

# Hydrothermal dolomitization, mineralization and brecciation at the Mississippi-Valley type Zn-Pb Polaris Mine, central Arctic Islands, Nunavut

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## Summary

Drilling and underground mapping from the Polaris Mine provide excellent control on the distribution of brecciation, collapse features, ore textures, and paragenesis around the deposit.

## Introduction

Teck Cominco Limited's Polaris zinc-lead mining operation was located on the southwest side of Little Cornwallis Island, Nunavut, at 75° 23' N and 96° 57' W. The high grade, carbonate-hosted, sphalerite-galena deposit was put into production in late 1980 and closed in September, 2002 due to depletion of reserves. Polaris produced 20.1 Mt of ore at 13.4% Zn, 3.6% Pb and 3.6% Fe.

The Polaris deposit is spatially related to where structures of the Boothia Uplift, a Late Silurian to Middle Devonian intraplate fold-and-thrust belt, were re-folded by north—south compression of the Late Devonian Ellesmerian Orogeny (Jobber et al., 2007). Age dating of the Polaris deposit indicates a Late Devonian age (Christensen et al., 1995, Selby et al., 2005, Symons and Sangster, 1992).

Polaris deposit was formed by warm (105°C), saline (25 to 35 wt. %) hydrothermal fluids (Randell and Anderson, 1997; Savard, et al, 2000). These fluids precipitated ore minerals in carbonates of the Ordovician-aged Thumb Mountain Formation.

## Collapse features at Polaris

The mined ore body is 300 m wide by 800 m long by 20 to 150 m high, with the long axis parallel to strike. Sulphide mineralization decreases rapidly away from the ore boundary. A broad dolomite alteration halo (with traces of Zn-Pb mineralization) surrounds the ore body and is about 1200 m long by 800 m wide. The dolomite halo shows sharp margins on its downdip (east) and southern limits, but extends 550 m up dip where it is exposed at surface on Polaris Peninsula.

Thinning caused by dissolution of calcite and dolomite in the Thumb Mountain Formation starts at the edge of the dolomitized halo. Grabens formed within the Thumb Mountain Formation over the main areas of mineralization leading to collapse of the overlying Irene Bay Formation. The upper Thumb Mountain Formation is thinned by 50% in the centre of the deposit. Dissolution led to the formation of numerous, interconnected breccia bodies. The following breccia types were mapped:

*Crackle Breccia* is fractured dolostone with dolospar cement. Dolostone fragments are angular and may be slightly displaced but show little rotation. The host rock-vein contacts are sharp, with little dissolution.

*Pseudobreccia* consists of subangular dolostone fragments in white dolospar cement. The fragments have embayed, irregular contacts. Sparry dolomite lines vugs with either sharp or gradational contacts with the matrix dolostone.

*Solution Recrystallization Breccia* consists of pebble-sized dolostone fragments preserved in a matrix of recrystallized dolomite, resulting in a chaotic breccia. Fragments are subrounded to rounded, and with smooth to corroded margins.

*Solution "Cobble" Breccia* is composed of subangular to subrounded, elongate dolostone fragments within a dark brown, clay-rich matrix.

*Collapse Breccia* is a substantial area (>15 m diameter) of breccia formed by the collapse of overlying rock into an open space. Dolostone blocks, 0.5 m to > 5 m across, are rotated between 10° and 60° in dip and strike away from the regional pattern. Another common feature in the collapse breccias are black argillaceous partings 1 to 10 cm thick, often showing slickensides. When traced along strike these argillaceous partings may either terminate abruptly, coalesce, abruptly change direction or splay into a more through-going, uniformly striking and dipping fault structure.

*Solution Pipe* is a subvertical, cylindrical to irregular channel 0.5 to 2 m wide that is filled with detrital matter and mineralization.

*Fault Breccia* is associated with planar, slickensided features or crushed zones showing structural deformation. These are narrow, planar intervals averaging 5 cm thick but ranging from 1 mm to 1 m.

## Ore features at Polaris

*Sphalerite* occurs in three non-radiating textures: 1) discrete crystals are subhedral to euhedral, roughly equant, and very fine to very coarse in size (<0.1mm up to 3mm). Discrete crystals are often found scattered throughout the recrystallized matrix dolomite. 2) granular aggregates consist of a few to hundreds of subhedral sphalerite crystals ranging from very fine to coarse. Aggregates are irregular in shape and range from less than 1 mm up to several cm across. 3) veinlets of sphalerite in the host rock. Crystals tend to be equant, with sizes ranging from very fine to medium.

Two types of radiating sphalerite crystal growth form are also recognized: 1) botryoidal aggregates consisting of concentric bands of radiating sphalerite crystals. The aggregates vary in size from one mm up to several cm in diameter. 2) encrusting aggregates are crusts of sphalerite crystals which form on vein or fracture walls, on dolomite host rock clasts or on other sulphide mineralization. Crystals radiate outward and tend to coarsen outward.

Mapping the distribution of sphalerite ore textures in the deposit shows that radiating sphalerite occurs in the main feeder zone of the ore body and in the tabular, upper part of the deposit. Veins and disseminated ore form a halo around the main ore body.

*Marcasite* occurs in three forms in the Polaris ore body. 1) scattered fine crystals. Occurs only within dolomite host rock, both filling the pore-spaces between dolomite crystals and replacing dolomite crystals. Crystals are less than 50 µm. 2) discrete crystals to dense crystal masses. This marcasite texture ranges from individual sub-millimetre buds and blades to small agglomerations of buds/blades to massive replacement. Typically replaces sparry dolomite, and less commonly sphalerite. 3) open space-filling crystals. Occurs in vugs and veins on the surface of saddle dolomite. Several crystal habits occur, including very fine needle shaped

(size), euhedral cubic (0.3 to 2 mm) and altered striated crystals of variable shapes (0.5 to 5mm).

Mapping the distribution of iron in the deposit shows that marcasite is most abundant above high-grade sphalerite zones.

*Dolomite* is present in the Polaris deposit both as a replacement mineral and as void-filling cement. Replacement dolomites range from: (1) dolomicrospar to, (2) mosaic dolomite to, (3) coarse sparry dolomite. Crystal shape is subhedral to euhedral. Replacement dolomites typically exhibit cloudy cores in thin section. Void-filling dolomite cements include: (4) clear sparry crystals (both 0.2 mm to >5.0 mm) which fill vugs and veins. Void-filling dolomite crystals are subhedral to euhedral in shape. In hand sample they are white or slightly pink.

*Calcite* is typically the last gangue mineral to precipitate, post-dating sulphides and dolomite cement. Four phases of calcite were observed: (1) calcite crust, which is a fine-grained, grey calcite that forms narrow sheets bridging open spaces. (2) intermingled calcite/dolomite. Void-filling coarse, sparry carbonate with smooth to irregular contacts between calcite and dolomite portions of individual crystals. In some cases small remnants of dolomite are surrounded by calcite. This phase is interpreted as dedolomite. (3) coarse crystals (<5mm) which are euhedral and clear, found in pores, vugs and fractures. (4) very coarse crystals (2-5 cm), which are cloudy and brownish, euhedral and often double terminated.

*Barite*: Rarely observed as white, platy crystals lining the walls of veins or cavities in mineralized Thumb Mountain dolostone.

*Silica*: Rare within the Polaris deposit, but a chalcedonic form fills void space and replaces sphalerite and pore-filling dolomite

## Paragenesis

The paragenetic sequence at Polaris can be divided into early, main and late stages. The earliest stage in mineralization of the Polaris deposit is dolomitization of original limestones. The resulting crystals range from dolomicrospar to mosaic dolomite to coarse sparry dolomite.

The main stage of mineralization is recorded by sulphide ore precipitation and brecciation and dissolution of the Thumb Mountain Formation. Within the brecciated Thumb Mountain Formation, replacement dolomites are commonly replaced by sphalerite and galena. Less commonly, dolomite replaces sphalerite and galena, indicating that replacement dolomite continued to form during main stage sulphide ore precipitation. Some void-filling dolomite was deposited during the main stage of mineralization. Brecciation and dissolution of carbonate host-rock and sulphides continued during the main stage of the paragenetic sequence. Multiple phases of sphalerite are visible where sphalerite has been fragmented and overgrown with additional sphalerite.

Towards the end of the main stage of mineralization, marcasite became the dominant sulphide mineral. Marcasite replace sparry dolomite (preferentially) and earlier sphalerite. In addition, euhedral marcasite crystals ranging from fine (size) needles to small (0.3 to 2.0 mm) cubes precipitated in vugs and veins on the surface of void-filling saddle dolomites. Euhedral cubo-octahedral crystals of galena also precipitated in veins and vugs during the late stages, in close association with late stage sparry dolomite.

The last stage in the paragenesis was dominated by the precipitation of calcite, post-dating sulphides and void-filling dolomite. Calcite occurs as both a primary precipitate (calcite crust, coarse calcite and very coarse calcite) and as an alteration product (dedolomite). The low-salinity fluid which formed calcite was geochemically distinct from the earlier dolomitizing and mineralizing fluids. Minor barite and marcasite occurs with the calcite.

## Conclusions

Three diagenetic facies are recognized at the Polaris deposit:

The upper part of the deposit is an elongate, tabular Zn>Fe>Pb body in which carbonate is almost completely replaced by botryoidal sulphide. Marcasite is common, especially on the fringes of the high-grade sphalerite zones. This zone is roughly concordant with the upper Thumb Mountain Formation.

The lower and eastern part of the ore body cuts the lower Thumb Mountain Formation and is comprised of a Zn>Pb>Fe stockwork of sphalerite veins and disseminated sphalerite. Collapse features are narrower and focused on the main fluid conduit

Dolomite and disseminated sphalerite forms a halo around the main deposit for several hundred metres.

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