Lesson 9: Active Interior and Crustal Change

Summary
Students will become familiar with the theory of plate tectonics on Earth and evaluate the possibility of plate tectonics on Mars using the evidence (continental puzzle, faunal correlation, magnetic reversals etc.) utilized on Earth to support plate tectonic theory.

Learning Goals

Students will be able to:

- Identify Earth's geographic and magnetic North and explain the reasoning for their positions.
- Evaluate the use of magnetic reversals on Mars as a means to prove/disprove plate tectonic activity on Mars
- Compare and contrast Valles Marineris and Earth's Grand Canyon
- Find and analyze data using Google Earth and Google Mars software.

Context for Use
Students need a background in basic rock classification in order to be successful in this exercise as well as a general knowledge of the geography of Mars. Make sure students are familiar with navigation in Google Earth and Google Mars software. They should be able to access imagery and use the layers in the programs. Before assigning Homework 1 provide some instruction on faulting and fault types.

Description and Teaching Materials
In-Class Activity
In-Class Activity 1: Plate tectonics & The Magnetic Reversals
Homework/Lab
Homework 1: Valles Marineris vs. The Grand Canyon

Teaching Notes and Tips

1. If appropriate use the JPL Valles Marineris "fly-by" to introduce Valles Marineris to your class (see **References and Resources**)
2. For *In-Class Activity 1* you may provide copies to each student for them to fill-in and follow along or simply run through the exercise with the students. We maintain student attention better if students have their own copy and are required to turn in the activity for class participation points.

Assessment
Methods of assessment are within each individual *In-Class Activity* and *Homework*.

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References and Resources

1. Image File: Active Interior & Crustal Change
2. General Grand Canyon info: http://www.nps.gov/grca/index.htm
3. Valles Mariners animated "fly-by" courtesy of JPL: http://www.youtube.com/watch?v=JUbQM47QXwQ
4. Earth's Magnetic Field references: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magearth.html
5. NASA Geomagnetism reference: http://image.gsfc.nasa.gov/poetry/magnetism/magnetism.html
6. Connerney, J., 2005. Tectonic implications of Mars crustal magnetism. PNAS 102(42): 14970–14975; http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1250232/
7. Fault Classification reference: http://www.opensha.org/glossary-hangingFootWall

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In-Class Activity 1
The Active Interior and Crustal Change
Plate Tectonics & The Magnetic Field

Preparation

1. Discuss and review the "puzzle" evidence of continental drift and plate tectonics. See examples of government sites such as:
   http://volcanoes.usgs.gov/about/edu/dynamicplanet/wegener/

   http://pubs.usgs.gov/gip/dynamic/dynamic.html

2. Other evidence such as fossil correlation and magnetic reversals on Earth may be discussed prior to this activity.
3. **Reference:** Connerney et al. (2005) Tectonic implications of Mars crustal magnetism: Proc Natl Acad Sci USA 102(42), p. 14970–14975, available online at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1250232/

Materials Needed:
Compasses and labeled magnets (positive-negative) to meet the size of the class.

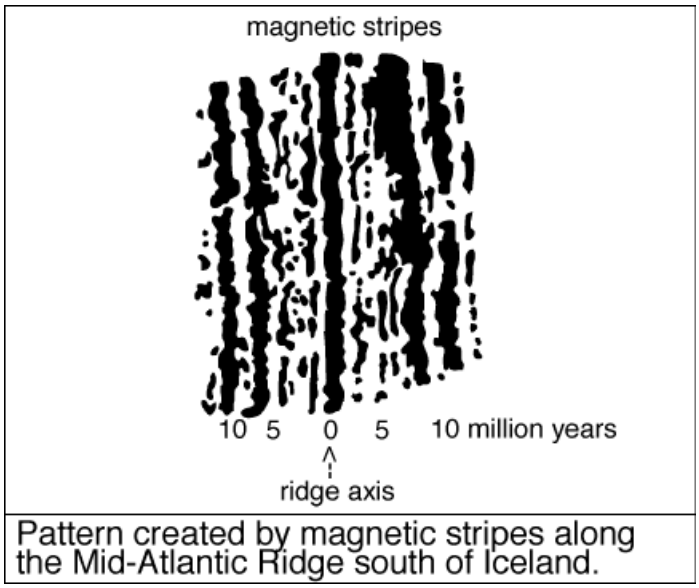

Figure 1: Source: http://www.london-oratory.org/chemistry_folder/Revision/Earth&Rocks/New/student%20workbook%202.htm

Engage
Have students observe the following image (Figure 1) and explain that the banding is associated with normal and negative polarity reversals in Earth's Magnetic Field as recorded by basaltic rocks at the Mid-Atlantic Ridge. Note the "ridge axis of the Mid-Atlantic Ridge" in the image. This is used as evidence for continental drift.

Ask students the following:

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1. What is a polarity reversal?

2. How is this image proof that the Earth's crust is moving?

3. Why are the rocks recording a reversal/change in polarity?

Explore

In order to understand the previous section, explore the following link and use it to help answer questions 1-3 (http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magearth.html):

1. What creates the Earth's magnetic field?

2. What is the Dynamo effect?

3. What benefits does a magnetic field provide?

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4. Describe the crustal magnetism of Mars at Meridiani Terra (Figure 3). Do you see any banding? If so, what is the orientation?

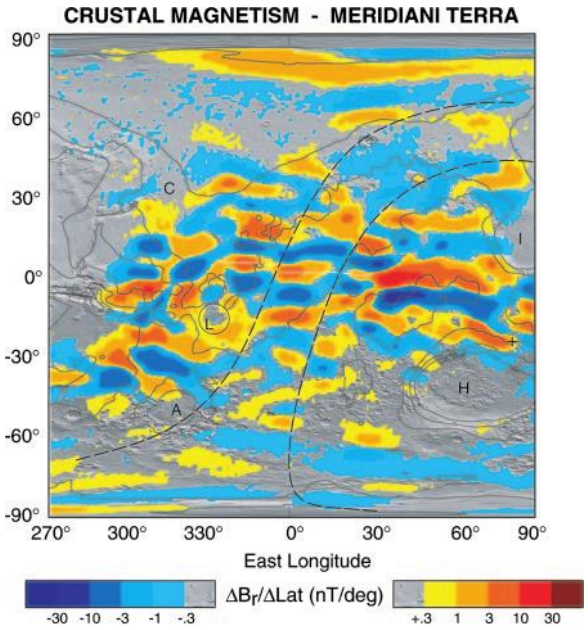

Figure 2: Crustal magnetism at Meridiani Terra Mars. Warmer colors are positive anomalies (Connerney, 2005).

Explain

1. The Earth itself is a magnet due to the convection of Earth's inner core causing electrical currents and a resulting electromagnetic field.
2. The South Pole of the Earth's magnet is in the geographical North because it attracts the North Pole of the suspended magnet and vice versa. Thus, there is a magnetic S-pole near the geographical North, and a magnetic N-pole near the geographical South. The positions of the Earth's magnetic poles are not well defined on the globe; they are spread over an area. The axis of Earth's magnet and the geographical axis do not coincide. The axis of the Earth's magnetic field is inclined at an angle of about 15° with the geographical axis. Due to this a freely suspended magnet makes an angle of about 15°with the geographical axis and points only approximately in the North-South directions at a place. In other words, a freely suspended magnet does not show exact geographical South and North because the magnetic axis and geographical axis of the Earth do not coincide.

Elaborate

Different stations on Earth are recording the changes in the electromagnetic field on Earth. One such station is found in Sweden.

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1. Navigate to the following website: http://www.irf.se/Observatory/?link[Magnetometers]=Data/
2. Ask students to note the legend and discuss the "description" tab
3. Ask students observe the "real time" data of the EM field ask them to postulate reasons for why there is activity in the data.

Evaluate

In a class discussion environment, ask the class if Mars has a magnetic field and what studies in the future could reveal new discoveries about the potential for Mars to have had a magnetic field in the past?