March 11, 2004

FUN WITH FOOD!
*PLATE TECTONICS AND OUR NATIONAL PARKS**

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Areas are designated National Park Service lands because of their historical significance or natural beauty. The latter category includes areas of mountains, valleys, seashores, or rock formations, features commonly associated with very large scale, or tectonic processes. And visitors can simulate tectonic features and processes in national parks using Oreo® cookies! (Fig. 1).

The term ***tectonics*** originates from the Greek word "tektõn," referring to a builder or architect. ***Plate tectonics*** suggests that large features on Earth's surface, such as continents, ocean basins, and mountain ranges, result from interactions along the edges of large plates of Earth's outer shell, called the ***lithosphere*** (Greek "lithos," hard rock; Figs. 2, 3). The plates, composed of Earth's crust and uppermost mantle, ride on a warmer, softer layer of the mantle, the ***asthenosphere*** (Greek

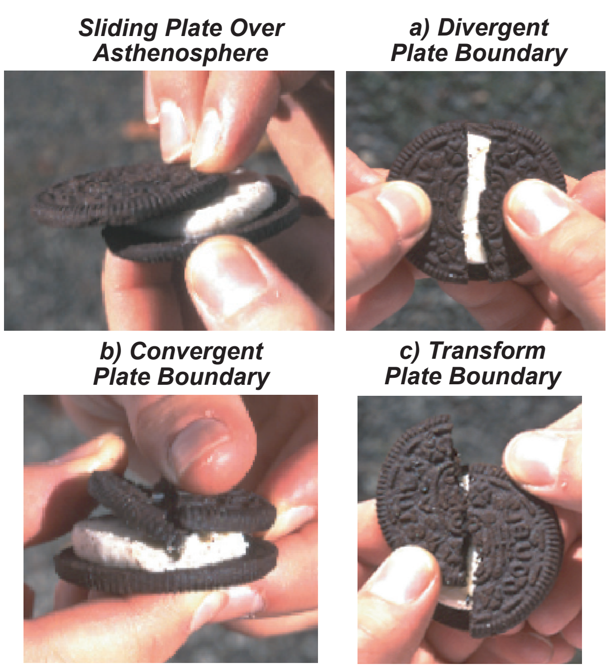

Fig. 1. ***Simulating plate boundaries with Oreo® cookies.*** The upper cookie is the ***lithosphere***, the creamy filling the ***asthenosphere***, and the lower cookie the ***lower mantle***. (Be sure to get the "Double Stuff" variety, which has adequate asthenosphere)! First, carefully remove the upper cookie (a "twisting" motion is required). Slide the upper cookie over the creamy filling to simulate motion of a rigid lithospheric plate over the softer asthenosphere. Next, break the upper cookie in half. As you do so, listen to the sound it makes. What does that sound represent? (An earthquake. Message: it takes cold, brittle lithosphere to make earthquakes – earthquakes do not occur in the soft, flowing asthenosphere). a) To simulate a ***divergent plate boundary***, push down on the two broken cookie halves and slide them apart. Notice that the creamy filling between the two broken "plates" may tend to flow upward, similar to the rising, decompression, and partial melting of hot asthenosphere at mid-ocean ridges and continental rift zones. b) Push one cookie piece beneath the other to make a ***convergent plate boundary***. Note that this is the only situation where the cold, brittle lithosphere extends to great depths, and hence the only place where deep earthquakes occur. The very largest earthquakes are at subduction zones where two plates get stuck together for centuries, then suddenly let go. c) Simulate a ***transform plate boundary*** by sliding the two cookie pieces laterally past one another, over the creamy filling. You can feel and hear that the "plates" do not slide smoothly past one another, but rather stick then let go, stick then let go. The cracking sound you hear each time is like an earthquake occurring along the San Andreas Fault in California. d) A ***hotspot*** can be simulated with the demonstration in the upper left photo. Imagine if a piece of hot, glowing coal were imbedded in the creamy filling – a chain of "volcanoes" would be burned into the overriding cookie.

**Excerpted and modified from "Parks and Plates: The Geology of Our National Parks, Monuments, and Seashores," by Robert J. Lillie, in press, 2004, New York: W. W. Norton and Company.*

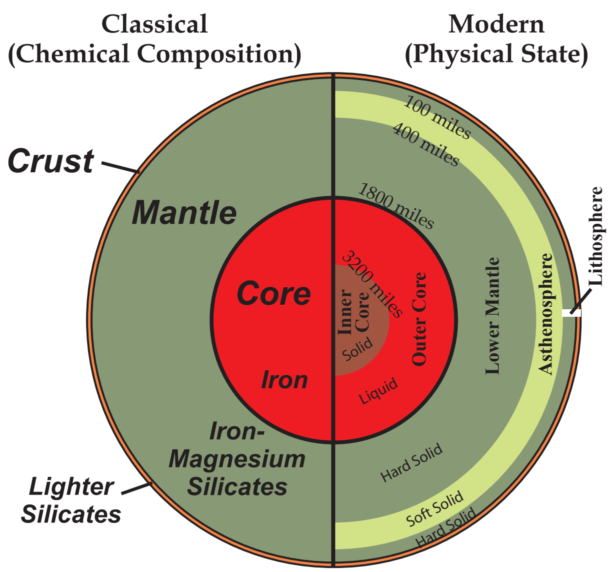

Fig. 2. ***Gross layers of the Earth.*** *Left: The classical division of the Earth is according to* **chemical composition**, *the heavier materials concentrated toward the center. Right: In modern times the three chemical divisions are classified into five zones according to* **physical state** *caused by temperature and pressure changes within the Earth.*

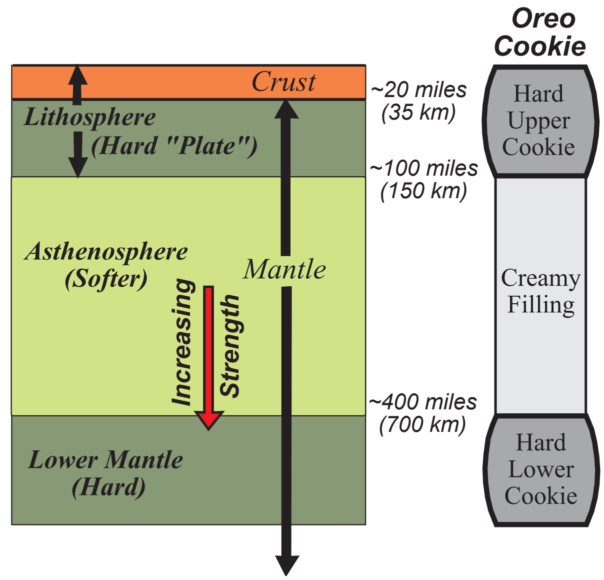

Fig. 3. ***Cross section of the upper 600 miles (1,000 kilometers) of the Earth, including the crust and part of the mantle.*** *Increases in temperature and pressure with depth cause the mantle to exist in three different states. The uppermost mantle and crust comprise the cold, rigid plates of lithosphere. Hotter mantle below forms the somewhat softer asthenosphere. Pressure increase with depth causes the asthenosphere to increase in strength, to the more solid lower mantle. Lithospheric plates can be compared to a hard Oreo® cookie, riding on the soft, creamy filling (asthenosphere). The lower cookie (lower mantle) does not move.*

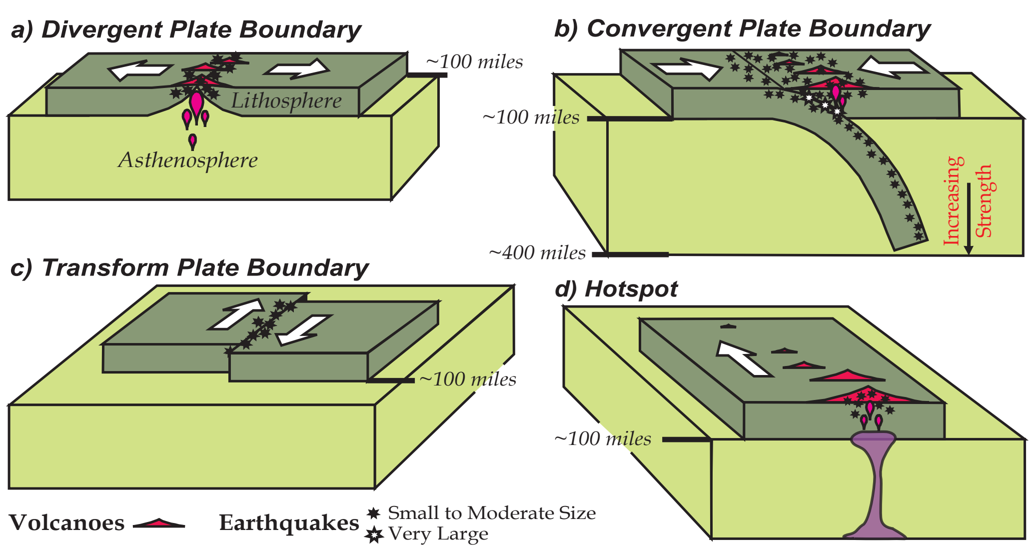

Fig. 4. ***Tectonic activity occurs at the three types of plate boundaries and at hotspots.*** *Volcanoes erupt in the zone where plates diverge, on the overriding plate where plates converge, and along a line where a plate rides over a hotspot. Only shallow earthquakes (less than 40 miles; 70 kilometers deep), of small to moderate size, occur at divergent and transform boundaries and at hotspots. The cold, brittle lithosphere may extend to great depths (up to 400 miles; 700 kilometers) at convergent boundaries, accompanied by a dipping zone of shallow to very deep earthquakes; the largest earthquakes occur at convergent boundaries where the two plates lock together for decades, then suddenly let go (white stars).*

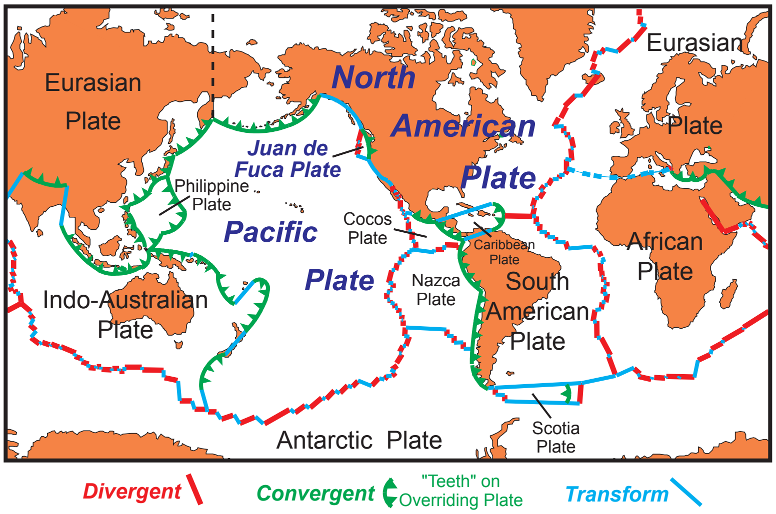

Fig. 5. ***Plate tectonic map of the world, showing the three types of plate boundaries.*** *Most of the current tectonic activity in the United States involves interactions between the* **North American**, **Pacific**, *and* **Juan de Fuca** *plates. The western United States is near plate boundaries and thus has volcanoes, earthquakes, and developing mountain ranges, while the East Coast is far from plate boundaries and lacks active tectonic features.*

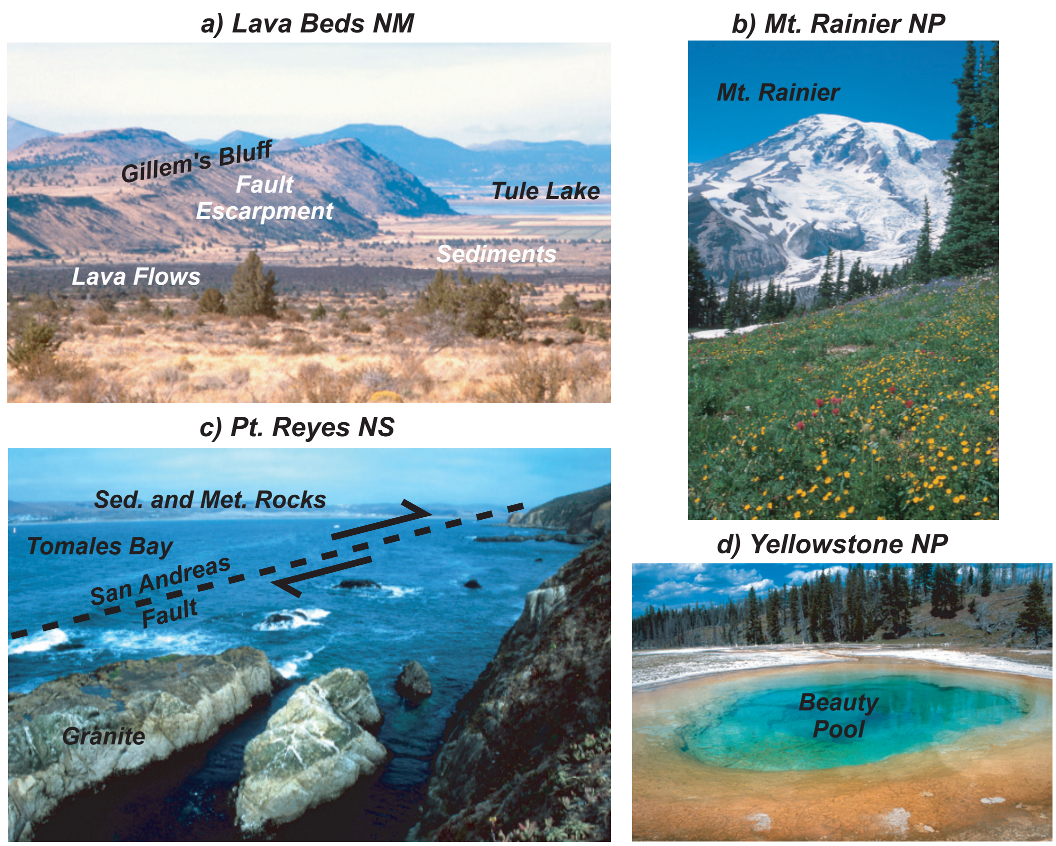

Fig. 6. ***Examples of national park landscapes and plate tectonics.*** *a) Lava Beds National Monument, California. A rift valley (filled by Tule Lake and sediments), block faulting (revealed by the steep escarpment of Gillem's Bluff), and dark, basalt lava flows reveal tectonic activity at a* **divergent plate boundary**. *b) Mt. Rainier National Park, Washington. Steep-sided, composite volcano is a consequence of one plate subducting beneath another at a* **convergent plate boundary**. *c) Pt. Reyes National Seashore, California. The San Andreas Fault runs through Tomales Bay. Granite on the Pacific Plate is being transported northward past sedimentary and metamorphic rocks on the North American Plate along a* **transform plate boundary**. *d) Yellowstone National Park, Wyoming. Hot springs, geysers, mudpots, and other geothermal features are manifestations of the North American Plate moving over a* **hotspot**. *(Photos by R. J. Lillie).*

"asthenos," lacking strength; Fig. 4). Earth's lithosphere is broken into a mosaic of seven major and several minor plates (Fig. 5). Relative motions between plates define three types of boundaries: ***divergent***, where plates rip apart, creating new lithosphere; ***convergent***, where one plate dives beneath the other and lithosphere is destroyed; ***transform***, where plates slide past one another, neither creating nor destroying lithosphere. Another large-scale feature is a ***hotspot***, where a plate rides over a fixed "plume" of hot mantle, creating a line of volcanoes. Plate tectonics helps us understand the inspiring landscapes that attract us to national parks, and to compare geologic features in one park with features we see in others (Fig. 6). For example, volcanoes in parks in the Pacific Northwest and Alaska are similar because they formed at boundaries where plates converge, whereas a different volcanic type occurs in Hawai´ian parks because those volcanoes formed over a hotspot.

Further Reading

General

Chronic, H., 1986, *Pages of Stone: Geology of Western National Parks and Monuments*, Seattle, Washington: The Mountaineers, 4 volume series.

Elwood, B. B., 1996, *Geology of America's National Park Areas*, Upper Saddle River, New Jersey: Prentice Hall, Inc., 372 pp.

Harris, A. G., E. Tuttle, and S. P. Tuttle, 2004, *Geology of National Parks*, 6th Ed., Dubuque, Iowa: Kendall/ Hunt Pub. Comp., 882 pp.

Kiver, E. P., and D. V. Harris, 1999, *Geology of U. S. Parklands*, 5th Ed., New York: John Wiley and Sons, Inc., 902 pp.

Moores, E. M. (editor), 1990, *Shaping the Earth: Tectonics of Continents and Oceans, Readings from Scientific American*, New York: W. H. Freeman and Comp., 206 pp.

McPhee, J., 1998. *Annals of the Former World*, New York: Farrar, Straus and Girous. 696 pp.

Wilson, J. T. (editor), 1976, *Continents Adrift and Continents Aground, Readings from Scientific American*, New York: W. H. Freeman and Comp., 230 pp.

Technical

Bally, A. W., and A. R. Palmer (editors), 1989, *The Geology of North America: An Overview*, Boulder, Colorado: Geological Society of America, Decade of North American Geology, v. A, 619 pp.

Cox, A. (editor), 1973, *Plate Tectonics and Geomagnetic Reversals: Readings with Introductions by Allan Cox*, San Francisco: W. H. Freeman and Comp., 702 pp.

Dewey, J. F., and J. M. Bird, 1970, Mountain belts and the new global tectonics, *Journal of Geophysical Research*, v. 75, p. 2625-2647.

Kearey, P., and F. J. Vine, 1996, *Global Tectonics*, 2nd Ed., Oxford: Blackwell Science Ltd., 333 pp.

Le Pichon, X., 1968, Sea-floor spreading and continental drift, *Journal of Geophysical Research*, v. 73, p. 3661-3697.

Moores, E. M., and R. J. Twiss, 1995, *Tectonics*, New York: W. H. Freeman and Comp., 415 pp.

Strahler, A. N., 1998, *Plate Tectonics*, Cambridge, Massachusetts: Geo-Books Publishing, 554 pp.

Sullivan, W., 1992, *Continents in Motion: The New Earth Debate*, 2nd Edition, New York: American Institute of Physics, 430 pp.

Vine, F. J., 1966, Spreading of the ocean floor: New evidence, *Science*, v. 154, p. 1405-1415.

Websites

National Park Service - http://www.nps.gov
- Park Geology Tour - http://www2.nature.nps.gov/grd/tour/index.htm
- Park Geology Photos - http://www2.nature.nps.gov/grd/edu/images.htm
- Individual Park Photos - http://www.nps.gov/pub_aff/imagebase.html

U. S. Geological Survey - http://www.usgs.gov/
- Geology in the Parks - http://www2.nature.nps.gov/grd/usgsnps/project/home.html
- National Park Photos - http://libraryphoto.er.usgs.gov/parks1.htm

U. S. Forest Service - http://www.fs.fed.us/
- Geology - http://www.fs.fed.us/geology/mgm_geology.html

Bureau of Land Management - http://www.blm.gov/nhp/index.htm
- Environmental Education - http://www.blm.gov/education/

National Science Teachers Association - http://www.nsta.org/
- Plate Tectonics - http://www.scilinks.org/retrieve_outside.asp?sl=92635699108810331055

University of California - Santa Barbara
- Plate Tectonic Animations - http://transfer.lsit.ucsb.edu/geol/projects/emvc/cgi-bin/dc/list.cgi?lis

SyperKids Educational Software Review - http://www.superkids.com
- Oreo Psycho-Personality Test - http://www.superkids.com/aweb/pages/humor/050199.sht