

Gold Potential and Paleogeography of Mannville Outcrop Sediments (Lower Cretaceous) of North-central Saskatchewan: A New Exploration Concept

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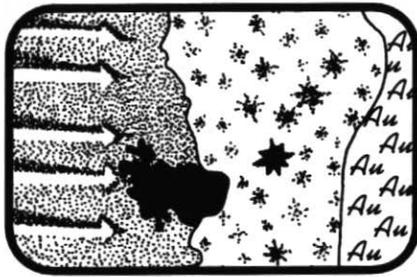
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Résumé de l'article

Les affleurements des sédiments du Groupe de Mannville de la rivière Nipa-kamew, dans le centre de la Saskatchewan, permettent d'étudier la nature et la provenance des sédiments crétacés de la marge nord-est du bassin d'avant-pays de l'Ouest canadien. À cet endroit, les paléocourants témoignent d'un drain-âge albien (Crétacé) vers le sud, du Bouclier canadien aurifère. Les données palynologiques indiquent qu'il s'agit probablement de sédiments Albien inférieur à moyen. Les affleurements portent les indices d'une sédimentation anasto-mosée de milieu fluvial et intertidal sur la bordure est du bassin. La désagrégation physique et chimique des roches cristallines grenues du Bouclier canadien a été à l'origine des matériaux qui ont été transportés vers le sud. La présence d'affleurements à moins de 70 km au sud du socle précambrien aurifère et l'existence de paléocourants vers le sud sont des conditions justifiant l'exploration de paléo-placers aurifères dans les sables et graviers de l'époque de Mannville. Ces couches se retrouvent dans une bande qui traverse la portion centrale de la Saskatchewan. La granulométrie grossière ainsi que le faciès des sédiments montrent bien que ces rivières puissantes auraient aussi pu transporter et concentrer des grains d'or.



Gold Potential and Paleogeography of Mannville Outcrop Sediments (Lower Cretaceous) of North-central Saskatchewan: a New Exploration Concept

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SUMMARY

Outcrops of Mannville Group sediments at Nipakamew River, central Saskatchewan, provide an opportunity to study the nature and provenance of Cretaceous sediments on the northeastern margin of

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the Western Canadian Foreland Basin. At this locality paleocurrents document Albian (Cretaceous) drainage southward from the gold-bearing Canadian Shield. Palynological data indicate a probable lower to middle Albian age. Outcrop provides evidence of braided-fluvial and tidal sedimentation on the eastern margin of the basin. Physical and chemical breakdown of the coarsely crystalline Canadian Shield rocks provided detritus for southerly transport. Outcrop location of less than 70 km south of known gold-bearing Precambrian basement, and the presence of southerly directed fluvial paleocurrents, provide an opportunity for paleoplacer gold exploration in Mannville-aged

sands and gravels. These deposits occur in a belt which trends across central Saskatchewan. The coarse nature and facies of the sediment demonstrate the action of powerful streams that likely were capable of transporting and concentrating gold.

RÉSUMÉ

Les affleurements des sédiments du Groupe de Mannville de la rivière Nipakamew, dans le centre de la Saskatchewan, permettent d'étudier la nature et la provenance des sédiments crétacés de la marge nord-est du bassin d'avant-pays de l'Ouest canadien. À cet endroit, les paléocourants témoignent d'un drainage albien (Crétacé) vers le sud, du

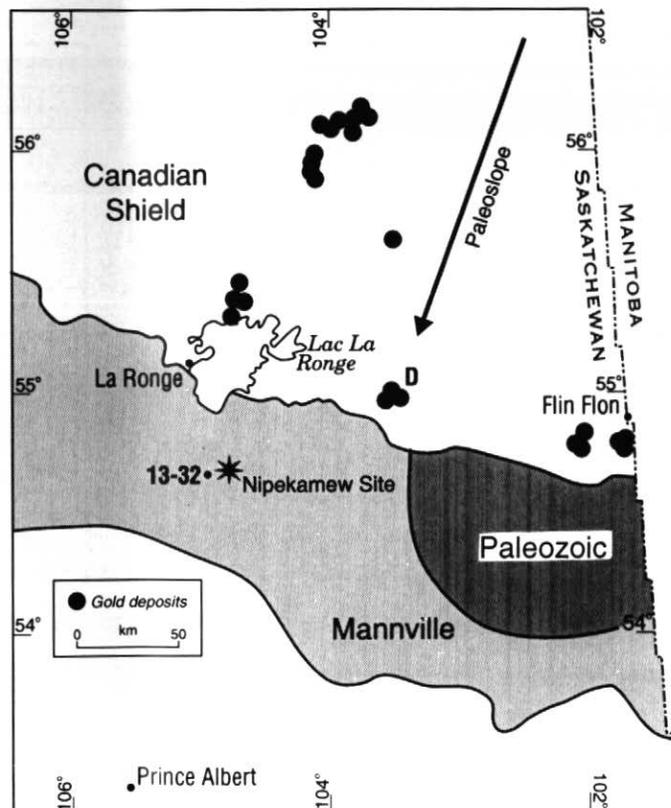


Figure 1 Location map and regional geology. Geology from Whitaker and Pearson, 1972). "13-32" shows location of Amerada Bear River #1 well; D shows location of Deschambault Lake. Solid circles show general occurrences of gold on the Precambrian Shield. More detailed gold locations are shown in Figure 12.

Bouclier canadien aurifère. Les données palynologiques indiquent qu'il s'agit probablement de sédiments Albien inférieur à moyen. Les affleurements portent les indices d'une sédimentation anastomosée de milieu fluvial et intertidal sur la bordure est du bassin. La désagrégation physique et chimique des roches cristallines grenues du Bouclier canadien a été à l'origine des matériaux qui ont été transportés vers le sud. La présence d'affleurements à moins de 70 km au sud du socle précambrien aurifère et l'existence de paléocourants vers le sud sont des conditions justifiant l'exploration de paléo-placers aurifères dans les sables et graviers de l'époque du Mannville. Ces couches se retrouvent dans une bande qui traverse la portion centrale de la Saskatchewan. La granulométrie grossière ainsi que le faciès des sédiments montrent bien que ces rivières puissantes auraient aussi pu transporter et concentrer des grains d'or.

INTRODUCTION

Outcrops of the Mannville Group in Saskatchewan are restricted to the vicinity of the northeastern erosional edge of Cretaceous sediments, which trend northwest-southeast across the central portion of the province. Most localities are poorly exposed and difficult to access. There are few published descriptions of the sediments (*e.g.*, Pearson, 1961; Christopher *et al.*, 1973; Christopher, 1984; McNeil and Caldwell, 1981). Here we describe and interpret one of the few easily accessible outcrops of the Mannville Group in Saskatchewan (Fig. 1). We present a sedimentological interpretation with paleocurrent data indicating the source of the sediments, a palynological age assignment, and a petrographic assessment. Implications of the coarse-grained, quartzose sands and gravel for paleoplacer gold exploration are presented as a new exploration concept.

STRATIGRAPHY AND CORRELATION

The stratigraphy of the Cretaceous Mannville Group in south-central Saskatchewan and east-central Alberta is shown in Figure 2. The outcrop occurs within sediments mapped as Cretaceous (Fig. 1; Whitaker and Pearson, 1972). Christopher *et al.* (1973) lithologically correlated outcrop in this area with the "lower part of the Mannville Group farther south." Christopher (1984)

assigned the sediments to the Swan River-Nipekamew Facies and suggested that the coarse grain size and large trough and tabular crossbed sets exhibited by the upper facies (facies 2, discussed below) may imply uplift of the Canadian Shield in late Mannville time.

Palynological study (discussed below) indicates a lower to middle Albian age for the strata (Fig. 2). This age eliminates a correlation with the Dina Formation which is of Aptian age (Fig. 2). Correlative units to the west and southwest may include the Cummings, Lloydminster, Rex or GP formations (Fig. 2). In a diamond exploration drill hole located ~100 km south of the Nipekamew River exposures, quartzose fluvial sediments occur in the GP and Rex formations,

which overlie quartzose tidal deposits of the Lloydminster and Cummings formations (Leckie, unpublished data).

PLACER GOLD OCCURRENCES IN SASKATCHEWAN

Placer gold in central Saskatchewan has been reported previously from near the Waterhen River in the west, Leaf Lake south of Flin Flon, and along the North Saskatchewan River from Alberta to Prince Albert (Coombe, 1984). The gold in the North Saskatchewan River is fine flour and was likely derived from westerly sources. The Waterhen River, however, drains sediments mapped as Cretaceous Mannville Group (Whitaker and Pearson, 1972). Paleoplacer gold occurrences within the Cypress Hills

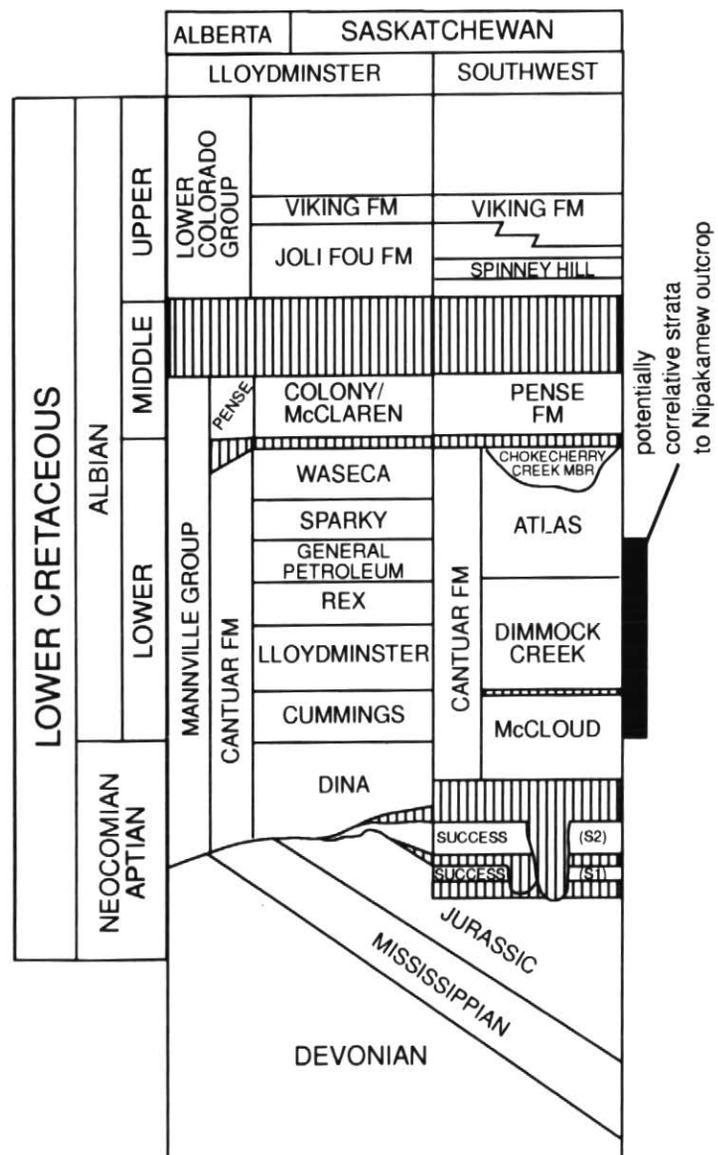


Figure 2 Stratigraphy and correlative strata of the Mannville outcrop exposed at Nipekamew River. Modified from J. Christopher (pers. comm., 1995).

aminated but not measured in detail, owing to steep outcrop faces. Both outcrops consist of friable, weakly cemented sand and gravel with up to 16 m of section exposed.

Five clay and silt samples from Site 1 (Fig. 3) were examined for palynological content to assess age and paleoecological setting. All samples contain abundant pollen and spores but have limited species diversity.

Three samples (Fig. 3) were analyzed for Au plus 33 other elements by Can-Tech Laboratories, Calgary (Table 1). Gold was analyzed by conventional fire assay with a detection limit of 5 ppb from an original 2 kg sample from which a 30 g aliquot was taken. The 33 elements were determined by instrumental neutron activation analysis. Approximately 2 kg of each of the three sam-

ples was processed by Overburden Drilling Management Ltd., Ottawa, for visible gold grains using heavy liquid separation (specific gravity of 3.2), followed by use of a shaking table and panning. Gold grains recovered were described and classified.

Sediment from three samples, representing the tidal and fluvial facies encountered at Site 1, were examined in petrographic thin sections for framework mineralogy and provenance determination. Supplemental back-scattered scanning electron microscopy (Philips, Model XL30) was conducted to determine clay mineral identification and origin (*i.e.*, detrital *versus* authigenic). Two samples of drill cuttings recovered from correlative sediments in a nearby hydrocarbon exploration well at 13-32-65-21W2M (Fig. 1) were examined in thin sections

for comparison.

DESCRIPTION

At both outcrops, the stratigraphic section can be subdivided into two units based on sedimentary facies (*e.g.*, Fig. 4).

Facies One

Description

The lower unit is a predominantly fine-grained, micaceous sand, with laminae and thin beds of coarse-grained sand. Laterally continuous bounding surfaces, exposed across the outcrop face, are 0.8 to 1.5 m apart and dip at an angle of 20° towards N50°E. Millimetre to 7 cm thick mudlayers occur on several of these bounding surfaces (Fig. 5A). Stratification between bounding surfaces is predominantly planar-tabular crossbedding with sets from 10 cm to

Table 1 Gold results. (A) Gold plus 33 multi-element analysis (Instrumental Neutron Activation Analysis. (B) Visible gold grain recovery. Corrected PPB (parts per billion) Visible Gold is an estimate of original rock volume; it is likely a low estimate. (C) Visible gold grain dimensions.

(A) Elements: Gold by fire assay; others by instrumental neutron activation analysis

Sample	Au	Ag	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	Hg	Ir	Mo	Na	Ni	Rb	Sb	Sc
Det.	5	5	2	100	1	1	5	10	2	0.02	1	1	5	5	0.01	50	30	0.2	0.1
Limits	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
2 m	6		4	170				200		0.36	3			12	<0.05			0.5	1.2
4.4 m	4		2	170				230		0.35	3			16	0.05			0.6	1.6
8.5 m	13							220		0.38	10			13	0.05			0.5	3.2

- no value indicates results below detection limit
- gold values by fire assay
- all other values by Instrumental Neutron Activation Analysis

(B) Visible gold recovery

Sample	Sample Weight	Gold Grains	Calculated PPB Visible Gold	Corrected PPB Visible Gold
2 m	3.45 kg	3	9	9
4.4 m	2.45 kg	10	1157	116-174
8.5 m	2.75 kg	0	0	0

(C) Visible Gold Grain Dimensions

Sample 2 m	Sample 4.4 m
25 x 25 x 5 μ	25 x 100 x 13 μ
25 x 25 x 5 μ	50 x 50 x 10 μ
25 x 50 x 8 μ	50 x 75 x 13 μ
	50 x 75 x 13 μ
	50 x 125 x 18 μ
	50 x 200 x 25 μ
	75 x 75 x 15 μ
	75 x 75 x 15 μ
	75 x 100 x 18 μ
	100 x 75 x 27 μ

50 cm thick. Most of the stratification is southerly-directed with some bipolar (herringbone) bedding present (Figs. 5D, 6A,B). One 20 cm crossbed set grades laterally from thick foresets of sand, to thin foresets containing abundant carbonaceous debris, to sanddominant thick foresets.

Kaolinitic muds occur as millimetre-thick laminae on foresets (Fig. 5B), and as centimetre-thick (up to 7 cm), black beds between sand bedsets and the dipping surfaces described above (Fig. 5A). Double mud drapes were noted on one crossbed set. Mud chips and clasts to 5 cm long occur on foresets.

Interpretation

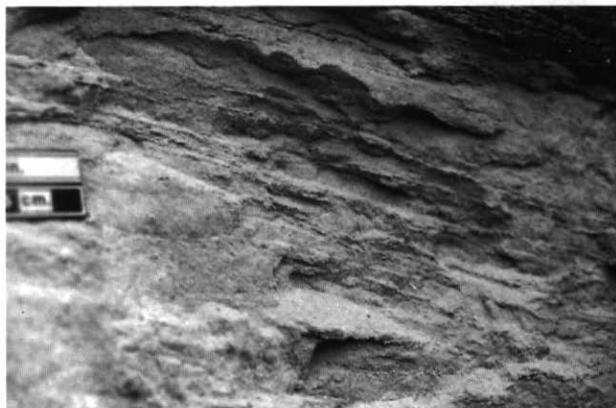
Several aspects of facies 1 indicate deposition in a sand and gravel dominated tidal environment. An abundance of mud drapes, including double mud drapes, indicates a tidal setting, possibly semi-diurnal, and at least locally subtidal (Visser, 1980; Boersma and Terwindt, 1981). Bidirectional cross stratification includ-



Figure 4 Panoramic view of outcrop showing braided fluvial sediments erosionally overlying tidal facies. Nipekamew river, outcrop faces westwards.



A



B



C



D

Figure 5 Examples of tidal facies from Site 1. (A) Several centimetre thick mud layer overlying a laterally continuous bounding surface that is traceable over much of outcrop. F designates fluvial facies; T designates tidal facies. (B) Millimetre-thick mud drapes on foresets. (C) Northerly-directed crossbeds overlain by crossbedded fluvial facies overlying crossbedded tidal facies. Note intraformational mudstone clast directly above basal fluvial contact. (D) Mud-draped, bidirectional ("herringbone") crossbeds.

ing herringbone bedding indicates reversing paleoflows, and is indicative of the ebb and flood flows of tidal currents. The crossbed set grading laterally from sand to thin carbonaceous sand foresets to sand foresets is suggestive of spring to neap to spring cyclicity (*cf.* Visser, 1980; Boersma and Terwindt, 1981).

Overall, this facies suggests a sand- and gravel-dominated, bedload-controlled fluvial system which was partly influenced by tides, possibly in the upper reaches of an estuary.

Facies Two

Description

The base of facies 2 is erosional (Fig. 7C) with 4.5 m of relief across the 30 m width of the outcrop at Site 1. Facies 2 sediment is predominantly gravel with a lesser amount of coarse to very coarse sand (Fig. 3). At Site 1 the basal unit consists of 1.0-1.5 m of granule to pebble gravel, averaging 1 cm in diameter. Intraformational mud clasts to 30 cm by 6 cm occur along the contact (Fig. 5C). At 8 m above the base of the section (Fig. 3), a 3 cm mud layer is overlain by 20 cm of medium-grained sand. Sand intervals contain isolated pebbles and discrete pebble layers.

The gravel is predominantly pebble size (average = 1 cm) with a maximum clast size of ~3 cm. Clast shape is predominantly subangular with a lesser amount of subrounded clasts (Fig. 8). Sand grains are subangular to subrounded. Mud clasts up to several centimetres diameter occur locally on crossbeds.

Stratification consists mainly of planar-tabular beds, 10-50 cm thick, in both sand and gravel lithologies (Figs. 7A, D). In some intervals stratification consists of poorly defined, parallel bedding 10-20 cm thick (Fig. 7B). Many crossbedded gravel beds are normally graded, with pebbles predominating toward the bases of the foresets. Planar-tabular crossbeds indicate a consistent southerly paleoflow with a vector mean toward 204° (Fig. 6).

At Site 2, sand of facies 1 is truncated erosively by 3 m of pebble gravel with poorly defined parallel stratification (Fig. 7B). Grey mud clasts to 20 cm occur at the base of the unit. Overlying sediments vary from 10-50 cm-thick planar-tabular crossbed sets. Ten crossbed sets have a vector mean indicating paleoflow toward 201° (Fig. 6B), consistent with those at Site 1 (Fig. 6A).

Interpretation

Sediments of facies 2 are interpreted as those of a gravel- and sand-dominant braided river which flowed to the south. The predominant planar-tabular crossbeds suggest relatively shallow channels having a high width-to-depth ratio, and with minimal mud deposited in the system. The relatively thick accumulation of sand and gravel (~12 m) indicates an episode of net fluvial aggradation. The deposits are most likely first-cycle in origin, eroded directly from the weathered Canadian Shield to the north. This assessment is, in part, based on the angular nature of the sand and gravel.

PALYNOLOGICAL AGE ASSESSMENTS AND PALEOECOLOGY

The five clay and silt samples examined from Site 1 (Fig. 3) have microfossil assemblages of limited diversity. Conifer pollen predominates in all samples but only a few species of pteridophyte spores are present. The conifer pollen consists mainly of *Alisporites bilateralis*, *A. grandis*, *Cedripites cretaceus*, *Parvisaccites radiatus*, *Podocarpidites biformis*, *P. ellipticus* and *P. multesimus*. The

spore species are primarily *Impardecispora apiverrucata* and *I. marylandensis*.

The presence of *I. apiverrucata* indicates an Albian or older age whereas the occurrence of *Pilosisporites verus* shows that the section is not younger than middle Albian. The abundance of *I. marylandensis* in most samples suggests an Albian age. The presence of *Pristinuspollenites inchoatus* suggests that the strata may be not older than Hauterivian. Thus, the palynological data indicate a probable lower to middle Albian age.

All samples contain abundant fusain fragments and small amounts of terrestrial plant tissue. Dinoflagellates were not observed and the palynological assemblage provides no indication of marine influence. The algal types *Botryococcus*, *Lecaniella foveata* and *Schizophaucus spriggii* found in some samples indicate fresh water. The abundance of conifer pollen suggests deposition close to a coniferous forest.

PETROGRAPHIC CHARACTERISTICS AND SOURCE OF SEDIMENTS

The fluvial sediments at the Nipakamew

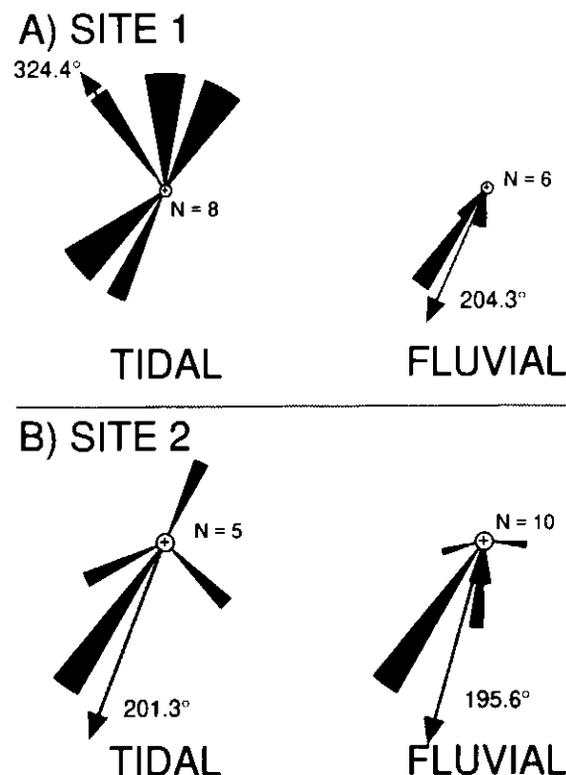


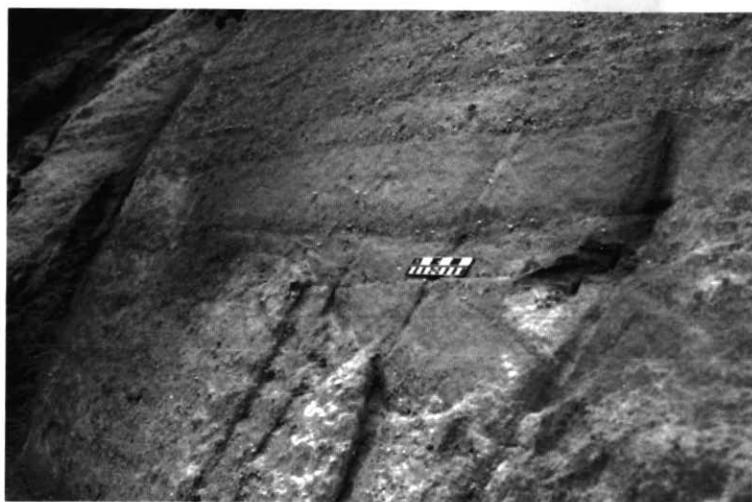
Figure 6 Paleocurrent data from fluvial vs tidal planar tabular crossbeds from outcrop at (A) Site 1 (B) Site 2. Arrows point to the vector mean. The tidal deposits of facies 1 show reversing crossbeds. The fluvial deposits of facies 2 show downstream-oriented crossbeds, indicating a south-south-westerly paleoslope draining the Canadian Shield.

River outcrop (Site 1) consist predominantly of a poorly sorted to bimodal granule to pebble gravel with lesser amounts of coarse to very coarse, pebbly sand intervals. These texturally immature sediments are composed mainly of angular to subangular grains with significant volumes of kaolinite clay. The kaolinite is predominantly detrital and

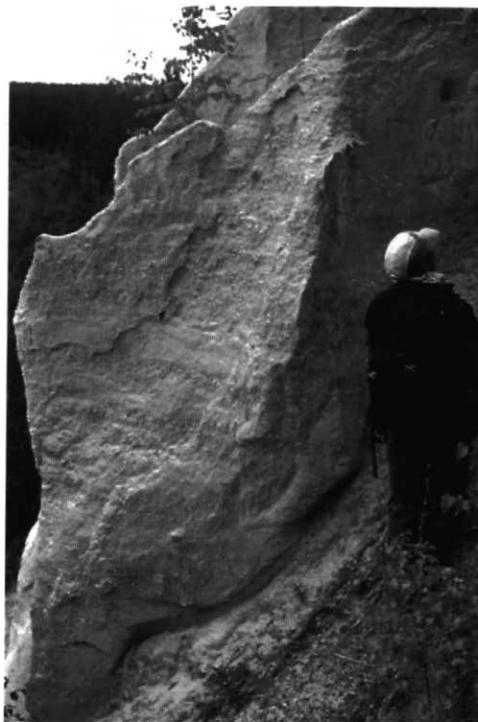
likely formed by primary alteration of feldspar at the original weathering source; lesser amounts of authigenic kaolinite also occur.

These poorly consolidated sediments are compositionally mature and can be classified as subarkose (quartzose) according to Folk 1968 (Fig. 9A). The framework grains are mainly polycrys-

talline quartz with lesser monocrystalline quartz and subordinate feldspar. Muscovite mica is a minor to trace component together with angular zircon and tourmaline heavy minerals, opaques and rare chert. Monocrystalline quartz grains are the most abundant, with common polycrystalline grains, derived from plutonic (granitic) and high-grade meta-



A



B



C



D

Figure 7 Fluvial facies. (A) Planar-tabular crossbedded sands and gravels at Site 1. (B) Crudely bedded, decimeter thick pebbly sands and gravels at Site 1. (C) Erosional contact of fluvial facies overlying tidal facies. Note grain size difference and abundant intraformational mudstone clasts in fluvial facies at Site 2. (D) Large ~60 cm thick, southerly-directed planar-tabular crossbeds, PT, overlain by crudely bedded gravel at Site 2.

morphic gneissic rocks (Fig. 10C,D). Feldspar grains are commonly altered (Fig. 10E) to very fine crystalline kaolinite, which imparts a light brown, cloudy appearance to most of the grains. The alterations do not mask the feldspar identity, however. Preserved feldspar grains include mainly K-feldspar and lesser plagioclase with minor perthite and myrmekitic granite rock fragments.

Clays are predominantly kaolinite and, locally, very coarsely crystalline dickite. The kaolinite is typically a poorly crystalline detrital form, whereas well-defined crystalline authigenic booklets are less common. Detrital kaolinitic clasts with a characteristic concentric structure were rarely identified (Fig. 11A). The poorly crystalline kaolinite aggregates (<2 μm diameter) are characterized by abraded or ragged outlines (Fig. 11C) indicative of a detrital origin. Detrital kaolinite and dickite likely resulted from extensive feldspar alteration ("primary alteration") in the source area (grus; see below), where a prevailing warm, humid climate promoted feldspar destruction by chemical weathering (e.g., Meyer, 1997). Diagenetic processes, either feldspar dissolution and precipitation of authigenic kaolinite *in situ* or re-crystallization of detrital clays, produced well-crystallized kaolinite booklets (Figs. 10, 11B).

Sediments from the tidal deposits are generally finer grained with mineralogically more mature quartzarenite composition (Fig. 9A) than the overlying fluvial sediments. Monocrystalline quartz is the main framework component with subordinate polycrystalline quartz, feldspar and kaolinite, both detrital and authigenic. Winnowing by tidal currents may have removed detrital clay fines.

For comparison with outcrop, shallow-buried sediments recovered from drill cuttings in the nearby 13-32-65-21W2M well (at 210 m and 295 m depths) were examined. The borehole sediments consist of poorly consolidated, coarse-grained quartzarenite to subarkose sand with a mature composition similar to the fluvial (outcrop) facies. Polycrystalline quartz is the main component of the framework grains, with less common monoquartz and subordinate feldspar. Authigenic kaolinite is a minor diagenetic component with rare detrital kaolinitic matrix clay. The limited occurrence of detrital and authigenic clay can be attributed to the poorly consolidated nature of the sediments and,

generally, to poor recovery of the finer fractions from drill cuttings.

The importance of tectonic setting as one of the main controls on sand composition and mineralogical maturity has been documented by many authors (e.g., Dickinson *et al.*, 1983; Dickinson and Suczek, 1979). In addition, climate (Suttner and Dutta, 1986), outcrop weathering (McBride, 1985) and diagenesis, as well as the transport distance and depositional environment, can also be important in provenance interpretation.

The modal composition of outcrop and subsurface sediments, as plotted on a Dickinson *et al.* (1983) QFL diagram (Fig. 9B), demonstrates that these sediments were derived from the nearby exposed craton consisting of granitic and, less commonly, gneissic basement. In addition, the high degree of textural immaturity indicated by grain angularity and common feldspar alteration suggests a hot, humid climate where the sediments (grus?) either were transported for a short distance and rapidly deposited by a relatively high-energy river system of facies 2, or were reworked by tidal currents, producing the finer-grained tidally influenced sequence of facies 1.

The similarities in mineral composition of outcrop and shallowly buried sediments show that the effect of outcrop weathering on provenance determination was minimal. Because most of the kaolinite is detrital, and most of the feldspar grains still have their primary character, diagenesis appears to have been minimal and therefore has not complicated provenance determina-

tion. This interpretation can also be supported by the similarities between final modal compositions and the "reconstructed" ones. A reconstructed composition is one in which authigenic kaolinite is re-calculated as feldspar deposited at the time of sedimentation (Figs. 9A,B).

GOLD RECOVERY

Three samples of gravel from Site 1 (Fig. 3) were processed for mineral potential by conventional fire assay (Table 1) and for visible gold grains. Two of the three samples contain visible gold grains (Table 1). The lower sample (a1, 2 m, Fig. 3), from the tidal facies, contains three visible grains: two grains 25 x 25 x 5 μm , and one grain 25 x 50 x 8 μm . The sample, from sand, gives a calculated visible gold assay value of 9 ppb, which compares to a value of 6 ppb obtained by conventional fire assay from the same sample (Table 1).

The sample from the lower part of the fluvial facies (a2, 4.4 m, Fig. 3) contains 10 visible gold grains ranging from 25 x 100 x 13 μm to 100 x 175 x 27 μm . The sample is from a planar-tabular cross-bedded, pebble gravel with a medium to coarse-grained sand matrix. Cross-bed sets are ~50 cm thick. Sand comprises 10-15% of the original material. The calculated visible gold assay value is 1157 ppb for the sand matrix, a value that converts to a corrected visible gold assay value of 116-174 ppb (see Table 1). A value of 5 ppb was obtained by conventional fire assay from the same sample (Table 1). No visible gold was recovered from the uppermost sample a3 at 8.5 m (Fig. 3), which contains 13

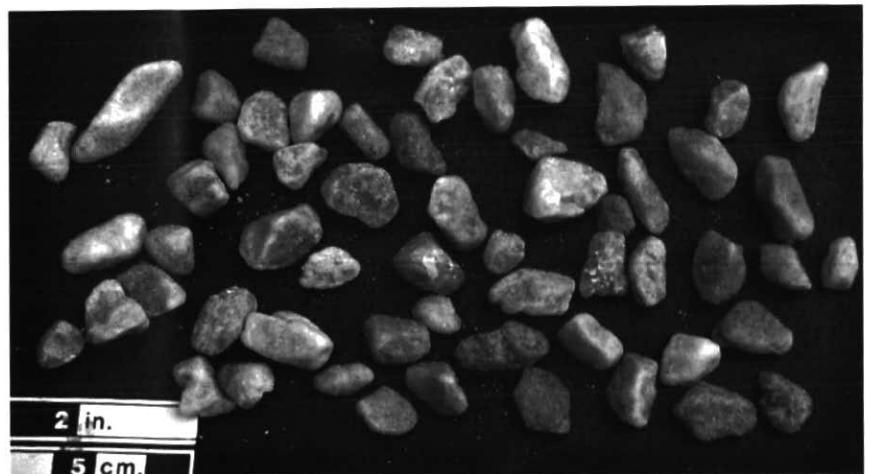


Figure 8 Pebble clast shape of the fluvial gravel from the fluvial deposits of facies 2; from Site 1 at 11 m on Figure 3. The majority of the quartz clasts are subangular with a lesser amount of subrounded clasts. White bar on scale is 2.54 cm.

ppb Au based on conventional fire assay (Table 1). The discrepancy between fire assay results and visible gold analysis appears to be explained by the difference in sample sizes (H.J. Abercrombie, pers. comm., 1998). Fire assay is typically completed on a 30 g aliquot, whereas visible gold recovery is carried out on a 2 kg sample. The 2 kg samples actually provide a much better estimate of gold content than the fire assay values (H.J. Abercrombie, pers. comm., 1998), largely because of the difference in sample sizes.

Although the limited sampling and analysis completed has returned generally low gold content (Table 1), the lowermost fluvial sample (4.4 m, Fig. 3) pro-

vided an anomalous gold recovery of visible grains, with corrected values of 116-174 ppb. Further detailed sampling of exposed Mannville sediments is warranted, as deposits of poorly indurated, near-surface material, that can be easily handled, disaggregated, and efficiently concentrated, may prove the presence of significant amounts of gold.

IMPLICATIONS FOR MINERAL EXPLORATION

The southerly paleoflow directions of facies 2 at the Nipekamew River and the craton-derived quartz and feldspar grains demonstrate that the fluvial drainage system derived its source detritus primarily from Precambrian cratonic

rocks of the La Ronge and Glennie lithotectonic domains. Gold occurrences hosted within these domains are shown in Figure 12. The Saskatchewan Energy and Mines SMDI-Database lists 366 known gold occurrences, including two producing gold mines from the domains. Coombe (1984) documented known Precambrian Shield gold deposits in Saskatchewan, describing their general geological setting. Within the La Ronge Domain, gold occurs predominantly in volcanic supracrustal rocks and felsic intrusives. All known gold within the Glennie Domain occurs within volcano-sedimentary belts as structurally hosted quartz veins associated with volcanogenic massive sulphides (De-laney, 1992).

As has been demonstrated above, potential should have existed during Early Cretaceous time to erode and transport southward gold-bearing weathered rocks of the Canadian Shield. The initial extent of potential paleo-placer exploration targets can be determined by examining the geological map of Saskatchewan (Whitaker and Pearson, 1972) and gold occurrence maps (Mac-Dougall and Guliov, 1990). Mannville Group sediments extend at surface across north-central Saskatchewan as a band 35-120 km wide and 630 km long (Fig. 1). Most of the Mannville Group deposits in Saskatchewan are quartzose, but the Mannville becomes increasingly lithic westward into Alberta. Several of the Precambrian-hosted gold occurrences and deposits (Fig. 12) are situated less than 70 km north of the Nipekamew Mannville outcrop. Some bedrock gold occurrences, such as those at Deschambault Lake (Fig. 1) lie within 20 km of Mannville outcrop. Future gold prospecting should be concentrated in Mannville-aged sediments of the eastern half of the province, situated south of the Glennie and La Ronge Domains. This prospective belt covers an area that is approximately 275 x 100 km in size.

Any residual or eluvial gold enrichment that had formed above base level may have been mobilized into the fluvial drainage systems. Liberated gold or other heavy, resistate minerals entrained within these rivers provide potential for elutriation and placer development. Exploration should focus initially on large scale targets using geomorphic-hydraulic principles. This would delineate environments where the deposition of coarse-grained silicate mate-

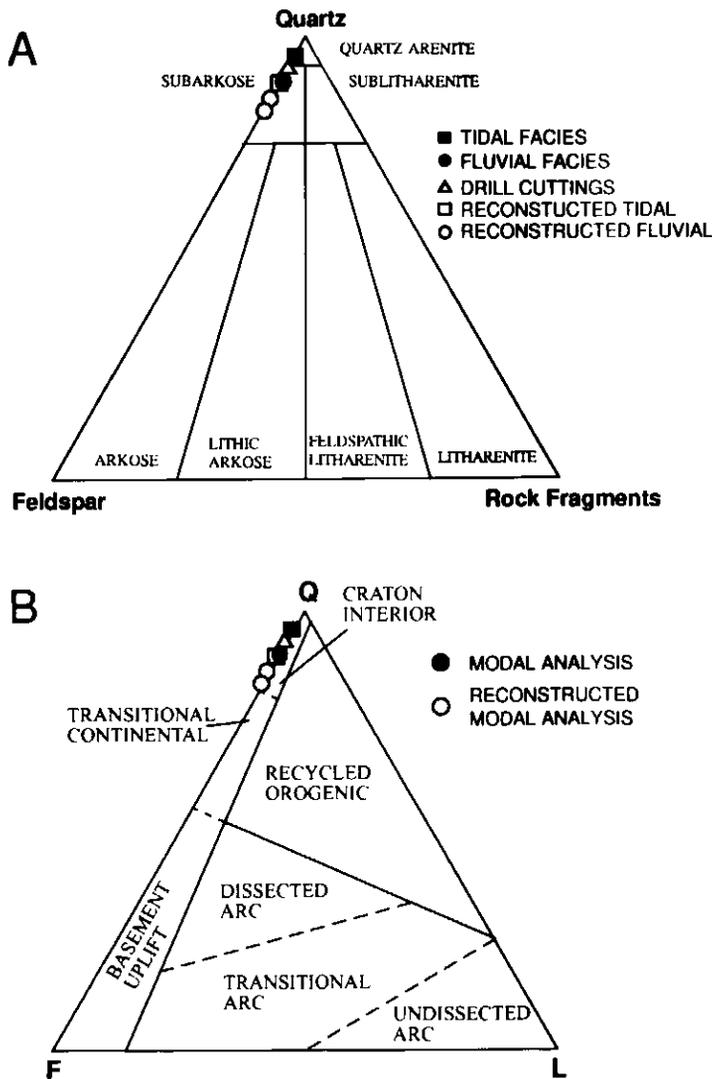


Figure 9 (A) Ternary plot showing sandstone framework-grain composition following Folk (1968). Data are from modern-day composition and reconstructed composition for the tidal and fluvial facies. (Reconstructed composition results from the addition of detrital kaolinite to the original feldspar counts.) See text for details. (B) Inferred tectonic setting as indicated by petrographic results (method after Dickinson *et al.*, 1983).

rial has accompanied the winnowing of finer clays and silts while withholding small dense grains that are hydraulically equivalent to the coarse, less-dense material.

In a review of the origin of placer deposits, Slingerland and Smith (1986) summarized where occurrences of water-laid placers might be expected. Slingerland and Smith's list is modified in

Table 2, to propose potential occurrences which might be expected with respect to the Mannville sediments. On the largest scale, the erosional contact separating facies 1 and 2 may be a re-

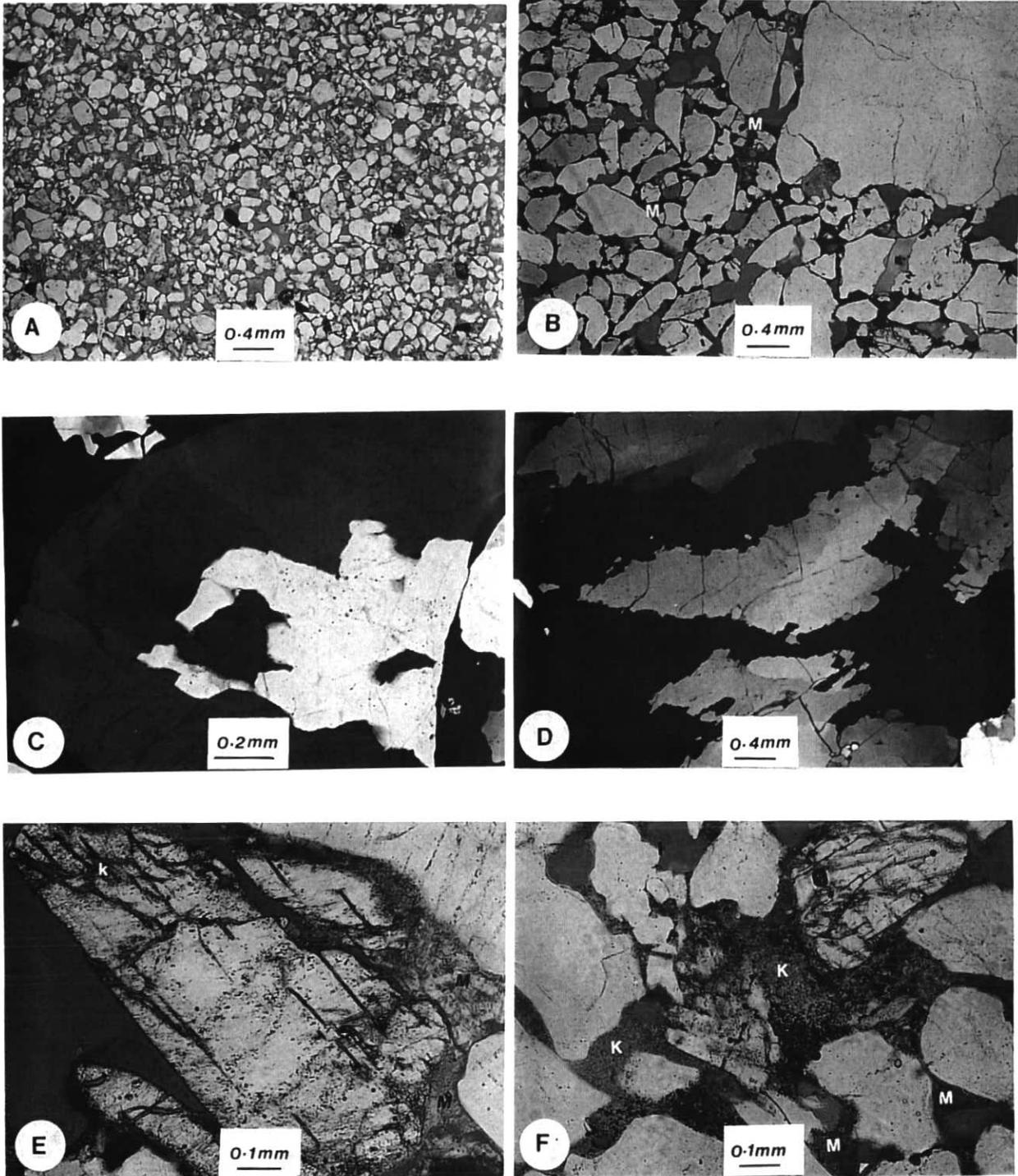


Figure 10 Photomicrographs of the tidal (A) and fluvial facies (B-F). (A) Fine-grained quartzose sandstone, characterized by more mature composition than the fluvial facies. (B) Texturally immature, medium to coarse-grained, pebbly sandstone with common detrital matrix clay, M, and poorly consolidated fabric. (C) and (D) Polycrystalline quartz from a plutonic (granitic) and high grade metamorphic (gneissic) source respectively. (E) A potassium-feldspar grain partially altered to kaolinite, k; note well crystalline authigenic kaolinite booklets, K. (F) Very finely crystalline kaolinite, K, possibly resulting from recrystallization of detrital kaolinitic matrix, M.

gional unconformity. If so, a concentration of placer gold deposits may be expected on this surface. It is from just above this surface that we recovered the greatest amount of visible gold (Fig. 3, 4.4 m; Table 1). Given the tidal interpretation of facies 1, proximity to a shoreline is predicted, indicating the possibility of gold concentration in a Mannville beach deposit, perhaps to the south. Gold concentrations may occur parallel to depositional strike. If the Canadian Shield was being stripped of gold-bearing sediment during Cretaceous time, concentrations of placer deposits may be expected as ancient pediment mantles, now possibly buried.

At an intermediate scale (Table 2), gold may be concentrated at the heads of mid-channel bars, scour holes at tributary confluences, on bed rock riffles directly on Canadian Shield bedrock (possibly buried now) and on constricted channels between banks and channel bars.

On the small scale (Table 2), placer gold could be concentrated on the scoured bases of trough crossbeds, on winnowed tops of gravel bars, as heavy mineral concentrations on upper flow regime plane parallel laminae, or in the lee of any obstacles.

DISCUSSION

The Nipekamew outcrop provides an isolated data point for lower to middle Albian-aged Mannville Group sediments in an area where there are virtually no other data. Paleocurrent and petrographic observations together indicate that a south-dipping paleoslope drained the Canadian Shield at this time, which is consistent with earlier observations by Christopher (1984). The vertical sedimentary succession of Mannville Group sediments exposed at Nipakamew River suggests a progradational sequence with fluvial coarse sand and gravel erosionally overlying finer-grained tidal sand. Southerly directed paleoflow is

consistent with the predominantly quartz and minor feldspar sediments (Christopher *et al.*, 1973; this study) derived from the Canadian Shield. We envisage rivers draining a low-relief hinterland on the Canadian Shield to the north. Gold, derived from weathering of Canadian Shield rocks, would have been transported and concentrated in the Mannville fluvial and tidal sediments. The coarse grain size and large crossbed sets do not necessarily indicate uplift of the Canadian Shield in late Mannville time as suggested by Christopher (1984).

The original, weathered surface of the Canadian Shield has been weathered and eroded, initially during the Cretaceous and then during the Tertiary. Quaternary glaciations stripped the shield of most friable material. It is not known how much Canadian Shield material has been eroded since the Cretaceous.

A partial analogue to that proposed for the placer deposits within the Mann-

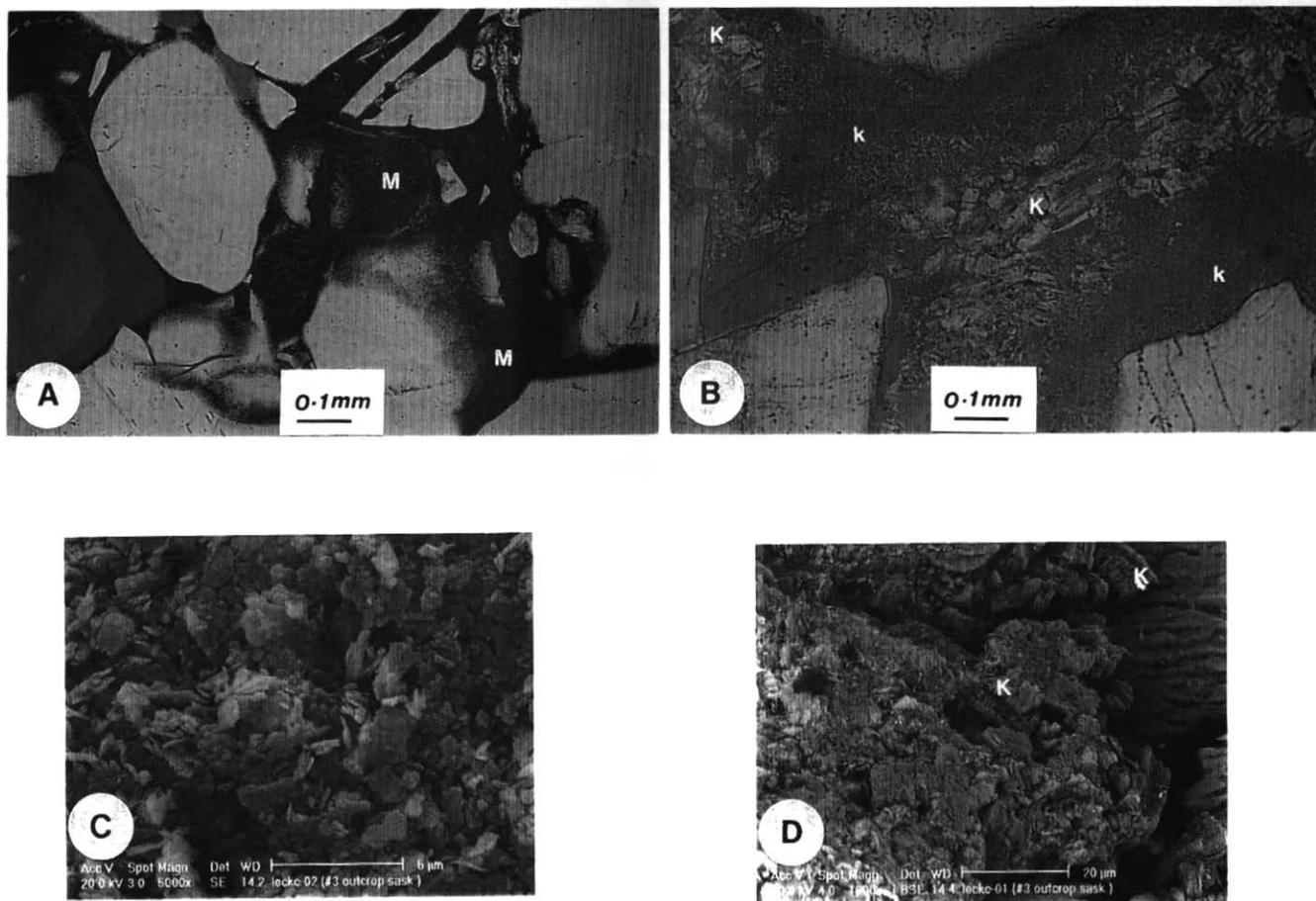


Figure 11 Thin section and SEM photomicrographs of detrital and authigenic kaolinite from the fluvial facies. (A) Detrital (poorly crystalline) kaolinitic matrix, M, resulting from extensive feldspar alteration at the source. (B) Authigenic, fine, k, and coarse crystalline, K, kaolinitic aggregates, most probably resulting from recrystallization of detrital matrix. (C) SEM view of a local concentration of very finely crystalline aggregates. Note poor crystallinity and ragged nature of the kaolinite booklets, suggestive of its detrital origin. (D) Back-scattered electron microscope image of authigenic kaolinite, K, characterized by well crystalline booklets (compared to view C).

ville Group can be found within the Late Archean Witwatersrand Supergroup in South Africa. Within the Witwatersrand, gold occurs within shallow, braided-river quartz sandstones and pebble conglomerates (Els, 1988, 1991, 1993), not unlike those proposed for the Mannville deposits discussed herein. The Witwatersrand Basin was a foreland basin (Burke *et al.*, 1986; Winter, 1987) located within the interior of the Kaapvaal Craton (Stanistreet, 1993). The Witwatersrand sediment was derived from weathering and corrosion of the craton. Gold is concentrated within sheets of sandstones and conglomerates, generally less than 3 m thick and extending laterally for up to several kilometres.

CONCLUSIONS

1. The paleocurrent and petrographic results presented in this paper indicate a Canadian Shield provenance from the north. The immature nature of the sediment indicates a short transport distance.
2. Southerly flowing braided rivers drained a weathered Canadian Shield during the lower to middle Albian. Weathering is indicated by the abundant angular quartz and feldspar pebbles and detrital kaolinite clay. The latter resulted from bedrock weathering.
3. The outcrop also provides evidence of tidal sedimentation on the eastern margins of the basin.
4. The southerly flowing rivers would have eroded and transported gold from bedrock on the Shield. Nearest gold occurrences within the Canadian Shield are within 70 km to the north. Mannville sediments thus provide a potential paleoplacer gold exploration target. Consequently, we suggest that these and other Cretaceous-aged sediments exposed in central Saskatchewan may be worthy of gold exploration.
5. Of the three samples processed for gold, both the fluvial and tidal deposits yielded limited recovery. The basal fluvial gravel yielded the most visible gold with one anomalous value of 116 ppb to 174 ppb. Gold grains from the fluvial gravel are coarser than gold recovered from the tidal facies.
6. The most prospective area to explore for paleoplacer gold is located in the east half of the province, in Mannville sediments occurring south of the La-Ronge and Glennie domains.

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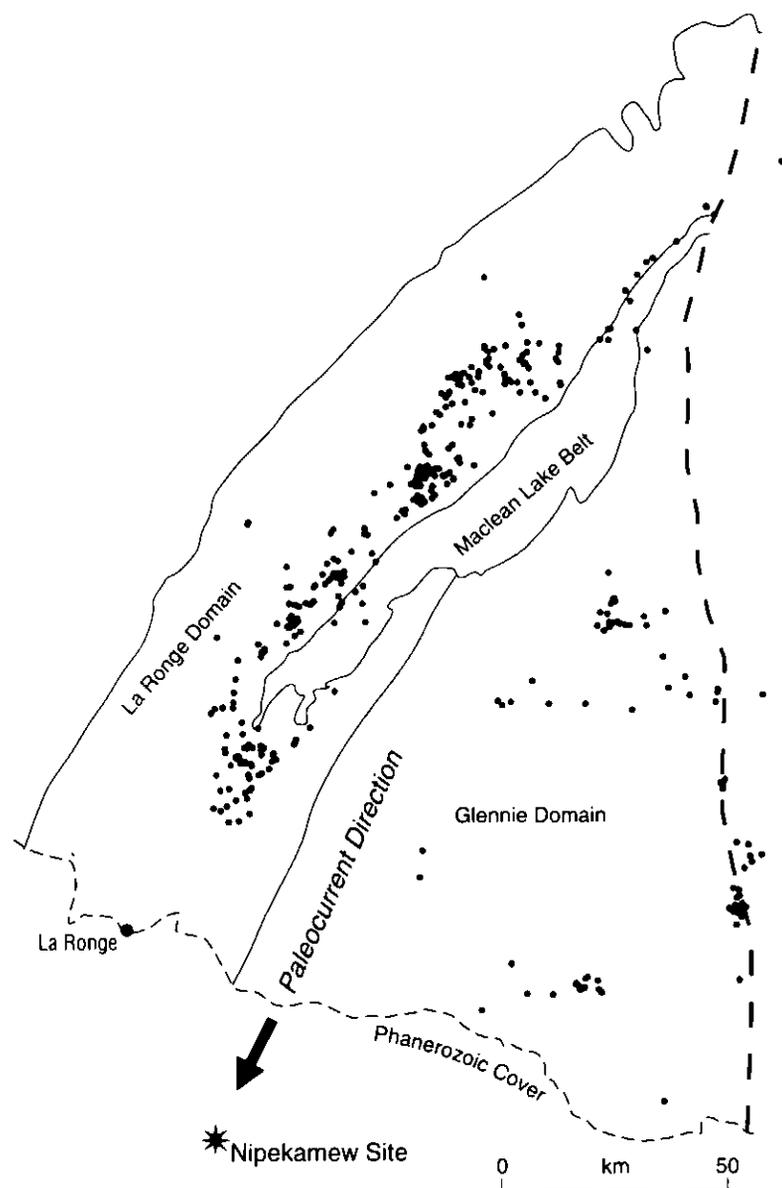


Figure 12 Gold occurrences on the Canadian Shield as potential sources for placer gold deposition in Mannville Group sediments. Data from Saskatchewan Energy and Mines SMDI-Database.

Table 2 Possible sites of occurrence of placer gold within Mannville Group sediments.

Depositional Site	Comments
Large Scale (10⁴ m)	
• bands parallel to depositional strike	- given the tidal aspect of facies 1, shoreline and beach deposits should be explored for
• regional unconformity	- the contact between facies 1 and 2 may be a regional unconformity; as such, it has excellent potential
• strand-line deposits	- given the tidal aspect of facies 1, strand-line deposits may be expected
• pediment mantle	- given the stripping of Precambrian Shield regolith that took place during the Cretaceous, a pediment mantle, possibly buried might be expected
Intermediate Scale (10² m)	
• heads of midchannel bars	- facies 2 is interpreted as braided fluvial; midchannel bars would be common
• scour holes, at tributary confluences	- scour holes are expected to have been relatively common
• inner bedrock channels	- bedrock channels will be expected where the rivers or tidal currents scoured down to Precambrian bedrock (likely now buried)
• bedrock riffles	- bedrock riffles will be expected where the rivers or tidal currents scoured down to Precambrian bedrock (likely now buried)
• constricted channels between banks and bars	- in the braided river environment, this may be expected
• beach swash zones	- given the tidal interpretation for facies 1, a coastal zone with beach swash zones might be expected
• flood lag deposit	- during riverine floods, lag deposits will armour channel bottom and trap gold grains
Small Scale (10⁰ m)	
• scoured bases of trough crossbed sets	- expected
• winnowed tops of gravel bars	- expected in a braided river environment
• plane parallel laminae	- heavy mineral concentrations will be expected in upper flow regime stratification
• leeward side of obstacles	- expected
• beach berms	- expected given the tidal interpretation of facies 1

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