

Developing Effective Learning Exercises in the Geosciences: Utilizing Online Databases and Data Repositories

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ABSTRACT

Using data to explain difficult geologic concepts and to illustrate fundamental spatial relationships has long been an important aspect of geoscience education. Because online databases and mapping tools are readily available, students can now collect, manipulate, visualize, and analyze large geoscience datasets easily. As such, these online resources give educators an excellent opportunity to develop a large range of active and experiential learning exercises. Within the classroom, these exercises foster open discussions and challenge students to explore current geoscience issues. These exercises are also an important way for students to apply knowledge and to develop fundamental skills necessary for a career in the geosciences. This contribution focuses on the development of online exercises specific to upper- and lower-division geoscience courses.

At the lower-division level (physical geology, environmental geology, and natural hazards), some specific online exercises include: 1) evaluating flooding recurrence intervals through online data from the USGS National Water Information System; 2) evaluating the rate of plate movements using JPL GPS time series data; and 3) evaluating climate data using NOAA National Centers for Environmental Information. In upper-level igneous petrology courses, research specimens and bulk geochemical rock analyses can be incorporated into lab activities, giving students a first-hand opportunity to explore data with a real geologic context. By comparing bulk rock analyses to analytical data retrieved from online repositories (e.g. EarthChem, NAVDAT, GEOROC), students are better able to recognize the fundamental relationships between the chemistry of an igneous rock and its associated tectonic setting. Thus, activities like these give students a greater appreciation for hypothesis testing, data collection, analysis, and interpretation. These exercises also increase the amount of time students spend in the learning cycle outside of class, which is arguably an important factor influencing student performance.

TEACHING OBJECTIVE

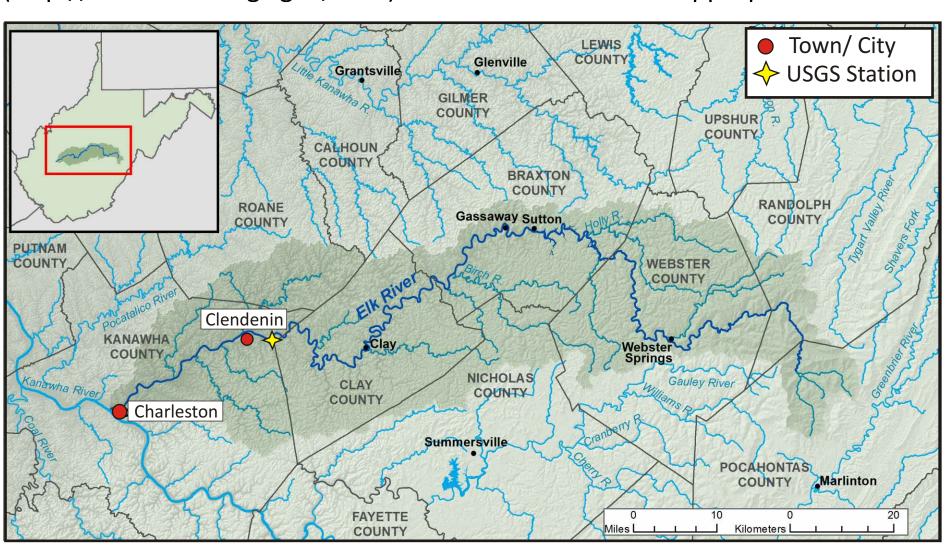
As educators, we are challenged with keeping students engaged and actively participating during class. Regardless of the approach we take, our efforts must resonate beyond the classroom. One method of keeping students engaged is to use exercises that demonstrate the relevance of course topics to everyday life. Exercises centered around online databases and repositories are an excellent way to accomplish this task. These exercises keep students engaged, reinforce lecture content, and promote science literacy. Key Earth Science Literacy Principles (http://www.earthscienceliteracy.org/) addressed in these exercises include

- 1) Earth Scientists use repeatable observations and testable ideas to understand and explain our planet
- 2) The Earth is constantly changing and evolving through time
- 3) Water is an essential component of the Earth
- 4) Humans have the capability to significantly alter the Earth

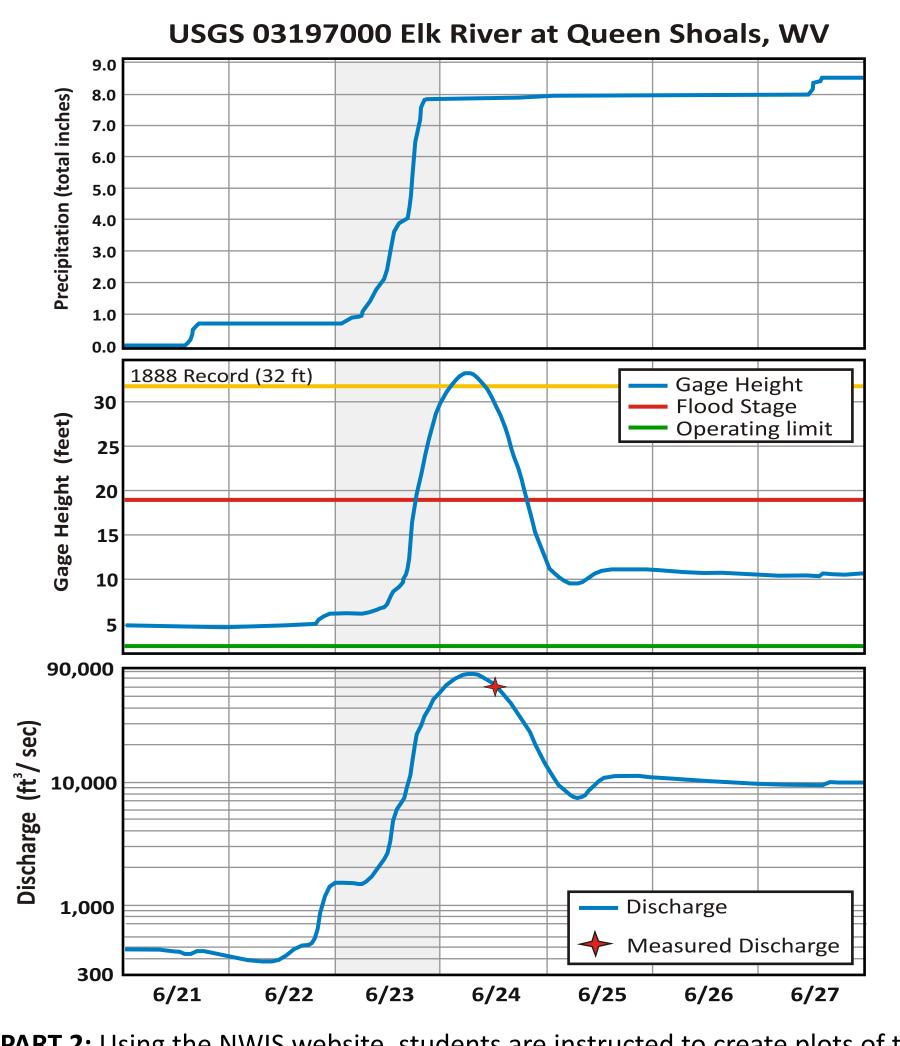
LOWER-DIVISION EXERCISE

GEOHAZARDS EXERCISE

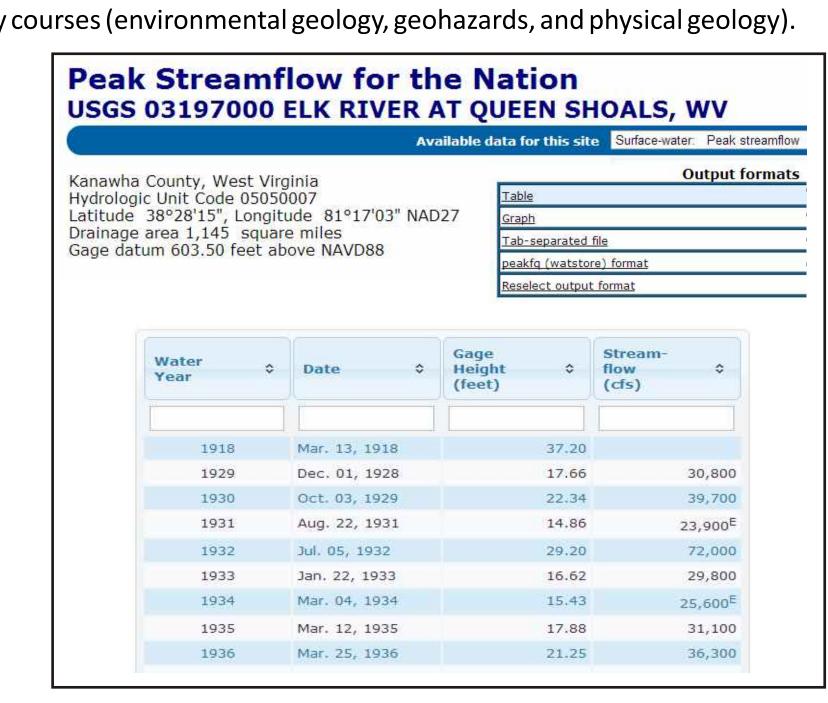
On June 23, 2016, torrential rainfall produced widespread flooding throughout much of West Virginia. Along the Elk River in Kanawha County, the small town of Clendenin, WV was especially hit hard (see map below). To help illustrate the importance and magnitude of this event, students are asked to evaluate streamflow data collected by the USGS. In this exercise, students access online data stored on the USGS National Water Information System (NWIS) website (http://waterdata.usgs.gov/nwis). This exercise would be appropriate for introductory courses (environmental geology, geohazards, and physical geology).



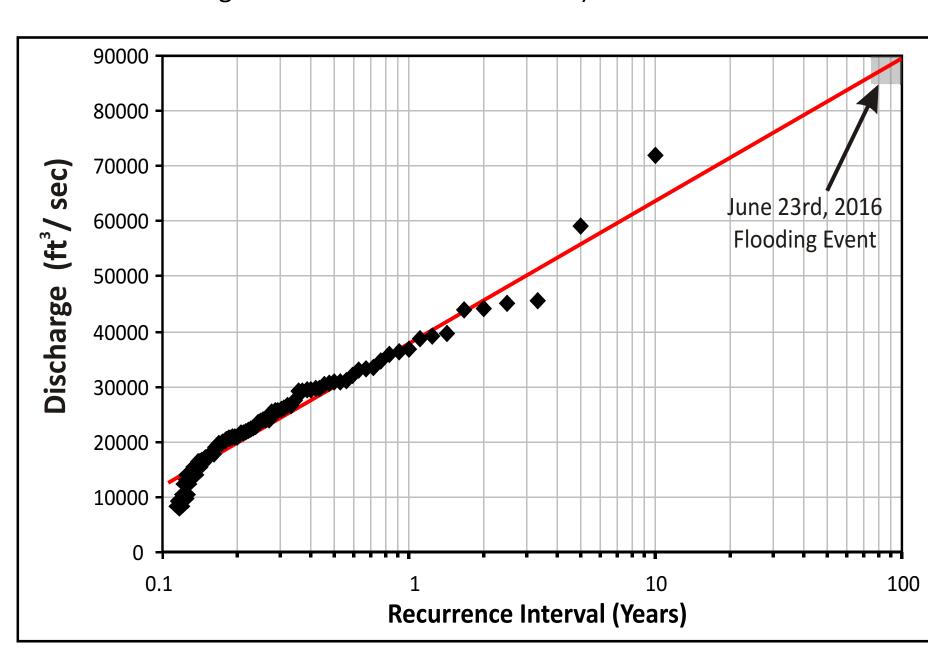
PART 1: First, students must locate the Elk River and the town of Clendenin, WV (Image above - Elk River watershed, modified from www.wikipedia.org).



PART 2: Using the NWIS website, students are instructed to create plots of the streamflow data. The plots above contain NWIS data for USGS station 03197000 (Elk River at Queen Shoals, WV from June 21, 2016 to June 27, 2016).



PART 3: Using the NWIS website, students are instructed to navigate to the annual peak streamflow data for the Elk River. The image above is a screen capture, showing the different types of output formats available. The students are expected to download the raw data and import it into a spreadsheet (see Part 4 - calculating the recurrence interval below).



PART 4: After importing the data, students analyze the Elk River peak streamflow events. Once they record their observations, students determine the recurrence interval of the 6/23/16 event. The image above illustrates the rating curve for the Elk River, showing annual peak streamflow data from Dec. 1st, 1928 to present. Students then complete a series of guided questions and participate in active discussions regarding the impact of this event and the term "100-year flood".

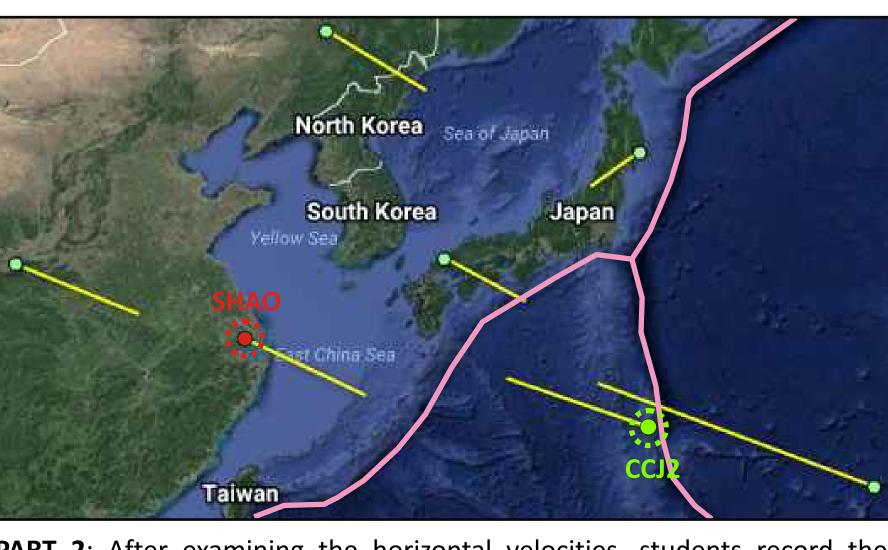
LOWER-DIVISION EXERCISES

GPS TIME SERIES EXERCISE

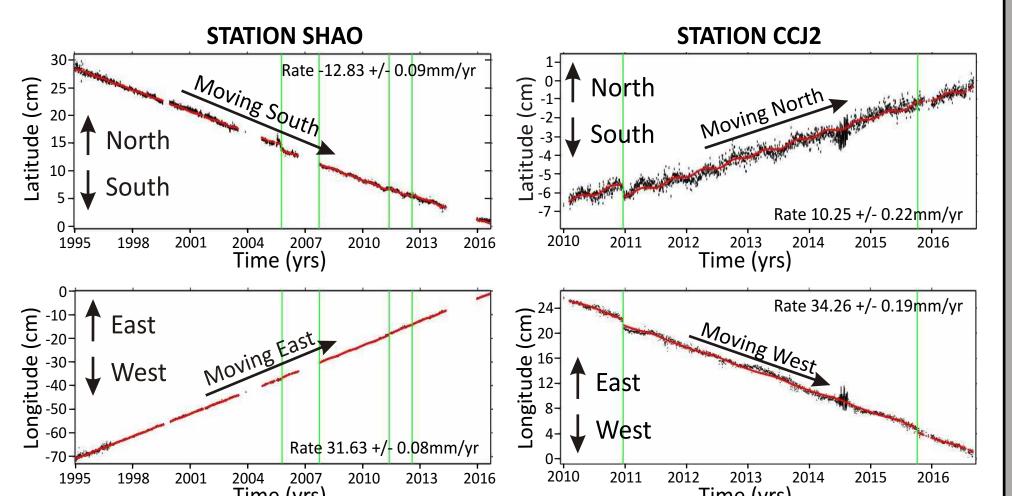
Following a brief introduction to plate tectonics, students are asked to complete an in-class exercise that is aimed at 1) helping students visualize the movements o tectonic plates; 2) recognize plate boundary types; and 3) calculate the rates and directions of plate motions. This exercise is appropriate for introductory courses and requires students to access the global positioning data stored on the NASA Jet Propulsion Laboratory GPS Time Series website (http://sideshow.jpl.nasa.gov/post/series.html).



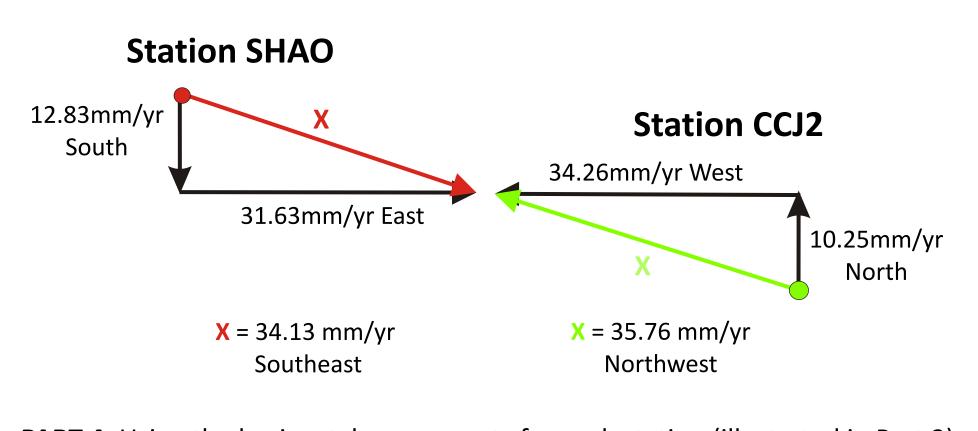
PART 1: Using the interactive Google map tool, students are instructed to locate specific GPS stations. (Image above - screen capture from NASA JPL website highlighting stations SHAO and CCJ2).



PART 2: After examining the horizontal velocities, students record their observations, predict plate boundary types, and sketch the plate boundary on the map (Image above shows plate boundary sketch - pink line).



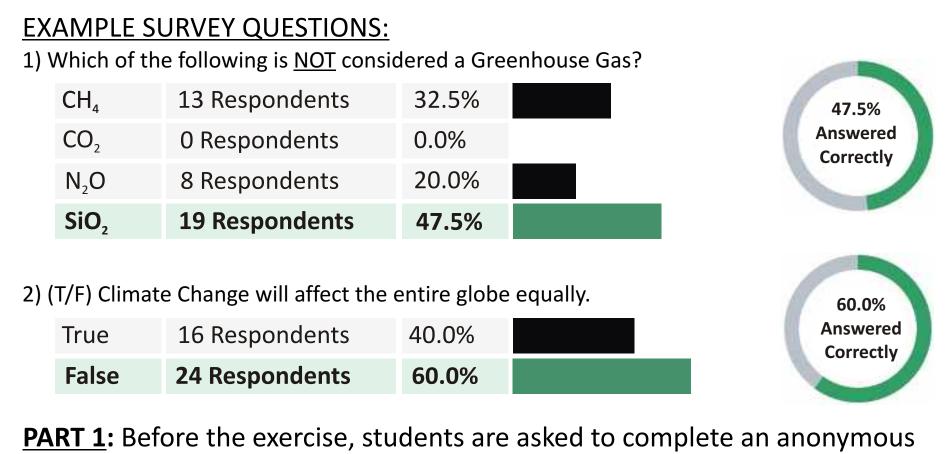
PART 3: Students then examine the online GPS time series data to determine the relative motions of each GPS station. As an example, station SHAO (above left) shows a decrease in latitude with time (moving south) and an increase in longitude with time (moving east). The overall direction of station SHAO is southeast.



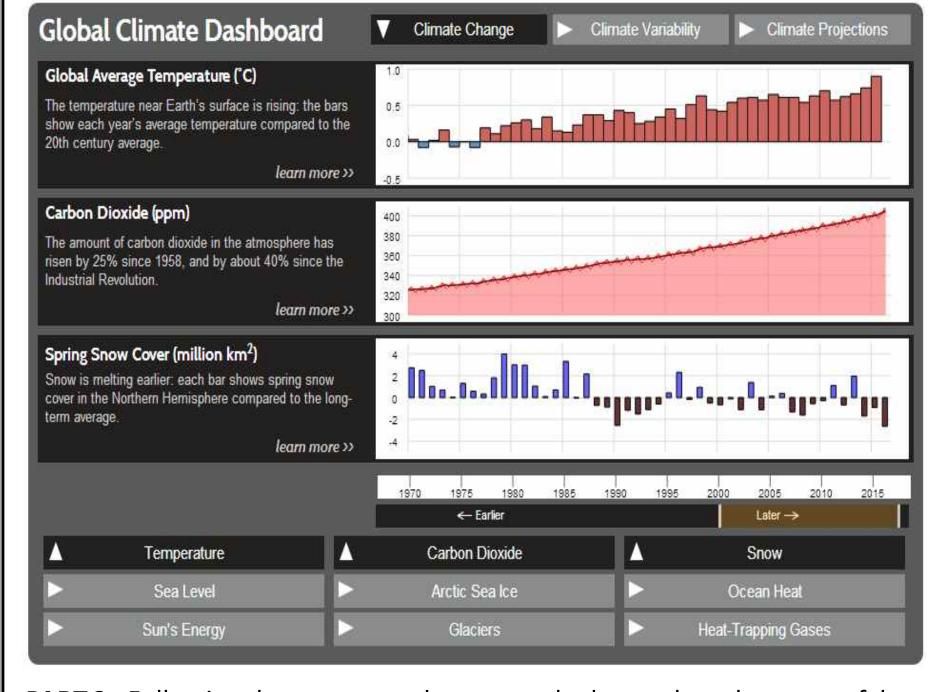
PART 4: Using the horizontal components for each station (illustrated in Part 3) students are then asked to create a simple sketch of the relative motions for both GPS stations (shown above). After making the sketch, the students calculate the final horizontal velocity for each station and determine the rate of plate motions.

CLIMATE CHANGE EXERCISE

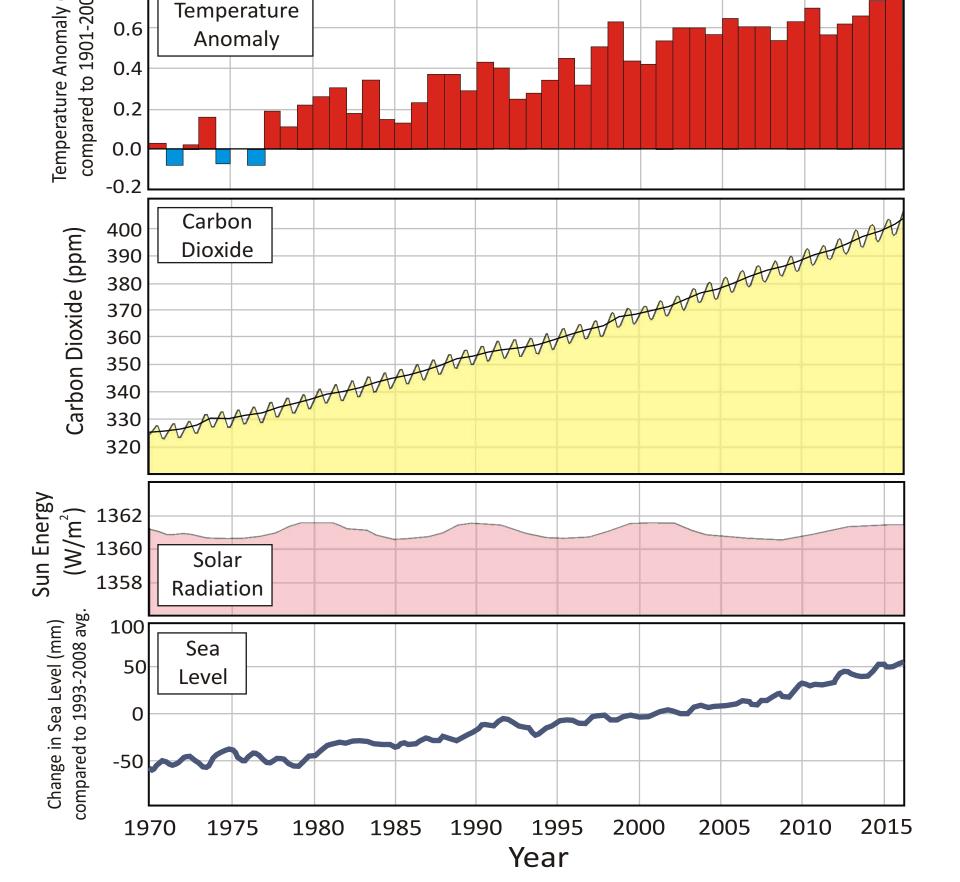
Climate change is becoming an increasingly more important topic to society. Thus, giving students an opportunity to examine climate-related data allows them to reach their own conclusions about the changes occurring to our planet. Following a brief introduction, students are asked to complete an exercise that analyzes climate change data. This exercise requires students to access online data stored on the NOAA Climate.gov website (https://www.climate.gov/).



survey regarding climate change. This survey helps to assess student perceptions and their current understanding of key information about climate change. Illustrated above are some examples of questions and responses used in this assessment (N=40 students).

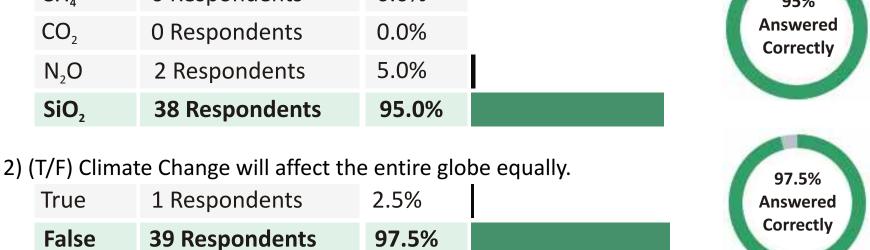


PART 2: Following the survey, students are asked to explore the range of data available on the website. This allows them to become familiar with the website and to explore their curiosity. The image above is a screen capture of the "Global Climate Dashboard" on the NOAA Climate.gov website. For this exercise, students are instructed to examine the data within each of the nine categories located on the dashboard (at the bottom of the image).



PART 3: Illustrated above are plots from the global climate dashboard categories (temperature anomaly, carbon dioxide, solar radiation, and sea level). Students are expected to analyze each of the trends in the data, evaluate potential correlations, and record their observations.

Post-Exercise Assessment: 1) Which of the following is <u>NOT</u> considered a Greenhouse Gas?



PART 4: Following the exercise, students complete the survey again. Student responses are evaluated to assess the quality of student learning.

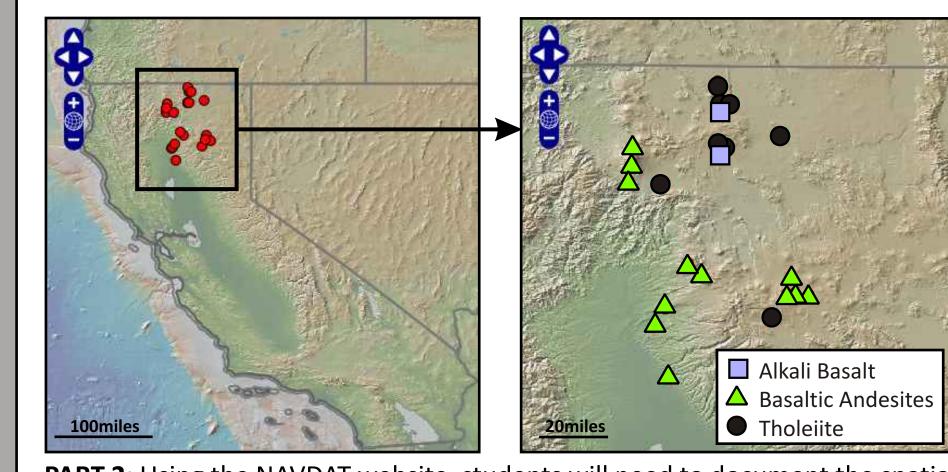
UPPER-DIVISION EXERCISE

PETROLOGY-GEOCHEMISTRY EXERCISE

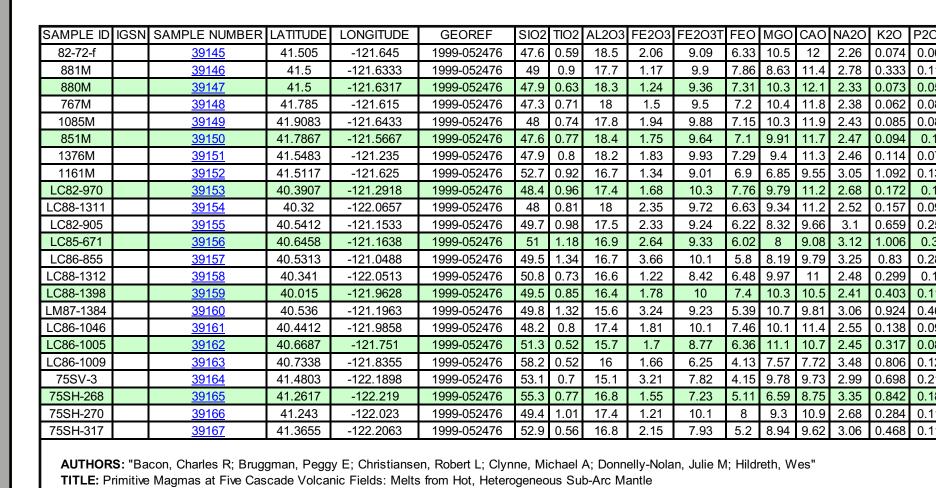
In this exercise, students use whole-rock major- and trace-element compositions of igneous rocks from the southern Cascade Volcanic Arc in the Western U.S. to evaluate the compositional diversity of volcanic fields. For this particular exercise, students are asked to download data from the North American Volcanic and Intrusive Rock Database (NAVDAT): (http://www.navdat.org/). In addition to using the NAVDAT database, students gain experience using Excel spreadsheets, interpreting geochemical data, working in groups, citing scientific sources, and formulating hypotheses. Because this exercise is aimed at upper-level undergraduate students, it may be appropriate for a lab activity in an igneous and metamorphic petrology or advanced igneous petrology course.



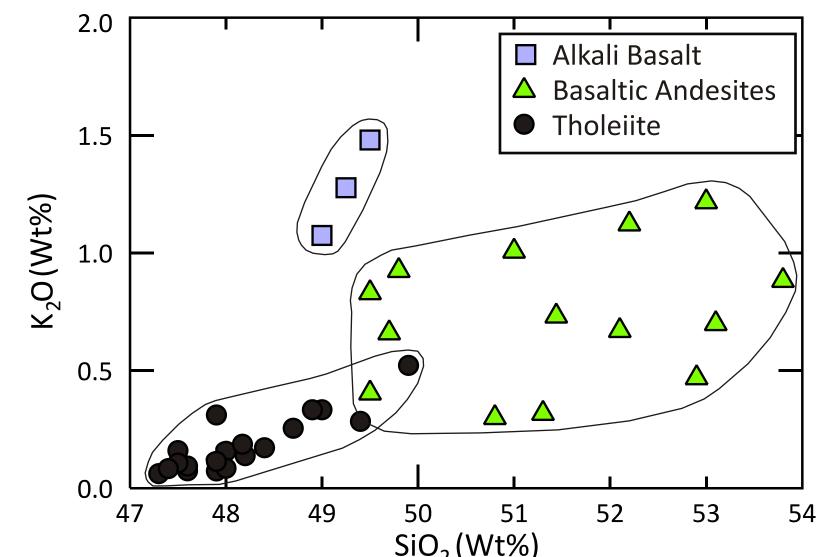
PART 1: Students are asked to navigate to the NAVDAT database to locate specific dataset. The image above is a screen capture of the NAVDAT website, showing the range of search options that students can explore.



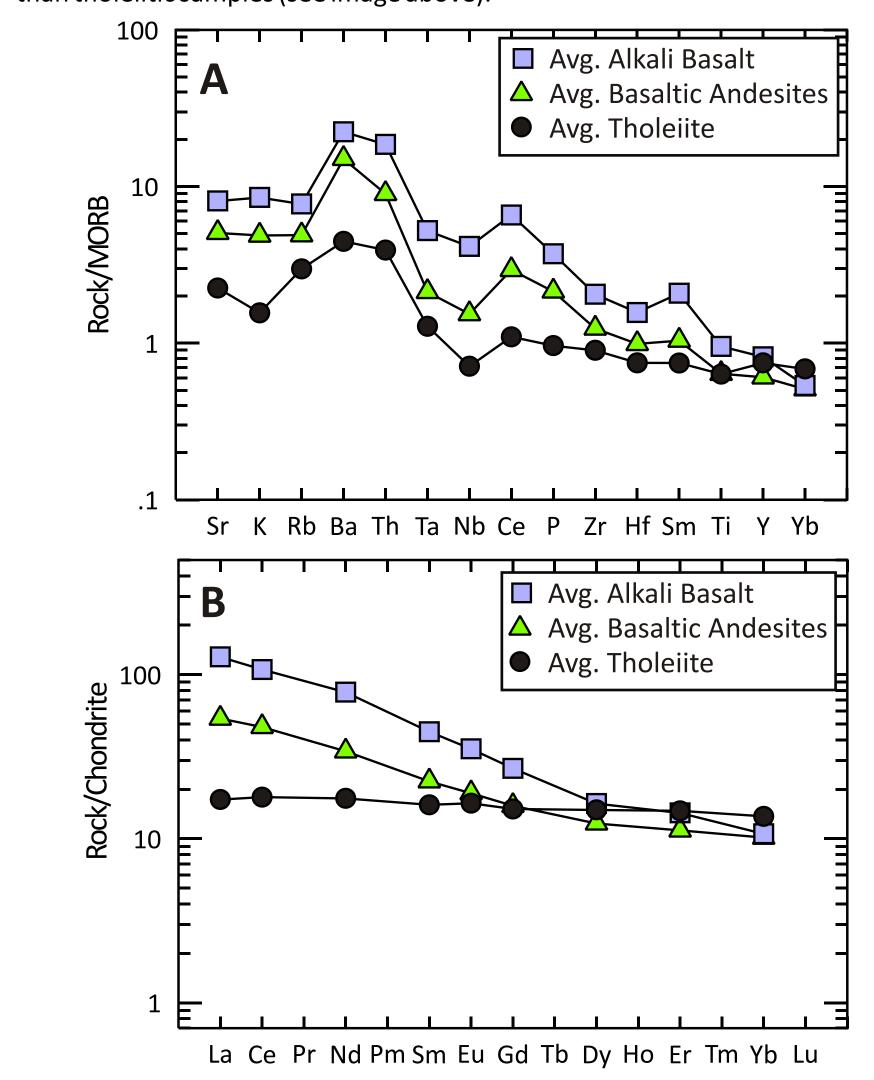
PART 2: Using the NAVDAT website, students will need to document the spatial distribution of each sample. This places the samples into a geologic context and helps the students look for spatial patterns that may help explain the geochemical diversity. The image above (left) is a screen capture from the NAVDAT website, showing the sample locations. The image above (right) shows the distribution of volcanic rock groups, as reported by Bacon et al. (1997).



PART 3: After successfully downloading the data from the NAVDAT website, students are asked to view the data in an Excel spreadsheet. The image above is a 1989). Again, students are instructed to record their observations. Throughout screen capture of the downloaded data (data from Bacon et al., 1997). this activity, students are asked open-ended questions about the data.



PART 4: One of the main objectives of this exercise is to have students explore the data, make geochemical plots (Harker Plots), and record their observations. In the plot above, for example, the alkali basalts have much higher alkali content than tholeiitic samples (see image above).



PART 5: Finally, students will need to create two additional plots that show the variability of trace element concentrations (MORB-normalized and Chondritenormalized REE plots - shown above). For this portion, students are given the normalizing data (MORB - Pearce, 1983; Chondrites - Sun and McDonough,

DISCUSSION AND FUTURE DIRECTIONS

Online databases and repositories are excellent resources for geoscience educators. Because these resources are readily accessible, they can be used to develop activities appropriate for any course (major and non-major). By creating in-class exercises that utilize these resources, an instructor can shift their course from "teacher-focused learning" to "student-focused learning". Shifting the course in this direction allows the students to take charge of their own learning with minimal guidance and direction from the instructor.

Some benefits of well-developed activities centered on online databases and repositories include:

- 1) The activities can be a lot of fun!
- 2) Promotes exploration and curiosity
- 3) Fosters open discussions among peers
- 4) Develops quantitative literacy and verbal reasoning skills 5) Promotes new ideas while reinforcing previously obtained knowledge
- 6) Provides an opportunity to analyze real data and draw valid conclusions about current geologic issues
- 7) Encourages the formulation of new hypotheses
- 8) Exercises can be easily assessed

Although these activities have already been tested in various classroom settings, ongoing work will focus on the assessment of these activities to better document the quality of student learning.

LeBas, M.J., LeMaitre, R.W., Streckeisen, A., and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745-750. · NASA - Jet Propulsion Laboratory GPS Time Series, 2016, S. Desai; W. Bertiger; J. Gross; B. Hai; N. Harvey, C. Sell; A. Sibthorpe; J. Weiss; A. Moor; S. Owen; M. Hefli; data available on the World Wide Web at (http://sideshow.jpl.nasa.gov/post/series.html).

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