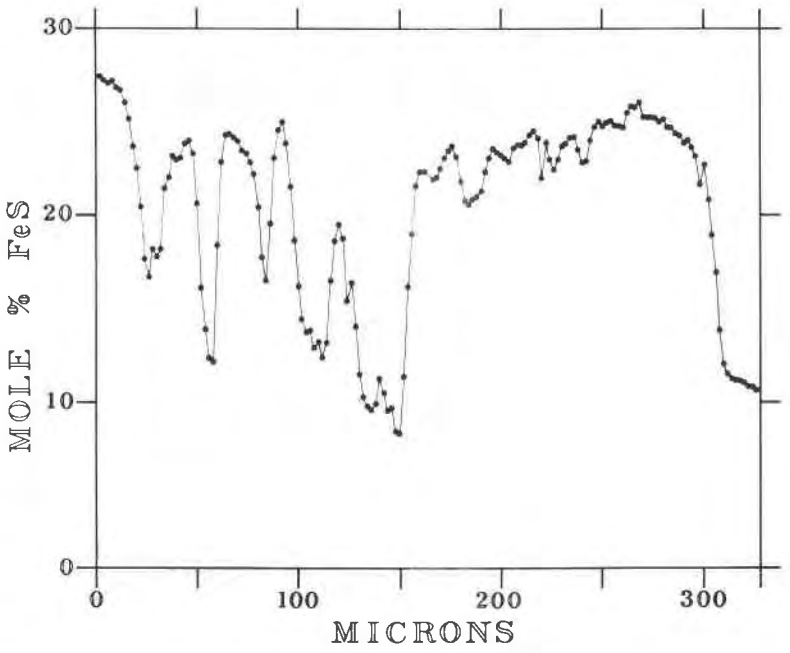

FIG. 2. The iron content of the zoned sphalerite crystal shown in Figure 1, as determined by step scanning at 2 μm intervals with an electron microprobe.

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SCANDIUM CONTENT OF ORE AND SKARN MINERALS AT FRANKLIN, NEW JERSEY

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ABSTRACT

Skarn zones in the Franklin orebody contain scandium chiefly in andradite (5–50 ppm), pyroxene (12–95 ppm) and amphibole (18–40 ppm), with very small amounts present in hendricksite, rhodonite, hyalophane and idocrase. The partition ratios for various mineral pairs in different specimens vary widely, indicating non-equilibrium conditions. Volumetrically, the great bulk of the scandium in the deposit is present in substitution for Fe^{3} in the franklinite of the normal ore and in the andradite of the skarns.

[1] Mineralogical Contribution No. 473.

The skarn zones locally present in the orebody at Franklin, New Jersey, are believed to represent metamorphosed interbedded lenses of argillaceous material in a sedimentary Mn-*Z*n deposit of Grenville age. Callahan (1966) has suggested that the original deposit was of the subaqueous volcanic exhalative type. The skarn zones are intercalated with normal franklinite-willemite-tephroite-calcite ore and consist mainly of andradite, rhodonite, hyalophane, pyroxenes, amphiboles, hendricksite and calcite, together with a large number of minor constituents. Descriptions of the skarn minerals have been given by Palache (1937), Frondel and Ito (1966a, b, c), Klein and Ito (1968) and others.

The geologic setting of the Franklin area has been described by Hague et al. (1956). The age of the normal ore has been dated[2] as 955 ± 30 m.y. by lead isotope methods on uraninite. Comparable but much less precise ages were obtained on thorite and zircon from the metasedimentary Cork Hill gneiss. The age of the skarn has been determined[3] by K-Ar measurements on hendricksite as 900 ± 45 m.y. Earlier K-Ar measurements by Long and Kulp (1962) gave 905 m.y. for phlogopite from Sterling Hill, 810 m.y. for hendricksite from Franklin, and 903 ± 25 m.y. for the Franklin marble. These ages indicate that the present mineralogy of both the ore and the skarn was imposed during the same metamorphic event. Lower grade metamorphism may have taken place during Paleozoic orogenies. The carbonate veinlets present along fractures in the orebody, and small replacement areas in the skarns, may be related thereto. They contain a low temperature hydrothermal assemblage of minerals that derived their content of metal locally.

The Franklin orebody represents a type of deposit from which Sc analyses have not hitherto been reported (Table 1). The main host minerals for Sc in the skarn are pyroxene, amphibole and garnet. These minerals together with biotite are also the main host minerals for Sc in metamorphic and igneous rocks. The general level of Sc content found here is low in comparison. Very small amounts of Sc are found in the hendricksite, feldspar, rhodonite, idocrase and accessory minerals of the skarn. The low content of Sc in hendricksite, a *Z*n-Mn mica, is noteworthy, since the biotite of metamorphic and igneous rocks typically contains Sc from roughly 20 to 80 ppm.

The equilibrium Sc partition ratio for hornblende/biotite reported by Tilling, Greenland and Gottfried (1969) in various igneous rocks mostly range from 3 to 10 and tend to be higher than in metamorphic rocks.

[2] Private communication, Dr. G. J. Wasserburg, California Institute of Technology, 1969.

[3] Private communication, Dr. Oliver Schaeffer, University of New York at Stony Brook, 1969.

TABLE 1. SCANDIUM CONTENT OF SKARN MINERALS. SC CONTENTS STATED IN PPM, AND OBTAINED BY NEUTRON ACTIVATION.[a] VERTICAL COLUMNS INDICATE MINERALS ASSOCIATED IN INDIVIDUAL SPECIMENS. CALCULATED LOWER DETECTION LIMITS ARE VARIABLE, DEPENDING ON SAMPLE COMPOSITION AND SIZE, BUT RANGING FROM 0.1 TO 3 PPM.

	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-9	Normal ore[c]
Hendricksite			0.98±.08		2.2±.1	not found		0.47±.06		
Rhodonite	1.3±.1	1.8±.1	not found		2.7±.2	0.28±.01	1.4±.1		2.5±.1	
Andradite	8.0±.1	6.3±.1	29.7±.3	7.0±.1		22.6±.4	50.2±.5	14.5±.2	4.8±.1	
Amphibole		18.0±.3			40.1±.4					
Pyroxene				12.1±.3					95 0±.8	
Hyalophane	not found	0.20±.02		not found						
Idocrase	not found					0.64±.04	not found	not found		
Franklinite										3.0±.2
Willemite										not found
Zincite										not found
Tephroite										not found
Miscellaneous[b]										

[a] Plus or minus values represent one standard deviation determined from counting statistics only. The Sc determinations were made on samples and standards irradiated for 2 hours at a thermal neutron flux of 1.8×10^{12} n/cm²-sec. The samples and standards were counted, after allowing 2 weeks for shorter-lived radioactivities to decay, on a 45 cc Ge (Li) semiconductor detector coupled to a 4096 channel pulse-height analyzer. Counting times ranged from 1 to 15 hours. The Sc contents were calculated by comparing sample and standard photopeak count rates from either the 0.89 MeV of 1.12 MeV gamma rays of 84 Sc.[46] The analyses were performed by the activation analysis service of Gulf General Atomic, Inc., San Diego.

[b] Gahnite, not found; friedelite, not found, johannsenite, not found; hematite, 1.0±.1.

[c] From large bulk samples.

Hendricksite generally is absent in Franklin assemblages that contain abundant amphibole or pyroxene. The only partition ratio that could be obtained on the pair amphibole [cummingtonite]/hendricksite had the high value of 18.6. The Sc partition ratios for garnet/biotite reported by Engel and Engel (1960) for various paragneisses are in the range 8 to 10. The two determinations here obtained on andradite/hendricksite both gave values of 30. There is a wide variation in the Sc content of an individual mineral in different skarn specimens, and in the partition ratio of andradite/rhodonite (from 1.9 to 80). This variation is indicative of non-equilibrium conditions.

In the normal ore, franklinite is the main host mineral (Table 1). This correlates with the mutual substitution of Sc^{3+} and Fe^{3+} observed experimentally in the spinel structure-type (Maxwell and Pickart, 1954). The average content of Sc in the normal ore, calculated from the relative abundance of the minerals as given by Frondel and Ito (1966a), is 1.3 ppm. The average Sc content of the skarn, calculated from the average contents of the minerals listed in Table 1 and their relative abundance, is about 10 ppm. Volumetrically, the great bulk of the Sc in the deposit is present in solid solution, in substitution for Fe^{3+}, in the franklinite and andradite.

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