DENSE INCLUSIONS IN THE SULLIVAN BUTTES LATITE, CHINO VALLEY, YAVAPAI COUNTY, ARIZONA.

Richard J. Arculus (Research School of Earth Sciences, Australian National University, Canberra, A.C.T. 2600, Australia)
Douglas Smith (Department of Geological Sciences, University of Texas at Austin, Austin, Texas 78712, U.S.A.)

Dense inclusions are abundant in potassic latite about 25 m.y. in age which occurs in the southwestern structural transition zone of the Colorado Plateau (Krieger, 1965; Krieger and others, 1971). The host rock (1, Table 1) consists of shallow intrusions, breccias, and flows in Precambrian and Paleozoic country rock. Phenocrysts of biotite (Mg/Mg+ Fe = 0.65), clinopyroxene ($Ca_{44}Mg_{46}Fe_{10}$), feldspar ($An_{55}Ab_{43}Or_{2}$) and apatite are present in the latite of Table 1; amphibole is prominent elsewhere. The inclusions are distributed on the order of 1 per 0.25 square meter on host rock surfaces and vary in size from 1 to 50 cm. Freshest samples are near country rock contacts.

Estimates of rock type abundances are based on grid counts and indicate approximately 60% of the nodules at the chief locality are eclogites. These are composed of variable proportions of garnet (near $Pyr_{37}Alm_{37}Gross_{26}$) and clinopyroxene (5-25 mol.% jadeite). Crystal sizes vary from 0.1 to 10 mm although most eclogites contain equant grains ≤ 2 mm. Amphibole is a common additional phase together with rutile, apatite, ilmenite and rare, altered clinozoisite. The eclogites are typically phase-layered and assemblages of strikingly different garnet/clinopyroxene proportions are in sharp contact. Compositional differences exist between different layers. Representative chemical analyses of eclogites of contrasted phase proportions together with microprobe analyses of individual phases are presented in Table 1.

Inclusions with major pargasitic amphibole comprise about 30% of the population at the chief locality and are more abundant elsewhere. Assemblages grade from eclogites with trace amphibole to those with 90% amphibole and minor clinopyroxene and garnet. Phlogopite, apatite, and Fe-Ti oxides are usually associated with amphibole-rich inclusions. In some samples, rutile and garnet are phase-layered with amphibole, giving rise to layers with up to 20 modal % rutile. In these nodules, amphibole crystals are up to 15 mm in length.

Websterites and orthopyroxenites form 2% of the inclusion population and typically contain deformed low-Ca pyroxene porphyroclasts with exsolved garnet in a groundmass of mosaic-textured garnet and pyroxene. The pyroxene porphyroclasts also contain exsolution lamellae of clinopyroxene, and broad beam microprobe analysis suggests that the assemblage results from the reaction of original aluminous pyroxene to an opx-cpx-gnt assemblage (8-10, Table 1). The porphyroclasts are up to 30-50 mm in length and display an undulatory schistosity defined by the garnet and cpx-opx lamellae, with superimposed kink deformation.

In general, the inclusions have metamorphic fabrics ranging from granular mosaic through to lineated. Rare undeformed biotite-apatite-clinopyroxenite inclusions may be cumulate from the host magma, but the other inclusions cannot be direct high-pressure cumulates from the host.

The occurrence of amphibole, phlogopite and biotite in association with eclogitic assemblages is of direct interest in relation to K2O and H2O budgets of the lower crust and upper mantle. Amphibole and phlogopite (Table 1) occur as apparently primary crystals in some inclusions and have shared a common deformation history with garnet and pyroxene. However, at some host rock-eclogite contacts, amphibole and biotite are developed at gnt-cpx contacts. Amphibole without biotite is present along fractures in the eclogite and absent from the unfractured portions of the inclusion where clinopyroxene appears fresh. As a minor phase in eclogitic assemblages, amphibole commonly occurs as an anhedral, interstitial phase formed later than the original assemblage.

Late stage partial melting of some inclusions has resulted in distinctive textures and the formation of plagioclase, hercynite and corundum. Rare kyanite and quartz-feldspar veins in clinopyroxenite may also be related to a partial melting event.

The Fe-Ti oxide assemblages are complex and varied. For example, within a single amphibole-rich inclusion, the four phases rutile, pseudobrookite$_{ss}$, ilmenite$_{ss}$ and ulvospinel-magnetite$_{ss}$ occur. Rutile with exsolved pseudobrookite$_{ss}$ is particularly common. Tyically, all of the oxides other than rutile are highly magnesian with up to 10-13 wt.% MgO in ilmenite and spinel. Full characterization is incomplete but polybaric cooling and oxidation are likely factors involved in the generation of the assemblages.

Distribution coefficients for Fe and Mg between garnet and clinopyroxene in eclogites and websterites range from 3.4 to 7.0. Typical orthopyroxene coexisting with garnet contains 1.4 to 2.5 wt.% Al_2O_3. These data permit estimates of pressures and temperatures of equilibration in the region 650-900^oC, $<$10-20 kbar using the empirical and experimentally-derived geobarometers and geothermometers of Wood (1974) and Raheim and Green (1974). A possible explanation for the petrographic relationships is that an original high-pressure cumulate assemblage of gnt-cpx-amph-phlog has been subjected to later (lower P) equilibration and partial melting events with generation of secondary amphibole, biotite and Al/Si-rich assemblages. The inclusions may be re-equilibrated samples of a cumulate sequence formed in the lower crust and uppermost mantle during Precambrian igneous activity (c. 1700 m.y.) in the last major magmatic event preceeding the Tertiary (Anderson and Silver, 1976). The possible remelting of amphibole and phlogopite-bearing assemblages may have direct bearing on the formation of high-K ("shoshonitic") lavas in the Tertiary.

References

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Table 1. Analyses of host latite, bulk eclogites and individual phases

	1	2	3	4	5	6	7	8
SiO_2	61.61	51.62	45.24	53.65	54.37	39.93	40.32	51.40
TiO_2	0.76	0.44	0.41	0.18	0.13	0.07	0.08	0.00
Al_2O_3	13.89	6.59	15.62	4.31	3.88	22.40	22.59	6.68
FeO*	4.45	6.30	11.59	5.04	3.50	18.58	16.83	15.20
MnO	0.08	0.06	0.29	0.03	0.03	0.45	0.50	0.28
MgO	3.69	12.45	12.85	13.74	14.75	8.48	11.87	24.70
CaO	4.63	19.88	12.77	21.67	22.11	11.06	8.29	1.66
Na_2O	2.79	1.91	0.85	2.01	1.71	0.01	0.01	0.00
K_2O	5.49	0.02	0.04	0.00	0.00	0.01	0.00	0.00
P_2O_5	0.36	0.09	0.11	—	—	—	—	—
CO_2	0.00	0.00	0.00	—	—	—	—	—
H_2O^+	0.73	0.30	0.36	—	—	—	—	—
H_2O^-	0.31	0.06	0.06	—	—	—	—	—
Total	99.20	99.72	100.19	100.64	100.48	100.98	100.50	99.92

	9	10	11	12	13	14	15
SiO_2	54.90	54.40	39.80	45.60	38.69	40.54	37.06
TiO_2	0.02	0.11	0.00	1.05	0.24	0.49	2.17
Al_2O_3	1.34	3.50	22.80	11.02	17.88	14.83	15.40
FeO*	14.00	4.50	20.70	8.08	16.03	4.53	17.25
MnO	0.00	0.00	0.68	0.00	0.00	0.01	0.00
MgO	29.90	14.50	12.10	17.26	10.12	23.58	13.63
CaO	0.17	20.75	5.35	10.77	11.40	0.00	0.13
Na_2O	0.04	2.34	0.00	2.81	1.69	0.38	0.36
K_2O	0.00	0.00	0.00	1.34	2.15	9.91	8.66
Total	100.37	100.10	101.43	97.88	98.19	94.68	94.66

* Total Fe as FeO for microprobe analyses and columns 2 and 3 due to problems of undecomposed garnet. Columns 1-3 are modified rapid method analyses by G. K. Hoops. See code for FeO/Fe_2O_3 in host latite.

Code: 1 = host latite(Fe_2O_3 = 4.14 wt.%, FeO = 0.72 wt.%); 2 = cpx-rich layer in eclogite; 3 = gnt-rich layer of same eclogite; 4 = cpx in cpx-rich layer; 5 = cpx in gnt-rich layer; 6 = gnt in cpx-rich layer; 7 = gnt in gnt-rich layer; 8 = broad beam average of px porphyroclast in websterite; 9 = opx lamella in porphyroclast; 10 = cpx lamella; 11 = mosaic gnt in websterite groundmass; 12 = possible "primary" amphibole; 13 = interstitial amphibole; 14 = phlogopite; 15 = biotite.