**Inquiry Labs Information Sheet**

**1. Name of Lab: Plate Tectonics and the Scientific Process**

* Module 1: Development of the Theory of Plate Tectonics
* Module 2: Discovering Plate Boundaries
* Tutorial: How to Use Google Earth (Pre-lab for Modules 3-5)
* Module 3: Using Google Earth Pro to Build Context
* Module 4: Using Google Earth Pro to Calculate and Manipulate Data
* Module 5: Using Google Earth Pro to Evaluate Tectonic Hazards

**2. Authors:**

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**3. Delivery Format** - This is intended for an asynchronous online course, however, it can be adapted for other modalities. It consists of five interchangeable learning, plus a tutorial module on how to use Goo gle Earth Pro and this data set. As numbered, they are scaffolded guided-inquiry activities. They can be used alone or rearranged to meet the needs of the instructor. These may be used as in-class activities or as lab activities. The tutorial and modules 3-5 require the use of a computer, and cannot be done on a tablet, Chromebook or similar device.

**4. Audience:** Students in introductory geology, physical geography, oceanography or planetary geology courses.

**5. Learning Objectives:**

*By the end of this activity, students will be able to …*

**Module 1: Development of the Theory of Plate Tectonics**

• Explain the scientific process using the development of the theory of plate tectonics

• Discuss why multidisciplinary studies and a diversity of voices in the sciences were necessary for the synthesis of the theory of plate tectonics

• Compile the evidence in support of plate tectonics

**Module 2: Discovering Plate Boundaries**

• Learn the locations and names of the major and minor lithospheric plates

• Recognize the boundary types that define each plate

• Explain the geologic phenomena associated with each type of boundary

• Describe the relative motion of the plates and the data that support this description

• Apply knowledge of plate boundaries, and their consequences, to create an internal image of a part of Earth’s anatomy

**Tutorial: How to Use Google Earth (Prelab for Modules 3-5)**

• Load and manipulate Google Earth files

• Pull data out of visual datasets

• Take screenshots of work and make annotations to submit for grade

**Module 3:**  **Using Google Earth Pro to Build Context**

**•** As part of Plate Tectonics Theory, describe how certain plate boundaries lead to specific physiographic features (mid-ocean ridges are formed at divergent plate boundaries, and deep oceanic trenches are formed at convergent plate boundaries)

• Using topographic profiles with Google Earth visualization software, identify mid-ocean ridges and deep oceanic trenches

• Develop a spatial understanding of where ridges and trenches are situated in relation to tectonic boundaries

• Evaluate tectonic processes (earthquakes and volcanoes) at mid-ocean ridges and deep oceanic trenches, and how features are produced from plate tectonic motions

• Conceptualize the earth’s interior in the vicinity of mid-ocean ridges and trenches.

**Module 4: Using Google Earth Pro to Calculate and Manipulate Data**

• Develop a spatial understanding of plate motion data

• Conceptualize how plate motions differ in speed, direction, and time (e.g. plate motions are not constant)

• Use plate motion data to examine geological processes more fully (hot spot volcanism and seafloor spreading)

**Module 5: Using Google Earth Pro to Evaluate Tectonic Hazards**

• Relate data across different kinds of datasets

• Use data to infer initial tectonic events or margins as a mechanism for observed disasters

• Demonstrate ability to design a geological research study

**6. Intended levels of Inquiry included (per Buck et al., 2008)**

**Module 1: Development of the Theory of Plate Tectonics**

This is a Level 3: Guided-Inquiry module

**Module 2: Discovering Plate Boundaries**

This is a Level 2-3: Guided-Inquiry module

**Tutorial: How to Use Google Earth (Prelab for Modules 3-5)**

This is a Level 3: Guided-Inquiry module.

**Module 3:**  **Using Google Earth Pro to Build Context**

This is a Level 3-4: Guided Inquiry module

**Module 4: Using Google Earth Pro to Calculate and Manipulate Data**

This is a Level 3-4: Guided Inquiry module

**Module 5: Using Google Earth Pro to Evaluate Tectonic Hazards:**

This is a Level 4-5: Open Inquiry module

**7. Expected Prior Knowledge (e.g. previous lab activities)**

These modules are set for early in the term (first or second lab) and are intended to guide the students to an understanding of the topic and use of the technology. Therefore, no previous knowledge is expected beyond the introductory lecture content.

**8. Expected Time for Lab (or for modifications)**

This is not one 3-hour lab. It is a series of scaffolded activities that can be used together to present a comprehensive look at Plate Tectonic theory in a guided inquiry-style course. Any one of these modules could be used as a stand alone lab activity.

**Module 1: Development of the Theory of Plate Tectonics**

1 ½ hours to complete.

**Module 2: Discovering Plate Boundaries**

2 hours to complete.

**Tutorial: How to Use Google Earth (Prelab for Modules 3-5)**

This activity should take students 1 ½ to 2 hours to complete but may take more depending upon their comfort using Google Earth Pro Desktop (assuming they have no prior experience). It may also take some time to download and install the program and data file to their hard drive. Advise them to have patience.

**Module 3:**  **Using Google Earth Pro to Build Context**

2 hours to complete.

**Module 4: Using Google Earth Pro to Calculate and Manipulate Data**

2 hours to complete.

**Module 5: Using Google Earth Pro to Evaluate Tectonic Hazards**

1 to 2 hours to complete.

**9. Materials Required:**

Students must have access to the internet, Google Earth Pro (free download), scanner or scanner app, and word processing software. Students must use the desktop version of Google Earth only, and therefore, a laptop or desktop is required for them to complete this assignment. Chromebooks and tablets will not run this software application. Alternative images can be created for mobile-only formats.

The instructor will need to download and post the file: Plate Tectonics Lab-Lines of Evidence.KMZ for the students to use.

**10. Materials Provided**

**a. Student Files:**

Module 1 Plate Tectonics Pre-Lab Reading.docx

*Files for Module 1 Readings and video (in zipped folder):*

* Earth science\_ How plate tectonics clicked \_ Nature News \_ Comment.pdf
* How Diversity Makes Us Smarter - Scientific American.pdf
* Seeing Is Believing\_ How Marie Tharp Changed Geology Forever \_ History \_ Smithsonian Magazine.pdf
* A\_002\_PlateTectonicHistory.mp4

Module 1 Student.docx

Module 2 Student.docx

Module 2 Maps.pdf

GE\_Training Student.docx

Module 3 Student.docx

Module 4 Student.docx

Module 5 Student.docx

Google Earth data files: *Plate Tectonics Lines of Evidence.kmz*

**b. Instructor Materials:** Instructor teaching notes, answer keys and some grading rubrics.

 Inquiry Labs Information Sheet *(this page)*

Module 1 Instructor.docx

Module 2 Instructor.docx

GE\_Training Instructor.docx

Module 3 Instructor.docx

Module 4 Instructor.docx

Module 5 Instructor.docx

**10. References**

**Module 1: Development of the Theory of Plate Tectonics**

*Pre-lab:*

*Deline, Bradley; Harris, Randa; and Tefend, Karen, "Laboratory Manual for Introductory Geology" (2015). Geological Sciences and Geography Open Textbooks. 1.*[*https://oer.galileo.usg.edu/geo-textbooks/1*](https://oer.galileo.usg.edu/geo-textbooks/1)

*Earle, S. (2019). Physical Geology – 2nd Edition. Victoria, B.C.: BCcampus. Retrieved from* [*https://opentextbc.ca/physicalgeology2ed/*](https://opentextbc.ca/physicalgeology2ed/)

*In this activity, students are asked to read and respond to several articles. PDF versions are provided within the module folder.*

*Blakemore, Erin. Seeing is Believing: How Marie Tharp Changed Geology Forever, Smithsonian Magazine, August (2016).* [*https://www.smithsonianmag.com/history/seeing-believing-how-marie-tharp-changed-geology-forever-180960192/*](https://www.smithsonianmag.com/history/seeing-believing-how-marie-tharp-changed-geology-forever-180960192/) *Retrieved 20 August 2020.*

*Oreskes, N. Earth science: How plate tectonics clicked. Nature* ***501,*** *27–29 (2013).* [*https://doi.org/10.1038/501027a*](https://doi.org/10.1038/501027a) *Retrieved 20 August 2020.*

*Phillips, Katharine W. How Diversity Makes Us Smarter, Scientific American, October (2014).* [*https://www.scientificamerican.com/article/how-diversity-makes-us-smarter/*](https://www.scientificamerican.com/article/how-diversity-makes-us-smarter/) *Retrieved 20 August 2020.*

**Module 2: Discovering Plate Boundaries**

*This activity is a variation on an original activity, Discovering Plate Boundaries developed by Dale Sawyer at Rice University.*

*Sawyer, Dale S., Alison T. Henning, Stephanie Shipp, Robyn W. Dunbar. A Data Rich Exercise for Discovering Plate Boundary Processes, Journal of Geoscience Education, v. 53, n. 2, p. 65-74. 2005.*

*A similar activity and the high-resolution maps come from the Teach The Earth website from SERC:*

*Plate Tectonics Jigsaw, by Anne Egger of Central Washington University, https://serc.carleton.edu/NAGTWorkshops/intro/activities/29360.html Retrieved: 18 Sept. 2020.*

*Similar Activities and Further Reading:*

* *Johnson, Chris, Matthew D. Affolter, Paul Inkenbrandt, and Cam Mosher. An Introduction to Geology – Salt Lake Community College, online publication (http://opengeology.org/textbook/) 2017.*
* *Kious, W. Jacquelyne and Robert I. Tilling. This Dynamic Earth: The Story of Plate Tectonics, Third Edition, U.S. Geological Survey, Geologic Investigations Map I-2800, online publication (https://pubs.usgs.gov/gip/dynamic/dynamic.html) 2006.*
* *Reid, Leslie F., Ben Cowie, Michelle Speta. Learning Assessment #1 – Plate Tectonics, Dept. Geoscience, Univ. Calgary. Univ. Alberta. (https://serc.carleton.edu/NAGTWorkshops/intro/activities/65696.html) 2012.*
* *O’Dunn, Shannon and William D. Sill. Exploring Geology, T.H. Peek Publishers, Palo Alto, CA. 292 p. 1988.*

**Module 3:**  **Using Google Earth Pro to Build Context**

*Educational Multimedia Visualization Center website, 3 - Regional Plate Tectonics, Global Views, South Pacific: Drift and Seafloor Spreading, draft animation,* [*http://emvc.geol.ucsb.edu/2\_infopgs/IP3RegTect/eSoPacific.html*](http://emvc.geol.ucsb.edu/2_infopgs/IP3RegTect/eSoPacific.html) *Retrieved: 5 August 2020*

*Similar activities can be found at Teach The Earth website from SERC:*

* *Investigating Plate Tectonics with Google Earth by Beth Pratt-Sitaula of UNAVCO,* [*https://serc.carleton.edu/NAGTWorkshops/structure/SGT2012/activities/63925.html#file144342*](https://serc.carleton.edu/NAGTWorkshops/structure/SGT2012/activities/63925.html#file144342) *Retrieved: 5 August 2020*
* *Introduction to Plate Tectonics by Elizabeth Cochran, University of California, Riverside https://serc.carleton.edu/NAGTWorkshops/geophysics/activities/19435.html Retrieved: 5 August 2020*

**Module 4: Using Google Earth Pro to Calculate and Manipulate Data**

*Nail (anatomy). Wikipedia.org Website, https://en.wikipedia.org/wiki/Nail\_(anatomy). Retrieved 12 August 2020.*

*Hotspotting in the Pacific. Seth Stein Teaching Demonstration Website, https://sites.northwestern.edu/sethstein/a-small-is-beautiful-approach-to-upgrading-a-beginning-geophysics-course/hotspotting-in-the-pacific/. Retrieved 18 August 2020.*

*Simple Euler Poles. Seth Stein Teaching Demonstration Website, https://sites.northwestern.edu/sethstein/simple-euler-poles/. Retrieved 18 August 2020.*

*Wilson, J. Tuzo, “A Possible Origin of the Hawaiian Islands.” Canadian Journal of Physics, vol. 41, No. 6, 1963, pp. 863-870, doi:10.1139/p63-094.*

*Similar activities can be found at Teach The Earth website from SERC:*

* *Determining Plate Rates From Hot Spot Tracks Using Google Earth by Susan Schwartz and Erin Todd, University of California-Santa Cruz, https://serc.carleton.edu/integrate/workshops/online\_learning/activities/178208.html Retrieved: 17 August 2020*
* *Similar activities with plate velocity calculations and investigations of hotspot tracks:*
* *Kortz, Karen, and Jessica Smay. “Hotspots.” Lecture Tutorials for Introductory Geoscience, Third, W. H. Freeman, 2019.*
* *Robinson, Laurel and Klosko, Eryn. “Hotspots”. Earth Science Lecture Tutorial Activities, 2019, CC BY-NC-SA 4.0 license.*
* *Tarbuck, Edward, et al. “Plate Tectonics”, Applications and Investigations in Earth Science (9th Edition). 9th ed., Pearson, 2018.*

**Module 5: Using Google Earth Pro to Evaluate Tectonic Hazards**

*Atwater, B.F., Musumi-Rokkaku, S., Satake, K., Tsuji, Y., Ueda, K., and Yamaguchi, D.K., 2015, The orphan tsunami of 1700—Japanese clues to a parent earthquake in North America, 2nd ed.: Seattle, University of Washington Press, U.S. Geological Survey Professional Paper 1707*

*Simkin, Tom, Robert I. Tilling, Peter R. Vogt, Stephen H. Kirby, Paul Kimberly, and David B. Stewart. This Dynamic Planet: World map of volcanoes, earthquakes, impact craters, and plate tectonics: U.S. Geological Survey Geologic Investigations Series Map I-2800, 1 two-sided sheet, scale 1:30,000,000. (https://pubs.usgs.gov/imap/2800/) 2006*

*Hunter, D. 2016, Thunderbird and the Orphan Tsunami: Cascadia 1700. Scientific American, a Division of Springer Nature America, Inc. January, 2016.*

*NASA Exoplanet Exploration website.* [*https://exoplanets.nasa.gov/*](https://exoplanets.nasa.gov/) *Retrieved 7/27/20*