# Sedimentary hosted lead-zinc deposits in British Columbia

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BRITISH COLUMBIA
Ministry of Mining and Critical Minerals

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**Mine Authorizations and Competitiveness Division**
**British Columbia Geological Survey**

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**Front cover:**
Drill rig in saddle of Road River Group rocks, Cirque SEDEX project. **Photo by Paul Jago.**

**Back cover:**
Mottled sphalerite with intergrown galena and barite near Cardiac Creek zone, Akie SEDEX project. **Photo by Paul Jago.**

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**Abstract**
Autochthonous and parautochthonous terranes in the eastern part of the Canadian Cordillera in British Columbia are among the few global settings prospective for sedimentary-hosted lead-zinc deposits. These deposits contain most of the provincial zinc inventory and have the potential to host other critical-mineral companion metals. Known sedimentary exhalative (SEDEX), Mississippi Valley (MVT), and related Irish-type deposits are grouped into nine geographical regions based on occurrence clusters and comparable geology, with a tenth category for outliers of related occurrences beyond these regions. SEDEX deposits fall into six of the nine regions and into three age categories from Mesoproterozoic to Paleozoic. Shelf MVT deposits are in an overlapping set of six of the nine regions and are typically younger than their deep-water basin SEDEX counterparts. Exploration in the identified prospective areas offers the best likelihood of success, with opportunities to expand into adjacent regions with similar geological settings.

**Keywords:** Lead-zinc deposits, sedimentary-hosted, sedimentary exhalative, SEDEX, Mississippi Valley type, MVT, Irish-type, manto, Broken Hill, siliciclastic-hosted, carbonate-hosted, zinc inventory, British Columbia

## 1. Introduction

Sedimentary hosted lead-zinc deposits include a class found in off-shelf deep-water siliciclastic rocks and a class found in shallow-water shelf carbonate successions. The deep-water deposits, collectively referred to as sedimentary exhalative (SEDEX), are generally considered to form by circulating mineralized saline brines and sea-floor precipitation, although diagenetic replacement processes operating below the sea floor are increasingly being recognized as an alternative to exhalative processes. Carbonate-hosted deposits, most commonly of the Mississippi Valley type (MVT), form on shallow-water carbonate platforms and are considered epigenetic. A sub-type of carbonate-hosted deposits (Irish) shares some characteristics with SEDEX and MVT and is considered to form during shallow sea floor diagenesis. Manto deposits, another carbonate-hosted sub-type, are carbonate replacements related to magmatism.

Sedimentary hosted lead-zinc deposits are the largest global producers of zinc and host the largest estimated zinc resources (Taylor et al., 2009; Mudd et al., 2017). Examples include Red Dog (Alaska, U.S.A.), Mount Isa (Queensland, Australia), McArthur River (Northern Territory, Australia), Rampura-Agucha (Rajasthan, India), and Navan (Ireland). The North American Cordillera is one of a limited number of areas in the world prospective for sedimentary hosted lead-zinc deposits (Fig. 1).

Most important past zinc producers in British Columbia have been in the eastern Cordillera (Fig. 2). SEDEX deposits at the historic Sullivan mine, which operated from 1901 until its closure in 2001, yielded the greatest production in the province, followed by carbonate-hosted deposits (including MVT, Irish, and manto) at HB, Jersey, Bluebell, and Reeves MacDonald in the Kootenay arc). SEDEX deposits at Cirque, Akie, and Ruddock Creek are yet unexploited but have reported resources.

Sedimentary-hosted deposits also have the potential to produce several elements on the most recent version of the Canadian critical minerals list (NRCan, 2024). For example, Red Dog is known to have a germanium as a companion metal, although recovered quantities are difficult to track (USGS, 2024), and the Sullivan deposit produced bismuth, antimony, cadmium, copper, tin, gold and silver as by-products with primary commodities lead and zinc (Graham et al., 2025).

Sedimentary exhalative and related lead-zinc deposits in eastern British Columbia formed first in rocks deposited in a Mesoproterozoic intracratonic basin (Belt-Purcell) that occupied the western interior of Laurentia, and then during protracted (Neoproterozoic to Paleozoic) breakup of the supercontinent Rodinia in passive margin successions deposited on the west-facing flank of Ancestral North America and also in a distal back arc setting (Fig. 2; e.g., Nelson et al. 2013). Mississippi Valley type deposits are epigenetic, and with some exceptions, are younger than their deeper basin SEDEX counterparts. This paper first reviews current models for the generation of sedimentary hosted deposits (including tectonic setting and age), continues with the production history of these deposits in

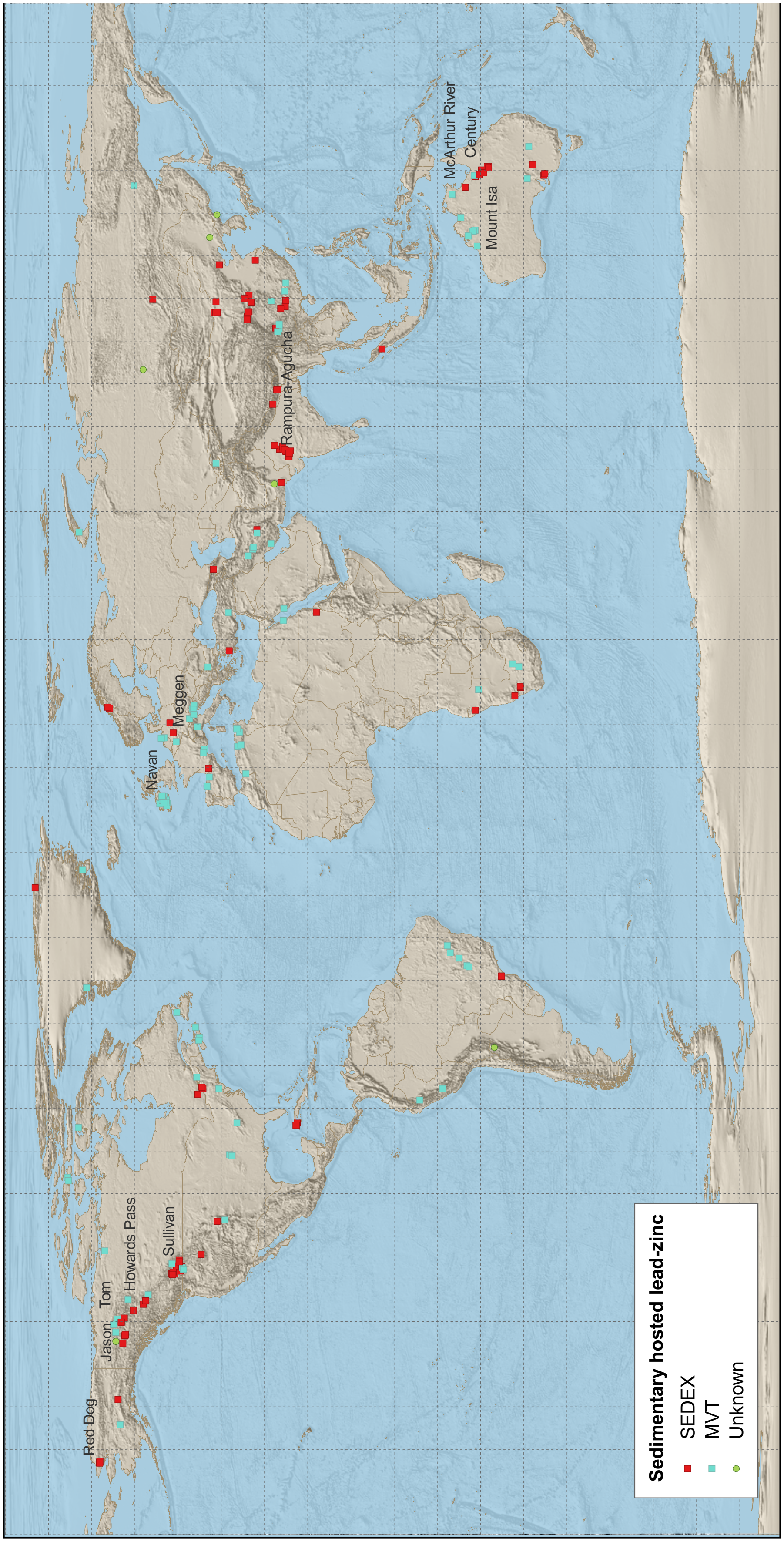


**Fig. 1.** Worldwide distribution of sedimentary hosted lead-zinc deposits. After Taylor et al. (2009).

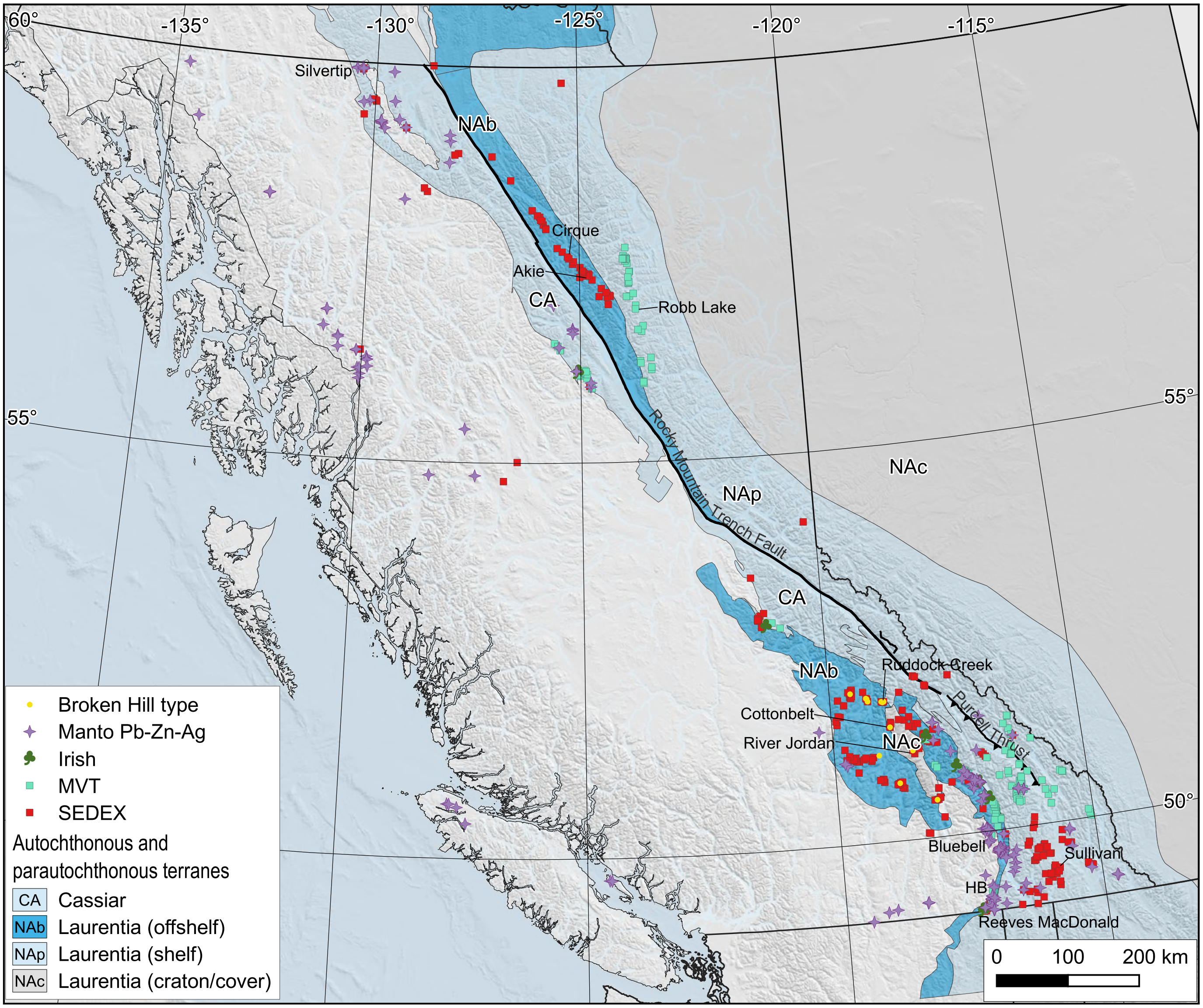


**Fig. 2.** The distribution of MINFILE occurrences assignable to SEDEX, MVT, Irish type, and manto sedimentary hosted lead zinc models. Manto type replacement lead-zinc occurrences are not limited to the Laurentian margin, but they are most abundant in the parautochthonous terranes.

British Columbia, then provides an inventory of these deposits in geographic areas (Fig. 3) based on information in MINFILE, the British Columbia Geological Survey database of mineral occurrences (British Columbia Geological Survey, 2025) and recent exploration data.

## 2. Deposit types, genetic models, tectonic settings, and age of mineralization

Recognizing natural, commonly regional, variations, different workers have classified sedimentary hosted lead-zinc deposits into a proliferation of models that are partly genetic and partly descriptive (e.g., Goodfellow and Lydon, 2007; Paradis et al., 2007; Emsbo et al., 2016; Leach et al., 2010; Wilkinson, 2014; Lefebure and Jones, 2022). In some cases, individual deposits have ambiguous characteristics and classification assignment is uncertain. Typically, sedimentary hosted lead-zinc deposits form on passive margins during continental breakup and in intracratonic basin successions (Figs. 3, 4). Basement features may influence growth faults that control paleotopography and provide fluid pathways, including linear structures transverse to regional trends (e.g., Lund, 2008; McMechan, 2012). End members are commonly grouped into two main types: sedimentary exhalative (SEDEX; in deep-water siliciclastic settings) and Mississippi Valley (MVT; in shallow-water carbonate platform settings). Carbonate-hosted deposits of the Irish type share some characteristics of both end members (Table 1; Wilkinson, 2003, 2014). Broken Hill deposits have been considered a subset of SEDEX, having characteristics atypical of the classic SEDEX model (Table 2; Höy, 2002). Manto carbonate replacement deposits are related to coeval magmatism.

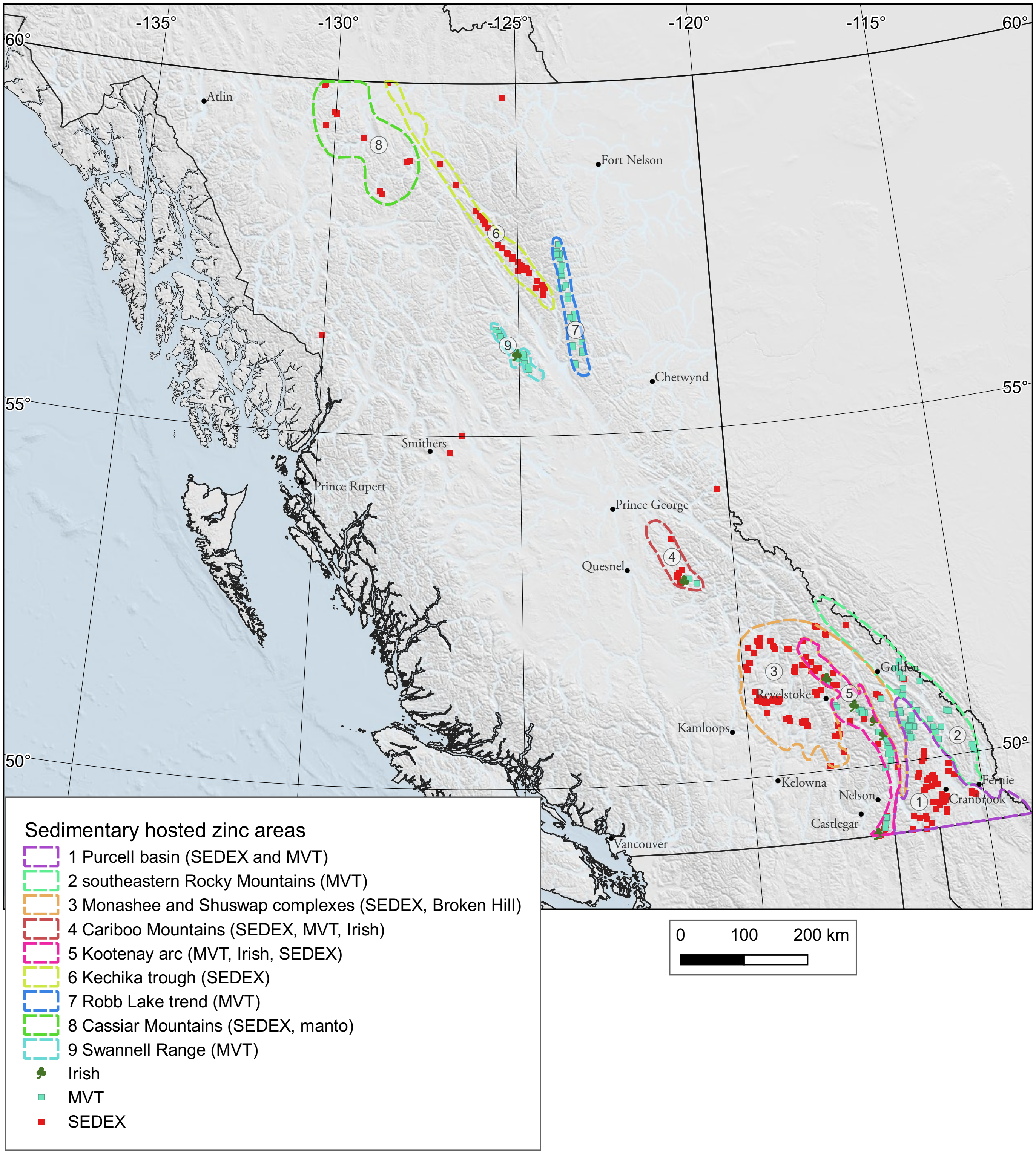


**Fig. 3.** Sedimentary hosted zinc-lead regions.

**2.1. Sedimentary exhalative (SEDEX)**

SEDEX deposits form in deep-water, off-shelf depositional systems coeval with background sedimentation of fine-grained argillaceous material in rifted margin, back-arc basin, and intracratonic basin tectonic settings (Fig. 4). The SEDEX end member may be qualified because ores may be vent proximal or distal (Fig. 5). Also, replacement models with diagenetic to epigenetic rather than exhalative processes have increasingly been recognized, such as at MacMillan Pass (Magnall et al., 2020), Red Dog (Reynolds et al., 2021), northern Alaska Range (Dusel-Bacon et. al., 2024; Figs. 6, 7). Some authors have suggested that Broken Hill type deposits are metamorphosed

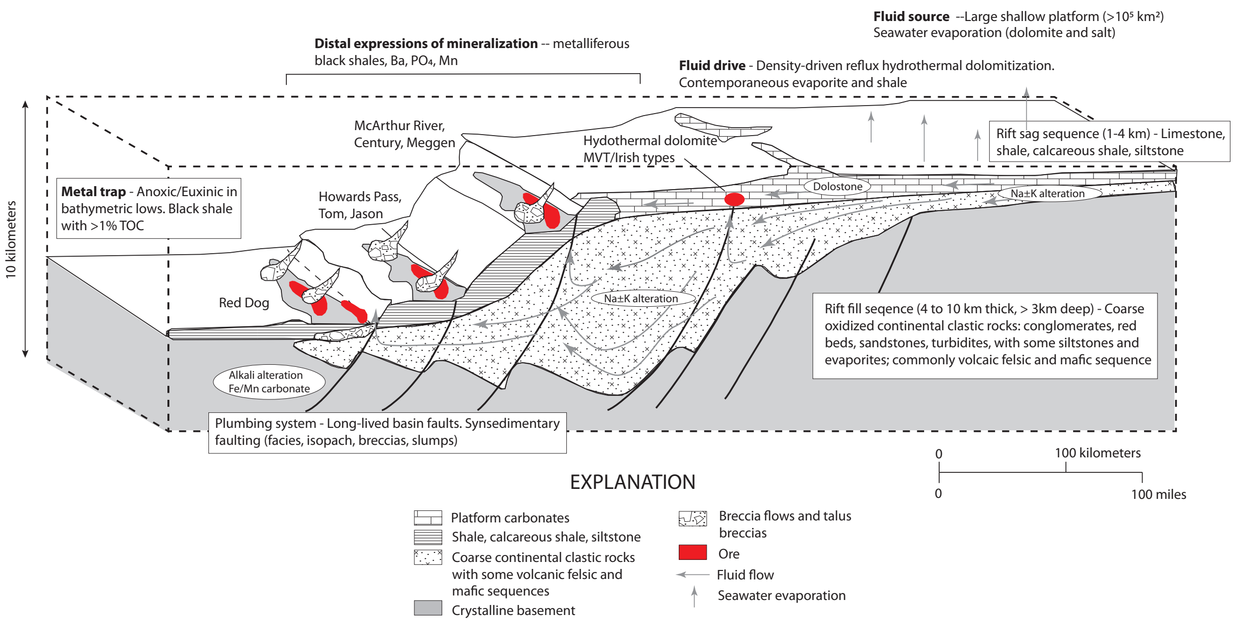


**Fig. 4.** Settings of SEDEX, MVT, and Irish type sedimentary hosted lead-zinc deposits. After Emsbo et al. (2010; cf. Magnall et al., 2020 and Reynolds, et al., 2021 with respect to Red Dog and Selwyn basin deposits).

**Table 1.** Comparison of typical SEDEX, Irish, and MVT characteristics, after Wilkinson (2014).

| Features | SEDEX (Leach et al., 2005) | Irish-Type (Wilkinson, 2003) | MVT (Leach et al., 2005) |
|---|---|---|---|
| Tectonostratigraphic setting (at the time of mineralization) | Intracratonic, rift, and off-shelf passive margin basins. | Carbonate platform on passive margin. | Carbonate platform on passive margin or foredeep. |
| Host rocks | Shales, carbonates, calcareous and organic-rich siltstones; less common sandstone and conglomerate. | Non-argillaceous carbonates in mixed carbonate–siliciclastic succession. | Mainly dolostone and limestone; rarely sandstone in predominantly carbonate sequences. |
| Structural controls | Synsedimentary faults controlling subbasins and associated fractures. | Synsedimentary faults controlling subbasins and associated fractures. | Normal, transtensional, and strike-slip faults and associated fractures. |
| Ore-body morphology and controls | Single or multiple wedge- or lens-shaped, or sheeted stratiform morphology. Hosted in, or intercalated with, preferred sedimentary horizons. May be underlain by feeder zone. | Single or multiple lenses with generally stratiform but strictly stratabound morphology in preferred sedimentary horizons, sedimentary and hydrothermal breccias. May be underlain by feeder zone. | Highly variable; commonly stratabound, pipes or tabular zones, locally stratiform. Veins, dissolution breccias. |
| Principal ore and gangue minerals | Sphalerite, galena, pyrite, pyrrhotite, marcasite, minor sulfosalts, chalcopyrite±calcite, siderite, dolomite, ankerite, and quartz. Barite is common to absent; local apatite is common; rare fluorite. | Sphalerite (low Fe), galena, pyrite, marcasite, minor sulfosalts, chalcopyrite±dolomite, calcite, quartz. Barite is common, locally economic; extremely rare fluorite. | Sphalerite, galena, pyrite, marcasite, minor sulfosalts±dolomite, calcite. Barite is minor to absent and fluorite is rare. |
| Texture | Bedding-parallel, fine-grained, layered, and banded textures with or without coarser-grained brecciated, veined, fragmental, or chaotic textures. | Predominantly massive sulfide but highly variable and complex textures. Mostly replacement, common veins, and locally open-space filling. | Coarsely crystalline to fine-grained, massive to disseminated. Replacement and open-space filling. |
| Trace metal content | Cu, As, Cd, Sb, Tl, Hg, Se, Bi, Ge, Ni | Cu, Cd, Ag, As, Ni, Co | Cu, Co, Ni, Ag, Sb, Cd, Ge, Ga, In |
| Lead isotope signature | Within-deposit homogeneity; mostly relatively non-radiogenic crustal Pb. | Within-deposit homogeneity; regionally variable, relatively non-radiogenic crustal Pb. | Within-deposit heterogeneity; crustally derived, highly radiogenic in the United States and Canada. |
| Sulfur isotope signature | Predominantly positive; reduced seawater sulfate (BSR or TSR) in host rock or second fluid. | Predominantly negative; reduced seawater sulfate (BSR) in second fluid. | Predominantly positive; reduced seawater sulfate (TSR) in host rock or second fluid. |
| Ore fluid | Low to high temperature (70-300 °C) infiltrated or connate, variably evaporated seawater. | Low to moderate temperature (70-280 °C) infiltrated partially evaporated seawater re-circulated as hydrothermal fluids. | Mostly low temperature (90-150 °C) connate bittern brines or evaporite dissolution brines. |
| Timing of mineralization | Syngenetic and/or during early diagenesis in unlithified to lithified sediment. | Mostly during diagenesis, in partly and wholly lithified sediments. Minor syngenetic component. | Epigenetic, tens to hundreds of millions of years after host-rock deposition. |
| Associated igneous activity | No direct association with igneous activity, but tuffs related to synchronous distal volcanism may be present. | Close spatial and temporal association with volcanic activity in Limerick province of Ireland. | Not associated with igneous activity. |
| Tectonic or metamorphic overprint | Weakly to intensely deformed and Metamorphosed. | Most deposits have some evidence of post-ore thrusting and strike-slip faulting. | No examples recognized. |

BSR, bacteriogenic sulfate reduction; TSR, thermochemical sulfate reduction.

equivalents of SEDEX, but they may have other genetic differences such as a higher temperature magmatic component and an oxidized host (Table 2; Höy, 2002; Abdale et al., 2024).

Worldwide, SEDEX deposits heavily favour the Proterozoic; the youngest significant deposits are in the mid-Paleozoic (Taylor et.al. 2009; Morelli et al. 2004). In British Columbia, SEDEX mineralization appears to fall into three broad ages: Mesoproterozoic (Purcell Basin, including Sullivan), Neoproterozoic-Paleozoic (Ruddock Creek, Cottonbelt, River Jordan), and mid-Paleozoic (deposits of the Gataga region in the Kechika trough). The Neoproterozoic-Cambrian phase of mineralization in and around the Monashee complex and Shuswap assemblage includes some deposits with Broken Hill type characteristics (Höy, 2001).

### 2.2. Mississippi Valley type-(MVT)

In contrast to the typical deep-water setting of SEDEX deposits, MVT deposits are hosted by relatively shallow-water platformal carbonate successions in which both penecontemporaneous dolomitization of original calcium carbonate sediment and karst processes create voids for base-metal sulphides to precipitate from low-temperature hydrothermal fluids forming stratabound epigenetic deposits (e.g. Fig. 4; Sangster, 1990; Paradis et al., 2007). Although in the type region of MVT deposits (Ozarks, USA), where

**Table 2.** Contrasts between SEDEX and Broken Hill type deposits, after Höy (2002).

| | SEDEX | Broken Hill |
|---|---|---|
| Mineralogy | Pyrite; Py>Sph>Gal | Magnetite host; Sph+Gal>Po>Py |
| Chemistry | Mg, $CO_2$, Fe, Ba, Mn; weak Mn halo | Ca, Mn, Fe, F, P, REE, Si; Mn enrichment |
| Zoning | (Cu), Pb, Zn, Ba | (Cu), Zn, Pb, Mn |
| Host rocks | Reduced facies (sulphidic) | Qtz-feldspar sediments, oxidized facies |

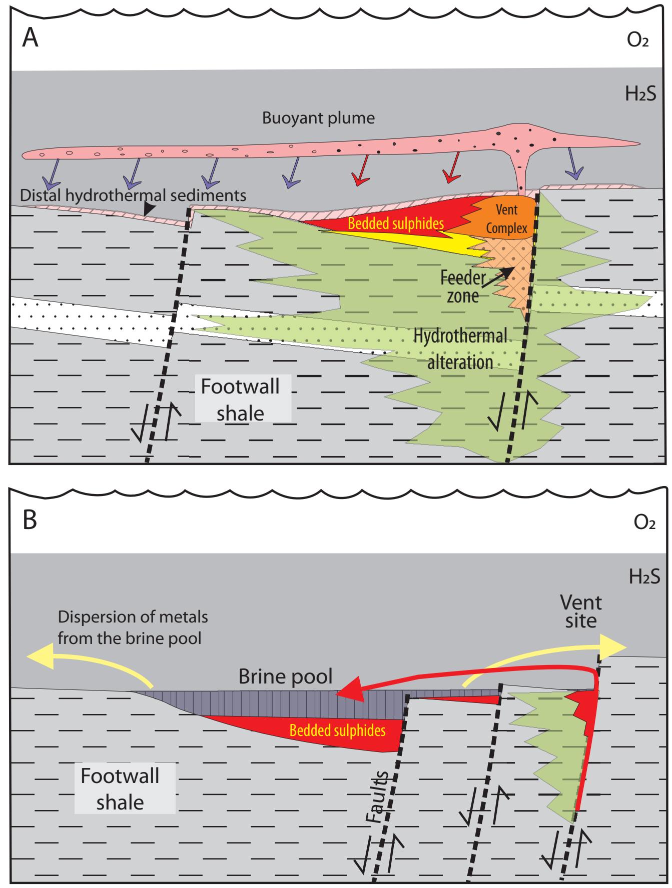


**Fig. 5**. Models of **a)** vent-proximal SEDEX and **b)** vent-distal SEDEX; from Goodfellow and Lydon (2007). Vent-proximal model would apply to Sullivan and vent-distal model to Howards Pass (Yukon) and possibly Cirque, Driftpile, and Akie (British Columbia).

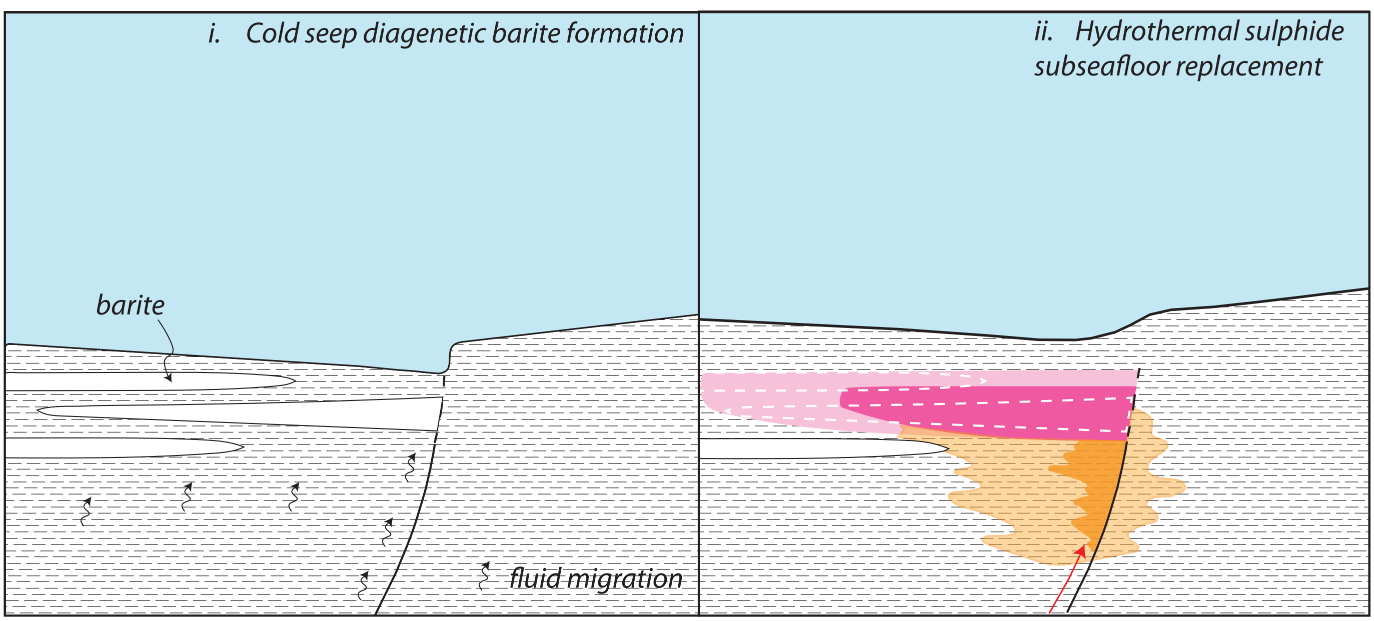


**Fig. 6.** Model for replacive SEDEX deposits after Magnall (2020). The two-stage model proposes replacement of subseafloor diagenetic barite by hot (300° C) hydrothermal fluids. This model does not rely on euxinic conditions in a stratified water column but invokes a highly reducing environment during anoxic diagenesis. This model would apply to the Tom and Jason deposits in the Selwyn basin.

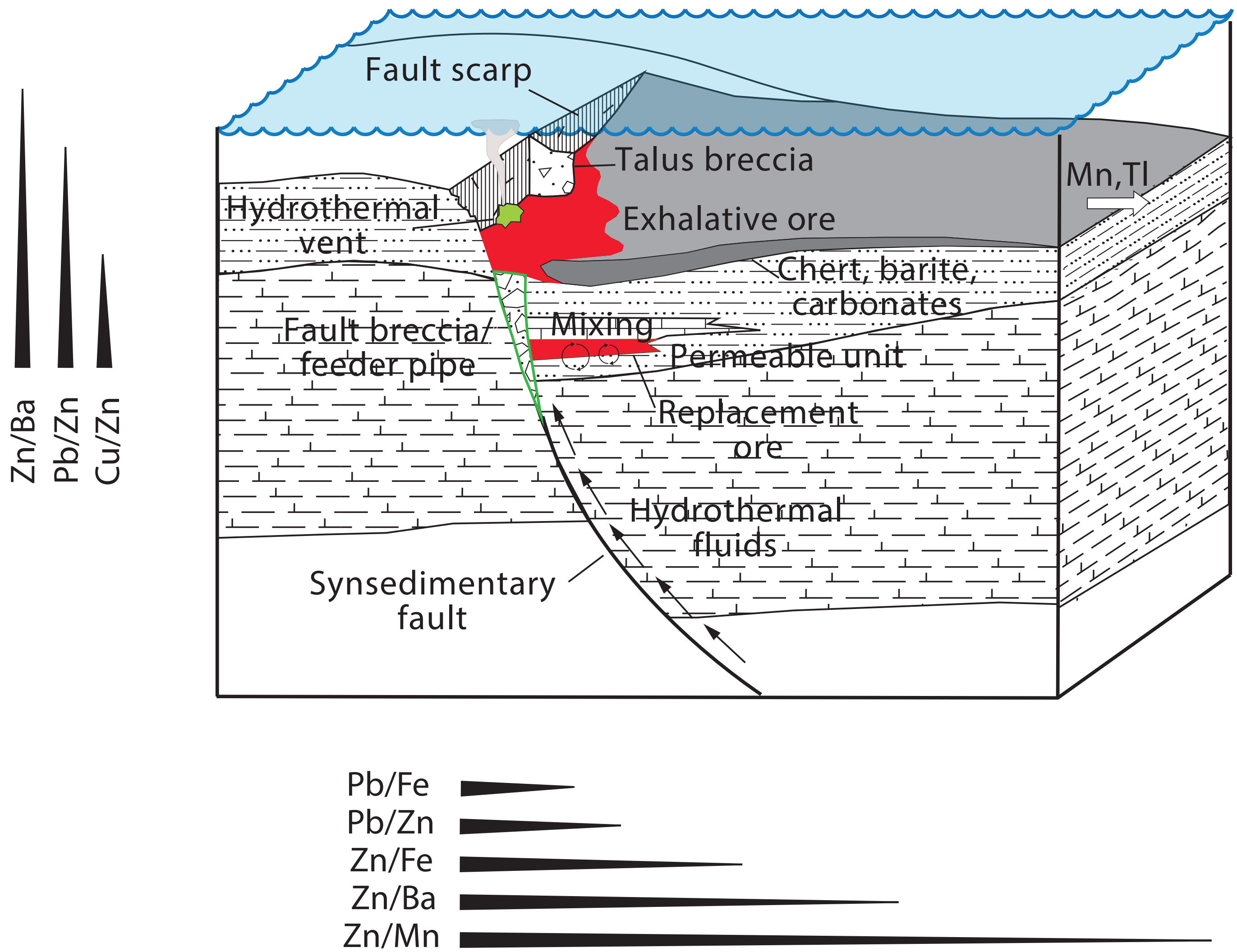


**Fig. 7.** Model of a typical SEDEX deposit including replacement ore in addition to exhalative ore. Arrows show dispersion of denominator over numerator element; after Wilkinson (2014).

carbonate platform depositional systems occupied an orogenic foreland during crustal shortening (Fig. 8), MVT deposits commonly form on continental margins in extensional settings. MVT deposits may form 100s of million years after host-rock deposition but, in some cases, they pass laterally to deep-water SEDEX deposits (Fig. 9). For example, the Kechika trough SEDEX deposit and the Robb Lake trend of Mississippi Valley type deposits in the northern Rocky Mountains appear to be contemporaneous (Nelson et al., 2002; Hnatyshin, 2018). In contrast, although carbonate-hosted deposits in northern Purcell basin and along the northeast basin margin have a spatial relationship with SEDEX mineralization to the south; the SEDEX is Mesoproterozoic and the MVT occur in hosts as young as Paleozoic (Cambrian-Ordovician).

### 2.3. Irish

Irish-type deposits form on carbonate ramps, in part at temperatures (to 280°C) higher than MVT basinal brines (Table 1, Fig. 4). The deposits invariably have a close spatial relationship to faults and are considered to form by relatively deep circulation of sea-water brines, with mineralization taking place during or after penecontemporaneous dolomitization at levels beneath the sea floor shallow enough to enable intraformational reworking (Wilkinson, 2003; 2014). Irish-type deposits of the Kootenay arc are mainly in Cambrian to Devonian hosts (Badshot, Laib, and Index formations). The ages of at least two of the deposits appear to be Late Devonian to Mississippian, based on Re-Os dating (Hnatyshin, 2018). Irish-type mineralization at Pend Oreille in Washington State portion of the Kootenay arc has a Cambrian Re-Os date (Paradis et al., 2020).

### 2.4. Manto

Manto deposits define blanket-like concordant to discordant pipe-like replacement bodies in carbonate successions. The deposits are spatially related to intermediate to felsic igneous rocks due to interactions with heated magmatic waters and near-surface waters. Manto carbonate replacement deposits may occur anywhere mineralizing magmatic rocks interact with a structurally prepared carbonate host. The relative abundance

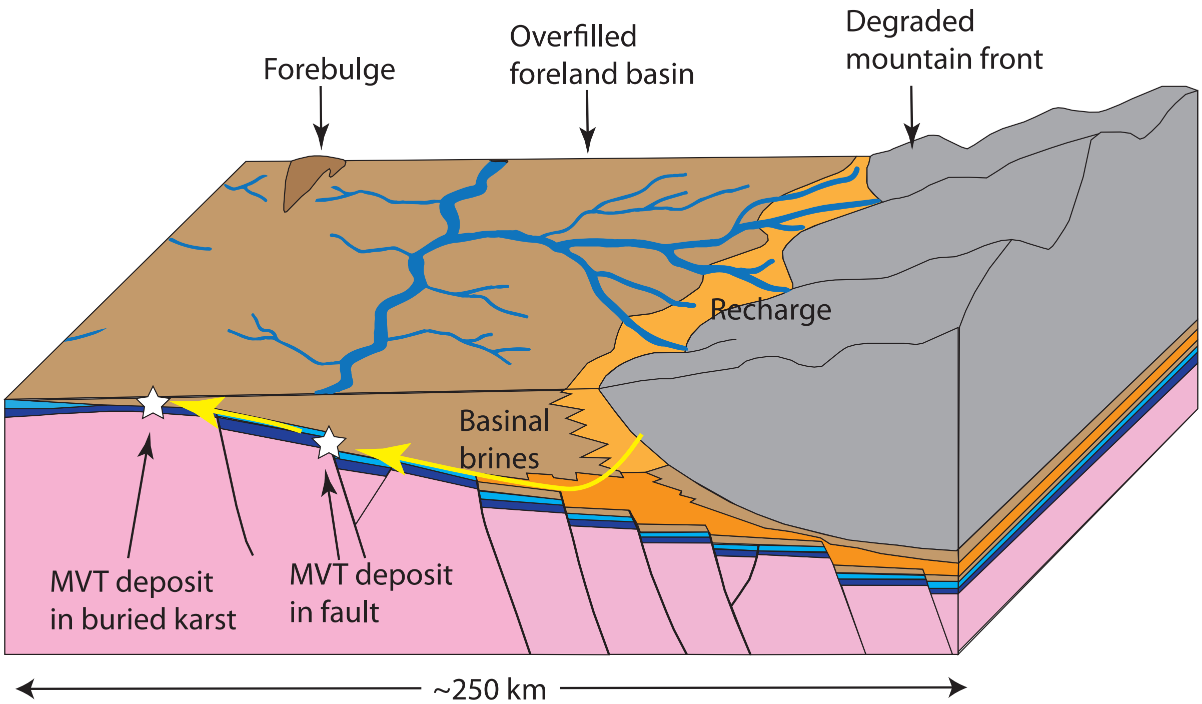


**Fig. 8.** Foreland basin model for the origin of MVT deposits from the Ozark type region; from Bradley and Leach (2003).

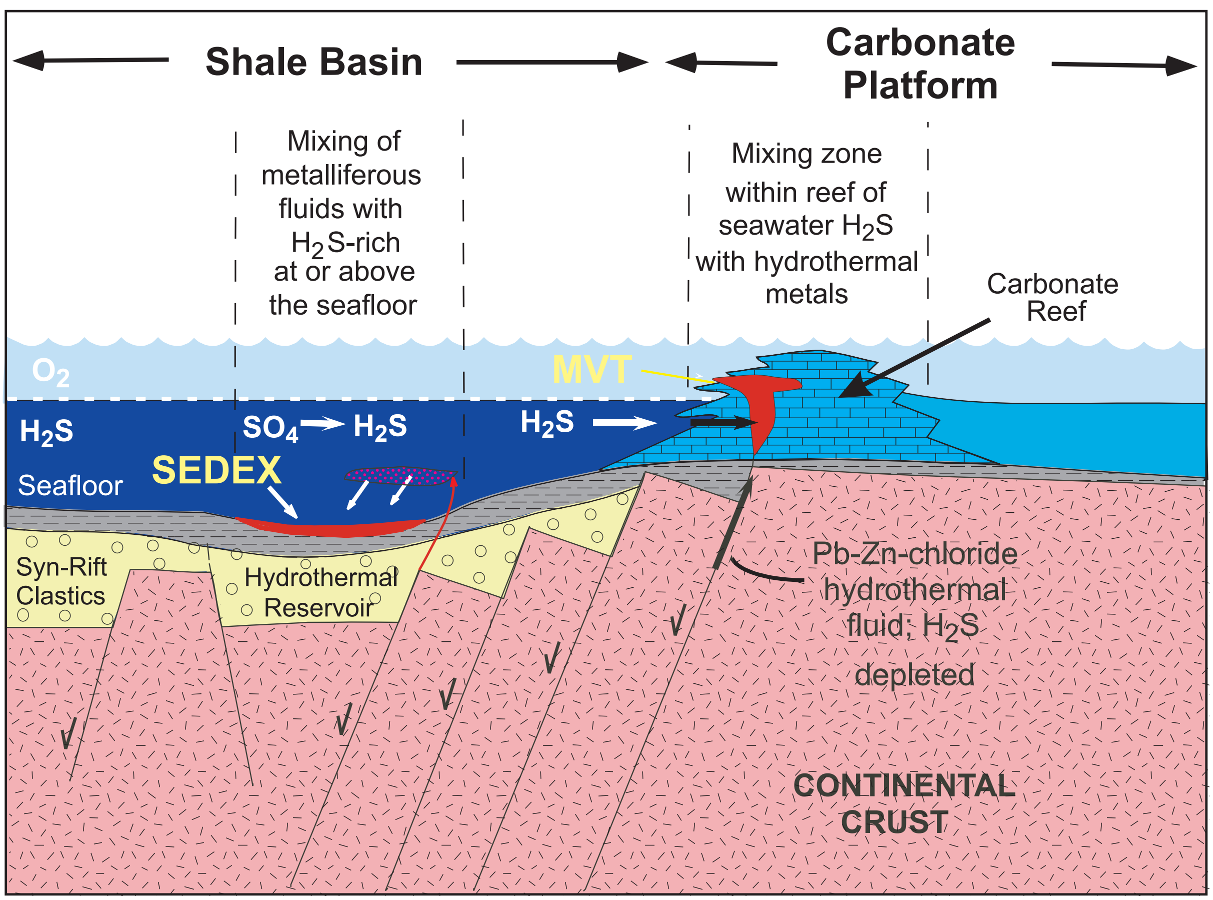


**Fig. 9.** Model for the cogenetic formation of Late Devonian SEDEX and MVT in Selwyn basin and Mackenzie platform; from Goodfellow (2007).

of platform carbonates along the ancient continental margin makes the area prospective for these deposits, although they are not exclusively restricted to these areas (Fig. 2). Significant examples of manto Pb-Zn carbonate replacement include Silvertip (Late Cretaceous; Nelson and Bradford, 1993) and Bluebell (Paleogene; Moynihan and Pattison, 2011).

## 3. Geographic distribution of British Columbia's zinc inventory

A plot of zinc resource and production data extracted from the British Columbia Geological Survey MINFILE database, supplemented with recent exploration results, shows the distribution of known zinc inventory by location and deposit type (Fig. 10a).

SEDEX deposits host the largest total zinc inventories. Carbonate-hosted deposits of the Mississippi Valley and Irish types also have recorded resources (Fig. 10b) and production (Fig. 10c), mostly historical and, except for the Robb Lake prospect, in the Kootenay arc. There was some historical production at Mineral King and other locations in northern Purcell basin and at Monarch-Kicking Horse to the east, in the southeastern Rocky Mountains. Manto replacement deposits host significant zinc at Silvertip and historically at Bluebell.

## 4. British Columbia sedimentary hosted lead-zinc regions

The following treatment considers sedimentary hosted lead-zinc deposits in 10 areas (Fig. 3) separated on the basis of geography and host units: 1) Purcell basin (SEDEX and MVT); 2) southeastern Rocky Mountains (MVT); 3) Monashee and Shuswap complexes (SEDEX, Broken Hill); 4) Cariboo Mountains (SEDEX, MVT, Irish); 5) Kootenay arc (MVT, Irish type, SEDEX); 6) Kechika trough (SEDEX); 7) Robb Lake trend (MVT); 8) Cassiar Mountains (SEDEX, manto); (MVT); 9) Swannell Range (MVT); and 10) outliers.

### 4.1. Purcell basin (SEDEX and MVT)

Mesoproterozoic rocks of the Purcell Supergroup in Canada and equivalent rocks in the USA (Belt Supergroup) were deposited in an intracratonic basin near the western margin of Laurentia (Winston, 1990; Lydon 2007) that developed at ca. 1.47 Ga (e.g., Anderson and Davis, 1995; Evans et al., 2000) well-before the protracted breakup of the supercontinent Rodinia in the Neoproterozoic to Cambrian (e.g., Bond and Kominz, 1984; Colpron et al., 2002). During the Mesozoic and Cenozoic, these rocks were deformed, creating the southern part of the Rocky Mountain fold and thrust belt, including the Purcell anticlinorium (Fig. 11; e.g., Price, 1981; Price and Sears, 2000).

The Purcell basin and its deposits have been intensively studied (e.g., Höy, 1983;1993; Lydon, 2000; Höy and Jackaman, 2004; Lydon, 2007; MacLean and Sears, 2014, and references therein). About 50 SEDEX occurrences are reported in the MINFILE database, but fewer than 10 have historical resources or past production. Although exploration continues (Hancock, 2025), the historical Sullivan mine is the only large SEDEX zinc producer with 7,944,446 t of zinc, 8,412,077 t of lead, and 297,850,977 ounces of silver; also recovered were cadmium, gold, bismuth, indium, iron, sulphur and antimonial lead and tin concentrate. The deposit is hosted at the top of the Lower Aldridge Formation, which has been a primary exploration target. Nearly all SEDEX-assigned MINFILE occurrences in the basin are in rocks mapped as Aldridge Formation (Fig. 11). A major transverse basement structure in subsurface of southern Alberta (Vulcan low; Villeneuve et al., 1993) projects to intersect Purcell basin and the Sullivan area (Fig. 11) and is considered to have influenced paleogeography and mineralization (e.g., McMechan 2012).

At the northern end of the Purcell basin, southwest of the Purcell thrust fault, is a cluster of carbonate-hosted Pb-Zn (-Ba) occurrences (Fig. 11), some of which are hosted by dolomitic carbonate rocks of the Mount Nelson Formation (Mesoproterozoic), Beaverfoot Formation (Ordovician to Middle Silurian) and Horsethief Creek Group (Neoproterozoic-Paleozoic). Zinc production from these deposits was modest. Paradise (082KSE029) produced 3624 t Zn from 1901 to 1953 with lead and byproduct cadmium silver and gold. Mineral King (082KSE001) produced silver, barite, zinc, lead and cadmium between 1954 and 1974, including 90,372 t of Zn. Redmac (082KSE064), Iron Cap (082KSE036), Ptarmigan (082KSE030) produced very small amounts by modern standards. Although the timing of mineralization has not been established, Lydon (2010) proposed an early Paleozoic (Ordovician) metallogenic event was responsible for MVT mineralization in northern Purcell basin and in the Rocky Mountains to the northeast (see below; Monarch-Kicking Horse).

### 4.2. Southeastern Rocky Mountains (MVT)

Cambrian to Silurian platformal carbonate rocks northeast of Purcell basin deposited on the west-facing passive margin on the flank of Ancestral North America southwest of the Alberta border host about 25 MINFILE-recorded lead-zinc occurrences with MVT characteristics (Fig. 12). The occurrences include Monarch-Kicking Horse in the north to Shag, Monroe, Alpine, and Boivin showings to the southeast (see Paradis et al., 2022); host units include the Chancellor Formation (Middle to Upper Cambrian), Cathedral (Middle to Upper Cambrian), Jubilee (Cambrian), Palliser (Upper Devonian), Beaverfoot (Upper Ordovician to Middle Silurian), and McKay Group (Cambrian to Ordovician).

The most historically significant are the Monarch-Kicking Horse deposits, hosted by the Cathedral Formation (082N 019, 082N 020) with production between 1890 and 1957 of 0.82618 Mt 5.6% Pb, 8.6% Zn, 30.4 g/t Ag. The host rock is Cathedral Formation. Various ages have been proposed for these Rocky Mountain deposits, ranging from Cambrian to Early Tertiary. The actual age is unresolved (Hnatyshin, 2018). A roughly arcuate trend in Cambrian to Silurian strata on the northeastern margin of the Purcell basin southwest of the Purcell thrust comprises 13-14 MINFILE occurrences assigned to the Mississippi Valley type (Fig. 12). These include the Lead Mountain (082KNE019), Silver Giant (082KNE018), Hidden Treasure (082KNE063), Lancaster (082KNE028), which produced barite and copper in addition to lead, zinc, silver, cadmium and antimony.

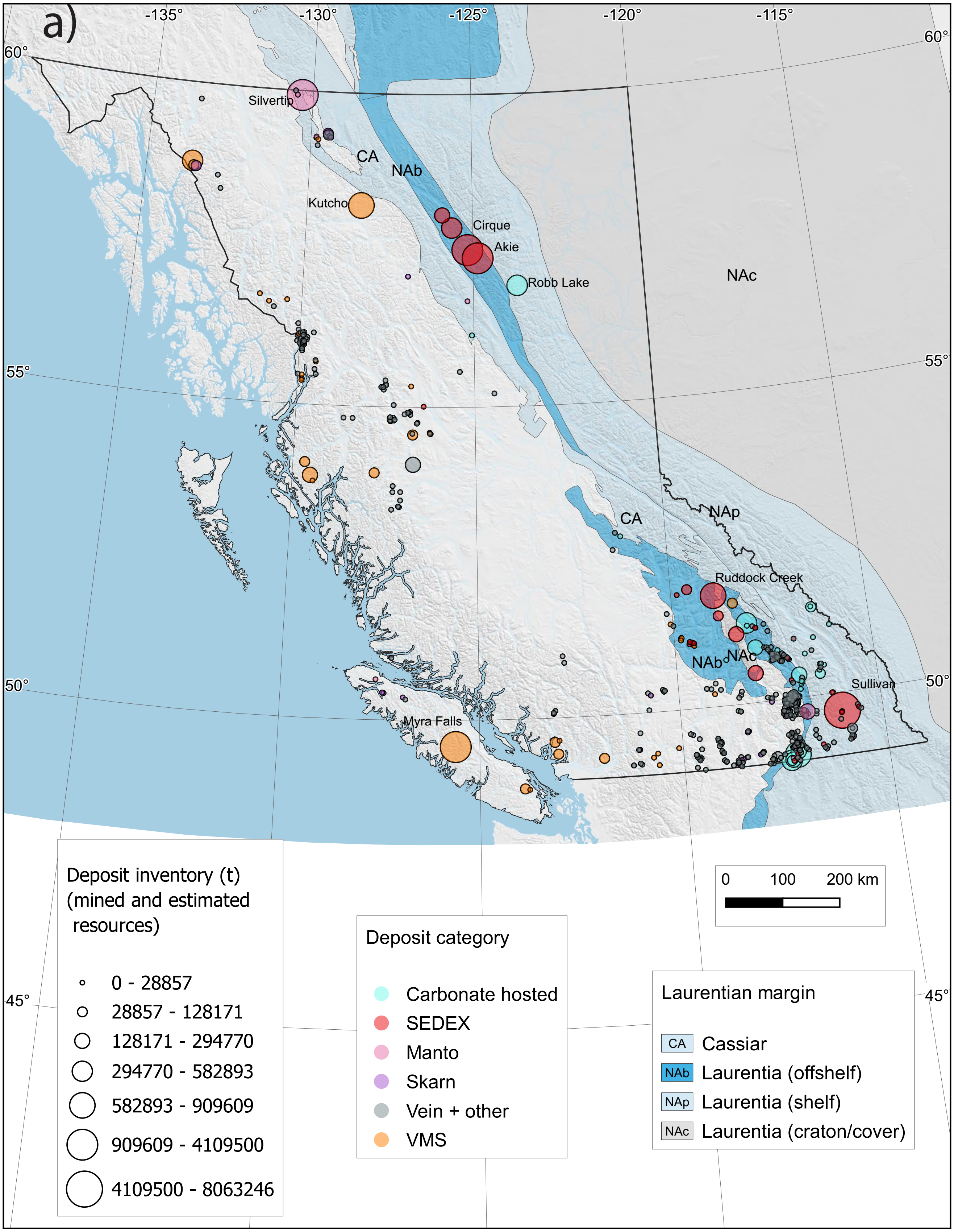


**Fig. 10.** Distribution of provincial zinc inventory. **a)** Total resources+production. **b)** Unmined resources. **c)** Historical production. For the sake of completeness, zinc in volcanogenic massive sulphide (VMS, see Northcote, 2022) and in vein and skarn deposits is also shown.

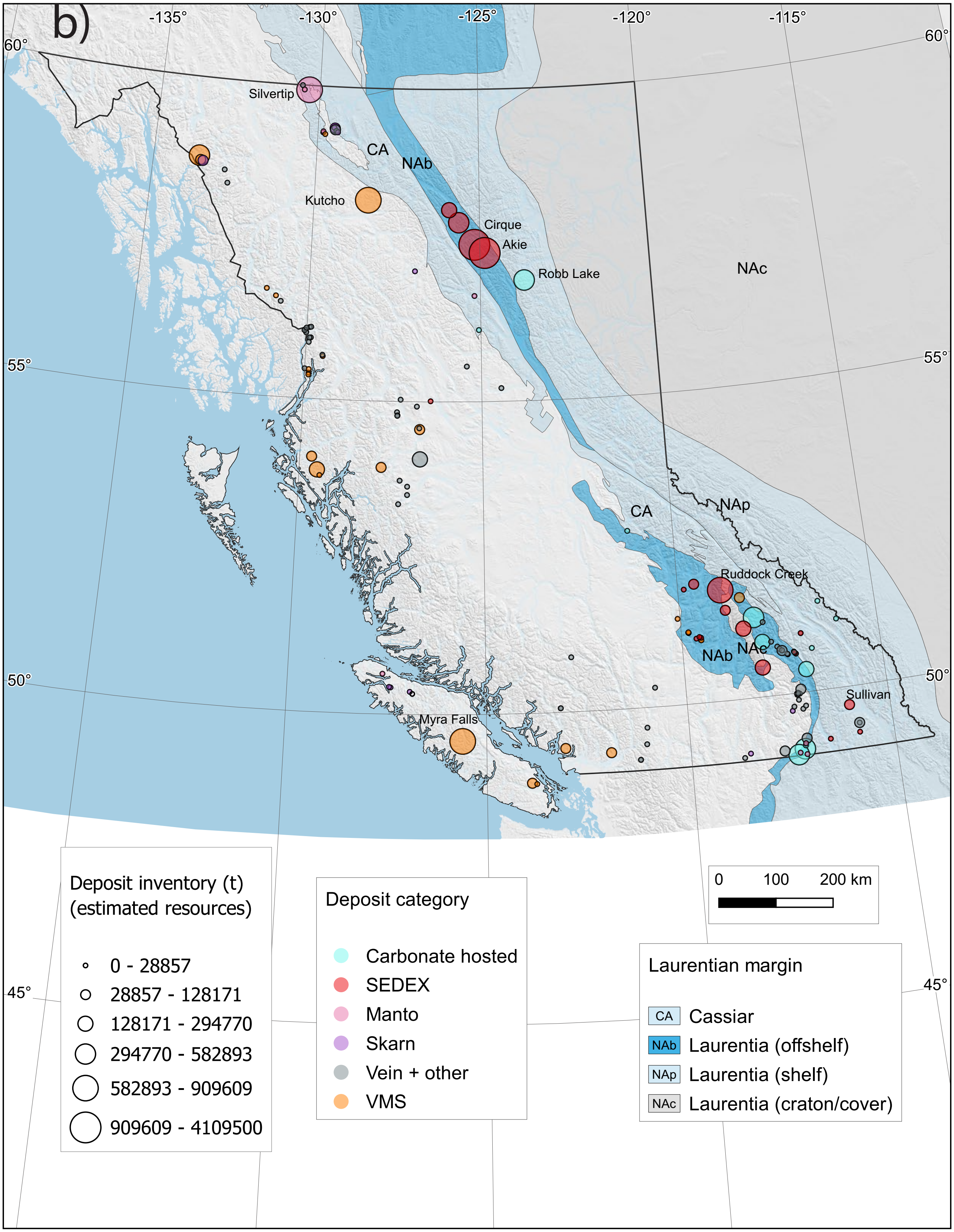


**Fig. 10.** continued.

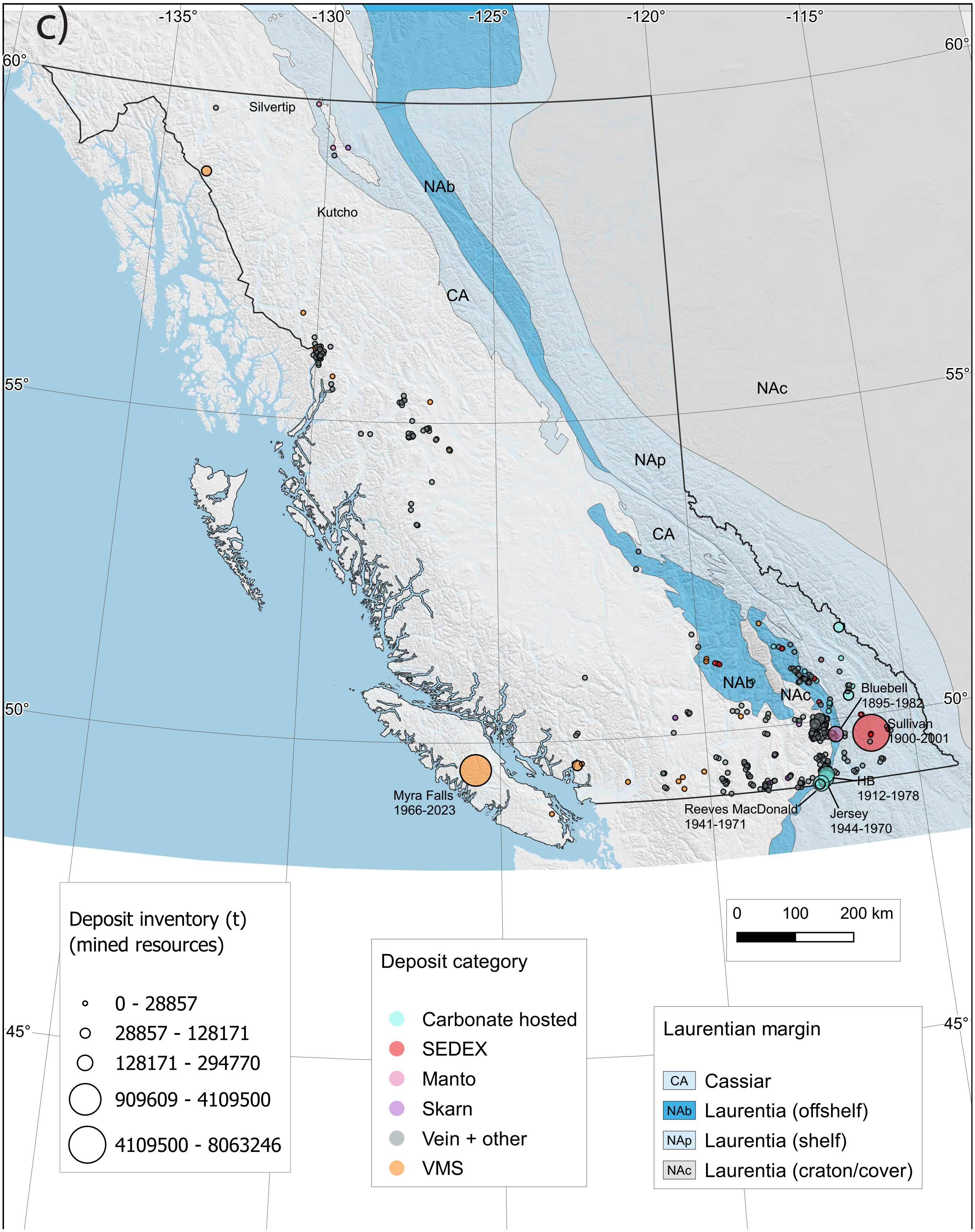


**Fig. 10.** continued.

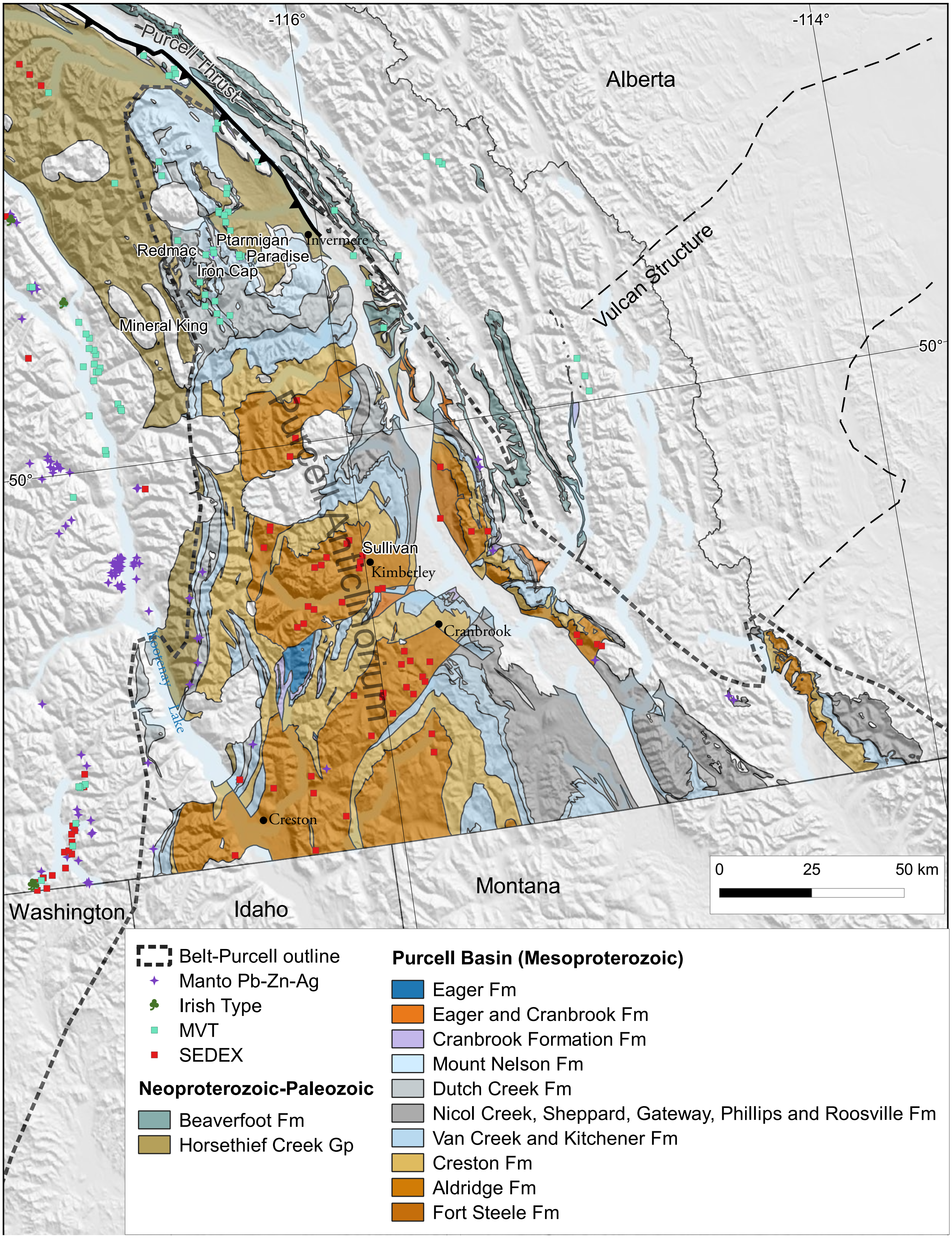


**Fig. 11.** Sedimentary hosted SEDEX and MVT lead-zinc deposits of Purcell basin.

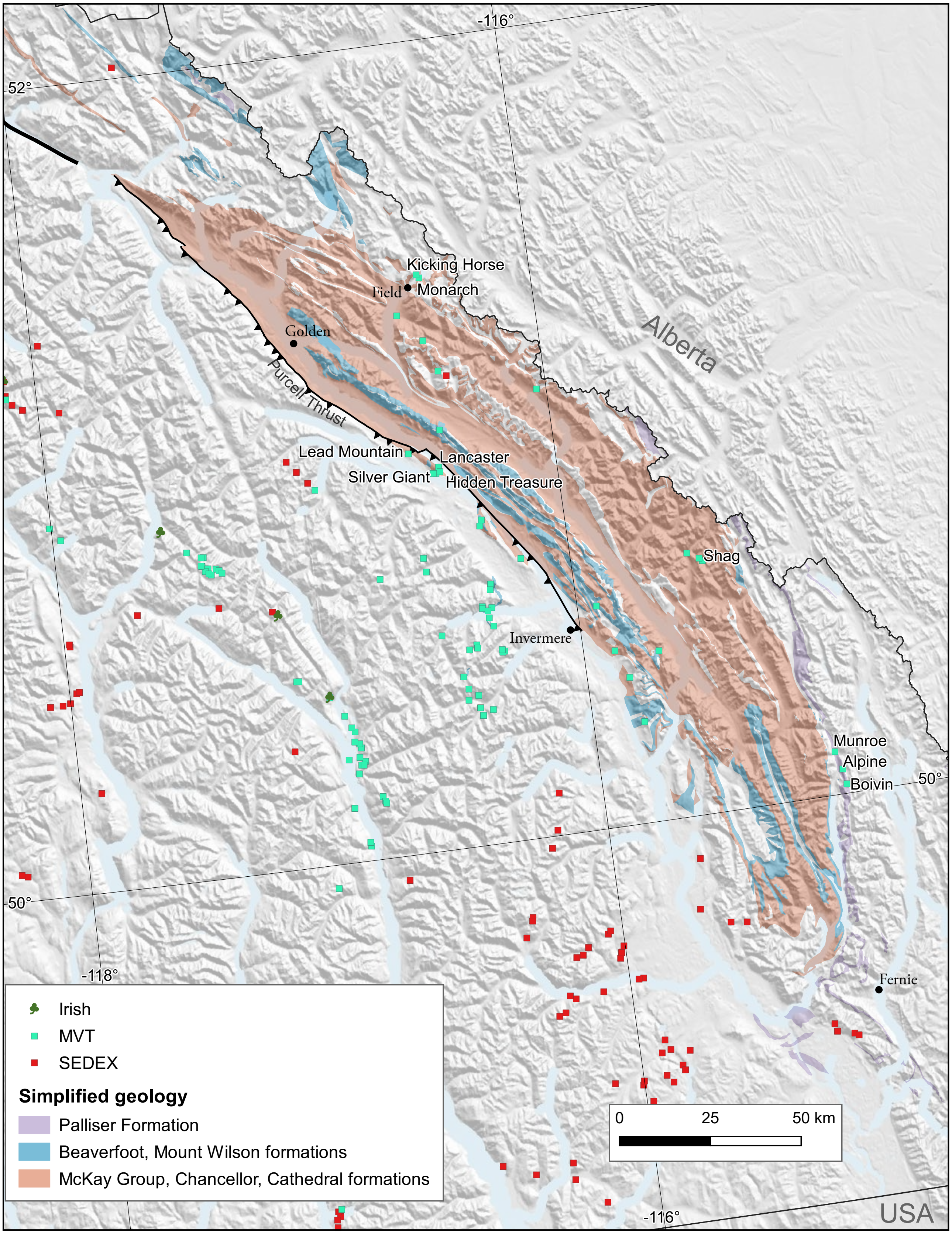


**Fig. 12.** MVT occurrences, southeastern Rocky Mountains.

### 4.3. Monashee and Shuswap complexes (SEDEX, Broken Hill)

Breakup of the Rodinian supercontinent was protracted, starting with rifting in the Neoproterozoic and culminating with opening of the Panthalassic ocean and passive margin sedimentation on the western flank of Ancestral North America in the early Cambrian (e.g., Bond and Kominz, 1984; Colpron et al., 2000). SEDEX mineralization during this protracted interval took place at different times and, as a group, the stratigraphic settings and structural and metamorphic histories vary, and ages of mineralization are not well-constrained. SEDEX-Broken Hill type occurrences in the region have a roughly arcuate, or ovoid distribution around the core of the Monashee complex and around Shuswap metamorphic complex rocks, with a centre at the northern end of Adams Lake (Fig 13). SEDEX related deposits are relatively sparse outside this approximately 100 km diameter cluster. Exceptions include the Ruth Vermont (082KNE009) which produced approximately 5900 t zinc and 3200 t lead and 555,000 ounces of silver in addition to by-product copper, gold, and cadmium between 1892 and 1981.

Deposits in and surrounding the Monashee complex and Shuswap assemblage (Fig. 13) include Cottonbelt (082M 086), River Jordan (082M 001), Big Ledge (082LSE012) and Ruddock Creek (082M 084), which Höy (2001) considered of Broken Hill affinity. Ruddock Creek has a modern, compliant resource estimate of 6.25 Mt 6.50% Zn and 1.33% Pb in the Indicated category and 6.78 Mt 6.33% Zn and 1.20% Pb in the Inferred category (Simpson and Miller-Tait, 2012). The deposit is hosted by metamorphosed and deformed Neoproterozoic rocks, considered equivalent to the Windermere Supergroup (Theny, et al., 2015; Theny, 2016). Jordan River has a 1961 resource estimate with 2.6 Mt grading 37.7 g/t Ag, 5.1% Pb and 5.6% Zn and a possible resource of 20 Mt. Cottonbelt has a 1996 estimate of 725,000 t 11% combined Pb+Zn and 58.3 g/t Ag. Big Ledge has a 1982 estimate of 6.5 Mt 3% Pb and 3% Zn. As at Ruddock Creek, host rocks are metamorphosed and highly deformed. It is unclear whether the deposits are of similar ages or related to a single protracted period of basin development (Theny et al., 2015). However, Cottonbelt has an inferred Neoproterozoic-Cambrian (ca. 580 Ma) based on lead isotope data (Höy and Godwin, 1988; Abdale et al., 2024).

The Snowshoe Group and Eagle Bay assemblage (surrounding and including Shuswap assemblage metamorphic rocks) appear to host additional sediment-hosted Pb-Zn deposits. Most suspected sediment-hosted Pb-Zn in the Eagle Bay assemblage (Cambrian) have no resource estimates, or small estimates. Some deposits with SEDEX characteristics in the Eagle Bay assemblage occur in rocks possibly as young as Devonian. The CK (082M 224), has a 1980 resource estimate of 1.49 Mt 8.6% Zn, 1.4% Pb and 8.5 g/t Ag. The Summit has a 1956 estimate of 244,000 t 4.5% Zn, 1.0 % Pb, 0.7% Cu and 27.4 g/t Ag.

There may be links between Monashee SEDEX type deposits and those of the Kootenay arc (see below). Metamorphic rocks of the Shuswap assemblage may be correlated with Neoproterozoic to Cambrian Horsethief Creek Group and Showshoe Group sedimentary rocks. The Eagle Bay assemblage may be correlated with the Badshot Formation, Lardeau Group, Hamill Group and Snowshoe Group.

### 4.4. Cariboo Mountains (SEDEX, MVT, Irish)

There is a cluster of lead-zinc and barite occurrences 75 km east of Quesnel in Neoproterozoic to Paleozoic Snowshoe Group rocks (Figs. 3, 13). Only one (Maybe, 093A 110) is developed to the stage of a small, historical resource (400,000 t 3.2% Zn, 0.8 % Pb). The northwestern cluster (e.g., Black Stuart 093A 222, Babcock Lake 093H 071, Wolf 17 093A 248) are hosted by shale or shaly limestone and classified as SEDEX. To the southeast are MVT and Irish type (Maybe 093A 110, Comin Throu Bear 093A 148, Grizzly Lake 093A 065).

The two probable MVT type occurrences are found in platform margin rocks (Comin Through Bear, 093A 148 and Grizzly Lake 093A 065, Black Stuart Group and Cariboo Group) near the western margin of the Cariboo terrane. The Indy prospect is a probable SEDEX occurrence approximately 60 km to the north, also in Black Stuart Group sedimentary rocks (Ordovician to Mississippian).

A small cluster of occurrences assigned to the SEDEX model lies to the northwest of the MVT and Irish types in rocks assigned to the Snowshoe Group around the Wolf 17 and Black Stuart occurrences (Fig. 13).

### 4.5. Kootenay arc (MVT, Irish type, SEDEX)

The Kootenay arc consists of Neoproterozoic to Paleozoic strata deposited on Ancestral North America. The rocks of the Purcell basin may have acted as a resistant backstop during deformation, resulting in the present narrow, arcuate form (Rioseco, 2020).

Pb-Zn deposits of the Kootenay arc (see Table 3 for production numbers) are commonly stratiform and occur in distinct stratigraphic units (Fig. 14): Badshot Formation (lower Cambrian); Index Formation (Devonian); Laib Formation (Cambrian). They do not always fit neatly into the main established deposit models and are variously classified as MVT, Irish, or SEDEX. Some authors distinguish local subtypes, for example: Kootenay arc (Weissenborn et al., 1970); Salmo type, Metaline type, Bluebell type (Fyles, 1970); and Remac type (Sangster, 1970).

Hnatyshyn (2018) obtained Late Devonian to Mississippian Re-Os ages for Salmo area mineralization (at HB and Reeves-MacDonald) and Paradis et al. (2020) obtained a Cambrian age for Irish mineralization at Pend Oreille. The Kootenay arc also hosts numerous occurrences classified as manto carbonate replacement deposits. Manto type replacement and polymetallic vein deposits (e.g., Bluebell mine) may be much younger than the deposits discussed above (Moynihan and Pattison, 2011).

### 4.6. Kechika trough (SEDEX)

In southern Yukon, Selwyn basin (Paleozoic) hosts the most significant unexploited stratiform lead-zinc mineralization deposits in western Canada. In northeastern British Columbia, the southern arm of Selwyn basin (referred to as the Kechika trough) also hosts stratiform lead-zinc (Fig. 15). In addition to rocks deposited during continent-scale extensional processes during the Neoproterozoic to early Paleozoic breakup of Rodinia (e.g., Campbell et al., 2019), Kechika trough contains Upper Devonian strata considered to have been deposited along the western margin of Laurentia while subduction was taking place immediately to the west. Lithospheric extension related to this Late Paleozoic subduction is considered responsible for

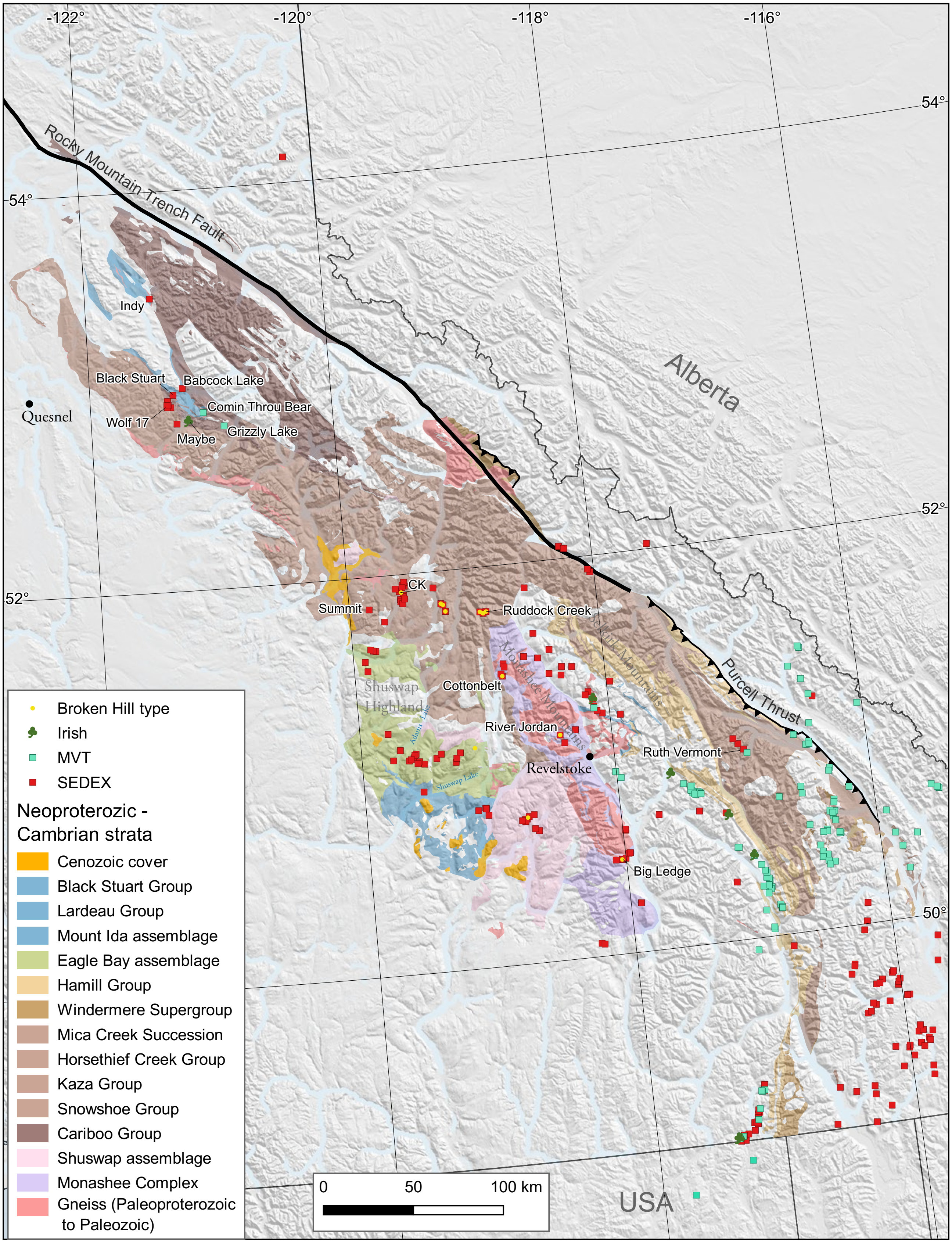


**Fig. 13.** Sedimentary hosted lead-zinc occurrences in Neoproterozoic to Paleozoic rocks of the Monashee and Shuswap complexes and the Cariboo Mountains.

**Table 3.** The largest lead-zinc deposits in the Kootenay arc.

| MINFILE # | Name | Status | Latitude | Longitude | Deposit type | Zinc inventory (t) | Zinc production (t) | Total Zn (t) |
|---|---|---|---|---|---|---|---|---|
| 082FSW009 | Jersey | Past producer | 49.099 | -117.221 | MVT Pb-Zn | 460,428 | 263,716 | 724,144 |
| 082M 003 | J & L | Developed prospect | 51.286 | -118.122 | Irish Zn-Pb | 496,934 | 0 | 496,934 |
| 082FSW024 | Red Bird | Developed prospect | 49.017 | -117.388 | Irish Zn-Pb | 402,752 | 0 | 402,752 |
| 082KNW068 | Wigwam | Developed prospect | 50.88 | -117.968 | MVT Pb-Zn | 294,770 | 0 | 294,770 |
| 082FSW004 | HB | Past producer | 49.152 | -117.2 | MVT Pb-Zn | 1,488 | 272,912 | 274,400 |
| 082KSE023 | Duncan | Developed prospect | 50.364 | -116.951 | MVT Pb-Zn | 261,000 | 0 | 261,000 |
| 082FNE043 | Bluebell | Past producer | 49.763 | -116.861 | Polymetallic manto Ag-Pb-Zn | 0 | 249,022 | 249,022 |
| 082FSW026 | Reeves Macdonald | Past producer | 49.024 | -117.352 | MVT Pb-Zn | 0 | 203,616 | 203,616 |
| 082FSW012 | Jackpot | Developed prospect | 49.264 | -117.147 | MVT Pb-Zn | 75,000 | 0 | 75,000 |
| 082M 141 | Goldstream | Past producer | 51.625 | -118.429 | Besshi VMS Cu-Zn | 52,000 | 7,988 | 59,988 |
| 082KNW030 | Thor | Past producer | 50.707 | -117.5 | Polymetallic vein Ag-Pb-Zn+/-Au | 55,066 | 130 | 55,066 |
| 082FSW219 | Annex | Past producer | 49.014 | -117.379 | MVT Pb-Zn | 0 | 42,680 | 42,680 |
| 082KNW045 | Spider | Past producer | 50.779 | -117.609 | Polymetallic vein Ag-Pb-Zn+/-Au | 1,610 | 11,519 | 13,130 |
| 082FSW003 | Libby | Past producer | 49.01 | -117.187 | Polymetallic manto Ag-Pb-Zn | 13,000 | 0 | 13,000 |
| 082N 004 | Woolsey | Past producer | 51.195 | -117.906 | Polymetallic veins Ag-Pb-Zn+/-Au | 7,443 | 26 | 7,469 |

rifting the continental margin and initiating the Slide Mountain ocean as a back-arc basin in which SEDEX mineralization took place (e.g., Nelson et al., 2002; Nelson et al., 2013). Upper Devonian Zn-Pb- Ba-Ag SEDEX occurrences with characteristics of vent-distal types (Paradis and Goodfellow, 2012) are hosted by the Gunsteel Formation (Earn Group) and lie within a northwest-trending belt about 175 km long (Fig. 15). Sedimentary hosted barite deposits overlap with the lead-zinc deposits but tend to cluster in the north.

Two lead-zinc deposits approximately in the centre of the trend have resource estimates. Akie (094F 031) is reported to have 30.2 Mt 8.0 % Zn, 1.515 % Pb, 13.595 g/t Ag (all categories) and Cirque (094F 008) has historical resources at North Cirque estimated over 38.5 Mt 8% Zn, 2.2% Pb, and 47.2 g/t Ag. The South Cirque orebody has an estimate of 15.5 Mt 6.9% Zn, 1.4% Pb, and 32 g/t Ag (all categories). Companion metals have been reported from Akie and Cirque (Graham et al., 2025). In addition, Driftpile Creek (094K 066) has a 1994 estimate of 2.44 Mt 11.9% Zn and 3.1% Pb for the main zone and a 1979 estimate of 18.145 Mt 2.38% combined Zn+Pb in eleven areas.

### 4.8. Robb Lake trend (MVT)

In Upper Devonian platformal carbonate rocks east of the Kechika trough is a 200 km long north-trending string of more than 30 Mississippi Valley type occurrences that extends from Cay (094G 017) in the north to Jet (093O 015) in the south (Fig. 15). Most of these occurrences are at early stages of exploration; Robb Lake near the midpoint of the trend is the most advanced with a historical (1984) resource of 6.5 Mt 7.11% Pb+Zn using a cutoff of 2.4 m mining width and 5% Pb+Zn. Carbonate-hosted barite deposits overlap this MVT string at its northern end (Fig. 16).

The age of mineralization is probably Late Devonian-Mississippian (Nelson et al. 2002, Hnatyshin, 2018). Of similar age but positioned inboard with respect to the western margin of Ancestral North America relative to the Kechika trough to the west, the Robb Lake MVT deposits may be lateral equivalents to SEDEX deposits in the Kechika trough and also formed during back-arc extension and opening of the Slide Mountain ocean (Goodfellow, 2007).

### 4.8. Cassiar Mountains, Cassiar terrane (SEDEX, manto)

The Cassiar terrane, a sliver of the North American passive margin displaced several 100 km northward along the Tintina-Rocky Mountain trench fault (e.g. Nelson and Bradford, 1993; Pyle and Barnes, 2001 and references therein) hosts clusters of SEDEX and carbonate lead-zinc ±barite occurrences northwest of the Kechika SEDEX trend. With the exception of Silvertip (104O 038), these occurrences are undeveloped. Silvertip is a recent manto carbonate replacement lead-zinc-silver producer and current exploration project (Clarke et al., 2025), initially discovered as a SEDEX deposit. Manto type carbonate replacement occurrences are widely scattered in the area. Most occurrences are in the Earn Group, a few in other sedimentary units mapped as Road River Group and Atan Group.

### 4.9. Swannell Range, Cassiar terrane (MVT)

In the Swannell Range of Cassiar terrane are MINFILE MVT (one possible Irish) occurrences in Ordovician to Lower Devonian dolostone and limestone, the largest cluster of which is in Echo Lake Group rocks in the Osilinka River area north of Germansen Landing (Fig. 15). This grouping includes Par (094C 024), Carie (094C 130), and Bevely (094C 023), which

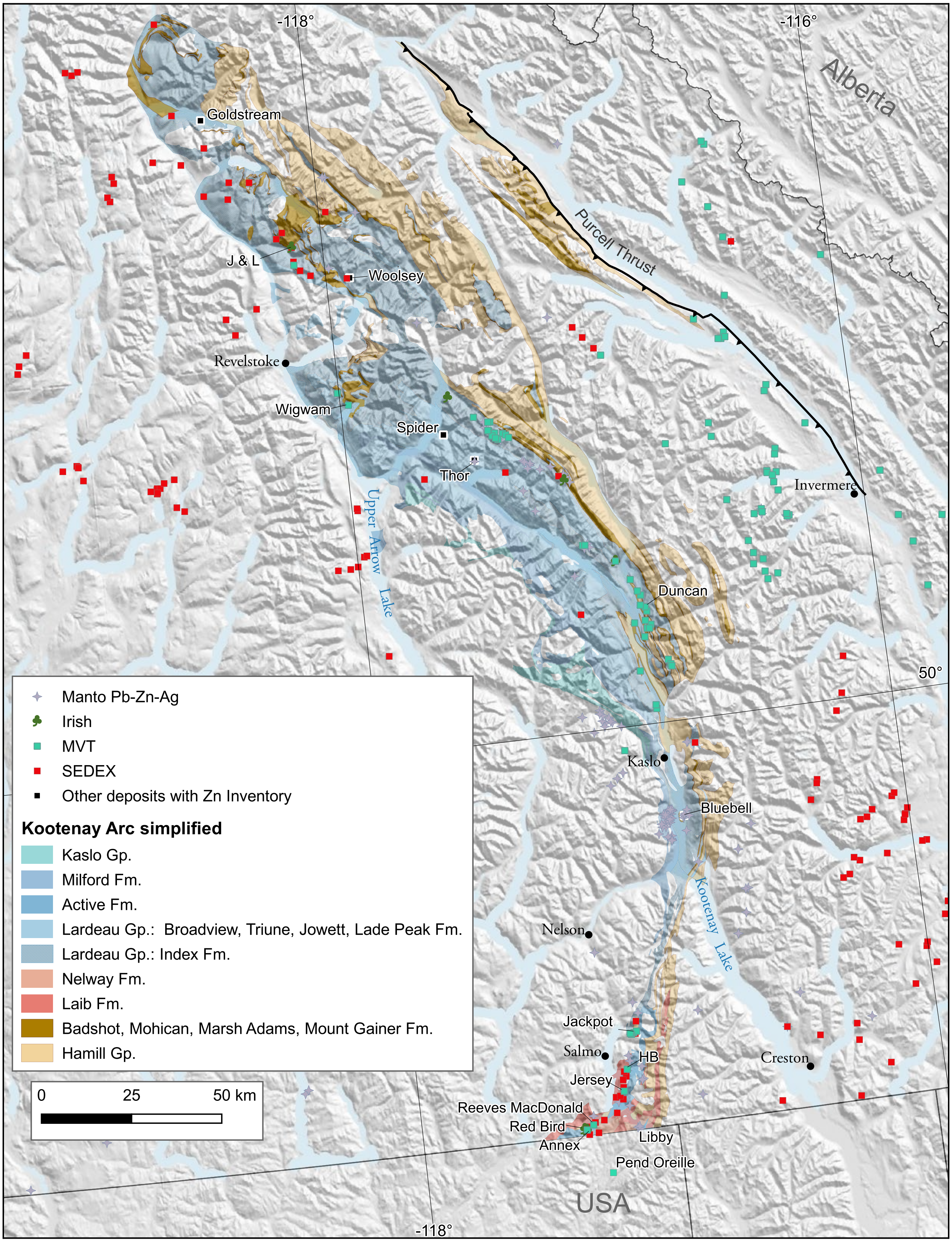


**Fig. 14.** Irish-type, MVT, SEDEX, and other occurrences with Zn inventory in the Kootenay arc.

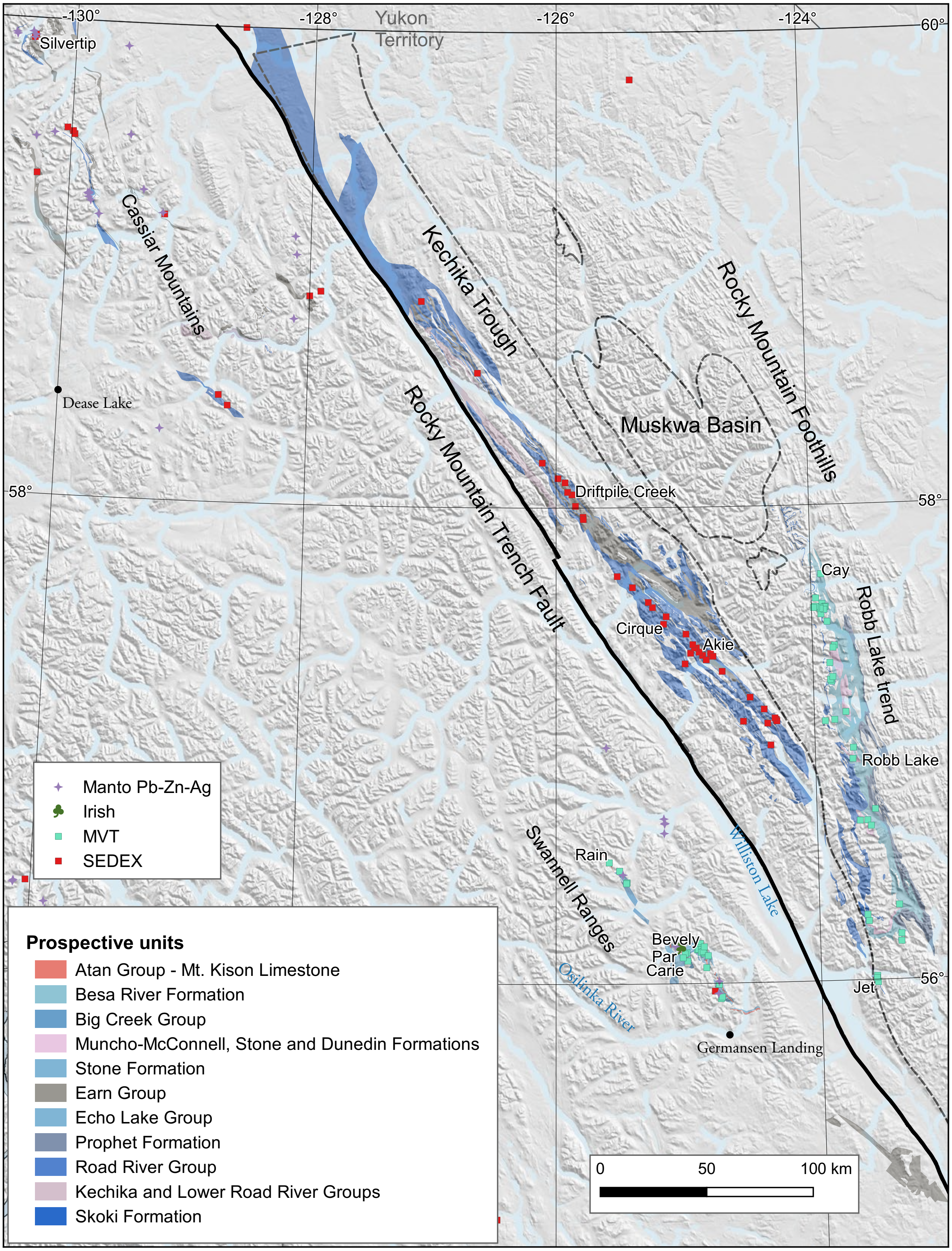


**Fig. 15.** Sedimentary hosted lead-zinc occurrences of northeastern British Columbia.

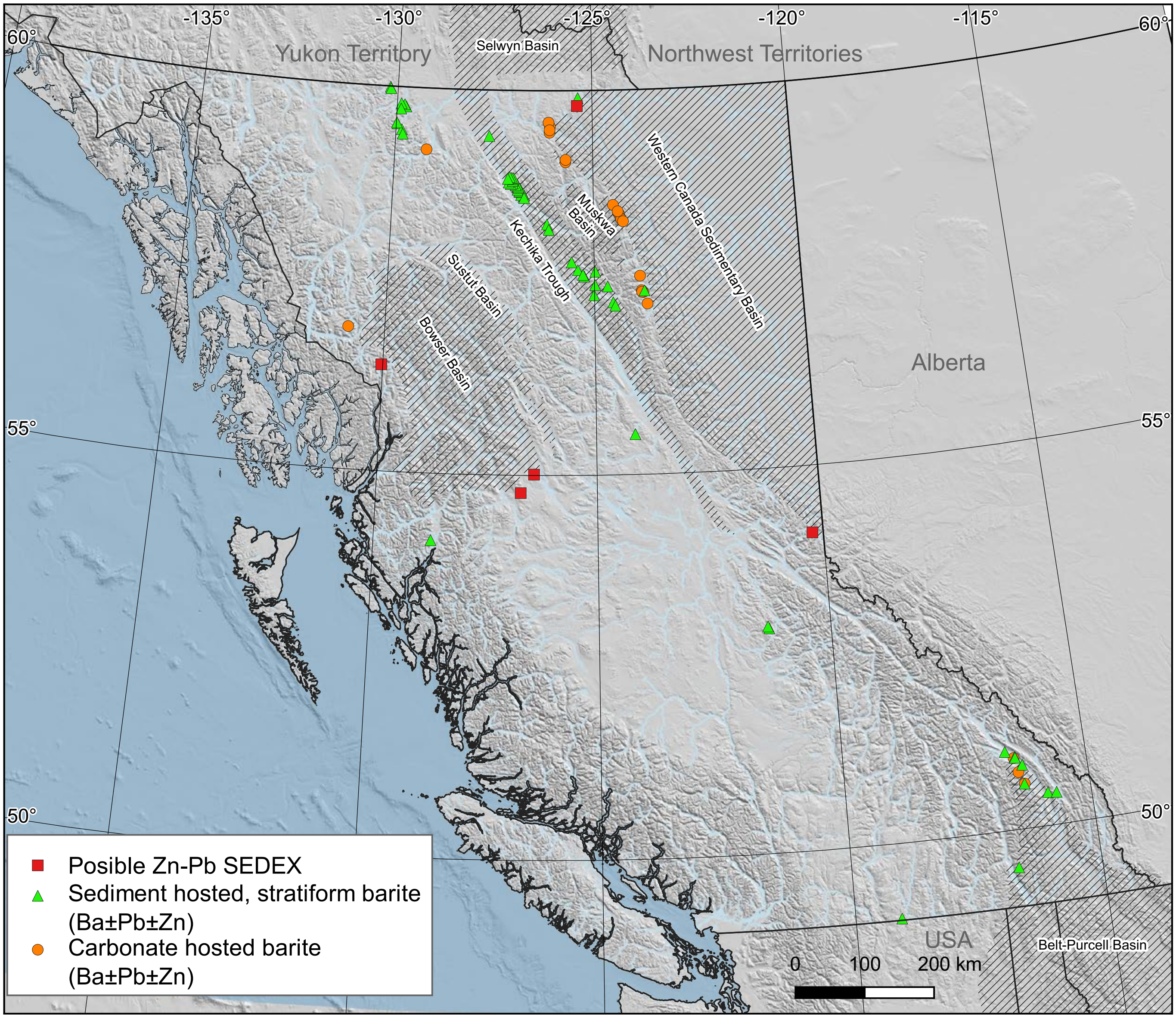


**Fig. 16.** Outlier possible SEDEX lead-zinc and barite occurrences and carbonate-hosted barite occurrences.

has indicated and inferred resources of 100,000 t and 2.7 Mt of Ag, Pb and Zn. About 40 km to the northwest, a group of four occurrences (e.g. Rain, 094C 074) appears to define a northwest trend 12 km long, also in Echo Lake Group rocks (or possibly Atan Group, lower Cambrian).

### 4.10. Outliers

Lead-zinc occurrences identified as representing SEDEX mineralization are scattered in the interior of the province well west of autochthonous and parautochthonous Ancestral North America basement such as near the margins of Bowser basin (Mesozoic; Fig. 16). These occurrences may record SEDEX processes; alternatively, some may simply be misclassified, based on sparse geological information and a superficial similarity.

Some barite occurrences are spatially (and in some cases genetically) related to lead-zinc SEDEX occurrences and contain lead and zinc, but none have lead or zinc resource estimates. The distinction between primary zinc and primary barite occurrences does not appear to be precise because some lead-zinc SEDEX occurrences contain significant barite. Stratiform, sediment-hosted barite occurrences in some cases are distal equivalents of Pb-Zn SEDEX occurrences.

Carbonate-hosted barite occurrences have been recognized along the eastern margin of Muskwa basin in the Rocky Mountains of northeastern British Columbia (Fig. 16). The age of the Muskwa assemblage is not well-defined. Although it appears to be Mesoproterozoic, broadly similar in age to Purcell basin (Ross et al., 2001), sedimentary hosted lead-zinc deposits such as those found in Purcell basin are unknown.

## 5. Ongoing mineral potential modelling studies

In the 1990s, the British Columbia Geological Survey initiated a mineral potential assessment project that ranked more than 700 geological tracts, collectively comprising the entire province (Kilby, 1995; 2004). Geologists ranked metallic and industrial mineral potential according to prospectivity for various subsets of about 120 mineral deposit profiles (see Lefebure and Jones, 2022).

In contrast to the 1990s project, ongoing mineral potential modelling work at the British Columbia Geological Survey adopts a mineral system approach, which emphasizes similarities between deposits and uses a large-scale view of all the factors that control generating deposits and can be used to consider deposit types and specific commodities (e.g., Hickin et al., 2024; Wearmouth et al., 2024a, b). Based on mineral occurrence (MINFILE), bedrock geology, geochronologic, geochemical, and geophysical data, Wearmouth et al. (2024c) have generated mineral potential maps using the weights of evidence method for SEDEX and MVT lead-zinc in the northeastern part of British Columbia (see also Lawley et al., 2022; McCafferty et al. 2023).

## 6. Conclusion

As outlined in the present inventory, the most prospective sedimentary hosted lead-zinc areas have been recognized for many years (e.g., Purcell basin, Kechika trough, Kootenay arc). Nonetheless, some areas may be worthy of further exploration, such as the cluster of occurrences in Ordovician-Silurian strata in the Swannell Ranges and the cluster in Neoproterozoic rocks of the Cariboo Mountains. The northeastern margin of the Purcell basin stands out as a geological trend with several documented MVT occurrences. The Robb Lake trend of MVT deposits has previously been documented but remains underexplored. Viewed together, the deposits of the Monashee and Shuswap complexes form an arcuate, possibly elliptical trend (e.g., CK, Ruddock Creek, Cottonbelt, River Jordan, Big Ledge) that may be worthy of further investigation as might the overlapping spatial relationship of base metal and barite SEDEX mineralization.

British Columbia is among a limited number of jurisdictions worldwide with potential to host significant sediment-hosted lead-zinc mineralization. Although zinc is not currently being produced as a primary commodity in the province, existing resources may be exploited as controlled by market conditions. Critical companion metals that accompany lead and zinc mineralization could be significant by-products.

## References cited

Abdale, L., Nelson, J. and Groat, L.A., 2024. Testing the relationship between the Cottonbelt Pb-Zn deposit and the carbonatite-syenite province of the Frenchman Cap dome area, southeastern British Columbia (NTS 082M/6, 7, 10). In: Geoscience BC Summary of Activities 2023, Geoscience BC Report 2024-01, pp. 3-10.

Anderson, H.E., and Davis, D.W., 1995. U-Pb geochronology of the Moyie sills, Purcell Supergroup, southeastern British Columbia: implications for the Mesoproterozoic geological history of the Purcell (Belt) basin. Canadian Journal of Earth Sciences, 32, 1180-1193.

Bond, G.C. and Kominz, M.A., 1984. Construction of tectonic subsidence curves for the Early Paleozoic miogeocline, southern Canadian Rocky Mountains: implications for subsidence mechanisms, age of breakup, and crustal thinning. Geological Society of America Bulletin, 95, 155-173

Bradley, D.C., and Leach, D.L., 2003. Tectonic controls of Mississippi Valley-type lead-zinc mineralization in orogenic forelands. Mineralium Deposita, 38, 652-667. https://doi.org/10.1007/s00126-003-0355-2

British Columbia Geological Survey, 2025. MINFILE database. British Columbia Ministry Mining and Critical Minerals. British Columbia Geological Survey. https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/british-columbia-geological-survey/mineralinventory

Campbell, R.W, Beranek, L.P, Piercey, S.J., and Friedman, R., 2019. Early Paleozoic post-breakup magmatism along the Cordilleran margin of western North America: New zircon U-Pb age and whole-rock Nd- and Hf-isotope and lithogeochemical results from the Kechika group, Yukon, Canada. Geosphere, 15. https://doi.org/10.1130/GES02044.1

Clarke, G., Northcote, B.K., Corcoran, N.L., Pothorin, C., Heidarian, H., and Hancock, K., 2025. Exploration and Mining in British Columbia, 2024: A summary. In: Provincial Overview of Exploration and Mining in British Columbia, 2024. British Columbia Ministry of Mining and Critical Minerals, British Columbia Geological Survey Information Circular 2025- 01, pp. 1-60.

Colpron, M., Logan, J.M., and Mortensen, J.K., 2002. U-Pb zircon age constraint for late Neoproterozoic rifting and initiation of the lower Paleozoic passive margin of western Laurentia. Canadian Journal of Earth Sciences, 39, 133-143.

Dusel-Bacon, C., Aleinikoff, J.N., Paradis, S., Slack, J.F., 2024. Sulphide petrology and ore genesis of the stratabound Sheep Creek sediment-hosted Zn–Pb–Ag–Sn prospect, and U–Pb zircon constraints on the timing of magmatism in the northern Alaska Range. Canadian Journal of Earth Sciences, 61, 471-504. https://doi.org/10.1139/cjes-2023-0089

Emsbo, Poul, Seal, R.R., Breit, G.N., Diehl, S.F., and Shah, A.K., 2016. Sedimentary exhalative (sedex) zinc-lead-silver deposit model. U.S. Geological Survey Scientific Investigations Report 2010-5070-N, 57 p. https://doi.org/10.3133/sir20105070N

Evans, K.V., Aleinkoff, J.N., Obradovich, J.D., and Fanning, C.M., 2000. SHRIMP U-Pb geochronology of volcanic rocks, Belt Supergroup, western Montana: Evidence for rapid deposition of sedimentary strata. Canadian Journal of Earth Sciences, 37, 1287-1300.

Fyles, J.T.,1970. Geological setting of Pb-Zn deposits in the Kootenay Lake and Salmo areas of British Columbia. In: Wessenborn, A.E., Armstrong, F.C., and Fyles, J.T., (Eds.), Pb-Zn deposits of the Kootenay Arc, N.E. Washington and adjacent British Columbia. Department of Natural Resources, State of Washington, Bulletin 61, pp. 41-53.

Goodfellow, W.D., 2007. Base metal metallogeny of the Selwyn Basin, Canada. In: Goodfellow, W.D., (Ed.), Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, pp. 553-579.

Goodfellow, W.D., and Lydon, J.W., 2007. Sedimentary exhalative (SEDEX) deposits. In: Goodfellow, W.D., (Ed)., Mineral Deposits of Canada: A Synthesis of Major Deposit Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, pp. 163-183.

Graham, A.C., Wearmouth, C.D., Northcote, B., and Ootes, L., 2025. A preliminary assessment of critical companion elements in SEDEX deposits of eastern British Columbia: Examples from the historic Sullivan mine and the Cirque project. In: Geological Fieldwork 2024, British Columbia Ministry of Mining and Critical Minerals, British Columbia Geological Survey Paper 2025-01, pp. 141-152.

Hancock, K., 2025. Exploration and mining in the Southeast Region, British Columbia. In: Provincial Overview of Exploration and Mining in British Columbia, 2024. British Columbia Ministry of Mining and Critical Minerals, British Columbia Geological Survey Information Circular 2025-01, pp. 145-156.

Hickin, A.S., Ootes, L., Orovan, E.A., Brzozowski, M.J., Northcote, B.K., Rukhlov, A.S., and Bain, W.M., 2024. Critical minerals and mineral systems in British Columbia. In: Geological Fieldwork 2023, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2024-01, pp. 13-51.

Hnatyshin, D., 2018. Development and application of the Re-Os isotope system to sediment-hosted Zn-Pb ores and sedimentary pore waters. Unpublished Ph.D. thesis, University of Alberta, 306 p.

Höy, T., 1983. Geology in the vicinity of the Sullivan Deposit, Kimberley, British Columbia. In: Geological Fieldwork 1982, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1983-1, pp. 9-17.

Höy, T., 1993. Geology of the Purcell Supergroup in the Fernier west-half map area, southeastern British Columbia (NTS 82G/W1/2, 82F/E1/2). British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Bulletin 84, 164 p., 1:100,000 scale.

Höy, T., 2001. Sedex and Broken Hill-type deposits, northern Monashee Mountains, Southern B.C. In: Geological Fieldwork 2000, British Columbia Ministry of Energy and Mines, Geological Survey Paper 2001-01, pp. 85-114.

Höy, T., 2002. BHT and SEDEX Deposits of the Kootenay terrane. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Geofile 2002-4 (poster).

Höy, T., and Godwin, C.I., 1988. Significance of a Cambrian date from galena lead-isotope data for the stratiform Cottonbelt deposit in the Monashee Complex, southeastern British Columbia. Canadian Journal of Earth Sciences, 25, 1534-1541.

Höy, T., and Jackaman, W., 2004. Geology of the St. Mary map sheet (NTS 82F/09). British Columbia Ministry of Energy and Mines, British Colombia Geological Survey Geoscience Map GM2004-1, 1:50,000 scale.

Kilby, W.E., 1995. Mineral Potential Project - overview. In: Geological Fieldwork 1994, Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1995-01, pp. 411-416.

Kilby, W.E., 2004. The British Columbia Mineral Potential Project 1992-1997 - methodology and results. Ministry of Energy and Mines, British Columbia Geological Survey, GeoFile 2004-02, 324 p.

Lawley, C.J.M., McCafferty, A.E., Graham, G.E., Huston, D.L., Kelley, K.D., Czarnota, K., Paradis, S., Peter, J.M., Hayward, N., Barlow, M., Emsbo, P., Coyan, J., San Juan, C.A., and Gadd, M.G., 2022. Data-driven prospectivity modelling of sediment-hosted Zn-Pb mineral systems and their critical raw materials. Ore Geology Reviews, 141, article 104635 https://doi.org/10.1016/j.oregeorev.2021.104635.

Leach D.L., Sangster D.F., Kelley K.D., and Large, R., 2005. Sediment-hosted lead-zinc deposits: A global perspective. In: Hedenquist J.W., Thompson J.F.H., Goldfarb R.J., and Richards JP (Eds.) Economic Geology 100th Anniversary Volume, pp. 561-607. https://doi.org/10.5382/AV100.18

Leach, D.L., Taylor, R.D., Fey, D.L., Diehl, S.F., and Saltus, R.W., 2010. A deposit model for Mississippi Valley-Type lead-zinc ores, Chapter A of Mineral deposit models for resource assessment: U.S. Geological Survey Scientific Investigations Report 2010–5070-A, 52 p. https://doi.org/10.3133/sir20105070A

Lefebure, D.V., and Jones, L.D., (compilers) 2022. British Columbia Geological Survey mineral deposit profiles, 1995 to 2012; updated with new profiles for VMS, porphyry, and mafic-ultramafic deposits. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile 2020-11, 652 p.

Lund, K, 2008. Geometry of the Neoproterozoic and Paleozoic rift margin of western Laurentia—Implications for mineral deposit settings. Geosphere, 4, 429-444. https://doi.org/10.1130/GES00121.1

Lydon, J.W., 2000. A synopsis of the current understanding of the geological environment of the Sullivan deposit. In: The Geological Environment of the Sullivan Deposit, British Columbia, Lydon, J.W., Höy, T., Slack, J.F., and Knapp, M., (Eds.), Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, p. 12–31.

Lydon, J.W., 2007. Geology and metallogeny of the Belt-Purcell basin. In: Goodfellow, W.D., (Ed.), Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, p. 581-607.

Lydon, J. W., 2010. Tectonic evolution of the Belt-Purcell basin: implications for the metallogeny of the Purcell anticlinorium. Geological Survey of Canada, Open File 6411, 38p. https://doi.org/10.4095/261389

MacLean, J.S., and Sears, J.W., (Editors), 2016. Belt Basin: Window to Mesoproterozoic Earth. Geological Society of America, Special Paper 522, 384 p.

Magnall, J.M, Gleeson, S.A., Creaser, R.A., Paradis, S., Glodny, J., and Kyle, J.R., 2020. The mineralogical evolution of the clastic dominant-type Zn-Pb ± Ba deposits at Macmillan Pass (Yukon, Canada)-tracing subseafloor barite replacement in the layered mineralization. Economic Geology, 115, 961-979. https://doi.org/10.5382/econgeo.4730

McCafferty, A.E., San Juan, C.A., Lawley, C.J.M., Graham, G.E., Gadd, M.G., Huston, D.L., Kelley, K.D., Paradis, S., Peter, J.M., and Czarnota, K., 2023. National-scale geophysical, geologic, and mineral resource data and grids for the United States, Canada, and Australia: Data in support of the tri-national critical minerals mapping initiative. U.S. Geological Survey data release. https://doi.org/10.5066/P970GDD5

McMechan, M.E., 2012. Deep basement structural control of mineral systems in the southeastern Canadian Cordillera. Canadian Journal of Earth Sciences, 49, 693-708. https://doi.org/10.1139/e2012-013

Morelli, R.M., Creaser, R.A., Selby, D., Kelley, K.D., and King, A.R., 2004. Re-Os sulfide geochronology of the Red Dog sediment-hosted Zn-Pb-Ag deposit, Brooks Range, Alaska. Economic Geology, 99, 1569-1576. https://doi.org/10.2113/gsecongeo.99.7.1569

Moynihan, D.P., and Pattison, D.R.M., 2011. The origin of mineralized fractures at the Bluebell mine site, Riondel, British Columbia. Economic Geology, 106, 1043-1058. https://doi.org/10.2113/econgeo.106.6.1043

Mudd, G.M., Jowitt, S.M., and Werner, T.T., 2017. The world's lead-zinc mineral resources: Scarcity, data, issues and opportunities. Ore Geology Reviews, 80, 1160–1190.

Nelson, J.L., and Bradford, J.A. 1993. Geology of the Midway–Cassiar area, northern British Columbia (104 O, 104 P). British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Bulletin 83, 94 p, 1:200,000 scale map.

Nelson, J.L., Colpron, M., Israel, S., 2013. The Cordillera of British Columbia, Yukon, and Alaska: Tectonics and metallogeny. In: Colpron, M., Bissig, T., Rusk, B., and Thompson, J.F.H., (Eds.). Tectonics, Metallogeny, and Discovery: The North American Cordillera and Similar Accretionary Settings. Society of Economic Geologists Special Publication 17. 53-109. https://doi.org/10.5382/SP.17.03

Nelson, J., Paradis, S., Christensen, J., and Gabites, J., 2002. Canadian Cordilleran Mississippi Valley-Type deposits: A case for Devonian-Mississippian back-arc hydrothermal origin. Economic Geology, 97. 1013-1036. https://doi.org/10.2113/gsecongeo.97.5.1013

NRCan, 2024. Critical Minerals in Canada. https://www.canada.ca/en/campaign/critical-minerals-in-canada/critical-minerals-an-opportunity-for-canada.html [accessed May 06, 2025]

Paradis, S. and Goodfellow, W., 2012. SEDEX Deposits in the Cordillera: Current concepts on their geology, genesis, and exploration; Geological Survey of Canada, Open File 7144.

Paradis, S., Hannigan, P., and Dewing, K., 2007. Mississippi Valley-type lead-zinc deposits. In: Goodfellow, W.D., (Ed.), Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, pp. 185-203.

Paradis, S., Hnatyshin, D., Simandl, G.J., Creaser, R.A., 2020. Re-Os pyrite geochronology of the Yellowhead-type mineralization, Pend Oreille mine, Kootenay Arc, Metaline District, Washington. Economic Geology, 115, 1373-1384. https://doi.org/10.5382/econgeo.4720

Paradis, S., Simandl, G.J, Drage, N., D'Souza, R.J., Kontak, D.J, and Waller, Z., 2022. Carbonate-hosted deposits (Mississippi Valley-type, magnesite, and REE-F-Ba) of the southeastern Canadian Cordillera: a review and isotopic data comparison. In: Peter, J.M., and Gadd, M.G., (Eds.), Targeted Geoscience Initiative 5: Volcanic- and Sediment-hosted Massive-sulfide Deposit Genesis and Exploration Methods, Geological Survey of Canada Bulletin 617, pp. 39-87. http://doi.org/10.4095/327995

Price, R.A., 1981, The Cordilleran foreland thrust and fold belt in the southern Canadian Rocky Mountains. In: McClay, K.R., and Price, N.J., (Eds). Thrusts and Nappe Tectonics. The Geological Society of London, Special Publication 9, pp. 427-448.

Price, R.A., and Sears, J.W. 2000. A preliminary palinspastic map of the Mesoproterozoic Belt–Purcell Supergroup, Canada and USA: Implications for the tectonic setting and structural evolution of the Purcell anticlinorium and the Sullivan deposit. In: Lydon, J.W., Höy, T., Slack, J.F., and M.A. Knapp, M.A. (Eds), The Geological Environment of the Sullivan Deposit, British Columbia. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 1, pp. 61-81.

Pyle, L.J., and Barnes, C.R., 2001. Conodonts from the Kechika Formation and Road River Group (Lower to Upper Ordovician) of the Cassiar terrane, northern British Columbia. Canadian Journal of Earth Sciences 38, 1387-1401. https://doi.org/10.1139/e01-033

Reynolds, M.A., Gleeson, S.A., Creaser, R.A., Frielander, B.A., Haywood, J.C., Hnatyshin, D., McCusker, J., and Waldron, J.W.F., 2021. Diagenetic controls on the formation of the Anarraaq clastic-dominated Zn-Pb-Ag deposit, Red Dog district, Alaska. Economic Geology, 116, 1803-1824. https://doi.org/10.5382/econgeo.4849

Rioseco, N.A., 2020. Structure, metamorphism, and mica thermochronology across the interface between the Purcell anticlinorium and the Kootenay arc, Omineca belt, southeastern British Columbia. Unpublished M.Sc. thesis, University of Calgary, 108 p.

Ross, G.M., Villeneuve, M.E., and Theriault, R.J., 2001. Isotopic provenance of the lower Muskwa assemblage (Mesoproterozoic, Rocky Mountains, British Columbia): new clues to correlation and source areas. Precambrian Research, 111, 57-77.

Sangster, D. F., 1970, Geological exploration guides for Canadian lead-zinc deposits in carbonate rocks. Canadian Mining Journal, 91, 49-51.

Sangster, D.F., 1990. Mississippi Valley-type and sedex lead-zinc deposits: a comparative examination. Transactions of the Institution of Mining and Metallurgy, 99, B21-B42.

Simpson, R.G., and Miller-Tait, J., 2012. Technical Report, Ruddock Creek lead-zinc deposit, Kamloops Mining Division, British Columbia, 89 p. https://www.sedarplus.ca/

Taylor, R.D., Leach, D.L., Bradley, D.C., and Pisarevsky, S.A., 2009. Compilation of mineral resource data for Mississippi Valley-type and clastic-dominated sediment-hosted lead-zinc deposits. U.S. Geological Survey Open-File Report 2009-1297, 42 p.


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