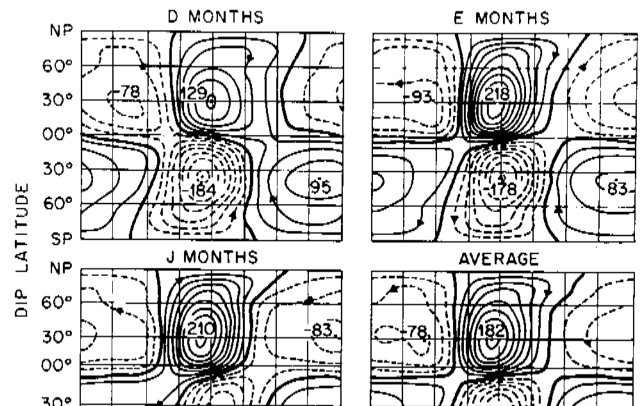

FIGURE 16.2 (a) External *Sq* current systems averaged worldwide for *D* months (northern winter; top left), *E* months (equinox, top right), and *J* months (northern summer, bottom left), and their yearly average (bottom right). The current intensity between two consecutive lines is 25×10^3 A; the thick solid curves indicate the zero-intensity lines. The numbers near the central dots are the total current intensities of these vortices in units of 10 A. (b) Internal *Sq* current systems averaged worldwide for *D* months (top left), *E* months (top right), and *J* months (bottom left), and their yearly average (bottom right). Notice the disagreement with Figure 16.1; the rotational senses of the vorticies are opposite. This figure adapted from Matsushita (1967).

geomagnetic field. Considering only the former cause, the longer the period of the time-varying field, the greater the depth in the Earth where the induced currents can be expected to flow. A quantitative criterion can be given in terms of electromagnetic induction in a half-space of uniform conductivity (note that this is a highly idealized case that practically never occurs in reality). The "skin depth" (i.e., the depth at which the external field is damped by a factor $1/e$) is given by $S = 0.5\,(T/\sigma)^{0.5}$ km, where is the conductivity in mhos/meter and T is the period of the variation in seconds. A signal with period of about 24 h is generally believed to have a skin depth of 600 to 800 km (Hutton, 1976; Gough and Ingham, 1983). (The skin-depth only provides, however, a rough approximation of the depth at which actual telluric currents of a given period are flowing. In fact, the actual conductivity structure underground is most often a matter of considerable indeterminacy.) Saltwater has a conductivity of about 4 mhos/m, hydrated sediments have a conductivity of about 0.1 mho/m, and dry rock has a conductivity of about 0.0001 mho/m. Practically all the materials of the usual geologic environment (see, e.g., ACRES, 1975; Keller, 1966) can be placed between these extremes. Nomograms by which T, σ, and S can be evaluated for different materials and for the "actual" Earth are shown in Figure 16.4. The conductivity of water is largely affected by salinity (and to a minor extent by temperature). The conductivity of soil is largely affected by the state of hydration. Porous materials and sediments can easily be hydrated (see below) by considerable amounts. Hence it might eventually be possible, by electromagnetic means, to distinguish materials of equal density but with different porosities, and hence different hydration (and electrical conductivities), that cannot be distinguished by seismic techniques.

The distributions of sediments, particularly important for shorter-period variations, should be considered on local or regional scales, because minor details in the distributions can be relevant to telluric current flow. A worldwide pattern of sediments has been given by Hopkins (reproduced in Green, 1977, and in Gregori and Lanzerotti, 1982). Fainberg (1980) provided a worldwide model map of the total conductivity of the water shell plus sedimentary cover [Figure 16.5(a)]. Such a map is the result of a more detailed mapping given by Fainberg and Sidorov (1978). For example, Figure 16.5(b) shows the conductivity profile for Europe. Clearly shown are the sedimentary structures responsible for the North German conductivity anomaly and for the channeling in the Seine Basin. The North German anomaly, with a depth-integrated conductivity >3000 mhos, is equivalent to $\gtrsim$ 750 m of seawater.

Another physical factor affecting conductivity, and thus telluric currents, is temperature. Since the temperature increases with depth in the Earth, the conductivity is higher with increasing depth. However, the effect is not uniform; the heat flux through the Earth's surface is greater in certain regions than in others, providing thermal anomalies. Whenever a larger geothermal flux