folds may, therefore, be defined as contortions affecting only incompetent beds, which have thickened and thinned without the aid of ruptures above microscopic levels.

This communication is submitted by permission of the Director of the British Guiana Geological Survey.

EMYR WILLIAMS

Geological Survey Department,
P.O. Box 789,
Georgetown,
British Guiana.

[1] de Sitter, L. U., *Structural Geology* (McGraw-Hill, New York, 1956).
[2] de Sitter, L. U., and Zwart, H. J., Int. Geol. Congr., Rep. Twenty-first Session, Copenhagen, **17**, 248 (1960).
[3] Ball, T. K., *Amer. J. Sci.*, **258**, 274 (1960).
[4] Rice, C. M., *Dictionary of Geological Terms* (Edwards Brothers, Michigan, 1955).
[5] Leith, C. K., *Structural Geology* (Henry Holt, New York, 1913).
[6] Williams, E. (submitted for publication in *Geol. Mag.*).
[7] Scheideggar, A. E., *Principles of Geodynamics* (Springer-Verlag, Germany, 1958).
[8] Cloos, E., *Bull. Geol. Soc. Amer.*, **58**, 843 (1947).
[9] Carey, S. W., *J. Geol. Soc., Aust.*, **1**, 67 (1954).
[10] Carey, S. W., A Tectonic Approach to Continental Drift: Continental Drift, a Symposium (University of Tasmania, Hobart, 1958).
[11] Spry, A. H., *Geol. Mag.*, **90**, 248 (1953).
[12] Williams, E., *Geol. Mag.*, **97**, 208 (1960).

Basutoland Kimberlites

SINCE 1954 a prospecting programme for diamonds in the British Protectorate of Basutoland has led to the discovery of a new predominantly basaltic kimberlite province to the east of the micaceous kimberlite province in the Orange Free State of the Union of South Africa. The kimberlites are intruded into Karroo sediments and lavas and comprise both dykes and diatremes. Petrographically the kimberlites are similar to kimberlites in other parts of South Africa[1,2] and they contain inclusions of eclogite, granulite, peridotite and ilmenite in addition to inclusions of the Karroo country rocks.

Spectrographic analyses of the kimberlites reveal that the trace elements, like the major elements, can be divided into two contrasting suites: (*a*) those in amounts typical of ultrabasic rocks; (*b*) those in amounts typical of alkaline late differentiates. Like the ultrabasic potassic rocks of Uganda which exhibit similar chemical features[3,4], it is believed that kimberlite owes its origin to reaction between a carbonatitic magma and crustal granite. More detailed results are to be published shortly.

J. B. DAWSON*

Geological Survey of Tanganyika,
Box 69, Dodoma.

* Formerly of the Department of Geology, University of Leeds.

[1] Wagner, P., *The Diamond Fields of Southern Africa* (Johannesburg, 1914).
[2] Williams, A. F., *The Genesis of the Diamond* (London, 1932).
[3] Holmes, A., *Amer. Mineral.*, **35**, 773 (1950).
[4] Higazy, R. A., *Geol. Soc. Amer. Bull.*, **65**, 39 (1954).

PHYSICS

Normal Mode Interpretation of the Sound Propagation in Whispering Galleries

THE propagation of sound in 'whispering galleries'[1] is a very remarkable phenomenon, and in Lord Rayleigh's *Theory of Sound* he gives his well-known interpretation based on observations at St. Paul's Cathedral in London. According to my observation, which agrees with Lord Rayleigh's comment in his book, the opinion of the Astronomer Royal ascribing the phenomenon to the reflexion at the upper dome is hard to accept. This follows because at the diametrically opposite point of the gallery the whisper can scarcely be heard, whereas it becomes stronger as one approaches the speaker.

Lord Rayleigh's explanation is, to use present-day terminology of elastic surface waves, based on 'ray theory'. There is, however, another way of describing so-called 'normal mode theory', and the following analysis based on this theory is in accord with the ray theory interpretation given by Lord Rayleigh.

Adopting the velocity potential ϕ, we have a solution referred to polar co-ordinates R, θ and φ as follows:

$$\phi = ([p/c]R)^{-1/2} J_{n+1/2}([p/c]R) Y_n(\theta,\varphi)\exp(ipt) \quad (1)$$

where p is the frequency, c the velocity of sound, J_ν is the Bessel function and $Y_n(\theta,\varphi)$ the spherical surface harmonics. Assuming that the wall is approximately rigid, the boundary condition, a, being the radius of the gallery, is:

$$\text{at } R = a; \quad \partial\phi/\partial R = 0 \quad (2)$$

which gives an equation of the form:

$$\partial[\xi^{-1/2} J_{n+1/2}(\xi)]/\partial\xi = 0, \quad \xi = (p/c)a \quad (3)$$

Since the circumference of the gallery is roughly 100 yards, and the wave-length of the voice is about 1 yard, n is about 100.

Trying the numerical solution for smaller values of n, we find that $n + 1/2 < \xi$. Hence we employ the next form of asymptotic formula for the Bessel function with large orders[2]:

$$J_\nu(\nu \sec\beta) \sim \left(\frac{2}{\pi\nu\tan\beta}\right)^{1/2}\left[\cos Q + \frac{1}{\nu}\cot\beta \, . \left(\frac{1}{8} + \frac{5}{24}\cot^2\beta\right)\sin Q\right] \quad (4)$$

$$Q = \nu(\tan\beta - \beta) - \pi/4$$

and put it into the above expression. Then we have the characteristic equation:

$$\frac{1}{\nu}\left(\frac{7}{24}\tau^3 + \frac{7}{8}\tau\right) + \left[\frac{1}{\nu^2}\left(\frac{35}{48}\tau^6 + \frac{35}{24}\tau^4 + \frac{9}{8}\tau^2\right) + 1\right] . \tan Q = 0 \quad (5)$$

$$\tau = \cot\beta$$

$$\nu = n + 1/2 \text{ and } \nu\sec\beta = \xi \quad (6)$$

The approximate solution of this equation is obtained assuming that $\nu\beta^3$ tends to a certain value different from zero when ν increases indefinitely, namely:

$$\frac{7}{24}\frac{1}{\nu\beta^3} + \left(\frac{35}{48}\frac{1}{\nu^2\beta^6} + 1\right) . \tan\left(\frac{1}{3}\nu\beta^3 - \frac{\pi}{4}\right) = 0 \quad (7)$$

The root is

$$\nu\beta^3 = 1{\cdot}99 \quad (8)$$

which, combined with (6), gives:

$$\xi = (n + 0{\cdot}5) + 0{\cdot}79(n + 0{\cdot}5)^{1/3} \quad (9)$$

The intensity distribution of ϕ with regard to radial direction is given by the function:

$$\Phi = A \, . ([R/a] \, . \, \xi)^{-1/2} J_{n+1/2}([R/a] \, . \, \xi) \quad (10)$$

in which n and ξ are connected by the relation (9). This function can be evaluated by the above asymptotic expansion (4) and other similar formulæ.