UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Southern Extension of the Churchill Province (Trans-Hudson Orogenic Belt) Midcontinent Strategic and Critical Minerals Project 1985 Workshop Report

By

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This report was prepared under contract from the U.S. Geological Survey and has not been reviewed for conformity with USGS editorial standards and stratigraphic nomenclature. Opinions and conclusions expressed herein do not necessarily represent those of the USGS.

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INTRODUCTION

This report is a summary of the current state of knowledge of the geology and early Proterozoic history of the western margin of the Canadian Churchill province, and its southward extension into the United States, which for reasons stated below is referred to herein as the Trans-Hudson orogenic belt. The report is a product of a December 1985 workshop that was sponsored by the U.S. Geological Survey (USGS), under the auspices of its Midcontinent Strategic and Critical Minerals project (see below). The principal objectives of the workshop were to review the state of geologic knowledge and interpretations of the Trans-Hudson orogenic belt, and to recommend a plan of study for additional research that could be sponsored by the USGS as an appropriate part of the mineral-resource program. The present report was prepared from the information presented and discussed at the workshop and from recent publications by workshop participants and others, and fulfills the first of the principal objectives. It is being released in this form in order to make this information available to other investigators interested in the Trans-Hudson orogenic belt. The workshop's recommendations for additional research have been duly transmitted to the USGS for implementation and are not included in this report.

The Midcontinent Strategic and Critical Minerals project is a USGS-multi-state cooperative investigation of the mineral potential of the Midcontinent region, initially focussed on an area bounded by 36^{o}-46^{o} N. lat. and 88^{o}-100^{o} W. long. The project formally began in January 1984 with the establishment of a series of subprojects and the identification of subproject leaders to make selected regional compilations based on data contributed by the states, or to pursue selected topical investigations. At a project review and planning session in February 1985, several additional subprojects were defined, among which was an investigation of the southern extension of the Churchill province. A general progress report on the Midcontinent project was released in November 1985 (Pratt, 1985). A new 1:1,000,000 Precambrian basement map of the project area, also released in late 1985 (Sims, 1985), is of particular importance to Precambrian studies in the region and formed part of the basis for the Trans-Hudson workshop study.

The workshop reported on here was held in Denver, Colorado, December 4-5, 1985; it was sponsored primarily by the USGS and included representatives from the state geological surveys of Iowa, Kansas, Nebraska, Illinois, South Dakota, and Minnesota; universities in Kansas, Wyoming, Oklahoma, North Dakota, Nebraska, Illinois, Wisconsin, and Saskatchewan; the USGS; and the Canada Department of Energy, Mines, and Resources. The attendees are listed in Table 1, and the workshop program is reproduced in Table 2.

GEOLOGY OF THE TRANS-HUDSON OROGENIC BELT

The name "Churchill province" has been periodically applied to all of the basement rocks between the Canadian Archean Superior, Slave, and Nain cratons, including rocks ranging in age from Archean to Middle Proterozoic. The western "Churchill province" was defined by Lewry and others (1985) as that part of the "Churchill province" west of Hudson Bay. Rocks exposed along the western margin of the Superior province in northern Saskatchewan and Manitoba include deformed supracrustal rocks, Early Proterozoic eugeoclinal sediments, arc volcanics, and Cordilleran-type batholith complexes. By the early 1970's these rocks were identified as products of tectonism consistent with plate tectonic models (e.g. Gibb and Walcott, 1971). Hoffman (1981) proposed the name Trans-Hudson orogen for the closing of the ocean between the Superior

Table 1. Trans-Hudson orogenic belt, 1985 workshop, participants

NAME	AFFILIATION	CITY
Anderson, Ray	Iowa Geological Survey	Iowa City, IA
Berendsen, Pieter	Kansas Geological Survey	Lawrence, KS
Bickford, M. E.	University of Kansas	Lawrence, KS
Black, Ross	University of Wyoming	Laramie, WY
Carlson, Marv	Nebraska Geological Survey	Lincoln, NE
Collerson, Ken	University of Regina	Regina, Sask.
Cordell, Lin	U.S. Geological Survey	Denver, CO
Crowley, Kevin	University of Oklahoma	Norman, OK
Day, Warren	U.S. Geological Survey	Denver, CO
Eidel, Jim	Illinois State Geological Survey	Champaign, IL
Gosnold, Will	University of North Dakota	Grand Forks, ND
Green, Alan	Dept. Energy, Mines, and Res.	Ottawa, Ont.
Hildenbrand, Tom	U.S. Geological Survey	Denver, CO
Houston, Bob	University of Wyoming	Laramie, WY
King, Elizabeth R.	U.S. Geological Survey	Reston, VA
Klasner, John S.	Western Ill. University/USGS	Macomb, IL
Kleinkopf, Dean	U.S. Geological Survey	Denver, CO
La Berge, Gene	University of Wisconsin/Oshkosh	Oshkosh, WI
Lewry, John	University of Regina	Regina, Sask.
Papike, Jim	South Dakota School of Mines & Tech.	Rapid City, SD
Peterman, Zell	U.S. Geological Survey	Denver, CO
Redden, Jack A.	South Dakota School of Mines/USGS	Rapid City, SD
Schoon, Robert	South Dakota Geological Survey	Vermillion, SD
Schulz, Klaus J.	U.S. Geological Survey	Reston, VA
Sims, P. K.	U.S. Geological Survey	Denver, CO
Southwick, David L.	Minnesota Geological Survey	St. Paul, MN
Treves, Sam	University of Nebraska	Lincoln, NE
Van Schmus, W. R.	University of Kansas	Lawrence, KS

Table 2. Trans-Hudson orogenic belt, 1985 workshop, program

Wednesday, December 4, 1985, "What we know, and think"

8:30 - Welcome and opening remarks
Wally Pratt (USGS)
8:45 - Description of the study
Ray Anderson (Iowa Geological Survey Bureau)
9:00 - Western Churchill province outcrop belt
John Lewry (Univ. of Regina)
9:30 - Churchill province in the subsurface of south-central Canada
Ken Collerson (Univ. of Regina)
10:00 - Seismic evidence for the eastern margin of the western Churchill province - Alan Green (Canada Department of Energy, Mines & Min.)
10:30 Break
11:00 - Western Churchill province in subsurface of north-central U.S.
Zell Peterman (USGS)
11:30 - Western Churchill province in the subsurface of the Dakotas
John Klasner (Western Illinois Univ.)
12:00 - Lunch Break
1:00 - Western Churchill province in the study area, some ideas
Ray Anderson (Iowa Geological Survey Bureau)
1:30 - Subsurface structures in central Kansas
Pieter Berendsen (Kansas Geological Survey)
2:00 - Precambrian terranes in the central U.S.
Randy Van Schmus (Univ. of Kansas)
2:30 - General discussion*
3:00 - Break
3:30 - Open discussion* of ideas and interpretations

Thursday, December 5, 1985, "Where from here"

8:30 - Open discussion* of what can be done to define the southern extension of the Churchill province into the study area and to evaluate its potential mineral resource potential
10:00 - Break
10:30 - Continue discussion*
12:00 - Lunch break
1:00 - Continue discussion*
2:30 - Summary of discussion and recommendation for future research
Ray Anderson (Iowa Geological Survey Bureau)
3:00 - Meeting adjourned

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* These discussions included informative presentations of the following topics:
- The Nd-Sm geochronology techniques - Ken Collerson (U. of Regina)
- Fission track ages in the Midcontinent - Kevin Crowley (U. of Oklahoma)
- Heatflow data in the Dakotas and Nebraska - Will Gosnold (U. of North Dakota)
- Regional gravity and magnetic data and interpretations - Tom Hildenbrand (USGS)
- Geochemistry procedures and costs - Klaus Schulz (USGS)
- Precambrian geology of the north-central U.S. - Paul Sims (USGS)
- Possible DOSECC projects in the north-central U.S. - Randy Van Schmus (U. of Kansas)

province and the "Western craton," the Archean-age component of the Churchill province (Lewry and Sibbald, 1978).

Since the Archean Wyoming craton lies west of the Superior craton in the continental United States (its relationship to the Archean components of the Churchill craton is unclear and they may be continuous), it does not seem appropriate to use the name Churchill in referring to the orogenic belt between them. However, geophysical anomaly maps do imply a continuity of the rocks of the Trans-Hudson orogen in Canada and the rocks at the western margin of the Superior craton in the United States. The workshop participants agreed that the name "Churchill province" for this southern extension should be abandoned in favor of "Trans-Hudson orogenic belt."

Recent studies (Lewry and Sibbald, 1978, 1980; Stauffer, 1984; Lewry and others, 1985; and Green and others, 1985) described the component terranes of the Trans-Hudson orogenic belt and proposed genetic models. They described (figs. 1 and 2), from west to east, the Cree Lake zone (composed of the Virgin River, Mudjatik, and Wollaston domains), the Wathaman-Chipewyan batholith, the Reindeer-South Indian Lakes (Rottenstone) belt, the LaRonge-Lynn Lake belt, the Flin Flon-Snow Lake belt, and the Thompson belt. Additionally, Pikwitonei granulites of north-central Manitoba apparently represent Archean rocks (lower crustal levels of the Superior province Granite-Greenstone terrane) thrust up during a late Archean tectonic event (Green and others, 1985) and probably are not a part of the Trans-Hudson orogenic belt. These descriptions that follow draw heavily on the work of Green and others (1985) and other authors cited.

Cree Lake zone

The Cree Lake zone (fig. 2) represents the eastern margin of the Archean-age "Western craton" and overlying Early Proterozoic stable shelf- and platform-type rock sequences. The Proterozoic sedimentary sequence, as described by Lewry and Sibbald (1978), includes a basal coarse clastic unit composed of quartz arenite, pelite, and conglomerate, overlain by a pelite-dominated unit that contains interbedded sandstone, limestone, banded iron-formation, and mafic intrusives and extrusives. A thick unit of calcareous and non-calcareous arkose with minor shale and massive carbonate interbeds is overlain by an upper calcareous shale. Lewry and Sibbald (1980) compared the basal sequence to early continental rift assemblages elsewhere.

Remobilization of the Proterozoic supracrustal sequence during the Hudsonian orogeny included widespread high to very high grade metamorphism, and anatexis (Lewry and others, 1985) and deformation, defining three linear domains parallel to the orogenic front. The more mobile high-grade core of the metamorphic front is seen in the Mudjatik domain, where remobilized basement and supracrustal anatectic granitoid plutons are more abundant than supracrustals. To the west, the Virgin River domain is also dominated by granitoid rocks, but to the east the Wollaston domain is predominantly a supracrustal sequence (Lewry and Sibbald, 1980). The western margin of the Cree Lake zone is defined by the Virgin River-Black Lake shear zone, the eastern margin by the Needle Falls shear zone.

Wathaman-Chipewyan batholith

The Wathaman-Chipewyan batholith is a composite of granitic to monzonitic and granodioritic intrusive rocks, present along the entire 800 km-long eastern margin of the Cree Lake zone (Fumerton and others, 1984; Green and others, 1985). The batholith was described by Lewry (1981) as a "Hudsonian ´Cordilleran-type´ arc massif."

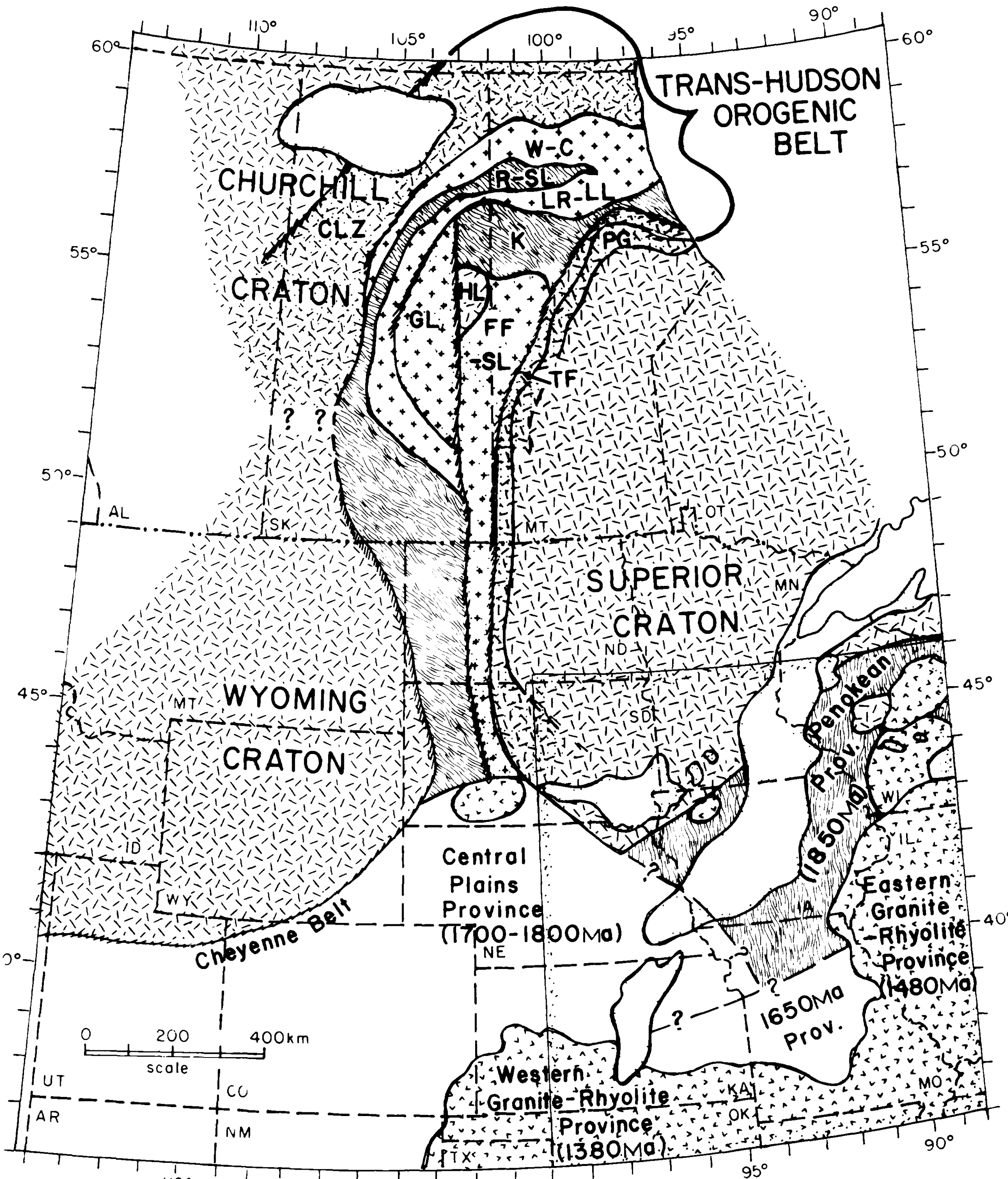


Figure 1. Geology of the Trans-Hudson orogenic belt and adjacent areas of south-central Canada and north-central U.S. CLZ (Cree Lake Zone), WC (Wathaman-Chipewyan batholith), R-SL (Reindeer-South Indian Lake belt), LR-LL (LaRonge-Lynn Lake belt), K (Kisseynew belt), GL (Glennie Lake domain), HL (Hanson Lake block), FF-SL (Flin Flon-Snow Lake belt), TF (Thompson-Fox River belt), PG (Pikwitonei granulite domain). Modified from Green and others (1985), Peterman and Zartman (1985), and Van Schmus and others (in press).

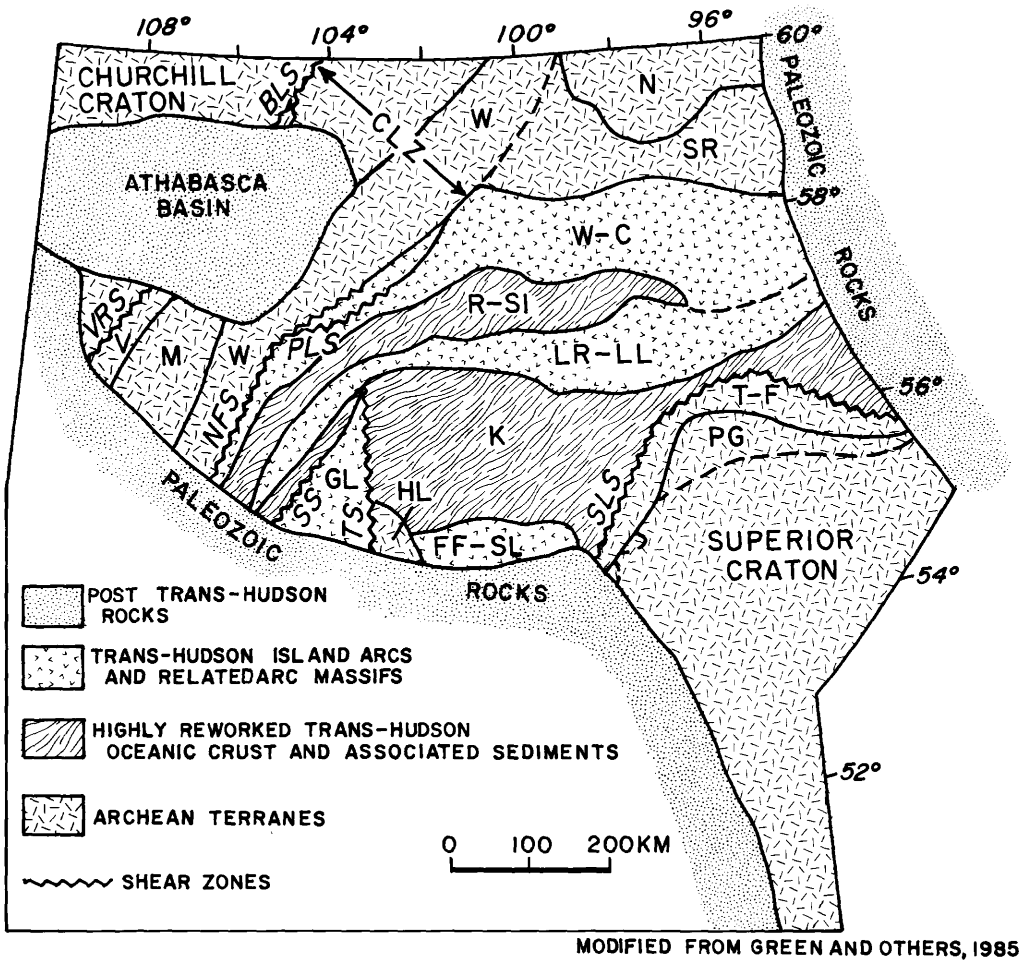


Figure 2. Bedrock geology of northern Manitoba and adjacent areas of Saskatchewan. CLZ - Cree Lake Zone; V - Virgin River domain; M - Mudjatik domain; W - Wollaston domain; N - Nejanilini domain; SR - Seal River domain; W-C - Wathaman-Chipewyan batholith; R-SI - Reindeer-South Indian Lake belt; LR-LL - LaRonge-Lynn Lake belt; K - Kisseynew belt; GL - Glennie Lake domain; HL - Hanson Lake belt; FF-SL - Flin Flon-Snow Lake belt; T-F - Thompson-Fox Lake belt; PG - Pikwitonei granulites; VRS - Virgin River shear zone; BLS - Black Lake shear zone; NFS - Needle Falls shear zone; PLS - Parker Lake shear zone; SS - Stanley shear zone; TS - Tabbernor shear zone; SLS - Setting Lake shear zone.

Reindeer-South Indian Lakes belt

Wedged between the Wathaman-Chipewyan batholith and the LaRonge-Lynn Lake belt, the Reindeer-South Indian Lakes belt is composed of a sequence of graywacke, siltstone, and mudstone with minor mafic volcanics, including pillow and massive lavas (Green and others, 1985). Baldwin and others (1985) reported a U-Pb age of about 1910 Ma from zircons recovered from a rhyolite flow in the belt. High-grade metamorphic rocks, migmatites, and anatectic granitic rocks characterize this sequence, which has been interpreted as the remnant of a back-arc basin by Green and others (1985).

LaRonge-Lynn Lake belt

Southwest of the Reindeer-South Indian Lake belt lies the LaRonge-Lynn Lake belt. The LaRonge-Lynn belt is a Proterozoic granite/greenstone belt composed of submarine volcanic flows and fragmental rocks ranging in composition from rhyolite to basalt, associated plutonic rocks, and volcaniclastics. Rare-earth and trace-element abundances, major element chemical trends, and lithologies are similar to those observed in modern volcanic island arcs.

Kisseynew belt

Composed mainly of highly metamorphosed graywacke, siltstone, and mudstone with a central region of anatectic granite, the rocks of the Kisseynew belt apparently originated as volcanic detritus from nearby volcanic island arcs. Green and others (1985) interpreted the belt in part as a remnant fore-arc basin to the LaRonge-Lynn belt and in part as a remnant basin which formed north of the Flin Flon-Snow Lake belt. It is similar in lithology, deformation, and metamorphism to the Reindeer-South Indian Lakes belt.

Flin Flon-Snow Lake belt

The Flin Flon-Snow Lake belt, like the LaRonge-Lynn Lake belt, is composed of rock sequences similar to those present in modern-day volcanic island arc complexes. Rocks described in the belt include a lowermost tholeiitic volcanic suite, overlain by a suite of submarine volcanic flows and fragmental rocks ranging in composition from basalt to rhyolite, and a distinctly younger calc-alkaline sequence. Above these volcanics, a series of sedimentary rocks including graywacke, siltstone, and mudstone is overlain by arkosic sandstone and conglomerate and intruded by gabbroic and granitic plutons. Flin Flon-Snow Lake belt rocks have been subject to multiphase deformation and greenschist to amphibolite facies metamorphism (Green and others, 1985).

Glennie Lake domain

The Glennie Lake domain was described by Lewry (1981) as dominantly composed of "early quartz dioritic to granodioritic orthogneisses later foliated to undeformed dioritic to granitic plutons" with subordinate supracrustal rocks in the form of "narrow arcuate belts within the orthogneiss," which he noted were continuous with similar supracrustals in the adjacent LaRonge-Lynn Lake belt to the northwest. The domain was thought to represent an Archean microcontinental block, caught within the Hudsonian orogeny (Lewry, 1981; Green and others, 1985; Lewry and others, 1985), but recent isotopic studies suggest that the domain formed between 1850 and 1900 Ma ago (J.F. Lewry, oral communication, 1985).

Hanson Lake block

The Hanson Lake block is composed of granitoid and supracrustal rocks and is bounded by the Flin Flon belt and Glennie Lake domain. Metavolcanic rocks in the block have yielded a Rb-Sr whole-rock age of 2465±65 Ma, a granite 2395 Ma, and a gneiss 2430±30 Ma, described by Lewry and others (1985), who suggested they may represent reset Archean basement rocks. Most active workers (e.g. Lewry and others, 1985; Green and others, 1985; Klasner and King, 1986) consider the Hanson Lake block to be an Archean microcontinent that was accreted to North America during the Trans-Hudson orogeny.

Thompson-Fox River belt

The Thompson-Fox River belt, like the Cree Lake zone, is developed on Archean continental crust (in this case the Superior province) and consists of a sequence of supracrustal metasedimentary and metavolcanic rocks and younger ultramafic intrusions and associated volcanic rocks. The metasedimentary rocks include layered siltstone, sandstone, shale, dolomite, chert, and iron formation which Green and others (1985) suggested are rift-margin sediments. The supracrustal rocks of the Thompson belt are metamorphosed to upper greenschist facies, whereas the underlying Pikwitonei granulite has been retrogressively metamorphosed to amphibolite facies gneiss. Two deformational phases have modified the Thompson belt, the second (considered the main phase of the Hudsonian orogenic activity by Green and others, 1985) being responsible for widespread, intense shearing, faulting, and mylonitization. The Fox River belt supracrustal rocks are relatively unmetamorphosed and undeformed, but they have been tilted to near vertical and may be allochthonous. The large ultramafic bodies are dominantly serpentinized peridotites and are reported to intrude metasediments, metavolcanics, and the gneisses. Peredery (1983) suggested that the ultramafic rocks were emplaced during the waning stages of volcanism.

Important nickel sulfide mineralization appears to be associated with the ultramafic bodies, especially those emplaced in the metasediments. The Thompson-Fox River belt is separated from the Kisseynew belt by a well defined fault zone, the Setting Lake-Moak Lake shear zone (Stauffer, 1984).

REGIONAL EARLY PROTEROZOIC TECTONIC HISTORY

Huronian taphrogeny

Apparently the first major Early Proterozoic tectonic activity in the Midcontinent study area was a northeast-trending rifting event, interpreted from a sequence of rift-related, continental margin sedimentary, volcanic, and plutonic rocks. This activity is best known east of the study area from the rocks of the Huronian Supergroup of southeast Ontario. The age of this sequence is constrained by the ages of the underlying Creighton Granite, $2333^{+33}/_{-22}$ Ma (Frarey and others, 1982), and cross-cutting dikes of the Nipissing Diabase, 2150±50 Ma (Van Schmus, 1965). To the south and west the continental margin that developed at that time may be delineated by a sequence of supracrustal rocks that have been correlated with the Huronian Supergroup (fig. 3a). These include the Chocolay Group of Northern Michigan (correlated with the Huronian Supergroup by Young, 1983), the Mille Lacs Group of central Minnesota (correlated with the Chocolay Group by Morey, 1983), a banded-iron formation and layered mafic pluton, and a rhyolite that yielded a U-Pb age of about 2300 Ma (W. R. Van Schmus, personal commun., 1986) in northwest Iowa, the Nemo and Estes groups and Bluebird and equivalent units (Kurtz, 1981) in the Black Hills, the Deep Lake and Lower Libby Creek groups of southeast Wyoming (correlated with the Huronian Supergroup by Young, 1975), and the Red Creek Quartzite of northeast Utah (correlated with the Lower Libby Creek Group by Sears and others, 1982).

Similar miogeoclinal supracrustal rocks, which were deposited on the Archean basement on both the east and west flanks of the present-day Trans-Hudson orogenic belt, may be correlative with the Huronian sequence. The Hurwitz Group (correlated with the Huronian Supergroup by Young, 1975) has been correlated with many other sequences in Saskatchewan and Manitoba including the Amer and Wollaston groups (Lewry and others, 1985). Green and others (1985) suggested that these rocks were emplaced between 2000 and 2400 Ma. This age would make these approximately the same age as the Huronian Supergroup. This may be the case for lower units; however, some of these supracrustal rocks (e.g. the Ameto and "Post Ameto Complex" of the Cree Lake zone) are probably the product of renewed miogeoclinal deposition about 1900 Ma.

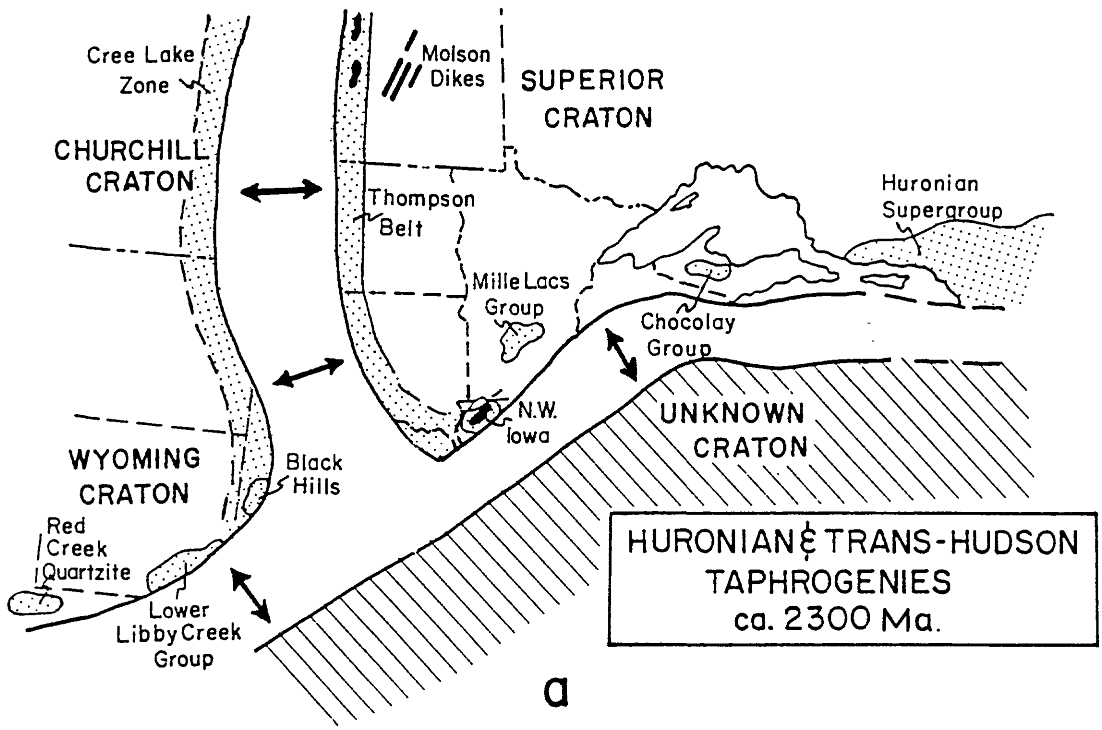
Penokean/Trans-Hudson taphrogeny

A second period of extensional tectonics affected the region and led to the emplacement of supracrustal rocks between about 2160 and 1950 Ma. The maximum age is defined by mafic dikes and sills, including the Nipissing Diabase of Ontario (dated 2160±60 Ma by Fairbairn and others, 1969), the Kenora-Kabetogama dikes of northern Minnesota (dated at 2120±67 Ma by Beck and Murthy, 1982), and probable coeval rocks, considered the product of extensional tectonics by Fairbairn and others (1969) (fig. 3b). The minimum age is constrained by the 1910±10 Ma age (recalculated from Van Schmus, 1976) of a felsic intrusion in the Hemlock Formation, Marquette Range Supergroup of Michigan. Along the trend of the Trans-Hudson belt the Molson dikes and probably other Thompson belt mafic plutons were emplaced about 1883 Ma (Heaman and others, 1986).

Graben sedimentation and associated bimodal vulcanism and plutonism produced the rocks of the Marquette Range Supergroup of Michigan and Wisconsin and the Animikie Group of Minnesota, described by many workers including Larue and Sloss (1980) and Morey (1983). These units include valuable iron resources. Contemporaneous rifting and the emplacement of supracrustal rocks possibly occurred on all margins of the Superior province, including the Labrador trough, Cape Smith-Wakham Bay belt, Belcher-Richmond Gulf zone, and the Mistassini basin. This was also a time of rifting activity along the Trans-Hudson belt, with supracrustal sedimentation on the eastern (Thompson-Fox River belt) and western (Cree Lake zone) margins.

Penokean/Trans-Hudson orogeny

The Penokean ocean, on the southern margin of the Superior craton, closed with a continent-island arc collision between about 1860 Ma and 1820 Ma (Van Schmus and Bickford, 1981) (fig. 3c). The newly accreted terrane, the Penokean Volcanic belt (or Wisconsin Magmatic Terrane of Sims, 1985), is presently best exposed in central Wisconsin, where it is dominated by metamorphosed basalt, rhyolite, and andesite, intruded by plutonic rocks ranging in composition from quartz diorite to granite (Schulz, 1984). The terrane shows no evidence of being floored by Archean rocks, but includes at least one exotic Archean block. Late stage vulcanism and plutonism may have continued to about 1760 Ma.



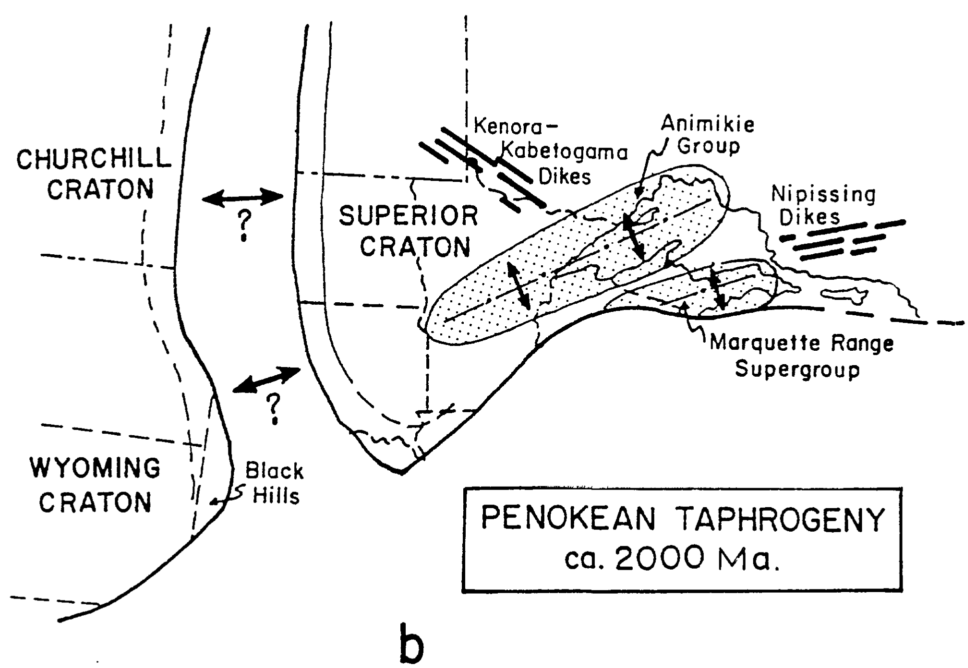
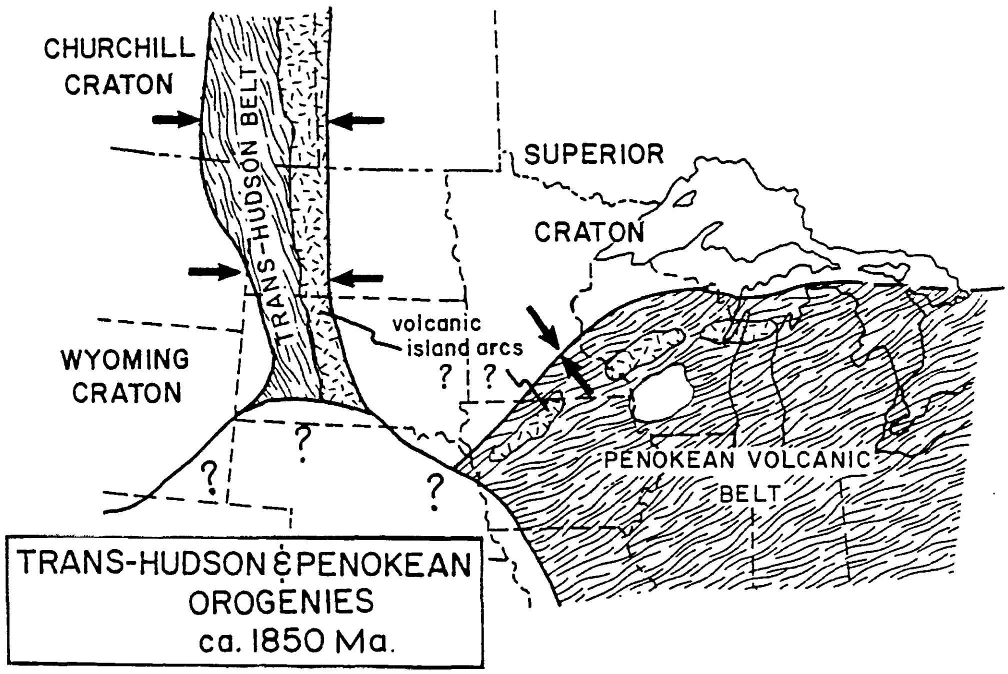
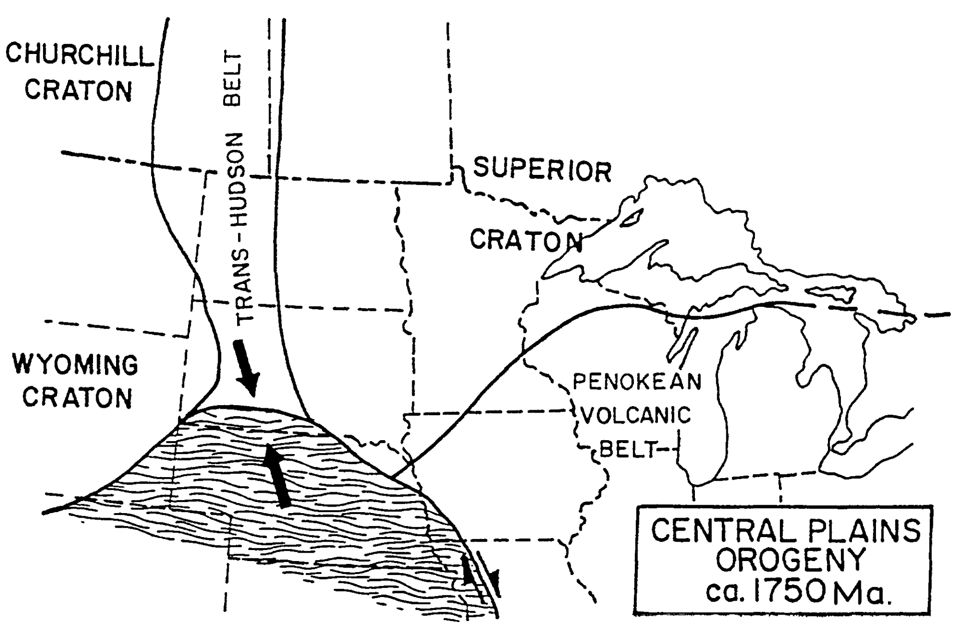


Figure 3. Possible sequence of Proterozoic tectonic events and the development of north-central U.S. during the (a) Huronian and Trans-Hudson taphrogenies, (b) the Penokean taphrogeny, (and on next page) (c) the Trans-Hudson/Penokean orogenies, and (d) the Central Plains orogeny.


CHURCHILL CRATON
TRANS-HUDSON BELT
SUPERIOR
CRATON
volcanic island arcs
WYOMING CRATON
PENOKEAN VOLCANIC BELT
TRANS-HUDSON & PENOKEAN OROGENIES ca. 1850 Ma.

c


CHURCHILL CRATON
TRANS-HUDSON BELT
SUPERIOR
CRATON
WYOMING CRATON
PENOKEAN VOLCANIC BELT
CENTRAL PLAINS OROGENY ca. 1750 Ma.

d

The Trans-Hudson ocean also closed at about the same time, accreting a sequence of oceanic island arcs and associated ocean floor and sediments between the Superior and "Churchill" cratons. This newly accreted terrane is dominated by mafic and intermediate composition volcanic and plutonic rocks and associated metasediments and large late-stage felsic plutons. At least one exotic Archean block, the Hansen Lake block, was also caught in this orogeny.

Central Plains orogeny

The fourth major episode of Early Phanerozoic tectonism occurred between about 1800 and 1700 Ma with the accretion of new crust south of the Trans-Hudson orogenic belt and Archean Wyoming province and southwest of the Penokean orogenic belt (fig. 3d). This terrane, known as the Central Plains orogenic belt (Sims and Peterman, 1986), is dominated by metavolcanics and associated metavolcanics but produced felsic plutonism and vulcanism in the Trans-Hudson and Penokean belts.

Mazatzal taphrogeny/orogeny

Rocks from Arizona and New Mexico, described and dated by Silver (1978), suggest another continental rifting event and the associated ocean development and emplacement of a suite of supracrustal rocks in that area between about 1700 and 1680 Ma. The closing of the Mazatzal ocean occurred between about 1680 and 1625 Ma (Van Schmus and Bickford, 1981) and included the probable accretion of new continental crust and the emplacement of volcanic and plutonic rocks in the central Midcontinent.

Middle Proterozoic tectonic activity

Two large-scale crustal heating events led to crustal melting and felsic vulcanism and epizonal plutonism over much of the continent between about 1480-1430 Ma and about 1390-1340 Ma (Van Schmus and others, in press). This was followed by the opening of the Grenville ocean on the eastern margin of the continent beginning about 1340 Ma, with associated extension-related development of the Sibley clastic basin in southern Ontario. The Grenville orogeny between about 1200 Ma and 1000 Ma, and the Llano orogeny (on the southern cratonic margin) about 1000 Ma, led to the development of the Midcontinent Rift system about 1000 Ma.

GEOLOGIC HISTORY OF THE TRANS-HUDSON OROGENIC BELT

While many of the details of the events that led to the development of the Trans-Hudson orogenic belt are not well understood, there is a basic scenario that seems to be generally accepted by most current workers. As generally outlined by Green and others (1985), this scenario begins with Early Proterozoic extensional tectonics leading to the initiation of rifting and associated sedimentation, vulcanism, and plutonism along the western margin of the Superior craton. The sediments and bimodal volcanics of the Thompson-Fox River belt (and probably also of the Cree Lake zone), associated mafic and ultramafic plutons, and the Molson dikes were emplaced during this taphrogeny. Recent U-Pb age determinations on Molson intrusives yielded an age of about 1883 Ma (Heaman and others, 1986). This activity is probably coeval with taphrogenic supracrustal rocks on all margins of the Superior Craton, including the Cape Smith-Wakam Bay belt, Belcher Island-Richmond Gulf zone, Labrador trough, Otis Mountain-Mistassini area, Marquette and associated troughs, and Animikie basin. Similar sequences of the same age are also found on the margins of the Wyoming, Churchill, and Slave provinces.

The rifted western margins of the Superior province continued to develop with the opening of an ocean basin, the Manikewan Ocean of Stauffer (1984), continuing until shortly after about 1900 Ma when Phanerozoic-style subduction was initiated, and volcanic arc development began in the Glennie, LaRonge-Lynn Lake, and Flin Flon terranes. As the ocean closed and the volcanic arcs grew, deep-water, eugeoclinal sediments spread out into the diminishing ocean basins of the Reindeer-South Indian Lake and Kisseynew belt. Trans-Hudson orogenic activity continued, with tectonism in the various domains as they were compressed and jostled about between the converging Superior and Churchill (Western) provinces. Syntectonic plutonism observed in all Trans-Hudson domains probably records the major period of this interaction (J.F. Lewry, oral commun., 1985). Preliminary U-Pb age data by Bickford and Van Schmus (1985) yielded ages for felsic volcanic and plutonic rocks of the Glennie Lake and LaRonge-Lynn Lake domains. They concluded that the igneous activity began with vulcanism about 1885 to 1875 Ma followed by plutonism between about 1870 and 1850 Ma, including some of the rocks of the Wathaman Batholith. Shearing and compression continued to some degree beyond that time, expressed by the emplacement of the remainder of the massive, late syntectonic Wathaman-Chipewyan batholith. It was emplaced about 1863 Ma, initiating a period of major plutonism throughout the Trans-Hudson orogenic belt, followed by undeformed, late stage, felsic plutons emplaced between 1850 and 1835 Ma (J.F. Lewry, oral commun.). The area of the Trans-Hudson orogenic belt was subjected to thermal overprinting about 1750 Ma (Bell and Bickerman, 1985; Lewry and others, 1986). This included apparent late magmatism in the Thompson belt (Krogh and others, 1985) and may relate to Central Plains orogenic activity to the south.

SOUTHERN EXTENSION OF THE TRANS-HUDSON OROGENIC BELT

The southern extension of the Trans-Hudson orogenic belt has been recently investigated by Green and others (1979, 1985), Peterman and Zartman (1985), and Klasner and King (1986). Since the Precambrian rocks of the orogenic belt are buried beneath Phanerozoic sediments in southern Manitoba and Saskatchewan and the Dakotas, its extent and composition must be inferred by interpretation of potential field geophysical data, limited deep reflection seismic data, and sparse drill data. These workers generally agree with the interpretations of Green and others (1985). They extended the Thompson-Fox River belt southward to at least 46° latitude, based on its expression as a "quiet" zone of low-amplitude magnetic anomalies. To the west, a shear zone separates the Thompson-Fox River belt from a volcanic island arc sequence that may be a continuation of the Flin Flon-Snow Lake belt. This domain is delineated by a series of relatively high-amplitude, north-south trending magnetic anomalies and may continue south to the southern terminus of the Trans-Hudson orogenic belt in southern South Dakota. To the west of another probable shear zone, the Glennie Lake domain continues southward to about 41° N., bounded on the west by the southern extension of the LaRonge-Lynn Lake volcanic arc domain which continues to about 50° N. An Archean microplate similar to the Hanson Lake block has also been identified beneath Phanerozoic sediments in North Dakota by Klasner and King (1986) who cited a 2900 Ma zircon age for gneiss cored in north-central North Dakota (Peterman and Goldich, 1982). Other such Archean microplates may also exist.

The volcanic island arc sequence is in turn bounded by the southern extension of the Reindeer-South Indian back-arc basin sequence, which Green and others believe continues southward to at least 44° N. The magnetic expression of this terrane is a sequence of broad, low-amplitude anomalies without a pronounced orientation. The Cree Lake zone and western Churchill craton extend south to about 50° N where they abut the Archean Wyoming craton. Metasediments exposed in the Black Hills may represent rock units emplaced in a tectonic environment similar to and coeval with those in the Cree Lake zone. Recent Nd-Sm mantle separation ages by Burwash and Frost (in press) suggest that the two Archean terranes are continuous.

The southern limit of the Trans-Hudson orogenic belt is probably located in southern South Dakota where it is truncated by the Central Plains orogenic belt, a tectonically similar orogenic belt emplaced between 1700 Ma and 1800 Ma. The exact location and the nature of the contact between these two orogenic belts is not known.

RELATIONSHIP OF THE TRANS-HUDSON BELT TO THE PENOKEAN AND CENTRAL PLAINS OROGENIC BELTS

One key to understanding the history of the Trans-Hudson orogeny is its relationship to the Penokean and Central Plains orogens. The incomplete nature of Precambrian lithologic and age data in the north-central United States makes this relationship difficult to determine. The area that is now the Trans-Hudson belt was subjected to extensional tectonics, rifting, and the development of the Manikewan Ocean, perhaps as long ago as 2300 Ma but more likely between about 2100 and 1900 Ma. This taphrogenic activity is roughly coeval with similar activity along the Penokean volcanic belt. The closing of the Manikewan Ocean and the Trans-Hudson orogeny took place between about 1885 Ma and 1850 Ma (J.F. Lewry, oral commun., 1985) with late stage plutonism continuing to about 1835 Ma. The closing of the Penokean Ocean during the Penokean orogeny probably took place between 1890 Ma and 1830 ma (Van Schmus and others, in press), whereas late stage plutonism continued until at least 1810 Ma and possibly 1760 Ma. Therefore, the taphrogenic and orogenic activity that led to the formation of the Trans-Hudson and Penokean volcanic belt were probably roughly contemporaneous (see fig. 3b, c).

The ages of the rocks of the Central Plains province, adjacent to the Trans-Hudson belt, range from 1800 to 1700 Ma (Van Schmus and others, in press). This most likely represents the age of accretion by orogenesis. No evidence has been discovered to date of rifting, after the Trans-Hudson and Penokean orogenies and prior to this 1800-1700 Ma Central Plains orogeny in the region, but rocks characteristic of rifting would lie deeply buried by younger sediments and may still exist. Alternatively, the Trans-Hudson and Penokean orogenies may have developed along oceanic plates that closed along a complex set of transform faults (fig. 3b, c). There is no evidence to favor one interpretation over the other.

MINERALIZATION IN THE TRANS-HUDSON OROGENIC BELT

Mineral deposits of economic significance occur in the exposed part of many of the terranes in the Trans-Hudson orogenic belt. Ore minerals include nickel, platinum, copper, zinc, gold, silver, iron, lithium, cobalt, cadmium, selenium, lead, and tellurium. Because much of the mineralization is controlled by host rocks within specific lithotectonic domains of the Trans-Hudson belt, it is reasonable to expect these mineral suites to be present in the subsurface extension of their host domains.

LaRonge-Lynn Lake belt

Economic mineralization in the Lynn Lake area, described by Lang and others (1981), includes nickel, platinum, cobalt, and copper, occurring as massive or breccia-type concentrations, disseminations, or stockworks in mafic intrusives. The minerals present in these deposits include pyrrhotite, pentlandite, and chalcopyrite. Cobalt is present in association with the nickel and copper mineralization. In Saskatchewan, north of Lac LaRonge, the Anglo-Rouyn mines produce copper, nickel, gold, and silver from ultramafic intrusions in gneiss.

Kisseynew domain

The most valuable mineral deposits known in the Kisseynew domain are produced by the Sherritt-Gordon mines, and include copper, zinc, gold, and silver. The pyrrhotite-chalcopyrite-sphalerite ore is produced from the contact between gneissoid quartzite and hornblende gneiss (Lang and others, 1981).

Hanson Lake block

The Hanson mine in the Hanson Lake block has produced zinc, lead, copper, gold, silver, and cadmium. Lang and others (1981) reported that the ore is concentrated in a sheared tuff between two dacite flows.

Flin Flon-Snow Lake belt

A number of mines in the Flin Flon Lake area produce gold, silver, zinc, and copper from shear zones in quartz porphyry and faulted, metamorphosed mafic volcanics. Cadmium, selenium, tellurium, and lead are also recovered from these deposits. Similar deposits occur in the eastern part of the Flin Flon-Snow Lake domain, near Snow Lake and Herb Lake. Lithium is also produced in this area.

Thompson-Fox River belt

"The largest nickel deposits associated with ultramafic rocks are those of the Thompson belt," according to Lang and others (1981). Most of the ore bodies occur in a series of colinear lenticular pods of Alpine-type peridotite surrounded by metasediments and gneisses. Sulfide mineralization is commonly associated with dike-like granites and pegmatites that intrude the older ultramafic rocks. Nickel and copper are the two primary minerals produced in the belt; however, platinum and cobalt are also locally economically significant.

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