TH-RARE EARTH ELEMENT VEIN DEPOSITS
(MODEL 11d; Staatz, 1992)

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SUMMARY OF RELEVANT GEOLOGIC, GEOENVIRONMENTAL, AND GEOPHYSICAL INFORMATION

Deposit geology

Deposits consist of thorium and rare earth element minerals in a gangue consisting of smoky quartz, potassic feldspar, iron oxide minerals, fluorite, and barite, in thorium- and rare earth element-bearing veins and carbonatite dikes. Archean to Recent alkaline intrusive rocks and intrusive carbonatite stocks are frequently spatially and perhaps genetically related to the deposits. At some localities, alkaline rocks and carbonatites have not yet been identified. Veins are less than 1 m to 1,350 m long and less than 1 cm to more than 15 m wide and are localized along fracture zones of varying prominence. Carbonatite dikes are less than 1 m to 100 m long and 1 cm to 6 m wide. Narrow fenitized (alkali metasomatized) wall-rock selveges are adjacent to veins and dikes. Thorium veins have relatively high thorium-rare earth element ratios; carbonatite dikes have relatively high rare earth element-thorium ratios and may also contain significant concentrations of niobium.

Examples

Thorium veins: Wet Mountains area and Powderhorn district, Colo.; Capitan Mountain and Laughlin Peak, N. Mex.; Lemhi Pass district, Idaho; and Bokan Mountain district, Alaska. Carbonatite dikes: Wet Mountains area (especially Gem Park) and Powderhorn district (especially near Iron Hill), Colo.; Mineral Hill district, Idaho-Mont.; Rocky Boy's Indian Reservation, Bearpaw Mountains, Mont.; Bear Lodge Mountains, Wyo.; Mountain Pass, Calif.; and Magnet Cove and Potash Sulphur Springs, Ark.

Spatially and (or) genetically related deposit types

Deposits of niobium, titanium, iron, vermiculite, manganese oxide, uranium, and fluorite are present within and immediately adjacent to thorium and rare earth element veins and carbonatite dikes.

Potential environmental considerations

Because of their elongate nature, both thorium-rare earth element veins and carbonatite dikes could be developed by underground mining techniques. Ore and waste dump rock are highly radioactive because of their thorium content; fenitized host rock is similarly radioactive. Thorium-rare earth element veins have moderately high sulfur content, but the sulfur is present chiefly as sulfate in barite because of relatively high oxygen fugacity that prevails during deposit genesis. Sulfide mineral content of these veins is very low, and thus, potential for acid mine drainage generation is low. Thorium-bearing minerals in thorium-rare earth element veins are quite stable under natural conditions and tend to concentrate as detrital, relatively insoluble, even in low pH conditions, resistate minerals. Thorium complexing with various organic compounds may increase thorium-bearing mineral solubility, but thorium concentrations in natural water (pH 5 to 9) rarely exceed 1 ppb (Langmuir and Herman, 1980). Mining of most carbonatite dikes generally results in limited acid drainage generation, as well as minimal other environmental effects downstream because of the high acid buffering capacity of carbonate-rich ore.

Exploration geophysics

Alkaline intrusive complexes and carbonatite complexes, with which thorium-rare earth element veins and carbonatite dikes may be associated, have highly variable geophysical expressions that depend on their mineralogy, type of carbonatite stock, if present, intensity of host rock fenitization, and depth of weathering (Hoover, 1992). Some complexes contain major amounts of magnetite, ilmenite, and (or) perovskite, which result in positive magnetic anomalies. Abundant contained thorium- and uranium-bearing minerals, such as thorite, monazite, perovskite, and apatite may result in large positive radiometric anomalies. Gamma-ray spectrometry can quantitatively measure thorium, uranium, and potassium contents in veins and associated rocks. Detailed spectral data from remote sensing surveys can identify CO_3, ferrous iron, and rare earth elements associated with these deposits.

References

Dellwig (1951), Olson and others (1954), Kaiser (1956), Olson and Wallace (1956), Anderson (1958, 1981), Christman and others (1959), Hedlund and Olson (1961), Sharp and Cavender (1962), Staatz (1974, 1978, 1979, 1985), Staatz and others (1979, 1980), Armbrustmacher (1979, 1980, 1988), Olson and Hedlund (1981), and Thompson (1988).

GEOLOGIC FACTORS THAT INFLUENCE POTENTIAL ENVIRONMENTAL EFFECTS

Deposit size

Average deposit size is about 0.2 M metric tons of ore with a thorium-oxide grade of 0.4 weight percent (Bliss, 1992); these values are highly uncertain because none of the deposits have been mined to exhaustion. Most deposits are of low tonnage and high grade; associated environmental impact is limited because of their small size.

Host rocks

Alkaline intrusive rocks, granitic rocks, high-grade metamorphic rocks, aureoles surrounding alkaline intrusive complexes and fenitized carbonatite complexes, black shale, and novaculite are host rocks for thorium-rare earth element veins and carbonatite dikes.

Surrounding geologic terrane

Thorium-rare earth element veins and carbonatite dikes are frequently associated with alkaline intrusive complexes and carbonatite complexes. The majority of these complexes are located in relatively stable, intracratonic areas, but some are found close to tectonic plate margins and may be associated with orogenic rifting. Complexes are commonly located on major lithospheric domes or are related to major lineaments, or both. These complexes, typically mantle- or upper lithospheric-derived, intrude a wide variety of host rocks.

Wall-rock alteration

Thorium-rare earth element veins and carbonatite dikes are typically surrounded by, at most, several-m-wide aureoles of metasomatically altered rock. The process of alteration, fenitization, is caused by peralkaline fluids emanating from cooling alkaline silicate or carbonatite magmas. Fenitized aureoles surrounding veins and carbonatite dikes have limited geoenvironmental impact.

Nature of ore

Thorium-rare earth element veins and carbonatite dikes are structurally controlled. Veins and dikes directly associated with alkaline intrusive complexes and carbonatite complexes may occupy radial fractures, related to their host complexes. At other localities, fractures parallel to, and controlled by the dominant structural lineaments of the area, may be occupied by veins and dikes.

Deposit trace element geochemistry

Both veins and dikes contain primary enrichments of uranium, barium, strontium, lead, zinc, and niobium, as well as major amounts of thorium, rare earth elements, especially light rare earth elements, ferric iron oxide, silica, and sulfur as sulfate.

Ore and gangue mineralogy and zonation

The major ore minerals in thorium-rare earth mineral veins are thorite, thorianite, brockite, monazite, and a group of rare earth minerals including bastnaesite, parisite, synchysite, and similar rare earth carbonate minerals; sulfide minerals may be present but are rare. Gangue minerals include quartz, especially smoky quartz, potassium feldspar, barite, ferric iron oxide minerals, and trace amounts of galena and sphalerite. Many other minerals are found in specific deposits. Carbonatite dikes contain similar rare earth carbonate minerals and thorium-bearing minerals. Niobium-bearing minerals, especially pyrochlore and niobium-bearing rutile, may be abundant. Gangue minerals include calcite, dolomite, ankerite, siderite, sometimes strontianite, and other carbonate minerals. Allanite, monazite, magnetite, anatase, brookite, rutile, perovskite, barite, and a large number of additional minerals may be present.

Mineral characteristics

Thorium-rare earth mineral veins are chiefly quartz-barite veins with irregularly distributed thorium and rare earth minerals. In some veins, quartz and barite are coarse grained; euhedral smoky quartz lines vein walls and paragenetically later barite forms vein interiors. Other thorium-rich veins are fine grained; red, due to ferric iron oxide content; and have odoriferous fresh surfaces. Ore minerals are irregularly disseminated throughout carbonatite dikes.

Secondary mineralogy

Weathering of thorium-rare earth mineral vein and carbonatite deposits results in localized carbonate mineral dissolution.

Topography, physiography

These elongate, areally restricted deposits seem to have neither topographic nor physiographic expressions that are distinct.

Hydrology

The hydrologic regime is unaffected by thorium-rare earth element vein deposits, which are commonly small.

Mining and milling methods

Thorium-rare earth element vein deposits have been exploited only by very small-scale prospecting and mining. Workings generally consist of shallow surface pit and trench excavations. Very little if any ore from these operations has been milled.

ENVIRONMENTAL SIGNATURES

Drainage signatures

No data available. The facts that thorium-rare earth element vein deposits contain very low sulfide mineral abundances and consist of low-solubility, resistate minerals suggests that these veins contribute insignificantly to the geochemistry of water draining these deposits.

Metal mobility from solid mine wastes

Thorium-bearing minerals tend to have low solubility and form deposits of resistate minerals; metal mobility from solid mine waste associated with thorium-rare earth element vein deposits is consequently very limited.

Soil, sediment signatures prior to mining

Stream-sediment samples collected for the NURE study of the Pueblo 1°x2° quadrangle, Colo., failed to identify the Wet Mountains thorium district. Thus, it appears that thorium-bearing minerals do not widely disperse, and that geochemical haloes associated with thorium deposits are small. More detailed surveys would probably show that thorium abundances in soil near thorium-rare earth element vein deposits are elevated. Residual soil can contain elemental suites similar to those in underlying deposits.

Potential environmental concerns associated with mineral processing

Neither thorium-rare earth mineral vein nor carbonatite deposits are likely to have significant associated natural or mine-related acid drainage. Unless all thorium is recovered during mining and milling, waste dumps and tailings contain radioactive materials. Fenitized rocks surrounding these deposits contain anomalous amounts of radioactive minerals that might pose an environmental hazard in associated waste dumps.

Smelter signatures

The absence of significant ore having been produced from thorium-rare earth element vein deposits precludes environmental impact attributable to smelting.

Climate effects on environmental signatures

The effects of various climatic regimes on the geoenvironmental signature specific to thorium-rare earth element veins deposits are not known. Because most of these deposits have relatively low sulfide mineral contents environmental signatures associated with thorium-rare earth element vein deposits probably are not much affected by climatic regime variation. Dispersal of radioactive solid waste associated with deposits in areas with high precipitation may be more widespread as a function of increased surface runoff.

Geoenvironmental geophysics

Egress of radioactive particles from mine areas and waste dumps can be identified and monitored by gamma-ray spectrometry or total count scintillometers; detailed airborne or ground-based surveys can be employed, depending on the type of coverage that is warranted.

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