

(b) In the second evaluation of the rate of sedimentation the decay of beryllium-10 (aluminium-26) was plotted as a function of the core depths (Fig. 1). A regular decrease in the activities with the depth was found except in the fraction *D* (83–110 cm depth) of the South Pacific core. In fraction *D*, both the beryllium-10 content and the aluminium-26 content were exceedingly high. Although the reason for this irregularity of the fraction *D* is not known, we have eliminated temporarily the data of the fraction *D*.

The rate of sedimentation is obtained from the gradient of the decay curves. We found a rate of about 0.3 mm/1,000 yr from the decay of beryllium-10, which should be considered to be the mean rate of sedimentation between cores 0 and 1 m deep. Good agreement was found between this rate and the sedimentation rates of the surface layer determined by method (a). This means that there has been a constant sedimentation rate in these cores, and a constant cosmic ray intensity during the last  $3 \times 10^6$  yr, with the reservation of fraction *D*.

The activity of aluminium-26 in each fraction was recalculated from the data of Amin *et al.*<sup>1</sup>. Because of the large statistical errors involved in measuring the rate of counting, it was not possible to determine the gradient of the decay curve, but a sedimentation rate of 0.3 mm/1,000 yr seems to be consistent with the decay curve. The decrease of the aluminium-26 to beryllium-10 ratio with depth was also consistent with this rate of sedimentation. All values from the beryllium-10 and aluminium-26 methods therefore indicate a sedimentation rate of about 0.3 mm/1,000 yr for these two cores. This rate may have an uncertainty factor of 2, because of the experimental errors in measurements of the cross-sections and the activities.

These figures obtained from the beryllium-10 and aluminium-26 methods agree well with the sedimentation rates, determined by Goldberg and Koide<sup>8</sup> with the ionium to thorium ratio method, of 0.3 to 0.6 mm/1,000 yr in South Pacific cores.

Although discrepancy has sometimes been reported between the results by the ionium to thorium ratio method and those obtained by the protoactinium and carbon-14 methods, recent studies<sup>9</sup> have indicated the ionium to thorium ratio method or the ionium method with the protoactinium method are consistent. On the other hand, the carbon-14 method is not adequate to determine the very low sedimentation rate, because of its short half-life. We can therefore consider the low (about 0.4 mm/1,000 yr) sedimentation rate of the South Pacific Ocean as a well established fact.

The agreement of the sedimentation rates, measured by the beryllium-10 method and the aluminium-26 method, with the rates by the ionium to thorium ratio method indicates the usefulness of the former two methods in the measurements of the sedimentation rates and also the time variation of cosmic rays over the past few million years.

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YUJI YOKOYAMA

Centre des Faibles Radioactivités, CNRS,  
Gif-sur-Yvette, Essonne, France.

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<sup>1</sup> Amin, B. S., Kharkar, D. P., and Lal, D., *Deep-Sea Res.*, **13**, 805 (1966).

<sup>2</sup> Lal, D., and Venkatavaradan, V. S., *Science*, **151**, 1381 (1966).

<sup>3</sup> Yiou, F., Baril, M., Dufaure de Citres, J., Fontes, P., Gradsztajn, E., and Bernas, R., *Phys. Rev.* (in the press).

<sup>4</sup> Lal, D., and Peters, B., in *Handbuch der Physik*, **46/2** (Springer, Berlin, 1967).

<sup>5</sup> Honda, M., and Lal, D., *Nucl. Phys.*, **51**, 363 (1964).

<sup>6</sup> Reeves, H., *J. Physiq.* (suppl.), colloque No. 1, Cl. 28 (1966).

<sup>7</sup> Nilsson, C., *Science*, **153**, 1242 (1966).

<sup>8</sup> Goldberg, E. D., and Koide, M., *Geochim. Cosmochim. Acta*, **26**, 417 (1962).

<sup>9</sup> Teh-Lung Ku, thesis, Columbia Univ. (1966).

## Emission of BO<sub>2</sub> from Injection of Triethylborane into the Upper Atmosphere

Hoffman, Palmer and Smith<sup>1</sup> recently presented a low resolution emission spectrum obtained from the sunlit release of triethylborane at a height of between 90 km and 178 km above the Earth. They assigned the observed bands to an  $A^2\Pi-^3\Pi$  transition of boron oxide, even though they noted the absence of a band expected at 6025 Å on the basis of this assignment. Their communication does not make clear which oxide of boron is assigned as responsible for the emission.

I believe the observed emission spectrum is that of the boric oxide fluctuation bands—a spectral system arising from a transition of the BO<sub>2</sub> radical<sup>2</sup>. A comparison is given in Table I between the wavelengths of maximum emission observed in ref. 1 and those reported in absorption for flames containing boron<sup>3</sup>. The correspondence between these data is as good as can be expected when a complicated spectrum of many lines is observed at low resolution. The 6025 Å band shown in ref. 4 and mentioned by Hoffman *et al.* is not a part of the BO<sub>2</sub>  $A^2\Pi-X^2\Pi$  system; therefore its absence in the upper atmosphere emission supports this assignment rather than presenting a difficulty.

Table 1

Emission maxima from upper atmosphere release <sup>1</sup>	Absorption maxima for BO <sub>2</sub> in flames <sup>3</sup>
6,420	—
6,200	6,200
5,795	5,790
5,465	5,470
5,170	5,180

The boric oxide fluctuation bands were erroneously assigned to B<sub>2</sub>O<sub>3</sub> for many years<sup>5,6</sup>. The correct assignment of the spectrum to the BO<sub>2</sub> radical was made independently in Russia<sup>7</sup> and in the United States<sup>8</sup> on the basis of spectral and chemical kinetic studies. This assignment was confirmed when this electronic spectrum was resolved, analysed and the molecular constants of BO<sub>2</sub> determined<sup>9</sup>. The key to success in this work lay in production of the emitter with a low rotational temperature by flash photolysis of boron trichloride-oxygen mixtures at low pressures. Those conditions are strikingly similar to those which obtained in the upper atmosphere release of Hoffman *et al.* Both experiments probably involve non-thermal excitation processes which obviate the use of the relative band intensities for thermometry.

In spite of its recent discovery, the properties of the BO<sub>2</sub> molecule are now well known. This is partly a result of the fact that its electronic spectrum is one of the best examples of the Renner effect. The thermodynamic properties of BO<sub>2</sub> have been computed<sup>10</sup> and its heat of formation determined<sup>11</sup>. It may therefore usefully serve as a chemical probe for species with which it reacts in the upper atmosphere.

R. C. MILLIKAN

Department of Chemistry,  
University of California,  
Santa Barbara, California.

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<sup>1</sup> Hoffman, J. M., Palmer, M. A., and Smith, J. B., *Nature*, **215**, 1158 (1967).

<sup>2</sup> Pearce, R. W. B., and Gaydon, A. G., in *The Identification of Molecular Spectra*, second ed., 60 (John Wiley and Sons, Inc., New York, 1950).

<sup>3</sup> Kaskan, W. E., and Millikan, R. C., *Eighth Symposium (International) on Combustion*, 282 (Williams and Wilkins Co., Baltimore, 1962).

<sup>4</sup> Mavrodineanu, R., and Boiteux, H., in *Flame Spectroscopy* (John Wiley and Sons, Inc., New York).

<sup>5</sup> Soulen, J. R., Sthapitanonda, and Margrave, J. L., *J. Phys. Chem.*, **59**, 132 (1955).

<sup>6</sup> Soulen, J. R., and Margrave, J. L., *J. Amer. Chem. Soc.*, **78**, 2911 (1956).

<sup>7</sup> Mal'tsev, A. A., Matveev, V. K., and Tatevskii, V. M., *Sci. Rep. No. 210*, Chemistry Faculty, Moscow State University (1958).

<sup>8</sup> Kaskan, W. E., and Millikan, R. C., *J. Chem. Phys.*, **32**, 1273 (1960).

<sup>9</sup> Johns, J. W. C., *Canad. J. Phys.*, **39**, 1738 (1961).

<sup>10</sup> McBride, B. J., Heibel, S., Ehlers, J. G., and Gordon, S., NASA SP-3001, 123 (Off. Tech. Ser., Washington, D.C., 1963).

<sup>11</sup> Rusin, A. D., and Tatevskii, V. M., *Rus. J. Phys. Chem.*, **37**, 376 (1963).