Introductory Remarks

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Introductory remarks

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The suggestion for this Discussion Meeting was put forward more than three years ago. The format of the programme has changed many times since the original version, reflecting in part changing interests in different aspects of the subject. Of the 25 papers to be presented, only 5 discuss the constitution of the core, 13 deal with the geomagnetic field (including the secular variation and reversals) and all but 1 of the remaining 7 on geophysical interpretations are also concerned with the geomagnetic field. This emphasis on geomagnetism reflects the additional constraints that the absence or presence of a magnetic field may put on the constitution of all the planets and the Moon. In contrast to the Earth, the record of the first 10^9 years of planetary history is still at least partly preserved on the Moon, Mercury and Mars (and perhaps on Venus), and a study of this record on these other bodies may yield some information on the early history of the Earth. We have some seismic data for the Moon, but it is only for the Earth that we have a rich store of such data. In this connection, a word of caution is in order. It must not be forgotten that the structure of the Earth as revealed by seismic data is only a snapshot of what it is like today, and in many ways a very imperfect snapshot. There is no science of palaeoseismology, and seismic data tell us nothing about the structure of the Earth in the past nor of its evolution.

The detailed mechanism of core formation is not well understood and only one paper to be presented at this meeting discusses the evolution of the Earth's core. It appears most probable that all the terrestrial planets (including the Moon) have cores, although the size and time of differentiation of core and mantle may be very different. In addition to an early and extensive exogenic heat source, an appreciable source of heat in the terrestrial planets would have been produced by core formation. Evidence for the formation of a core early in the Earth's history comes from Pb isotopic data (Oversby & Ringwood 1971; Vollmer 1977) and palaeomagnetic fields observed in rocks at least 3500 Ma old (McElhinny & Senanayake 1980). On the other hand, Solomon & Chaiken (1976) have shown that the simplest thermal history models for Mars involve late core–mantle differentiation compared with the other terrestrial planets. Could this be the reason that Mars has at most a very weak magnetic field (with a magnetic moment about 1/5000 that of the Earth)? Could the reason that Venus has no (at least no detectable) magnetic field be that it has no solid inner core – if we believe that the dynamo is driven by gravitational differentiation (see, for example, Gubbins & Masters 1979)? Alternatively, if the magnetic field of Venus experienced self-reversal as with the Earth (a subject of much discussion at this meeting), could the gods be teasing us and allowing us to see the Venusian field at the time of a reversal when perhaps its intensity is virtually zero, as has been reported in some cases for the Earth (Kawai *et al.* 1977)?

I do not wish to pre-empt any of the remarks to be made by the main speakers. I would like, however, to make a few general observations. Although we have far more observational data on the Earth than on the other planets, the materials of the Earth's core and mantle are much more complicated than the simple elements H and He so that in some respects (e.g. equation of state) we know more about the interior of Jupiter than we do about that of the Earth. I should like to see more experimental work at high pressures and temperatures simultaneously and more investigations of multi-component systems. Both experimental and theoretical work is necessary, and particular attention should be paid to phase transitions in mantle materials and to the nature of the core–mantle boundary. It is our lack of detailed knowledge of phase transitions in rocky planetary material that makes it so difficult to trace the evolution of our planet. We can only hope to understand the past when we know the various states of planetary material under changing thermodynamic conditions. Further studies are also needed on the thermal evolution of the Earth. Our knowledge of melting, particularly at high pressures, even for single elements, is still woefully weak, whereas our estimates of adiabatic gradients rely on physical assumptions that may not be applicable at least in the fluid outer core of the Earth.

Another unresolved problem of the Earth's core is its chemical composition, particularly the light alloying component in the outer core. In this regard, attention should be paid to the question of liquid immiscibility, a subject in which I have just become interested. Experiments at normal pressures have shown that immiscibility develops in the Fe–Ni–S system after the introduction of a small percentage of either P, Si or C (Vogel 1963, 1964). Whether such immiscibility persists at pressures corresponding to those in the outer core is not known. If so, it would be interesting to know what constraints this would impose on convection in the outer core. Verhoogen (1973) suggested that the Fe–S system at high temperature and pressure may resemble that of the S–Sb system at low pressures, which exhibits liquid immiscibility between Sb and the eutectic. If this were so in the Earth's core there would be two liquids above the liquidus: a heavy liquid with a low S content (about 2.5 % by mass), representing the composition of layer F in equilibrium with the solid inner core, and a lighter liquid with a higher S content (about 15 % by mass), representing the composition of layer E. Of course we do not know what the effect of pressure would be on such phase diagrams. If this is true for the Earth, then, because of liquid immiscibility above the inner core boundary, the upward flux of S at the inner core boundary could not alloy with the heavy liquid. This would lead to the nucleation of liquid droplets with a sulphur content of about 15 % by mass. Such droplets would grow to such a size where buoyancy forces become strong enough to enable them to rise, perhaps releasing enough gravitational potential energy to drive the geodynamo. Another possibility is that the liquid immiscibility is confined to a small region above the liquidus. If this were so, the droplets would dissolve in the outer core, leaving only compositional convection in the rest of the outer core. I have not carried out any quantitative calculations for such models, but I mention the possibility of liquid immiscibility in the core as another area that warrants further research.

REFERENCES (Jacobs)

Gubbins, D. & Masters, T. G. 1979 *Adv. Geophys.* **21**, 1–50.
Kawai, N., Sato, T., Sueishi, T. & Kobayashi, K. 1977 *J. Geomagn. Geoelect., Kyoto* **29**, 211–223.
McElhinny, M. W. & Senanayake, W. E. 1980 *J. geophys. Res.* **85**, 3523–3528.
Oversby, V. M. & Ringwood, A. E. 1971 *Nature, Lond.* **234**, 463–465.
Solomon, S. C. & Chaiken, J. 1976 In *Proc. Lunar Sci. Conf. 7th*, pp. 3229–3243.
Verhoogen, J. 1973 *Physics Earth planet. Inter.* **7**, 47–58.
Vogel, R. 1963 *Arch. EisenhüttWes.* E **3**, 211–216.
Vogel, R. 1964 *Arch. EisenhüttWes.* E **10**, 1019–1021.
Vollmer, R. 1977 *Nature, Lond.* **270**, 144–147.