ACTIVITY NAME: The Panama Passageway: Using the PBDB to constrain the timing and extent of the The Great American Biotic Interchange

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SUMMARY

Students learn how to use the Paleobiology Database to map changes in the distribution of fossil vertebrates in the Americas through time. They will generate distribution maps for several key fossil groups and use these to estimate the timing of the development of the Isthmus of Panama (connecting North and South America).

GOALS

After completing this activity, students will be able to:

- Generate maps showing the distribution of perissodactyls and glyptodonts for four different epochs of the Cenozoic Era.
- Interpret these maps in terms of their tectonic implications.
- Test their interpretation with a suite of other relevant fossil organisms.
- Test their interpretation with a set of relevant paleogeographic maps.
- Apply these techniques to other regions, times, and species, and use the PBDB to test these ideas (though not necessarily conclusively).

CONTEXT FOR USE

Educational level: To be used in an introductory or intermediate undergraduate course, including (but not limited to) physical geology, historical geology, and paleontology.

Class size: Students can work as individuals or in pairs and class size can range from a small seminar (< 10 students) to a large lecture (> 100), as long as computer facilities are available.

Institution type: Can be used with non-majors or majors from two or four year institutions. Each student or student pair will need access to a laptop or desktop computer connected to the internet, either running both Microsoft Word and an internet browser, or (if paper handouts are provided) simply running the internet browser.

Is it lab, lecture, or field exercise?
This activity can be used in lecture, lab, or as a homework activity.

How much time is needed:
30-45 minutes total, depending on the level/breadth of discussion.

Skills or concepts that students should have already mastered before encountering this activity:
Student should be able to:
- briefly describe the landscape changes that result from plate tectonic activity.
- describe the difference between terrestrial and marine organisms.
- outline the basic subdivisions of geologic time.

How is this activity situated in the course?
It may be incorporated into a lesson on late Cenozoic tectonics. It could also serve equally well as a general case study of the role of tectonics in facilitating the migration (or isolation) of species.

How easy (or hard) would it be to adapt the activity for use in other settings?
Very easy. It can be modified by picking and choosing which questions to include.

Grade level:
High school (9-12)
College (13-14)
College (15-16)

ACTIVITY DESCRIPTION AND TEACHING MATERIALS

Students use computers to access the Paleobiology Database Navigator and Ron Blakey's paleogeographic maps (at "Deep Time Maps") to evaluate the timing of the buildup of the Isthmus of Panama (and the connection of the Americas).

TEACHING NOTES AND TIPS
The activity requires a web browser, so students should be reminded to stay on task and only visit relevant websites. Googling images of the animals in question is fine (glyptodonts are very cool to contemplate, for instance), but no one should be checking Facebook. The instructor may wish to demonstrate how to narrow down the results in Navigator by taxon and time period -

using examples not relevant to this activity's focus - Cretaceous and *Tyrannosaurus*, for instance. A tutorial is available online at https://www.youtube.com/watch?v=db2He3p-Jco .

ASSESSMENT

Formative assessment: If conducted in class, the instructor should walk around and mix troubleshooting advice with informal observations of whether the relevant time periods and taxa are being investigated.

Summative assessment: The four maps with two genera each (separate during the Oligocene and Miocene, beginning to mix during the Pliocene, and on both continents during the Pleistocene) and the conclusion that the Isthmus of Panama formed during the Pliocene are key summative assessment points.

RESOURCES

Relevant web sites that students will need:
https://paleobiodb.org/navigator/
http://cpgeosystems.com/namkeyframe.html

SHORT DESCRIPTION

Students use the Paleobiology Database Navigator to examine the end of biotic "isolation" of South America relative to North America. The fossil occurrences, when plotted on a series of maps, suggest the timing for the connection of the two continents via the Isthmus of Panama.

Name _____

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Introduction

During the Cenozoic Era, volcanic and orogenic activity along the western edge of the North and South American plates created the Isthmus of Panama, uniting the North and South American continents. The Panama land bridge has had a significant effect on global climate and species migration. The land bridge obstructed westward flow of the Atlantic Ocean and is responsible for initiating the Gulf Stream that moves warm water into the North Atlantic and thus provides warmer climates to northwestern Europe. Plants, animals, and humans have migrated between the two continents as a result of the Isthmus of Panama. This activity will explore the distribution of odd-toed ungulates and giant armadillos.

Delving into the Database

Open the PBDB Navigator and spend some time getting comfortable with how it works: https://paleobiodb.org/navigator/

The Navigator consists of three parts:

1. Map (CENTER) showing continents with dots representing fossil occurrences. The color of these dots represents their geologic age. If you click on the dots, you can see all of the information on each site and the species that occur there.
2. Geologic time scale (BOTTOM) showing the major eras, periods, and stages. If you click on the timescale, the map will show you the location of fossil occurrences from a time interval.
3. Tool bar (LEFT) showing the tools you can use to explore the database. These include:

zoom in/out on the map

reconstructs plate tectonic configurations for time interval (era or smaller) you are exploring

select which taxonomic group is plotted on map

create a diversity curve for the occurrences currently plotted on map

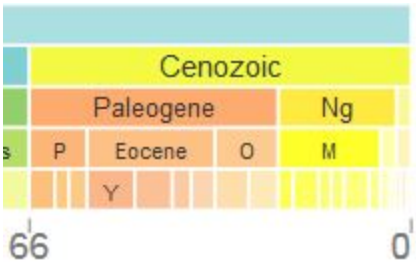
download the data (lat/long, geologic age, etc.) for the occurrences plotted on map

Need help? Here's a Youtube video to help you get started:
https://www.youtube.com/watch?v=db2He3p-Jco

Odd-Toed Ungulates

An odd-toed ungulate ("perissodactyl") is a hoofed terrestrial mammal that has an odd number of toes (*i.e.*, horses, zebras, donkeys, rhinos, and tapirs). In this part of the activity, you will be constructing distribution maps for odd-toed ungulates for the Oligocene, Miocene, Pliocene, and Pleistocene epochs.

You will need to return to the PBDB "navigator" view and filter your results to show occurrences of the order = "Perissodactyla".



Then use the time scale at the bottom of the screen to filter the fossils by epoch. If you need a refresher on the epochs of the Cenozoic, check the International Commission on Stratigraphy's time scale:
http://www.stratigraphy.org/index.php/ics-chart-timescale

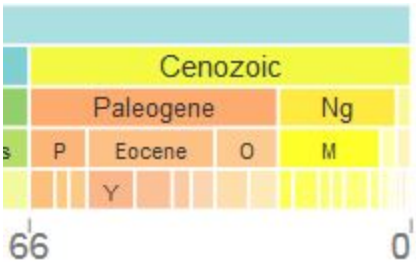
4) Pick a color to represent the perissodactyls on your maps. Using a colored pencil, draw the perissodactyl distribution for each epoch on the maps provided on the following four pages: one each for the Oligocene, Miocene, Pliocene, and Pleistocene. Create a small "key" on each map with "Perissodactyla" and the color you have chosen. Use the same color for the Perissodactyls on all four maps.

5) Briefly describe the geographic distribution of perissodactyl ungulates through time.

Glyptodonts

The Cenozoic has been a time of great mammal diversity. One group of note, sadly no longer with us, is the glyptodonts, which looked something like massive turtles. Their heavily armored shells are something that we still see today in the armadillos. In this part of the activity, you will be constructing distribution maps for glyptodonts for the same four epochs: the Oligocene, Miocene, Pliocene, and Pleistocene.

You will need to return to the PBDB "navigator" view and filter your results to show occurrences of the order = "Glyptodontidae".



Then, as before, use the time scale at the bottom of the screen to filter the fossils by epoch.

6) Pick a (new, different) color to represent the glyptodonts on your maps. Using a colored pencil, draw the glyptodonts distribution for each epoch on the maps provided on the following four pages: one each for the Oligocene, Miocene, Pliocene, and Pleistocene. Create a small "key" on each map with "Glyptodontidae" and the color you have chosen. Again, use the same color for the Glyptodonts on all four maps.

7) Briefly describe the geographic distribution of glyptodonts through time.

8) Based on the maps that you created, consider the distribution of both groups of organisms. Infer **when** the Isthmus of Panama land bridge must have formed. Explain.

9) Your inference about when the Isthmus of Panama formed is a **hypothesis**. If your hypothesis is valid, there will be other organisms besides glyptodonts that used the Isthmus as a corridor to move between continents. Make a prediction for when other groups (such as pampatheres, bears, and cats) would move between the two Americas if your answer to #8 is true.

10) Test your hypothesis (i.e., your answer to #8) with these other terrestrial mammal groups:

Pampatheriidae, Ursidae, Felidae

Do these other groups show the same pattern? **Explain** why this might be.

11) Test your hypothesis (i.e., your answer to #8) with these other terrestrial mammal groups:

Sparassodonta, Gomphotheriidae, Canidae

Do these other groups show the same pattern? **Explain** why this might be.

12) Would these groups make good tests of the question of when the Isthmus of Panama formed? **Explain** why or why not.

Chiroptera, Pinnidae

12) Now test your hypothesis with a different dataset entirely. Examine the paleogeographic maps found on the Deep Time Maps website (find them under "Key North American time slices"): https://deeptimemaps.com/north-america-key-time-slices-thumbnails/
Each of these maps is an artistic synthesis of the sum of peer-reviewed paleogeographical studies. According to these maps, when did the Isthmus of Panama form? (It is acceptable to express your answer as a range of years.)

13) Where else on Earth, in the course of geologic time, would be a good place to look for something similar: fossils providing a timing constraint on a collisional or accretionary event? What about a single original population being subdivided by a rifting event? Brainstorm particular times and places, and what the characteristics of the fossils would be in order to be useful for answering these tectonic questions. Test your ideas using the PBDB, and report the results here.

Oligocene

Miocene

Pliocene

Pleistocene