

CARBONATITE DEPOSITS (MODEL 10; Singer, 1986a)

by Peter J. Modreski, Theodore J. Armbrustmacher, and Donald B. Hoover

SUMMARY OF RELEVANT GEOLOGIC, GEOENVIRONMENTAL, AND GEOPHYSICAL INFORMATION

Deposit geology

Carbonatites are intrusive carbonate-mineral-rich igneous rocks, many of which contain distinctive abundances of apatite, magnetite, barite, and fluorite, that may contain economic or anomalous concentrations of rare earth elements, phosphorus, niobium, uranium, thorium, copper, iron, titanium, barium, fluorine, zirconium, and other rare or incompatible elements. They may also be sources of mica or vermiculite. Carbonatites may form central plugs within zoned alkalic intrusive complexes, or as dikes, sills, breccias, and veins.

Examples

Oka, Quebec; Iron Hill and Gem Park, Colo.; Magnet Cove, Ark.; St. Honore, Quebec; Mountain Pass, Calif.; Phalaborwa, South Africa; Jacupiranga, Brazil; Kovdor, Russia.

Spatially and (or) genetically related deposit types

Vein deposits of thorium, fluorite, or rare earth elements may be associated with carbonatites.

Potential environmental considerations

Most carbonatite deposits are likely to be mined on a large scale in open pit mines. Potential impacts include radioactivity from uranium and (or) thorium in waste rock or sediment; dust from mining activities; acid- and (or) metal-contaminated drainage from pyrite-rich carbonatites; and possible water contamination from spillage or leakage of chemical solutions used to leach and process ore. Asbestiform amphiboles, such as riebeckite, that are present in waste dumps associated with some carbonatite deposits may pose another health risk.

Exploration geophysics

The geophysical signature of carbonatite complexes is variable (Hoover, 1992). In many complexes, concentrations of magnetic minerals produce positive magnetic anomalies. Similarly, concentrations of radioactive minerals cause pronounced radiometric anomalies associated with many carbonatite complexes.

References

Heinrich (1966), Erdosh (1979), Bell (1989), Notholt and others (1989).

GEOLOGIC FACTORS THAT INFLUENCE POTENTIAL ENVIRONMENTAL EFFECTS

Deposit size

Minable carbonatite deposits typically range in size from approximately 6 to 300 M metric tons (Singer, 1986b).

Host rocks

Rocks constituting carbonatite deposits may include varieties of carbonatite, including calcite-rich (sölvite), dolomite-rich (rauhaugite), iron-rich carbonatite, silico-carbonatite, etc. Carbonatite is typically associated with concentrically zoned complexes of alkaline-igneous rocks, though some deposits may consist of dikes or thick sheets. Associated igneous rocks typically include ijolite, melteigite, pyroxenite, and nepheline syenite. Carbonatites are typically associated with undersaturated igneous rocks that are miaskitic (nearly peralkaline) rather than agpaitic (peralkaline). Any rock type, often including granite and other intrusive rocks, gneiss and other metamorphic rocks, may host the alkaline-igneous complexes. Host rocks are often fenitized (alkali metasomatized) by alkali-rich fluids evolved from carbonatite complexes.

Surrounding geologic terrane

Carbonatite and carbonatite-alkaline igneous complexes are typically located in relatively stable, intra-plate regions, often within Precambrian shield or continental platform areas. Some may develop near plate margins or be associated with rifted or incipiently rifted continental plates. Some are associated with alkaline volcanic activity. Carbonatites range in age from Archean to Recent.

Wall-rock alteration

Carbonatite-containing complexes are typically surrounded by an aureole of metasomatized rock that is characteristically moderately to intensely fenitized. Quartz-feldspathic wall rocks are typically converted to quartz-free rocks composed of alkali feldspar, aegirine and other sodic pyroxenes, and subordinate alkali amphibole. Other types of hydrothermal alteration, such as chloritization of ferromagnesian minerals, may also be present.

Nature of ore

Ore minerals may be disseminated throughout a large volume of carbonatite, or may be banded and concentrated in certain intrusive, alteration, or breccia zones, or in carbonatite dikes and sills.

Deposit trace element geochemistry

Most deposits are enriched in Th, U, Ti, Zn, Nb, Y, Mo, Cu, V, P, Mn, S, La, Ce, Sm, Eu, Pb, Zr, and Ba.

Ore and gangue mineralogy and zonation

Ore minerals may be disseminated throughout carbonatites, or concentrated in bands or zones. Multiple stages of igneous activity and metasomatic replacement may have produced localized ore mineral concentrations. Carbonatite complexes may include multiple stages of carbonatite dikes and veins, which cut earlier carbonatite and host rocks, crosscut each other, and grade into low-temperature veins containing carbonate minerals, fluorite, and quartz.

Mineral characteristics

Elemental and mineral associations include: phosphate-iron (fluorapatite, carbonate-fluorapatite, magnetite); niobium (pyrochlore, perovskite, niocalite); rare earth element-barium (bastnaesite, monazite, parisite, barite). Other common major and accessory minerals include calcite, dolomite, ankerite, ilmenite, strontianite, fluorite, pyrrhotite, pyrite, molybdenite, galena, chalcopyrite, sphalerite, biotite, phlogopite, pyroxenes, amphiboles, forsterite, hematite, zircon, anatase, brookite, and rutile.

Secondary mineralogy

Dissolution of carbonate and residual concentration of iron oxide are the dominant secondary processes. Partial dissolution and reprecipitation of apatite may result in near-surface enriched deposits of francolite (carbonate-apatite).

Topography, physiography

Variable. Topography is often controlled by the more resistant silicate rocks associated with carbonatite. Carbonatite plugs have a tendency to form subdued topography due to dissolution of carbonate minerals by ground and meteoric water. Dikes may stand out as resistant features in arid climates, but may be removed by dissolution in wet climates. Karst processes may produce topographic lows filled by lake sediment and underlain by residual concentrations of insoluble minerals from carbonatite.

Hydrology

Most carbonatite deposits are within concentrically zoned igneous complexes. Most rock in this type of setting is relatively solid, unfractured, and not associated with major fault or shear zones. Consequently, features that focus water flow are scarce in association with carbonatite complexes. Some parts of deposits may, however, contain vuggy or breccia zones with increased permeability. Dissolution by ground water does create the potential for genesis of permeable channels in particularly calcite-rich carbonatites.

Mining and milling methods

Most carbonatite deposits are mined by large scale, open-pit methods. Separation of ore from waste depends on the commodity being sought. Physical concentration by density and flotation is commonly employed. Rare earth element recovery requires leaching by acid or alkaline solutions, and specific rare earth element concentrates are typically purified using solvent extraction.

ENVIRONMENTAL SIGNATURES

Drainage signatures

Stream sediments downstream from carbonatite deposits commonly contain anomalous abundances of thorium, barium, niobium, and rare earth elements, including lanthanum, cerium, neodymium, and samarium (U.S. Geological

Survey, 1991; Haxel, in press).

Metal mobility from solid mine wastes

Rare earth elements, uranium, thorium, and niobium are likely to be present in relatively stable, insoluble mineral forms that decompose slowly. Production of metal-charged acid drainage may be appreciable from pyrite- or sulfide-rich carbonatite. However, carbonate-rich host rocks buffer acid drainage in most cases.

Soil, sediment signatures prior to mining

Soil and weathered rock associated with carbonatite deposits are likely to be enriched in iron, phosphorous, niobium, and rare earth elements and potentially thorium, uranium, titanium, barium, zirconium, and other elements as well.

Potential environmental concerns associated with mineral processing

Tailings or waste are likely to contain above-normal amounts of uranium and (or) thorium. Weathering of waste from pyrite-rich carbonatites has the potential to produce acid drainage but abundant carbonate minerals generally consume acid so generated. Chemical processing used to extract phosphate has the potential to produce acid drainage if liquids or solids escape treatment cycles.

Smelter signatures

Little data available. Most mineral commodities recovered from carbonatites are those separated by mechanical separation means or chemical solution; neither smelting nor associated emissions are relevant factors.

Climate effects on environmental signatures

The effects of various climatic regimes on the geoenvironmental signature specific to carbonatite deposits are not known. Because these deposits have relatively low sulfide mineral contents and because carbonate minerals that have abundant acid consumption potential are abundant in association with these deposits, environmental signatures associated with carbonatite deposits probably are not much affected by climatic regime variation.

Geoenvironmental geophysics

Where radon hazards may be of concern, gamma-ray spectrometry can easily distinguish between the three natural radioelements, potassium, thorium, and uranium, and provide quantitative estimates of their concentrations. Where sulfide minerals are present, in mineralized rock or mine waste, induced polarization methods can detect their presence. Enhanced vegetation development, typically associated with complexes in which phosphorous and potassium abundances have been enriched, can be detected by remote sensing.

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