artinite‖[110]MgO, [001]artinite∧[001]MgO = 22° and [110]artinite∧[1$\bar{1}$0]MgO = 13°.

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SCANDIUM-RICH MINERALS FROM RHYOLITE IN THE THOMAS RANGE, UTAH

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Abstract

Scandium is present in the range 0.1 to 0.7 weight percent Sc_2O_3 in late-stage minerals, including pseudobrookite, bixbyite, spessartite, hematite and beryl, in the lithophysae of the rhyolite flows of the Thomas Mountains, Utah. The Sc^{3+} ion substitutes for Fe^{3+} and Al in these minerals. Scandium also is enriched in bixbyite from volcanic rocks in Argentina, but is present only in a few ppm in bixbyite from metamorphosed sedimentary manganese deposits.

The literature on the topaz, pseudobrookite, bixbyite, beryl, garnet and other minerals present in the lithophysae of the rhyolite flows of the Thomas Range, Utah, has been summarized by Staatz and Carr (1964). Analyses by neutron activation techniques reveal that some of these minerals contain exceptionally large amounts of scandium, extending to over 0.5 percent Sc_2O_3 (Table 1).

Sc is a dispersed element usually present in amounts up to a few hundred ppm in solid solution in its various host minerals. Only a very few of the over 1500 analyses of minerals containing Sc as a vicarious constituent, tabulated in large part by Vlasov (1966), Borisenko (1963) and Phan (1963, 1967), report over 0.5 percent Sc_2O_3. Among them are a beryl with about 1.5 percent Sc_2O_3 (Oftedal, 1943), chevkinite with 4.14 percent Sc_2O_3 (Semenov, et al., 1966), and columbite and ilmenorutile with 6.1 and 0.78 percent Sc_2O_3 respectively (Phan, 1967).

The presence of Sc in substitution for Fe^{3+} and Al in the various host minerals in the Thomas Range rhyolite is well substantiated on crystallochemical grounds. In the case of pseudobrookite, a complete solid solution has been shown by Ito (personal communication) to extend

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TABLE 1

Mineral	Locality	Sc_2O_3 content in weight percent or ppm as noted[a]
Pseudobrookite	Thomas Mtns.[b]	$0.74_1 \pm .006$ (percent)
Spessartite	do.	$0.55_8 \pm .003$ do.
Beryl	do.	$0.53_2 \pm .003$ do.
Bixbyite	do.	$0.38_4 \pm .003$ do.
Hematite (specular)	do.	$0.16_2 \pm .0015$ do.
Topaz	do.	$4.5_9 \pm .03$ (ppm)
Rhyolite	do.	$4.2_2 \pm .03$ do.
Spessartite	Nathrop, Colorado	$0.70_5 \pm .0045$ (percent)
Bixbyite	Argentina	$0.35_4 \pm .003$ do.
Bixbyite (sitaparite)	India	$1.9_1 \pm .17$ (ppm)
Bixbyite (partridgeite)	South Africa	$3.4_0 \pm .17$ do.

[a] Plus or minus values represent one standard deviation determined from counting statistics only. The samples were irradiated at a thermal neutron flux of 1.8×10^{12} n/cm^2-sec and several weeks were allowed for the decay of shortlived radioisotopes. Samples and standards were counted on a 45 cc Ge(Li) semiconductor detector coupled to a 4096 channel pulse height analyzer. The Sc content was calculated by comparing sample and standard photopeak counting rates from either the 0.89 Mev or 1.12 Mev gamma rays of 84 days Sc^{46}. The high Sc content of the pseudobrookite obviated a correction for the Sc^{46} contribution from the fast neutron interaction with the Ti present. The analyses were made by the Activation Analysis Service of Gulf General Atomic, San Diego, California.

[b] All analyses were made on crystallized specimens from a single place not precisely located but believed to be on Topaz Mountain.

between Fe_2TiO_5 and Sc_2TiO_5 in synthetic material. Bixbyite, α-(Mn, Fe)$_2$O$_3$, is isostructural with Sc_2O_3. In synthetic material, a considerable mutual solubility has been found between Sc_2O_3, Mn_2O_3 and Fe_2O_3 (Geller, *et al.*, Z961; Komissarova, *et al.*, 1966). The preferences of Sc^{3+}, Mn^{3+}, and Fe^{3+} for the two nonequivalent cation sites in bixbyite, however, are not known. Sc also is high in the bixbyite from Argentina, which occurs in a silicic volcanic rock, but it is present only in very small amount in bixbyite from the metamorphosed sedimentary manganese ores of South Africa and India.

The substitution of Sc^{3+} for Al appears in the beryl and spessartite, but is virtually nil in the topaz. Sc is a typical trace element in both beryl and garnet. Synthetic scandium analogues of both minerals are known, and establish that the Sc enters the 6-coordinated structural sites normally occupied by Al, Fe^{3+} or other trivalent ions (Frondel, 1968). Nassau and Wood (1968) and Staatz and Carr (1964) report that the Thomas Range beryl contains relatively large amounts of Fe, Mn and certain other trace elements. The garnet usually is called spessartite, but the data of Staatz and Carr (1964) indicate that it is about midway between spessartite and almandine in composition. The spessartite from Nathrop, Colorado, also occurs in rhyolite lithophysae and has been described by Cross (1886); it is near Sp 67 Al 33.

The gray rhyolite of the Thomas Range contains about 76 percent SiO_2 and 4.22 ppm Sc_2O_3. This Sc content is close to the average of 4.28 ppm reported by Norman and Haskin (1968) for 221 granites containing over 70 percent SiO_2, and to values reported for rhyolites of comparable composition by Frycklund and Fleischer (1963).

In the Thomas Range occurrence, it is evident that some Sc was flushed out during the consolidation of the rhyolite and was concentrated in crystallochemically favorable host minerals during the pneumatolytic stage. This is analogous to the well known concentration of Sc in particular host minerals, among them wolframite, cassiterite, micas, beryl and various yttrium and zirconium minerals, in the hypothermal veins, greisens and pegmatites derived from deeper seated granitic intrusives.

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