COURSE CHANGE FORM

Signature Routing Log

General Information:

Course Prefix and Number: GLY 150 (chg mtg. pattern, add gen ed)

Proposal Contact Person Name: D. Ravat Phone: 7-4726 (e-mail preferred) Email: dhananjay.ravat@uky.edu

INSTRUCTIONS:

Identify the groups or individuals reviewing the proposal; note the date of approval; offer a contact person for each entry; and obtain signature of person authorized to report approval.

Internal College Approvals and Course Cross-listing Approvals:

Reviewing Group	Date Approved	Contact Person (name/phone/email)	Signature
Earth & Envirn. Sci., DUS	9/3/10	David Moecher / 7-6939 / moker@uky.edu	[signature]
Earth & Envirn. Sci., Chair	9/3/10	D. Ravat / 7-3758 / dhananjay.ravat@uky.edu	D. Ravat dm
		/ /	
A&S Ed. Policy Cmte.	11/2/10	G. Murthy / 7-4729 / ganpathy.murthy@uky.edu	[signature]
A&S Dean's Office	11/2/10	Anna Bosch / 7-6689 / bosch@uky.edu	ARK Bosch

11/5/10 sent to UGC

External-to-College Approvals:

Council	Date Approved	Signature	Approval of Revision[8]
Undergraduate Council	10/11/2011	S.Gill sgill@uky.edu	
Graduate Council			
Health Care Colleges Council			
Senate Council Approval		University Senate Approval	

Comments:

[8] Councils use this space to indicate approval of revisions made subsequent to that council's approval, if deemed necessary by the revising council.

COURSE CHANGE FORM

Complete 1a – 1f & 2a – 2c. Fill out the remainder of the form as applicable for items being changed.

1.	**General Information.**						
a.	Submitted by the College of:	Arts & Sciences		Today's Date:	23 Aug 2010		
b.	Department/Division:	Earth & Environmental Sciences					
c.	Is there a change in "ownership" of the course?			YES ☐		NO ☒	
	If YES, what college/department will offer the course instead?						
d.	What type of change is being proposed?	☒ Major	☐ Minor[1] (place cursor here for minor change[OSC1] definition)				
e.	Contact Person Name:	D. Ravat	Email:	dhananjay.ravat@uky.edu	Phone:	7-4726 (e-mail preferred)	
f.	Requested Effective Date:	☐ Semester Following Approval	OR	☒ Specific Term[2]:	Fall 2011		
2.	**Designation and Description of Proposed Course.**						
a.	**Current Prefix and Number:**	GLY 150	*Proposed Prefix & Number*:	*GLY 150*			
b.	**Full Title:**	Earthquakes and Volcanoes	*Proposed Title*:	*Earthquakes and Volcanoes*			
c.	**Current Transcript Title** (if full title is more than 40 characters):	N/A					
c.	*Proposed Transcript Title (if full title is more than 40 characters)*:	*N/A*					
d.	**Current Cross-listing:**	☒ N/A	OR	Currently[3] Cross-listed with (Prefix & Number):			
	Proposed – ☐ ADD[3] Cross-listing (Prefix & Number):						
	Proposed – ☐ REMOVE[3, 4] Cross-listing (Prefix & Number):						
e.	**Courses must be described by <u>at least one</u> of the meeting patterns below. Include number of actual contact hours[5] for each meeting pattern type.**						

Current:	_____ Lecture	_____ Laboratory[5]	_____ Recitation	_____ Discussion	_____ Indep. Study
	_____ Clinical	_____ Colloquium	_____ Practicum	_____ Research	_____ Residency
	_____ Seminar	_____ Studio	_____ Other – Please explain:		
Proposed:	*2 Lecture*	_____ *Laboratory*	*1 Recitation*	_____ *Discussion*	_____ *Indep. Study*
	_____ *Clinical*	_____ *Colloquium*	_____ *Practicum*	_____ *Research*	_____ *Residency*
	_____ *Seminar*	_____ *Studio*	_____ *Other – Please explain:*		

f.	**Current Grading System:**	☒ Letter (A, B, C, etc.)	☐ Pass/Fail
	Proposed Grading System:	☒ *Letter (A, B, C, etc.)*	☐ *Pass/Fail*
g.	**Current number of credit hours:** 3	*Proposed number of credit hours:*	*3*

---

1 See comment description regarding minor course change. *Minor changes are sent directly from dean's office to Senate Council Chair*. If Chair deems the change as "not minor," the form will be sent to appropriate academic Council for normal processing and contact person is informed.
2 Courses are typically made effective for the semester following approval. No course will be made effective until all approvals are received.
3 Signature of the chair of the cross-listing department is required on the Signature Routing Log.
4 Removing a cross-listing does not drop the other course – it merely unlinks the two courses.
5 Generally, undergrad courses are developed such that one semester hr of credit represents 1 hr of classroom meeting per wk for a semester, exclusive of any lab meeting. Lab meeting generally represents at least two hrs per wk for a semester for 1 credit hour. (See *SR 5.2.1*.)

COURSE CHANGE FORM

h.	**Currently, is this course repeatable for additional credit?**	YES ☐	NO ☒
	Proposed to be repeatable for additional credit?	*YES* ☐	*NO* ☒
	If YES: *Maximum number of credit hours:*		
	If YES: *Will this course allow multiple registrations during the same semester?*	*YES* ☐	*NO* ☐

i.	**Current Course Description for Bulletin:**	An introduction to earthquakes and volcanoes, primarily through case studies. Using the basic principles of plate tectonics, students will learn why, where and how earthquakes and volcanoes occur. The hazards associated with earthquakes and volcanic eruptions will be discussed at length, as well as their societal implications in both the United States and developing world. Earthquake and volcanic hazard mitigation techniques will be addressed. Finally, earthquake hazards in the central United States will be discussed.
	Proposed Course Description for Bulletin:	*An introduction to earthquakes and volcanoes through theory, active learning assignments, and case studies. Using the basic principles of plate tectonics, students will learn why, where and how earthquakes and volcanoes occur. The hazards associated with earthquakes and volcanic eruptions will be discussed, as well as their societal implications in both the United States and the developing world. Earthquake and volcanic hazard mitigation techniques will be addressed. In addition, earthquake hazards in the central United States will be discussed.*
j.	**Current Prerequisites, if any:**	None
	Proposed Prerequisites, if any:	*None*

k.	Current Distance Learning(DL) Status:	☒ N/A	☐ Already approved for DL*	☐ *Please Add*[6]	☐ *Please Drop*

*If already approved for DL, the Distance Learning Form must also be submitted unless the department affirms (by checking this box ☐) that the proposed changes do not affect DL delivery.

l.	**Current Supplementary Teaching Component, if any:**	☐ Community-Based Experience	☐ Service Learning	☐ Both
	Proposed Supplementary Teaching Component:	☐ *Community-Based Experience*	☐ *Service Learning*	☐ *Both*

3.	**Currently, is this course taught off campus?**	YES ☐	NO ☒
	Proposed to be taught off campus?	YES ☐	NO ☒
4.	**Are significant changes in content/teaching objectives of the course being proposed?**	YES ☒	NO ☐
	If YES, explain and offer brief rationale:		
	As part of GenEd intellectual inquiry in natural/physical/mathematical sciences, the 1/3 of the revised course contains active learning assignments either in recitation section and/or in-class		
5.	**Course Relationship to Program(s).**		
a.	**Are there other depts and/or pgms that could be affected by the proposed change?**	YES ☐	NO ☒
	If YES, identify the depts. and/or pgms:		
b.	**Will modifying this course result in a new requirement[7] for ANY program?**	YES ☐	NO ☒
	If YES[7], list the program(s) here:		

[6] You must *also* submit the Distance Learning Form in order for the course to be considered for DL delivery.

6.	**Information to be Placed on Syllabus.**			
a.	☐	Check box if changed to 400G or 500.	If changed to 400G- or 500-level course you must send in a syllabus and *you must include the differentiation* between undergraduate and graduate students by: (i) requiring additional assignments by the graduate students; and/or (ii) establishing different grading criteria in the course for graduate students. (See *SR 3.1.4*.)	

[7] In order to change a program, a program change form must also be submitted.

GLY150: Earthquakes and Volcanoes
Potential recitation or in-class exercises. The instructor will review the material with the TAs in the prior week.
Some assignments are full class period length. For other recitation periods, appropriate lecture materials will be reinforced through inquiry process. When time is available during recitations and lectures, quizzes to prepare students for the exams will be given.

Week 1) The Scientific Method: reinforce classroom discussion of the scientific method. Distinction between the scientific process of discovery and knowledge and the pseudoscience is clarified. Advantages and limitations of the method of multiple working hypotheses is discussed.

- This assignment could be done in a number of different ways.One approach is to ask students to come up with examples of pseudoscience and ask them to give reasons for why it is a pseudoscience and how a scientific process may be able to (or how they would) prove that it is a pseudoscience.

Week 2) Geometry of the Earth, Latitude and Longitude using Google Earth and discussion

Weeks 3 to 7, excluding week 4) Discovering Plate Boundaries exercises (3 recitation or in-class periods + 1 in-class periods for **group presentations**) – see the abstract of an attached paper of this exercise

Week 4) Review for exam #1

Week 8) Faults and Folds using Google Earth and discussion

Week 9) Locating earthquakes from the origin time and three or more earthquake records

Week 10) Figuring out earthquake magnitude from amplitude of earthquake record and the distance to the earthquake (from multiple seismometer stations from the same earthquake) – leading also to thinking about and discussion of errors in data and imperfection of mathematical and physical models connecting data to information

Week 11) Review for exam #2

Week 12) Volcanic landforms using Google Earth and discussion

Weeks 13 – 14) Using data from Hawaii Volcanic Observatory on the web (vepp.wr.usgs.gov – the current access userid/password for this site are: greensand/Mg2SiO4 – don't divulge – the site can be made available to students with prior permission of the site manager): to observe and evaluate real data from the GPS, Tilt-meter, and Seismic instruments to assess the risk of eruption and the likely location of the next eruption. A research paper is required – the paper will include design, data collection, analysis, summary of the results, conclusions, alternative approaches, and future studies.

Week 15) Review for exam #3

Other potential recitation or in-class exercises:

- Minerals and Rocks
- Geologic age
- Figuring out plate speeds from a chain of hotspot islands
- Calculation of frequency, period, and speed of seismic waves

A Data Rich Exercise for Discovering Plate Boundary Processes

Dale S. Sawyer — Department of Earth Science, Rice University, MS-126, P.O. Box 1892, Houston, TX 77001, dale@rice.edu

Alison T. Henning — Department of Earth Science, Rice University, MS-126, P.O. Box 1892, Houston, TX 77001, ahenning@rice.edu

Stephanie Shipp — Department of Earth Science, Rice University, MS-126, P.O. Box 1892, Houston, TX 77001

Robyn W. Dunbar — Stanford University, 110 Sweet Hall, Stanford, CA 94305, robyn.dunbar@stanford.edu

ABSTRACT

"Discovering Plate Boundaries" is a classroom exercise based on four world maps containing earthquake, volcano, topography, and seafloor age data. A novel aspect of the exercise is the "jigsaw" manner in which student groups access the maps and use them to discover, classify, and describe plate boundary types. The exercise takes three 50 minute class periods to complete and involves the students making presentations to one another in small groups and to the whole class. The students are first organized into four groups where they work together to become "specialists" in a particular data type. They are later reorganized into groups containing a specialist in each data type to study the boundaries of a particular tectonic plate. The exercise concludes with student presentations of their group work, followed by a presentation by the teacher and a group discussion.

The exercise is useful at a wide variety of levels because it is based only on observation and description. We have used it successfully with middle school, high school, and college major and non-major Earth science classes, as well as with pre-service and in-service K-12 teachers. The students come away from the exercise with knowledge of the key features of each type of plate boundary and a sense of why each looks the way it does. While the materials to conduct the exercise are available on the Internet (http://terra.rice.edu/plateboundary/), the actual exercise is not based on student access to the Web and does not require sophisticated classroom technology equipment.

INTRODUCTION

The questions addressed in this exercise are "Where are the boundaries between tectonic plates?" "What observations are useful for characterizing plate boundaries?," and "What physical processes occur at plate boundaries?" Answering these questions forms the foundation of Earth science understanding. These topics are included in the National Science Education Standards and many state science standards for K-12 education. The Discovering Plate Boundaries activity allows students to build accurate content knowledge through their own observations, classifications, and descriptions, and it also promotes group collaboration, written and oral communications skills.

We have used Discovering Plate Boundaries with middle school students, high school students, university students not majoring in science, university students majoring in Earth science, and pre-service and in-service teachers. It is extremely versatile because it requires the students to observe, describe, and classify data. Students do not need previous knowledge of plate tectonics, geography, or Earth science. In fact, we often find that students who are bright and curious, but have no knowledge of the subject, get the most out of the exercise. It is desirable for students to have an idea what earthquakes and volcanoes are and to be familiar with the world map and know the names of the continents and oceans. We have found that most middle school students are familiar with these topics. If students are not familiar with names of geographic locations, the teacher can use a world map in the classroom to introduce these. We vary the expectations we have of the students doing the exercise according to their age level. From older students, we expect more detail in their descriptions of the data at plate boundaries. We expect them to be more insightful into anomalies in the datasets and give clearer, more organized, presentations to the class. When the teacher moves through the room while the students are meeting in their groups to discuss the data, they should push older students to think more deeply about the data. We are surprised to find that 7th graders often do this exercise as well as college freshmen!

We use this exercise as an introduction to plate tectonics; it is a natural stepping stone for subsequent exploration of other Earth science topics (e.g., volcanic processes, seismology, the rock cycle). We do not ask the students to read about plate tectonics before doing this exercise. We find that students learn more efficiently if they begin without too many pre-conceived ideas. In our experience and that of others (Bransford et al., 1999; Harcombe, 2001), prior knowledge of plate tectonics and plate boundary processes often includes as many misconceptions as it does correct perceptions. A sense that one already knows all about something is a tremendous impediment to actually confronting data and letting the data suggest models of how a process really works. This is something faced by scientists everyday; stopping frequently to really see data is a key to scientific progress. It is also important in daily life! If students let the observations they make during the exercise guide their thinking, they can come to understand the basics of plate tectonic boundary processes.

We do not suggest that this exercise covers the entire plate tectonic story. For example, it teaches little about plate motions, past plate tectonic configurations, or Earth history. We recommend that the teacher follow Discovering Plate Boundaries with other, possibly more computer-based exercises. Unlike Discovering Plate Boundaries, most of these exercises are designed for a particular age group. Thus, teachers must identify those most suited to their students' level.

The teacher should expect to be very active with his or her students during this exercise. It is not something that can be handed out with the expectation that the students will complete the exercise on their own. It is also important that the teacher be familiar with the data on each map and how they relate to plate tectonic boundary processes.

MATERIALS

An exercise based on observing, describing, and classifying data must be built on rich and well-displayed data (Figures 1-4). We use 4 data maps that contain information about large-scale plate tectonic processes on the Earth. These geophysical datasets have been acquired over many years by many scientists. When the maps are examined together, most of the basic tenets of plate tectonics are laid bare. Scientists developing the key ideas of plate tectonics over the past 40 years had only fragments of these data to work with as they tried to describe, classify, and interpret what they saw. In Discovering Plate Boundaries, you will be asking your students to walk the same path, but with the advantage of more complete data sets.

An important feature of the maps used in this exercise is that they are all displayed at the same scale, projection and graticule (grid). Uniformity of the map base makes it easy for students to compare data from map to map. The students are asked to observe data on one map and relate its location to the position of plate boundaries on another map. Depending on the level of the students, we use two different versions of the data maps. Younger students (elementary and middle school) benefit from having the plate boundaries superimposed on the data maps: these students need the visual cues to make the connections. Plate boundaries do not need to be superimposed for older students. The additional challenge of relating features from map to map hones their observational skills and often leads to deeper questions. Map uniformity is an important aspect of the exercise. It is possible to obtain excellent maps (better than ours!) of each of these data from other sources, but they are unlikely to be displayed in exactly the same way. We have found inconsistent display to be a source of frustration for students.

The four data maps (Figures 1-4) can be expensive to produce, but are not consumed during the exercise. They are attached to the walls of the classroom for the students use, but the students are asked not to mark on them. Most teachers use 24x36 inch maps and laminate them for durability. We know teachers that have used a single set of maps many times and one school district that shares a set among several schools.

The students are asked to do their work on black and white plate boundary maps (Figure 5). We use 11x17 or 8.5x11 inch photocopied maps for this purpose. Each student uses 2 of these maps during the course of the exercise. We also provide each group of 4 students with an 8.5x11 inch overhead transparency of the plate boundary map, and they are asked to make a presentation using an overhead projector at the end of the exercise.

The students will use colored pencils and overhead transparency markers during the exercise. Each student will use about 5 colors to do the exercise. They work in groups and do not all need to use the same colors at the same time so it is easy to share. We keep a bucket of colored pencils available in the room. Each group of 4 students will need to prepare an overhead transparency. We provide a set of transparency markers to each group.

Seismology Data Map (24x36 inch)	1 per class
Volcanology Data Map (24x36 inch)	1 per class
Geography Data Map (24x36 inch)	1 per class
Geochronology Data Map (24x36 inch)	1 per class
Plate Boundary Maps (11x17 or 8.5x11 inch paper)	2 per student
Plate Boundary Maps (8.5x11 inch transparency)	1 per 4 students
Student Instruction Handout	1 per student
Colored Pencils, 5-6 colors	2-3 pencils per student
Transparency markers, non-permanent, 5-6 colors	1 set per 4 students
Tape for mounting data maps to wall	1 per class
Overhead projector on Period 3 of the exercise	1 per class
Set of overhead transparencies for wrap up discussion	1 per class
Seismology Data Map (11x17 inch) (optional)	1 per 4 students
Volcanology Data Map (11x17 inch) (optional)	1 per 4 students
Geography Data Map (11x17 inch) (optional)	1 per 4 students
Geochronology Data Map (11x17 inch) (optional)	1 per 4 students

Table 1. Materials.

We find that it is convenient, but not mandatory, to have smaller versions (11x17 inch) of the four data maps for quick reference by the student groups during Period 2 of the exercise.

The only classroom equipment needed for this exercise is the overhead projector used by the students and the teacher giving presentations during Period 3 of the exercise.

METHOD

We usually do the exercise over three 50 minute periods. These can be distributed over several days, or over one 3-hour lab period. The exercise sometimes runs over into an additional period. We will refer to the main parts of the exercise as Period 1, Period 2, and Period 3.

We have used the exercise with classes of 4 to 120 students, but have most often done it in classes of 20-30. The number of students is an issue because each student is assigned to one of four science specialties and one of ten tectonic plates. A "perfect" class for this exercise would have an integer multiple of four students. In this case, the teacher would use as many tectonic plates as needed and have each science specialty covered. If the number of students is not evenly divisible by 4 then it is better to have a duplicate specialist for a plate than a missing specialist. In this case, assign one duplicate specialist to each plate to handle each of the 1-3 extra students. Because there are 4 specialties and 10 plates, the basic exercise using one set of maps tops out at 40 students. We have accommodated groups larger than 40 (in college level classes) by having multiple sets of the data maps and teaching assistants to work with the groups.

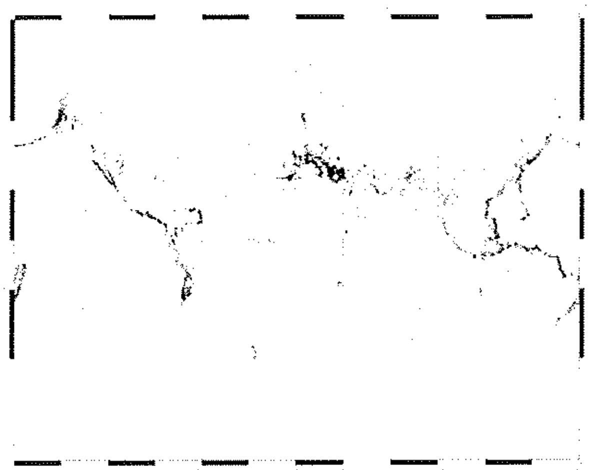

Figure 1. The seismology map shows earthquake locations and depths (Data obtained from Incorporated Research Institutions for Seismology (IRIS) databank at http://www.iris.washington.edu/). This is a black and white rendition of the map. The map we use for teaching the exercise is in color. The location of each earthquake is indicated by a dot and its depth is indicated by the color of the dot. The red dots indicate earthquakes having depths between zero and 33 km. The orange dots indicate earthquakes having depths between 33 and 70 km. The green dots indicate earthquakes having depths between 70 and 300 km. The blue dots indicate earthquakes having depths between 300 and 700 km. Our maps show all earthquakes of magnitude 4 and greater between 1990 and 1996. We found that a 6 year period provided the right density of events. The time period chosen was up-to-date when the exercise was originally created. We can update it at any time, but it will have no effect on the exercise. The color version of this map may be found at http://terra.rice.edu/plateboundary/quakes.24.36.pdf .

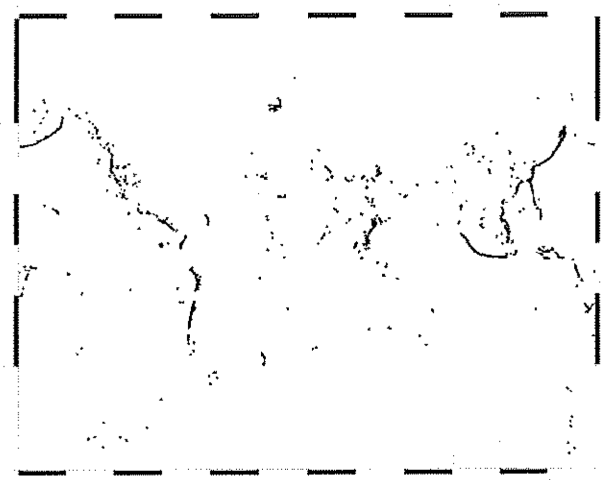

Figure 2. The volcanology map shows locations of recently active volcanic features on the Earth (Siebert and Simkin, 2002). This is a black and white rendition of the map. The map we use for teaching the exercise is in color. In this dataset, "recent" refers to the past 10,000 years. The dots represent volcanoes, geysers, hot springs, and similar features. The color version of this map may be found at http://terra.rice.edu/plateboundary/volc.24.36 .pdf .

BEFORE THE ACTIVITY

Before the students arrive, we hang the four data maps up on the walls of the room, far enough apart that groups of 8-10 students can stand around a map and not interfere with a group standing around and discussing another map. 24x36 inch laminated versions of the maps are large enough for everyone in such a group to see the map readily and participate in the group discussion. We try to do the exercise in a room where the students have access to some space in front of each of the maps. Sometimes we move tables and chairs to accomplish this. We find that students discuss the maps more readily if they are standing, rather than sitting, around the map. It makes it less likely, and more obvious to the teacher, that one or two students are not participating in the map discussions. There must also be places in the classroom where groups of students can sit together, ideally at a lab table, to discuss their plate boundary classifications during Period 2 of the exercise.

Summary of Discovering Plate Boundaries

Period 1 Students work in "Specialty" Groups
- The students assemble in their specialty groups in front of their data map
- They are instructed to become familiar with their map and to observe how their data behave on or near plate boundaries
- They are to OBSERVE rather than INTERPRET, and discuss what they see with their group
- They are to look at the whole world
- They are to develop a classification scheme for up to 5 boundary types using their data.
- They should write a description of each boundary type on the back of their plate boundary map
- They should assign a pencil color to each boundary type and color the boundary with that color

Period 2 Students work in "Plate" Groups
- Each plate group will consist of four students, each an expert in one specialty
- The group will visit each data map for a briefing by their expert on that map.
- Each plate group now focuses on the boundaries of their plate
- Students classify those boundaries using data from all four data maps
- Each group will prepare for one spokesperson to present their work to the class during Period 3

Period 3 Full class Presentations and Discussion
- Each plate group spokesperson presents their work to the class
- The teacher wraps up the exercise with a presentation/discussion on plate boundary processes

Table 2. Summary of project.

Period 1 - When the students arrive for Period 1, each student receives a Student Instruction sheet and a plate

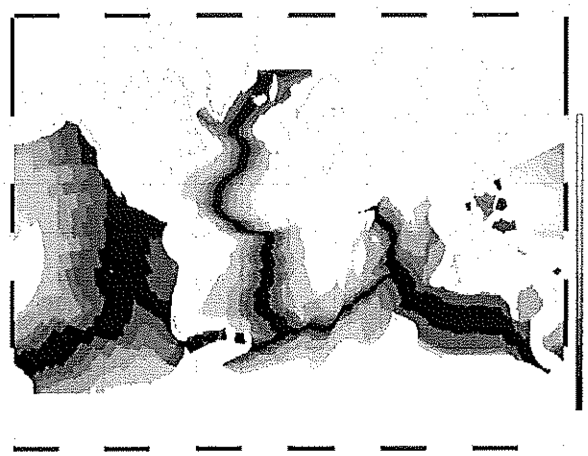

Figure 3. The geochronology map shows age of the oceanic crust under most of the world's oceans (Müller et al., 1997). This is a black and white rendition of the map. The map we use for teaching the exercise is in color. The scale bar on the right shows how the colors correspond to age of the seafloor in millions of years. Red signifies the youngest crust while blue signifies the oldest known oceanic crust. The color version of this map may be found at http://terra.rice.edu/plateboundary/age.24.36.pdf .

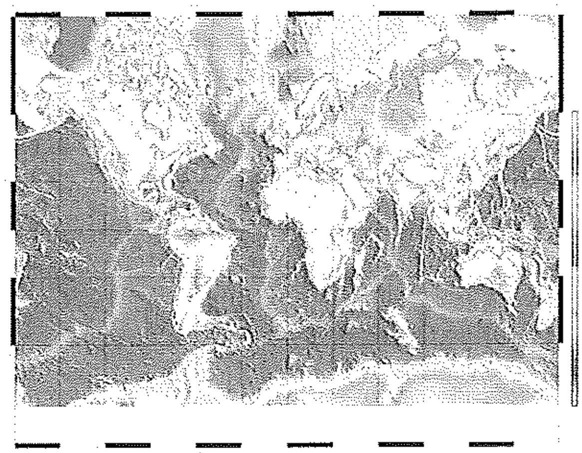

Figure 4. The geography map shows topography and bathymetry of the Earth (Data are ETOPO2 available from the National Geophysical Data Center, http://www.ngdc.noaa.gov/). This is a black and white rendition of the map. The map we use for teaching the exercise is in color. This is the elevation of the land surface and the depth of the oceans. The map uses color to indicate varying elevation and depth and simulates sun shading to add a sense of 3-dimensionality to the map. The scale bar on the right shows how colors on the map correspond to elevation in meters. The color version of this map may be found at http://terra.rice.edu/plateboundary/topo.grad.24.36.pdf .

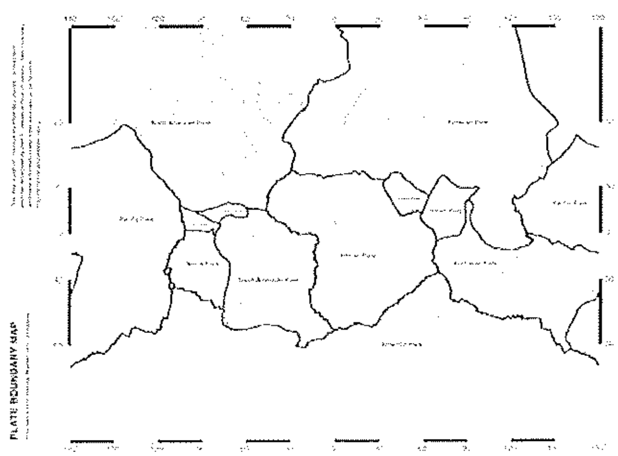

Figure 5. Plate boundary map (digital plate boundary locations from Müller et al., 1997).

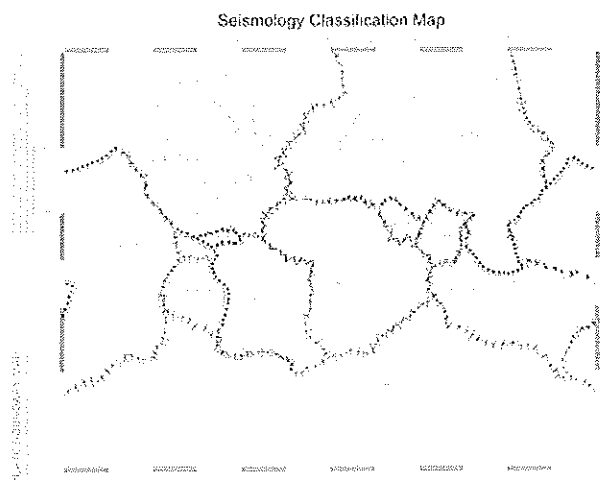

Figure 6. Example of an ideal Seismology based classification map for Period 1 of the exercise. The companion legend for this map is shown in Fig. 7. Note that the students will be using colored pencils to symbolize these boundary types. The use of color makes this much easier!

boundary map. We have the students count off by 4 to determine their Scientific Specialty (e.g. 1-Seismology, 2-Geochronology, 3-Volcanology, or 4-Geography). We prefer that student groups be determined randomly, so that one of the benefits of the exercise is to have students work with others outside their usual social groupings.

The students then assemble in their specialty groups at their respective maps: Seismologists at the Earthquake map, Volcanologists at the Volcano map, Geo- chronologists at the Seafloor Age map, and Geographers at the Topography map. Each group is asked to become familiar with their map. They should read the side label to see what is being displayed and how it is displayed. Some maps show locations of events (Seismology and Volcanology). Other maps show contoured data using colors (Geography and Geochronology). The students should work as a group to figure out what they are looking at. Often, those who dominate the discussion at the maps at first are the students who normally talk in class. After a while, other leaders usually emerge, because they really begin looking carefully at the map and the data.

These specialty names, for example "geochronology," may seem daunting at first to students. One 7th grade teacher we work with presents the word "geochronology" to his students and asks them to break the word apart to figure out its meaning. The students

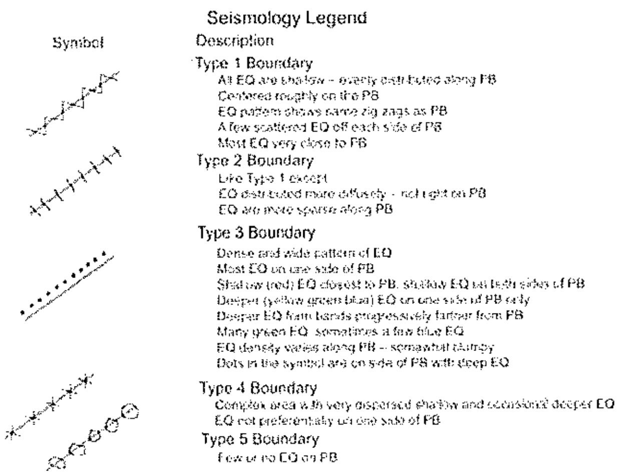

Figure 7. Example of a Seismology based classification map legend to accompany the map in Figure 6. Note that the students will be using colored pencils, rather than black and white symbols, to symbolize these boundaries. In this case, the Type 1 and 2 plate boundaries generally correspond to divergent boundaries, the Type 3 plate boundary generally corresponds to convergent (subducting) boundaries, and the Type 4 plate boundary generally corresponds to transform plate boundaries. Type 5 is a catchall for boundaries not well characterized by seismicity.

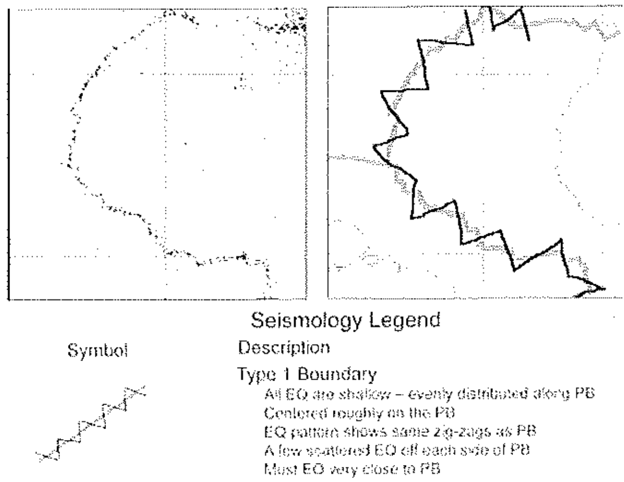

Figure 8. The upper left is a close-up of the Seismology data map (Figure 1) showing a portion of the plate boundaries in the central Atlantic Ocean. The black dots are shallow earthquakes. The gray lines are the plate boundaries, shown here for reference. Based on these data, a student might describe the earthquakes along the Mid Atlantic Ridge as shown at the bottom. They would invent a symbol for plate boundaries of that type. This symbol would then be added to their plate boundary map as shown in the upper right.

get "Earth" from "geo" and "study of" from "ology" readily, but have to work on getting "time or age" from "chrono." He does the same with "seismology", "geography", and "volcanology." It is very effective, even at the 7th grade level.

While the students are discussing their maps, the teacher circulates among the groups to listen, answer questions, and clarify any misconceptions that pop up. When each group has reached an understanding of the basics of their data display (this usually takes about 5-10 minutes), we ask the students to begin to describe and classify their data. Each group is to work only with its data map. They are to OBSERVE rather than INTERPRET. Their descriptions should include words like wide or narrow, straight or curved, symmetric or not symmetric, deep or shallow, ridge or valley, and active or inactive.

A brief discussion about "classification" can be helpful at this point. Students often understand classification in the context of problems where they are given objects and a defined classification scheme to apply. Sorting a bag of US coins by denomination would be an example of such a problem. They handle this type of problem fairly easily when given the classification scheme, provided that each object falls into one of several defined classes, and that each class assignment they make can be clearly identified as right or wrong.

In Discovering Plate Boundaries we are asking them to do something much harder: to invent a classification scheme of their own. There are many "correct" answers to this type of problem! We often ask students to think about a big box full of diverse clothing items, and ask them to invent a classification scheme for the clothing. They will easily come up with classification by type of clothing, ie. shirts in one pile, shoes in another and etc., classification by color, classification by size, and sometimes others. This illustrates the idea that there is no "one right way" to classify things. We then ask them to imagine that they have hundreds of such boxes and helpers to do the sorting for them. In order to make things work, they will have to devise an appropriate classification scheme, and then define it so that the others can apply it to their boxes. This requires that they write a simple description of the categories that they created. We also note that they may find clothing items that they do not recognize or cannot put into one of their categories. In that case they may need a new category for items that fit no category!

Each scientific specialty group is now asked to come up with a classification of the plate boundaries of the world based on their data. They are instructed to use up to 5 plate boundary type classifications of their creation. The boundary types that they invent are to be given generic names such as boundary type 1, boundary type 2, etc. They are asked not to use plate tectonic terminology. They are to write a description of how they identified their plate boundary types. The description should be clear enough so that someone unfamiliar with their map could use their description to find examples of that boundary type on the map (refer back to the clothing sorting helpers in the example). They use a colored pencil to mark (on their individual map) all plate boundaries in the world which fit that description. They should use different colored pencils for each of their boundary types. Figures 6 and 7 illustrate what we have in mind. Note that we have done this in black and white in these examples because of the journal format. Color makes it much easier!

The students write their boundary type descriptions on the back of their plate boundary map or on a separate piece of paper. They select the boundary symbol they want to use to represent the data. Note that for plate

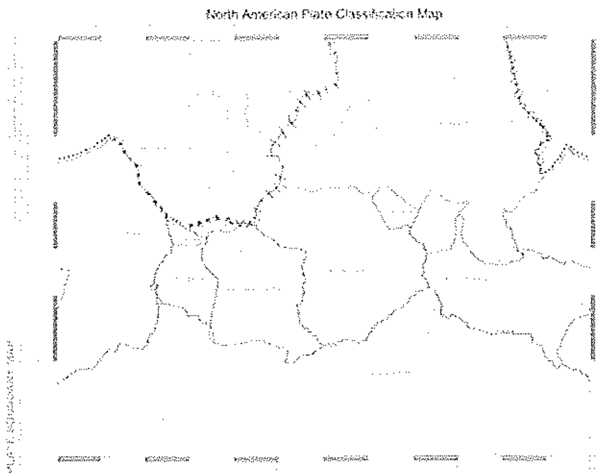

Figure 9. Example of an ideal North American Plate classification map for Period 2 of the exercise. The companion legend for this map is shown in Fig. 10. Note that the North American Plate boundaries span the edge of the map. During Period 2, only the boundaries of the assigned plate are classified. Note that the students will be using colored pencils to symbolize these boundary types.

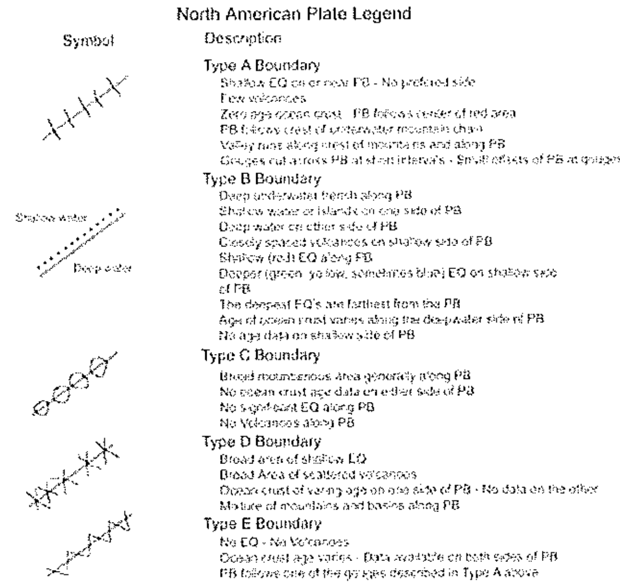

Figure 10. Example of a North American Plate classification map to accompany the map in Figure 9. Note that the classifications now include observations from all four data types.

boundary types with no asymmetric component (such as types 1, 2, 4, and 5 in Figs. 6 and 7) a simple colored line may be used. The colors may be chosen based on what colored pencil each student can find. The colors do not need to match from student to student or group to group. The Type 3 boundary symbol shown here reflects that the deep earthquakes occur on one side of the boundary. The students should invent a symbol for this. I chose to use dots on one side of the PB to indicate this (Fig. 6). Note that the nature of this symbol (that the dots are on the side of the plate boundary that has deep earthquakes) is described in the Type 3 Boundary description (Fig. 7). If it were clearly stated in the description, the symbol could just as well been on the side of the plate boundary without deep earthquakes.

In spite of the earlier discussion of classification, students are often stumped by the instruction to classify data without being given the classification descriptions in advance. The teacher can usually get them on track by asking someone in the specialty group to select (by pointing it out on the data map) a plate boundary segment. They might choose, for example, the boundary between the North American Plate and the Eurasian Plate in the Atlantic Ocean. The teacher can then ask the group to describe their data on or near that plate boundary segment (Figure 8). The seismologists might notice that there are only shallow earthquakes along that boundary. They might add that the quakes are almost all exactly on the boundary, and that the line of quakes and the plate boundary both have a matching zig-zag pattern. The teacher can then suggest to them that they have just defined their "Type 1" plate boundary. Each student writes the definition of their groups' Type 1 boundary, as they have just described it, on the back of their copy of the plate boundary map (Figure 8) and marks the boundary type in colored pencil over the plate boundary segment they have been discussing, on their map (Figure 8).

Students then examine the plate boundary and data maps to find other plate boundary segments that fit this description. They usually find others quite easily and then mark those boundaries with the color they have assigned to Type 1 plate boundaries. When they run out of plate boundary segments that they wish to call "Type 1," they should locate a plate boundary segment they have not yet classified and repeat the whole process to define a Type 2 plate boundary. At this point, they usually "get it" and can often proceed without aid for the rest of the period. They will each be asked to turn in these marked maps with accompanying descriptions at the end of the exercise. This keeps everyone engaged in the group discussions and creates individual accountability.

There are a number of student misconceptions that arise while they are doing this exercise. We find that we have to explain, sometimes several times, that we are classifying the boundaries, not the interiors, of the plates. Students are more accustomed to "coloring in" the white areas on a map than in coloring on top of the lines. This is something that the teacher should watch for when visiting the groups on Period 1. We have also noticed that some students assigned to the Seismology specialty try to color the area over the deeper earthquakes, rather than associating the earthquakes with the plate boundary nearby. We try to lead them to make this association and to include the pattern in their description of the plate boundary type. Geochronologists often start off coloring their maps to mimic the seafloor age map. They must be reminded that they are trying to represent the seafloor age along their plate boundary, not copy it. We have not seen similar problems appear with the other specialties.

The marked-up map and plate boundary type descriptions shown in Figs. 6 and 7 are idealized examples and we do not expect students to reproduce them exactly. Encouraging students to be as descriptive as possible often elicits appropriately detailed descriptions of the boundaries. Note also that Figures 6 and 7 do not represent the only correct answer. The classification labels are completely arbitrary. What we look for in assessing these maps is a sense that the students have really observed the data and then created

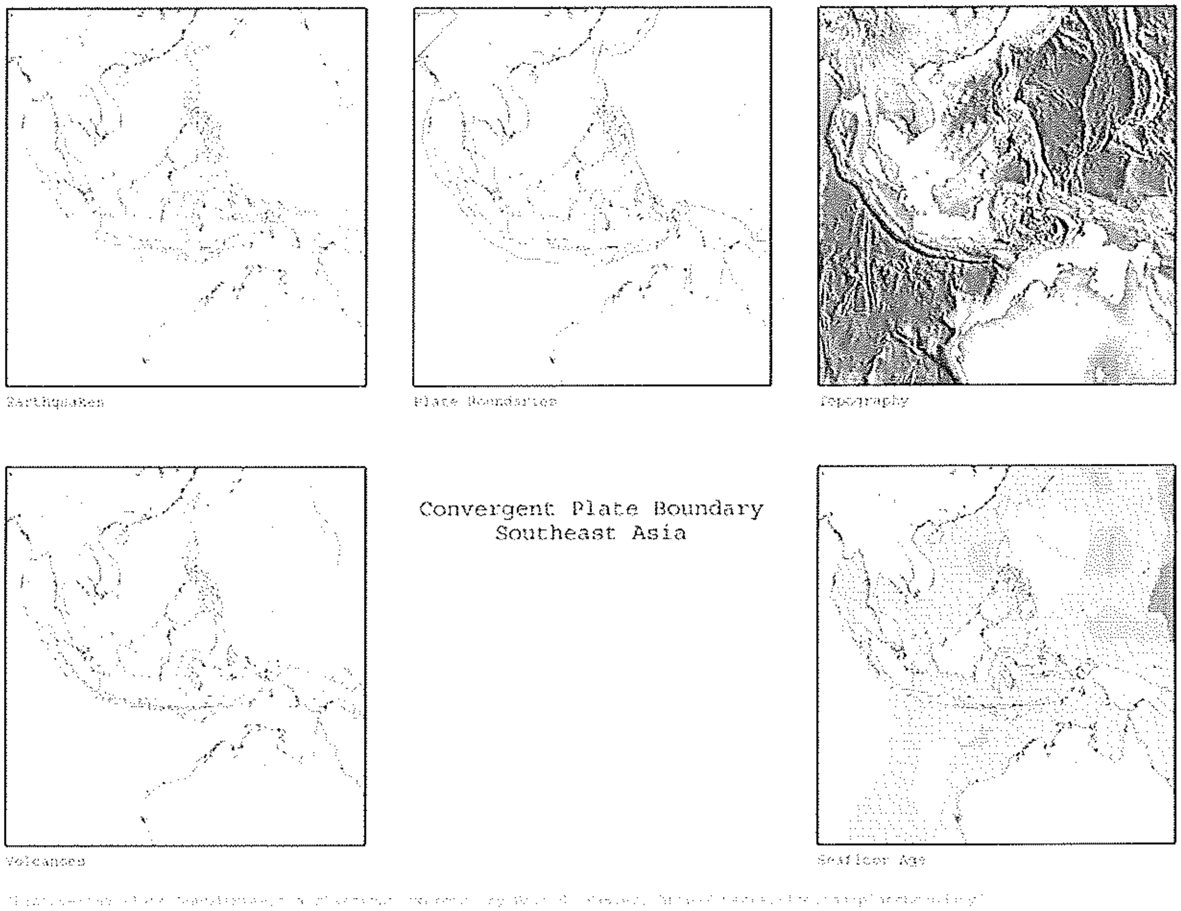

Figure 11. Example of overhead transparency used to relate the 4 types of data to the plate boundary location. We use about 15 similar transparencies to illustrate different plate boundaries. A color version of this figure may be seen at http://terra.rice.edu/ plateboundary/seasia1.4map.pdf. All the overhead transparencies we use in the Period 3 presentation can also be obtained at http://terra.rice.edu/

logical classifications. For example, we check whether they have correctly identified all the Type 1 boundaries on their map, or whether they have missed some that also fit their description of a Type 1 plate boundary. At this stage, we do not worry about them having classifications that match exactly with current plate tectonic understanding. These links will be made during Period 3. We also find that many students (particularly younger ones) are not able to complete their maps during the class period. Usually, they have identified most of the areas that are fairly simple in their data, while leaving the more complicated areas blank. A teacher might elect to extend the time that they have for this part of the exercise. Teachers must adjust their level of expectation based on student age. This is one of the characteristics of the exercise that makes it so flexible. Sometimes students will ask if we can leave the data maps up for them to work on between classes. We take that as a sign that they are engaged in the exercise!

With older students, we have the students keep their maps and Plate Boundary Type classifications after Period 1 to be used again on Period 2. We have them turn them in at the end of Period 3. With younger students, we recommend that the teacher collect the Period 1 maps at the end of Period 1 and then redistribute them at the beginning of the Period 2 class period.

Period 2 - When the students gather for Period 2 of the exercise, we ask them to initially assemble in their scientific specialty groups from Period 1. We then have each specialty group count off from 1 to n, where n is the number of plate groups needed for the class size (see earlier discussion of class size issues). Each student is assigned a plate group based on their number (e.g. 1-North American, 2-Pacific, 3-African, 4-South American, 5-Eurasian, 6-Indian, 7-Australian, 8-Antarctic, 9-Cocos/Nazca/Caribbean, or 10-Arabian). We end up with groups of four students assigned to each plate group. Each plate group should consist of a seismologist, a volcanologist, a geographer, and a geochronologist.

We usually have each plate group move to a lab table together. This will be a different group of students than they worked with during Period 1, the jigsaw aspect of the exercise. The jigsaw concept was first developed by Aronson, et al (1978) and has become a widely used cooperative learning technique.

We then explain that each group contains experts on all the data types, but that each expert has only looked at data in their own specialty area. Therefore each plate group needs to sequentially visit each of the data maps to become familiar with all the data. As a plate group stands at each map, the expert on that map should make an informal oral presentation to the others in their group about their data. The expert should first tell what the data are and how they are symbolized. They should then point out the most important features shown on their map. They should briefly introduce the plate boundary types they came up with on Period 1 and where they can be found in the world. They may want to pay particular attention to the boundary types they found at the boundaries of the plate to which they are now assigned. Note that during this part of the exercise, every student makes a short presentation to the other members of their group. This is less imposing that speaking to the whole class. Each speaker is also at a relative advantage because they are presenting information that the others in their group have not seen before.

After about 15 minutes, each plate group should have visited and learned about all of the four data maps. Their next task is to come up with a new classification scheme for the boundaries of their plate (not the whole world). This scheme should be labeled boundary type A, B, and etc, and should be based on all four types of scientific data. For example, plate boundary type A might be described as "having shallow earthquakes right on the plate boundary, sparse or no volcanoes, lying on a topographic high with deeper water to either side, and following a line of very young seafloor." In most cases the students will do this by bringing together the classification maps they did the first period. Hopefully they will notice that the plate boundary types based on a single data set, correlate well with data of another type. Students write their new boundary type descriptions on the back of their new map and color the boundaries on the map (Figures 9 and 10). Again, each student will turn in a map with accompanying descriptions. We also pass out the transparencies and markers and tell the students that a spokesperson from each group will need to speak to the whole class, using the marked-up transparency, at the beginning of Period 3.

Much of Period 2 is spent with plate groups working together at lab tables and occasionally consulting the data maps. The teacher should move from table to table listening in and asking leading questions of the groups. We often provide each plate group with a set of 11x17 in versions of the data maps. This allows the plate group to consult and discuss the data without having to move around the room. We keep the big maps on the wall so that they are available to the groups.

Period 3 - Period 3 of the exercise begins with the student group spokespersons making their presentations to the class using the overhead projector. We generally ask them to describe their plate boundary classifications and then to give us a tour around their plate. Often there are questions from other students. Sometimes we ask questions to draw out some feature they have on their map, but have not talked about. Each presentation usually takes 2-3 minutes. Older students can be asked to pay particular attention to the presentations of plate groups for plates that border their own plate and to note similarities and differences between the groups' classification schemes.

We lead the students in applause for each talk and thank the speaker. We are sure to listen carefully to what they say, as we try to repeat their observations when we are describing plate boundary processes later in the class. This emphasizes to the students that they have been successful in identifying the key data patterns that characterize plate boundary processes.

We then spend the remainder of the Period 3 class leading a discussion of plate boundary processes and introducing the terminology Earth scientists use to describe these plate boundaries. We first use several graphics from the USGS "Dynamic Earth" (Kious and Tilling, 1996) to discuss the broad categories: divergent boundaries, convergent (subducting) boundaries, and transform boundaries. We discuss why each of these boundaries have the particular observable phenomena the students have observed and classified. We try to frequently repeat words that they used in their presentations to describe these.

We have designed a set of transparencies that show close-ups of the Discovering Plate Boundaries data maps for locations that are particularly good examples of each type of plate boundary. These are very handy for illustrating the data relationships that characterize each fundamental type of plate boundary. The example in Fig 11 illustrates (ocean-ocean) convergent plate boundaries in Southeast Asia. Each map in the transparency covers exactly the same area, making comparison of data easy. We try to let the students steer this wrap-up discussion based on their interests. There are usually many questions about what is going on at various plate boundaries, and sometimes away from plate boundaries (ie. Hawaii). This type of discussion inevitably finishes off Period 3 of the exercise and may usefully continue into the next class period.

An important aspect of these data and of observational science in general often emerges in the Period 3 discussion. We like to let the students raise it, but will lead them to it if they do not. It is the issue of data quality and completeness. One example that the students almost always notice is the lack of volcanoes along the mid-ocean ridges. When we present the Period 3 discussion of divergent plate boundaries we usually say that most of the volcanic activity on earth takes place along these boundaries. A hand usually shoots up with the obvious question. We use this opportunity to discuss the methods employed in assembling the volcanic activity data, direct observation or historical accounts of eruptions, and the difficulty of observing seafloor eruptions. We show that where the divergent boundary rises above sea level (i.e. Iceland) there are many volcanoes on the map. We discuss whether it is reasonable to conclude that these data are flawed. They do not really represent all volcanic activity on Earth, but rather the easily observable activity. We go on to point out that although incomplete, the volcano dataset is incredibly useful in characterizing the location and polarity of most of the convergent plate boundaries on the Earth. Therefore, we would not want to throw away the volcano data just because they are not perfect. We note that scientists almost always have to work with incomplete or flawed data. If used carefully, even flawed data may yield great understanding.

Another similar "flaw" that students usually pick up is that the Plate Boundary Map we distribute does not have all the plate boundaries on it. We consciously eliminated some of the very small plates from the exercise because we wanted the plate groups to work on the large plates with diverse boundary types. For example, the boundary between the Phillipine plate (not included) and the Pacific plate is very clear in the data. Students also almost always comment on the lack of a boundary on our map along the African Rift Valley. We have considered "fixing" these problems, but find it useful to let the students observe them and ask questions. Interesting discussions invariably result!

For strong middle school students and all older students, we often have the students reassemble in their plate groups during the next class period to re-examine their classifications in terms of the terminology and processes that were presented and discussed during Period 3. The students can usually recognize their classifications as corresponding to divergent, convergent, and transform boundary types. They are often more insightful in looking at the data given a better grasp of the reasons why earthquakes, volcanoes, topography, and etc. behave as they do near each type of boundary. We consider this to add an "interpretation" phase to the exercise, an important part of the scientific process.

ASSESSMENT

We ask the students to turn in their two annotated plate boundary maps after Period 3. We usually grade these in a very simplified way. We give them a zero, check minus, check, or check plus for each map. Check minus reflects very little or careless work on the map. Check plus reflects an above average product relative to the age and ability of the students. We also check for consistency within their classification schemes.

As mentioned above, we do not insist that the students' maps match an "answer key." There are many reasonable ways to classify these complicated data. Remarkably, even with this potentially "chaotic" characteristic, the classifications done by the students generally pull out the important distinctions that allow them to "discover" the plate boundary types.

BENEFITS OF THE EXERCISE

Relation to National Science Standards - The objectives of this exercise mesh very well with National Science Education Standards, for Earth and Space Science (Content Standard D, Structure of the Earth System) and for Science in Personal and Social Perspectives (Content Standard F, Natural Hazards) at Levels 5-8. Some fundamental concepts of the standards are addressed explicitly by Discovering Plate Boundaries, while others are most effectively addressed using this exercise as a framework.

The national standards for levels 9-12 include fundamental concepts and principles that build on the knowledge gained in Discovering Plate Boundaries. It is our experience that students at these levels (and also at the college level) often have been introduced to plate tectonics, but have developed many important misconceptions. Because plate tectonics is the basis on which almost all Earth science is built, we suggest that an exercise like Discovering Plate Boundaries is not wasted on, and is indeed very valuable for, these more advanced students. The data sets are quite rich and permit increasingly sophisticated observations to be made. We, and most professional geoscientists, often find ourselves pausing to look at maps just like these to gain new insights into the working of the Earth!

COLLABORATIVE LEARNING

The exercise involves random student groups interacting to reach consensus on patterns in the data. Normally, the groups reach consensus and each student in the group uses the group's classification on the map that they turn in at the end of the exercise. However, the exercise accommodates differences of opinion, because each student's work turned in can be unique. We like to see groups of students standing around a data map presenting alternative interpretations of data that all can see and evaluate. This is exactly how scientists work and science progresses.

The jigsaw aspect of the exercise enables each student to have a clear role in the work of their group, and specific kinds of information that they bring to the table. It has proven to be an effective tool for promoting collaborative learning. A side effect of the jigsaw method with random groups is that students work with classmates they would be unlikely to choose if left to form their own groups. When we have let students self-select groups, we find that the usual students do all the work, and those that do not normally participate do none. Unusual mixes of students encourage different students to come forward with good ideas.

CONCLUSIONS

Discovering Plate Boundaries is a versatile classroom exercise that encourages active learning. Understanding plate tectonic concepts is crucial for all students, whether or not they choose to pursue careers in science. Plate boundary processes govern the locations and frequency of natural hazards, such as earthquakes and volcanoes, and generate the topography that influences flooding and weather patterns. A significant portion of the world's population lives near plate boundaries. The construct of Discovering Plate Boundaries provides a new way for students to develop understanding about these fundamental plate tectonic processes by encouraging active learning. Rather than being provided information in a lecture format, students discover the different types of plate boundaries by examining four global geophysical data sets: earthquake locations and depths, recent volcanic activity, topography and bathymetry, and seafloor age. These four data sets represent cutting-edge data generated and used by today's Earth scientists. Students work in teams to classify the boundaries of the plates according to their own observations of these data, thus experiencing the process of science. Discovering Plate Boundaries allows students to build their own knowledge of the Earth system and challenges common misconceptions about how our Earth works. This activity can be used with middle school, high school, and college-level students (including pre- and in-service educators), as well as with a wide variety of class sizes. Minimal resources are required to conduct this exercise, which makes it extremely versatile because it does not rely on expensive classroom equipment. It is thus an ideal activity to use in many settings to introduce a wide variety of learners to a fundamental concept of Earth science.

ACKNOWLEDGEMENTS

We thank all the teachers with whom we have interacted over the past years. They have provided many insights into how students learn and what methods are effective for teaching Earth science. DSS is particularly grateful to Joanne Wilton of Trafton Middle School, and Cliff Claflin of Youth Engaged in Service (YES) College Preparatory Charter School, both in Houston, TX, for sharing their classrooms and students.

Electronic versions of these maps and extensive supporting materials are available free at: http://terra.rice.edu/plateboundary/ .

REFERENCES

Aronson, E., Blaney, N., Stephan, C., Sikes, J, and Snapp, M., 1978, The Jigsaw Classroom, Beverly Hills, CA., Sage Publications.

Bransford, J.D., Brown, A.L., and Cocking, R.R. (Eds.), 1999, How People Learn: Brain, mind, Experience, and School, National Research Council, National Academy Press, Washington, D.C., 319 p.

Harcombe, E.S., 2001, Science Teaching/Science Learning: Constructivist Learning in Urban Classrooms, Columbia University Teachers College Press, 211 p.

Kious, W.J., and Tilling, R.I., 1996, This Dynamic Earth: The Story of Plate Tectonics, U.S. Government Printing Office.

Muller, R.D., Roest, W.R., Royer, J.Y., Gahagan, L.M., and Sclater, J.G., 1997, Digital isochrons of the world's ocean floor, J. Geophys. Res., v. 102, p. 3211-3214.

National Research Council (U.S.), 1996, National Science Education Standards, National Academy Press, 262 p.

Siebert L, Simkin T., 2002, Volcanoes of the World: an Illustrated Catalog of Holocene Volcanoes and their Eruptions. Smithsonian Institution, Global Volcanism Program Digital Information Series, GVP-3, (http://www.volcano.si.edu/gvp/world/).

General Education Course Submission Form

Date of Submission: 23 Aug 2010

1. Check which area(s) this course applies to.

Inquiry – Arts & Creativity	☐	Composition & Communications - II	☐
Inquiry – Humanities	☐	Quant Reasoning – Math	☐
Inquiry – Nat/Math/Phys Sci	X	Quant Reasoning – Stat	☐
Inquiry – Social Sciences	☐	Citizenship – USA	☐
Composition & Communications - I	☐	Citizenship - Global	☐

2. Provide Course and Department Information.

Department: Earth and Environmental Science

Course Prefix and Number : GLY150 Credit Hours: 3

Course Title: Earthquakes and Volcanoes

Expected Number of Students per Section: 100 Course Required for Majors in your Program? no

Prerequisite(s) for Course? none

This request is for (check one): A New Course ☐ An Existing Course X

Departmental Contact Information

Name: D. Ravat Email: dhananjay.ravat@uky.edu

Office Address: Slone 305A (inside office) Phone: 7-4726 (e-mail preferred)

3. In addition to this form, the following must be submitted for consideration:

- A syllabus that conforms to the Senate Syllabi Guidelines, including listing of the Course Template Student Learning Outcomes.
- A narrative (2-3 pages max) that explains: 1) how the course will address the General Education and Course Template Learning outcomes; and 2) a description of the type(s) of course assignment(s) that could be used for Gen Ed assessment. See the inquiry in natural/physical/mathematical sciences checklist.
- If applicable, a major course change form for revision of an existing course, or a new course form for a new course.

4. Signatures

Department Chair: D. Ravat D. Ravat dm Date: 9/3/10

Dean: Anna R. K. Bosch ARKBosch Date: 9/3/10

College Deans: Submit all approved proposals electronically to:
Sharon Gill Sharon.Gill@uky.edu
Office of Undergraduate Education

Check List for *Inquiry in the Natural/ Physical/ Mathematical Sciences*

Area-Level Learning Outcomes Checklist

Using the course syllabus as reference, identify when and how the following learning outcomes are addressed in the course.

- **Course activities that enable students to demonstrate an understanding of methods of inquiry that lead to scientific knowledge and distinguish scientific fact from pseudoscience.**

Date/location on syllabus: *Recitation Week 1*

Brief Description: *Reinforce reading and classroom discussion of the scientific method in the context of the Geosciences and plate tectonics. Distinction between the scientific process of discovery and knowledge and the pseudoscience it clarifies.*
- One approach is to ask students to come up with examples of pseudoscience and ask them to give reasons for why it is a pseudoscience and how a scientific process may be able to (or how they would) prove that it is a pseudoscience. This assignment could be done in a number of different ways.

- **Course activities that enable students to demonstrate an understanding of the fundamental principles in a branch of science.**

Date/location on syllabus: *Recitation Week 9*
Brief Description:
Locating earthquakes from the origin time and three or more earthquake records

- **Course activities that enable students to demonstrate the application of fundamental principles to interpret and make predictions in that branch of science.**

Date/location on syllabus: *Recitation Weeks13 and 14*
Brief Description: *Using data from Hawaii Volcanoes Observatory on the web (vepp.wr.usgs.gov) to observe and evaluate real-time measurements from the GPS, tilt-meter, gas analysis, and seismic instruments to assess the risk of eruption and the likely location of the next eruption.*

- **Course activities that enable students to demonstrate their ability to discuss how at least one scientific discovery changed the way scientists understand the world.**

Date/location on syllabus: *Recitation Weeks 3 to 7 (excluding Week 4)*
Brief Description: *Discovering Plate Boundaries Exercises (see the attached abstract of the student discovery of the unifying theory of how the Plate Tectonics*

was figured out).
Also includes oral PowerPoint based group presentations in the last period.

- **Course activities that enable students to demonstrate their ability to discuss the interaction of science with society.**

Date/location on syllabus: *Several occasions. Example: Lecture Meetings 16 and 18*

Brief Description: *- Earthquake Mitigation: Where and where not to put resources in mitigating effects of earthquakes is a question that comes down to priorities of the society*
- New Madrid Video - The Day the Earth Shook: This video has footage of fires, damage to houses, interviews with scientists in addition to discussion of scientific concepts related to New Madrid region and also a few of the world's major earthquakes. In-class or homework assignments can be designed so that students could demonstrate their ability to discuss the interaction of science with society.
-Discussion of Mt. Pinatubo, Philippines video (NOVA: In the Path of a Killer Volcano) that documents the impact of volcanic eruptions on developing cultures.

- **A description of the required student product (paper/laboratory report) based on the hands-on project. This project to enable students to demonstrate their ability to conduct a scientific project using scientific methods that include design, data collection, analysis, summary of the results, conclusions, alternative approaches, and future studies.**

Date/location on syllabus: *Recitation Weeks 13 and 14*

Brief Description: *Using data from Hawaii Volcanic Observatory on the web (vepp.wr.usgs.gov) to observe and evaluate real data from the GPS, Tilt-meter, and Seismic instruments to assess the risk of eruption and its location. A research paper that includes design, data collection, analysis, summary of the results, conclusions, alternative approaches, and future studies.*

- **Course activities that demonstrate the integration of information literacy into the course**

Date/location on syllabus: *Class meetings 13, 21, and 30* (*Exams #1, #2, and #3, respectively)*
Brief Description: *The exams in the course will demonstrate the integration of information literacy. When time is available during recitations and lectures, quizzes to prepare students for the exams will be given.* ***Other assignments such as Discovering Plate Boundaries exercises and Hawaii Volcanic Observatory project also achieve integration of information literacy.***