GEOLOGY

Carbonatitic Lavas

RECENTLY, von Knorring and du Bois[1] described a vesicular lava of high carbonate content from western Uganda which shows close geochemical affinities with intrusive carbonatites. They stated: "It must be emphasized that the lavas examined are fresh and unaltered and that the carbonated nature cannot be attributed to alteration after solidification". Descriptions of extrusive equivalents of carbonatites are rare, but two other examples have been reported recently from Africa. Bailey[2] concluded that certain carbonate-rich tuffs in Northern Rhodesia were primary, and not alteration products of more normal rocks. On p. 58 of his report, he wrote: "Indigestible though the fact may be to some philosophical systems —the pyroclastics around the Rufunsa vents are effusive carbonatite". Reference is made, in both papers, to the 1954 eruption of Oldonyo Lengai in Tanganyika, during which showers of dust and ashes, largely composed of calcium and sodium carbonates, were observed to fall on the flanks of the volcano[3].

We have presented experimental evidence for the magmatic origin of carbonatites elsewhere[4,5]. Evidence from the system $CaO—CO_2—H_2O$ indicates that simplified carbonatite magmas can exist through a wide range of pressure at moderate temperatures. The lowest pressure reached in these experiments was 27 bars. Since then, Wyllie and Raynor[6], at the University of Leeds, have confirmed the existence of these melts down to pressures of 10 bars, and the minimum pressure could be considerably less than this. Addition of other components would lower the pressure even further; alkali carbonates which melt at low temperatures without dissociation at 1 bar can be especially effective in this way. On the basis of the experimental evidence, therefore, it can be concluded that carbonatite magmas could reach levels very near to the surface (10-bars pressure is developed by a rock overburden of about 140 ft.), and such magmas could be erupted as tuffs. If the alkali-bearing carbonatitic magmas persist down to pressures approaching 1 bar, then the eruption of vesiculating carbonatitic flows appears to be a reasonable possibility.

Experimental studies of multicomponent systems related to carbonatites are now well advanced. Preliminary data for the system $CaO—MgO—CO_2—H_2O$ have already been reported[5]. Fluorine is known to be an important constituent in many carbonatites, and phase relations in the system $CaO—CaF_2—CO_2—H_2O$ have therefore been studied[7]. Apatite is ubiquitous in carbonatites and investigation of the systems $CaO—CO_2—H_2O—P_2O_5$ and $CaO—CaF_2—H_2O—P_2O_5$ has confirmed that calcite and apatite can be precipitated together from a melt through a wide pressure and temperature interval, extending to below 650° C.[8] In the system $CaO—CO_2—H_2O—SiO_2$, calcite is precipitated along with a silicate mineral (calcio-chondrodite) from a low-temperature melt[9]. More detail on the crystallization of alkali carbonate melts has been obtained in the systems $CaO—Na_2O—CO_2—H_2O$ and $CaO—K_2O—CO_2—H_2O$[10]. The significance of these systems is evident from the eruption of alkali carbonates at Oldonyo Lengai and from the widespread fenitization associated with carbonatite complexes.

Von Knorring and du Bois concluded that the existence of carbonatitic lava flows was evidence for the primary origin of carbonatite magmas. The problem of whether carbonatite magmas are primary or derivative is also being studied experimentally. Systems such as $CaO—CO_2—H_2O—NaAlSiO_4$, $CaO—CO_2—H_2O—NaAlSi_3O_8$, $CaO—CO_2—H_2O—KaAlSi_3O_8$, and $CaO—CO_2—H_2O—NaFeSi_2O_6$ are being investigated, and it is hoped that the data obtained will indicate which of these suggested origins is more likely. However, whatever the ultimate origin of carbonatites may be, the nature of the reactions involving alkalis and basic oxides, with either solid-vapour or solid-liquid-vapour equilibria, is of fundamental importance for understanding the processes involved in the development, emplacement, or eruption of carbonatites and carbonatitic rocks.

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[1] Knorring, O. von, and du Bois, C. G. B., *Nature*, **192**, 1064 (1961).
[2] Bailey, D. K., Ministry of Labour and Mines Geological Survey, Northern Rhodesia, *Bulletin* No. 5 (1960).
[3] James, T. C., *Rep. Carbonatites and Rift Valleys in East Africa* (Geol. Survey, Tanganyika, 1956).
[4] Wyllie, P. J., and Tuttle, O. F., *J. Petrol.*, **1**, 1 (1960).
[5] Wyllie, P. J., and Tuttle, O. F., *Rep. Twenty-first Intern. Geol. Cong.*, **13**, 310 (1960).
[6] Wyllie, P. J., and Raynor, E. J. (unpublished).
[7] Gittins, and Tuttle, O. F. (unpublished).
[8] Biggar, G. M., and Wyllie, P. J. (unpublished).
[9] Haas, J. L., and Wyllie, P. J. (unpublished).
[10] Gittins, and Tuttle, O. F. (unpublished).

PHYSICS

Influence of Particle Rotation on Radial Migration in the Poiseuille Flow of Suspensions

Segré and Silberberg[1] recently observed that when an initially uniform dilute suspension of rigid spheres passes through a circular tube in laminar flow, the spheres tend to concentrate into an annular region about half-way between the tube centre and tube wall. It was suggested that the inward motion of the spheres resulted from a force, akin to the Magnus effect, which was present because the spheres rotated as they passed through the tube. Work by Tollert[2], Saffmann[3] and Rubinow and Keller[4] has also indicated the presence of an inward force of the above type, while the 'minimum energy dissipation' theory of Jeffery[5] shows that the spheres should move inwards and eventually travel along the tube axis. Unfortunately no satisfactory explanation has been given of the fact that, in the above experiment[1], the inner spheres moved outwards while the outer spheres ceased to move inwards when they reached the region of the annulus.

I have recently made observations with single particles which clearly indicate that the rotation of the spheres results in an outward movement and not inward as previously suggested[1-4]. In the absence of rotation, the spheres normally drift towards the tube centre. This behaviour is obtained when the densities of the sphere and liquid are equal, the tube Reynolds number is in the range 100–500 and the relative particle Reynolds number[6] is in the range