Late Caenozoic Shoshonitic Lavas in North-western Viti Levu, Fiji

MOST petrologists recognize two fundamental types of basaltic magma—tholeiite and alkaline olivine basalt[1]. The ratio of alkalis to silica is consistently higher in alkaline olivine basalts than in tholeiitic (sub-alkaline[2]) basalts[3,4]. Kuno[5] recognized a third type of magma, high-alumina basalt characterized by high contents of alumina and intermediate alkali, and Hamilton[6] noted its apparent genetic relationship to the calc–alkaline intermediate magmas of island arcs. Joplin[7] recognized a fourth type of basaltic magma characterized by high potash content, and proposed the name shoshonite[8] for the magma series derived from a high-potash parent magma. The potash-rich shoshonites are as alkalic as the soda-rich alkaline olivine basalts, but the ratio of potash to soda in shoshonites is near or in excess of 1·0, whereas the same ratio is 0·5 or less in typical alkaline olivine basalts and their derivatives. Joplin noted that shoshonitic lavas seem to be especially characteristic of newly stabilized or just consolidated orogenic regions. The possibility that shoshonitic lavas might be characteristic of the late Caenozoic volcanic sequence of Fiji was called to our attention by G. A. Joplin and A. J. R. White on the basis of an analysis obtained by V. Iyengar and quoted by Rickard[9]. The estimated volume of late Caenozoic shoshonite in Fiji is about 10^4 km^3; therefore the origin of the magma presents a significant challenge to petrologic theory.

Fiji stands well out to sea at the centre of a bathymetric spiral whose arms are the opposed arc-and-trench systems of the New Hebrides and Tonga[10]. The oldest rocks in Fiji are strongly deformed and partly metamorphosed volcanic and volcaniclastic early Tertiary strata which are intruded by mid-Tertiary stocks and batholiths of gabbro and granitic rocks, and are overlain unconformably by less deformed late Tertiary volcanic and sedimentary strata[11]. Local unconformities are present in the late Tertiary sequence, the older parts of which are strongly folded. The younger beds are only broadly tilted or warped, and among these is the late Pliocene Koroimavua volcanic group of Rickard[9] on north-western Viti Levu, the principal island of Fiji. The central stocks of the eruptive centres were studied by Higgs and Coulson[12], and later by Smith and Dickinson[13], who also studied the facies patterns of volcanic and volcaniclastic strata within the group.

The eroded volcanic centres—of which three are definitely known—are steep-walled composite stocks, with equant outlines, each 1–10 km^2 in area and spaced 5–10 km apart. The rocks of the stocks are phanerites, microphanerites and porphyries with modal compositions in the following approximate ranges: labradorite, 40–60 per cent; augite, 15–45 per cent; K-feldspar, 0–35 per cent; biotite, 5–10 per cent; opaques, 5 ± 2 per cent. The extremes of the compositional range are monzonites and gabbros. Pyroclastic breccias and minor lavas with platy jointing built multiple stratovolcanic accumulations above the volcanic centres. The lavas and breccia blocks are porphyritic aphanites with a grey, translucent, commonly glossy groundmass in which are small phenocrysts of plagioclase and augite, lesser hornblende in some rocks, and biotite in variable amounts. Leucite–phyric lavas occur at the base of the Koroimavua sequence in at least three places.

Three extrusive breccia blocks collected by Dickinson from widely separated localities are shoshonite (Table 1). The mineralogy of the analysed specimens as determined by Lawrence is as follows: plagioclase (19–23 per cent), zoned from An_{70-73} cores to An_{63-65} rims; pale yellow–green augite (15–20 per cent), $2V = 50°–60°$, $ZC = 38°–43°$, $\gamma - \alpha = 0{\cdot}025–0{\cdot}026$, R.I. ~ 1·65–1·70; yellow–brown biotite (2–5 per cent); opaque grains (3 per cent); and groundmass (54–55 per cent). Thin jackets of alkali feldspar (?) are present on some plagioclase phenocrysts. The average chemical composition of three phanerites collected by Coulson[12] from the central stocks is nearly identical to the mean of the three breccia blocks which were analysed (Table 1).

Table 1. CHEMICAL COMPOSITION OF ROCKS OF THE KOROIMAVUA VOLCANIC GROUP, NORTH-WEST VITI LEVU, FIJI

	1	2	3	4	5
SiO_2	48·81	50·06	50·53	49·80	49·06
Al_2O_3	17·90	16·76	18·12	17·59	17·95
TiO_2	0·65	0·69	0·71	0·68	0·86
Fe_2O_3	5·29	6·19	5·58	5·69	5·09
FeO	2·65	3·28	2·96	2·96	4·41
MgO	4·27	5·45	4·97	4·90	4·75
MnO	0·21	0·18	0·16	0·18	0·22
CaO	9·33	9·40	9·44	9·39	9·68
Na_2O	2·66	2·24	2·40	2·43	2·86
K_2O	4·69	3·90	2·85	3·81	2·83
P_2O_5	0·48	0·55	0·38	0·47	0·40
H_2O	2·51	1·54	1·72	1·92	1·85
Total	99·45	100·24	99·82	99·84	99·96

Columns 1–3 are individual analyses of porphyro–aphanitic breccia blocks; localities are on file with the Fiji Geological Survey Department in Suva as follows: column 1, spec. NA-3; column 2, spec. LD-39; column 3, spec. BB-2.

Column 4 is the mean of columns 1–3.

Column 5 is the mean of three phaneritic intrusive rocks from the central stocks.

(Figures are weight percentages from rapid-silicate chemical analyses by A. G. Loomis.)

To the east across northern Viti Levu[11], extensive basaltic lavas of the Mba Volcanic Group studied by P. Ibbotson also have chemical compositions representative of the shoshonite magma series[14]. These rocks are the host for telluride gold deposits at Vatukoula controlled by fracture systems at the margin of a large caldera. The alkalic intermediate differentiates of the Mba are potash-rich tristanites[15] which differ from the soda-rich benmoreites[15], found in association with the alkaline olivine basalts of Hawaii.

In comparison with more familiar lavas, the chemistry of the shoshonites of Fiji is distinctive in the following salient respects: (*a*) the silica and lime contents are similar to those of basalt despite the high potash content and the high ratio of potash to soda; (*b*) the silica and total alkali contents are similar to those of hawaiite or mugearite, but the lime content is higher, and the potash to soda ratio is reversed; and (*c*) the silica content is less than in latite.

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