	942	54	96.90%	http://www.sfusd.edu/assets/sfusd-staff/rpa/profile/prfl-708.htm
El Camino High School	9-12	1486	91		http://www.ed-data.k12.ca.us/App_Resx/EdDataClassic/fsTwoPanel.aspx?#!bottom=/_layouts/EdDataClassic/profile.asp?Tab=0&level=07&reportnumber=16&county=41&district=69070&school=4132551
Sunset Ridge Elementary	K-5	588	45		http://www.ed-data.k12.ca.us/App_Resx/EdDataClassic/fsTwoPanel.aspx?#!bottom=/_layouts/EdDataClassic/profile.asp?Tab=0&level=07&reportnumber=16&county=41&district=68932&school=6044069

Risk Factors Worksheet

Paper Map Version

This activity addresses the following learning objective:

3. *Students will evaluate information about seismic hazard, building construction, and population to quantify risk on the Pacific/North America plate boundary near San Francisco.*

Although the 1906 San Francisco Earthquake devastated both life and property in the San Francisco Bay area, it also taught geologists and engineers a great deal about what makes for earthquake-safe buildings. In the prework, you saw some examples of buildings that failed in the 1906 earthquake. In this activity, you will collect information about several schools to assess their likelihood of failure. Most school buildings are built to fairly high standards. However, no building is perfect, and some schools in earthquake-prone California have a higher seismic *risk* than others. Risk here refers to the potential for loss, either of property or of life. Here we assess risk as the potential for loss of life. Factors that affect seismic risk include:

- *Hazard*: The chance that the building will experience strong shaking (see Unit 1a), soil liquefaction, or a landslide.
- *Vulnerability*: The likelihood that the building will collapse due to those geological hazards.
- *Value*: The number of lives potentially affected (number of students).

Scenario

The city of San Francisco has passed a bond measure that will give $10 million each to retrofit two schools out of a set of five that have the highest seismic risk. Your job is to identify which of the schools has the highest risk, and to give the city and the school board advice on where to use the $20 million.

Procedure

Examine the overview maps of the San Francisco area schools that the class will be using in this activity. Find each of the labeled schools on the San Francisco and San Francisco Marina District maps. Your group will be assigned to examine *one* of the schools.

> While some of the steps in this risk analysis sound straightforward, others are somewhat subjective. To make sure that your reasoning is in line with that of your teammates, use the "think out loud" protocol: as you are discussing your group's assessment of risk at your assigned site, **describe out loud the information you are using to come to a conclusion, and the reasoning you are using to come to your conclusion**.

1. Use the San Francisco and San Francisco Marina District maps to determine the seismic hazard potential at the school site that you have been assigned.
   a. Put the school's name in a new row of the seismic risk analysis spreadsheet.
   b. Examine the Strong Shaking Potential map. This is a map of the peak ground acceleration that is 98% likely to occur in 50 years. Basically, the value of peak ground acceleration is a measure of the most violent shaking expected in a likely earthquake. The higher the acceleration, the stronger the shaking. Colors on the map correspond to peak ground acceleration in terms of the fraction of free-fall acceleration ("%g"). Values of %g associated with each color are listed on the legend. Use the following categories to score the seismic hazard due to strong shaking. Score each school's location using the numbers in parentheses, based on the ground acceleration. Put the score in the column labeled A on the seismic risk spreadsheet.
      i. <30% g: Low hazard (1)
      ii. 30-60% g: Moderate hazard (2)

        iii. >60% g: Significant hazard (3)

    c. Examine the Liquefaction Susceptibility map. This is a map of the likelihood of liquefaction due to earthquake shaking. Colors on the map correspond to different categories of liquefaction susceptibility (indicated in the legend). Score each school's location using the numbers in parentheses, based on the liquefaction hazard. Put the score in the column labeled B on the seismic risk spreadsheet.
        i. Low / Very Low hazard (1)
        ii. Moderate hazard (2)
        iii. High / Very High hazard (3)
    d. Examine the LIDAR Hillshade map if available for your school. This is a detailed map of topography (elevation) made using Light Distance and Ranging. If topographic data is not available for your school, examine the photographs of your school's location to gauge the slope at your school's site. Estimate the landslide hazard using the categories below. Score each school's location using the numbers in parentheses, based on the landslide hazard. Put the score in the column labeled C on the seismic risk spreadsheet.
        i. Low hazard: on flat land (1)
        ii. Moderate hazard: at foot of slope or on gradual slope (2)
        iii. High hazard: Building is on a steep slope (3)

2. Building construction plays a large role in determining risk, as you've seen when looking at the destruction from the 1906 earthquake. You can assess some major construction issues using the photos provided of the school buildings. Note that most schools have multiple buildings. Do your best to search all of the buildings and give the maximum score for each category ($10 million is more or less enough to retrofit one school building).
    a. Examine the building the see if there are any "soft stories," floors of the building with few supporting walls, such as parking garages or large auditoriums, that are underneath other floors of the building.
    b. Buildings made of unreinforced masonry (brick or concrete without reinforcement) are particularly susceptible to earthquake damage. Unfortunately, you have little information besides the photos to go on. If there is clear evidence that a building is made of unreinforced masonry, that building gets a 2 in column C. If the building is made of masonry and it was built before 1970, give it a score of 1.5.
    c. Buildings with a vertical irregularity (different parts at different heights) or plan irregularity (deviations from a box-shape) tend to fare poorly in earthquakes. Give each building with either type of irregularity a score of 0.5.
3. The "value" we are using when calculating risk in this exercise is the number of lives at risk. Information about the number of students, faculty, and staff is provided in the packet of information about your school.
4. Calculate risk using the following:

$$Risk = \frac{(A + B + C)}{9} \times \frac{(D + E + F)}{3.5} \times population$$

Once your group has determined a risk for your school, share your information with the class in the report-out session. Also be ready to discuss which factors, aside from population, had the most influence on the risk that you calculated. The risk that you and your classmates calculate will allow you to compare schools in terms of the number of students protected by an earthquake retrofit.

	Hazard			Vulnerability			Value	Analysis	
School	A: Peak Ground Acceleration (1: less than 0.3g, 2: 0.3-0.6g, 3: >0.6g)	B: Liquefaction Potential (1: low / very low; 2: medium; 3: high / very high)	C: Landslide Potential (1: low; 2: medium; 3: high)	D: Soft Stories? (0=N/1=Y)	E: Unreinforced Masonry (1=N/1.5=maybe/2=Y)	F: Vertical or Plan Irregularity (0-=N/0.5=Y)	G: Number of Students	**Risk Factor R = (A+B+C)/9 x (D+E+F)/3.5 x G**	**Recommendation**

禪
zenstoves.net
96×96 dots/inch

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96×96 dots/inch

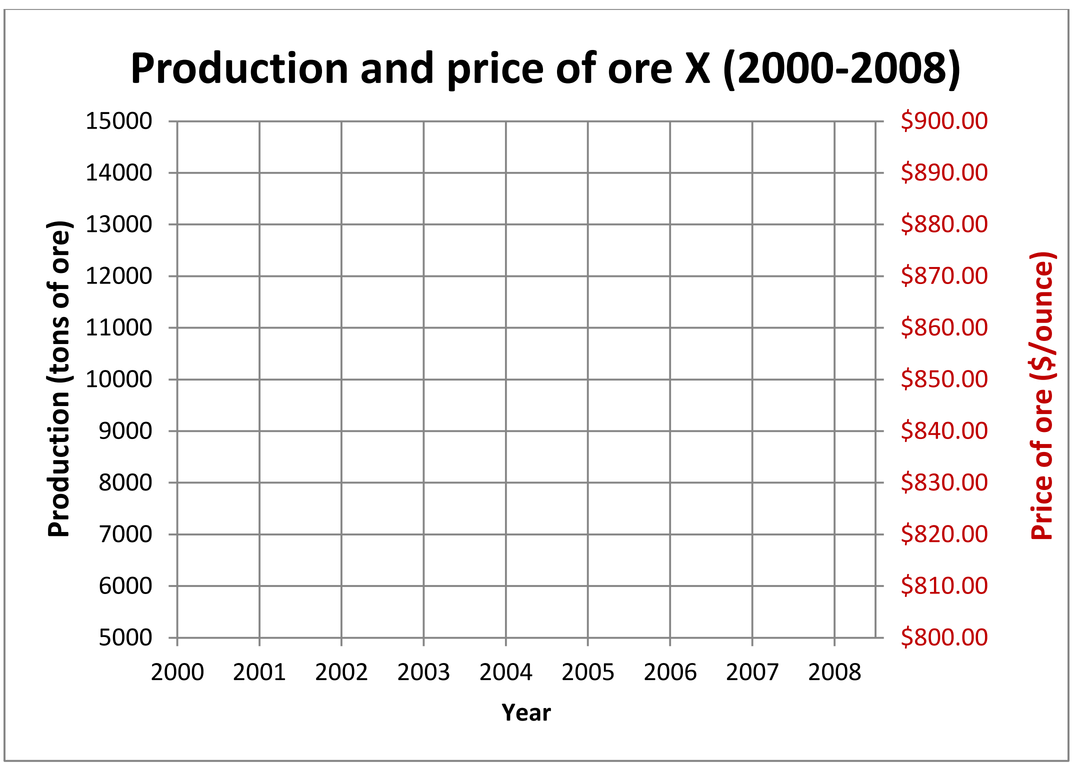
Production and price of ore X between 2000 and 2008

A. Plot the data on the graph. Note that the graph has two axes. Use squares for ore price and use triangles for ore production. Connect ore prices with a line and connect ore production values with another line.

1. Based on the information in the table, does there appear to be a relationship between ore production and ore price?
a. yes
b. no

2. As ore production increased, ore price ______________.
a. stayed the same
b. increased
c. decreased
d. fluctuated in a random way

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Price of ore ($/ounce)	$889.90	$890.11	$883.24	$884.23	$853.90	$816.01	$829.53	$839.03	$834.21
Production (thousands of tons)	8008	7991	8541	8462	10888	13919	12838	12078	12463



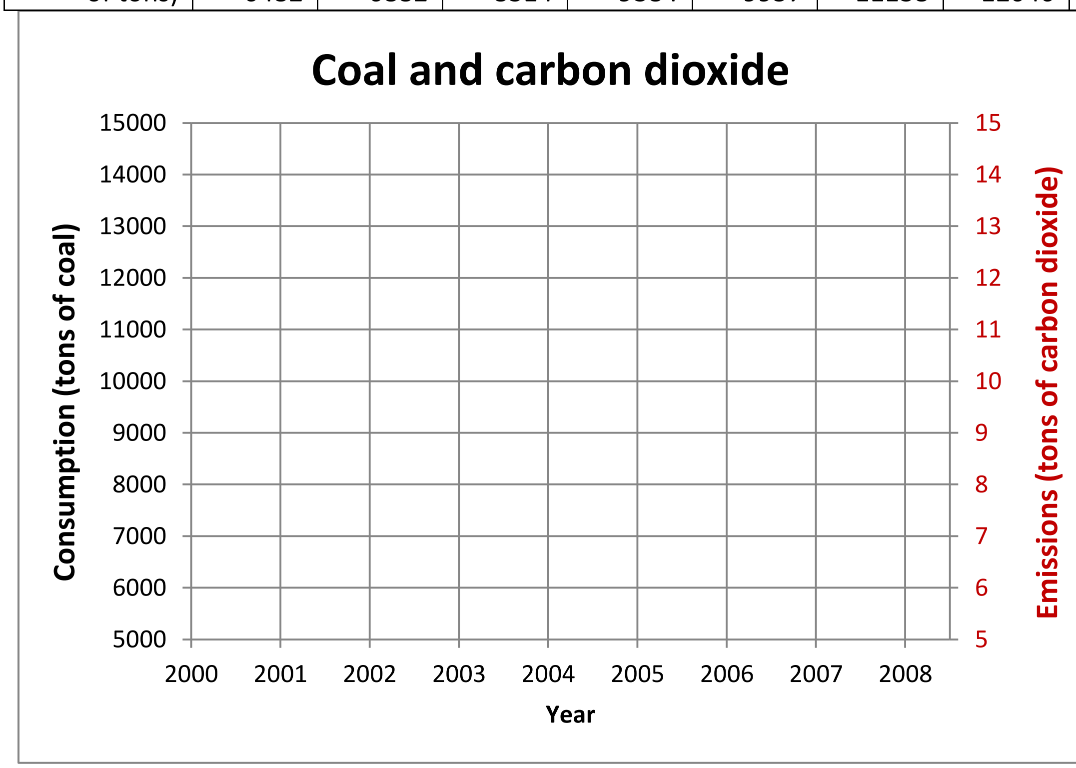
Coal consumption and carbon dioxide emissions between 2000 and 2008

B. Plot the data on the graph. Note that the graph has two axes. Use squares for coal consumption and use triangles for carbon dioxide emissions. Connect coal consumption values with a line and connect carbon dioxide emission values with another line.

1. Based on the information in the table, does there appear to be a relationship between coal consumption and carbon dioxide emissions?
a. yes
b. no

2. As coal consumption increased, carbon dioxide emissions _______________.
a. stayed the same b. increased
c. decreased d. fluctuated in a random way

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Emission of carbon dioxide (tons)	5	6	7	8	8	9	10	11	12
Consumption of coal (thousands of tons)	6482	6882	8314	9384	9957	11138	12046	13181	14129



Earthquake frequency

D. The graph on the next page shows the frequency of earthquakes in the Aidanstown Seismic Zone between 1970 and 2000. Note that the vertical axis is logarithmic.

1. Approximately how many M3 or greater earthquakes happened each year in this seismic zone?

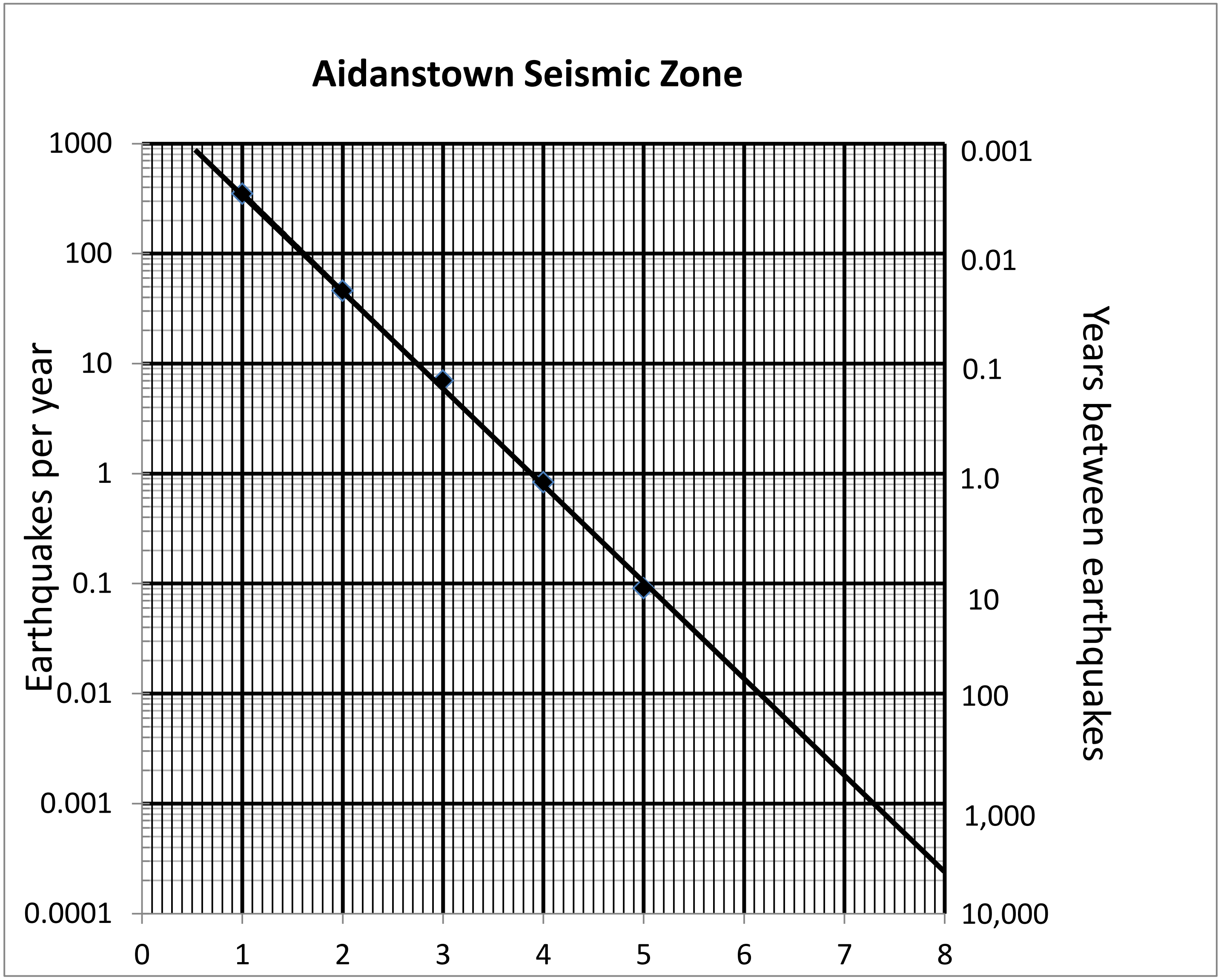
a. 0.7 b. 7 c. 17 d. 117

2. Based on the frequency of small earthquakes, the time between M8 earthquakes might be approximately _________.

a. 80-90 years b. 800-900 years c. 8,000-9,000 years d. 80,000-90,000 years

3. Your answer to #2 is an example of an hypothesis.

a. true b. false



Earthquake magnitude

2.

ANSWERS

A.

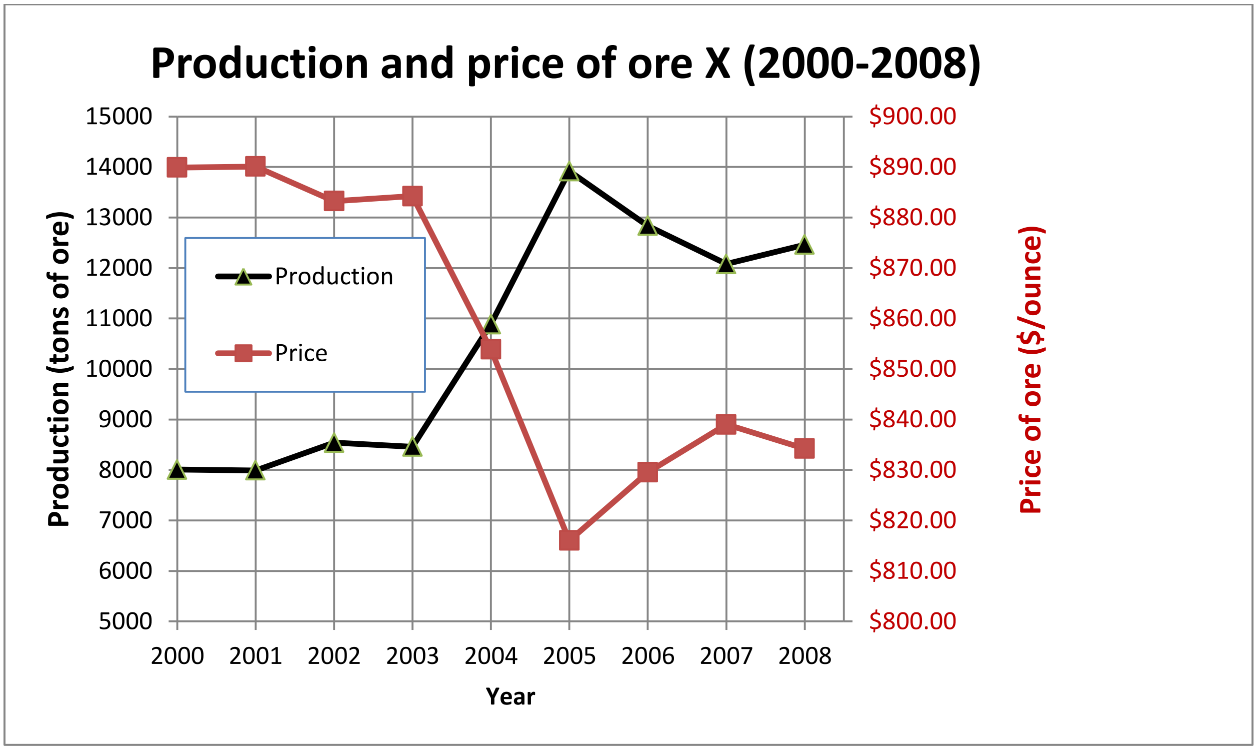
1. Based on the information in the table, does there appear to be a relationship between ore production and ore price?

a. yes

b. no

2. As ore production increased, ore price ______________.

a. stayed the same
b. increased
c. decreased
d. fluctuated in a random way



B.

1. Based on the information in the table, does there appear to be a relationship between coal consumption and carbon dioxide emissions?

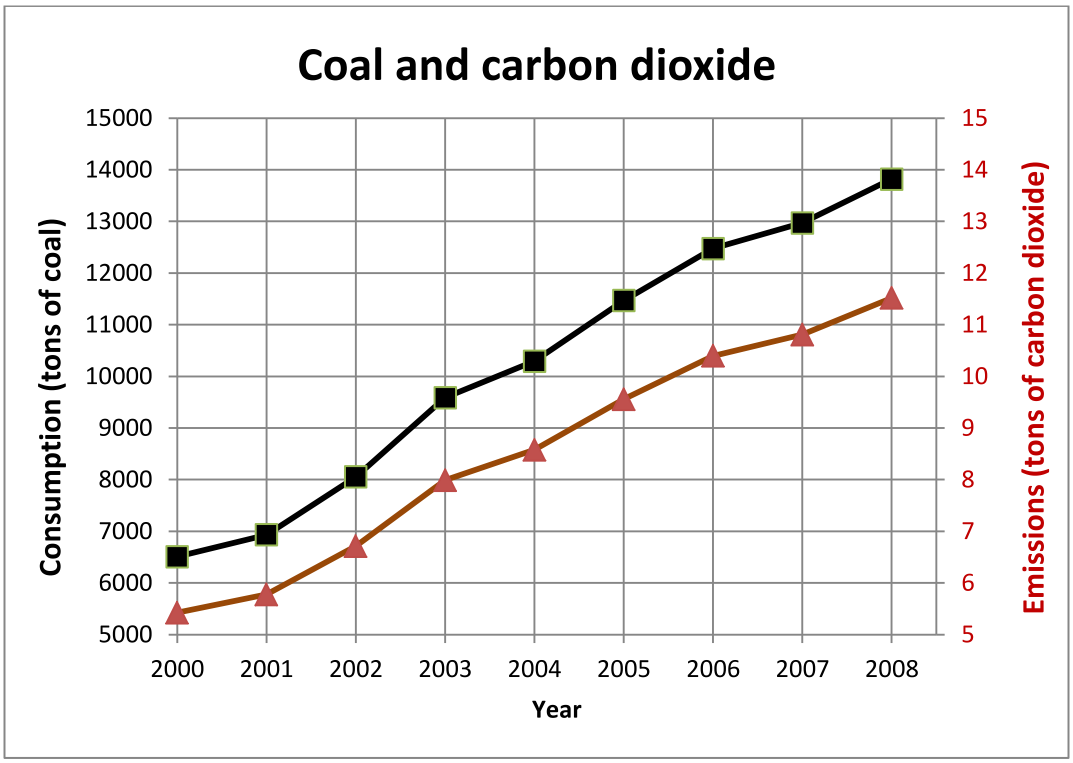
a. yes

b. no

2. As coal consumption increased, carbon dioxide emissions _______________.

a. stayed the same **b. increased**

c. decreased d. fluctuated in a random way



D.

1. Approximately how many M3 or greater earthquakes happened each year in this seismic zone?

a. 0.7 **b. 7** c. 17 d. 117

2. Based on the frequency of small earthquakes, the time between M8 earthquakes might be approximately _________.

a. 80-90 years b. 800-900 years **c. 8,000-9,000 years** d. 80,000-90,000 years

3. Your answer to #2 is an example of a hypothesis.

a. true b. false