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Indium in Zinc-Lead and Other Mineral Deposits—A Reconnaissance Survey of 1118 Indium Analyses Published Before 1985

By Joseph A. Briskey

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Introduction

Indium is a very soft, silvery-white metal. Alloys of indium can be plated onto metal and evaporated onto glass in a variety of critical technology applications. Its uses include: the manufacture of portable computer screens, television screens, video monitors, watches, infrared detectors, high-speed transistors, high-efficiency photovoltaic devices, electrical fuses, dental alloys, solders, nuclear control rods, fog- and frost-free windshields, and energy-efficient windows and light-emitting diodes (George, 2004 and 2005).

World consumption of indium is increasing. Imports by the United States increased 10 percent in 2003, the last year for which import data are available. The United States is 100 percent reliant on imported indium from China (49%), Canada (21%), Japan (9%), France (6%), and other countries (15%). (George, 2005 and 2004).

Indium does not form primary mineral deposits, but is recovered principally as a byproduct from the smelting of the zinc-sulfide mineral sphalerite to make zinc metal. Higher concentrations of indium occur in tin minerals in certain types of tin deposits, but are difficult to recover economically.

The growing use of indium in high-tech applications, total U.S. import dependency, and a restricted supply dependent on the production of other metals like zinc, make it imperative to have a better understanding of indium distribution and concentration in a wide variety of minerals and mineral deposits around the world.

This report provides a reconnaissance summary and survey of 1118 indium analyses of a diverse suite of minerals, including monomineralic and polymineralic ores and mineral concentrates, from 12 mineral-deposit types, principally zinc-lead deposits, from 16 countries. These analyses are presented in table 1, which was compiled in 1984 from published literature. Analyses are reported for 159 single samples or multi-sample suites variably composed of 16 minerals, mainly sulfides.

Types of Mineral Deposits Analyzed

Twelve mineral-deposit types have reported indium analyses:

1. Bauxite
2. Black shale
3. Coal

4. Cornwall-type tin deposits
5. Michigan-type native copper deposits
6. Mississippi-Valley-type zinc-lead deposits
7. Pegmatite deposits
8. Sandstone-hosted base-metal deposits
9. Porphyry copper deposits
10. Sediment-hosted zinc-lead deposits
11. Vein, replacement, and contact metasomatic base- and precious-metal deposits; mainly deep-seated veins, including metamorphic veins
12. Volcanogenic massive sulfide deposits

Material Analyzed

The material analyzed included one or more of the following 16 minerals or mineral groups:

Arsenopyrite	Chalcocite	Galena	Sphalerite
Barite	Chalcopyrite	Molybdenite	Stannite
Bornite	Coal	Pyrite	Tetrahedrite
Cassiterite	Digenite	Pyrrhotite	Vanadium minerals

Countries Represented

Analyzed samples were from a variety of mineral deposits in 16 countries:

Argentina	China	India	Poland
Bolivia	Former Czechoslovakia	Japan	Switzerland
Bulgaria	England	Mexico	USA
Canada	Germany	Peru	Former Yugoslavia

Results

The indium analyses presented in table 1 are not amenable to rigorous statistical analysis, principally because they are presented in summary form and there is uncertainty about some of the analytical techniques used and their precision. Moreover, many analyses are below the limits of detection of the analytical technique used. Individual analyses are shown for 87 single samples. For most of the remaining 72 multi-sample suites, the high, low, and average indium contents are reported. For 16 of these suites, the averages may be biased slightly toward higher values because some of the analyses were below the analytical limits of detection. Nevertheless, sorting and visual inspection of the data in table 1 can give a good idea of where indium occurs, and in what amounts, in a variety of minerals, mineral deposits, and regions of the world.

Indium-rich Minerals

Minerals in table 1 containing 100 ppm or more indium are listed below. Sphalerite and chalcopyrite dominate.

Sphalerite ....<5— 12,500
Chalcopyrite.......<5— 9,800
Stannite.............400— 2100
Digenite 1100
Cassiterite..........200— 700
Galena........................500
Pyrite.........................100

Geographic Areas Where the Highest Indium Value Equals or Exceeds 1000 ppm

Mount Pleasant, New Brunswick; Canada
Bingham district, Utah; U.S.A.
Central district, New Mexico; U.S.A.
Central City district; Colorado; U.S.A.

Geographic Areas Where the Highest Indium Values are Between 100-1000 ppm

Cornwall; England
Balmat-Edwards district, New York; U.S.A.
Maine, New Hampshire, Connecticut, and Rhode Island; U.S.A.
Rammelsberg mine, Germany
Argentina, various areas
Yugoslavia, various areas
Metaline district, Washington; U.S.A.
Coeur d'Alene district, Idaho; U.S.A.
Pinos Alto district [incl. Cleveland mine], New Mexico; U.S.A.

Mineral-Deposit Types Having The Highest Indium Contents

1000-12,500 ppm from sulfide minerals in:

Sphalerite, chalcopyrite, tetragonal stannite, and digenite from the Cornwall-type Mount Pleasant tin deposit in New Brunswick, Canada.

Sphalerite from porphyry copper, vein, replacement, and (or) contact metasomatic deposits in the Central district of New Mexico, USA.

Chalcopyrite from peripheral veins and possibly replacement deposits in the Bingham district, Utah, USA.

Sphalerite from Au-Ag-rich base-metal veins in the Central City district; Colorado; U.S.A.

100-1000 ppm indium occurs in a variety of sulfide and oxide (cassiterite) minerals in a wide variety of deposit types around the world, including:

Cornwall-type tin deposits
Mississippi-Valley-type zinc-lead deposits
Porphyry copper deposits
Sediment-hosted zinc-lead deposits
Vein, replacement, and contact metasomatic base- and precious-metal deposits
Volcanogenic massive sulfide deposits

Mineral Deposit Types Having Lowest Indium Contents

<1 to <10 ppm indium are common in the same deposit types that also have high values. In addition, 157 samples of Bulgarian coal average only .03 ppm indium.

Indium Content by Deposit Type Alphabetically

Bauxite

Red slimes: 17 ppm.

Black Shale (sediment-hosted or volcanogenic pyrite?)

Twelve samples of pyrite from the Rohtas district, India, ranged from 25-70 ppm, and had an average of 45 ppm.

Coal

Bulgaria: .03 ppm average for 157 samples.

Cornwall-Type Tin Deposits

Sphalerite ....300—12,500 ppm
Chalcopyrite............1620—9800 ppm
Tetragonal stannite ....2100 ppm
Digenite ....1100 ppm
Cassiterite...............200—700 ppm
Galena....................500 ppm
Hexastannite............400 ppm
Pyrite.....................100 ppm
Arsenopyrite............50 ppm
Molybdenite............<10 ppm.

Michigan-Type Native Copper Deposits

<8 ppm in copper concentrate.

Mississippi-Valley-Type Zinc-Lead Deposits

Sphalerite	<5-166 ppm; usually <50 ppm
Galena	<3 ppm

Mixed Porphyry Copper, Vein, Replacement, and Contact Metasomatic Ores

Analyses of 112 sphalerites had values up to 1,000 ppm, but average only 41 ppm. Chalcopyrite samples and suites contained up to 200 ppm, but the suites average only about 20 to 50 ppm.

Pegmatite Deposits

One sphalerite analyzed from a pegmatite in Newry, Maine; U.S.A., contained 29 ppm.

Porphyry Copper Deposits

Chalcopyrite from the Bingham deposit, Utah, U.S.A. had up to 150 ppm indium, but the average of 42 samples was only 11 ppm.

Sandstone-hosted base- and precious-metal deposits

Three zinc and lead concentrates, from remobilized(?) minerals, were all below the 8 ppm detection limit.

Sediment-Hosted Zinc-Lead Deposits

Most indium was in sphalerite: as high as 360 ppm, but sample suites usually averaged <100 ppm.

Vein, Replacement, and Contact Metasomatic Base- and Precious-Metal Deposits (mainly deep-seated veins, including metamorphic veins)

Most indium was in sphalerite: highs ranged from about 45 to 1000 ppm, but averages were less than 100 ppm, except in the Central City district in Colorado, U.S.A., where the average of 17 sphalerites was 262 ppm.

Chalcopyrite and copper concentrates generally were low in indium, having high values <30 ppm; but 11 samples from the Bingham district were as high as 1,000 ppm and averaged 263 ppm.

Galena, including Pb concentrate, usually was below the limits of detection of 8 ppm.

Two samples of Mo-V concentrate from the Old Hat district, Arizona; U.S.A., contained 83 ppm indium.

Volcanogenic Massive Sulfide Deposits

Chalcopyrite up to 90 ppm; sphalerite and pyrite <42 ppm.

Table 1 Abbreviations

Chemical Elements

Ag	Silver
Cu	Copper
Fe	Iron
Mo	Molybdenum
Pb	Lead
Sn	Tin
V	Vanadium
Zn	Zinc

Mineral Deposit Types

Cornwall Sn	Cornwall-type tin deposits.
Michigan Cu	Michigan-type native copper deposits.
MVT	Mississippi-Valley-type zinc-lead deposits.
PC	Porphyry copper deposits.
PG	Pegmatite deposits.
SSH	Sandstone-hosted base-metal deposits.
SX	Sediment-hosted zinc-lead deposits.
VMS	Volcanogenic massive sulfide deposits.
VRC	Vein, replacement, and contact metasomatic base- and precious-metal deposits; mainly deep-seated veins; includes metamorphic veins.

Analytical Abbreviations and Comments

Blank	Not analyzed; analytical technique unknown; or other data, unknown or not recorded.
n.d.	Not detected.
ppm	Parts per million.
S	Spectrographic analysis.

Value or Average (Column J). "Value," if only one, or an unknown number, of samples were analyzed. "Average," if more than one sample was analyzed.

Minerals

cc	chalcocite
cp	chalcopyrite
gn	galena
po	pyrrhotite
py	pyrite
sl	sphalerite

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