How the Earth Works

Scope:

Because the daily lives of most people nowadays can be so busy and hectic, it is appealing to think that at least the ground beneath our feet is steady, constant, and unchanging. Nothing could be further from the truth. We live on a vibrant, dynamic planet that is constantly in motion, inside and out. If you could view Earth's history sped up, like a movie on fast-forward, our planet would look more like the swirling eddies of a whirlpool than a ball of rock. Continents would whiz about the surface, and rocks would continuously be cycling from the surface to the deep interior and back again. You would no more be likely to recognize the planet of our past than you would the planet of our future, the surface changes so much over time. Recent discoveries in the Earth Sciences (Geology, Geophysics, Geochemistry, and Geobiology) are now revealing what our planet is Earth is made of, what its history has been, and, more importantly, "How it Works."

The analogy of the movie is really not a bad one. Our current scientific investigations give us a "snapshot" of our planet as it is today. From this single image, we attempt to reconstruct its past and predict its future. It is a difficult task, like trying to reconstruct the plot of a movie like Humphrey Bogart's "The Big Sleep" from just one *still*. The detective movie's plot, with all of its twists and turns, is hard enough to follow with repeated viewings, but to jump in the middle and figure things out would be daunting, if not impossible. But this is what geologists do. They are like detectives themselves, examining the geological clues at hand in order to not only reconstruct Earth's history, but also make predictions about its future.

While it is true that our world is in flux and we may be, as Etta James sang, "Standin' on Shaky Ground," there really are some constants in our world. As far as we can tell, there are definite laws to the universe. The fundamental forces that control the motions of objects and flow of energy seem constant and unchanging. In fact, given these laws, once the Big Bang occurred, 13.7 billion years ago, the eventual formation of stars and planets was inevitable. The machinery of our universe was set in motion, and gravity, electromagnetism, and the strong and weak nuclear forces made sure that there were lots of planets orbiting lots of stars in lots of galaxies. However, we have a particular interest in one specific planet: Earth. Though there are likely to be many billions of planets in just our galaxy alone, it turns out that very few might be like our own. The conditions required to maintain liquid water on a planet's surface for four billion years (the time needed for single-celled life to evolve into something that can dribble a basketball or write a love sonnet) are remarkably unusual, and I will explore this idea in more detail later on in the course.

One very important part of the study of *How the Earth Works* is the interdisciplinary nature of it. Earth Science is not for the faint-of-heart: this is not "rocks for jocks." In a modern-day university Earth Science department lecture, you are as likely to hear about the biological DNA of rock-chewing bacteria, the physics of the magnetic field of Jupiter or the chemistry of ozone reactions in the atmosphere as your are to hear about more traditional topics of "geology." This is because the divisions between the different sciences are entirely artificial. Nature doesn't know about biology, physics and chemistry. There is only Nature, and all of the sciences are involved in it. This is nowhere more true than in the study of a planet and how it works.

And yet, in very general terms, Earth's story is a simple one. Earth was intensely hot when it first formed, and has cooled ever since. In fact, by about 50 million years after the origin of the solar system (which we now think was about 4.567 billion years ago), Earth may have been entirely molten. Since that time, Earth has steadily cooled down, losing its heat into space. This is what all planets do, and the *particular* size, location and composition of Earth (including, very importantly, the amount of heat internally generated through radioactivity) has determined *how* Earth has cooled down. For our planet, the flow of heat from the interior to the surface takes the form of *plate tectonics*, which involves vigorous convection of Earth's rocky mantle layer and the horizontal motion of broken pieces ("plates") of Earth's outermost layer. As the plates move, they drag the continents about the surface, and the history of these continental collisions has been largely responsible for the geology we find about us. Even today, dramatic occurrences like earthquakes, volcanoes, the opening of oceans and the upward thrust of mountains result from the inexorable motions of plate tectonics, releasing unfathomable amounts of energy.

Any good story has to have conflict, however, and it turns out that *plate tectonics* has a nemesis: the sun. As fast as mountains go up and lands are formed, sun-driven erosion tears them down. Sunlight drives the cyclic flow of water through the oceans and atmosphere, and the scouring of water and ice destroys rock and carries it to the oceans. Rivers are the highways of this destruction, carrying hundreds of millions of tons of former mountains toward the oceans each year. The surfaces of the continents are therefore like a battleground, torn and ravaged by the two armies of Earth's interior and the sun, each relentlessly expending their arsenals of energy upon it. At various times in Earth's history one or the other may appear to be the victor, but it is the struggle between the two, known deceptively unassumingly as the *rock cycle*, that has shaped the lands we live on.

There is one more frequent characteristic of a great movie: a surprise twist of the plot in the end. *We* are that that surprise; humans. It is not possible for us to examine the Earth objectively, as if we were something *other* than the planet we live on. We are an integral part of Earth, constantly sharing our atoms with it (there are atoms in your body that were in dinosaurs, volcanoes, Julius Caesar, and that have flowed out the mouth of the Nile River many, many times). In fact, we might be considered as Earth's experiment in consciousness. Life has always played an important role in shaping Earth's surface, on the land, in the oceans, and in the atmosphere. But we have now reached a critical moment where humans have become the dominant agent of geologic change on Earth. We are altering Earth's land, water, and air faster than any other geologic process. It is therefore vitally important that we understand, in the context of *How the Earth Works*, the nature of our geologic powers, if we are to have any hope of being able to control them.