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Introductory Remarks

Kingsley Dunham

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Introductory remarks

By Sir Kingsley Dunham, F.R.S.

The substratum of the Earth, as Arthur Holmes originally described it, now generally known as the *mantle*, is the envelope, mainly of magnesium silicates, surrounding the fluid metallic core. It is separated from the continental and oceanic crusts which overlie it by the Mohorovičic seismic discontinuity, where there is a sharp change from earthquake wave velocities less than 7.2 km s^{-1} above to 7.8–8.1 km s^{-1} below. The thickness of the envelope is of the order of 2900 km, compared with about 4 km for ocean crust and 30 km for unthickened continental crust. Much attention has been devoted by geophysicists to the properties of the mantle, particularly in the course of the Geodynamics Project of I.U.G.G./I.U.G.S., during which important conclusions regarding sea floor spreading, plate tectonics and mantle convection have been reached. The fact that the overwhelming bulk of the mantle is not, and never will be, accessible for direct collection has perhaps resulted in less interest so far from the geochemical side. Accepting, however, that a partly indirect approach is inevitable, the time is now ripe for a thorough examination of the contribution that geochemical techniques can make.

Perhaps it was natural that many geologists should feel that the mantle is broadly homogeneous. Most accept that it has been stirred up through geological time by convection currents, and that these are still periodically or even steadily active, though probably beneath an outer layer about 50 km thick. Further, the sampling of the oceanic crust made possible by deep sea dredging, and by drilling under the JOIDES/D.S.D.P. and IPOD projects, has shown it to be monotonously composed of basalt, with some peridotite. Compared with the immensely inhomogeneous continental crust, ocean crust must be regarded as approximately homogeneous and consistent; and since it is clearly the direct product of partial melting of the mantle, these might be *a priori* reasons for regarding the mantle itself as not markedly heterogeneous in its chemistry. Nevertheless, the process of partial melting and fractionation, since it is a local or small regional rather than a global effect, must lead to heterogeneity in the mantle by reason of selective removal of the elements necessary to make basalt. In this symposium J. J. Gurney shows that there is evidence of widespread coarse peridotite of depleted composition in the mantle beneath southern Africa.

On the basalts themselves, the data to be presented cover not only the variations in major elements, but also in important minor elements, particularly rare earths and those of the so-called incompatible group (including Nb, Rb, K, Zr, Sr, P and Ti). Determinations of ratios of the isotopes of Sr, Pb and Nd show regional trends and variations that demand explanation. C. J. Allègre and his collaborators argue that a correlation, albeit an imperfect one, between the isotopes of Sr and Nd is a consequence of fractionation during partial melting of the mantle. C. H. Langmuir and G. N. Hanson ask whether major element variations in basalts reflect those in the mantle, and M. J. O'Hara warns that contamination in the magma chamber during fractionation may explain some of the variations without proving that the mantle is heterogeneous.

Not only do the basalts provide indirect evidence of mantle variations, they also yield nodules and fragments believed to be of the mantle itself. The best source of such material is, however, found in the kimberlite pipes which have drilled their way through the continental crust. The pressure and temperature conditions necessary to crystallize the diamonds that some of them contain show that they have certainly come from within the mantle, and the contained fragments are thus evidence of its nature. They are also evidence that gases, including particularly CO_2, periodically accumulate in the mantle at pressures sufficient to break through the more stable parts of the continental crust; thus there is inhomogeneous distribution of fluids in the mantle. Not surprisingly under the conditions of fluidization that must characterize kimberlitic eruptions, chemical alteration of the transported material has occurred, but how widespread this metasomatism may be in the mantle itself is a more debatable point.

The extent to which the highly heterogeneous composition of the continental crust can be held to throw light on previous or present compositions of the mantle is a more difficult question, if only because of the extensive differentiation of the crust that has resulted from the interplay of exogenous as well as endogenous process in its evolution. R. N. Thompson and his collaborators, A. J. Erlank and R. Macdonald, look at the evidence of regions of continental basalt, M. J. Norry *et al.* consider the alkali basaltic and other volcanics from the Kenya rifts and B. Jahn *et al.* reach out through Archaean igneous rocks to argue that the Archaean mantle was perhaps more homogeneous than its present equivalent. Certainly the evolution of the continental crust, small as it is in volume compared with the mantle, must have depleted the mantle of many of the light elements once present in it. The whole question of change against time is one of great interest.

This Discussion, then, presents evidence that the assumption of a reasonably uniform composition in the mantle is probably not justified; it does so by examining first the ocean crust basalts, then several suites of continental crust basalts, then the evidence of the kimberlite pipes. Data on trace elements and much new information on Pb, Sr and Nd isotopic ratios, the evidence of remarkable high-Mg glassy rocks, of 'fertile' lherzolite and 'barren' harzburgite lead towards models that introduce the geochemical aspect into the portrayal of the Earth's evolution. That this model has metallogenic as well as petrological interest is a fair conclusion from Janet Watson's recent contribution (*Proc. R. Soc. Lond.* A **362**, 305–328 (1978)).