Peralkaline Silicic Volcanic Rocks in Northwestern Nevada

Abstract. *Late Tertiary silicic ashflow tuffs and lavas peralkaline in chemical character (atomic Na + K greater than Al), mainly comendites, occur over wide areas in northwestern Nevada and appear to be widespread in southeastern Oregon. Such peralkaline rocks—which are not uncommon in the western United States—and other chemically unusual silicic rocks are found near the margins rather than toward the center of the Great Basin.*

Peralkaline silicic volcanic rocks, both tuffs and lavas, are widespread in northwestern Nevada (Fig. 1); most appear to belong to the comendite-pantellerite series of quartz-saturated peralkaline rocks, but some, lacking quartz phenocrysts, may be transitional toward alkali trachyte. Comendites and pantellerites are the peralkaline equivalents of rhyolite, being silica-rich rocks, with an atomic excess of alkalis over aluminum, that contain somewhat less aluminum and more iron, titanium, and sodium than do nonperalkaline rhyolitic rocks. The term comendite refers to the less peralkaline and iron-rich members of the series; the term pantellerite, to the more peralkaline and iron-rich members.

The peralkaline rocks were readily identified in the field during rapid reconnaissance by the presence within gas cavities of distinctive euhedral needles or prisms of amphibole of vapor-phase origin. Such amphibole often occurs only locally within a rock unit, presumably in areas where conditions during cooling and crystallization were not too oxidizing or otherwise unfavorable for its formation or preservation. The absence of biotite and plagioclase phenocrysts and the gray-to-bluish or greenish-gray-to-green hues of many of the rocks also suggested peralkaline composition. Abundant sodic amphibole (typically arfvedsonite) and, in certain rocks, aegirine-augite are present in the groundmass material of representative specimens that were later studied in thin section. Phenocrysts of sodic amphibole also occur in certain tuffs.

Table 1. Data (percentages by weight) from partial chemical analyses of comendites from northwestern Nevada and southeastern Oregon. Specimens 1–3 are densely welded and granophyrically crystallized. Quartz, sanidine, arfvedsonite, and aegirine-augite (specimen 3) occur as large crystals of vapor-phase origin lining lensoid gas cavities localized by partially collapsed pumice fragments, as well as in the dense groundmass material of specimens 1–3. Analyses, by x-ray fluorescence methods, by D. L. Giles and D. C. Noble. Specimen 1: Comendite ash-flow tuff (NR-11) collected from cooling unit in SW¼, Sec. 24, T. 40 N., R. 25 E.; contains broken phenocrysts of quartz (9 percent), sanidine (15 percent), and sodic amphibole (0.5 percent). Specimen 2: Aphyric comendite ash-flow tuff (NN-31-3-6) collected from lower part of compositionally zoned cooling unit in the northwest corner of Sec. 1, T. 43 N., R. 36 E. Specimen 3: Comendite ash-flow tuff (OR-1) collected from cooling unit in the center of W½, Sec. 26, T. 39 S., R. 36 E; contains broken phenocrysts of quartz (15 percent), sanidine (7 percent), and altered mafic minerals (1 percent). Specimen 4: Nonhydrated comendite glass (NN-10) collected from glassy part of aphyric lava flow in SE¼, Sec. 12, T. 37 N., R. 20 E.; n_d, 1.491. Specimen 5: Nonhydrated comendite glass (NN-25A) collected from glassy part of aphyric lava flow in center of south margin of Sec. 5, T. 46 N., R. 28 E.; n_d, 1.491_5.

Specimen	Fe as FeO	TiO_2	CaO	Zr
1	2.6	0.24	0.15	0.07
2	3.4	.22	.19	.08
3	2.1	.22	.19	.04
4	2.1	.16	.29	.04
5	2.0	.26	.17	.05

Many cooling units of peralkaline ash-flow tuff crop out throughout Black Rock Range, eastern parts of Calico Mountains, and the Summit Lake area, and on the eastern side of Rock Spring Table, all in western Humboldt County (*1*). A distinctive dark-brown-weathering cooling unit of blue-to-bluish-gray tuff 50 to 150 meters thick, containing abundant quartz and sanidine phenocrysts, caps the central part of Black Rock Range and crops out over a wide area north, west, and south of Soldier Meadow. Another striking cooling unit, dark-brown-weathering and typically green-to-greenish-gray on fresh surface, crops out north of Summit Lake; this unit, thicker than 100 m in the Idaho Canyon area, is vertically zoned from very phenocryst-poor tuff at the base to tuff containing 10 to 15 percent of phenocrysts at the top. Both cooling units have undergone primary granophyric crystallization and locally show evidence of appreciable postcompaction flowage.

Paleontologic or radiometric ages for the ash-flow units are unavailable, but regional relations (*2*) strongly suggest a Miocene or Pliocene age.

Generally phenocryst-free or phenocryst-poor peralkaline lavas, which in several areas appear to be younger than certain of the tuffs, crop out over wide areas in northern Washoe County and locally in westernmost Humboldt County. Nonhydrated glass from the chilled margins of these flows has the green tint in transmitted light commonly found in silicic peralkaline glasses. Green obsidian also has been found in Warner Mountains near Lake City, California.

Silicic peralkaline welded tuffs and lavas have been reported from several localities in east-central and south-central Oregon (*3*), and we have recognized several peralkaline ash-flow units in the southeastern part of the Adel quadrangle (1:250,000) in central Oregon. Many of the silicic volcanic rocks of late-Tertiary age in the southeastern third of Oregon are probably peralkaline types, mainly comendites.

Preliminary analytical data (Table 1) show that iron contents are not extremely high; thus all the specimens may be termed comendite according to Lacroix (*4*). The contents of Zr (large) and CaO (small) are consistent with the peralkaline character of the rocks (*5*, *6*).

Peralkaline silicic volcanic rocks also are common toward the southern margin of the Great Basin, where they are either the dominant or an important rock type of the Black Mountain (*7*, *8*), Silent Canyon (*7*, *9*), and Kane Springs Wash (*10*) volcanic centers (*11*) of south-central and southeastern

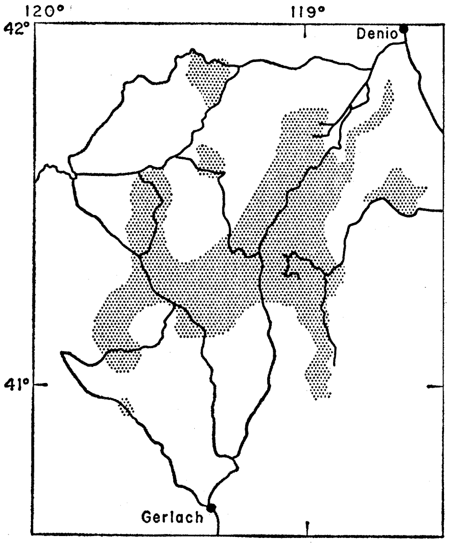

Fig. 1. Northwestern Nevada. Stippled is the approximate area where peralkaline tuffs and lavas crop out, or where they can be confidently projected beneath younger rocks. Other areas of peralkaline rocks almost certainly occur. Solid lines trace traverses by road and foot during geologic reconnaissance.

Nevada. [Again we emphasize an earlier conclusion (*5*): Peralkaline silicic rocks—until recently often considered to be little more than petrologic curiosities—are not uncommon in the western United States.] Other chemically unusual, and presumably highly differentiated, late-Tertiary silicic rocks, such as the Sr-poor rhyolites of Glass Mountain in Mono County, California (*12*), the F-rich and Be-rich rhyolites of western Utah (*13*) and southwestern Idaho (*14*), and the Sn-rich and topaz- and fluorite-bearing rhyolites of northernmost Lander County, Nevada (*15*), also appear to be restricted to or more prevalent in the marginal parts of the Great Basin area. Silicic volcanic rocks in the center of the Great Basin, on the other hand, appear to be almost exclusively relatively primitive quartz latites rich in strontium and potash.

Silicic volcanic rocks younger than about 20 million years are abundant only toward the margins of the Great Basin, being absent or rare toward the center (*16*). The significance of this annular distribution pattern is not fully understood, but it may be genetically related to the apparent restriction to the margins of the Great Basin area of peralkaline and other chemically unusual types of silicic rock.

DONALD C. NOBLE
DAVID W. CHIPMAN
DAVID L. GILES

Department of Geological Sciences,
Harvard University,
Cambridge, Massachusetts 02138

References and Notes

1. U.S. Geological Survey, *U.S. Series of Topographic Maps 1:250,000*, sheet VYA.
2. R. Willden, *U.S. Geol. Surv. Mineral. Invest. Field Studies Map MF-236* (1961); *U.S. Geol. Surv. Bull. 1141-D* (1963), pp. D1–D65; *Nevada Bur. Mines Bull. 59* (1964), p. 1; G. W. Walker and C. A. Repenning, *U.S. Geol. Surv. Misc. Invest. Map. 1-446* (1965).
3. W. R. Dickinson, *Oregon Dept. Geol. Mineral Ind. Bull. 58* (1965); G. W. Walker, *U.S. Geol. Surv. Profess. Paper 424-C* (1961), pp. C142–C145; ——— and D. A. Swanson, *Geol. Soc. Amer. Spec. Paper*, in press.
4. Lacroix [*Acad. Sci. Paris Compt. Rend.* **185**, 1410 (1927); *Mem. Acad. Sci. Paris* **61**, 169 (1934)], recognizing the continuity of the comendite-pantellerite series, proposed that rocks containing more than 12.5 percent of total normative femic constituents be termed pantellerite; those with less than 12.5 percent, comendite. Of 55 silica-rich, nonhydrated peralkaline glasses so classified by Noble, all the comendites have less than 4.0 percent by weight of total iron (as FeO) plus MnO, whereas all the pantellerites but one contain more than 4.0 percent by weight. Iron-plus-manganese content thus provides a simple and internally consistent method for classification of the silica-rich peralkaline rocks, one that is especially useful when the rocks have undergone various changes in oxidation and alkali content subsequent to deposition.
5. D. C. Noble, *Geol. Soc. Amer. Spec. Paper 87* (1966), pp. 117–118.
6. J. R. Bulter and A. Z. Smith, *Geochim. Cosmochim. Acta* **26**, 945 (1962); P. Bowden, *ibid.* **30**, 935 (1966); R. V. Dietrich and K. S. Heier, *ibid.* **31**, 275 (1967).
7. D. C. Noble, R. W. Kistler, R. L. Christiansen, P. W. Lipman, F. G. Poole, *Geol. Soc. Amer. Spec. Paper 82* (1965), p. 143.
8. D. C. Noble, R. E. Anderson, E. B. Ekren, J. T. O'Connor, *U.S. Geol. Surv. Profess. Paper 475-D* (1964), pp. D24–D27; R. L. Christiansen and D. C. Noble, *Geol. Soc. Amer. Spec. Paper 82* (1965), p. 246; D. C. Noble, *U.S. Geol. Surv. Profess. Paper 525-B* (1965), pp. B85–B90.
9. K. A. Sargent, D. C. Noble, E. B. Ekren, *U.S. Geol. Surv. Bull. 1224A* (1965), pp. A32–A36; D. C. Noble, K. A. Sargent, E. B. Ekren, H. H. Mehnert, F. M. Byers, Jr., in *Geol. Soc. Amer. Mem. 110*, in press.
10. D. C. Noble, in *Geol. Soc. Amer. Mem. 110*, in press.
11. Analytical data [D. C. Noble, unpublished; I. S. E. Carmichael, *Beitr. Mineral. Petrog.* **14**, 36 (1967)] show that the rhyolites of Mono Craters and of Glass Mountain in Mono County, California, are not peralkaline as was indicated by the analyses reported by C. M. Gilbert, in *Geol. Soc. Amer. Bull. 52* (1941), pp. 781–815.
12. D. C. Noble and C. E. Hedge, unpublished.
13. D. R. Shawe, *U.S. Geol. Surv. Profess. Paper 550-C* (1966), pp. C206–C213; *U.S. Geol. Surv. Profess. Paper 550A* (1966), pp. A8–A9; R. R. Coats, P. R. Barnett, N. M. Conklin, *Econ. Geol.* **57**, 963 (1962).
14. W. R. Griffitts and H. A. Powers, *U.S. Geol. Surv. Profess. Paper 475-B* (1963), pp. B18–B19.
15. C. Fries, Jr., *U.S. Geol. Surv. Bull. 931-L* (1942); D. R. Shawe and S. Bernold, *U.S. Geol. Surv. Bull. 1214-C* (1966).
16. R. L. Armstrong, E. B. Ekren, E. H. McKee, D. C. Noble, *Geol. Soc. Amer. Spec. Paper*, in press.
17. Supported by grants from the Fellows of Harvard University and NSF. M. P. Billings read the manuscript; J. C. Drake advised on the analyses.

2 February 1968

Zinnwaldite: Octahedral Ordering in Lithium-Iron Micas

Abstract. *Ordering of the octahedral sheet of some lithium-iron micas is proposed on the basis of chemical compositions and crystallographic properties. The model of the ordered sheet has large and small sites in the ratio 2 : 1 and explains all observed properties—the small layer thickness, the "dioctahedral reflections," and the n(120 deg) motif in polytypism.*

Zinnwaldites are lithium-iron micas on the siderophyllite [$K_2Fe_4^{2+}Al_2Al_4Si_4O_{20}(F,OH)_4$]–polylithionite [$K_2Li_4Al_2Si_8O_{20}(F,OH)_4$] join. They are the characteristic micas of greisens (hydrothermally altered granitic rocks) and the veins associated with them. During geochemical study of these micas I measured the lattice parameters of several chemically analyzed specimens. The data suggest that the octahedral sheet of zinnwaldites differs from those of muscovite, annite, and phlogopite (*1, 2*) and resembles that of xanthophyllite (*3*).

Crystallographic parameters of micas have previously been related to composition. Mikheev (*4*) obtained a roughly linear plot of d_{060} (*5*) against the "average size of octahedral cations"; regression analysis by Radoslovich and Norrish (*6*) gave good linear correlation between b and octahedral composition. On the other hand, Munoz (*7*) found that b varied continuously with respect to composition, but distinct gaps appeared in plots of a and c for the system muscovite-polylithionite-trilithionite. Polytypism also appears to be a function of composition (*8*): lepidolites close to trilithionite crystallize usually as $2M_2$; muscovites, mostly as $2M_1$. The $1M$ polytype is found commonly in the "trioctahedral" micas but rarely in muscovites.

Additional structural differences are suggested by the presence or absence of the "dioctahedral reflections" [$06l$ and $h0l$ where $l \neq nN$ (*9*); because of pseudotrigonal symmetry, the same applies to $33l$, $3\bar{3}l$, $h3hl$, and $h3\bar{h}l$]. These reflections always appear in photographs of muscovite, but have not been reported for "trioctahedral" micas other than zinnwaldites (*10, 11*).

In this study, zinnwaldites from greisens and veins of the tin-tungsten-lithium formation in the Krušné Hory Mountains (Czechoslovakia) and the Erzgebirge (Germany) were chemically analyzed and examined with the precession camera; three pegmatite lepidolites and a skarn biotite were included.

The compositions of zinnwaldites lie close to the siderophyllite-polylithionite join in accordance with Foster's (*12*) findings. Among the octahedral cations (apart from the irregular number of vacancies), there are always close to two small ions (Al^{3+}, Fe^{3+}), as was noted (*12*). The sum of large ions (Li^+, Fe^{2+}, Mg^{2+}, Mn^{2+}) (*13*) is variable but never exceeds four. This finding is not true of the octahedral compositions of the pegmatite lepidolites [composition close to trilithionite: $K_2Li_3Al_3Al_2Si_6O_{20}(F,OH)_4$] and the skarn biotite [composition close to annite: $K_2Fe_6^{2+}Al_2Si_6O_{20}(F,OH)_4$].

Dimensions a and b of the studied micas are continuous functions of octahedral composition, but gaps appear in the d_{00N} (*9*) plot (Fig. 1); included in the plot are data from the literature. Values for siderophyllite (*D*), zinnwaldites, and polylithionite (*F*) lie distinctly below those for synthetic annite (*A* and *B*), synthetic aluminous biotite (*C*), trilithionite (*E*), and synthetic Li-Fe