there is still some doubt about this, chiefly because the bulk of the archaeomagnetic data used to define these fluctuations during the past 10,000 years have come from material within the relatively confined area of Europe and Western Asia. However, P. J. Smith and Doell (US Geological Survey) presented archaeomagnetic field intensities from lava flows from Hawaii (an area far from Europe where the non-dipole field was small) which demonstrated the reality of dipole moment fluctuations. The other possibility—that dipole moment variations merely reflect changes in dipole orientation—was ruled out by M. J. Aitken and H. W. Hawley (Research Laboratory for Archaeology and the History of Art, Oxford), who used archaeomagnetic direction measurements to show that although there is evidence for movement of the dipole during the past 2,000 years, such movement is not large enough to account for the observed intensity variations.

A realistic assessment of the assembly (which was held simultaneously with the general assembly of the International Association of Seismology and Physics of the Earth's Interior—IASPEI) would be that it was worthwhile but that two weeks exceeds the average human tolerance level. Conference organizers should really be more ruthless in rejecting unoriginal, and perhaps even many of the routine, papers. And it is a sad comment on the scientific community that so few participants are capable of sustaining a lively and coherent lecture for the short period of fifteen minutes.

MATERIALS SCIENCE

Conducting Ceramics

from our Materials Science Correspondent

ALTHOUGH ceramics are apt to be thought of as insulators, some of them conduct electricity moderately well, especially at high temperatures. Some ceramics behave in an anomalous manner, and for these it has been found necessary to postulate an inhomogeneous structure. Thus polycrystalline ferrites have long been described in terms of a model due to Koops: according to him, well conducting bulk material is separated into compartments by poorly conducting layers, which presumably coincide with grain boundaries. A recent paper from the Institute for Electrotechnical Materials at Aachen (F. Haberey, *J. Appl. Physics*, **40**, 2835; 1969) combines measurements of resistivity and of ferromagnetic relaxation of a barium ferrite as a function of both temperature and frequency, to derive separate activation energies for electron transfer between Fe^{2+} and Fe^{3+} , (a) W_b in the bulk and (b) W_i in the intergranular regions. Thus the electrical conduction at megacycle frequencies is attributable to the bulk (bypassing the boundary barriers), while at low frequencies the barriers determine the electrical behaviour. $W_b \sim 0.14$ eV and $W_i \sim 0.30-0.35$ eV. J. Krause of the same institute (*Z. Angew. Physik*, **27**, 251; 1969), by means of an elaborate analysis of the frequency and voltage dependence of ferrite resistivity, has reached the firm conclusion that the barrier layers coincide with given boundaries, although their nature remains to be identified.

This work includes nothing that would help identify the nature of the boundary barriers. Rather more is known about the corresponding barriers in certain ferro-

electric ceramics, especially those obtained by doping barium titanate. It has been known for some years that small dopant additions of rare earths can increase resistivity by many orders of magnitude, provided the ceramic has been sintered in an oxidizing atmosphere. The matter is further complicated by the fact that in doped, oxidized barium titanate the resistivity becomes very high only above the Curie points, which has led to proposals to use such PTC (positive temperature coefficient) materials as surge-suppressors and for other circuit functions (for example, W. Heywang, *J. Amer. Ceram. Soc.*, **47**, 484; 1964). Apart from that, doped barium titanates of high resistivity have also been widely used to form "barrier capacitors". In a recent study, Vojnovich and McGee (*J. Amer. Ceram. Soc.*, **52**, 386; 1969) have examined in detail the formation of the high resistivity variant in gadolinium-doped barium titanate, by varying the state of oxidation of the material and also by measuring the resistivity profile of the oxidized surface region of a previously reduced slab. The role of the dopant is still not entirely clear, but it seems that one of its functions is to prevent grain growth of the titanate by concentrating at grain-boundaries in the form of a separate phase. Because the oxygen-rich resistive barriers are concentrated at grain boundaries, a fine grain-size evidently favours the establishment of a high resistivity in the oxidized material. The present study included capacitance as well as resistance measurements and the two sets of measurements were used to deduce carrier concentrations as a function of depth below the oxidized surface; the two plots agreed remarkably well.

Another recent paper is devoted to a conducting ceramic which depends on ionic rather than electronic conduction. Beta-alumina, a polymorph of the normal hexagonal alpha-alumina structure, is formed only when some sodium oxide (or certain other alkali, alkaline earth or some other oxides) is added to alumina. Its technical importance arises from its use as a solid electrolyte in Ford's high-temperature sodium-sulphur battery, which has been the subject of a great deal of development effort. De Vries and Roth (*J. Amer. Ceram. Soc.*, **52**, 364; 1969) have now published a critical evaluation of the extensive published literature on beta-alumina, with special attention to the Al_2O_3 - Na_2O system, and have concluded that there are two " β - Al_2O_3 -like" phases, one at about $\text{Na}_2\text{O} : 11 \text{ Al}_2\text{O}_3$, and another in the 1 : 5 to 1 : 7 range. One contains two spinel blocks per unit cell, the other three; both variants have a fairly wide homogeneity range; just how wide is not known. The equilibrium relations between the two forms also remain to be established.

Apart from the equilibrium relations of the β -alumina phases in the Al_2O_3 - Na_2O system, interest is also growing in the exact crystal structure of these phases, in the hope of interpreting the remarkably high conductivity for the Na^+ ions. One recent approach has been through the computer-aided calculation of the Madelung constant for one of the β -alumina forms (W. van Gool and A. G. Piken, *J. Materials Sci.*, **4**, 95, 105; 1969); it was established that Na^+ lattice sites and interstitial sites have almost identical energies, and this in turn led van Gool *et al.* to the postulate that Na^+ ions may occur with a certain degree of disorder, akin to the stacking-fault disorder in ZnS and SiC. There is some evidence that the highly mobile Na^+ ions migrate between normal lattice and interstitial sites.