SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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Student Materials

Learning Sequence Item:

940

Density of Rocks

March 1996
Adapted by: Brett Pyle

Contents

Lab Activities

Readings

This micro-unit was adapted by **Brett Pyle** (Grady Middle School, Houston)

Student Sheet

Science as Inquiry

This Rock Is So Dense!

Use the information below along with your data table of rock densities to answer the questions.

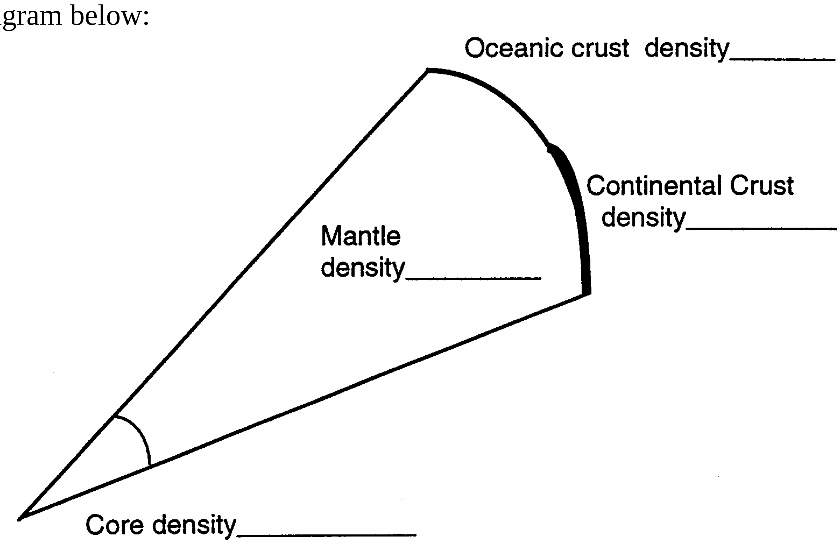
basalt—corresponds to oceanic crust, composed primarily of Ca, Na, and Al silicate minerals with some Fe and Mg silicate minerals

granite—corresponds to the continental crust, composed primarily of Ca, Na, and Al silicate miner als

peridotite—corresponds to the mantle, composed of concentrated Fe and Mg silicate minerals

iron—corresponds to the core, composed primarily of Fe with some Ni and Si

1. Use your data and the information above to fill in the densities of the various layers of the earth in the diagram below:



2. What relationship do you observe between the densities and locations of the various layers?

3. If oceanic crust collided with continental crust and one was forced under the other, which type of crust would be forced downward? Explain why based on your data.

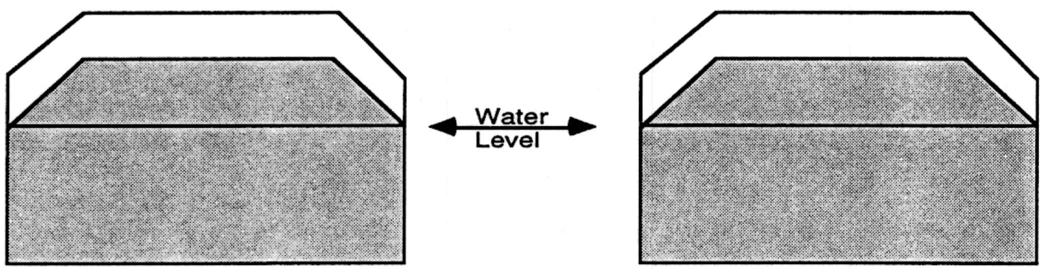
Student Sheet

Science as Inquiry

Continental Blocks

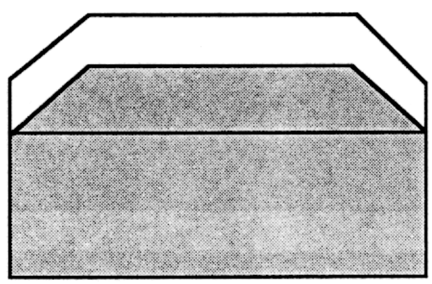
1 Based on your knowledge of the relative densities of the crust and mantle, explain what the wood blocks and the water in your tub correspond to.

2. Draw and describe what happens as you stack wood blocks on top of each other to build a "mountain range." Show the positions of the wood blocks at each stage of the experiment in the spaces below.



Three blocks side by side.

One block stacked on top of middle block.



Two blocks stacked on top of middle block.

3. Explain in terms of density the reason why what you observed happen in question 2 occurred.

4. Where would the thickest parts of continental crust be? Explain how you know using evidence from the lab.

Student Sheet

Science as Inquiry

Getting into Hot Water

1. Compare the temperature changes for the sand and the water during heating and cooling.

2. Which substance retained more of the heat energy from the lamp? Use your data to support your answer.

3. Use your data to explain how the climate in a city along the seacoast might be different from that of a city located far inland.

4. Most tropical fish (like you would have in a home aquarium) are very sensitive to temperature changes. Many fish will die from sudden temperature changes of a few degrees Celsius. Explain why these fish would have such a low tolerance to temperature changes.

Student Sheet

Science as Inquiry

Down by the Sea

Use the information in the data table to construct a line graph comparing average temperatures in each city per month. Each of a pair of cities listed in the data table lies at an approximately equal latitude to the other one. As you move down the data table, the latitudes of the city pairs increases. Use this information to answer the questions.

City	**Average Temperature (°C)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Dallas, TX	45	49	55	65	73	81	85	85	78	68	56	48
Savannah, GA	50	52	58	66	73	79	81	81	76	67	57	50
Kansas City, MO	27	32	41	54	64	73	78	77	68	58	42	31
Norfolk, VA	41	41	48	58	67	75	78	77	72	62	52	42
Bismarck, ND	8	14	25	43	54	64	71	69	58	47	29	16
Seattle, WA	38	42	44	49	55	60	65	64	60	52	45	41

1. Compare the yearly temperature ranges for the three pairs of cities that lie at approximately equal latitudes to their geographic locations. Explain any trends that you observe.

2. How does proximity to the ocean affect the temperature ranges in a city?

3. When answering question 2, why is it important to compare cities of approximately equal latitude?

4. What other characteristics of a city's location could affect temperatures?

Science and Technology

The Problem of Land Subsidence

Subsidence, or land-surface sinking, is a phenomenon that occurs in many parts of the world.

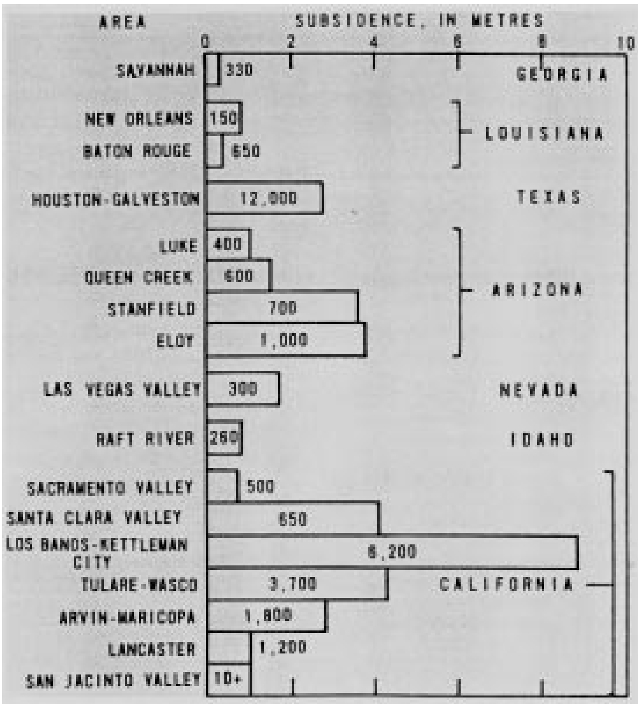
Subsidence results from the heavy withdrawal of groundwater, geothermal fluids, oil, and gas; the extraction of coal, sulphur, and other solids through mining; oxidation and shrinkage of organic deposits; and other phenomena. Over 150 areas of contemporary subsidence are known, some at rates of 10 m in countries such as Mexico, Japan, and the United States, for example. More areas of subsidence are likely to develop in the next few decades due to the accelerated exploitation of natural resources necessary to meet the demands of increasing population and industrial development in many countries.

Developers, as well as the engineers and scientists studying and planning industrial complexes, urban developments, water supply systems, and natural resource extractions, need to know about the potential hazards, costs, and socio-environmental impacts that can result from land subsidence.

To provide a forum for the exchange of such information between specialists who have had to deal with problems related to land subsidence, a series of international symposia on this topic have been organized since 1969 by the International Association of Hydrological Sciences (IAHS) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

The most recent symposium was held in Houston, Tex., a site of major subsidence-induced problems. Along the Houston Ship Channel, there has been approximately 2 m of subsidence due to the massive use of groundwater by the shipping industry. Nearby is the Goose Creek Oil Field, where subsidence amounts to 2 m due to the heavy pumping of oil. Also near the channel is the Brownwood Subdivision, where subsidence from groundwater pumpage caused nearly 3 m of subsidence, necessitating construction of a levee that formed an elevated road around several hundred homes. When hurricane Alicia hit the area in 1983, the resulting storm surge destroyed over 100 homes in the subsided area.

Because of mankind's continuous heavy impact on the surface and subsurface



Magnitude of land subsidence due to groundwater withdrawal in the United States. (Number in column represents area in square kilometers.) From *UNESCO Guidebook to Studies of Land Subsidence due to Groundwater Withdrawal*, edited by Joseph F. Poland, 1984.

environment, the problems of land subsidence have become increasingly critical over the years since 1969. Therefore, the purpose of the Houston symposium was to bring together international land subsidence specialists from various disciplines to present new research and practices that counter subsidence, and to exchange information on the cause, effect, control, and remediation of subsidence.

Science as Inquiry

The Dynamic Earth

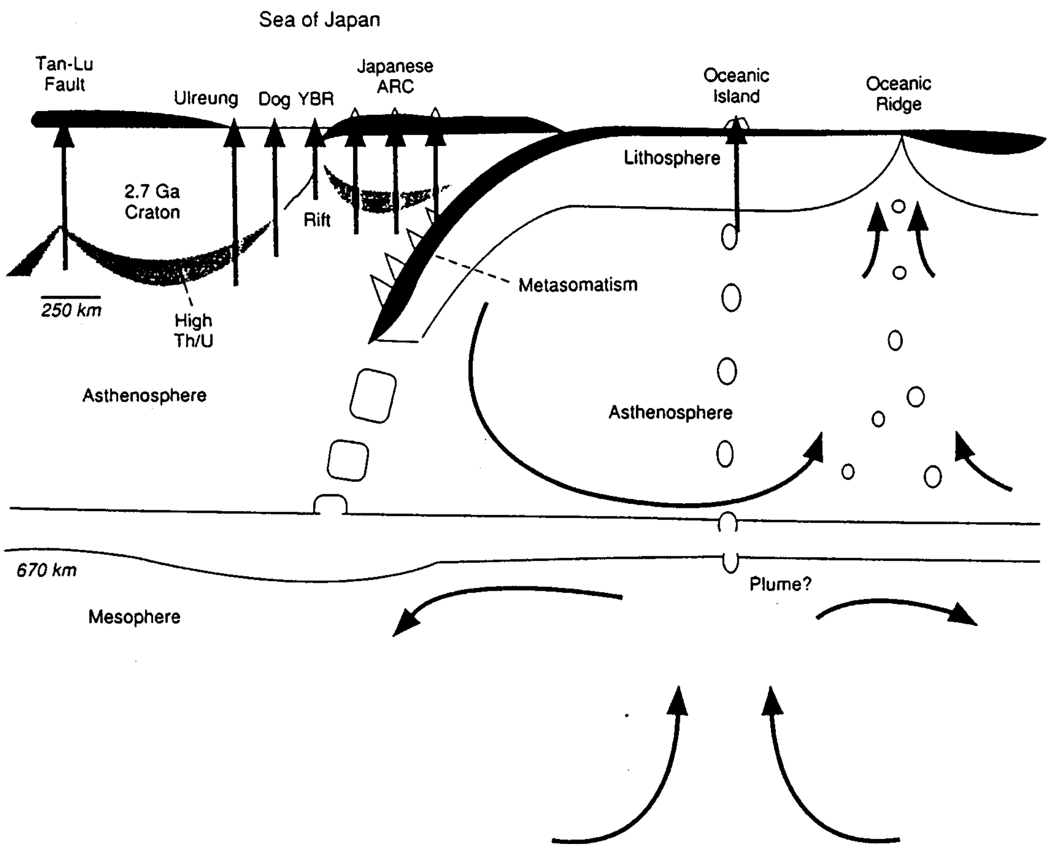
A new National Research Council report examines the status of the Earth sciences and the comprehensive picture of the Earth system that is emerging from the breakthroughs of the last 25 years and includes the integration of geochemistry, seismology, physics, and structural geology.

By the Committee on Status and Research Objectives in the Solid-Earth Sciences

Understanding Earth processes requires broad and eclectic thinking. The Earth system is complex, with open channels between interacting boundaries the norm rather than the exception. Many researchers think of the solid Earth as an engine driven by radioactive decay, while others expand this view to include the whole Earth system and consider the added processes driven by solar energy. Others see the Earth as a system of geochemical cycles with interchanges spanning ranges of time and space that extend back to the birth of the solar system. Finally, some scientists regard the planet as a series of concentric domains with ill-defined layers distinguished by the transfer of mass and energy.

The Earth is all of these and more. The accelerated understanding of the Earth system that characterized the past few decades is attributable to problem-solving strategies based on integration of these various interpretations. Contributions from geochemistry support theories developed from seismological data, structural geology depends on investigations in physics, and organic chemistry offers potential explanations for problems encountered in both resource extraction and waste management Since their adoption of this expanded tool kit for investigating the implications of plate tectonics, Earth scientists have made unprecedented progress.

The Earth began over 4.5 billion years ago with the accretion of material orbiting around the Sun, supplemented by the capture of other bodies from intersecting orbits. Early in the process of consolidation, proto-Earth collided with a Mars-sized body and the material from both reorganized



Schematic diagram illustrating plate recycling.

into the Earth-Moon system. Soon—in a geological sense—after that event, convection cells became established within the Earth's mantle, a crust developed, free water entered the atmosphere, plates diverged, ocean basins evolved, and mountains rose through tectonic forces at work along plate boundaries. These distinctive Earth phenomena are both cause and effect in a multiscaled arrangement of interacting processes.

From the perspective of geochemical cycles, there are two end-member processes, differentiation and mixing; two end-member domains, the exterior Earth environment and the interior; and two end-member time frames, hundreds of millions of years and the instant. Within each end-member pair, there is a continuum of possibilities. Generally, surface domain processes occur very quickly and interior processes endure over long intervals, although there are exceptions. Some continental material has endured for billions of years near the surface, and mantle plumes may erupt at the surface with no detectable warning, after migrating from the core-mantle boundary over mere millions of years. And while differentiation and mixing of large volumes continue for eons within the mantle, incremental changes within small volumes can take place quickly both at the surface and within the interior (see figure above).

The domains that extend above and beneath the surface contain the Earth's fluid envelopes. Water vapor in the atmosphere condenses and falls as rain. At the surface, water weathers the rocks physically and chemically: physically by impact and by freezethaw action and chemically by solution and the introduction of ions that foster reactions with rock minerals. Particles and solutions from crustal rocks wash downstream and enter the great water reservoirs of river, lake, ocean, and groundwater—settling out as detrital sediment and as precipitates.

At ocean spreading centers and in volcanic environments, water may aid in the precipitation of mineral concentrations that become valuable resources when discovered in accessible terrain. Magmas and other fluids that move through the crust have the potential of becoming significant sources of minerals and energy. Along subduction zones, hydrated crust and water-saturated ocean-bottom sediments descend into the interior beneath a mantle wedge that extends over the sinking plate.

Volcanos that build over hot spots, such as those in the Hawaiian Islands, erupt magmas that flow rather placidly because of their chemical makeup. They contain smaller proportions of silica, and gases escape readily. By the time the magma reaches the surface, it is less explosive and sticky, so it flows easily.

Core, mantle, crust; lithosphere, hydrosphere, atmosphere, magnetosphere—every layer, every component of the Earth system can be defined independently. But to understand the meaning of those definitions, the significance of the components, and the nature of the whole Earth system requires consideration that transcends the specific. Exchanges between the innermost center and the outermost reaches of the Earth system are ubiquitous and continuous. Earth scientists are discovering both explanations of the past and implications for the future by adopting this grand scale—the whole Earth system—in their ongoing inquiries.

Seismic studies have traced hot areas associated with spreading centers deep into the mantle and recently have detected slabs of cool lithospheric material descending deep beneath subduction zones. This cooler material persists over long periods; cool-temperature anomalies found in the mantle today are remnants of the breakup of the ancient continent on Gondwanaland about 150 million years ago. The breakup of Gondwana also caused drastic changes in climate patterns.

Science as Inquiry

The Midas Volcano

Geologist Fraser Goff did not go to Galeras Volcano in Colombia a prospecting for gold. But that's just what he found. And although he wasn't moved to run down the volcano's slopes shouting "There's gold in them thar hills," he did learn that Galeras is accumulating the glittering stuff fast enough to eventually create an economically exploitable deposit.

Goff and three of his colleagues journeyed to Galeras in January 1993 to gather crater gases, water from the volcano's acid hot springs and chunks of lava ejected during past eruptions (including one unanticipated blowout that had killed six scientists and three tourists earlier that month). Goff, a researcher at Los Alamos National Laboratory in New Mexico, planned to use these samples to gain insight into chemical processes at work deep below the mountain.

The scientists hired a local man to guide them to some gas vents along the Rio Guaitara, a river west of the volcano. The guide also pointed out a 10-foot-wide vein of rock (3 meters) in some old volcanic deposits. The vein contained tiny flecks of gold, each about the size of a pencil point. Lab tests revealed that parts of the vein contained 7.8 ounces of gold per ton of rock. That's pretty impressive, considering that some gold mines in the western United States are yielding a mere ounce per ton or less.

Gold is also dissolved in very low concentrations, on the order of thousandths or millionths of an ounce per ton, in Galeras' crater gases and hot springs. Goff estimates that if the volcano were to remain moderately active for 10,000 years, some 200 tons of gold—the makings of a gold mine—could accumulate in its internal plumbing. In fact, a gold mine in Summitville, Colorado, is the remains of an ancient volcano similar to today's Galeras.

Galeras' gold probably melts out of crustal rock as magma rises from deep sources hundreds of miles beneath the surface. The molten rock eventually collects in tht magma chamber beneath the volcano. Water vapor and other gases bubble out of the magma chamber and seep through the body of the volcano, which is worm-eaten by cracks and channels. The gold is dissolved in the dense mix of gases.

Over time this volcanic soup can deposit a crust of metals, minerals and chemical compounds in the volcano. In this way, Galeras acts like a distillery, separating and concentrating rare materials dissolved in escaping gases. Compared to other volcanoes known to have gold in their guts, Galeras appears to rank high. Its crater gases contain four times as much gold as those of White Island, a similar volcano in New Zealand.—*Daniel Pendick*

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Science as Inquiry

Volcanic Double Whammies

The vast, thick layers of basalt that cover Iceland and other parts of the world apparently formed when huge plumes of hot rock bubbled to the surface from deep within the Earth. Imitating this process in the laboratory with corn syrup, researchers can now explain why many of the basalt deposits occurred in staggered pairs of eruptions.

From the Deccan Traps of India to the Columbia River Plateau in the Pacific Northwest, lava plateaus tell the story of cataclysmic magma eruptions through fissures in the Earth's crust. These flood basalts, as they're known, often cover thousands of square miles and pile up hundreds of feet thick. Now, using rock dating techniques, mathematics and lab experiments with corn syrup, scientists at the University of Hawaii in Honolulu conclude that flood basalt eruptions often come two by two.

Geophysicists have long suspected that flood basalts are created by plumes of hot mantle rock that rise from sources hundreds of miles below Earth's surface and break through the crust. David Bercovici and John Mahoney now propose that plumes can separate into two independent masses as they pass through the boundary between the lower mantle and the slightly less dense upper mantle. This boundary occurs 600 miles underground (1,000 kilometers).

Bercovici and Mahoney believe that when a plume passes through the boundary, the change in density causes its bulbous head to break free. Now lighter, the head accelerates and after about a million years erupts through the crust. Meanwhile, the bottom half of the divided plume grows a new head. After rising for at least 10 million years, the second plume floods through the crust in the same region as the first.

According to the researchers, the ages of the individual flows that make up many of the world's flood basalts indicate they were deposited at different times. For example, although the Ontong Java Plateau in Southeast Asia was built by many eruptions, rock dating tests have shown that the individual

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eruptions cluster in two periods—one about 120 million years ago and the other about 90 million years ago.

A simple experiment with corn syrup of different concentrations supports the concept as well. Bercovici and Mahoney put two layers of the sticky, viscous fluid in a tall, narrow aquarium. The bottom layer contained 100 percent syrup and the top layer was 95 percent syrup and 5 percent water. Then they released a plume of 65 percent syrup and 35 percent water from the bottom of the tank. As the plume hit the boundary between the lower, thicker layer and the upper, less-viscous layer, the head broke free and shot to the surface. The remaining strand of syrup then stretched and thinned, but it eventually formed another plume head that rose to the top. "The physics is essentially the same as in the mantle," Bercovici says.

Next, the scientists will study in more detail the split between the head and body of mantle plumes, including how quickly the head accelerates once it passes into the region above the boundary layer. And they anticipate debate on the idea that double flood basalts are a common event in basic mantle-plume dynamics. "I doubt this will be the last word on it," Bercovici says.—*William Allen*