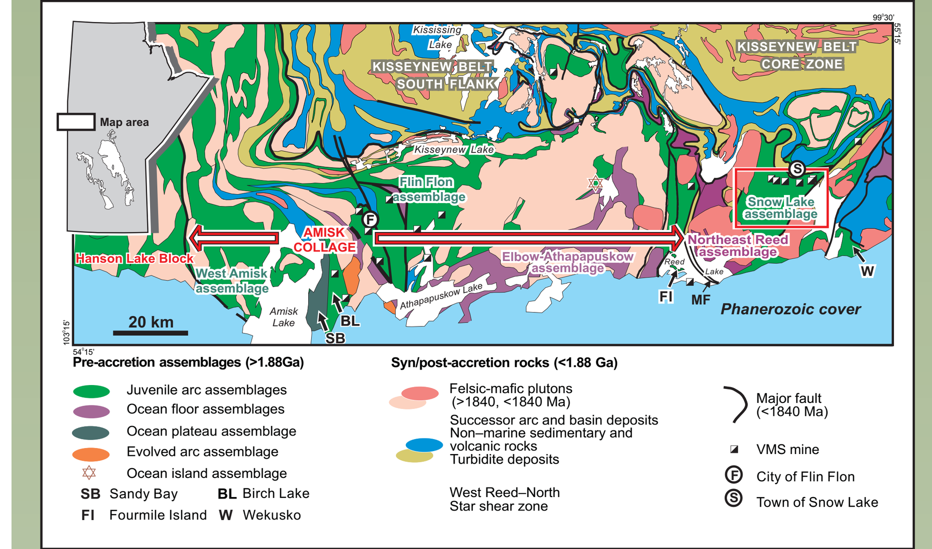


Simplified geology of the Flin Flon Domain, showing major tectonostratigraphic assemblages and plutons, and locations of mined VMS deposits. Inset shows the location of the Flin Flon Domain (white rectangle) in Manitoba. The Chisel-Anderson lakes map area, which is the rectangle at the east end of the domain that is outlined in red, is characterized by a structural style and rock types that are more comparable to the Kisseynew Domain than those in the Amisk Collage of the central Flin Flon Domain. The map area consists of a series of Kisseynew-type allochthons of 1.89 Ga volcanic and 1.85-1.83 Ga sedimentary rocks, soled by the Morton Lake Fault zone (MF).

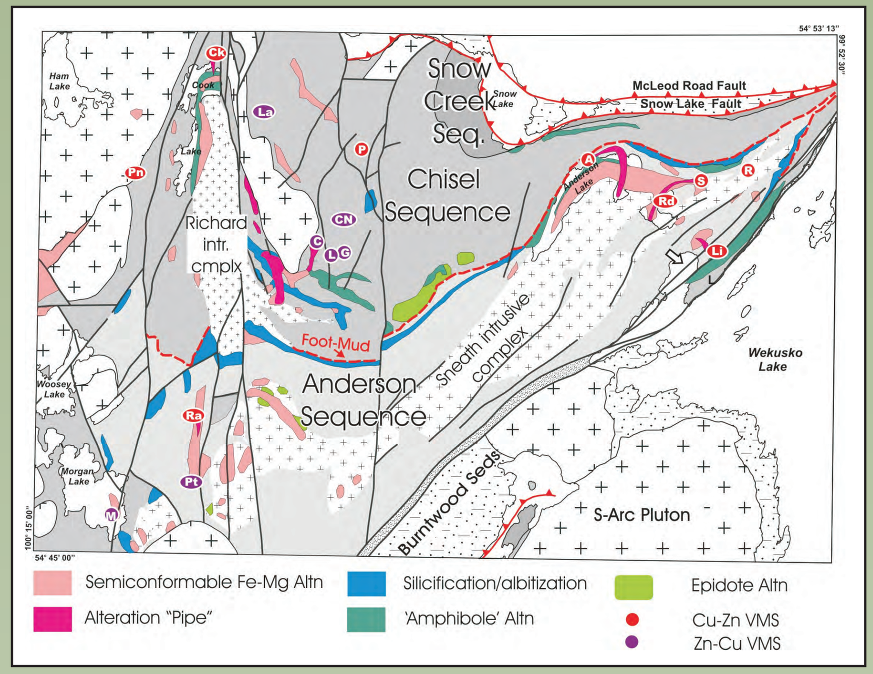
INTRODUCTION

The Chisel-Anderson lakes area is composed of deformed and metamorphosed volcanic, sedimentary and intrusive rocks that contain 8 of the Flin Flon domain's 27 producing and past-producing base metal mines. These include the currently producing Chisel North Zn-Cu mine and 7 past-producers, plus several unmined deposits, including the newly discovered Lalor deposit. The new map and accompanying notes (MAP2007-1) provide an up-to-date geological context for the VMS deposits as well as documenting the distribution of rocks that underwent alteration by VMS-producing hydrothermal systems.

Between 1986 and 1995 the Manitoba Geological Survey undertook a systematic geological remapping of the Snow Lake district, at scales ranging from 1:20 000 to 1:5 000. In addition, federal-provincial geological survey and industry collaboration in the Snow Lake area included a multidisciplinary study of new exploration approaches for base metal mineralization (1989-1994) and a study on the use of regional-scale alteration zones and subvolcanic intrusions in exploration for volcanic-hosted massive sulphide deposits (1994-1998). In combination with the many products of these studies (some of which are shown to the right), Geoscientific Map MAP2007-1 contributes to this area being one of the most completely understood base metal mining districts in the world.

A New Geological Map for the Snow Lake Volcanogenic Massive Sulphide (VMS) Mining Areas

complied by
A.H. Bailes and A.G. Galley[1]
1. Geological Survey of Canada

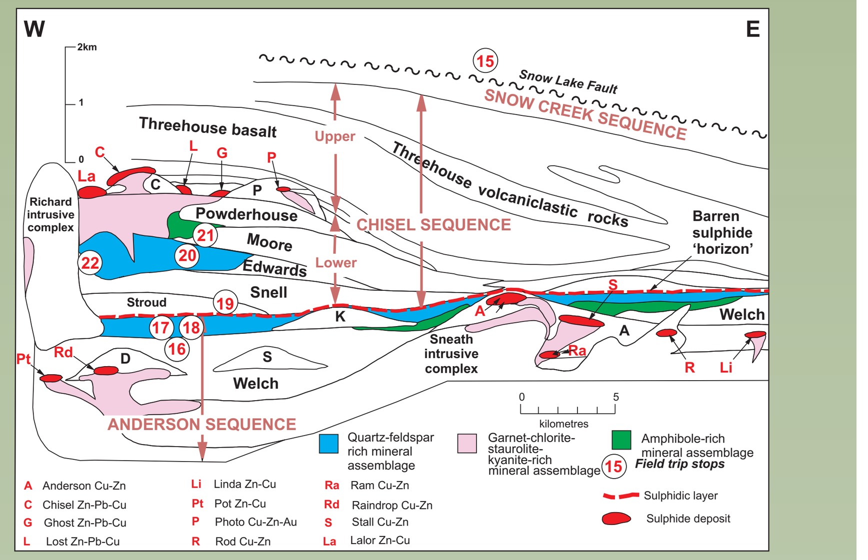


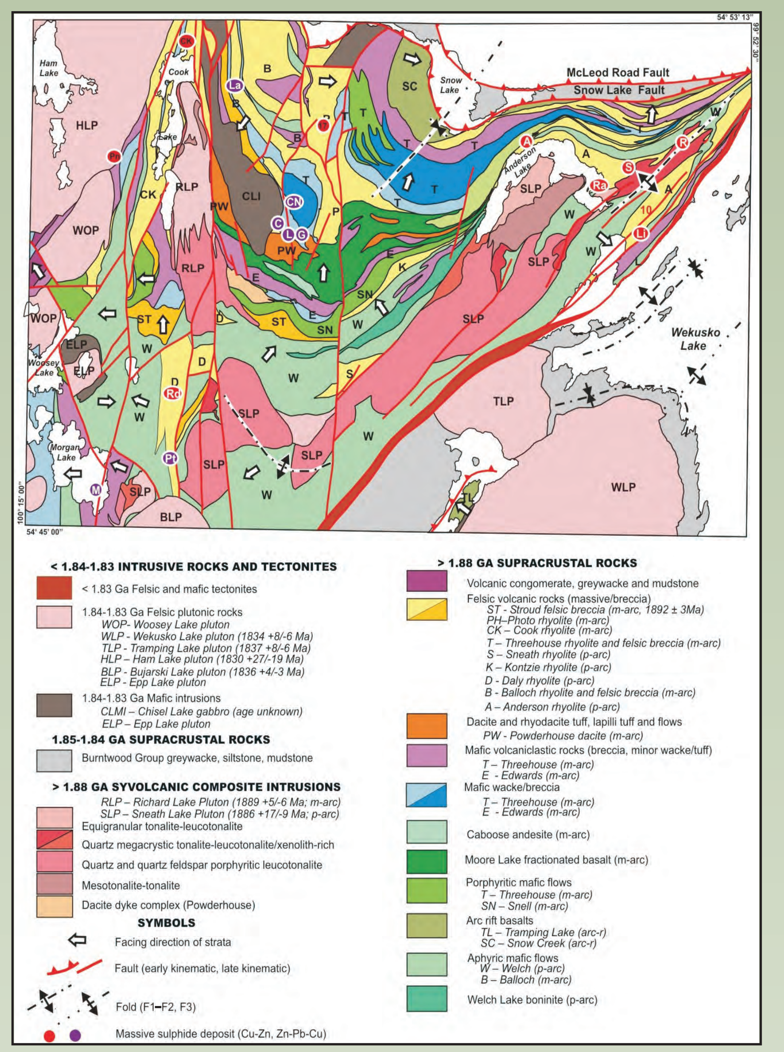
The volcanic sequences of the Snow Lake arc assemblage contain prominent zones of alteration that visibly affect approximately 25% of the volcanic strata and associated synvolcanic intrusions (see adjacent figures). These alteration zones, which were formed by synvolcanic hydrothermal activity, were subsequently recrystallized during 1.81 Ga regional metamorphism and can be readily recognized by their unique metamorphic mineral assemblages. Centimetre-scale, euhedral crystals of chlorite, phlogopitic biotite, amphibole, muscovite, garnet and staurolite are common within metamorphically recrystallized semiconformable alteration zones. Recrystallized discordant alteration zones also contain coarse-grained kyanite and andalusite. The alteration zones are depicted on MAP2007-1 by black-line patterns over the (in some instances interpreted) original lithological units. Three periods of robust hydrothermal activity are identified within the Snow Lake arc assemblage.

The first, and oldest, hydrothermal event occurs in the Anderson seqeunce rocks and is focused within the Anderson and Daly felsic extrusive complexes. It is interpreted to be genetically related to formation of the Anderson, Stall and Rod Cu-Zn VMS deposits, in the former complex, and the Raindrop and Pot Lake base metal occurrences, in the latter. This hydrothermal activity also affected the underlying Sneath intrusive complex, where it is manifested, most typically, as 'fracture-controlled' zones of alteration. These are interpreted to result from 'collapse' of the hydrothermal system into the subvolcanic intrusion as it cooled. The alteration caused by this hydrothermal activity includes both stacked, semiconformable zones, 35 km long and as much as 1000 m in total thickness, and discordant alteration 'pipes' that commonly terminate upsection at known VMS deposits and occurrences. These alteration zones are truncated by a late phase of the Sneath intrusive complex, which is considered evidence of the coeval nature of the volcanism, alteration and plutonism.

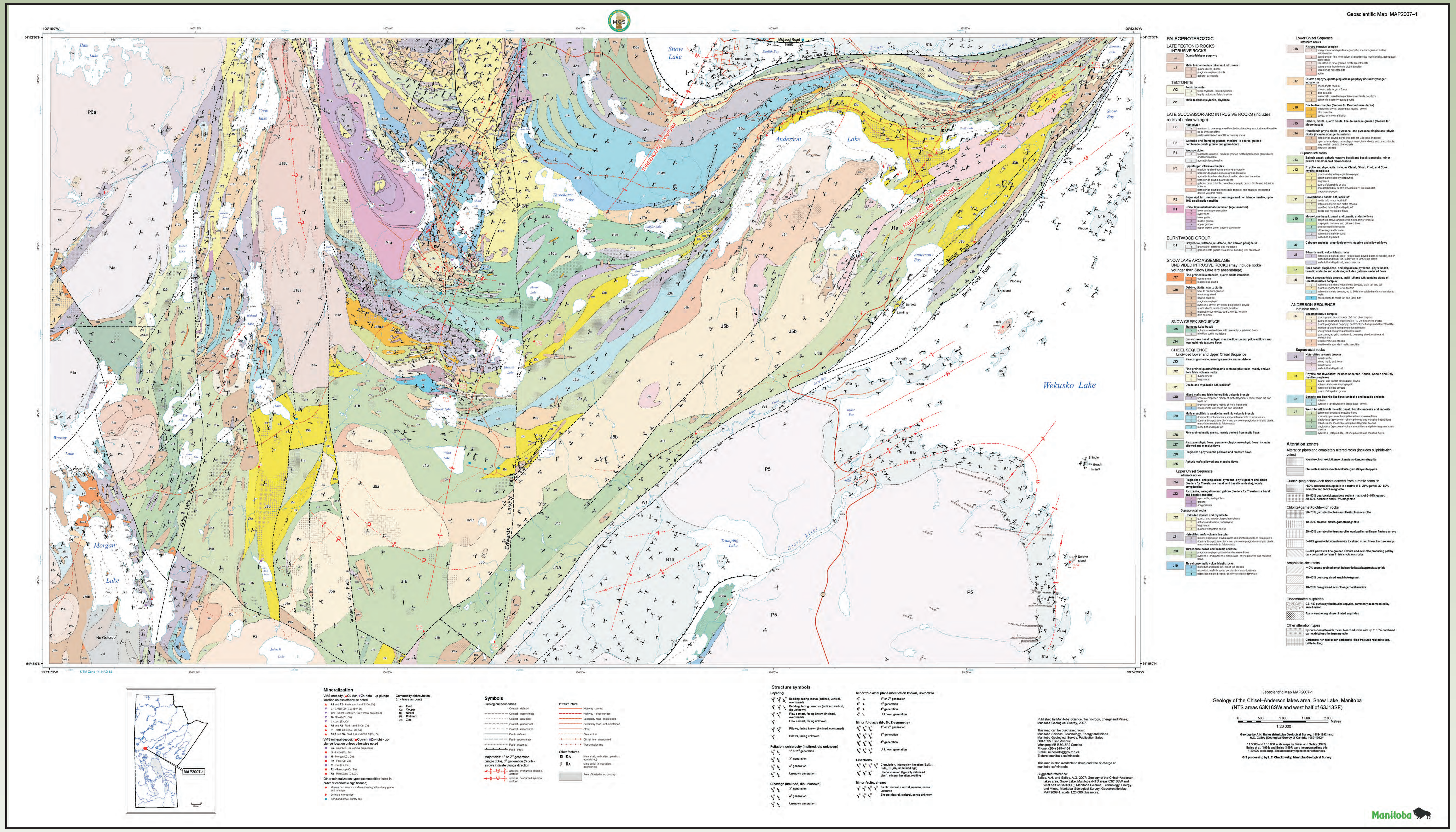
The second hydrothermal event took place at the end of Anderson sequence volcanism. This hydrothermal activity resulted in silica and epidote addition to Welch basalt at the top of the Anderson sequence. A 300-500 m thick zone of alteration was produced directly underlying the 'Foot-Mud tuff-exhalite' at the top of the Anderson sequence. Both the alteration and the Foot-Mud exhalite have the same strike length as the underlying Sneath subvolcanic intrusion.

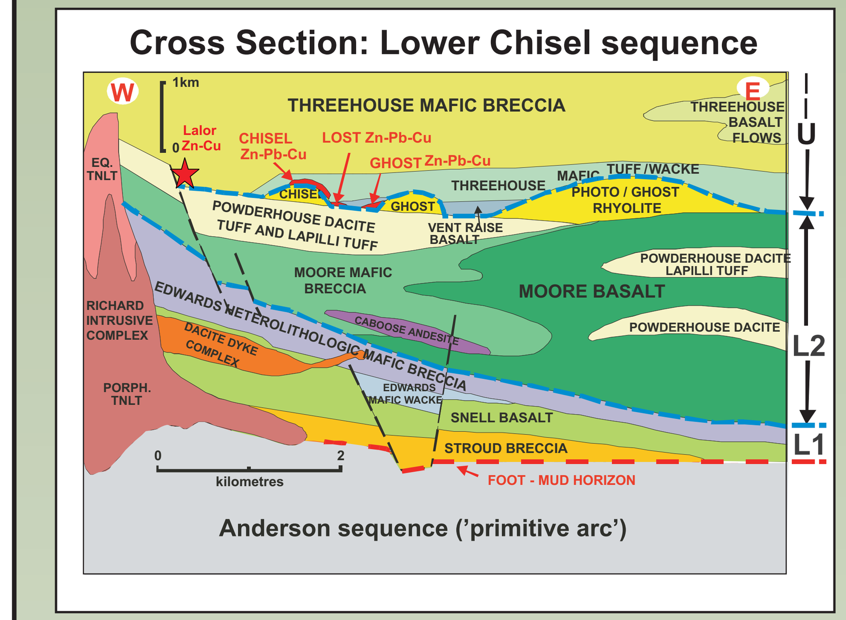
The third hydrothermal event is located within Lower Chisel volcanic rocks and is spatially associated with Lower Chisel intrusive rocks, in particular dikes of the 'Powderhouse' dacite and early phases of the Richard intrusive complex. Resultant alteration by the hydrothermal fluids, which is largely confined to the Edwards mafic volcaniclastic rocks, is interpreted to be synvolcanic and related to generation of VMS deposits, as it only affects strata underlying the Chisel-Chisel North-Ghost-Lost-Lalor VMS horizon. The alteration zone is truncated to the west by late phases of the Richard intrusive complex and by late faulting. An alteration system underlying the Cook Lake and Bomber VMS occurrences trends to the southwest into a large alteration system along Parisian Creek, Woosey Lake and Morgan Lake; it may represent the western extension of the 'Chisel footwall' alteration system.

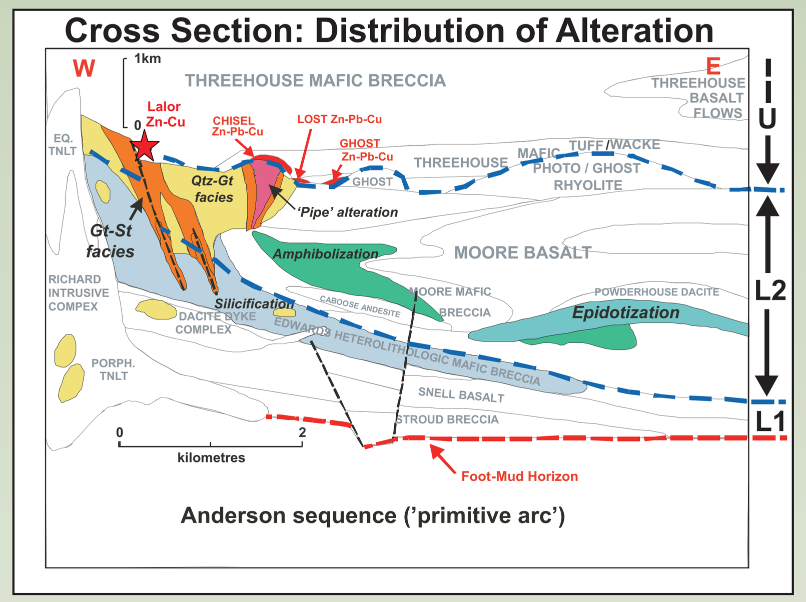




Simplified geological map of the Snow Lake area. The area covered is identical to Geoscientific Map MAP2007-1 but has been extended slightly north in order to show the location of the Cook Lake VMS deposit. Filled circles and ovals (red, Cu-Zn; purple, Zn-Cu) show distribution of VMS deposits: A, Anderson Lake; C, Chisel Lake; Ck, Cook Lake ; CN, Chisel North; G, Ghost Lake; La, Lalor; Li, Linda; L, Lost Lake; M, Morgan Lake; Pt, Pot Lake; P, Photo Lake; Pn, Pen; Rd, Raindrop; R, Rod; Ra, Ram; S, Stall Lake. The 'Foot-Mud horizon' (thick red dashed line) is a pyritic, fine-grained volcaniclastic unit located at the contact between the Anderson ('primitive arc') and Chisel ('mature arc') sequences.





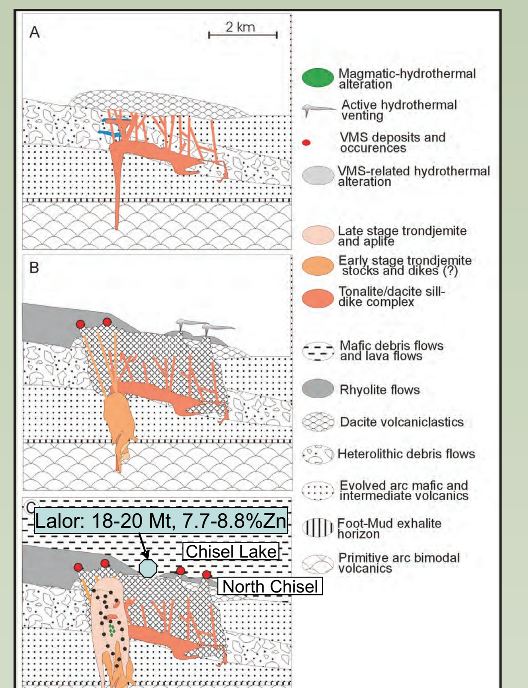


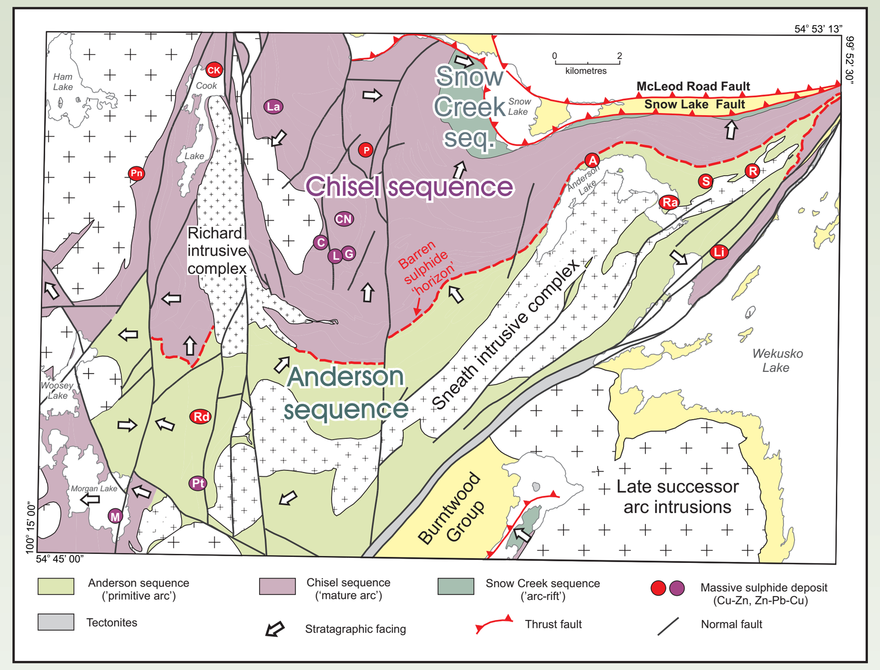
THE CHISEL-LALOR VMS SYSTEM

The Lower Chisel supracrustal rocks contain two discrete components (see figures). The first consists of felsic and mafic volcaniclastic rocks (L1), which are derived by mass wasting of a source terrane located to the west (current co-ordinates), and a geochemically distinctive basalt flow (Snell) that was derived from more mature and evolved arc magmatism than that responsible for the underlying Anderson sequence. The second component (L2) is a suite of differentiated basalt, andesite, dacite and rhyolite flows that are geochemically distinct. The Zn-Cu VMS deposits are spatially associated with rhyolite flow-dome complexes (unit J12) lying atop this latter succession. The star in the figures to the left indiates schematically the location of the Lalor deposit within the sequence.

Ubiquitous pillows in the mafic flows, lobe and tongue facies in rhyolite flows, and graded bedding in mafic volcaniclastic rocks indicate that the Lower Chisel rocks were deposited subaqueously. The Lower Chisel sequence is cut by a wide variety of intrusive rocks, ranging from dikes less than a metre across to large plutons several kilometres in diameter. Most of these intrusions are demonstrably synvolcanic, and many can be clearly related to specific extrusive equivalents. The abundant (locally up to 50% by volume) synvolcanic dikes support the hypothesis that rifting and caldera development likely accompanied accumulation of the Lower Chisel sequence.

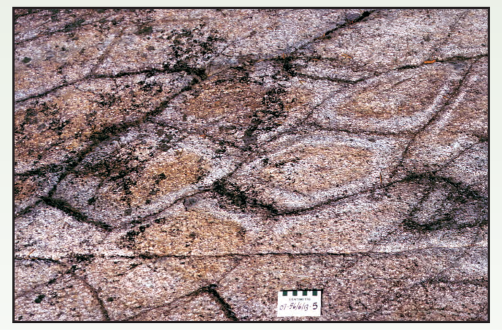
The 1.7 km by 7.3 km synvolcanic Richard intrusive complex is a long-lived intrusion that played an integral role in generating and sustaining the Chisel-Lalor VMS system. The evolution of the intrusion and its potential relationship to the VMS deposits is illustrated schematically on the diagram to the right. The synvolcanic character of the Richard intrusive complex is clearly supported by a U-Pb zircon date of 1889 +8/6 Ma and: 1) the presence of miarolitic cavities, which indicate shallow depth of emplacement; 2) geochemical similarity of the Richard tonalite and the overlying ore-hosting Chisel and Ghost rhyolite flows; 3) an increase in intensity of regional-scale semiconformable alteration zones in the Lower Chisel sequence close to the Richard intrusive complex; and 4) internal vein-breccia systems, which suggest epizonal intrusion.



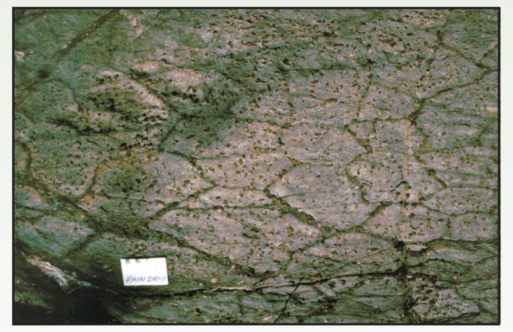


Plan view of the 1.89 Ga Anderson ('primitive arc'), Chisel ('mature arc') and Snow Creek ('arc-rift') sequences of the Snow Lake arc assemblage. The two large synvolcanic intrusive complexes, Sneath and Richard, belong to the Anderson and Chisel sequences, respectively. The ca. 1.84-1.83 Ga sedimentary Burntwood Group rocks are composed of detritus derived from volcanic and intrusive rocks of the Flin Flon Domain. Arrows show facing directions of supracrustal rocks. The late successor arc intrusive rocks truncate the ca. 1.84 Ga thrust faults (teeth) and are themselves cut by ca. 1.78 Ga normal faults (solid lines). Filled circles and ovals (red, Cu-Zn; purple, Zn-Cu) show distribution of VMS deposits: A, Anderson Lake; C, Chisel Lake; Ck, Cook Lake (located just north of map boundary); CN, Chisel North; G, Ghost Lake; La, Lalor; Li, Linda; L, Lost Lake; M, Morgan Lake; Pt, Pot Lake; P, Photo Lake; Pn, Pen; Rd, Raindrop; R, Rod; Ra, Ram; S, Stall Lake. The 'Foot-Mud horizon' (thick red dashed line) is a pyritic, fine-grained volcaniclastic unit located at the contact between the Anderson ('primitive arc') and Chisel ('mature arc') sequences.

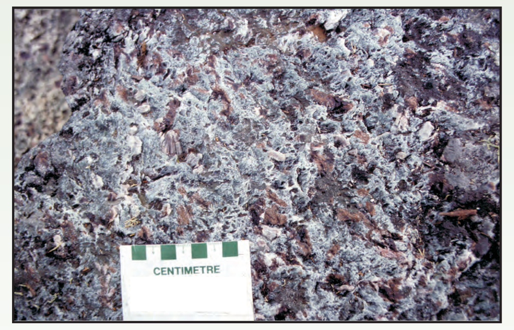
Coarse intrusion breccia, Sneath intrusive complex (subunit J5g). Note xenolith-rich tonalite as blocks in the intrusion breccia.



Polygonally jointed tonalite (subunit J5a) 30 m from chilled margin of Sneath intrusive complex. During collapse of the hydrothermal system into the cooling pluton the joints were altered and subsequently overgrown by porphyroblasts of garnet and staurolite formed during regional amphibolite facies metamorphism.



Staurolite prophyroblasts (dark) concentrated in polygonal joints that likely provided primary permeability for hydrothermal alteration, Daly rhyolite (subunit J3b). Located in the footwall to the Raindrop Cu-Zn massive sulphide deposit. T

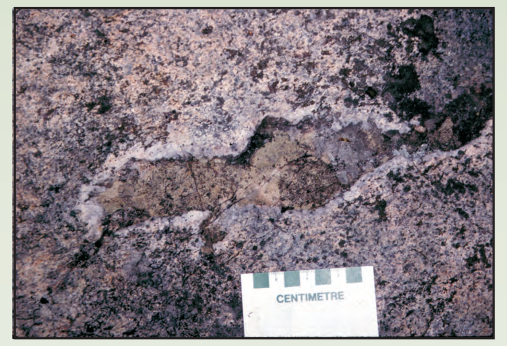


Staurolite (brown), biotite (dark) and kyanite (white) porphyroblasts in Anderson rhyolite (subunit J3b) in Ram 'pipe-like' alteration zone 1.5 km from the Stall VMS deposit.

Pillowed basalt with prominent mottled to pervasive albitization and silicification (dashed lines outline pillows), Welch basalt (unit J1a). Note draped pillow giving facing direction to top (north) of photograph.

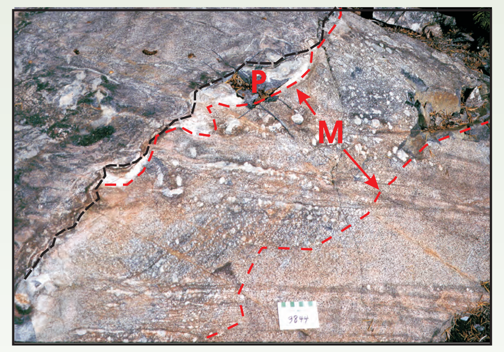
Pillowed Welch basalt (subunit J1b) 15m below the Foot-Mud 'horizon. The alteration of the pillows is part of a 0.5 by 20 km semiconformable zone of 'low temperature' silicification that occurs at the top of the Anderson 'primitive arc' sequence.

Amoeboid margin (note dark weathering chilled selvage) on synvolcanic mafic dyke (unit J15) intruding Edward heterolithologic mafic breccias (subunit J8b).



Quartz-rimmed, epidote-filled miarolitic cavitiy in tonalite (subunit J18b), Richard intrusive complex.

Zone of pervasive albitization/silicification (white) crosscutting bedded Edwards mafic tuff (subunit J8b). Note load structures.



Synvolcanic mafic dyke (unit J15) with adjacent zones of pervasive (P) and mottled (M) albitization/silcification overprinting bedded Edwards mafic tuff (subunit J8a). Note amoeboid margin of dyke indicating emplacement into wet unconsolidated material.

White orbicular domains of albitization/silicification (some with pale oange-green epidozite cores) overprinting Edwards mafic breccia (subunit J8a). Note breccia block with white bleached rim as well as internal orbicual domains of albitization/silicification.

Epidozite alteration domain with amphibole and quartz-feldspar rim overprinting fragment in heterolithlogic Edwards debris flow breccia bed (subunit J8a).

Manitoba