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THE COMPLEX OF ALKALINE ROCKS AT IRON HILL, POWDERHORN DISTRICT, GUNNISON COUNTY, COLORADO

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INTRODUCTION

The alkaline rocks, and especially the carbonatite stock at Iron Hill, near Powderhorn, Colorado, have been studied since 1912 (Singewald, 1912), not only because of their unusual lithologies but also because of the economically significant mineral concentrations associated with them. Various hypotheses regarding the origin of the Iron Hill rocks have paralleled the development of ideas concerning carbonatite petrogenesis from assimilation of marble followed by crystal differentiation (Larsen, 1942), to metasomatism of preexisting pyroxenite (Temple and Grogan, 1965) to formation through immiscibility of magmatic liquids (Nash, 1972). Economic minerals associated spatially and genetically with these rocks include vermiculite and minerals that contain thorium, iron, titanium, niobium, and rare-earth elements. Thorium deposits have been discussed by Armbrustmacher (1980), Staatz and others (1979, 1980), Hedlund and Olsen (1961), and Wallace and Olson (1956). Iron and titanium deposits have been discussed by Rose and Shannon (1960) and Singewald (1912). Niobium resources have been mentioned by Armbrustmacher (1980) and Hedlund and Olson (1961). Rare-earth minerals have been discussed by Olson and Wallace (1956) and Hedlund and Olson (1961).

GEOLOGIC SETTING

The Cambrian or Precambrian complex of alkaline rocks at Iron Hill (fig. 1), which is about 30 km^2 in area, was originally described

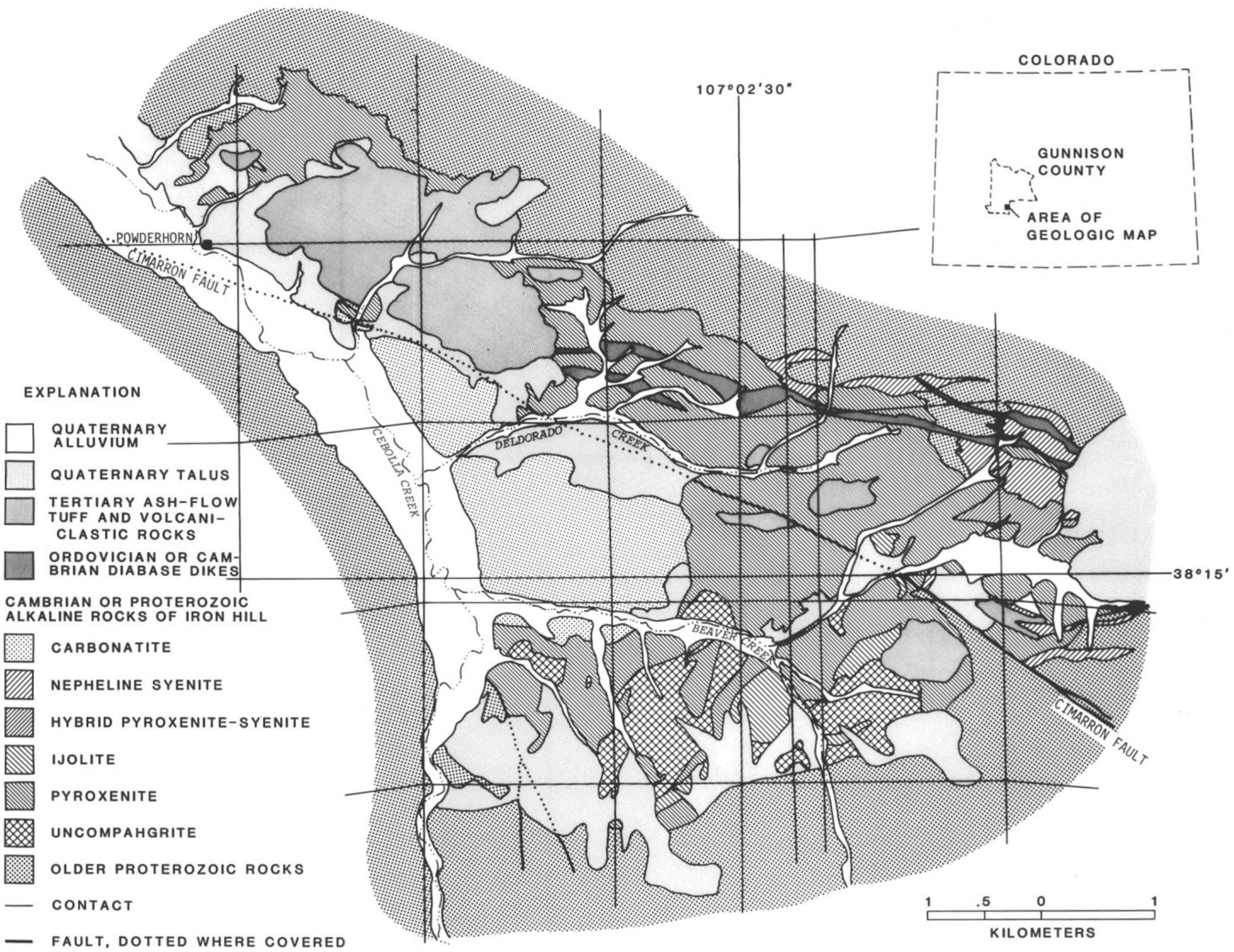

Figure 1. Geologic map of the alkaline complex at Iron Hill, Powderhorn district, Gunnison County, Colorado. Modified from Olson (1974) and Hedlund and Olson (1975).

by Larsen (1942). The complex consists chiefly of pyroxenite, magnetite-ilmenite-perovskite segregations, uncompahgrite, ijolite, hybrid pyroxenite-syenite rocks, nepheline syenite, and carbonatite, listed oldest to youngest (Hedlund and Olson, 1961). Probably prior to 570 million years ago (Olson and others, 1977), rocks of the complex were emplaced into Proterozoic X Powderhorn Granite and older Proterozoic metamorphic rocks, which are locally fenitized adjacent to the complex. Parts of the complex are covered by ash-flow tuffs, welded tuffs, and colluvium mainly of Oligocene age, and by colluvium and alluvium of Quaternary age, mainly along the drainages of Cebolla, Deldorado, and Beaver Creeks.

The complex is bisected by the Cimarron fault (fig. 1). Hedlund and Olson (1975) indicated that relative movement on the fault is such that a deeper structural level of the alkaline complex is exposed on the northeast side of the fault than on the southwest side. The interpretation of Temple and Grogan (1965), however, suggests that a deeper structural level is exposed on the southwest side of the fault. Regardless of the interpretation, nearly all the uncompahgrite, most of the ijolite, and the carbonatite stock are found southwest of the fault. The magnetite-ilmenite-perovskite segregations and the nepheline syenite seem to be restricted to the northeast side of the fault. Diabase dikes of Cambrian or Ordovician age intrude rocks of the complex on the northeast side of the Cimarron fault, although one diabase dike does cut fenitized Powderhorn Granite just southwest of the fault (Olson, 1974).

Carbonatite dikes, probably similar in age to the carbonatite stock, intrude all rocks of the complex except the carbonatite stock. They also intrude the Precambrian host rocks, especially those within the fenitized aureole. Martite-fluorapatite veins and jasper-rich veins, the latter probably representing silicified fracture zones, intersect the carbonatite stock. Rocks of the complex and the surrounding area have been mapped in detail by Hedlund and Olson (1968, 1975) and Olson (1974).

ROCKS OF THE COMPLEX

The intrusive igneous rocks at Iron Hill collectively constitute a classic example of the carbonatite-nephelinite magmatic igneous association (LeBas, 1977). Other examples include the igneous complexes at Fen, Norway; Alno, Sweden; Magnet Cove, Arkansas; and the alkaline intrusions of eastern Africa. The rocks at Iron Hill include many of the principal rock types of this classic association, which are carbonatite, nephelinite, ijolite, pyroxenite, and fenite. At Iron Hill, erosion may have removed the volcanic rocks usually associated with many of the carbonatite-nephelinite complexes elsewhere.

Descriptions of the major rock types at Iron Hill that follow are taken chiefly from Armbrustmacher (1980), Hedlund and Olson (1975), and Olson (1974).

Pyroxenite

The rock unit mapped as pyroxenite by Hedlund and Olson (1975) and Olson (1974) is highly variable in chemical and mineralogical composition. The medium- to coarse-grained, locally pegmatitic pyroxenite contains 55-70 percent clinopyroxene, 10-15 percent magnetite and ilmenite, 5-25 percent melanite garnet, 5 percent fluorapatite, and 10 percent biotite and phlogophite. Accessory minerals are chiefly sphene, brown amphibole, calcite, perovskite, leucoxene, sodic amphibole, melilite, sericite, pyrite, chalcopyrite, and pyrrhotite. Calcic plagioclase is absent. Vermiculite and magnetite-ilmenite-perovskite segregations are locally abundant. The alkali-silica diagram in Figure 2 shows the average $Na_2O + K_2O$ versus SiO_2 composition of pyroxenite analyses from Nash (1972) and Larsen (1942) and the average alkaline basalt from Nockolds (1954).

Magnetite-ilmenite-perovskite segregations

Dikes and segregations consisting chiefly of magnetite, ilmenite, and perovskite are confined to the pyroxenite northeast of the Cimarron fault. Apatite and biotite are minor constituents. The dikes and segregations are commonly less than 1 m thick but may attain a thickness of 50 m. The perovskite content, which may reach 50 percent, makes the dikes and segregations attractive titanium-prospecting targets. Seven samples of these rocks average 58.5 ppm uranium and 296 ppm thorium, and the anomalous radioactivity of these rocks is a useful characteristic in the exploration for these rocks. Outcrops of magnetite-ilmenite-perovskite segregations are too small to be shown at the scale of the geologic map (fig. 1).

Uncompahgrite

Uncompahgrite was described by Olson (1974) as a light-gray, medium-grained to very coarse-grained rock composed of melilite, variable amounts of clinopyroxene, and small amounts of magnetite, apatite, phlogopite, melanite garnet, and perovskite. The average composition of uncompahgrite is shown in Figure 2. The Iron Hill area is the type locality for this rock type (Larsen, 1942).

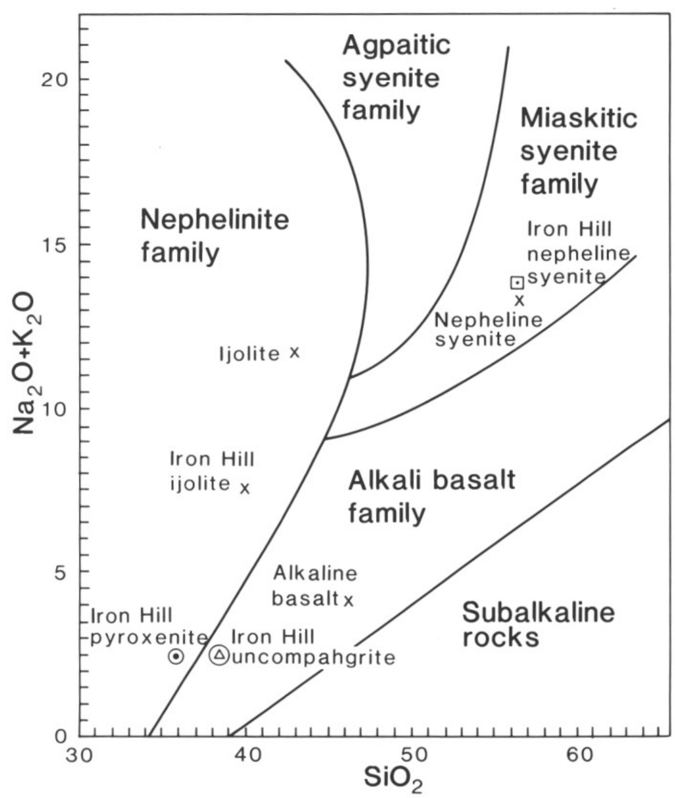

Figure 2. Average alkali and silica contents of rock types in the complex at Iron Hill. The diagram is modified from Currie (1976, p. 6). The rock types marked by x are average compositions of the data from Nockholds (1954), for comparison.

Ijolite

Ijolite is coarse to fine grained, and usually has a hypidiomorphic-granular texture (Hedlund and Olson, 1975). The rock commonly consists of 30-50 percent nepheline, 30-40 percent sodic clinopyroxene, 10-30 percent melanite garnet, and minor amounts of orthoclase, magnetite, apatite, biotite, sphene, and alteration products of nepheline. The average Na_20 + K_20 versus $Si0_2$ of available analyses is shown in Figure 2.

Hybrid pyroxenite-syenite rocks

According to Hedlund and Olson (1975), this rock consists of brecciated pyroxenite containing numerous irregular fracture fillings and small dikes of nepheline syenite. The pyroxenite contains clinopyroxene, melanite garnet, sphene, apatite, and melilite. The syenite contains orthoclase, microperthite, sodic clinopyroxene, nepheline, and melanite garnet.

Nepheline syenite

The light-gray to pinkish-gray nepheline syenite is medium to coarse grained, and commonly has a trachytic texture. The rock consists of orthoclase, microperthite, and albite, with about 10 percent interstitial sodic clinopyroxene, and nepheline, and accessory melanite garnet, magnetite, sphene, biotite, apatite, calcite, sericite, and zircon. The average Na_20 + K_2O versus SiO_2 composition is shown in Figure 2.

Carbonatite

The carbonatite stock at Iron Hill consists of light-brown to light-gray, foliated to massive carbonatite. The following minerals, listed approximately in the order of their frequency of occurrence, have been identified: dolomite, barite, goethite, hematite, calcite, quartz, fluorapatite, pyrochlore, pyrite, magnetite, biotite, rutile, fluorite, bastnaesite, aegirine, anatase, sphalerite, synchisite, zircon, magnesite(?), and manganese oxide minerals. In comparison with average igneous rocks, the carbonatite stock contains greater than 20 times more barium, cerium, neodymium, 15-20 times more lanthanum, niobium, phosphorus, and total rare-earth elements, and nearly 10 or more times manganese, molybdenum, and strontium (Armbrustmacher, 1980). The carbonatite is cut by narrow martite-fluorapatite veins and jasper veins, neither of which are shown on the geologic map (fig. 1).

PETROLOGY AND ECONOMIC POTENTIAL

Many aspects of the alkaline complex at Iron Hill suggest that it is a representative of the Ijolite Series as defined by Bailey (1974). Rocks of this series are characteristically undersaturated with respect to $Si0_2$ and contain fairly abundant Na_2O and K_2O. The complex at Iron Hill is also representative of the carbonatitic type of alkaline complex as defined by Rock (1976). These complexes are characterized by the occurrence of intrusive rocks such as carbonatite, ijolite, pyroxenite, melilitic rocks, and nepheline syenite, all lacking calcic plagioclase, and are also found occupying the root zones of nephelinitic volcanoes. King (1965) suggested that rocks of this type formed by differentiation from an immediate parental nephelinite- melteigite magma, which maintained $Si0_2$ undersaturation with a trend toward enrichment of CaO, Na_20, K_2O, and volatile elements. With increasing concentration of these components, a point was reached where a highly mobile fraction of alkali and calcium carbonates separated from the crystallizing silicate phase to form a carbonatite melt. Initially, the melt contained abundant alkali carbonates, which, according to King (1965), allowed the carbonatite to remain as a liquid at low temperatures and pressures. The presence of fenitized country rocks reflects the alkali content of the melt and shows that alkalies were removed from the melt through reaction with the host. The final product was a carbonatite probably not unlike that found at Iron Hill. Carbon isotopic ratios from the Iron Hill carbonatite (Taylor and others, 1967) are similar to ratios found in diamond, indicating that the CO_2 in the carbonatite had a deep-seated igneous source. The carbon isotopic data and oxygen isotopic data from the Iron Hill carbonatite both fall within the field of primary igneous carbonatite defined by Taylor and others (1967). Strontium isotopic data from various lithologies within the alkaline complex, including carbonatite (Powell and others, 1966), indicate that the rocks within the complex are comagmatic. Strontium isotopic values also suggest that carbonatite-alkaline rock associations, such as that observed at Iron Hill, are mantle derived. Analyses of calcite-dolomite and pyrite-pyrrhotite mineral pairs by Nash (1972), indicated crystallization temperatures between 435° C and 290° C for late-stage carbonatites. Samoylov (1975) determined formation temperatures of Iron Hill carbonatite at 600° C, using biotite-pyroxene geothermometry, and at 400° C, using amphibole-pyroxene geothermometry.

Deposits of possible economic value of a number of mineral commodities are known to be associated spatially and genetically with the alkaline complex at Iron Hill. In discussing the occurrence of thorium and rare-earth minerals, Olson and Wallace (1956) showed that thorium mainly is concentrated in veins and shear zones outside of the complex, and rare-earth elements mainly are concentrated in carbonatite dikes and in the Iron Hill carbonatite stock. Hedlund and Olson (1961) identified four environments containing thorium, niobium, and rare-earth minerals in the Powderhorn district: (a) carbonatite, (b) magnetite-ilm eniteperovskite bodies, (c) thorite veins, and (d) trachyte dikes. The magnetite-ilmenite-perovskite segregations were discussed as early as 1912 (Singewald, 1912) as a source of iron and titanium. Rose and Shannon (1960) reported an average grade of 6.5 percent titania and 11.7 percent iron and a possible tonnage in excess of 100 million short-tons in pyroxenites containing the segregations. In the February 25, 1976, issue of the Denver Post, Buttes Gas and Oil Company announced results of a study that indicated 419 million tons of reserves averaging about 12 percent TiO_2 occurred at Powderhorn. Studies of the carbonatite stock by E. I. DuPont de Nemours and Company (Temple and Grogan, 1965) indicated a niobium reserve of over 100,000 tons of Nb_2O_5 in rocks averaging at least 0.25 percent Nb_2O_5. More recent studies of the carbonatite stock (Armbrustmacher, 1980) showed a fairly in- homogeneous distribution of thorium with values ranging between 0.0007 percent and 0.017 percent ThO_2; the average thorium content is 0.0041 percent ThO_2. The carbonatite stock contains reserves as defined by Staatz and others (1979) totaling 29,775 tons of $Th0_2$, 9,180 tons of $L1_20_8$, 2,865,500 tons total rare- earth oxides, and 412,000 tons Nb_20_5 in the carbonatite that projects above the surrounding land surface. According to Staatz and others (1980), 13 carbonatite dikes contain reserves totaling 763 tons of ThO_2, 57 tons U_30_8, 21,000 tons total rare-earth oxides, and 1,330 tons Nb_2O_5. Vermiculite deposits are found in altered pyroxenite, but data on reserves are not available.

REFERENCES

Armbrustmacher, T. J., 1980, Abundance and distribution of thorium in the carbonatite stock at Iron Hill, Powderhorn district, Gunnison County, Colorado: U.S. Geological Survey Professional Paper 1049-B, 11 p.

Bailey, D. K., 1974, Nephelinites and ijolites, in Sorensen, H., ed., The alkaline rocks: New York, John Wiley and Sons, p. 53-66.

Currie, K. L., 1976, The alkaline rocks of Canada: Geological Society of Canada Bulletin 239,229 p.

Hedlund, D. C. and Olson, J. C., 1961, Four environments of thorium-, niobium-, and rare-earth-bearing minerals in the Powderhorn district of southwestern Colorado: U.S. Geological Survey Professional Paper 424-B, p. B283-B286.

1968, Geologic map of the complex of alkalic rocks at Iron Hill, Gunnison County, Colorado: U.S. Geological Survey Open-File Map.

1975, Geologic map of the Powderhorn quadrangle, Gunnison and Saguache Counties, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1178.

King, B. C., 1965, Petrogenesis of the alkaline igneous rock suites of the volcanic and intrusive centres of eastern Uganda: Journal of Petrology, v. 6, p. 67-100.

Larsen, E. S., Jr., 1942, Alkalic rocks of Iron Hill, Gunnison County, Colorado: U.S. Geological Survey Professional Paper 197-A, p. 1-64.

LeBas, M. J., 1977, Carbonatite-nephelinite volcanism: An African case history: New York, John Wiley and Sons, 347 p.

Nash, W. P., 1972, Mineralogy and petrology of the Iron Hill carbonatite complex, Colorado: Geological Society of America Bulletin, v. 83, p. 1361-1382.

Nockholds, S. R., 1954, Average composition of some igneous rocks: Geological Society of America Bulletin, v. 66, p. 1007-1032.

Olson, J. C., 1974, Geologic map of the Ruddlph Hill quadrangle, Gunnison, Hinsdale, and Saguache Counties, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1177.

Olson, J. C., Marvin, R. F., Parker, R. L., and Mehnert, H.H., 1977, Age and tectonic setting of lower Paleozoic alkalic and mafic rocks, carbonatites, and thorium veins in south-central Colorado: Journal of Research, U.S. Geological Survey, v. 5, p. 673-687.

Olson, J. C. and Wallace, S. R., 1956, Thorium and rare-earth minerals in Powderhorn district, Gunnison County, Colorado: U.S. Geological Survey Bulletin 1027-0, p. 693-723.

Powell, J. L., Hurley, P. M., and Fairbairn, H. W., 1966, The strontium isotopic composition and origin of carbonatites, *in* Tuttle, 0. F., and Gittins, J., eds., Carbonatites: New York, Interscience Publishers, p. 365-378.

Rock, N. M. S., 1976, The role of CO, in alkali rock genesis: Geological Magazine, v. 113, p. 97-113.

Rose, C. K. and Shannon, S. S., Jr., 1960, Cebolla Creek titaniferous iron deposits, Gunnison County, Colorado: U.S. Bureau of Mines Report of Investigations 5679,30 p.

Samoylov, V. S., 1975, The temperatures of formation of carbonatites (based on geothermometric studies): Geochemistry International, v. 12, no. 6, p. 52-58.

Singewald, J. T., Jr., 1912, The iron ore deposits of the Cebolla district, Gunnison, County, Colorado: Economic Geology, v. 7, p. 560-573.

Staatz, M. H., Armbrustmacher, T. J., Olson, J. C., Brownfield, I. K., Brock, M. R., Lemons, J. F., Jr., Coppa, L. V., and Clingan, B. V., 1979, Principal thorium resources in the United States: U.S. Geological Survey Circular 805,42 p.

Staatz, M. H., Hall, R. B., Macke, D. L., Armbrustmacher, T. J., and Brownfield, I. K., 1980, Thorium resources of selected regions in the United States: U.S. Geological Survey Circular 824,32 p.

Taylor, H. P., Jr., Frechen, Josef, and Degens, E. T., 1967, Oxygen and carbon isotope studies of carbonatites from the Laacher See district, West Germany, and the Alno District, Sweden: Geochimica et Cosmochimica Acta, v. 31, p. 407-430.

Temple, A. K. and Grogan, R. M., 1965, Carbonatite and related alkalic rocks at Powderhorn, Colorado: Economic Geology, v. 60, p. 672-692.

Wallace, S. R. and Olson, J. C., 1956, Thorium in the Powderhorn district, Gunnison County, Colorado: U.S. Geological Survey Professional Paper 300, p. 587-592.