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[1] Coxeter, H. S. M., *Illinois J. Math.*, **2**, 746 (1958).
[2] Mackay, A. L., *Acta Cryst.*, **15**, 916 (1962).
[3] Niggli, A., *Zeit. Krist.*, **111**, 288 (1959).
[4] Gedwill, M. A., Altstetter, C. J., and Wayman, C. M., *J. App. Phys.*, **35**, 2266 (1964).
[5] Wentorf, R. H., jun., in *The Art and Science of Growing Crystals*, edit. by Gilman, J. J., 192 (Wiley, New York, 1963).
[6] Ogburn, F., Paretzkin, B., and Peiser, H. S., *Acta Cryst.*, **17**, 774 (1964).
[7] Melmed, A. J., and Hayward, D. O., *J. Chem. Phys.*, **31**, 545 (1959)
[8] Melmed, A. J., and Gomer, R., *J. Chem. Phys.*, **34**, 1802 (1961).
[9] Bernal, J. D., *Nature*, **183**, 141 (1959).
[10] Bernal, J. D., *Nature*, **185**, 68 (1960).

GEOPHYSICS

Damping of *S* Waves

THE modified Lomnitz law of imperfection of elasticity makes the strain under constant stress P:

$$\varepsilon = \frac{P}{\mu}\left[1 + \frac{q}{\alpha}\{(1 + at)^{\alpha} - 1\}\right] \qquad (1)$$

a is probably such that at is large for $t = 1$ second. For longer times the relevant constants are the rigidity μ, α, and qa^{α}. The data used to estimate α and qa^{α} are the damping of the 14-monthly variation of latitude and the fact that S at a distance of about 80° is clear and attains half the value for pure elasticity in about 2 sec. An alternative, possibly better, is to take the ratio as $\frac{1}{4}$. These lead to estimates as follows[1]:

I	α	$10^4\, qa^{\alpha} \times (1 \text{ sec})^{\alpha}$	
$\frac{1}{2}$	0·256	3·247	(1)
$\frac{1}{4}$	0·236	4·415	

These lead to no contradictions with other data, such as have been found in attempts to apply the elastico-viscous law. Since estimates of damping have now been made from surface waves, it appears interesting to compare the results with those found from the foregoing law. In this communication values are found for S waves.

The exponent in the complex representation of a travelling harmonic wave is:

$$zt - \frac{zx}{\beta_0} - \frac{1}{2}\frac{qx}{\beta_0}(\alpha - 1)!\, a^{\alpha} z^{1-\alpha} \qquad (2)$$

where z is to be taken as imaginary. With $z = i\gamma, \gamma > 0$, this is:

$$i\gamma\left(t - \frac{x}{\beta_0}\right) - \frac{1}{2}\frac{qx}{\beta_0}(\alpha - 1)!\, a^{\alpha}\gamma^{1-\alpha} e^{\frac{1}{2}\pi i(1-\alpha)}$$

$$= i\left[\gamma\left(t - \frac{x}{\beta_0}\right) - \frac{1}{2}\frac{qx}{\beta_0}(\alpha - 1)!\, a^{\alpha}\gamma^{1-\alpha}\sin\tfrac{1}{2}\pi(1-\alpha)\right] \qquad (3)$$

$$- \frac{1}{2}\, q\frac{x}{\beta_0}(\alpha - 1)!\, \alpha^{a}\gamma^{1-a}\cos\tfrac{1}{2}\pi(1 - \alpha)$$

For $z = -i\gamma$ the imaginary part is reversed and the real part unaltered. The latter gives a damping, with exponent proportional to the distance travelled.

In the calculations the travel time x/β_0 was taken as 200 sec, corresponding to a distance for S of about 7°. The real part of the exponent is denoted by $-k$, and results are given for different periods of the wave, $2\pi/\gamma$, in sec.

Period	k: $a = 0{\cdot}256$	k: $a = 0{\cdot}236$
1	0·176	0·251
2	0·105	0·148
5	0·053	0·073
10	0·032	0·043
20	0·019	0·025
50	0·0096	0·013
100	0·0057	0·0074
1,000	0·0010	0·0013

For distance 20° these must be multiplied by nearly 3. But it is clear that the results do not account for the fluctuations of amplitude in S (or in P) at distances up to 20°, by factors of order 100. 5 sec can be regarded as a typical period of the first swing. I should expect results for surface waves to be comparable.

The data used sample the whole of the Earth's shell (now, rather unfortunately I think, usually called the mantle) and therefore refer to average properties. We should like to know to what extent they refer to the outer tenth of the radius. The amplitudes of both P and S decrease greatly to about 10° and rise to strong maxima about 20°. This has been attributed alternatively to variation in the rate of change of velocity with depth and to absorption; these could both produce similar effects on amplitudes. It seems that if the average imperfection of the shell is applicable to the outer tenth absorption is inadequate. Conversely, if the variations of amplitude in earthquake waves are attributed to absorption, this must be in a very thin layer.

The additional imaginary part of the exponent in equation (3) would imply a delay in travel time, proportional to (period)$^{\alpha}$, and therefore would have little effect for short periods.

The calculations in this communication were made by Miss A. A. Houston at the Mathematical Laboratory, Cambridge.

Estimates of damping of free oscillations are given by Alsop, Sutton and Ewing[2], in the form:

$$A(t) = A(t_0)\exp\left[-\frac{\pi(t - t_0)}{QT}\right] \qquad (4)$$

For the ${}_0S_2$ node they give the period T as 53 min, $Q = 370$. As this mode affects all the shell it should be comparable with the foregoing, with x about 3,000 km, and the expected damping coefficient would be of order 5×10^{-3}. Thus their value is of the order that would be expected from this rough comparison.

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[1] Jeffreys, H., and Crampin, S., *Mon. Not. Roy. Astro. Soc.*, **121**, 571 (1960).
[2] Alsop, L. E., Sutton, G. H., and Ewing, H., *J. Geophys. Res.*, **66**, 2911 (1961).

Cassiterite as a Carrier of Palaeomagnetism

IN an attempt to extend the scope of palaeomagnetism when investigating endogenous geological processes[1,2] the magnetic properties of high-temperature minerals were investigated. The main objective was to find other minerals not yet examined from this point of view which would be amenable to palaeomagnetic examination. The Japanese work on synthetic ferrites[3] suggested to us that certain natural high-temperature minerals (possessing a high isomorphic miscibility of elements) might have similar lattice structures and in consequence be ferromagnetic and capable of retaining a stable thermo-remanent magnetization. The investigation proved successful. Garnets were the obvious minerals for initial examination. All the garnets examined possessed a weak ferromagnetic moment of the order 10^{-5} E.M.U./c.c., but were found to be unstable and so of little use in palaeomagnetism. Of a number of other minerals examined, cassiterite was found to possess unique palaeomagnetic properties.

Cassiterites obtained from Czechoslovakia (Horní Slavkov, Cínovec), as well as foreign localities (Cornwall, south-west England, Altenberg, Eastern Germany, Swaziland, the Congo, Mexico and New England), showed values of natural remanent magnetization ($\mathbf{J}_n$) ranging from 10^{-7} to 10^{-3} E.M.U./c.c. Of a total of 44 samples examined, 18 had values of $\mathbf{J}_n$ lying between 10^{-4} and 10^{-3} E.M.U./c.c., which are values comparable to those exhibited, for example, by Central European basalts.