



## CARBONATE HOSTED $Cu \pm Pb \pm Zn$

EO2

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### IDENTIFICATION

SYNONYMS: Tsumeb or Kipushi type.

COMMODITIES (BYPRODUCTS): Cu, Pb, Zn, Ge (Ag, Ga, As, Cd).

EXAMPLES (British Columbia - Canada/International): Blue (Minfile 94F005); *Grinnell and Kanuyak Island (Northwest Territories, Canada), Kennecott, Ruby Creek and Omar (Alaska, USA), Apex (Utah, USA), Gortdrum (Ireland), Tsumeb and Kombat (Namibia), Kipushi (Zaire), M'Passa (Congo), Timna (Israel), Nifty (Australia), and portions of Dongchuan deposits (China).*

### GEOLOGICAL CHARACTERISTICS

**CAPSULE DESCRIPTION:** Irregular, discordant bodies of Cu sulphides (bornite, chalcopyrite, chalcocite, tennantite), sometimes with significant galena and sphalerite, form massive pods, breccia/fracture fillings and stockworks in carbonate or calcareous sediments. Igneous rocks are absent or unrelated to the deposition of metals.

**TECTONIC SETTING:** Intracratonic platform and rifted continental margin sedimentary sequences; typically gently folded and locally faulted.

**DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING:** Host carbonate sediments were deposited in shallow marine, inter-tidal, sabkha, lagoonal or lacustrine environments and are often overlain disconformably by oxidized sandstone-siltstone-shale units. Largest deposits are within thick sedimentary sequences.

**AGE OF MINERALIZATION:** Hosts rocks are Middle Proterozoic to Triassic; the largest deposits are in Upper Proterozoic rocks. Mineralization is at least slightly younger than host lithologies and may have spanned a large time interval.

**HOST / ASSOCIATED ROCK TYPES:** Dolomite or limestone, often stromatolitic or arenaceous, hosts the mineralization within a sequence which typically includes fine to coarse grained clastic sediments and evaporite. Occasionally basalt flows are nearby or part of sequence. Intrusive rocks are absent or different age than mineralization.

**DEPOSIT FORM:** The pipe-like to tabular deposits are irregular, discordant and often elongated in one direction up to 2 000 m or more. In cross section, deposits can be up to 100 by 200 m or 60 by 500 m in size. Sometimes Zn-Pb rich mantos project from the main zone of mineralization as replacement bodies parallel to bedding.

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**TEXTURE / STRUCTURE:** Massive, stringer/stockwork and disseminated mineralization styles occur and grade into one another; clots of sulphides are common. Features characteristic of a karst environment, including collapse breccias, are typical. Two or more breccia types may be present as a result of karst dissolution and hydrothermal fracturing. Open spaces within deposits are common. Narrow bodies or irregular masses of arenaceous sediment may occur within deposit. These clastics may have developed as a result of dissolution of an arenaceous carbonate host, with accumulation of clastic lag sediments, or by clastic sedimentation into karst openings as a result of submergence.

**ORE MINERALOGY (Principal and subordinate):** Chalcopyrite, bornite, chalcocite, tennantite (*tetrahedrite*), galena, sphalerite, pyrite, enargite, *renierite*, *germanite*, *arsenopyrite*, *marcasite*, *magnetite*, *gallite*, *Co-Ni arsenides*, *carrollite*, *molybdenite* and others. Deposits contain low to moderate Fe; pyrite may be common or virtually absent. Cu is sometimes crudely zoned vertically in deposits relative to Fe with the Cu-rich phases closer to surface. Cu may also be spatially partitioned with respect to Pb-Zn.

**GANGUE MINERALOGY (Principal and subordinate):** Dolomite, quartz, calcite, barite, fluorite, clay minerals, sericite, hematite, siderite and minor *pyrobitumen*.

**ALTERATION MINERALOGY:** Dolomite, silica, calcite and argillic alteration. Deposits are usually coincident with a zone of dolomitization. Dolomitization may be pre-, syn- and/or post-mineralization, and may extend 100's of metres beyond mineralization. Vuggy openings are often lined with calcite or baroque dolomite.

**WEATHERING:** Wide variety of secondary products form especially limonite, goethite, Cu minerals (malachite, azurite, diopside), cerussite and smithsonite. Some deposits are deeply oxidized (Kennecott, Tsumeb, Apex) as a result of fluid circulation through/along solution cavities, faults/fractures and bedding planes. Oxidation is typically developed at surface but there may also be an oxidized profile at considerable depth (>1,000m) as a result of continuation/reactivation of fluid flow along bedding planes aquifers.

**ORE CONTROLS:** The openings in carbonate rocks are created by brecciation, karsting, faulting, and/or alteration. Deposits form in proximity to a redox boundary between reduced carbonates and oxidized clastic sediments or occasionally oxidized basalt. Evaporites in the sedimentary sequences may have enhanced brine salinity and contributed sulphur.

**GENETIC MODEL:** Pre-mineralization plumbing systems were created by karsting, collapse zones, faulting/fracturing, collapse related to evaporite removal, and/or bedding plane aquifers and were enhanced by volume reduction during dolomitization, ongoing carbonate dissolution and hydrothermal alteration. Oxidized, diagenetic fluids scavenged metals from clastic sediments and their source area, with deposition in open spaces in reduced carbonates, often immediately below an unconformity. In a few examples, nearby basalts could have provided Cu. Fluid inclusion data indicate mineralizing solutions were saline and generally low temperature, in the 100-240°C range. Mineralization may have been initiated soon after host sediments became indurated and was likely a prolonged event, possibly continuing intermittently over 100's of millions of years in larger deposits. Deposits are basically formed through diagenetic processes and are an integral part of basin evolution. In some deposits, different fluids could have prevailed within oxidized and reduced strata leading to different metal sources - this could explain why only some deposits have a significant Zn-Pb-Ge component.

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**ASSOCIATED DEPOSIT TYPES:** Genetic processes which form carbonate-hosted  $Cu\pm Pb\pm Zn$  may be analogous to stratiform Cu (E04), carbonate hosted Zn-Pb (E12), unconformity U (I16) and sandstone U (D05) deposit types. Carbonate hosted  $Cu\pm Pb\pm Zn$  deposits have many similarities with carbonate hosted Zn-Pb deposits (E12), and are possibly a link between these deposits and stratiform Cu (E04).

**COMMENTS:** Deposits often occur in the same basin as stratiform Cu or carbonate-hosted Zn-Pb deposits. Other possible candidates for this type include: Mount Isa Cu, Kilgour, Yah Yah and Cooley (Australia), Nite and Ellesmere (Northwest Territories, Canada), Lord Aylmer and Acton Vale (Quebec, Canada).

## ***EXPLORATION GUIDES***

**GEOCHEMICAL SIGNATURE:** Dominantly elevated Cu but Zn, Pb, As, Ag and Ge are key indicators in rock samples; subtle Cu-stream silt geochemical anomalies occur in proximity to some deposits. Other elements which may be useful pathfinders are Co, Ga, Bi, Cd, V, Mo and Ba.

**GEOPHYSICAL SIGNATURE:** Resistivity, IP and gravity could be useful but there are no definitive tools.

**OTHER EXPLORATION GUIDES:** Tectonically disturbed zones and karsted areas within carbonate/oxidized clastic couplets of major basins are regional targets. Dolomitized zones should be carefully examined. Deposits often occur in clusters and/or in proximity to associated deposit types. Deposits oxidize readily forming gossans with secondary Cu and Fe minerals; many other secondary products and malachite-coated nuggets of copper sulphides may be present. Thermal maturation anomalies and clay mineral zoning, as applied to carbonate hosted Zn-Pb and unconformity uranium deposits, may be useful tools.

## ***ECONOMIC FACTORS***

**TYPICAL GRADE AND TONNAGE:** Tsumeb produced ~30 million tonnes at 4.0% Cu, 9.0% Pb and 3.2% Zn. Production plus reserves at Kipushi are believed to be about 70 million tonnes at 4.8% Cu, 8.8% Zn and 0.5% Pb. Kennecott production was 4.4 million tonnes at 12.4% Cu and 95 g/t Ag. These three deposits are the most significant producers and also reflect the highest average grades for Cu (Kennecott), Pb (Tsumeb) and Zn (Kipushi). The Ruby Creek resource is 90 million tonnes grading 1.2% Cu. Ge and Ga were produced at Tsumeb, Kipushi(?) and Apex; Apex grades were in the order of 0.06% Ge and 0.03% Ga.

**ECONOMIC LIMITATIONS:** Although several deposits have been partially mined by open pit methods, the elongate morphology usually requires underground mining. The complex suite of metallic minerals in some deposits could complicate metallurgy.

**IMPORTANCE:** Gross and unit metal values can be very high. Few significant deposits are recognized; however, the type is poorly understood and exploration efforts have been minimal.

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