

STATE OF ARIZONA
DEPARTMENT OF MINES AND MINERAL RESOURCES

1502 West Washington
Phoenix, AZ 85007-3210
(602) 255-3791 Toll Free in Arizona 1-800-446-4259

STRATEGIC MINERAL REPORT
(The Arizona Position)

COBALT

BY

Clifford J. Hicks
Field Engineer

Introduction: Cobalt has been used as a blue coloring agent for glass and enamel for almost 4,000 years. It derives its name from old German folklore in which a "kobold" is a gnome that inhabits mines and caverns. Currently, it is a little known, but strategic metal, being used as an essential alloying agent in many of the specialty steels required by the aerospace, cutting tool, permanent magnet, construction and mining industries. Additionally, its compounds are utilized in paints and related products. Cobalt is used by the chemical industry as a catalyst and in agriculture as a soil additive which, in turn, serves as a vital nutritive agent in crops. In most of its alloying applications cobalt imparts necessary characteristics such as wear and heat resistance, high strength (even at elevated temperatures) and superior magnetic properties. Cobalt is truly a most useful and versatile metal.

Isolated as a metal in 1742 by a Swedish scientist and recognized as an element in 1780 cobalt was used only as a glass coloring agent until 1907 when a patent was issued on a series of cobalt-chromium alloys called "Stellites". The Stellites were the prototypes of today's "superalloys" used in jet engines, guided missile controls, armor piercing shells and other military and civilian hardware. In 1930 the Japanese discovered that adding cobalt to alloys of iron, aluminum and nickel improved their performance as permanent magnets. This technological breakthrough led to General Electric's development of the famous "Alnico" (aluminum, nickel, cobalt) series of alloys.

Elemental Cobalt: A silvery gray metal (exhibits faint bluish tinge when polished), it has a density of 543.7 lbs/ft³ making it a little lighter than copper but heavier than iron. Cobalt melts at 2723°F which is lower than iron and higher than copper, however, when magnetized, it retains its magnetic properties up to 2050°F.

Mineralogy: Elemental cobalt is never found in nature. The chief minerals of cobalt are: Smaltite and Cobaltite and Erythrite.

Smaltite: A cobalt, nickel, iron arsenide (CoNiFeAs_2). The crystals are cubic or octahedral, however, it is usually massive or granular. Has an indistinct cleavage and uneven fracture. Hardness is 5-6. Minerals with a hardness of 5 are scratched with some difficulty with a knife or window glass; those with a hardness of 6 are scratched with a file, but will scratch glass. The specific gravity of smaltite is 6.4-6.9 meaning it is that many times heavier than an equal volume of water. It is not as heavy as good lead or iron ore. The color is tin white to steel gray and will tarnish dull. Its streak is grayish black. Smaltite is also an ore mineral of nickel as this metal may proxy for cobalt in any amount from none to complete substitution. It alters easily to the pink mineral erythrite.

Cobaltite: A sulpharsenide of Cobalt (CoAsS). The crystals are usually cubes or pyritohedrons, like pyrite. Cube faces often striated like pyrite. It can also be granular massive. Its crystals have good cubic cleavage, but have an uneven fracture. The hardness is 5.5 and specific gravity 6-6.3, both about the same as smaltite. Cobaltite has a metallic luster and silvery white color, at times with a reddish tinge. The streak is grayish black. It is soluble in nitric acid. Like smaltite, it alters easily to erythrite.

Erythrite: A hydrous cobalt arsenate ($\text{Co}_3\text{As}_2\text{O}_8 \cdot 8\text{H}_2\text{O}$). The crystals are prismatic and vertically striated. Erythrite also occurs as columnar masses of globular shape or as an earthy powder. It is very soft with a hardness of 1.5-2.5 (easily scratched by a fingernail) and light, with a specific gravity range of 2.95-3.18; just a little heavier than dry clay. The color is crimson to gray with a paler streak. In dry powder form it is a lavender blue. Erythrite is produced by the weathering of cobalt minerals and is therefore (and because of its color) appropriately called "cobalt bloom". Because of its unique color, cobalt bloom provides the prospector with a valuable guide to cobalt occurrences. Persons interested in cobalt prospecting should acquaint themselves first hand with a specimen. The museum of the Arizona Department of Mineral Resources contains representative samples of cobalt minerals for observation.

Other cobalt bearing minerals include linnaeite (Co_3S_4), skutterudite (CoAs_3), carrollite Co_2CuS_4 , safflorite (CoFeAs_2), and asbolite $\text{CoO} \cdot 2\text{MnO}_2 \cdot 4\text{H}_2\text{O}$.

Testing for Cobalt: (1) Cobalt can usually be detected by the color it imparts to the fluxes.

To make this test use a piece of No. 26 platinum wire about two inches long. Fasten one end in a holder so that when the wire is heated it will not burn the fingers (special holders can be purchased, but a cork or a piece of soft wood can be used for this purpose). Make a loop, about one-sixteenth of an inch in diameter, at the unattached end of the wire (this loop is easily made by winding the end of the wire around the point of a lead pencil). Heat this looped end in a flame until it is red-hot (an alcohol lamp is very satisfactory for this work). Dip the red-hot loop into some powdered borax or salt of phosphorus, a little of which will adhere to the wire loop. Fuse the borax or salt of phosphorus adhering to the wire by holding it in the flame. Continue these operations until a clear, glassy bead that fills the loop in the wire is secured. Add to this bead the mineral that is to be tested (touch the bead while it is red-hot to a very little of the finely powdered mineral). If the beads made from either borax or the salt of phosphorus and a cobalt mineral are heated before the blowpipe in either the reducing (yellow) flame or the oxidizing (bluish) flame the color of the beads formed will be deep blue.

Beginners practicing this cobalt test should use roasted smaltite or roasted cobaltite.

Note: A sulfide or arsenic ore must be thoroughly roasted (pulverized and heated on charcoal at a red heat until sulfur or arsenic fumes are no longer noticeable) before using the cobalt mineral in the bead tests.

(2) Cobalt compounds become magnetic when heated on charcoal before the blowpipe in the reducing flame.

To make this test: Mix thoroughly a little finely powdered mineral with about twice its volume of powdered sodium carbonate (baking soda). Transfer to a stick of charcoal as much of this mixture as can be held on the tip of a knife blade. Heat strongly before the blowpipe in the reducing (yellow) flame until the mixture is thoroughly fused. The resulting fused mass will contain a dark colored, more or less metallic button enclosed in the slag, and this button will be magnetic when cold if the mineral used contains cobalt.

Beginners practicing this test should use smaltite or cobaltite.

Note: Metallic iron and nickel are also magnetic; therefore a magnetic button obtained from any mineral, the metallic contents of which are unknown, should be tested further by applying test (1) for cobalt.

Source: Fansett, George R., 1926: Field Tests for the Common Metals (Fourth Edition), Arizona Bureau of Mines, Bulletin No. 121, University of Arizona, Tucson, Az. pp 11-12.

Geology: Whereas the normal composition of the earth's crust will average 20 ppm (0.002%) cobalt, mafic and ultramafic igneous rocks such as peridotites, dunites, and serpentinites will run around 270 ppm (0.027%). These rocks are a very dark black or greenish black. Specimens may be examined in the Mineral Museum of the Arizona Department of Mineral Resources in Phoenix.

Magmatic differentiation, which produces mafic and ultramafic rocks, seems to concentrate cobalt along with nickel, chromium, and some other metals. The ultrabasic rocks rarely contain cobalt in commercial quantities. The soil formed from them, however, has concentrations of iron, manganese, nickel, and cobalt after long successive weathering of the rocks, especially under tropical conditions that cause much laterization. The best known examples of such cobalt deposits are the lateritic iron ores. Most geologists believe that some hydrothermal activity as well as magmatic differentiation is important in the origin of these cobalt deposits. Where the deposits are large, such as at Sudbury, Ontario, some cobalt can be recovered as a byproduct during the recovery of nickel and copper. Seldom are any of the cobalt minerals found in sufficient quantity to be mined for cobalt alone. Consequently, the amount and concentration of cobalt and the presence of associated metals are factors in making deposits of economic value. The term ore may be applied to mineral deposits only if the material can be mined, processed and marketed at a profit.

In Zambia and Zaire (South Central Africa) which, according to the U.S. Bureau of Mines, have 52% of the world's cobalt, cobalt is a byproduct metal derived from deposits dominated by copper, lead, or zinc. Cupriferous strata-bound deposits are the largest producers with the cobalt grading as high as 3-4%.

Production Potential: Strategic minerals for which the U.S. must rely largely or entirely on imports are essential to national defense. Cobalt is such a mineral. The U.S. imports three-quarters of its cobalt from southern Africa. The largest profitable mining area for cobalt in the U.S. was the Blackbird district of Idaho. This district was one of the rare locations where cobalt has been mined as the principal product, but the mine was closed in June 1959. The ore grade was relatively high, averaging 0.6% cobalt. Other U.S. sources included Missouri, Pennsylvania, Minnesota and California. Oregon and Alaska also have large identified resources. Economics have inhibited production and development of these resources.

No commercial production of cobalt has been made in Arizona probably because of the lack of the prolonged rainy climate necessary for the laterization of the mafic and ultramafic rocks. However, there are a number of Arizona occurrences. The one with probably the greatest potential is the Old Dick mine, SW 1/4, Sec. 17, T14N, R9W, Yavapai County about 2 3/4 miles southwest of Bagdad. Spectrographic analyses of arsenopyrite from the mine revealed a cobalt content of as much as 0.6%. The ore zone consists of separate lenses of massive sulfides mainly chalcopyrite (CuFeS_2)

and sphalerite (ZnFeS). These lenses strike northeast, dip steeply westward to vertical and are essentially parallel to the foliation of the enclosing rocks. The sulfide masses are locally 30% cobalt-bearing arsenopyrite.

Other small prospects include:

<u>Location</u>	<u>Country Rock</u>	<u>Mineralogy</u>
Grapevine Gulch, Black Hills, 17 mi. NE of Prescott, Yavapai County	Patches of gabbro	Cobaltiferous arsenopyrite, erythrite
Monte Cristo mine near Constellation, Yavapai County	Medium grained granite	Chloanthite $(\text{NiCo})\text{As}_3$, with Ag & Cu
1/2 mile east of Mule Shoe Bend of the Salt River, Gila County	Unknown	Erythrite
Blue Bird mine, south of the Gila River, 25 mi. northwest Safford, Graham County	Unknown	Smaltite, Au, Ag
Comobabi Mtns. 50 mi. west of Tucson, Pima County	Unknown	Cobaltite

Additionally, Arizona county geologic maps show two quite extensive outcrops of pyroxenite (an ultramafic rock) which can be a favorable host rock for nickel and cobalt. These outcrops are in the Sunflower mining district of Maricopa and Gila counties T7N, R9, 10E and T7, 8N, R5, 6E. As far as the author can determine no cobalt occurrences have been reported in these outcrops but it is possible that they were never prospected for that metal. Barite, uranium and precious metals have been noted. County geologic maps may be studied at the Department of Mineral Resources offices in Phoenix and Tucson. Qualified engineers are also available for consultation.

Processing: Cobalt ores occur as oxides, arsenides or sulfides. Depending on the chemistry one or a combination of methods may be used for processing: magnetic concentration; flotation; roasting; leaching at normal or elevated temperature and pressure with an ammoniacal solution or sulfuric acid; and chemical precipitation by solids, liquids, or gases. Electrolytic reduction is common.

Most of the ores mined in the late 1970's contained 0.1 - 0.5% Cobalt. These grades require concentration by crushing, grinding, and flotation to produce a concentrate four to eight times higher in cobalt than that of the ore. A list of potential purchasers of cobalt concentrates may be obtained through the Arizona Department of Mineral Resources.

Market Outlook: Lower consumption, increased substitution, and unprecedented destocking have contributed to a current world glut in cobalt. Most producers, during 1980, held to the published \$25/lb. price, however, some quantities were marketed at discounts varying from 10 - 20% and even 30%. The U.S. Strategic Material Stockpile is only 48% of the 1980 goal, but the June 20, 1981 issue of Metals Week announced that the U.S. would buy 5.2 million pounds from Zaire at \$15/lb. The U.S. demands over 20 million lbs. annually which is traditionally 35 - 45% of total world consumption.

Arizona Cobalt and the Big Picture: Sparse cobalt discoveries in Arizona, the present market glut and falling prices would tend to discourage all but the most dedicated prospector, however, cobalt mine production in the U.S. ceased at the end of 1971. All production since that time has been from relatively minor amounts of secondary material derived from recycled alloys. The political instability of the countries which are our major source of supply must be kept in mind. Cobalt from these nations could be denied us at any time. As a strategic mineral cobalt is absolutely essential for national defense. War could deprive us of imports. A prospector holding claim to a mineable cobalt ore body could contribute greatly to the war effort. Additionally, the present administration's announced policy of decreasing dependence upon foreign sources for strategic minerals should encourage prospecting.



U.S. Cobalt Supply and Demand (Primary Metal)

