could be the principal source of microbial energy in deep-sea sediments that are much more depleted in organic matter than the eastern tropical Pacific sites discussed here. Such sediments with extremely low organic carbon flux cover large regions of the ocean floor, for example, in the central North and South Pacific Ocean.

This potential energy source is particularly interesting in that it is independent of biomass production by photosynthesis. It does not even require an external oxidant. Water radiolysis produces not only H_2 but also oxidants such as H_2O_2 or O_2, which may be directly used for the energy-generating reoxidation of H_2. Although the rich communities at deep-sea hydrothermal vents also live on inorganic chemical energy, for example, from H_2 or H_2S, they depend on O_2 produced from photosynthesis. An extreme low-energy subsurface biosphere driven by radioactivity would be different from all other ecosystems on Earth: It could proceed on a planet without surface life and solar energy.

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GEOCHEMISTRY

How Melted Rock Migrates

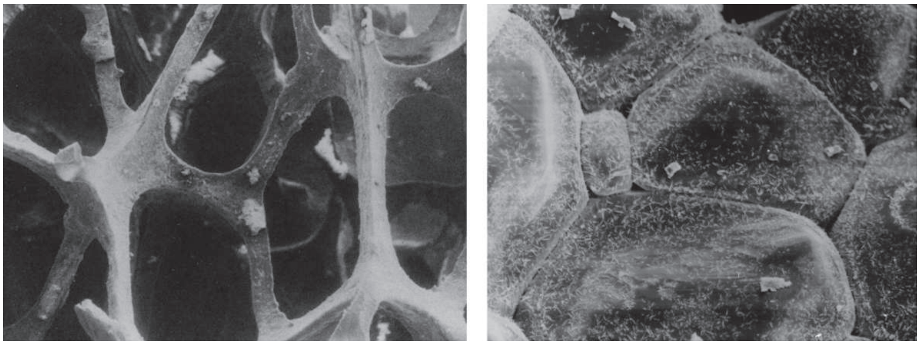
Magma flows through rock by different mechanisms than previously thought, which may cause a reevaluation of how data from Earth's mantle is interpreted.

Marian Holness

For most nongeologists, the idea of liquids moving through solid rock is a strange one. But liquids of one sort or another are thought to be ubiquitous in the Earth. There are the familiar hydrothermal fluids, dominated by water, which occur in the very shallow crust (the Old Faithful geyser in Yellowstone National Park in the United States is a dramatic example). But in the deeper parts of the Earth there are hydrous and carbon dioxide (CO_2) liquids formed by the heating of rocks as the minerals containing these molecules break down. At still higher temperatures, the rocks start to melt, generating a silicate liquid. The how and why of liquid flow through rocks is a very important problem in geology. This is because movement of liquid within the Earth is one of the primary ways that mass moves around and results in so-called geochemical differentiation. It was the movement of iron-rich liquids down to the center of the Earth that formed the core, for example. On page 970 of this issue, Schiano *et al.* (*1*) report new insights into flow mechanisms and the effects of fluid flow on the rock record .

Our understanding of what happens in the deep Earth is limited by our inability to get down there for a direct look. We are therefore reliant on three different sources of information: remote probing by geophysical methods such as seismic imaging; examining rock fragments that have been ripped off conduit walls and brought up to the surface by erupting lava; and laboratory experiments. All have their limitations. Geophysics can give hints as to what might be happening on a long length-scale, but can say very little about what may be happening on the grain scale. The fragmentary samples of the deep Earth that emerge with erupting lava flows have been separated from their original surroundings, and so the original spatial context is lost. And experiments are hampered by the difficulties of replicating the slow time scales typical of Earth processes within the time scale of a research grant. A further, perhaps not obvious, problem is that sometimes we do not carry out the right experiments. Researchers do not always know what to look for. We design experiments to investigate what we think might be there but sometimes, by chance or a fine instinct, we do something completely different and unexpectedly, serendipitously, happen upon a new and deeper understanding. The problem of silicate melt moving through its source rock provides an excellent example of this (*2*).

Driven by metallurgical insights, we thought for a decade or so that the distribution



Crystalline yin and yang. Porosity of texturally equilibrated polycrystals revealed in electron microscope images, showing the interplay of liquid and solid. This interconnected geometry of the melt phase was thought to dominate liquid flow in the mantle before Schiano *et al.* demonstrated that transcrystalline melt migration may also be important. (**Left**) A view of the pore structure in aluminum once the solid grains have been removed [reprinted from (*7*) with permission]. The elongated channels that form at three-grain junctions are evident (width of the image is 5 mm). (**Right**) Electron microscope image of quartz grains (with dimensions of about 100 μm) equilibrated with water at 6 kbar and 800°C, showing triangular ends of pores on three-grain junctions.

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of partial melts in the Earth was driven entirely by textural equilibrium, which occurs when the solid grains, and any liquid that might be present, rearrange themselves in the lowest-energy configuration. This generally results in smoothly curved grain boundaries and uniform grain size. In such a situation, the pore geometry is a function of the relative magnitudes of grain boundary energy and the energy of the fluid-solid interface. It is straightforward to demonstrate experimentally (*3*) that this results in a fine network of elongate pores along three-grain junctions and a very high permeability for silicate melts, even for tiny amounts of liquid (see the figure). However, when my colleagues and I started looking at real examples of melt-bearing rock, and in particular rocks from relatively shallow levels in the Earth, it became clear (*4*–*6*) that in the outer parts of the planet the overall temperatures are sufficiently low, and can change sufficiently fast, that textural equilibrium is very rarely achieved. In fact, most liquids flow along fractures formed during chemical reactions (like the process of melting itself) or during deformation.

But what about that part of the Earth that is below the crust and above the iron-dominated core—the mantle? Here the temperature is high, and relatively constant, so that reactions and deformation are probably not able to overtake the rate of textural adjustment driven by interfacial energies. It is therefore possible that partially molten mantle rocks are in, or close to, textural equilibrium, with liquid residing in grain edge channels. However, the new work by Schiano *et al.* shows that if we take temperature gradients into account we get another way of moving melts around that, for small quantities of relatively viscous melts, may be more important than the grain-edge channels.

Fluid inclusions are tiny pockets of liquid (either melt, brines, vapor, or a combination of these) trapped within single crystals. They are common in rocks and are believed to be representative of liquids that passed through the rock along fractures: The inclusions result from the incomplete healing of these fractures. Melt-filled inclusions are common in natural samples of the shallow parts of the mantle that we access. In a fashion similar to the migration of brine inclusions up a thermal gradient in rock salt (NaCl), Schiano *et al*. have shown experimentally that silicate melt-filled inclusions also migrate within single crystals subjected to a thermal gradient—they term this "transcrystalline melt migration." But what is important and exciting about their work is that they found that CO_2 bubbles within the fluid inclusion (formed by the separation of previously homogeneously mixed liquids) do not move. They remain in the same place while the melt of the inclusion moves away, up the temperature gradient. This means that one of the natural records that geologists rely on for discovering what really went on in the Earth may be misleading in some circumstances.

It has previously been assumed that the bulk composition of the inclusion remains constant, unless distinct signs of fracturing are present, but the work of Schiano *et al*. shows that this is not necessarily true and that the fluid-inclusion population may not be representative of the liquid that was present. It begs the question of how widespread this effect may be. How many other fluid-inclusion populations represent the remnants of a melt migration episode? It also poses interesting questions about how we read the rock record to interpret melt migration pathways. Schiano *et al.* show that transcrystalline melt migration can leave distinctively shaped vapor bubbles—will this be enough to detect whether this process operated? Or will the vapor bubbles change to the rounded shape indicative of lower-energy configurations, making it impossible to judge whether they record the movement of vapor alone along now-healed fractures, or whether they record the passage of melt through the grains themselves? This work opens up some exciting new avenues and will provoke much reinterpretation of our current understanding of melt movement, as well as rethinking of the CO_2 content of mantle melts.

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VIROLOGY

Sensing Viral RNA Amid Your Own

Viral RNA has a structural modification that cells recognize. This modification could be used in antiviral therapies and to modulate the immune system.

Takashi Fujita

Within hours of infection by a pathogen, our body initiates an arsenal of reactions, collectively known as the innate immune response, to eradicate the invader. In the case of a viral infection, this response involves the expression of numerous cytokine genes, such as type I interferon, to block viral replication and promote acquired immunity days after infection. At the frontline of this defense mechanism is the initial sensing of the virus within an infected cell. How does a cell distinguish viral nucleic acids (DNA or RNA) from its own? On pages 994 and 997 of this issue, Hornung *et al.* (*1*) and Pichlmair *et al.* (*2*) identify an important feature of this surveillance mechanism: Viral RNA is structurally different in a way that marks it as foreign to a host cell.

Creagh and O'Neill recently proposed that a "trinity" of pathogen sensors cooperate in innate immunity (*3*). Cellular NOD-like receptors detect bacteria, whereas viruses are detected by Toll-like receptors (which also recognize bacteria, fungi, and protozoa) and "RIG-like" receptors. The virus-detecting Toll-like receptors operate mainly in plasmacytoid dendritic cells by responding to viral nucleic acids that have been ingested by the cell through phagocytosis and incorporated into endosomal compartments. In these cells, the major immune response is production of type I interferon. But in other cell types, RIG-like receptors are considered the major, and indispensable, viral sensors, responding to viral RNA present in the host cell cytoplasm, which is already replete with self-RNA

Exactly how the RIG-like receptors identify nonself-RNA has not been clear. These

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