A hot time in the old lava fields

More than 2.5 billion years ago, extremely hot lava, behaving more like water than like molasses, splashed and tumbled its way across the earth's surface. This komatiite lava, as it is called, was so hot that it melted the rock over which it passed, eroding deep channels and taking up minerals from the ground.

This is the picture that emerges from a recent study of the physics and fluid dynamics of a komatiite lava eruption. "We conclude that komatiites probably flowed turbulently and cooled in part by convection," write Herbert E. Huppert and R. Stephen J. Sparks of the University of Cambridge in England and their colleagues in Australia and West Germany. Their report, which tries to account for many of the characteristic properties of komatiites, appears in the May 3 NATURE.

Komatiite lavas, originally recognized 15 years ago in South Africa and later found in Canada and Western Australia, are very rich in the mineral olivine, which contains a high proportion of magnesium oxide. These lavas show "all sorts of wonderful textures," says Euan G. Nisbet of the University of Saskatchewan in Saskatoon. The most distinctive feature is the "spinifex" texture (named for a needlelike, cloth-piercing Australian grass) that reveals itself in the form of long, shardlike plates of crystalline olivine. In contrast, olivine normally crystallizes into a stubby, rhombic form.

In order to be molten and to erupt, these lavas had to be at a starting temperature of at least 1,600°C, says Nisbet. Contemporary lavas don't get this hot. Because komatiites appear to be fairly common among rocks dating back more than 2.5 billion years and extremely rare in later rocks, this suggests that the earth's mantle, the layer of material beneath the earth's crust, may have been hotter then than it is now. Nisbet says, "Essentially, komatiites seem to be a direct window into the early mantle."

The high temperature and the high magnesium oxide content in the lava mean that the liquid had a low viscosity allowing it to flow easily and rapidly. Basing their work on this assumption, Huppert and his group calculated that komatiite lavas likely flowed turbulently. In such turbulent flows, heat is transferred much more quickly than in smooth or laminar flows. As a result, komatiites could have melted and assimilated underlying sediments and rock like basalt. The researchers note that other scientists have suggested that a similar thermal, lava erosion process may have carved some of the sinuous channels now visible on the moon's surface.

Huppert and his colleagues estimate that the lavas could have assimilated as much as 10 percent of the ground over which they flowed. This would contaminate the lavas by altering their composition and the proportions of trace elements present. As a result, it would be difficult to tell just by studying the lava samples whether particular elements originated in the mantle or came from eroded rock. The scientists also suggest that erosion of sulfur-rich sediments would account for the association between komatiites and deposits of nickel-bearing sulfide ores in some areas, especially in Western Australia.

After the lava settled into place, it would have continued to cool rapidly, helped by strong convection currents within the liquid, the researchers say. Under these conditions, olivine crystals would begin to grow and hang down in sheaves from the top surfaces of some komatiite flows to form the characteristic spinifex texture. The researchers simulated the development of this texture by observing crystallization within saturated aqueous solutions of sodium carbonate cooled from above. Their results confirmed the importance of convection currents within the liquids for producing the kind of texture seen in komatiites (SN: 2/11/84, p. 90).

The work of Huppert's group "tells us an awful lot about the physics of how these lavas flowed," says Nisbet. "The work they've done is very important indeed." However, he adds, "Their contamination argument is in some ways an annoying nuisance. But they've pointed it out, and it's there, and we've got to take it into account."

David Walker of the Lamont-Doherty Geological Observatory, associated with Columbia University in New York, says that the contamination effect "presents a rather extreme example of a process that is known to go on in eruptions today... so it's not surprising it would have gone on in the past."

Nisbet says, "Perhaps the recognition that contamination took place will help in resolving controversies about the extent of variation in chemistry of mantle source regions. More likely it will add to our uncertainty and send komatiitophiles scurrying back cheerfully to their field areas and to isotope laboratories."— *I. Peterson*

Gathering string in the cosmos

One of the serious difficulties in making theories of cosmology is accounting for the formation of galaxies. The universe is supposed to have started out smooth and undifferentiated, and so something somehow has to have initiated the concentrations of matter that developed into galaxies.

Now there is a plausible candidate for the position of trigger of galaxy formation. It is called cosmic string. String is a topological defect in the structure of space-time. Cosmologists first noticed it as a mathematical curiosity. Now, after more than a year of discussion, they are talking about observations that may show whether some of it exists.

String is an artifact of a phase change in the state of the universe. Most cosmologists like to believe that the universe began in a smooth, undifferentiated state, a state of very basic symmetry, as they put it. In this symmetric state the different kinds of matter and the various modes of interacting, of exerting forces and other influences, that we have today were unknown. The present variety arises from breaks in the primal symmetry, each break bringing into existence particular material particles or a particular mode of interaction. The breaks are spontaneous, arising for reasons embedded in the original nature of the universe. These breaks are phase changes, analogous to the change of water into steam or the formation of a crystal out of a cooled liquid. Such phase changes do not always occur instantaneously, perfectly and completely. Water boils away gradually; crystals often form with defects.

Cosmic string is such a defect. After a particular phase change in the history of the universe, long thin tubes of space-time are left behind in which the state of affairs before the change still prevails, analogous to the boiling water surrounding bubbles of vapor or to defects in a crystal. According to Alexander Vilenkin of Tufts University in Medford, Mass., who described them at last week's Inner Space/Outer Space conference held at Fermilab in Batavia, Ill., these relics of a previous age are thin and endless. Either they can be infinitely long or, as in most cases, they can close on themselves and form loops.

These loops are far from negligible, Vilenkin says. They contain something like 10^{14} to 10^{15} times the mass of the sun, and they move through the surrounding space-time (which has gone over to the new state of affairs) at very high speeds. Under the circumstances string could come to dominate the universe. Such an outcome would be very bad for cosmological theory, as today we manifestly do not live in a string-dominated universe.

Fortunately, Vilenkin points out, string loops contain the mechanism of their own destruction. There is a great tension along the length of the string, which causes the loop to wiggle. When something as massive as this wiggles, it produces gravitational radiation, undulations of gravitational forces that spread out through space the way light emanates from a bulb. Gravitational radiation carries away energy, and as its energy diminishes, the loop of string shrinks until it disappears.

While they are in the universe, however, the loops of string provide a signal service: