useful to alert potential readers to culmination, his Electromagnetic Theory showed him to be the greatest of all masters of analogical thinking.

This may be the point at which to mention some very minor blemishes in the book, for Maxwell spent his boyhood not in Aberdeenshire (p. 287) but Kirkcudbrightshire. Melloni's Christian name was Macedonio not Marcello (p. 227) and Poynting's initials were J. H. not M. H. (p. 328), and there are occasional mispellings.

Whether through common-sense Philosophy or not, the Scottish contribution to science up to 1870 was formidable. Besides those of Forbes and Maxwell it is easy to recall many names: Black, Brewster, Brown, Graham, Hutton, Leslie, Lyell, Nicol, Rankine, Ritchie, Robison, Tait, Waterston, Watt, the Gregorys, the Playfairs, and the Thomsons. Quite possibly there was more to it than the common-sense tradition alone: in Britain generally, religious dissent also seems to have been a factor, and the relative decline of the Scottish universities after 1870 was probably far less due to Forbes than to the revival of Oxford and Cambridge, with the abolition in 1871 of religious tests for university entrants. But Dr Olson has produced a book of remarkable interest, well worthy of detailed study by everyone interested in the philosophy of science.

R. V. Jones

Earth studies

The Earth's Density. By K. E. Bullen. Pp. xiii+420. (Chapman and Hall: London, 1975.) £12.90.

THIS book gives an historical account of developments concerning the variation of density within the Earth. The first five chapters are of an introductory nature covering noted ancient investigations, the determination of the Earth's mean density, spherical harmonics, theory of the Earth's gravitational attraction and the figure and moment of inertia of the Earth. The sixth chapter covers early models of the Earth's density variation including the Legendre–Laplace density law and the Williamson–Adams equation. The meat of the book (chapters 7–17) deals with seismic wave transmission and presents contributions from studies of P and S waves, surface waves, and free oscillations. The penultimate chapter deals with optimum and standard Earth models and the final chapter contains a discussion of the densities of the other planets.

The author, a mathematician, has been foremost in developing Earth models of the classical type based on the interpretation of travel time curves, and chapters 9 and 10 provide a resumé of the Bullen Earth Models of types A and B. Other procedures, such as the Monte Carlo technique and general inversion, are also discussed but somewhat unenthusiastically. The reader will naturally turn to the chapter on optimum and standard Earth models and there he may be disappointed. It seems we still do not have a standard Earth model and the Monte Carlo and general inversion models are treated with scepticism. Bullen's choice of the best model is shown in Fig. 16.1 but it is not clear which model this is and no error bars are shown; it is presumably a combination of Bullen–Haddon models. It is unfortunate that the big conclusion is somewhat obscure as the rest of the book is so beautifully meticulous.

Throughout, the Earth is assumed to be spherically symmetrical, and though lateral variations of density are frequently discussed they are usually dismissed as minor. This is a pity, as with more precise data (using WWSSN and seismic arrays) it is becoming apparent that the Earth is far from spherically symmetrical and that there is considerable local variation in travel time curves. Most of the work described dates from a time before the acceptance of sea floor spreading and 'rapid' plate movements. The outermost layers of the Earth are very mobile and we have few clues as to what causes the mobility, so studies of lateral variations of density are clearly of great importance. We will need to know how big they are and how deep they extend. With that kind of information it may become possible to develop theories to explain plate movements and the earthquakes associated with them. In the meantime, Bullen's book gives us all the hard facts of classical seismology with the warning that they mustn't be forgotten as the lesson for the day.

R. W. Girdler

The Viscosity of the Earth's Mantle. By Lawrence M. Cathles III. Pp. 386. (Princeton University: Princeton and London, 1975.) £13.10.

THE viscosity of the Earth's mantle is obviously important, not least because of the restrictions that its absolute value and variations with depth place on possible models of mantle convection. Nevertheless, it comes as something of a shock to learn that it can form the subject of a complete, long book. The shock is magnified (or perhaps diminished, depending on one's point of view) by the discovery that, although previous literature is briefly reviewed where appropriate, this is not a textbook but an original work. In short, it is really a long scientific paper which happens to be bound between hard covers. The normal rules of book reviewing therefore hardly apply; proper criticism of this work will only come from other workers in the field over a period of years, rather than weeks or months.

In the meantime, it would seem most Cathles' chief conclusions, especially as one or two of them, if not actually controversial, certainly defy the consensus. The study is based on the assumption that the Earth is a self-gravitating viscoelastic solid; and in the first part of the book the mathematical techniques required to model the isostatic adjustment of such a body are developed at length. The theoretical foundations thus acquired are then combined and compared with geological data on the way the Earth responded to Pleistocene glacial–water load redistributions to deduce mantle viscosity and its variations.

The 'average' Earth model thus constructed has a lithosphere which may be regarded as an elastic shell with effectively infinite viscosity and thickness varying between 70 and 150 km. Immediately below the lithosphere is a low viscosity layer (or 'channel') with an average thickness of about 75 km and a viscosity of about 4×10^{20} poise. The evidence for such a channel is widely distributed geographically, although both the thickness and viscosity of the channel probably vary considerably from place to place. Between depths of 75 and 1,000 km measured from the top of the low viscosity channel, the mantle (defined as the 'upper mantle') has a viscosity of $1.0\pm0.1\times10^{22}$ poise—a conclusion based largely on the uplift of Fennoscandia which has a further 30–50 m to rise.

Most interest, however, is likely to centre on the rest of the mantle (the 'lower mantle') which also has a viscosity of about 10^{22} poise, although at $0.9\pm0.2\times10^{22}$ poise it might be very slightly lower than that of the upper mantle. Many (but not all) workers believe that the lower mantle has a much higher viscosity and that mantle flow is limited to the asthenosphere. But a viscosity of about 10^{22} poise throughout permits full-mantle convection. Moreover, if full-mantle convection is occurring, its main function must be to transport heat from the Earth's interior into space (by way of lithospheric conduction), which can be done effectively only if the upwelling convective limbs are thin. In other words, Cathles' analysis supports mantle plumes, whether cylindrical or sheet-like. Following Morgan, the plumes may then be envisaged as spreading out at the top into the low viscosity channel, with at least a part of the convective return flow occurring uniformly through the mantle as a whole.

Last, but not least, Cathles' model assumes right from the start that viscosity is Newtonian throughout the mantle. This turns out to be entirely consistent with glacial uplift data.

Peter J. Smith