Introduction to the Geology of the Galápagos Islands

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We live on a very dynamic planet. Processes within the earth are constantly reshaping its surface. Change is the only constant and the Galápagos Islands are an excellent place to learn about the processes that shape our planet.

Earthquakes and volcanoes have fascinated and scared humans for millennia. The 20th century saw geology come of age, as a series of geologists finally proposed a mechanism to explain these and many other geological phenomena, and then found evidence that supported this idea. Wegener's theory of continental drift made the then startling proposal that the earth's surface is divided into plates that move. The discovery that the upper mantle was semi-liquid provided a mechanism for moving these massive plates. Convection currents in the mantle drag the plates along via friction.

Most of the real exciting action occurs where plates meet. At divergent boundaries, lava comes to the surface as the plates move apart. Volcanoes and earthquakes are associated with this surfacing of lava. The Mid-Atlantic Ridge, East Pacific Rise, and Africa's Rift Valley are examples of divergent boundaries.

Where two continental plates converge, mountains are thrust up, the Himalaya Range being a fine current example of this type of boundary. Strong earthquake activity is associated with this type of boundary. Oceanic plates are denser than continental plates, so when these two types of plates converge, the oceanic plate is subducted under the continental plate. As the oceanic plate dives into the mantle, it is heated, melting the rock. Since the rock is less dense in its liquid form, it rises through the edge of the continental plate, forming volcanoes. This is the process that built the volcanoes of the Pacific Ring of Fire, including the Andes, Cascades, Aleutian Islands, Kamchatka, Japan, the Philippines, and Indonesia. This type of boundary also generates very strong earthquakes, some of which are capable of causing devastating tsunamis, such as the December 2004 event off the northwest coast of Sumatra.

The final type of plate boundary is the transform boundary. Here the two plates grind past each other, storing immense amounts of energy as friction locks them together, and then releasing that energy periodically as earthquakes. The San Andreas Fault, running through California and Baja California, and the North Anatolian Fault, which generated seven earthquakes of magnitude 7.0 or greater in Turkey during the last century, are examples of this type of fault.

While most of the dramatic action occurs at plate boundaries, there are active areas that do not result from plate interactions. The Hawaiian Islands and the thermal zone around Yellowstone National Park in Wyoming long posed a puzzle for geologists. In 1963, geologist J. Tuzo Wilson proposed the idea that these areas could be the result of plates slowly moving over fixed hotspots in the earth's mantle. Less dense molten rock rises from these hotspots, penetrating the earth's plates to generate volcanoes. The Hawaiian Islands fit the pattern expected from this mechanism. The Pacific Plate is moving northwestward. The Hawaiian Islands form a long chain oriented northwest to southeast, with the oldest islands in the northwest and the youngest in the southeast. The next Hawaiian Island has already been detected, a mammoth volcano still under the ocean's surface, and much older volcanoes, now eroded under the ocean's surface have been detected in the northwest.

The Galápagos Islands appear to be the result of a fascinating interaction between a hotspot and plate boundary. The islands are on the Nazca Plate, which is diverging from the Pacific Plate at the East Pacific Rise, 1000 km west of the islands, and subducting under the South American Plate to the east. North of the islands lies the Cocos Plate, which is also moving from the East Pacific Rise and subducting under Central America. Along the Galápagos Rift, only 100 km north of the islands, the Nazca and Cocos Plates are diverging. The net result of this combination of boundaries is that the Nazca Plate is moving generally eastward and the Cocos Plate is moving northeastward.

Examination of subsurface soundings reveals that the Galápagos Islands are linked to each other underwater, representing a large chain of volcanoes, much like the Andes, but rising from the ocean floor. Long underwater ridges extend out from the Galápagos Islands. The Cocos Ridge passes under Cocos Island, 720 km to the northeast, and hits the coast of Costa Rica 1100 km to the northeast. The Carnegie Ridge extends eastward toward the coast of South America. This complex pattern appears to be the result of the interaction between the Galápagos Hotspot and the Cocos and Nazca Plates. The hotspot was likely once under the Cocos Plate. As that plate moved northeastward, the long Cocos Ridge was formed. At some point, the Galápagos Rift, the divergent boundary between the Cocos and Nazca Plates passed over the hotspot. The hotspot was now under the eastward moving Nazca Plate, forming the Cargenie Ridge and the Galápagos Islands, which are oldest in the east and youngest in the west.

Because the hotspot is penetrating oceanic crust, the lava in the Galápagos is basaltic, flowing out smoothly to form large shield volcanoes. This is in contrast to the andesitic and rhyolitic lavas, with much higher gas contents, that form the more explosive stratovolcanoes of the Andes and Cascades. The Galápagos continue to be a very active zone, with over 55 eruptions since the first European visit. The Cerro Azul volcano was reported to be active this year.

While on the Galápagos, one may see many geologic features, such as craters, calderas, fumaroles, spatter cones, cinder cones, and lava tubes. These are all evidence of the energy being released from the Galápagos Hotspot. One may also see strong evidence of erosion, caused principally by wind, rainfall, and wave action. This is the other major force shaping the islands. The interaction of volcanism and erosion has created the landscape that we see today.

Bibliography

Hewitt PG, Suchocki J, Hewitt LA. 2003. Conceptual Physical Science – Explorations. Addison Wesley, San Francisco.

Jackson, MH. 1993. Galápagos, A Natural History. University of Calgary Press.

Mathez, EA (ed). 2001. Earth, Inside and Out. American Museum of Natural History, The New Press, New York.

Press F, Siever R. 1978. Earth, 2nd ed. WH Freeman, San Francisco.

Stein RS, Barka AA, Dieterich JH. 1997. Progressive failure on the North Anatolian fault since 1939 by earthquake stress triggering. Geophysical Journal International 128:594-604.

White, WM. 1997. Galápagos Geology on the Web, A Brief Introduction to the Geology of the Galápagos. Department of Geological Sciences, Cornell University. http://www.geo.cornell.edu/geology/GalapagosWWW/GalapagosGeology.html. Last updated on 2 October 1997. Viewed on 30 June 2008.

Wikipedia Foundation. 2008. Hotspot (geology). http://en.wikipedia.org/wiki/Hotspot_%28geology%29. Last updated 23 June 2008. Viewed on 30 June 2008.