

## Plate Tectonics Map Set, Information and Credits

This is a set of 6 world maps that I compiled to help my students explore the distributions of earthquakes and volcanoes and their relationships to world plate boundaries. They show that lines of shallow earthquakes delineate many of the plate boundaries, that bands of deeper earthquakes and arc volcanoes locate the subduction zones, and that the locations of hot spot volcanoes are, for the most part, independent of the surface plate geometries, suggesting sources in the deeper mantle.

For each group of 3-4 students, I create a stack with Map 1 xeroxed onto a transparency and Maps 2-6 on paper. **IMPORTANT:** Do all the xeroxing at one time, both transparencies and paper maps; copy machines tend to drift in scale and you want them all to be exactly the same scale so that they overlay well.

Also **IMPORTANT:** you must acquire a pair (one red, one dark colored) of washable overhead pens for each student group.

The "Instructions" document describes the map exercise that I created for my classes. Use this or make up your own exercise.

The maps include:

1. coastlines (to be used as a transparent overlay for the other maps).
2. locations of shallow earthquakes, i.e. epicenters less than 70 km deep.
3. locations of plate boundaries.
4. locations of intermediate and deep earthquakes, i.e. epicenters 70 to 680 km deep.
5. locations of "arc" (subduction driven) volcanoes.
6. locations of "hot spot" volcanoes.

Made by Tanya Atwater from the 1990 computer collections of the Lamont-Doherty Earth Observatory. These materials may be used free of charge. When using these materials, please credit them to Tanya Atwater, <http://emvc.geol.ucsb.edu>.

Complaints, corrections, comments and, especially, suggestions for how to make these materials more useful are always welcomed: [atwater@geol.ucsb.edu](mailto:atwater@geol.ucsb.edu)

## **World Earthquakes and Volcanoes Map Exercise, Instructions**

The six maps are given as individual jpg files (and also as a layered Photoshop stack of maps).

Print out the six layers.

Xerox the instructions and Maps 2-6 onto paper, and xerox Map 1 onto a transparency.  
For best results do all the copying at the same time; machines tend to change scale from day to day. Make one set for each  
3-4 students.

Supply each group with one red and one dark-colored WASHABLE transparency pen. (If they use permanent, you will have to throw the transparency away and do the copying all over again.)

The written Exercise, below, is one I used on the first day in my Upper Division Plate Tectonics Class. Simpler versions work fine for elementary students.

Feel free to alter these materials to suit your own purposes.

Isn't plate tectonics great? Enjoy!

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## EARTHQUAKES, VOLCANOES AND PLATE TECTONICS: (In-class group activity.)

**Form a discussion group** of 3-4 students. Volunteer one to be the **Director**, one to be the **Artist**, and one to be the **Scribe**.

At the end of the session: **Turn in** the map set with the transparent overlay filled in and the Group Discussion Questions filled in (one sheet per group). You will be graded on the artist's work and the scribe's answers, so be sure they do a good job.

**Director:** Read the instructions aloud and keep the group organized, moving, and productive.

### Part 1. EARTHQUAKES.

#### a. Use shallow earthquake locations to draw world plate boundaries.

**Group:** Examine Map 2 (Shallow Seismicity). Can you see some plate boundaries in the pattern of earthquakes?

**Artist:** Carefully overlay the World Outline transparency on Map 2 and use a **dark, erasable pen** to draw the plate boundaries.

**Group:** Direct the artist. Also, start working on the Group Discussion Questions; come to a consensus about the answers, and dictate them to the **scribe**.

When the artist finishes drawing the boundaries (with help from the group), overlay them on Map 3 (the actual world plate boundaries) and see how you did. Use this comparison to answer the Earthquake Discussion Questions.

**Artist (with help from Group):** Write on the overlay the initials of the major plates.

NA: North American, CA: Caribbean, SA: South American, EU: Eurasian, AF: African, TK: Turkish, AR: Arabian, IN: Indian, AU: Australian, PH: Philippine, AN: Antarctic, PA: Pacific, NZ: Nazca, CO: Cocos, JF: Juan de Fuca.

#### b. Use deep earthquakes to locate the major subduction zones.

**Artist (with help):** Overlay the World Outline transparency on Map 4 (Deep Seismicity) and notice which plate boundaries are associated with deep earthquakes.

Put triangular teeth on the subduction zone boundaries. (As shown on Map 3, our symbol for subduction-type plate boundaries is a line with teeth pointing down the subducting plate.)

**Scribe (with group direction):** finish answering the Earthquake Discussion Questions.

### Part 2. VOLCANOES

#### a. Find the world's subduction-related volcanic arcs.

**Group:** Examine Map 5 (Arc Volcanoes). Can you find the "ring of fire" around the Pacific? Overlay the World Outline transparency on Map 5 and note the locations of these volcanoes compared to your plate boundaries.

**Artist:** Use a **red, erasable pen** to draw in the major arc volcanic belts on the overlay.

#### b. Check out the hot spot volcanoes.

**Group:** Examine Map 6 (Hot Spot Volcanoes) with and without the overlay. Do these volcanoes reflect the locations of plate boundaries?

**Scribe (with group direction):** Answer the Volcano Discussion Questions.

**Names:** *Director* \_\_\_\_\_ *Artist* \_\_\_\_\_

*Scribe* \_\_\_\_\_ *Sidewalk Superintendent(s)* \_\_\_\_\_

This page is due today, at the end of the session.

## **Discussion Questions. Part 1, Earthquakes.**

**Spreading centers:** How well do the shallow earthquakes locate and delineate the spreading centers?  
Compare slow spreaders vs fast spreaders (e.g. Atlantic vs Pacific)

**Transform faults:** How well do the shallow earthquakes locate and delineate the transform faults?  
Compare oceanic transform faults vs continental fault systems like the San Andreas.

**Continental collision zones:** How well do the shallow earthquakes locate and delineate the Continental collision zones? Are these clear, narrow plate boundaries?

**Subduction zones:** Why is the earthquake band at subduction zones so wide?

Where are the deep earthquakes located compared to the shallow earthquakes?

Where is the trench located within the shallow earthquake band?

Find two subduction zone segments that are a-seismic; i.e., they have almost no earthquakes.

**Plate interiors:** Are the plate interiors completely a-seismic? Compare oceanic vs continental plate interiors.

## **Discussion Questions. Part 2, Volcanoes.**

**Arc Volcanoes:** How are the arc volcanoes placed with respect to the bands of shallow and deep earthquakes along the subduction zones?

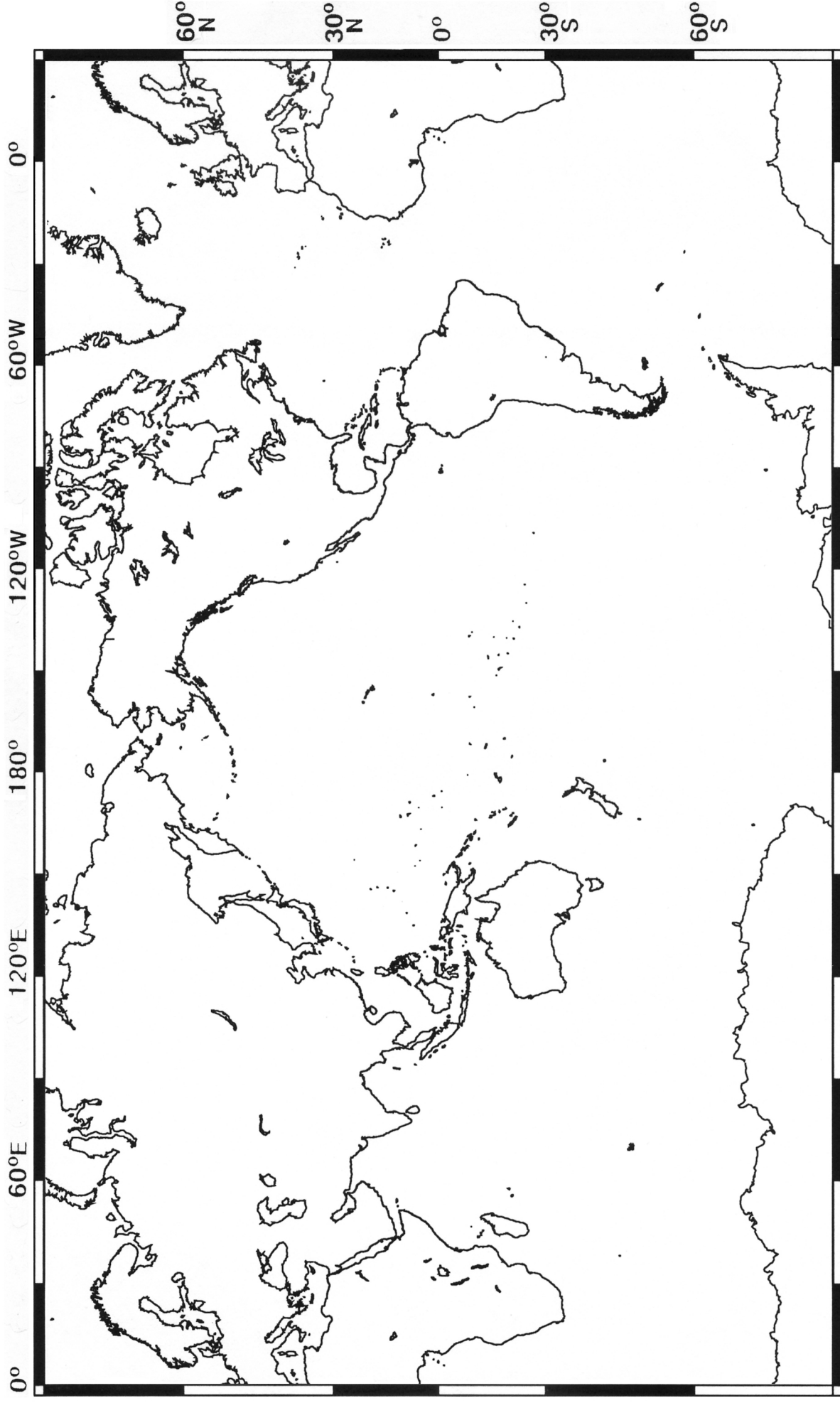
Find two subduction zone segments that have no arc volcanoes.

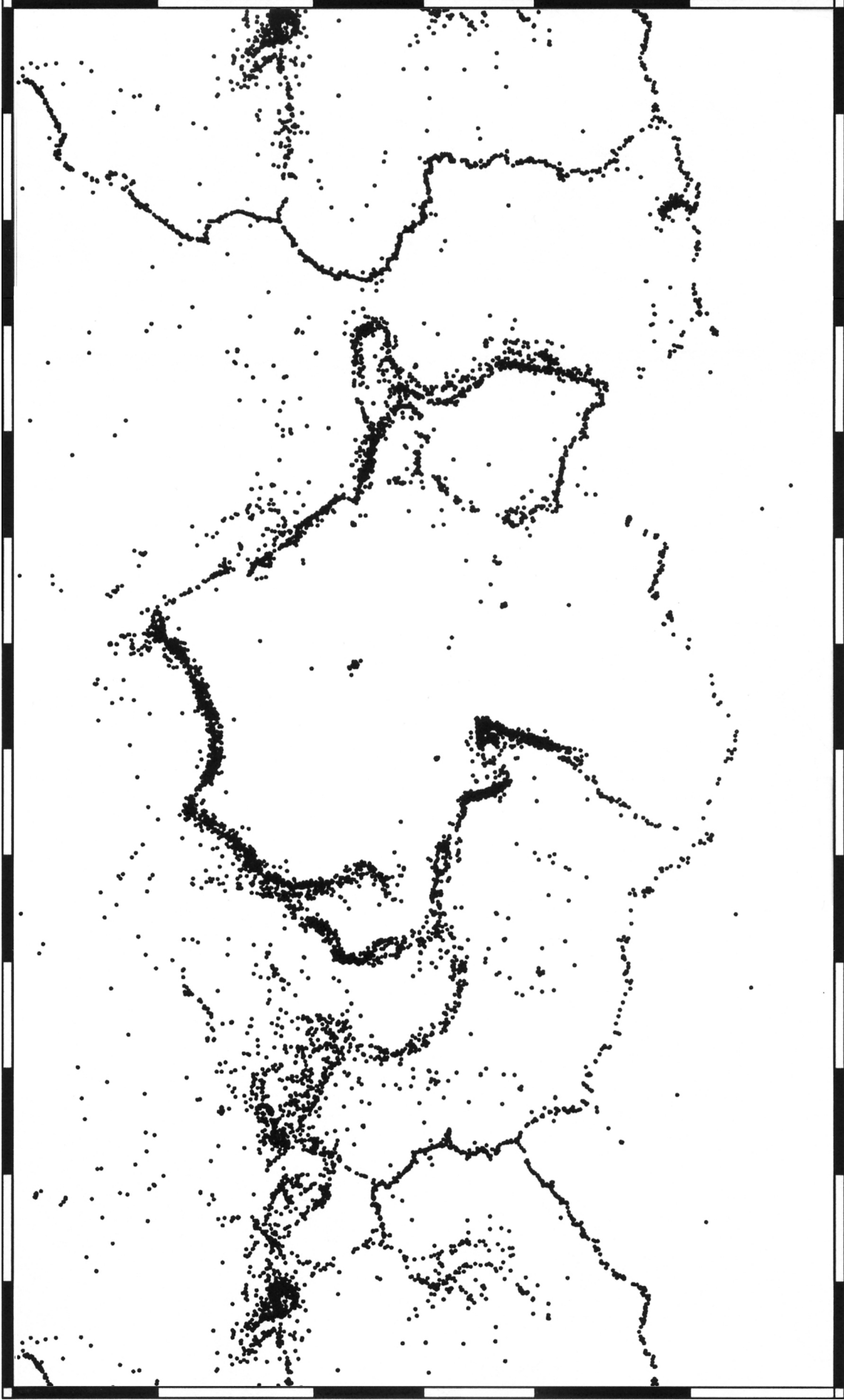
**Hot Spot Volcanoes:** In general, is there a relationship between the locations of the hot spot volcanoes and the plate boundaries?

Why, do you suppose, some of the hot spots (e.g., Iceland, Azores, Easter, Galapagos, Afar, East Africa) are near spreading centers?



MAP 1 World Coastlines (copy onto a transparency)



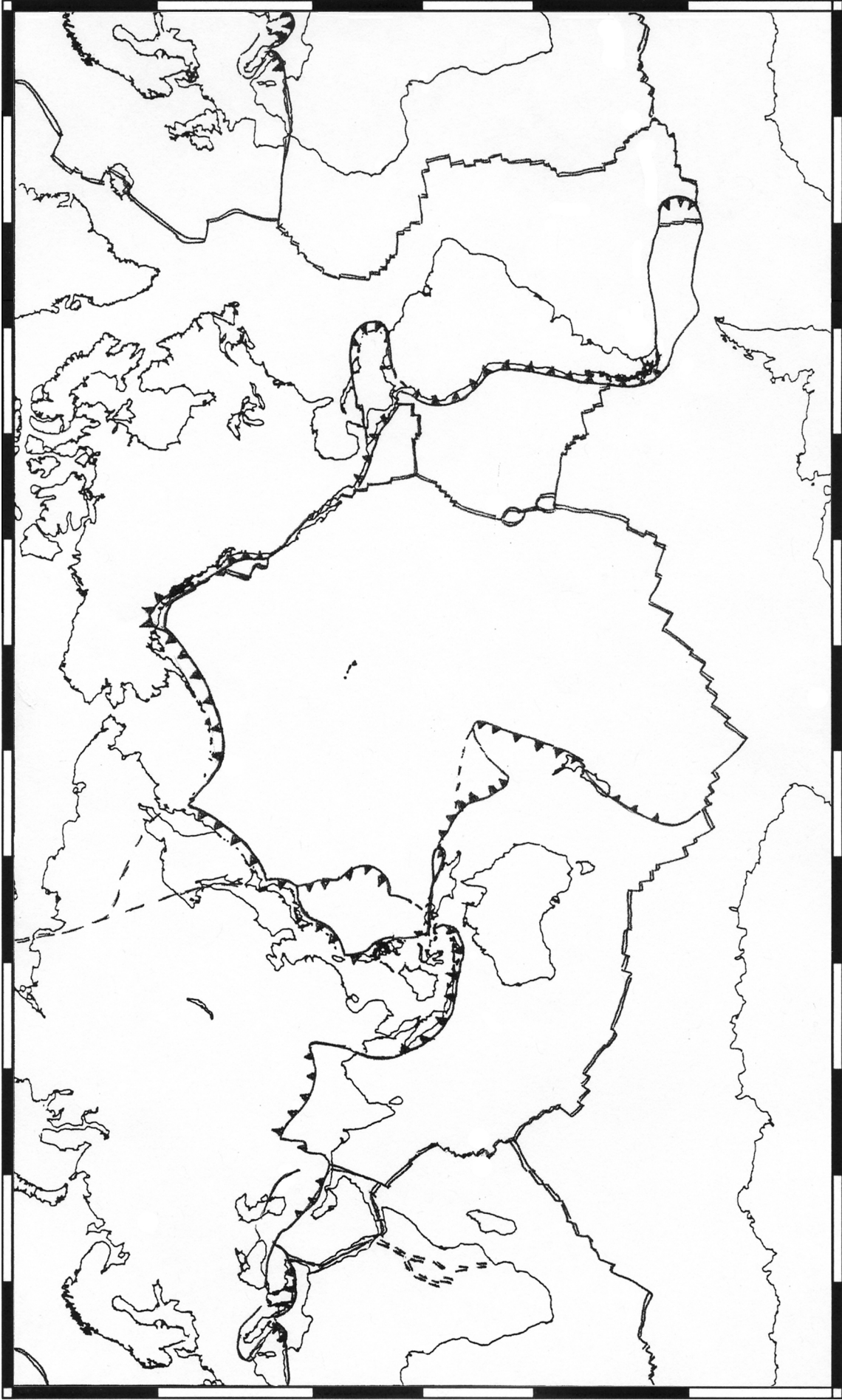


**SHALLOW SEISMICITY**

**FOCAL DEPTHS < 70 KM**

**MAGNITUDE > 4.5**

N.E.I.C. - I.C.S. earthquake data base  
from U. S. Geological Survey, National Earthquake Information Center  
Thanks to Lamont-Doherty Earth Observatory Data Base, 1990.



Locations of world plate boundaries

- spreading center
- transform fault
- subduction zone or continental collision

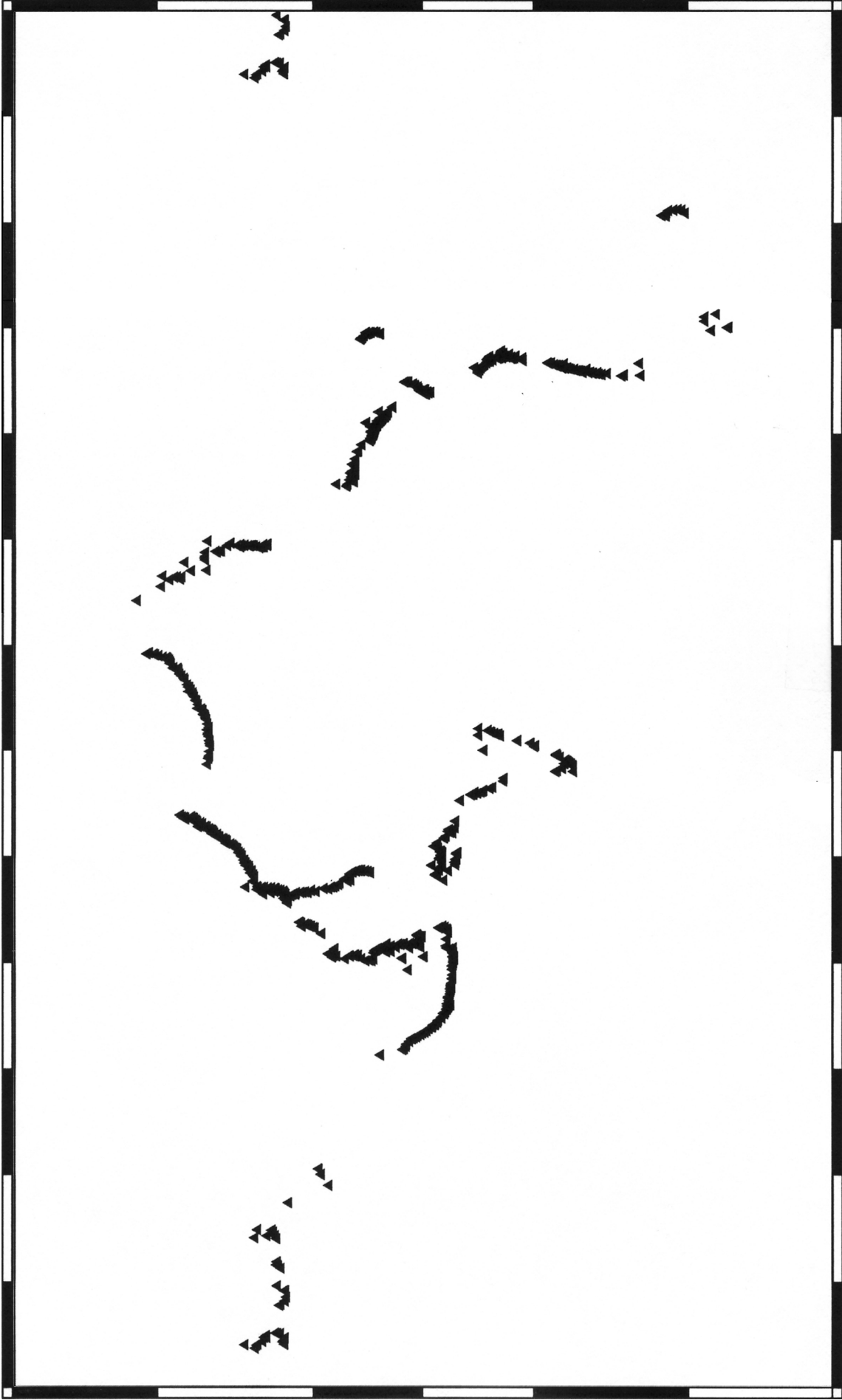


**DEEP SEISMICITY**

**EARTHQUAKES WITH FOCAL DEPTHS 70-700 KM**

**MAGNITUDE > 5.5**

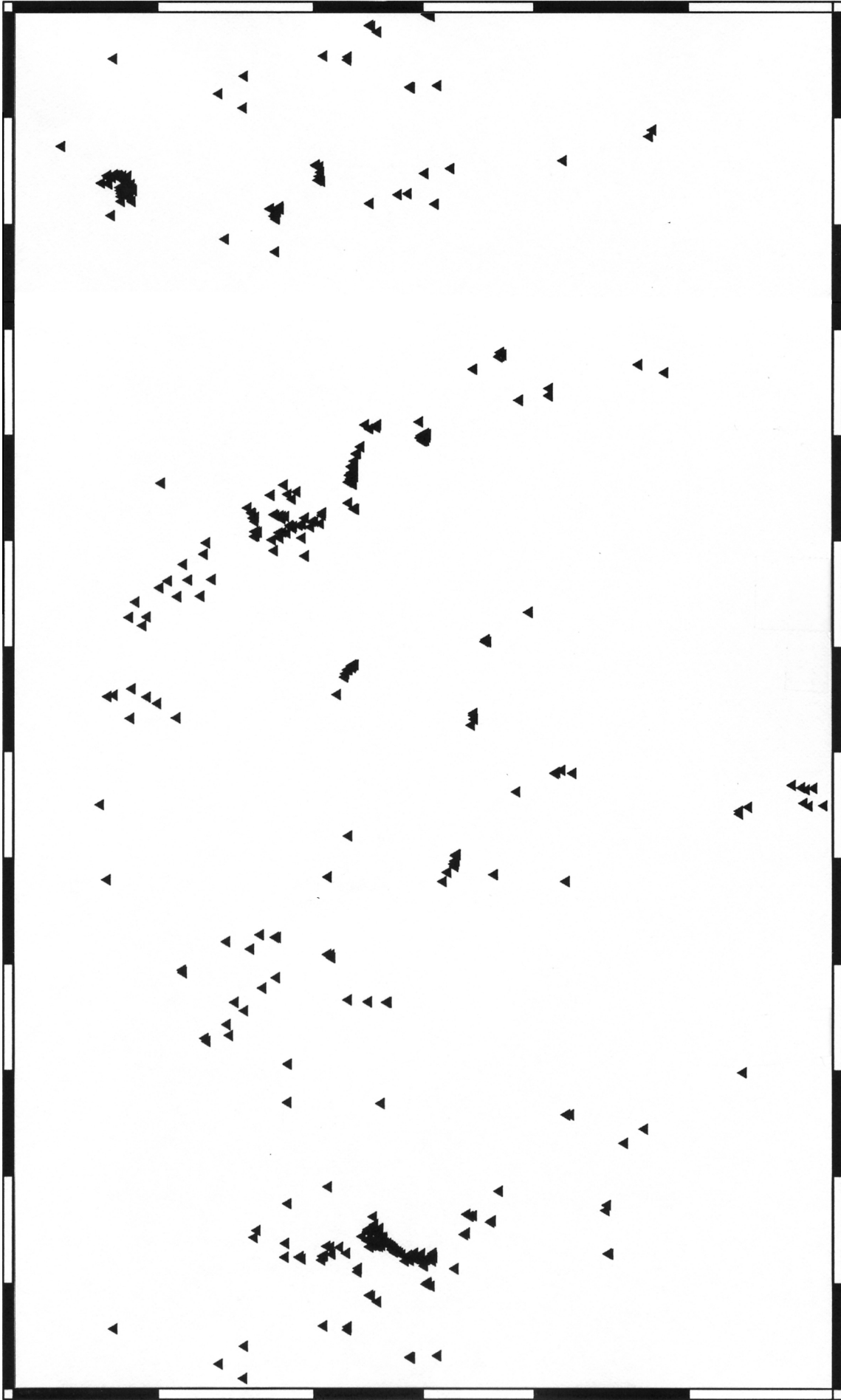
N.E.I.C. - I.C.S. earthquake data base  
from U. S. Geological Survey, National Earthquake Information Center  
Thanks to Lamont-Doherty Earth Observatory Data Base, 1990.



**WORLD DISTRIBUTION OF ARC VOLCANOES**

after T. Simkin, *Volcanoes of the World*, Hutchinson Ross Pub. Co., Stroudsburg, Penn., 1981

Thanks to Lamont-Doherty Earth Observatory Data Base, 1990.



## WORLD DISTRIBUTION OF SUSPECTED HOT SPOT VOLCANOES

after T. Simkin, *Volcanoes of the World*, Hutchinson Ross Pub. Co., Stroudsburg, Penn., 1981

Thanks to Lamont-Doherty Earth Observatory Data Base, 1990.

# World Earthquakes and Volcanoes Map Exercise

## Possible answers and background info for the Discussion Questions.

### Part 1, Earthquakes.

**Spreading centers:** How well do the shallow earthquakes locate and delineate the spreading centers? Compare slow spreaders vs fast spreaders (e.g. Atlantic vs Pacific)

They show the spreading centers very well for slow and medium rate centers (Atlantic Ocean, western Indian Ocean), less well for the fast spreaders (Pacific and eastern Indian Ocean).

*The ocean crust at fast spreading centers is too warm and weak to build up enough stress for medium/large earthquakes.*

**Transform faults:** How well do the shallow earthquakes locate and delineate the transform faults? Compare oceanic transform faults vs continental fault systems like the San Andreas.

All the oceanic transform faults are well shown by lines in the shallow earthquakes.

The continental transforms show up but tend to have broader seismic zones.

*Continental boundaries are always more diffuse (see Plate interiors, below).*

**Continental collision zones:** How well do the shallow earthquakes locate and delineate the Continental collision zones? Are these clear, narrow plate boundaries?

The continental collisions show up as broad deformation zones. During the collision, many new breaks are formed and many older breaks are re-activated.

**Subduction zones:** Why is the earthquake band at subduction zones so wide?

The plate descends into the mantle at an angle so, when seen from above, the earthquakes look like a band, with the shallowest earthquakes at the outer, ocean-ward edge and the slightly deeper ones at the inner, continent-ward edge.

*Note that the "shallow seismicity" map includes earthquakes down to 70 km deep.)*

Where are the deep earthquakes located compared to the shallow earthquakes?

They are on the inner, continent-ward side, showing that the subducting plate continues down into the mantle under the continent.

Where is the trench located within the shallow earthquake band?

It is along the outer, ocean-ward edge, where the dipping zone intersects the surface.

Find two subduction zone segments that are a-seismic; i.e., they have almost no earthquakes.

Cascade subduction zone (under Oregon and Washington states) and southern Chile.

*Both of these zones are subducting young, warm oceanic crust at very slow rates.*

**Plate interiors:** Are the plate interiors completely a-seismic? Compare oceanic vs continental plate interiors.

There are some earthquakes in each of the plate interiors, but they are much more common within the continental plates.

*The continental crusts are much more complex since they contain flaws from all the previous events over their long histories (more than 4000 million or 4 billion years). The oceanic plates are much simpler since they are just made at sea floor spreading centers, drift passively across the oceans, and are destroyed at subduction zones, all in about 200 million years.*

## Possible answers and information about the Discussion Questions.

### Part 2, Volcanoes.

**Arc Volcanoes:** How are the arc volcanoes placed with respect to the bands of shallow and deep earthquakes along the subduction zones?

They occur on the continents, i.e., on the continent-ward side of the trenches.

*They rise to the surface over the downgoing plates where the plates encounter the hot, almost molten mantle, about 100 km deep. When the plate releases its water into the hot mantle, it melts.*

Find two subduction zone segments that have no arc volcanoes.

There are two patches of the Andes (Peru and central Chile) that have no volcanoes, even though robust subduction is occurring.

*Earthquakes in the downgoing plates show that these plate segments are subducting at very low angles, so that they are in direct contact with the over-riding plate and the hot mantle can't get in between them.*

**Hot Spot Volcanoes:** In general, is there a relationship between the locations of the hot spot volcanoes and the plate boundaries?

Almost none, except that a few of them occur near spreading centers.

*This implies that the hot spots probably originate from some process not related to the plates. It appears that some come all the way up from the core-mantle boundary (3000 km deep!), so they may be the way that heat escapes from the core.*

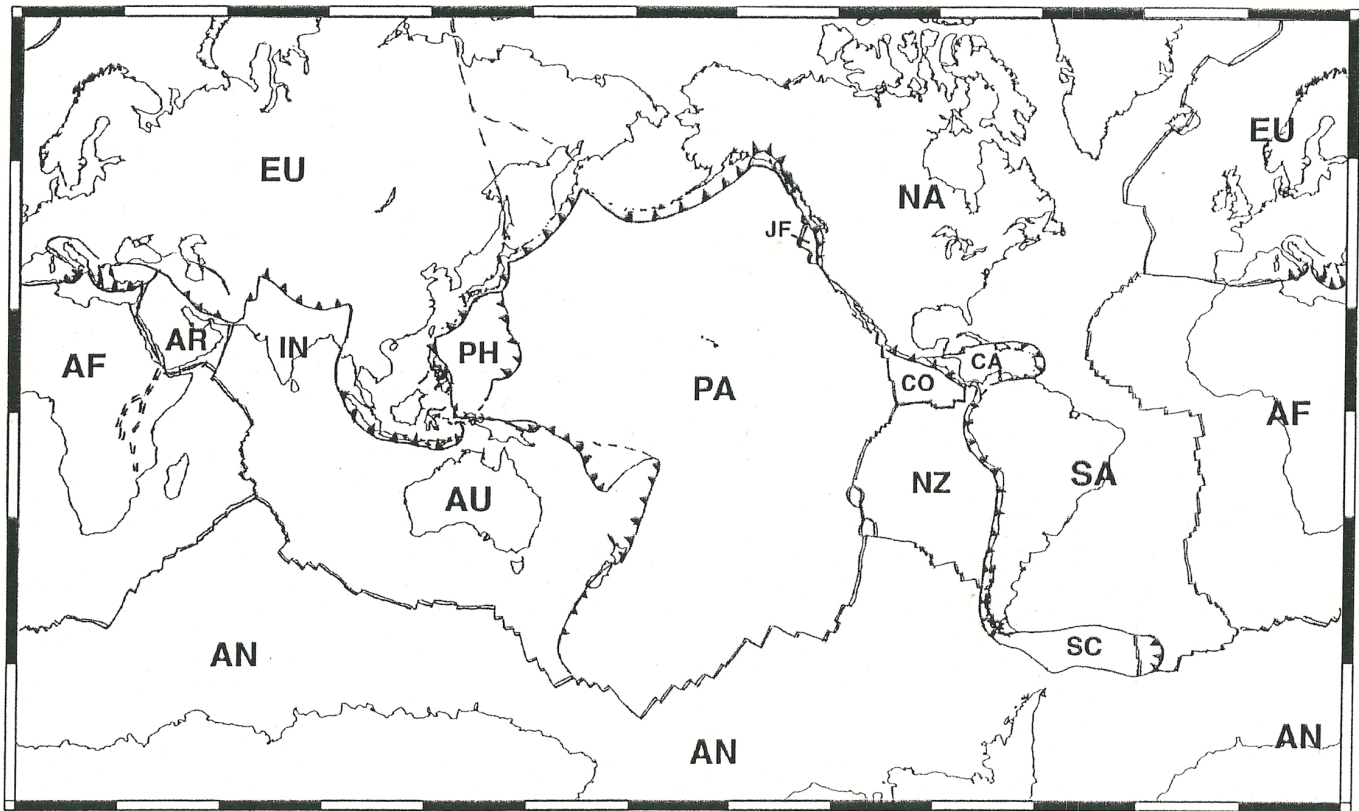
Why, do you suppose, some of the hot spots (e.g., Iceland, Azores, Easter, Galapagos, Afar, East Africa) are near spreading centers?

Since the hot spots break through the surface plates and warm them up, any nearby spreading center is likely to relocate into this weaker crust.

*Thus, the locations of these spreading centers is controlled by the hot spot locations, not vice-versa.*



## Names of Earth's Major Plates



Earth's major plates

┆ spreading center    ┆ transform fault    ┆ subduction zone or continental collision

**MAP 3A**

NA: North American,  
CA: Caribbean,  
SA: South American,  
EU: Eurasian,  
AF: African,  
AR: Arabian,  
IN: Indian,  
AU: Australian,  
PH: Philippine,  
AN: Antarctic,  
PA: Pacific,  
NZ: Nazca,  
CO: Cocos,  
JF: Juan de Fuca.