New Nouveau Brunswick

Energy and Mines
Minerals and Petroleum

Lead

Mineral Commodity Profile No. 10

Lead (Pb) is the 36th most abundant element in the Earth's crust and accounts for approximately 0.0014% of the crust by weight. Lead's symbol Pb is an abbreviation of its Latin name *plumbum* for soft metals; the English word *plumbing* is derived from this Latin root. Lead is bright and silvery with a very slight blue tint but upon contact with air it begins to tarnish. It is for this reason that lead is included with the base metals, which are those common metals that readily corrode by oxidation. It has a high relative density of 11.3 g/cm^3 and a low melting point of 328°C. Other diagnostic characteristics are its softness, ductility and malleability, poor electrical conductivity (compared to other metals), high resistance to corrosion, and ability to react with organic chemicals. The dominant mineral from which lead is produced is galena (PbS), which contains 86.6% lead by weight. Other common lead minerals are cerussite ($PbCO_3$) and anglesite ($PbSO_4$). Lead commonly occurs in ores with zinc (Zn), silver (Ag), and copper (Cu).

Galena (PbS) is the primary ore mineral of lead

Uses

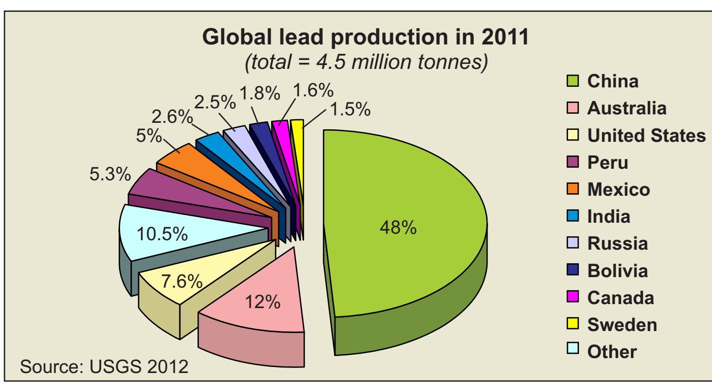
Lead has been used for at least 5,000 years primarily because of its resistance to corrosion, its ductility, and malleability. The earliest uses of lead were mainly as sheeting for roofs and as pipes for transporting water. Presently, lead is used mainly in the production of lead-acid storage batteries, which accounts for about 85% of world consumption. It is also used in ammunition (lead shot); in ball-bearing metals; as roofing shingles, flashing, cladding, and caulking material; as radiation shielding; as lead weights, and ballast on sailboats; as sheathing on high-voltage cables; as an oxide in crystal glass, and as an alloy in

Sealed lead acid battery

Lead chimney flashing

World Production and Reserves

In terms of tonnage produced, lead is 13th among all metals in world production. Canada accounted for 1.6% of global lead production in 2011, 84% of which was produced in New Brunswick.



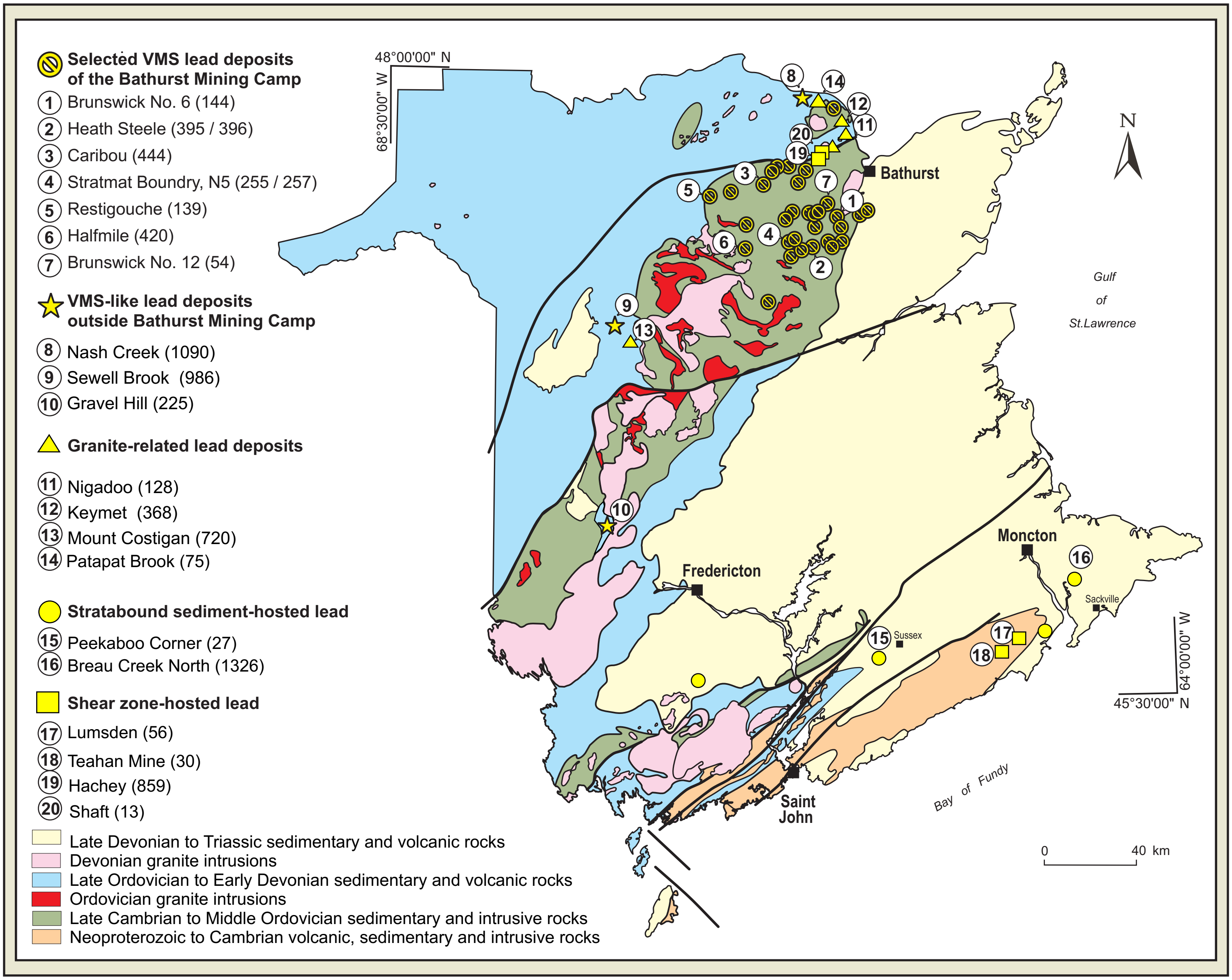


Figure 1. Significant lead deposits and occurrences in New Brunswick. Numbers in brackets correspond to unique record number in the New Brunswick mineral occurrence database.

Lead Mining in New Brunswick

Almost all of New Brunswick's present and historical lead production has come from the world famous Bathurst Mining Camp, located in the northeastern part of the Province (Figure 1). Historic production has come from open pit and underground mining operations at several volcanogenic massive sulphide (VMS) deposits (Figure 1), including: Brunswick No. 6 (1), Heath Steele (2), Caribou (3), Stratmat (4), Restigouche (5) and Halfmile (6). According to Lydon (2007) the value of total historical lead production from the Bathurst Mining Camp is approximately $4 billion (in 2005 Canadian dollars). The majority of New Brunswick's lead production has come from the giant Brunswick No. 12 underground mine (7), which to the end of 2010 had produced on the order of 2.6 million tonnes of Pb metal as well as appreciable amounts of Zn, Cu, and Ag (Xstrata, 2012). In 2011, production from the Brunswick No. 12 mine was 56,762 tonnes of Pb (Xstrata, 2012). Although this truly giant mine is expected to close in early 2013, production is ongoing at the recently opened Halfmile deposit and significant resources remain at Caribou and several other smaller deposits in the Bathurst Mining Camp.

VMS-like deposits also occur outside the Bathurst Mining Camp (Figures 1 and 2). Examples include Nash Creek (8), Sewell Brook (9), and Gravel Hill (10); however, thus far, these deposits have not been carried through to the development stages. In addition, a minor amount of lead production has come from granite-related polymetallic vein deposits such as those at Nigadoo (11) and Keymet (12) along with a small undeveloped resource at Mount Costigan (13).

New Brunswick Lead Deposits

Volcanogenic Massive Sulphide Deposits

New Brunswick lead resources come primarily from the VMS deposits associated with Ordovician felsic (silica-rich) volcanic rocks of the Bathurst Mining Camp (Franklin et al. 1981; McCutcheon et al. 2003; Goodfellow and McCutcheon 2003). VMS deposits form in marine basins that are undergoing extension, such as backarc basins where new ocean floor is being generated by spreading along oceanic ridges (Figure 2, top). In the case of the VMS-like deposits outside of the Bathurst Mining Camp, oblique collision of Laurentia (ancient North America) and Gondwana (ancient Africa and South America) in the Late Ordovician to Early Devonian led to tensional tectonic stress and resulted in basin formation, sedimentation and volcanism with associated deposit formation in northwest and west-central New Brunswick. VMS deposits, together with the closely related Sedimentary Exhalative deposits (SEDEX), have accounted for a significant percentage of the world's historical lead production with lead occurring almost exclusively in the mineral galena (PbS).

VMS deposits originate as bedded accumulations of Fe-, Pb-, Zn-, Cu- and Ag-bearing sulphides that have precipitated from hot metal-rich fluids discharged from hydrothermal vents (more commonly known as black smokers) located on the sea floor (Figure 3). These vents commonly occur in clusters, which accounts for the distribution of the 46 known deposits in the Bathurst Mining Camp that collectively contained an estimated massive sulphide resource of 500 million tonnes with historical production coming from seven of these deposits (Figure 1). These deposits range in size from small bodies of about 100,000 tonnes to the giant Brunswick No. 12 deposit with a size of 350 million tonnes. Likewise, grade can be highly varied among deposits ranging from low grades of <2% Pb + Zn to higher grade deposits containing 4% Pb, 8% Zn and 100 g/t Ag such as at Brunswick No. 12.

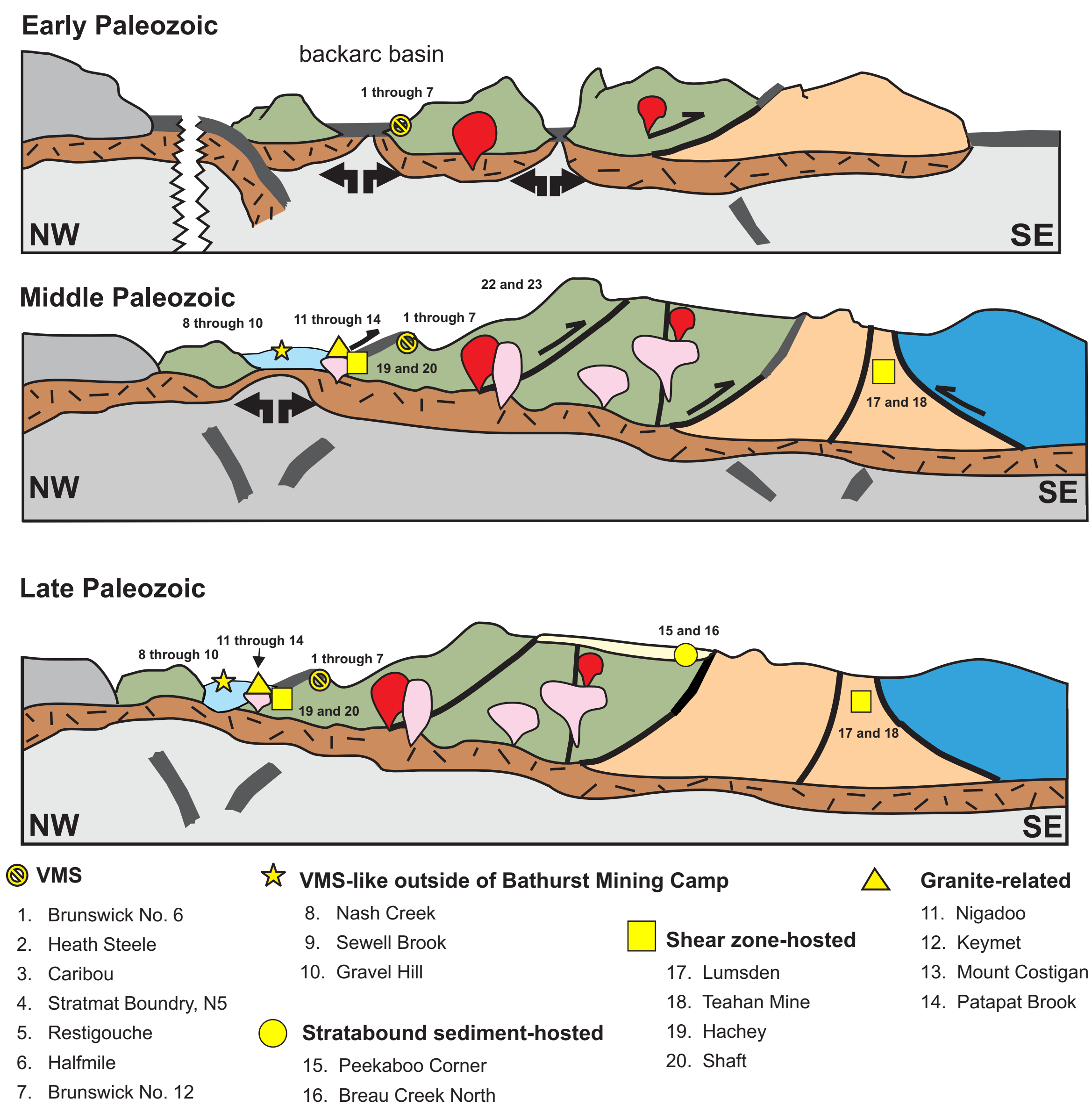


Figure 2. Schematic diagram showing tectonic setting of significant lead deposits in New Brunswick. See Figure 1 legend for ages and types of host rocks (dark blue are Cambrian to Early Ordovician sedimentary rocks found in Nova Scotia).

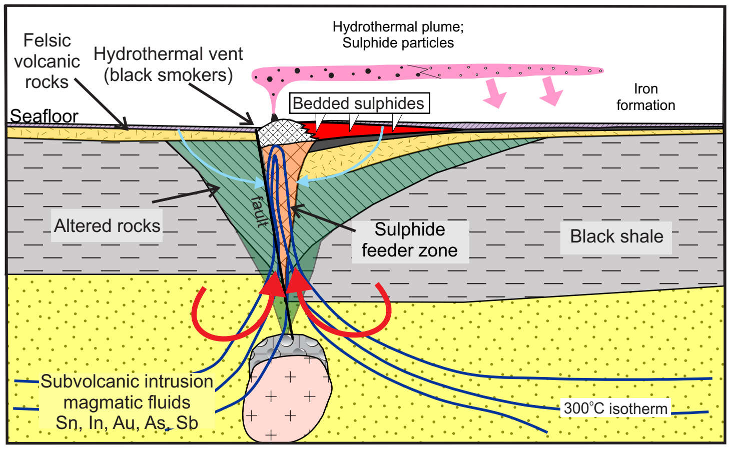


Figure 3. Model for the formation of VMS deposits. Modified from Goodfellow (2007).

Galena (bluish-grey) in high grade massive sulphide ore from Brunswick No. 12 deposit.

Granite-related Lead Deposits

Granite-related deposits in New Brunswick that contain lead include three types of mineralization – endogranitic, polymetallic veins, and skarn (Figures 1,2 and 4). These three types all formed from hot, hydrothermal fluids that were generated during the slow cooling and crystallization of granitic (silica-rich) magma as it rose high into the Earth's crust during the Devonian time period. Volatile-enriched fluids, containing CO_2, SO_2, and H_2S, and dissolved metals, including Pb, Zn, Cu, and characteristic granophile metals such as tungsten (W), molybdenum (Mo), tin (Sn), and antimony (Sb), were released from the ascending magma as the confining pressure of the overlying rocks decreased. The expanding fluid fractured the overlying rock and the subsequent sudden decrease in pressure, and the cooling that accompanied it, favoured the precipitation of complex ore-mineral assemblages.

Polymetallic vein deposits form when a single large quartz vein (or sets of quartz veins) precipitates from hydrothermal fluids injected into fractured country rocks surrounding granitic intrusions. Pb-rich veins of economic grade have been mined in New Brunswick at the Nigadoo (11) and Keymet (12) deposits in northern New Brunswick (Figures 1, 2 and 4).

Granite-related lead deposits hosted by calcareous rocks are known as skarn deposits (Dawson 1996). Mineralization and alteration in these deposits are most commonly stratabound (concordant to bedding) although discordant mineralization can occur. These deposits are formed by the interaction of hot, metalliferous hydrothermal fluids, derived from crystallization of nearby granite, with surrounding contact metamorphosed, calcareous rocks. The presence of highly reactive $CaCO_3$ (limestone) in these systems leads to a unique set of alteration minerals including wollastonite, epidote, magnetite and garnet. Although Pb can be the dominant economic metal in some skarn deposits (i.e., Patapat Brook (14); Figures 1 and 2), it can also be subordinate to other metals such as Cu and Zn. Skarn deposits may have a direct spatial relationship to felsic intrusions, whereas elsewhere, the spatial relationship to felsic intrusions is less obvious (Patapat Brook).

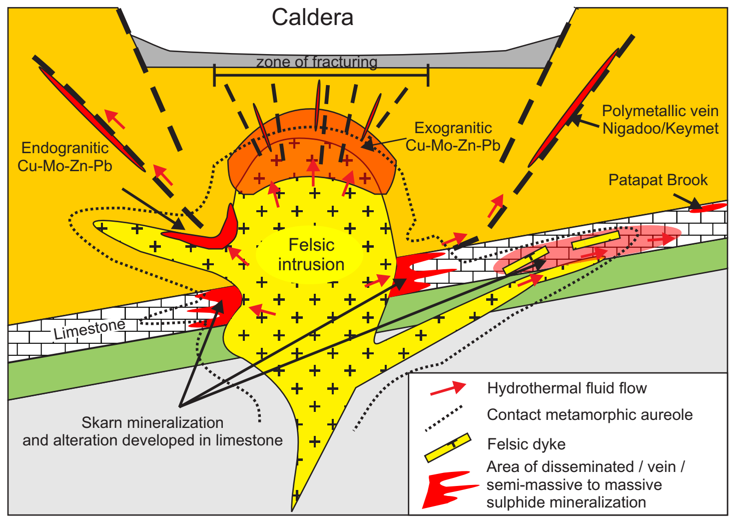


Figure 4. Model relating skarn and polymetallic vein-type lead mineralization to felsic intrusions, with examples cited in text. Note that there are no significant examples of endo- and exogranitic lead deposits in New Brunswick.

Shear zone-hosted Lead Deposits

Lead also occurs as galena in shear-zone hosted quartz veins. These veins occur within older rocks that have been affected by intense shear deformation adjacent to major fault systems. Two such deposits occur in Neoproterozoic rocks in southern New Brunswick (Figures 1 and 2). The former Teahan mine (18) was exploited for Cu in the 1880's and is reported to contain up to 1% combined Pb and Zn, and the nearby Lumsden deposit (17) that was reported to contain Pb grades up to 1.95%. It should be noted that ore-metal ratios and host rock associations suggest the possibility that both Teahan and Lumsden may have originated as VMS deposits prior to being concentrated in shear zones. In northern New Brunswick the, Hachey (19) and Shaft (20) deposits are hosted by Ordovician sedimentary rocks immediately adjacent the Rocky Brook- Millstream Fault and may represent shear zone-hosted deposits as well.

Stratabound Sediment-hosted Lead Deposits

A number of lead occurrences are hosted within Carboniferous sedimentary rocks of the Maritimes Basin. The relatively low temperature (<150°C), metal-bearing fluids responsible for the formation of these deposits originated as pore fluid in terrestrial to shallow marine sedimentary subbasins (Figure 5). These fluids circulate in porous beds deep in the subsurface and can migrate upward towards the surface along structural breaks (faults). When these fluids contact sedimentary beds that are in chemical disequilibrium with the metal-bearing fluid, Pb-Zn-Cu sulphide precipitation can be initiated. These stratabound deposits can be broadly divided on the basis of host rock type (Figure 5); those hosted by clastic sedimentary rocks are included in the sandstone-type (Sangster 1996a), whereas those hosted by limestone are included in the Mississippi Valley-type (Sangster 1996b).

The Breau Creek North occurrence (16; Figures 1, 2 and 5), represents sandstone-type lead mineralization. Organic carbon in fossilized logs in Late Carboniferous terrestrial sandstone at this location interacted with subsurface, metal-bearing brines that initiated the precipitation of Pb-Zn sulphides through the reduction of the sulphate ion (SO_4^{-2}) to the sulphide ion (S^{-2}) (Figures 2 and 5). This occurrence contains grades of up to 0.1% Pb and 1.28% Zn (St. Peter and Johnson 2009).

The Peekaboo Corner occurrence (15; Figures 1, 2 and 5), is the best example of Mississippi Valley type lead-zinc occurrence in New Brunswick but is of relatively low grade (widest interval, 54 m of 0.7% Pb and 0.2% Zn; Woods, 1992). The host rocks are shallow-marine limestone beds that lie unconformably on Neoproterozoic volcanic rocks that have been uplifted along a fault structure to form a basement high (Figure 5). The lead-zinc mineralization occurs in a carbonate-cemented, volcanic-clast breccia that sits directly on the basement rocks. Pb-Zn sulphides were precipitated when metal-bearing brine flowing along permeable (porous) sandstone beds encountered the fault structure and migrated upward to interact with the limestone beds sitting on the basement high.

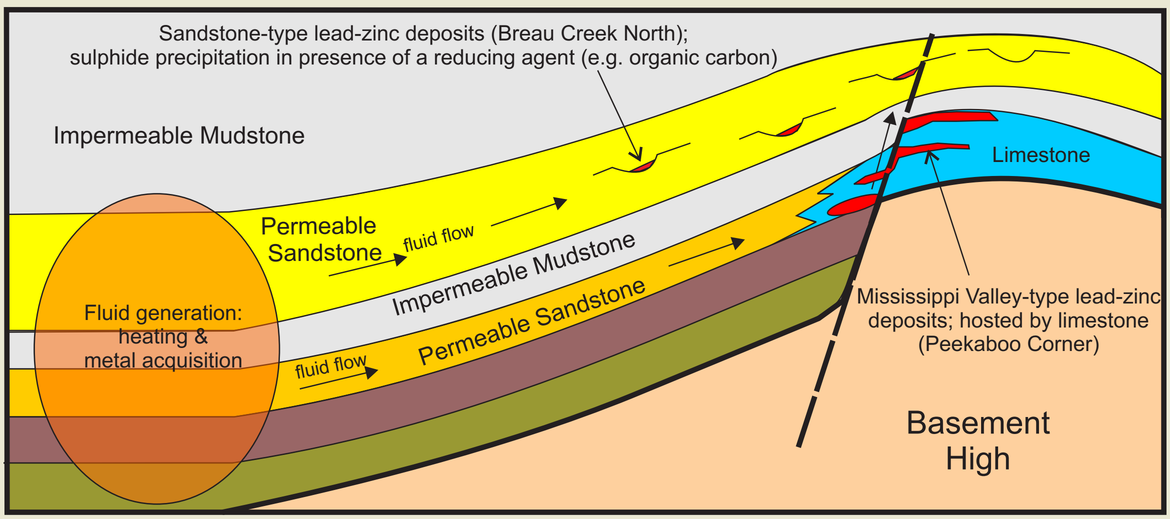


Figure 9. Conceptual model for the generation of sandstone-type and Mississippi Valley-type lead-zinc deposits, with New Brunswick examples. Compiled from Graves and Hein (1994), NBDEM (2013), and Sangster (1996a and b).

Summary

New Brunswick's diverse geology has provided favourable conditions for the formation of several types of lead deposits. These formed in response to four main geological events: 1) opening of a backarc basin on the southern margin of the Iapetus Ocean resulted in the formation of the Ordovician VMS deposits of the Bathurst Mining Camp; 2) continental margin rifting following closure of the Iapetus Ocean and oblique continental collision of Gondwana (ancient Africa and South America) with Laurentia (ancient North America) led to the formation of Early Devonian VMS-like deposits in northeastern and west-central New Brunswick; 3) emplacement of granitic magmas generated by continental collision and resulting Appalachian mountain-building event led to the formation of the various granite-related deposits (endogranitic, polymetallic vein, and skarn) in the Devonian and 4) fault movements during the waning stages of Appalachian mountain-building resulted in the formation of the various stratabound sedimentary-hosted lead deposits in the Carboniferous. Shear zone-hosted lead deposits occur in or proximal to the faults in older rocks (Neoproterozoic and Ordovician) that have undergone a long history of deformation.

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For More Information

For more information on lead and other New Brunswick Mineral commodities, please see the NBDEM Mineral occurrence database (NBDEM 2013) or contact:

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