# F. Appendices

# Titles and Abstracts of Recent Saskatchewan Energy and Mines Publications and Papers by Staff of the Saskatchewan Geological Survey

## 1. Reports

*Kreis, L.K. (1991): Stratigraphy of the Jurassic System in the Wapella-Moosomin area, southeastern Saskatchewan; Sask. Energy Mines, Rep. 217, 90p.*

*Scott, B.P. (1991): Metallogenic Map Series: Reindeer Lake South NTS area 64D; Sask. Energy Mines, Rep. 253, 18p, (accompanied by 1:250 000 scale map).*

## 2. Miscellaneous Reports

*Mineral Resources of Saskatchewan; Sask. Energy Mines, Misc. Rep. 91-5, 76p.*

*Bennett, R.W. (1991): Assessment Work Catalogue, Saskatchewan; Sask. Energy Mines, Misc. Rep. 91-6, 96p.*

## 3. Open Files

*Coombe Geoconsultants Ltd. (1991): Base Metals in Saskatchewan; Sask. Energy Mines, Open File Rep. 91-1, 218p.*

*Pearse, G.H.K. (1991): Building Stone Potential in the Creighton-Pelican Narrows Region of Saskatchewan; Sask. Energy Mines, Open File Rep. 91-3, 32p.*

*Roberts, R.G. (1990): Structural Controls of the Box and Athona Deposits, Beaverlodge Area, Saskatchewan; Sask. Energy Mines, Open File Rep. 90-2, 17p.*

## 4. Miscellaneous Publications

*Mineral Resource Map of Saskatchewan (1990): Sask. Energy Mines, 1990 Edition (in large (71 x 101 cm) and small (28 x 38 cm) formats).*

## 5. External Papers

*Ashton, K.E. and Leclair, A.D. (1991): Foliate: a useful term to complement the textural classification of foliated metamorphic rocks: Reply; Can. J. Earth Sci., v28, p829-831.*

*Delaney, G.D. (1991a): Gold in the Glennie Domain, Lower Proterozoic Trans-Hudson Orogen, northern Saskatchewan; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p11-12.*

When it is placed in production in November 1991, the Seabee deposit will become Saskatchewan's fifth and potentially largest gold mine. It will also be the first gold mine in the underrated and commonly overlooked Glennie Domain which encompasses over 40 gold occurrences, many discovered in recent years. All known gold showings are in or adjacent to greenstone belts. By far the greatest number, including the Seabee deposit, have been found in the extensive Pine Lake Greenstone Belt. For all greenstone belts which have been investigated the volcanics are primarily of tholeiitic composition and were formed in juvenile island arc settings. Host rocks comprise volcanics, plutons including both subvolcanic as well as younger post-volcanic suites, volcaniclastics, sediments and migmatites. Metamorphic grade is upper greenschist to amphibolite facies.

Most gold showings are structurally controlled (i.e. Seabee, Georges Lake and Manawan); a few are intrusive hosted (i.e. Kalix, and Jena around the Brownell Lake Pluton) and there is one example of a sediment-hosted occurrence (Pine Lake Joint Venture). Gold also occurs in association with volcanogenic massive sulphides. Structurally controlled mineralization typically occurs in secondary or higher order structures, proximal to major discordances, where they transect zones of lithologic heterogeneity. Gold is found within and adjacent to quartz veins; many of these are multistage although not all stages are mineralized. The element association of the gold-quartz veins is variable. There do, however, appear to be some locally distinctive associations. For example, tourmaline is found in most veins within or adjacent to the Laonil Lake intrusive complex; arsenopyrite is characteristic of showings (both structural and plutonic hosted) in the Brownell-Wapawekka Lakes Greenstone Belt. Timing of mineralization has varied. The Glennie Domain has a high potential for the discovery of other significant gold deposits.

*Delaney, G.D. (1991b): Footwall Fragmentals: A Key to understanding the evolution of the feeder system to the Sullivan orebody; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p37-38.*

The Sullivan deposit lies near the top of the Middle Proterozoic, Lower Aldridge Formation, a sequence of predominantly fine-grained, argillaceous siliciclastic sediments which accumulated in an abyssal setting. The 160 million tonne Sullivan massive sulphide deposit is approximately 2000 m long in a north-south direction by 1600 m wide, and has the shape of a convex lens that dips moderately east. It can be subdivided into two parts: a western, massive part which is up to 100 m thick and, separated by a transition zone, an eastern bedded part which consists of five bedded sulphide intervals intercalated in sedimentary rocks. A large volume of fragmental rock occurs in the footwall to the Sullivan deposit and defines the first stage in the evolution of the feeder system; a minor amount of these rocks is found in the hanging wall.

There are two textural varieties of footwall fragmental. Pebble fragmental, the most abundant type, comprises subangular to subrounded, granule- to predominantly pebble-sized fragments, forming a condensed to disrupted framework. The second type, chaotic breccia, consists of angular, granular- to boulder-size fragments forming a generally intact to locally disrupted framework. Underneath the southern half of the orebody, pebble fragmental occurs in several discrete bodies most of which crosscut stratigraphy. Fragmental dykes range in height and width from tens of centimetres to tens of metres, pinch and swell in thickness and locally bifurcate. In some dykes, clasts are characterized by wispy terminations. The lithologic spectrum of clasts matches that of the encompassing Lower Aldridge sediments although many of these clasts have been subjected to subsequent tourmalinization, albitization or chloritization. Locally near the margins of the fragmental bodies there are angular boulder size fragments which are of the same composition as the surrounding wall rocks. In the bedded sequence, below some of the cross-cutting fragmentals, there are commonly micro-faults and sand or silt dykelets; in rare cases stratiform apophyses occur at the top of the cross-cutting fragmentals.

Beneath the northern half of the orebody, to the west of the transition zone, the pebble fragmental is a more or less continuous body characterized by an irregular top and base as well as by variable thickness. The basal contact is slightly unconformable to distinctly cross-cutting and in the footwall there are commonly cross-cutting fragmental dykes. Also within this basal zone, some areas of angular fragments up to a few metres wide contain fragments with bedding in the same attitude as the adjacent undisturbed sediments. Elsewhere bedding has been rotated. The top of this part of the pebble fragmental is also highly irregular. Locally there is a conformable contact with overlying sediments of the Lower Aldridge Formation with up to 15 m of sediments occurring between the top of the fragmental and the sulphide footwall. More commonly, however, an irregular hummocky discordance characterizes the top of the fragmental and at several localities the sulphide footwall contacts the fragmental. Textural variations are illustrated by a framework ranging from condensed to disrupted and clasts from granule to pebble size. Locally, at the base, near the sides and in zones where chaotic breccia forms an admixture with the pebble fragmental, there are larger fragments and in places particularly near the contacts, there is a well developed clast fabric.

East of the transition zone, underneath the northern part of bedded ore, the pebble fragmental is a more regular, generally stratiform body characterized by an intact framework. Although most clasts are of fine-grained sedimentary rocks of the Lower Aldridge Formation, there are also rare isolated tourmalinite clasts. This stratiform fragmental, which is up to 30 m thick near the transition zone, gradually thins to the northeast. The basal contact of the fragmental sheet varies from conformable to slightly disconformable. Immediately east of the transition zone, there is up to 15 m of bedded sediment between the top of the fragmental sheet and the sulphide footwall; the thickness of this bedded interval gradually decreases to the northeast until sulphide rests directly on fragmental. Along its southern boundary the thickness of the stratiform pebble fragmental decreases abruptly; to the north relationships are masked by subsequent faulting.

A model for the early evolution of the Sullivan deposit is presented. The Lower Aldridge Formation, a sequence of predominantly fine-grained sediments, was deposited in a basinal setting. Elevated pore pressure developed in the sediment pile; contributing factors may have included rapid rate of sedimentation, an increase in thermal gradient and methane generation by anaerobic bacteria. Abrupt release of pore pressure formed cross-cutting fragmental dykes, some of which vented at the sediment water interface forming local slump deposits. Beneath what would become the western part of the orebody, growth and amalgamation of fragmental dykes resulted in a large mound of variably fragmented sediments which subsequently slumped into a northeast tending trough. During this phase an initial restricted pulse of tourmalinization occurred. Slumping was followed by subsidence of the core of the western fragmental complex and sedimentation continued. Rejuvenation of the core zone of the fragmental complex resulted in the development of new zones of fragmentation reaching the sediment water interface concurrently with the influx of tourmaline-rich brines. This was followed by the passage of metal rich brines which formed the orebody at or very close to the sea floor.

*Delaney, G.D., Czornobay, B. and Earle, S. (1991): Utilization of image processed aeromagnetic and Landsat thematic image data for the improved understanding of the lithologic and structural characteristics of the Glennie Domain; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p11.*

The Saskatchewan Geological Survey has completed a pilot study which investigated the use of image processed aeromagnetic data and filtered Landsat thematic mapper data for enhanced understanding of the lithologic and structural characteristics of the Glennie Domain. This survey also helped identify structural and lithologic features which are important from a mineral exploration perspective. Enhancement of aeromagnetic data, including the creation of multi-colour magnetic anomaly maps and shadow images was achieved by utilizing the software package RTI-CAD of GEOPAK SYSTEMS of Toronto. Landsat thematic image data was processed through digital

lineament detection filters in four directions with the ARIES-II software of DIPLIX Technologies of Ottawa. RTI-CAD was also used to create multi-layered images that integrated enhanced aeromagnetic, Landsat lineament and geological maps.

Several data sets were utilized. Aeromagnetic data from federal-provincial surveys flown at a line spacing of approximately 400 m was regridded to 200 m and then processed for the whole Glennie Domain. From the resulting magnetic anomalies and shadow maps it was possible to define major scale structural features and the morphology of many lithologic entities. For example, basic to ultrabasic intrusives in the central part of the domain, most of which contain structural-hosted gold showings, are defined by magnetic highs. These intrusives include the Laonil Lake intrusive complex, the Eisler Lake intrusion, the Leland Lake metagabbro and the Robinson Lake amphibolite. Detailed proprietary aeromagnetic surveys, flown at line spacings of 100 m to 200 m were processed for two areas: around Brownell Lake and between Laonil Lake and the junction of the Churchill and Reindeer Rivers. The resolution of features from the processed data of these surveys was greater and it was possible to delineate higher order structures and subtle lithologic features not apparent from the federal-provincial surveys flown at a wider flight line spacing. As an example, the major east-west trending Hartley Shear zone, which together with subsidiary faults has played an important role in localizing gold mineralization in the Brownell Lake area, is defined by a narrow, linear magnetic high.

Additional understanding of the character and distribution of high strain zones was obtained by integrating enhanced magnetic data with lineament maps derived from Landsat thematic mapper data and geologic maps. Northeast- to southeast-trending high strain zones of various magnitudes and which apparently formed late in the thermotectonic history of the domain, played a key role in localizing gold mineralization.

*Froese, E. and Ashton, K.E. (1991): Alteration zones in the Kisseynew Gneisses of Saskatchewan and Manitoba; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p25-26.*

The Kisseynew gneisses represent metamorphosed equivalents of lower-grade rocks present in the Flin Flon volcanic belt. In recent work, the Kisseynew gneisses have been mapped using the stratigraphic subdivisions established in the Flin Flon belt. A noteworthy feature is the presence of felsic volcanic rocks, previously regarded as metasediments. There are numerous occurrences of altered rocks; the precursors are thought to be rocks hydrothermally altered prior to metamorphism. Four types of alteration can be distinguished: 1. carbonatization (calc-silicate rocks); 2. moderate Fe-Mg metasomatism (cummingtonite-bearing rocks); 3. intense Fe-Mg metasomatism (cordierite-anthophyllite rocks); and 4. aluminous alteration (sillimanite-bearing rocks).

Sulphide deposits in carbonatized rocks commonly consist mainly of pyrite and pyrrhotite. Some rocks indicating Fe-Mg metasomatism and aluminous alteration are associated with base metal sulphides. Any possible zonation of alteration types has been obscured by deformation. The recognition of a greater proportion of volcanic precursors and the presence of altered rocks enhance the exploration potential of a substantial area in Saskatchewan and Manitoba.

*Gent, M.R. (1991a): Diamonds in Saskatchewan; Alta. Geol. Surv. and B.C. Energy, Mines Petrol. Resour., 27th Forum on the Geology of Industrial Minerals, May 1991, Banff, Prog. Abstr.*

*Gent, M.R. (1991b): Diamond Exploration in Saskatchewan; CIMM 93rd Annual General Meeting, May 1991, Vancouver, Prog. Abstr.*

The diamond industry has an attractive long term past and projected market stability. The exploration and mining costs for diamonds tend to be low. The industry has a high success factor in comparison to other mineral exploration.

The presence in Saskatchewan of eight kimberlite pipes of probable late Albian age has been reported. An abundance of aeromagnetic anomalies possibly attributable to kimberlite pipes have been identified and it is anticipated that industry has acquired reasonable proof of the presence of twenty to forty or more kimberlite pipes in Saskatchewan. Historical reports of diamonds, the discovery of kimberlite pipes and these aeromagnetic anomalies indicate the Phanerozoic Basin and some parts of the exposed Shield in Saskatchewan have an excellent potential for the occurrence of economically exploitable diamond deposits. The presence of some igneous minerals found in some salt solution breccias also indicates the probable occurrence of extensive diatreme activity during the Devonian.

A Laramide Orogeny-induced crustal hinging or arching of the eastern margin of the Phanerozoic Basin and probably dextral wrenching-induced arching and faulting within the basin are proposed as major factors in the emplacement of Cretaceous or younger kimberlites. Zones of crustal weakness between subcratonic Archean blocks and internal faults are also thought to be significant controlling factors in the location of kimberlites in Saskatchewan.

Mapped aeromagnetic anomalies interpreted as being possibly due to kimberlite pipes generally tend to be concentrated in areas underlain by a basement of or with components of Archean age. Within Saskatchewan, these anomalies occur within the probable Trans-Hudson Orogen zone, the Rae-Hearn Craton margin, and the northeast flank of the Elkpoint Basin. Recognized areas of potential for kimberlite emplacement are the Phanerozoic basin margin, the western limit of the Superior Province adjoining the Churchill Province, and a swath approximately 150 km wide along the NE-SW trending Shaunavon linear and other areas of inner basin arching.

*Harper, C.T. (1991): The Deception Lake lead-zinc discovery; A base metal enriched iron formation; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr. p10.*

Lead-zinc (± silver, gold) mineralization was discovered in 1989 near Northwest Bay of Deception Lake, 200 km north-northeast of La Ronge, Saskatchewan. The discovery was made in a little ex-

plored part of the Rottenstone Domain which comprises trondhjemitic granitoid and migmatitic metasedimentary gneisses and the extensive Wathaman Batholith. Northeast Bay lies in a transitional zone between granitoids to the northwest and metasediments to the southeast. Paleosomal remnants rarely compose more than twenty-five percent of the rocks, and include: psammitic to pelitic and amphibolitic gneisses and cal-silicate rocks. The most economically significant rock type is a calcareous, silicate-sulphide facies iron formation assemblage which hosts the lead-zinc-silver-gold mineralization. These rocks occupy an elongate, northeast-trending, overturned, moderately northwest-dipping, and shallow to moderately northeast-plunging, synformal $D_2$ fold. Syntectonic pegmatitic trondhjemite sheets are generally parallel to the axial surface of the regional fold.

The iron formation, which is found throughout the area, typically consists of diopside-quartz-plagioclase $\pm$ garnet $\pm$ graphite with an average of 10% finely disseminated pyrrhotite, but locally contains pods and lenses of massive pyrrhotite. Gahnite (zinc spinel), pyrite and chalcopyrite are rare. Thickness and composition of the iron formation is very uniform and can be traced by mapping and geophysics for many kilometres. The lead-zinc mineralization is associated with minor interlayered biotite and amphibolite schists, biotitic and sulphide-bearing diopsidites (calc-silicates) and impure marbles, which have a more restricted distribution. Pegmatitic trondhjemite, which intrudes the iron formation, is commonly tinted green and contains coarse pyrite, galena and sphalerite locally.

Galena and sphalerite occur as disseminations but more typically occur as millimetre to centimetre thick layers alternating with siliceous and calc-silicate layers. Sphalerite concentrations are greatest in the diopsidite rocks, whereas the highest silver and gold values are associated with the galena-rich sections.

The stratiform and layered character of the mineralization and its association with a regionally extensive iron-rich sedimentary assemblage (i.e. an iron formation) indicates that it formed in a sedex type environment. The skarn-type mineral assemblage is characteristic of calcareous iron silicate facies iron formation assemblages that developed during regional metamorphism, not by contact metamorphism. The Deception Lake iron formation and base metal mineralization is not unusual. Similar rocks and occurrences can be found elsewhere in the Rottenstone Domain (Zn-Cu Brown claim, Paskwachi Bay, Reindeer Lake), in the Crew Lake Belt (Zn-Pb-Ag Borys Lake prospect) and MacLean Lake Belt (Zn-Cu McKenzie deposit, Brabant Lake) of the La Ronge Domain and probably the Kisseynew Domain. This group of stratiform base metal deposits associated with iron-rich sediments has many world class deposits (e.g. Broken Hill, Sullivan, Aggenays and Gamsberg). Thus, a potential exists for finding economic base metal deposits of this type.

*Kreis, L.K. (1991): Depositional history of the Jurassic System and hydrocarbon accumulations in the Wapella-Moosomin area, southeastern Saskatchewan; in Christopher, J.C. and Haidl, F.M. (eds.), Sixth International Williston Basin Symposium, Sask. Geol. Soc., Spec. Publ. No. 11, p165-178.*

The Triassic/Jurassic section of southeastern Saskatchewan is an unconformity bounded sequence between the Mississippian subcrop and the Cretaceous Mannville Formation. Four lithostratigraphic units are recognized in the Jurassic of southeastern Saskatchewan: the Watrous, Gravelbourg, Red Jacket and Rierdon formations. The Red Jacket is the facies equivalent to strata between the lower member of the Gravelbourg and the Rierdon Formation.

The Triassic/Jurassic(?) red beds of the lower member of the Watrous Formation represent the earliest post-Mississippian deposits in the study area. They appear to have been laid down in a restricted marine environment but with repeated exposure, oxidization, and reworking. This phase was followed in the Bajocian by less restricted marine deposition, represented by anhydrites, dolomites and dolomitic mudstones of the upper member of the Watrous Formation and dolomitic limestones (unit A ) of the lower member of the Gravelbourg Formation. Interbedded clastics and carbonates (Unit B) of the lower Gravelbourg Formation were deposited in a near-normal marine environment. In contrast, clastics and subordinate carbonates of the succeeding Red Jacket Formation were deposited during the Bajocian and Bathonian in depositional environments ranging from freshwater to brackish-water to open marine. This variation was probably caused by minor yet frequent fluctuations in sea level, causing broad shifts in the depositional environments. The unstable period of Red Jacket deposition was followed by a major marine transgression and shales of the Rierdon Formation were laid down in the study area during the Bathonian to Callovian.

Most Jurassic hydrocarbon production in southeast Saskatchewan is from the Rocanville and Moosomin members of the Red Jacket Formation in the Wapella-Moosomin area. Oil shows are also in the lower member of the Gravelbourg Formation; however, only one well is presently producing from this unit.

The dissolution of salt beds from the Middle Devonian Prairie Formation appears to have played a significant role in the depositional and hydrocarbon accumulation history of the Wapella-Moosomin area.

*Kreis, L.K., Gent, M.R. and Vigrass, L.W. (1991): Subsurface brines in southern Saskatchewan; in Christopher, J.C. and Haidl, F.M. (eds.), Sixth International Williston Basin Symposium, Sask. Geol. Soc., Spec. Publ. No. 11, p283-292.*

Subsurface brines with anomalously high calcium and magnesium content are widespread in reservoirs of Cambrian to Devonian age in southern Saskatchewan. Geographically, the anomalous brines are reported most commonly in the potash mining area around Saskatoon (lat. 52° N, long. 106° 30' W) and in the southeastern part of the province (lat. 49° 30' N, long. 103° W). Some of the brines occur as potash-mine inflow and these have been shown to have anomalously high contents of bromine, iodine and strontium. Origin of the brines is uncertain but they appear to have undergone a complex evolutionary history that may have involved dissolution of evaporite minerals in the Prairie Formation.

Data on characteristics of the reservoirs containing the brines are limited. Analysis of mechanical logs and a few drill-stem tests show that some of the reservoirs

have significant thicknesses and permeabilities, and at least one may be large enough for commercial development.

In the Michigan Basin, subsurface brines provide the raw material for a billion dollar chemical industry. Preliminary work indicates that some of the Saskatchewan brines have calcium, magnesium, bromine and iodine contents that compare favourably with concentrations of these components in the commercial brines of the Michigan Basin.

*Lewry, J.F., Thomas, D.J., Macdonald, R. and Chiarenzelli, J. (1990): Structural relations in accreted terranes of the Trans-Hudson Orogen, Saskatchewan: Telescoping in a collisional regime; in Lewry, J.F. and Stauffer, M.R. (eds.), The Early Proterozoic Trans-Hudson Orogen of North America, Geol. Assoc. Can., Spec. Pap. 37, p75-94.*

The Reindeer Zone, western Trans-Hudson Orogen, is mainly a collage of juvenile, accreted(?) Early Proterozoic oceanic arcs and arc-related terranes. Structural relations and strain variation in the Saskatchewan part of the zone suggest that the main tectonism involved extreme crustal shortening, fold/thrust stacking, and the transportation of major allochthonous sheets, some evidently soled by initially flat-lying, regionally extensive high-strain zones. These early structures are refolded about more upright north-trending folds and later, regionally more important, northeast-trending folds to produce the present gross lithostructural patterns. Early structures were modified and, in many places, oversteepened during this refolding and also disrupted by late faulting. Modification of the prior domainal subdivision of the Reindeer Zone, involving revised definition and nomenclature of lithostructural elements, is proposed to more accurately reflect gross "three-dimensional" structural geometry.

La Ronge Domain is a stack of variably strained northwest/north-dipping tectonostratigraphic packages, most of which are bounded by high-strain zones. Glennie Domain largely comprises refolded nappe sheets soled by early mylonitic porphyroclastic gneisses/schists (Guncoat and Nistowiak gneisses). Early folds in much of Kisseynew Domain were probably initially highly overturned to recumbent. Flin Flon Domain is viewed as an imbricate thrust wedge soled by the Sturgeon Weir thrust and overlain by highgrade nappes of the Kisseynew Domain.

Windows of Archean basement are exposed at the lowest structural levels in the Glennie Domain and Hanson Lake Block, below allochthonous Early Proterozoic nappe sheets and their high-strain thrust soles. Thus, it seems possible that the Reindeer Zone is partly or wholly underthrust by lower plate continental lithosphere emplaced during terminal continental collision subsequent to arc formation. Seismic investigation and dating/isotopic characterization of late-/post-kinematic granites could test this possibility.

*O'Hanley, D.S., Kyser, T.K., Rees, M.I. and Sibbald, T.I.I. (1991): The age of the auriferous granites and mesothermal gold mineralization, Goldfields area, Saskatchewan; GAC/MAC Joint Annual Meeting, May 1991, Toronto, Prog. Abstr., v16, pA92.*

Previous U-Pb zircon studies of the North Shore Plutons of the Beaverlodge area in northern Saskatchewan yielded a spectrum of ages from 2356 ± 14 Ma (MacIntosh Granite) to 1994 ± 37 Ma (Box Mine Granite). This range of ages is in contrast to field relations which indicate that the granites, some of which host lode-gold quartz veins, were temporally related during emplacement (or formation) within the dominantly metasedimentary Murmac Bay Group. Single zircon ages obtained from the Mine Granites, using the Pb-evaporation technique, indicate that the age span of 360 Ma obtained from previous U-Pb zircon studies can be attributed to mixing of inherited zircon with primary zircon formed during the crystallization of the granites. The inherited zircons consist of a population having ages of near 2900 Ma and another having ages near 2500 Ma. The zircon populations are derived from proximal basement rocks with U-Pb ages of ≈3.0 to 2.9 Ga and ≈2.6 to 2.5 Ga. Zircons having the lowest $^{207}Pb/^{205}Pb$ ratios indicate that the Mine Granites were emplaced at ≈2000 Ma. The span of Pb-Pb ages from zircons in the Mine Granites is consistent with incorporation, by the granites, of detrital zircons from the quartzites of the Murmac Bay Group, into which the granites were emplaced.

Rb-Sr ages of gangue minerals in lode-gold quartz veins within the Mine Granites suggest that the deposits formed ≈1840 to 1900 Ma. Initial $^{87}Sr/^{86}Sr$ ratios of the gangue minerals are different for each granite, but are all greater than 0.757. These high and distinct initial Sr isotopic compositions indicate that old and discrete reservoirs were tapped by the mineralizing fluids.

*Sibbald, T.I.I., O'Hanley, D.S., Kyser, K., Rees, M.I., Appleyard, E.C. and Roberts, R.G. (1991): Geology of the gold deposits, Goldfields, Saskatchewan; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p14-15.*

The Goldfields gold deposits north of Lake Athabasca are hosted by granitic rocks (mine granites) emplaced within a shelf-type supracrustal sequence of Lower Proterozoic age. The supracrustals comprise quartzites, quartz-mica schists, dolomitic marbles, diopsidic calc-silicates and cordierite-anthophyllite-biotite schists. Amphibolites of predominantly mafic composition and of presumed igneous origin form sill-like units up to a few tens of metres thick.

Granitic rocks occur both as a basement to the supracrustals (Lodge Bay Granite) and as a granitic complex emplaced within the supracrustals. The granitic complex, which includes the mine granites, comprises several intermixed units with transitional relationships, both with each other and with the supracrustal rocks. Both magmatic and metasomatic processes are thought to have been instrumental in its formation.

The area is characterized by two major episodes of deformation. The first gave rise to the dominant regional foliation and the second to the major Goldfields syncline, whose axis plunges gently south and whose axial surface is subvertical and northerly trending. Regionally, both episodes appear to be characterized by inhomogeneous strain resulting in high and low strain zones and occasionally in discrete shear zones. Peak lower amphibolite facies metamorphism, marked by major new crystal growth and

recrystallization, occurred after the first deformation. Greenschist facies retrogressive metamorphism accompanied the second deformation episode.

The mine granites comprise lenticular sheets of leucocratic, homogeneous, felsic rock typified by disseminated pyrite and cut by stockworks of gold-bearing quartz veins. The Box and Athona granites contain distinct, 0.5 cm diameter, euhedral quartz, K-feldspar (microcline-perthite) and albite megacrysts in contrast to the Frontier granite which is more nearly equigranular. Post-crystalline second deformation cataclasis is variable, being most marked in the Athona and least apparent in the Frontier.

Chemically the Box and Athona granites are peraluminous alkali feldspar, S-type granites, whereas the Frontier is a quartz rich (>80% $SiO_2$) and albite poor (<0.5% $Na_2O$) granitoid.

Structural investigations, restricted to the Box and Athona deposits, have shown three groups of quartz veins of which Group 2 are significantly auriferous. Older but related Group 1 veins parallel $D_1$ foliation, and Group 3 veins are subvertical easterly-trending, vuggy, breccia veins of much younger age. Group 2 veins occur in five orientations, although not all of these are represented in both mine granites. In the Box granite the veins occupy brittle fractures, whereas in the Athona granite they parallel brittle ductile shears. These fractures and shears are found to belong to a common strain regime, itself related to the geometry of the $D_2$ fold structures (Goldfields syncline).

Fluid inclusions in quartz from the auriferous veins in the Box, Athona and Frontier granites resemble those from mesothermal Archean lode gold deposits. They comprise primary inclusions, associated with the gold mineralizing event, and secondary inclusions reflecting the access of later fluids. Primary inclusions are characterized by a high density $H_2O$-$CO_2$ fluid, with low salinity (6 wt % NaCl equiv.) and median homogenization temperatures of 250°C to 300°C. $CO_2$ content varies from about 5 to 90 volume %, but tends to be either high or low, indicative of fluid immiscibility and thereby a possible deposition mechanism, although there are signs of inclusion necking. Inclusion data suggest minimum trapping pressures of 2.5 kb to 3.0 kb.

Stable isotopic values of vein quartz, feldspar, chlorite and tourmaline also resemble those of Archean mesothermal lode gold deposits and calculated vein water composition ($\delta^{18}O$ = 8.6, $\delta D$ = -30) is compatible with that of metamorphic water. Calculated equilibrium temperatures from quartz-chlorite and quartz-tourmaline mineral pairs are similar at around 450°C, and are thought to be the temperature of vein formation, whereas those of quartz-feldspar pairs from the host granites are typically variable suggesting disequilibrium due to later isotopic exchange.

U-Pb zircon dating of the mine granites and nearby plutons of geologically similar field age has yielded a spectrum of dates between 1977 ±37 Ma (Box granite) and 2356 ±14 Ma (MacIntosh Bay granite). Recent Pb-Pb single zircon investigations suggest that this age span of 360 Ma arises through mixing of inherited zircons with those formed during granite emplacement. The inherited zircons consist of populations with ages ca. 3.0 Ga and 2.5 Ga, which are characteristic of basement rocks in the Greater Beaverlodge area. Zircons with the lowest $^{207}Pb/^{206}$ Pb ratios suggest that the mine granites were emplaced at ca. 2000 Ma. This date is in agreement with earlier Rb/Sr whole rock isochron determinations from the same intrusive bodies. Rb/Sr ages of gangue minerals in the gold-quartz veins yield ages in the range 1840 Ma to 1900 Ma and exhibit high (>0.757) and individually distinct initial $^{87}Sr/^{86}Sr$ values suggesting that the gold mineralizing fluids tapped discrete reservoirs in old basement rocks.

Multidisciplinary studies at Goldfields outline a coherent geological history for the area and its contained gold deposits. Lower Proterozoic shelf-type supracrustals deposited on a ca. 3.0 Ga granitic basement were intruded and metasomatically replaced by synorogenic granitic fluids some 2000 Ma ago. This event was coeval with regional subduction and continental collision in the Taltson magmatic zone to the northwest. Gold mineralization occurred some 100 Ma to 200 Ma later during regional deformation, accompanied by retrogressive greenschist facies metamorphism, which led to development of northerly trending upright folds. Mesothermal auriferous metamorphic fluids, tapped from reservoirs in the older basement were introduced into brittle and brittle-ductile structural traps.

*Thomas, D.J. and Harper, C.T. (1991): Gold in northern Saskatchewan: Alternative metallogenic models; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p20-21.*

This paper reviews the diversity of geological settings in which gold occurs in northern Saskatchewan and draws attention to potential metallogenic environments. The majority of gold occurrences are in the greenstone-plutonic belts of the La Ronge, Flin Flon and Glennie Domains. As most of the discoveries are classified as structurally-controlled or shear-hosted lode gold mineralization, there has been a strong bias toward this style of mineralization in exploration strategies in recent years. Significantly fewer gold occurrences are reported from metasedimentary-dominated or high grade gneissic terrains. Is the relative abundance of gold occurrences in the greenstone belts a function of more favourable metallogeny, or is it simply an exploration bias toward greenstone belts and shear-hosted mineralization?

This paper will emphasize the other widely differing geologic and metallogenic environments in which economic and subeconomic gold concentrations are found. Most of these environments have received only a cursory level of attention and include: (1) gold mineralization in high grade gneisses of the Mudjatik Domain (Ithingo Lake); (2) stratabound veins in metaarkosic rocks (North Lake); (3) iron formation-associated gold (Wedge Lake); (4) metagreywacke-hosted quartz-gold veins (Pine Lake showing); (5) epithermal Au-Ag mineralization associated with felsic volcanism (Laurel Lake); (6) Cu-Au-Mo-W porphyry-associated mineralization (Phantom Lake); and (7) gold mineralization related to S-type granites (Box, Athona mines). Although most of these occurrences display some degree of early mineralization or gold enrichment, later metamorphism and deformation have generally had a major role in formatting the final nature of the mineralization. Gold mineralization in older terrains can commonly be demonstrated to be the product of multistage geological processes involving

the cumulative effects of meteoric, hydrothermal, magmatic, and metamorphic fluids over time.

Shear-hosted lode gold mineralization in the major greenstone belts will continue to be the "model of choice" in many prospecting programs. However, the creative application of various gold metallogenic models may lead to new deposits in previously neglected areas of northern Saskatchewan.

*Thomas, D.J., Reilly, B. and Watters, B. (1991): Tectonostratigraphic controls on massive sulphide deposits in the Amisk Group: Flin Flon-Amisk Lake area; The Geological Society of CIM, First Annual Field Conference, Sept. 1991, Saskatoon, Prog. Abstr., p26.*

The Flin Flon-Snow Lake belt is an easterly-trending Early Proterozoic greenstone belt extending from Hanson Lake, Saskatchewan to Snow Lake, Manitoba along the southern edge of the Precambrian Shield. The belt comprises an older volcanic-sedimentary succession (Amisk Group, >ca. 1886 Ma) which is unconformably overlain by molasse sediments (Missi Group, ca. 1840), and intruded by major subvolcanic (1892 to 1876 Ma) and post-volcanic (1860 to 1840 Ma) plutons as well as post-Missi intrusions (ca. 1837 to 1773 Ma). Thermotectonism accompanied the on-set of post-volcanic plutonism (ca. 1860 Ma) and terminated ca. 1800 to 1780 Ma.

In the Flin Flon-Amisk Lake area the Amisk Group comprises a collage of contrasting volcanic regimes. Chemical and physical characteristics of the volcanic sequences indicate a variety of environments including: a mature calc-alkaline island arc setting comprising intermediate to felsic subaqueous to subaerial rocks intruded by high level subvolcanic felsic intrusions (west Amisk Lake); mafic subaqueous flows of tholeiite, ocean floor or back-arc spreading affinity (east Amisk Lake and West Arm, Schist Lake); and mafic flows and tuffs of tholeiitic to calc-alkaline, oceanic island arc affinity (Flin Flon-Phantom Lake). Preliminary investigations indicate these contrasting volcanic environments are tectonically discordant bounded by zones of brittle-ductile shearing and alteration which predate deposition of the Missi Group and emplacement of some of the major plutons. This structural event is tentatively interpreted as a period of early northeast-directed thrusting within the Amisk Group. This is best exemplified in the West Arm (Schist Lake) area where an oceanic island arc is juxtaposed with a possible back arc spreading environment.

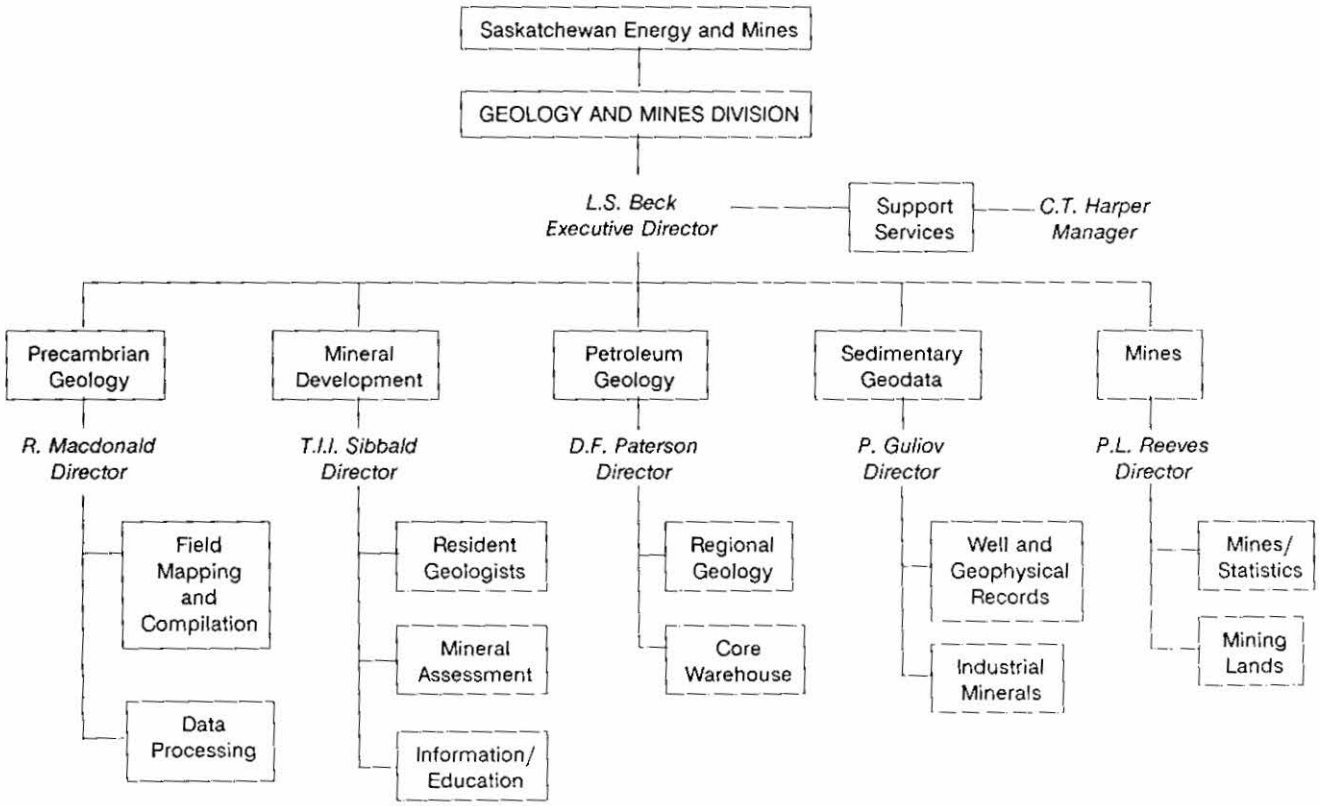
Thirty-three major massive sulphide deposits have been discovered to date in the belt (cumulative 150 million tonnes) of which 22 have had commercial production. The largest deposit, the Flin Flon Mine (HBMS), began production in 1930 and has produced about 63 million tonnes of ore grading 2.17% Cu and 4.1% Zn. Although the deposits have typical VMS characteristics, they vary greatly in ore grade, tonnage, host rocks and alteration.

The premise of this paper is that the distribution and ore tenor of massive sulphide deposits in the Flin Flon-Amisk Lake area reflect inherent differences in the volcanotectonic environments represented in the Amisk Group. Early thrust imbrication juxtaposed volcanic regimes of contrasting plate tectonic affinities. The differences in grade, size and mineralogy of base metal deposits in this area can be assessed in light of this new tectonostratigraphic model.

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The Saskatchewan Geological Survey comprises the geoscience activities of the Precambrian Geology, Mineral Development, Petroleum Geology and Sedimentary Geodata Branches, and is represented by R. Macdonald, Chief Geologist.

# Summary of Investigations 1991, Saskatchewan Geological Survey

## Errata

**In the text:**

page v; 7th paper, *S. Diegel*, should read... *S. Digel*,

15th paper, *He Chei*, should read... *Jie He*

page ix; project A.121b, *Diegel, S. et al.*, should read... *Digel, S. et al.*

page 72; the title of the paper and in the citation should read... Lithogeochemical Studies, Wildnest-Attitti Lakes Area

**In the map package:**

Revision Bedrock Geology, Mystic Lake Area, by B.A. Reilly
Sheets 1, 2 and 3: in the Legend for the Ruth Lake Assemblage:

**Unit Rmh** should read... **Mafic** heterolithic tuff breccia; not Felsic heterolithic...

**Unit Rmb** should read... **Mafic** monolithic tuff breccia; not Felsic monolithic...

Geology of the Broken Hammer Showing and NIKO Deposit, by P. Schwann
In the Legend for the Broken Hammer Showing.

**Unit 11** should read... **Graywacke:** Dark gray-green weathering,...

**Unit 12** should read... **Meta-arkose:** Buff-pink weathering,...

In the Legend for the NIKO Deposit:

**Unit 9** should read... **Tonalite Dyke:** White weathering,...

**Unit 10** should read... **Mafic Dyke:** Pale green weathering,...