

Challenge Worksheet



Geophysics of Earthquakes

Lab 4: Plate Tectonics & Earthquakes

- Your Mission:** (1) Investigate the relationship between tectonic plates, earthquakes, volcanoes, and other geophysical data through a computer mapping program.
- (2) Execute a simple calculation of how tectonic plates move.

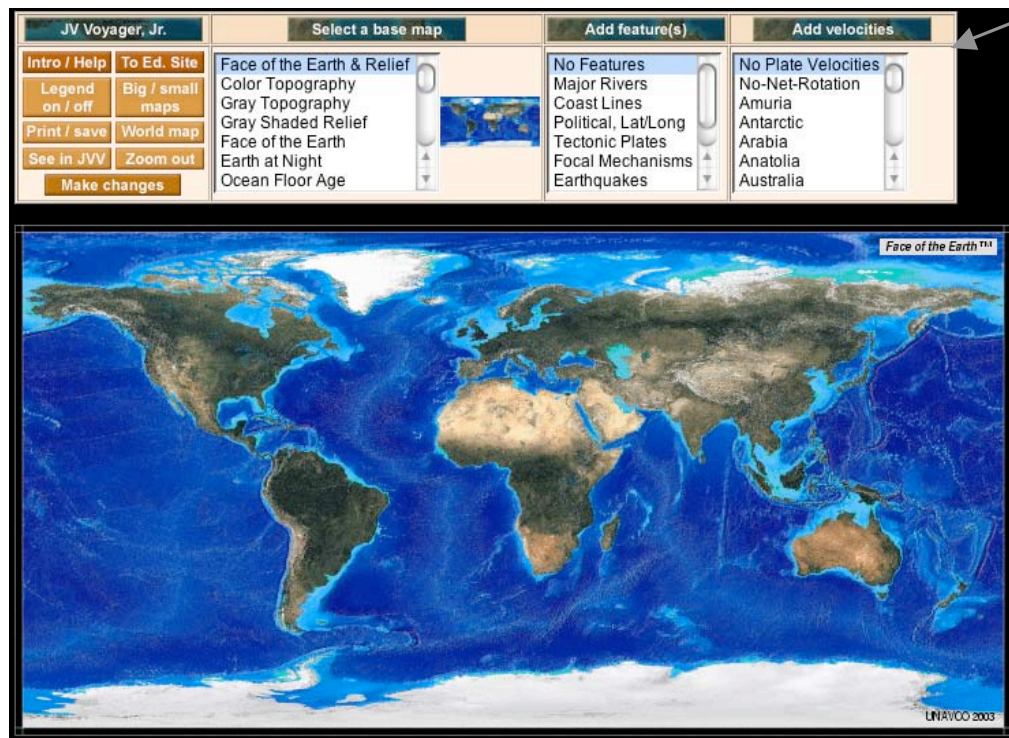
Your Supplies:

- (1) Earth's Tectonic Plates map handout
- (2) Protractor

Your Task: In this lab we are going to explore the nature of Earth's tectonic plates by using a new web-based mapping tool called the "*Jules Verne Voyager, Jr.*". To do this, login to a computer in the computer lab and open up Internet Explorer.

- (1) **Get started:** Type in the web address: <http://jules.unavco.org/VoyagerJr/Earth> and press return. This webpage provides a web-based mapping tool using state-of-the-art scientific observations such as satellite images, topography, rock ages, tectonic plates, plate motions, etc. You may want to bookmark it.

The webpage should look something like this:



Control panel

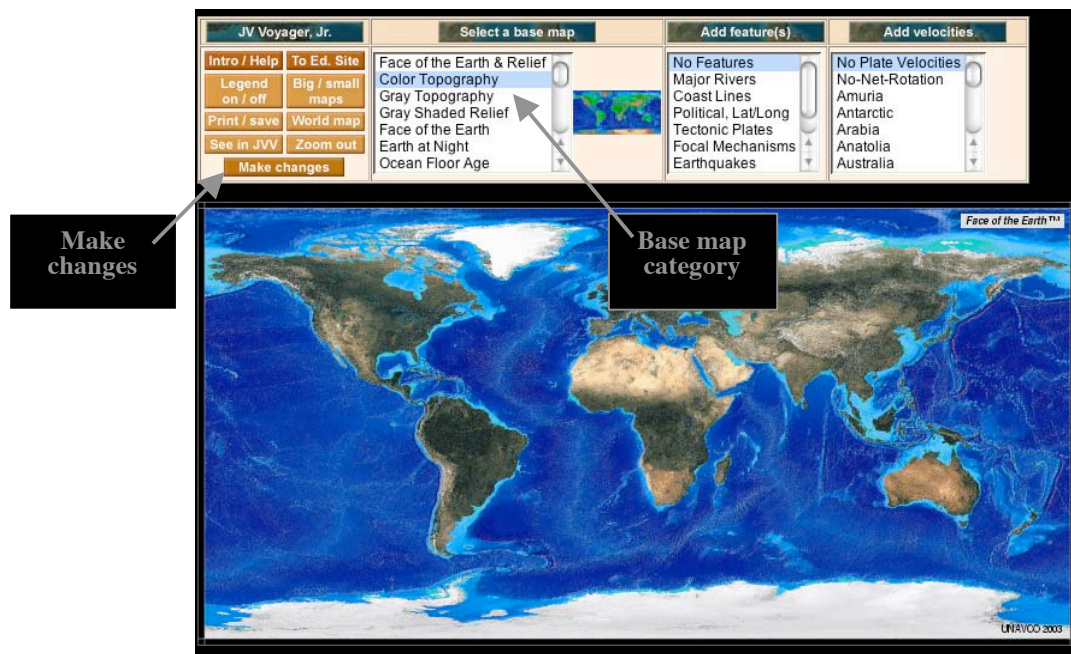
(2) **Background Information:** There is a lot of helpful information about this mapping tool available by clicking on the **JV Voyager, Jr.** button in the upper left corner of the control panel. Below are a few basic features to help you navigate your way through the website, but feel free to play around with the controls for a few minutes.

(3) **Practice using the website:** There are 6 tools of this website that you first need to practice before proceeding:

- (1) **Base map**
- (2) **Features**
- (3) **Velocities**
- (4) **Map Legend**
- (5) **Zoom**
- (6) **Restoring the view**

1. Base map: This tool includes a list of maps and satellite image databases that you can use for the background (also called base map) of your plots.

To view a new base map, click on your selection (Example: **Color Topography**) and click on the **Make changes** button.



The **Color Topography** base map, for example, would look like this:



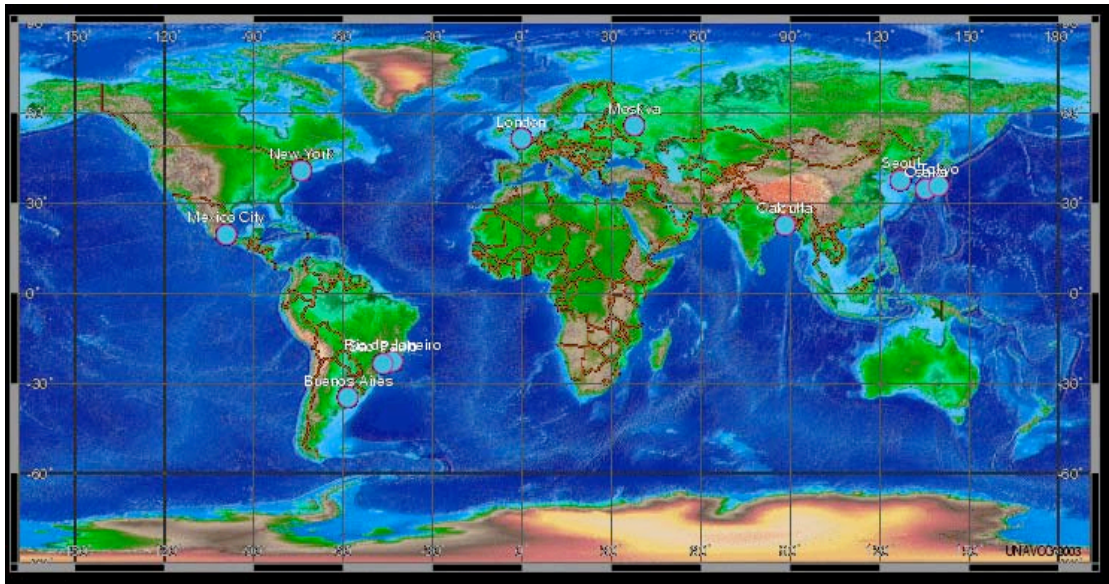
- 2. Add Features:** This tool allows you to overlay a variety of geological and geophysical features on top of your base map.

To view a feature, click on your selection (Example: **Political, Lat/Long**) and click on the **Make changes** button.

Note: to select more than one feature, hold down the CTRL key



The **Political, Lat/Long** feature, for example, would look like this:



- 3. Add Velocities:** This category allows you to overlay velocity vectors (represented by arrows that indicate the direction and speed of plate movement) on your base map. These velocity data originate from GPS (Global Positioning System) observations and modeling (we'll talk about this more in the upcoming weeks). The options under this category allow you to select a preferred 'reference frame'.

No-net-rotation shows how each of the plates moves with respect to the Earth's deep interior. Alternatively, you can select a specific plate and have all velocities reflect the motion of the other plates if you were to hold that selected plate completely still. You can also choose between **Model** and **Obs.** (observed) velocity options that show either a model of the velocity or the real (observed) data.

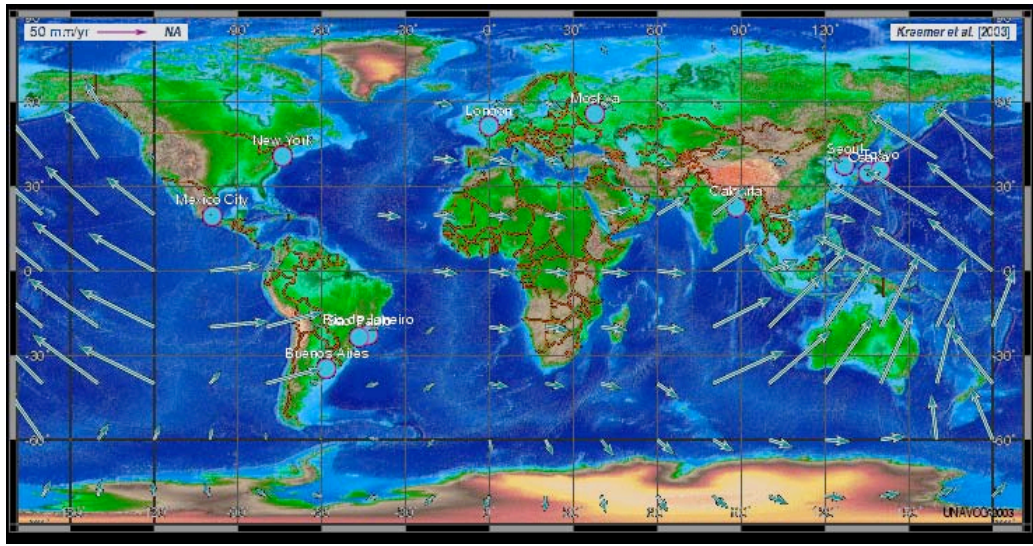
To view a velocity, click on your selection (Example: **N. America**) and click on the **Make changes** button.

JV Voyager, Jr.	Select a base map	Add feature(s)	Add velocities
Intro / Help To Ed. Site Legend on / off Big / small maps Print / save World map See in JVV Zoom out Make changes	Face of the Earth & Relief Color Topography Gray Topography Gray Shaded Relief Face of the Earth Earth at Night Ocean Floor Age	No Features Major Rivers Coast Lines Political, Lat/Long Tectonic Plates Focal Mechanisms Earthquakes	N. America Nubia Nazca Okhotsk Pacific Philippine Rivera Model Obs. Both

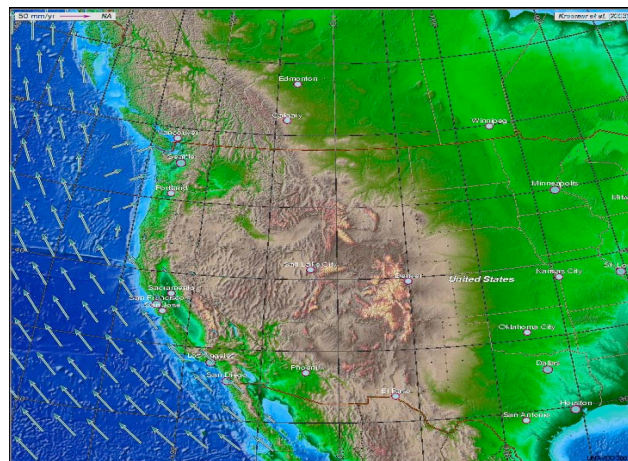
Make changes

velocities category

The **N. America** velocity reference frame, for example, would look like this:



- 4. Map legend:** The Jules Vern Voyager mapping tool also features a simple legend (separate window) that identifies the **Base map**, **Features**, and velocity reference frame. The legend also indicates what each of the symbols on the map represent and where the data came from (you'll need to scroll down through the legend window). You can get rid of the legend by clicking on the **Legend on/off** button in the control Panel.
- 5. Zooming:** You can zoom into a particular region of interest by simply clicking on the map in that region. You can typically do two 'rounds' of zooming before coming to a stop. For example, clicking twice on California will bring you to zoomed-in map of the U.S.:



- 6. Resetting your view:** To reset your view to the world map, simply click on the **World map** button in the control panel.

Now you are ready to begin making maps!

Scenario #1. Earth's Plates

Directions:

- Clear any previous setting by clicking on the **World Map** button, then select the **Face of the Earth & Relief** base map, **No Features**, and **No Velocities**. Click on **Make Changes**.
- Feature(s): select **Tectonic Plates**, click on **Make Changes**.
- Legend: click on **Legend on/off** if you do not already have a legend window visible. Note: the legend window will help you identify the types of plate boundaries.
- Zoom: you may need to zoom in and out to better inspect the plate boundaries.
- Using this map on your computer screen and the Tectonic Plates map handout, answer the following questions to help guide your exploration.

Note: it may also be helpful to select the Gray Topography base map to better view the plate boundaries. You can swap back and forth if necessary.

Challenge Question 1: Which appears to be the largest plate on the Earth?

Challenge Question 2: Which appears to be the smallest plate?

Challenge Question 3: Which plate(s) does/do California reside on?

Challenge Question 4: Which plate(s) does/do New Zealand reside on? Hint: New Zealand is an island located southeast of Australia.

Now use the table on the next page to complete the following information about each of the 13 major plates:

1. enter the names of the neighboring plates
2. enter the types of boundaries (convergent, divergent, transform) linking the listed plate to its neighboring plates

Plate Name	Neighboring Plates	Plate boundaries (convergent, divergent, transform)
African		
Antarctic		
Arabian		
Australian		
Caribbean		
Cocos		
Eurasian		
Indian		
Nazca		
North American		
Pacific		
Philippine		
South American		

Scenario #2. Plate Boundary Specifics

Directions:

- Base map: Same (**Face of the Earth & Relief**)
- Feature(s): Keep **Tectonic Plates** selected. Also select **Political Lat/Long** to turn on the latitude-longitude grid. Click on **Make Changes**.
- Zoom: You'll be zooming in on different regions of the map

Use the Zoom function to focus in on the following plate boundaries. Describe each plate boundary in terms of the following characteristics and enter the information in the following table:

- The plates on either side of it
- The type of expected plate motion (convergent, divergent, and transform). Note: the key to identifying the types of plate motions is displayed in the Legend window.
- The land forms associated with the plate boundary (mountains, valleys, trenches, etc.)

Plate Boundary	Plates on either side of the boundary	Type of expected plate motion (convergent, divergent, or transform)	Land forms associated with the plate boundary
A mid-ocean ridge: The northern mid-Atlantic Ridge region between Greenland & Iceland			
A subduction zone: The southwestern region of South America, along the country of Chile			
A continent-continent collision zone: The Himalayas near the India-Tibet border			

Scenario #3. Earthquakes & Volcanoes

Directions:

- Base map: Same (**Face of the Earth & Relief**)
- Feature(s): Remove **Political Lat/Long** but keep **Tectonic Plates**. In addition, select **Earthquakes** and **Volcanoes**. Click on **Make changes**.

Challenge Question: Are earthquake and volcano locations correlated in any way? If so, where do you see this? Can you explain why (what process)?

Scenario #4. Earthquakes & Plates

Directions:

- Base map: Same (**Face of the Earth & Relief**)
- Feature(s): Now de-select **Volcanoes** (keep **Earthquakes** and **Plate Boundaries**). Click on **Make changes**.
- Zoom: use the zoom utility to zoom into designated areas

Use the **Zoom** function to focus in on the following three regions:

1. West coast of South America (along Chile)
2. California
3. East of Australia (Tonga Trench)

Inspect the colors of earthquakes shown for each region. Use the map legend to figure out what the colors represent.

Challenge Question 1: What range of depths do earthquakes occur along the west coast of South America?

Challenge Question 2: What range of depths do earthquakes occur in California?

Challenge Question 3: What range of depths do earthquakes occur along the Tonga Trench (east of Australia)?

Challenge Question 4: What kind of plate boundary runs through California?

Challenge Question 5: What kind of plate boundary runs through Chile and the Tonga Trench?

Challenge Question 6: From your answers above, what conclusions can you make about plate boundaries and the depths of earthquakes?

Challenge Question 7: What pattern of earthquake depths do you notice along the boundaries along Chile and the Tonga Trench? (ie., do they get deeper in a certain direction? Which directions?)

Scenario #5. Plate Motions

Now we'll begin using the measurements of plate motion obtained through Global Positioning System (GPS) measurements and explore the relationship between movements of the surface of the Earth and the world's plate boundaries.

For this exercise, we'll be using the 'other' reference frame: No-Net-Rotation (NNR) reference frame. NNR is the motion of each plate with respect to the average of all the world's plate velocities. It is sometimes referred to as 'absolute plate motion', since it appears to approximately represent the motions of the surface plates with respect to the Earth's deep interior.

Using the velocity vectors shown on your computer screen, you will be estimating (by eye) the motion of the plates. Note that to fully describe the velocity, you will need to specify two quantities: the rate (usually measured in the units of mm/yr) and the direction (usually estimated in degrees measured clockwise from north). The rate can be estimated by comparison with the 50 mm/yr reference arrow shown in the **legend**. The direction can be measured by using a protractor placed against the screen. The direction (or azimuth) is measured in degrees clockwise (cw) from NORTH.

Directions:

- Base map: Same (**Face of the Earth & Relief**)
- Feature(s): Remove **Earthquakes** but keep **Tectonic Plates**.
- Legend: click on **Legend on/off** if you do not already have a legend window visible. Note: the legend window will help you identify the velocities of the plates and their direction of motion.
- Velocities: Select **No-Net-Rotation**, then the **Model** velocity field button. Click on **Make changes**.

Using the estimated plate velocities indicated by the blue velocity arrows on your map, answer the following questions:

Challenge Question 1: Which of the world's plate(s) appears to have the **highest** plate velocity? What does this mean?

Challenge Question 2: Which of the world's plate(s) appears to have the **lowest** plate velocity?

Challenge Question 3: What is the approximate direction of motion of the Australian Plate measured in degrees from the north?

Challenge Question 4: What is the approximate magnitude of motion of the Australian Plate (10 mm/yr?, 60 mm/yr?)?

Challenge Question 5: What is the approximate direction of motion of the Pacific Plate measured in degrees from the north?

Challenge Question 6: What is the approximate magnitude of motion of the Pacific Plate (10 mm/yr?, 60 mm/yr?) ?

Scenario #6. Calculating Plate Motions

Now we'll estimate the motion of the world's major plates and check these estimations against those predicted by a global plate motion calculator. Scientists have developed a calculator that computes the predicted motion for any point on the Earth's surface.

Directions:

- Base map: Same (**Face of the Earth & Relief**)
- Feature(s): Select **Political, Lat/Long**
- Velocities: Same (**No-Net-Rotation**). Click on **Make changes**.
- Zoom: Use the zoom utility to examine detailed maps as necessary.

Estimate the direction and magnitude of plate motion for the following table entries for Chicago & Honolulu. Enter your answers in the boxes highlighted in **RED**:

Location	Latitude	Longitude	Your estimated Plate Motion Direction (degrees from N)	Calculator result for Plate Motion Direction (degrees from N)	Your estimated Plate Motion Magnitude (mm/yr)	Calculator result for Plate Motion Magnitude (mm/yr)
Chicago, Illinois	42	-88				
Honolulu, Hawaii	21	-158				

Next open a new window in Internet Explorer (File → New Window) and type in the following internet address:

http://sps.unavco.org/crustal_motion/dxdt/nrcalc/

This is the internet address for the Plate Motion Calculator.

To use the Plate Motion Calculator, simply type in the latitude and longitude from above (in the 'degrees North' and 'degrees East' boxes) and click on the Submit button at the bottom of the green box:

Latitude:	<input type="text" value="32"/> degrees North <input type="text"/> minutes North <input type="text"/> seconds North <small>E.g. enter the latitude as -56.25 degrees or -56 degrees 15 minutes for 56 degrees 15 minutes South.</small>
Longitude:	<input type="text" value="-117"/> degrees East <input type="text"/> minutes East <input type="text"/> seconds East <small>E.g. enter the longitude as -102.5 degrees or -102 degrees 30 minutes for 102 degrees 30 minutes West.</small>
Height:	<input type="text"/> height (meters) <small>optional WGS-84 height of geographic coordinate (default = 0 meters)</small>
XYZ:	<small>... or enter the position in WGS-84 XYZ coordinates:</small> <input type="text"/> X (meters) <input type="text"/> Y (meters) <input type="text"/> Z (meters)
Site Name:	<input type="text"/> Site Name <small>optional, only for printout; for example: AIRP</small>
Multiple Geographic Coordinates (Lon Lat Height):	<small>... or enter multiple geographic positions (lon,lat in decimal degrees; height in meters) with optional site name; each position must be comma delimited from the others:</small> <input type="text"/>
Multiple XYZ:	<small>... or enter multiple WGS-84 XYZ positions (meters) with optional site name; each position must be comma delimited from the others:</small> <input type="text"/>
Model:	<input type="text" value="GSRM 1.2 (2004)"/>
Tectonic Plate of Attributed Motion:	<input type="text" value="Auto"/> <small>Auto = plate (based on plate selection of NUVEL 1A model) is determined automatically; other = plate is user-selected</small>
Reference:	<input type="text" value="NNR no-net-rotation"/> <small>motion referenced to NNR frame or fixed-plate, or HS "hotspot" frames for HS2-NUVEL1A or HS3-NUVEL1A models</small>
Your own pole of attributed motion:	<small>note: must be selected in Tectonic Plate menu above to use!</small> <input type="text"/> latitude of pole (°) <input type="text"/> longitude of pole (°) <input type="text"/> rotation rate (°/Myr) <small>or enter the pole in XYZ coordinates:</small> <input type="text"/> x-component of pole (°/Myr) <input type="text"/> y-component of pole (°/Myr) <input type="text"/> z-component of pole (°/Myr)
Your own reference pole:	<small>note: must be selected in Reference menu above to use!</small> <input type="text"/> latitude of pole (°) <input type="text"/> longitude of pole (°) <input type="text"/> rotation rate (°/Myr) <small>or enter the pole in XYZ coordinates:</small> <input type="text"/> x-component of pole (°/Myr) <input type="text"/> y-component of pole (°/Myr) <input type="text"/> z-component of pole (°/Myr)
Output format:	<input type="text" value="HTML table"/>
<input type="button" value="Submit"/> <input type="button" value="Reset"/>	

The Plate Motion Calculator will output a result looking something like this:

UNAVCO Plate Motion Calculator Output:								
Model	Latitude	Longitude	Speed mm/yr	Azimuth (cw from N)	N Vel. mm/yr	E Vel. mm/yr	Plate (reference)	Site Name
GSRM v1.2	42° N 42.000000°	90° W -90.000000°	15.58	257.56°	-3.36	-15.21	NA(NNR)	

The answers that you will be looking for will be under the “Speed” and “Azimuth” (meaning direction) boxes, as circled in red.

Use the plate motion calculator to calculate the motion at Chicago and Honolulu. Enter these results in the table above.

Challenge Question: How well do your estimated plate motion rates agree? What might explain the differences between the two sets of measurements?

Scenario #7: Now it is your turn to get creative and explore the JV Voyager mapping tool on your own. Create your own individualized map by selecting an interesting base map, features, and if you want, plate velocities. *Caution: only use base maps and features that you understand and can explain to the class!* Zoom in as far as you can to an area of interest and, when you are finished, print your map out on the colored printer. You may also want to print out the Legend window. Be prepared to share a few interesting aspects of your map with the class.

