FIELD GEOLOGY AND PETROLOGY OF THE MINETTE DIATREME AT BUELL PARK, APACHE COUNTY, ARIZONA

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Field relations and rock and mineral chemistry were investigated to understand the volcanology of the minette diatreme, the relationship between minette and kimberlite, and the genesis of minette varieties at Buell Park, Arizona. The compositional variation of the minettes there encompasses the range of compositions found in minettes throughout the Navajo volcanic field. "Minette" is used for a group of intrusive and extrusive rocks which are linked by their potassic nature (3-7.5% K_2O) and mineralogy (phenocrysts of diopside + phlogopite $\pm$ olivine in a groundmass of alkali feldspar + diopside + oxides $\pm$ mica $\pm$ analcime $\pm$ quartz $\pm$ amphibole). Previously kimberlite and minette were known to occur together at Outlet Neck and Buell Park within the Navajo field, but two new occurrences have been found: The Beast, a minette neck 5 km east of Buell Park, contains a block of kimberlite, and a small unnamed kimberlite pipe 8 km east of Buell Park is bisected by a minette dike. Furthermore, at Buell Park where a minette diatreme is nested within a kimberlite diatreme, evidence indicates an overlap in time of minette and kimberlite eruptions: the upper 75 m of the layered kimberlite contains subrounded, altered minette clasts (analysis BP-69, Table 1), and two small kimberlitic breccia pipes (Fig. 1) occur along the margins of two late minette intrusions. In addition to xenocrysts derived from minette, the kimberlitic breccia pipes contain xenocrysts of kinked olivine (Fo_{89-91}), chrome-rich spinel (39.5% Cr_2O_3, 25.1% Al_2O_3), chrome-rich diopside ($TiO_2 < 0.04\%$, 0.5% Cr_2O_3), and enstatite ($Wo_{0.5}En_{92}Fs_7$). The bulk of the kimberlite, however, was erupted before the minette.

The Buell Park minette diatreme occupies the southern third of Buell Mountain (Fig. 1); the northern two thirds consist of layered kimberlite lapilli tuff capped and intruded by minette. As at other minette centers explosive eruptions preceded extrusion and intrusion of massive minette. The floor of the maar could not have been more than 100 m above the presently exposed tuff-breccias; more likely, the tuff-breccias were just below the crater floor. Two types of tuff-breccia crop out: a light-colored variety, unsorted and unbedded, containing subangular nonvesicular glassy minette clasts up to a meter across, and a crudely bedded, more coherent dark-colored tuff-breccia containing both subangular minette clasts and flattened bombs. The light-colored tuff-breccia probably is a vent filling akin to the tuff-breccias that form Shiprock, while the dark-colored tuff-

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breccia formed from material plastered on the vent walls. The tuff-breccias and layered kimberlites were later intruded by numerous minette dikes and sills and a late quartz-bearing plug (Fig. 1).

Six K-Ar ages have been obtained on phlogopite from minettes: three from Buell Park, and one each from Fluted Rock, Black Rock (Ft. Defiance), and The Beast. Five of the six agree within experimental error and average 25.4 m.y., about 5 m.y. younger than previously reported ages (for example, Naeser, 1971; Armstrong, 1969). One clast from a tuff-breccia dike(?) at Buell Park was dated at 33 m.y. although field evidence conclusively demonstrates that it must be the same age as the other samples.

TABLE 1

Chemical Analyses of Buell Park minettes

	BPR-6	BPR-5	BP-69	BP-37	BP-41	BP-35
SiO_2	49.13	48.94	55.46	56.23	58.88	59.50
TiO_2	2.02	2.03	0.91	1.08	0.87	0.89
Al_2O_3	10.51	10.11	10.65	12.14	13.38	12.93
Fe_2O_3	3.82	4.47	3.68	4.38	3.77	3.02
FeO	4.30	3.60	1.08	1.36	1.17	1.46
MnO	0.12	0.12	0.05	0.08	0.06	0.06
MgO	9.87	10.03	9.17	6.63	4.31	4.90
CaO	9.06	8.98	4.34	6.37	6.12	5.30
Na_2O	2.06	1.28	1.42	2.60	2.87	2.53
K_2O	4.86	5.22	6.98	6.76	7.20	7.21
H_2O+	2.38	2.92	2.09	0.84	0.36	0.54
H_2O-	0.38	0.80	2.71	0.36	0.08	0.60
P_2O_5	0.97	1.08	0.63	0.77	0.74	0.64
CO_2	0.00	0.01	0.00	0.02	0.06	0.10
Total	99.48	99.59	99.17	99.62	99.87	99.68

BPR-6 = olivine-bearing minette, western end of the ring dike, Buell Park; BPR-5 = olivine-bearing minette, central portion of the ring dike, Buell Park; BP-69 = minette clast, layered kimberlite lapilli tuff, Buell Mountain; BP-37 = minette clast, minette tuff-breccia, Buell Mountain; BP-41 = felsic minette, northern end, Buell Mountain; BP-35 = quartz-bearing felsic minette plug, southern end, Buell Mountain (Analyst for all samples: G. Karl Hoops).

The felsic minettes of Buell Mountain contrast sharply with the mafic minette of a ring dike located within Buell Park less than 2 km to the south. The ring dike minettes are characterized by lower SiO_2, lower total alkalis, and higher total Fe, TiO_2, MgO, and CaO (Table 1) than the Buell Mountain minettes. The ring dike minette also differs from the felsic minettes in containing titaniferous phlogopite (7.5-11% TiO_2, Mg/Fe = 3.6-2), olivine phenocrysts (Fo_{86}-Fo_{78}, core to rim), groundmass analcime, and in the rarity of xenoliths. The felsic minettes of Buell Mountain lack olivine and analcime, many contain interstitial quartz, all contain abundant xenoliths (5% volume), including numerous spinel lherzolites and websterites, and the phlogopites are less titaniferous (TiO_2 $<6\%$, Mg/Fe = 3-6). The diopsides from all the minettes are similar, typically $Ca_{46}Mg_{45-50}Fe_{4-9}$. The spatial association suggests that the mafic minettes might be related to the felsic minettes by fractionation of olivine, diopside, and phlogopite, but the phenocryst compositions cannot be combined with the daughter composition (analysis BP-37), a clast from the tuff-breccias on Buell Mountain, to yield a satisfactory ring dike composition. Moreover, the presence of dense inclusions argues against crystal settling being effective above their original location, presumably the upper mantle. More likely, primary mafic and felsic minettes arose by partial melting of a heterogeneous, enriched portion of the mantle

Fig. 1. Geologic map of Buell Mountain. Units from youngest to oldest are: Q, Quaternary alluvial and colluvial deposits, undifferentiated; Qc, soil and talus; Ql, landslide masses; Qn, stream deposits currently being dissected; Tkb, kimberlitic breccia; Tmfp, quartz-bearing, felsic minette plug; Tmfa, altered felsic minette; Tmf, felsic minette, undifferentiated; Tmf4, quartz-bearing, felsic minette plug(?); Tmf3, platy-cleaved, diopside-rich minette; Tmf2, oxidized felsic minette; Tmf1, phlogopite-rich, schistose minette; Ttl, layered minette lapilli tuff; Ttbd, dark-colored minette tuff-breccia; Ttbl, light-colored minette tuff-breccia; Tkgl, layered kimberlite lapilli tuff; Pdc, De Chelly Sandstone.

consisting of garnet + phlogopite + diopside + apatite ± olivine ± ilmenite. The more felsic minettes (analyses BP-35, BP-41, Table 1) may be related by fractionation of diopside, phlogopite, and magnetite from a magma similar in composition to minette clasts in the tuff-breccias (analysis BP-37, Table 1), although magnetite appears to be restricted to the groundmass.

Distinctive, sparse green salite cores occur in diopside phenocrysts throughout the Navajo field (for example, Shiprock, Roof Butte, Church Rock, Twin Buttes, and Zildlitloi field). These cores rich in Na_2O (0.6-1.8%) and Al_2O_3 (2-4.8%) but notably poor in Cr_2O_3 ($\leq$0.10%). In contrast, normal diopside cores commonly have Cr_2O_3 contents greater than 0.15%. The low Cr_2O_3 contents of the green cores militates against a genetic relationship with the minette magmas; more likely, the cores are xenocrysts from a widespread rock type in the upper mantle or lower crust. S.N. Ehrenberg (written communication) has also concluded that similar salite cores at The Thumb are xenocrysts.

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