Information Series 124

Alberta Geological Survey Contributions to the CSPG Annual Convention
June 18 – 22, 2001

Alberta Energy and Utilities Board
Alberta Geological Survey

Alberta Geological Survey

Contributions to the CSPG Annual Convention

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THE CSPG ANNUAL CONVENTION JUNE 18 - 22/2001

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Contents

Coal bed Methane Potential of Selected Alberta Coal Deposits

(A review of coal geology, distribution and characterization as related to coal bed methane potential)

A. Beaton, D. Chen and R. Richardson, Alberta Geological Survey, and
J. Campbell, Jaycon Reconnaissance

The Alberta Plains area contains significant coal resources within strata ranging in age from Cretaceous to Tertiary. Shallow coal deposits are a traditional source of energy for power generation, but increasing demand for energy has led to a renewed interest in the coal bed methane potential within Alberta.

Coal characterization is an essential component of any coal bed methane project evaluation. Rank, composition, seam continuity, thickness and distribution are critical parameters in predicting gas generation and production potential.

The Cretaceous upper Mannville contains several thick, continuous coal seams that are potential coal bed methane targets. Cores and cuttings were sampled across the Alberta Plains, providing detailed coal rank and compositional data relevant to gas potential. Some shallow rank anomalies were observed suggesting favourable coal bed methane potential in selected areas of central Alberta.

Coal bed methane potential across Alberta is being assessed by the Alberta Geological Survey. Detailed regional and local cross sections across the Alberta Plains are being constructed to examine the geology, distribution and character of Cretaceous coals associated with the above-mentioned rank anomalies. Overlying coal zones within the Belly River Formation and Edmonton Group are being examined and their coal bed methane generation potential is currently being assessed. A detailed coal bed methane database including stratigraphy, lithology, coal quality and predicted gas potential is in preparation.

Acknowledgements: Funding for the coal bed methane evaluation of Alberta is in part provided by ASRA, the Alberta Science and Research Authority.

Bedrock Topography and Drift Thickness, Athabasca Oils Sands (in situ) Area and Adjoining Regions

Laurence D. Andriashek, P.Geol., John G. Pawlowicz, Mark M. Fenton, P.Geol., and Ilona M. Ranger

Bedrock topography and drift thickness maps provide valuable information to the energy industry on such aspects as: depth to bedrock, thickness and nature of drift cover, occurrence of buried aquifers for groundwater supply, potential for boulder or gravel horizons that may impede drilling operations, aberrations in airborne geophysical exploration surveys, and drill casing depths for groundwater protection. This poster consolidates the interpretations of previous bedrock topography studies in the region. In addition, the poster highlights the results and interpretations that are the outcome of 1) new projects that the AGS conducted in support of regulation of the energy development in the Oil Sands areas, and 2) initiation of the new AGS Minerals Program to support both exploration and development.

Landscape features that record the erosion and deposition from multiple glacial advances and retreats during the past 1.5 million years or more characterize the present-day topography of northern Alberta. Masked by these glacial sediments is a bedrock surface which displays a markedly different appearance - one that records a history of major fluvial channel systems that modified the bedrock landscape during the Tertiary, and later overprinted by deep channels scoured into the bedrock surface by glacial meltwater during Quaternary glacial periods.

This poster presents the Alberta Geological Survey's current understanding of the bedrock topography and buried fluvial channel features in the parts of northern Alberta defined by longitude 1100 to 1160 W and latitude 550 to 580 N (see figure). This area encompasses the Athabasca Oil Sands (in situ) Area as well as the Athabasca Oil Sands (surface mineable) Area, the northern part of the Cold Lake Oil Sands Area, and the western part of the Athabasca Oil Sands Area overlying the Grosmont and Wabasca oil sand deposits. Each of these areas has, is, or will be undergoing intensive oil sands development.

Buried channels form the most dramatic aspect of the bedrock topographic surface. Two major channel morphologies emerge from the interpretation of borehole logs in the region. The first consists of broad, shallow-walled channels or valleys that are interpreted to represent regional drainage systems formed during the Tertiary. In a few locations where the fluvial sediment resting on the floor of these channels has been sampled, the clast petrology is consistent with a preglacial source from the Cordillera west of the region. Rock types from the Laurentide Shield to the northeast (granite, gneiss) are conspicuously absent in the clast composition. The general trend of these channel, or valley, systems is north and east toward the Arctic Ocean. In some cases, opposing ends of channels display reverse gradients, indicative of headwall erosion and stream capture of older drainage systems. Stream piracy and subsequent channel abandonment is also indicated by abrupt, hanging wall confluences with other channel systems. All attest to the evolutionary degradation of the exposed bedrock surface during the late Cenozoic. Because of their broad width, preglacial valleys serve as depositional basins for subsequent geological events. In this regard, preglacial valleys are the foci for thick accumulations of both stratified glaciofluvial, and nonstratified glacial diamict (till). Accumulations of more than 250 m of drift are not uncommon in this region.

The second type of buried-channel form consists of deep, narrow, and steep-walled channels that are interpreted to have been scoured into the bedrock surface by catastrophic releases of glacial meltwater during any one of several glacial events that have occurred in the region. The composition of the clasts on the floors of these channels includes a significant component of Laurentide Shield rock types from northeast of the region, which could only have been transported into the area by glacial advances from that direction. The orientations of glacial meltwater channels are influenced as much by the position of glacial ice margins as they are by the underlying regional topography. As such they do not necessarily follow the same drainage direction as preglacial channels. The fact that some meltwater channels are incised onto the highest parts of the local bedrock surface, or exhibit shallow U-shaped longitudinal profiles, indicates that some were probably formed in a subglacial rather than subaerial environment.

Seismic Modeling of Upper Cretaceous Coal-Bearing Strata of the Willow Creek Area, East of Drumheller: Implications for CBM Exploration

C. Willem Langenberg[1], Frances J. Hein[1], Sarah Richardson[2] and Rudi Meyer[2]

Most of the coal resources in the Drumheller area (Drumheller Coal zone) are contained in estuarine, tidal and fluvial deposits of the Upper Cretaceous Horseshoe Canyon/Bearpaw transition zone. This sequence was deposited in an easterly prograding deltaic complex fed by rivers flowing from the West and draining into the Bearpaw Sea. Most of this delta complex is interpreted to have deposited in an embayment, where tidal currents dominated over wave and river processes. The paleo-swamps developed on the floodplains overlying, and in-land from the distributary and tidal channels. The upper part of the transition zone appears to have a higher proportion of fluvial channels and associated overbank deposits.

Ten measured stratigraphic columns were recorded along a 4 km stretch of the Willow Creek area. A structural cross section with 6 times vertical exaggeration was constructed from these columns with help from panoramic photographs taken from opposing valley walls. Six coal seams can be distinguished in this interval, whereby four (#0, #1, #4 and #5 seams) are continuous along the whole cross section and two (#2 and #3) are intermittently exposed. The distributary channel deposit below the #0 seam locally shows lateral accretion bedding (IHS) with dips in various directions, hence representing several amalgamated channel bars.

The seismic response along this cross section line was modeled by ray-tracing. Our modeling indicates that the coal seams and the inclined beds can be seismically imaged in areas of CBM exploration. Imaging of coal seams is possible given sufficiently high quality seismic data with dominant frequencies of approximately 100 Hz, whereas the more closely-spaced inclined beds require higher frequencies, approximately 150 Hz, to be effectively imaged.

Construction of synthetic seismograms from nearby wells shows that seismic definition of coal beds is dependent not only on coal bed thickness, but also on the nature of the surrounding matrix and the spacing of multiple coal seams. The majority of coals in these wells become seismically distinct (separate events for the top and base of a coal bed) at frequencies greater than 150 Hz, though single coal seams surrounded by homogeneous high-contrast sediments become distinct at much lower frequencies, approximately 100 Hz. These observations and predictions will be of great importance in areas of CBM production, where the best production will be expected from thick, continuous coal beds.

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The Drumheller Coal Zone, Lower Horseshoe Canyon Formation: Sedimentology and Sequence Stratigraphic Analysis for Coal Bed Methane (CBM) Exploration[1]

Cristina Pana, Frances J. Hein, C. Willem Langenberg and Andrew Beaton[2]

Renewed government interest in the coal bed methane (CBM) potential of Alberta has led to geologic studies in targeted areas of the Plains and Foothill regions of Alberta. One area of interest is the "Drumheller Coal Zone" (Lower Horseshoe Canyon Formation) of south central Alberta that has large reserves of coal present at an attractive depth. Detailed sedimentological and sequence stratigraphic analysis was done on continuous outcrop exposures of the Drumheller Coal Zone, and associated sediments, in the Willow Creek and Red Deer River valleys, along with subsurface analysis and correlation of oil/gas well logs. Much of this work used a multidisciplinary approach involving facies analysis of outcrops and cores, well-log analysis and correlation, regional mapping, as well as comparisons with modern analogues.

Three major sequences are recognized (from bottom to top):

Sequence A is defined by a major marine flood parasequence at the base, Bearpaw Formation (s. s.), considered as the most important transgression following the thick clastic sequence of non-marine Belly River Formation. Successively younger marine paraseqences southeasterly step farther basinward producing a progradational paraseqence set. The facies association is: floodplains bearing coals and channel fills.

The interbedded silts and shales of Sequence B represent the last widespread flooding event of Bearpaw Sea in the study area. Considered as a regional "Marine Marker", Sequence B is recognized as single retrogradational parasequence based on Gr-Resistivity traces. The marine-flooding Sequence B separates two major progradational cycles, the consistent coarsening upward unit (CU1) of Sequence C above and the last progradational event of Sequence A below.

Sequence C is the last progradational cycle defined in the study area by the CU1 unit at the base and the well-exposed fluvial floodplain - channels association at the top on the Willow Creek valley. The coarser parasequence sets are successively deposited farther basinward. Sequence C is dominantly fluvial in character interfering with restricted marine recurrences. Regional outcrop-subsurface correlation shows that CU1 unit as a major progradational event correlates with the Dorothy shoreline sandstones. The laterally persistent coarsening-upward CU1 parasequence is thought to be a result of a high rate of sediment supply, coupled with a lowstand marine system.

The spatial distribution of the different parasequences fits a model, originally proposed by Shepheard and Hills (1970), of a depositional platform for the Horseshoe Canyon deltaic system within a marine-continental transition zone. The regional correlation of the different coal seams within individual parasequences (i.e. not crosscutting parasequence boundaries), and the number and distribution of coals is directly related to the origin of the facies preserved within the different parasequences.

The present study shows that sequence stratigraphic analysis provides a realistic framework for deciphering the 3-D architecture of individual coal seams within the Drumheller Coal Zone. Such a framework, coupled with coal rank, cleat -orientation, structural and petrographic data, is useful for characterization of the coal bed methane potential of the Alberta Plains.

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[1] This study was funded by ASRA (Alberta Science and Research Authority)

[2] Technical Assistance: D. Magee, J. Delorme, C. Croque, M. Berhane and N. Koso

Hydrochemistry and Isotope Systematics of Regional Drift Aquifer Systems, Athabasca Oil-Sands (in situ) Area

Tony Lemay and Sheila Stewart

The extensive regional Quaternary drift aquifers and Quaternary/Tertiary buried valley complexes in the Athabasca Oil Sands (*in situ*) Area south of Fort McMurray, Alberta (Figure 1), have long been assumed to contain vast quantities of groundwater. The oil sand industry will need water of suitable chemistry for successful development of in situ projects. Where sufficient volumes of treatable brackish water from deep formations are limited or unavailable, potable to near-potable groundwater from drift aquifers may be used as a source of make-up water. Major questions remain as to the sustainable yields of these drift aquifers and the chemical nature of the groundwater therein.

Ongoing work at the Alberta Geological Survey seeks to determine the sustainable yields of the drift aquifers, understand the controls on groundwater chemistry, and document baseline hydrogeological conditions prior to intensive energy development. This poster provides an update on ongoing efforts towards understanding the geochemistry of the drift aquifers.

A field program was conducted during the summers of 1999 to 2001 to collect high quality groundwater samples. The program had three components:

1. Sampling of water from domestic water wells, existing observation wells, and springs discharging from drift aquifers;

2. Sampling of produced water from oil and gas wells;

3. Sampling of new piezometers installed as part of this program.

This poster will present preliminary results for the first two points.

Sampling Methods and Analytical Program

An extensive list of analytes was constructed (Table 1) in order to arrive at the best possible baseline characterization and geochemical understanding of the drift aquifers in the study area. The groundwater sampling protocols used in this program were developed from the combined practices of the United States Geological Survey, the United States Environmental Protection Agency, and geochemical specialists at the University of Calgary, the University of Alberta and the University of Saskatchewan.

Sampled wells were carefully chosen based on location, completion depth, and quality of well construction based on drillers' reports. High quality water samples from these wells, AGS piezometers, and samples from a spring discharging from an exposed section of a Quaternary/Tertiary buried channel were collected along with quality control samples. The samples were analyzed for major, minor and trace constituents, organic acids, naturally occurring radioactive materials, stable isotopes and radiogenic isotopes. Additional historical chemical information was gathered from analyses performed by the Alberta Research Council and Alberta Environment as well as produced water analyses collected by the Alberta Energy and Utilities Board. The additional sample points were selected based on well completion quality and charge balance criteria.

Initial Results

Initial interpretation of the collected data suggests a number of hydrogeological and geochemical processes are causing substantial regional variability in groundwater chemistry. The processes include mixing of waters of meteoric, and possibly glacial origin, with basinal waters emanating from deeper formations, as well as water-rock interactions. The piezometric surface developed for the Quaternary aquifers suggests that flow is dominated by topography, flowing from recharge in the Moostoos Uplands and other highlands towards Christina, Horse, Wandering and Athabasca River basins. Flow within the major Quaternary/Tertiary buried channel in the study area is towards the Athabasca River.

Ongoing Activities

Work continues on better defining the nature of the water-rock and water-water interactions. Statistical analyses of the data along with geochemical and GIS analyses will help explain not only point by point chemical characteristics, but also will place the data and results of analyses in a spatial context from which the regional chemical system can be examined and defined.

Table 1. List of analytes

Chemical Parameter	Reason for analysis
Major, minor and trace elements	Process identification (i) water rock interaction (ii) mixing of diferent waters (iii) mineral dissolution and precipitation Health concerns Geothermometry and age dating Oil and gas and mineral exploration tools
Organic acids	Many are water-soluble and naturally occurring. The potential exists for complexation between organic acids and metals, facilitating transport of the metals.
$\delta^{18}O$ and $\delta^{2}H$	Water source Paleohydrogeology Renewablility of the resource
$\delta^{13}C$	Process identification (i) dissolution of carbonate minerals (ii) dissolution of organic carbon (iii) solution of atmospheric of soil (iv) rates of decomposition and burial of organic matter (v) mixing of waters Tracing pathways by which C enters or leaves groundwater
$\delta^{34}S$	Process identification (i) dissolution of evaporite gypsum (ii) dissolution of organic matter (coal or peat) (iii) dissolution of sulphide minerals (iv) sulphate reduction Tracing pathways by which S enters or leaves groundwater
$\delta^{11}B$	Process identification (i) mixing of waters (ii) water rock interactions (iii) anthropogenic input
$\delta^{87}Sr$	Process identification (i) mixing of waters (ii) dissolution of carbonates (iii) weathering of continental crust or volcanic rocks Water source
NORMS	Health concerns Process identification (i) mixing of waters

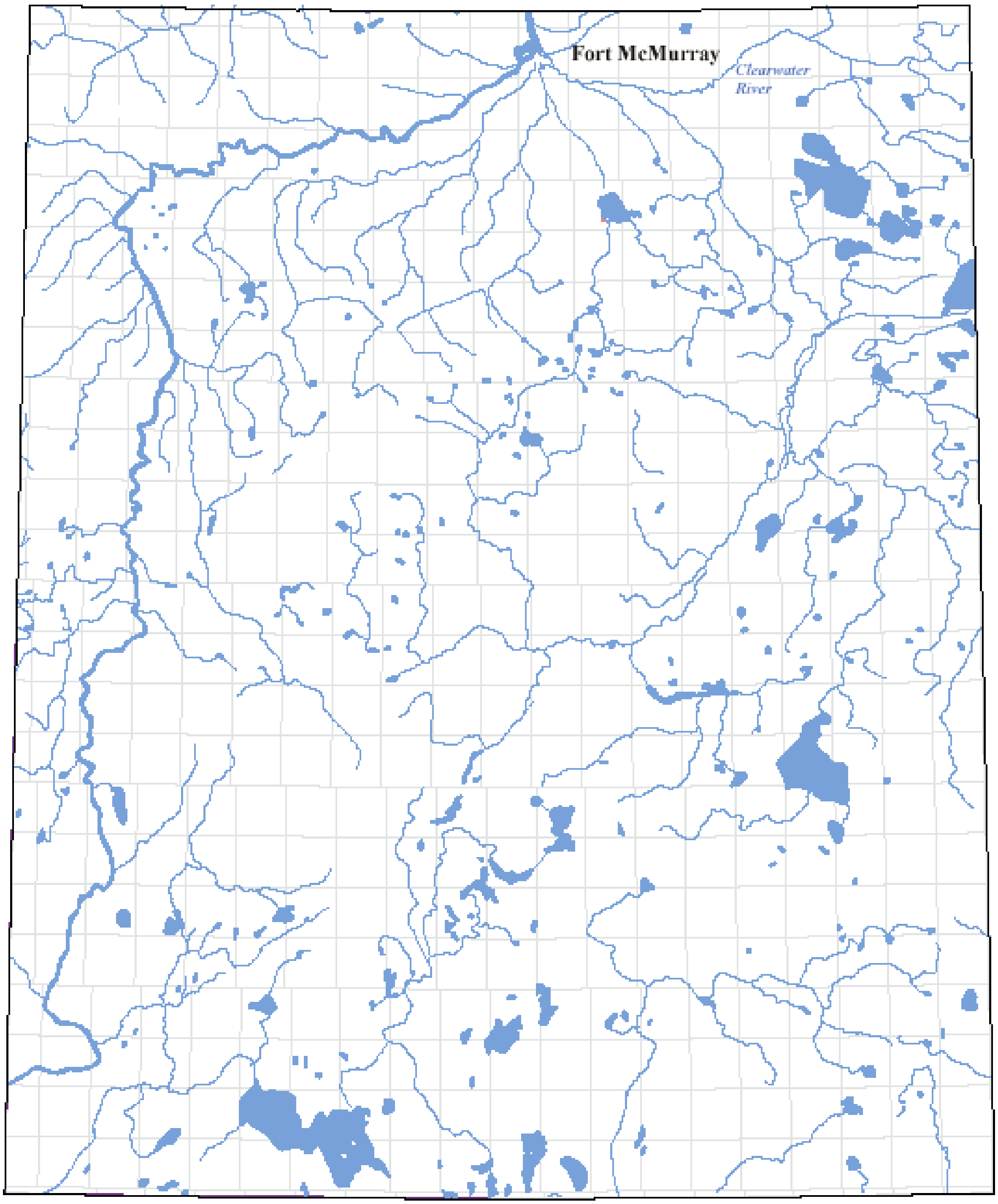
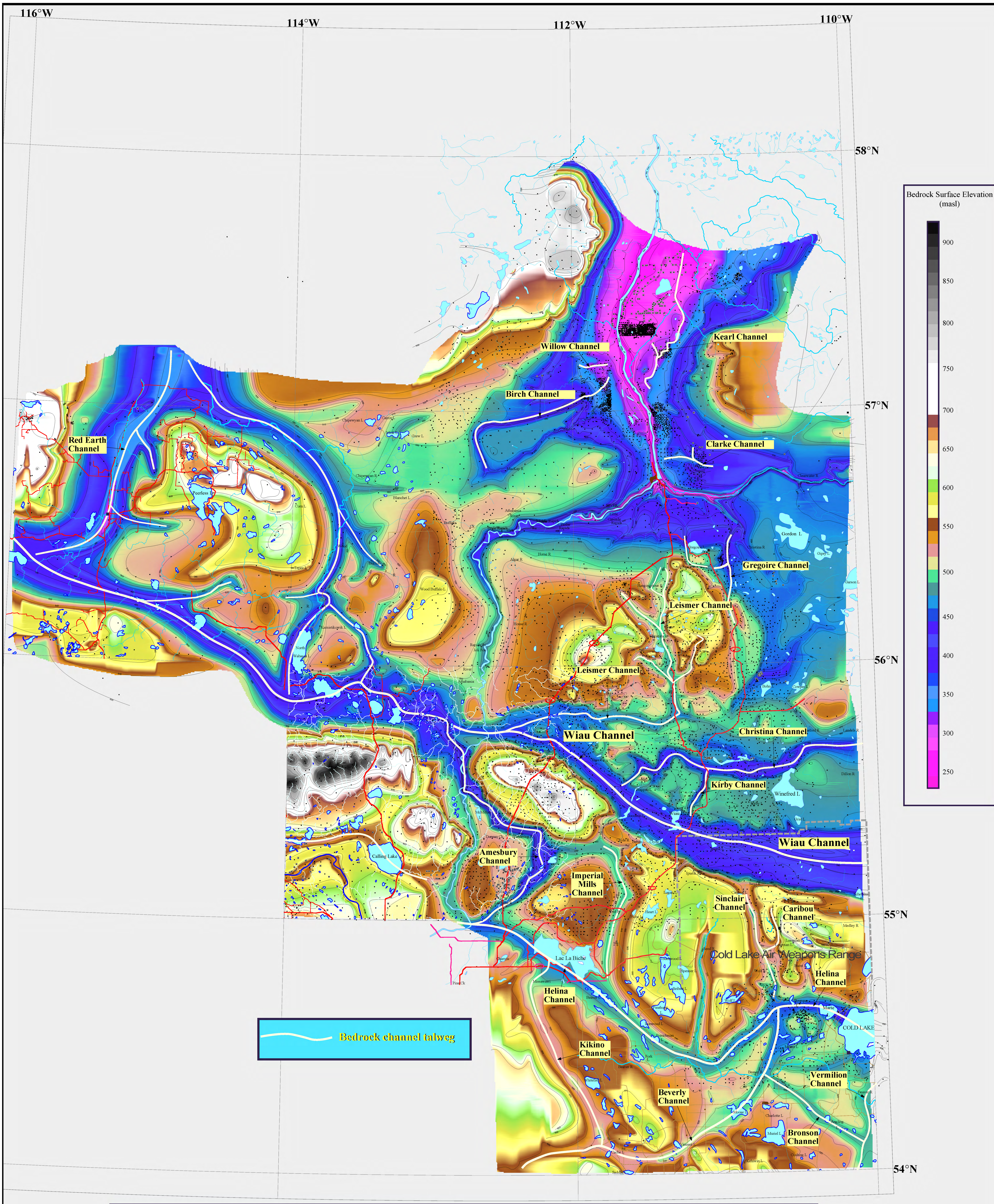


Figure 1. Study Area



Bedrock Topography, NE Alberta

EUB
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Bedrock Topography, Northeast Alberta

Contour Interval 10 m

(40 Km)

L. Andriashek & J. Pawlowicz

Date: 1/22/04 Scale 1:500,000

Hydrochemistry and Isotope Systematics of Regional Drift Aquifer Systems, Athabasca Oil Sands (in situ) Area

Tony Lemay and Sheila Stewart

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EUB Alberta Energy and Utilities Board · AGS Alberta Geological Survey · WD DEO Western Economic Diversification Canada / Diversification de l'économie de l'Ouest Canada

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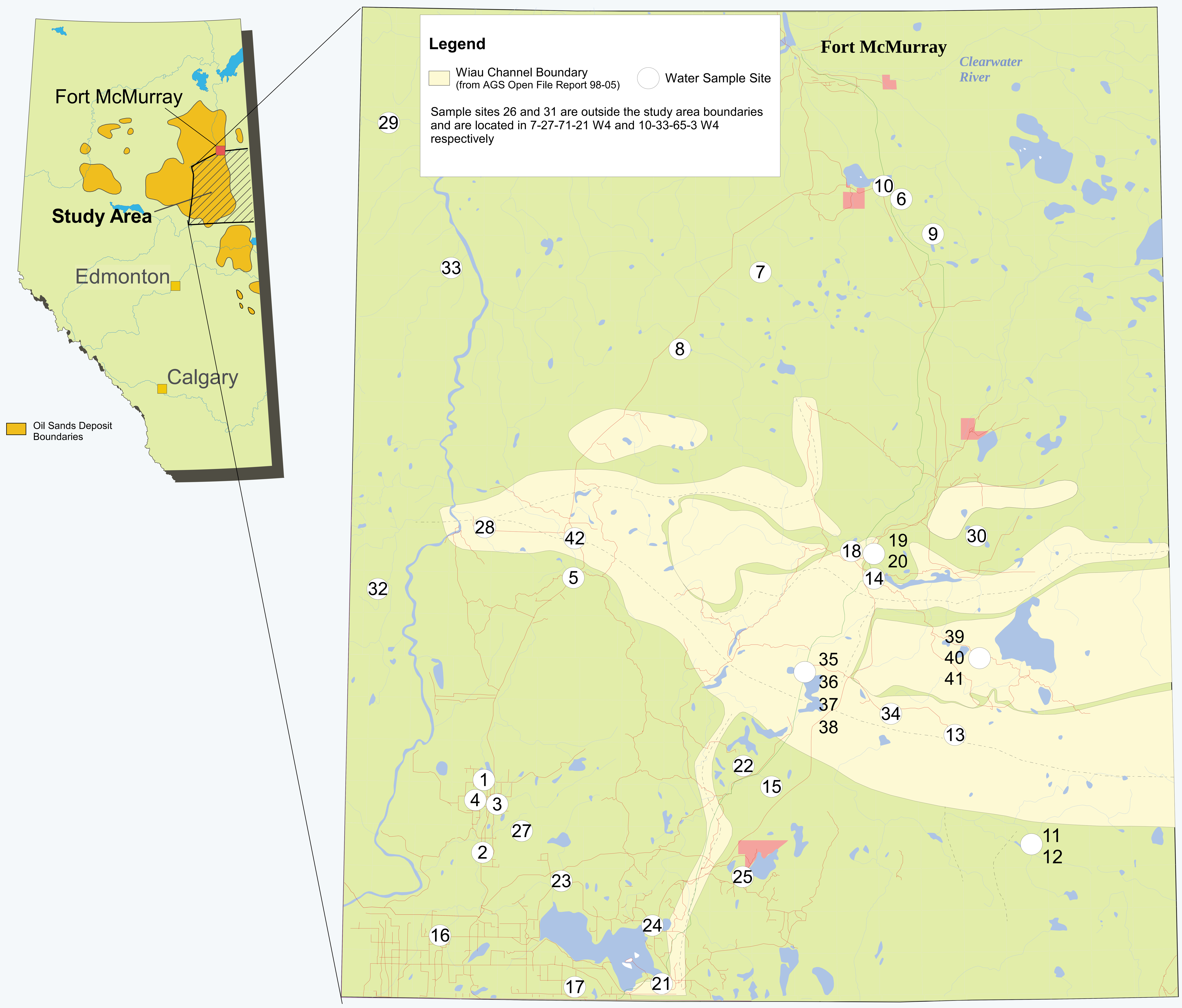

Where sufficient volumes of treatable brackish water from deep formations is limited or unavailable, potable or near-potable groundwater from drift aquifers may be used as a source of make-up water. Major questions remain as to the sustainable yields of these drift aquifers and the chemical nature of the water therein.

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The program had three components:

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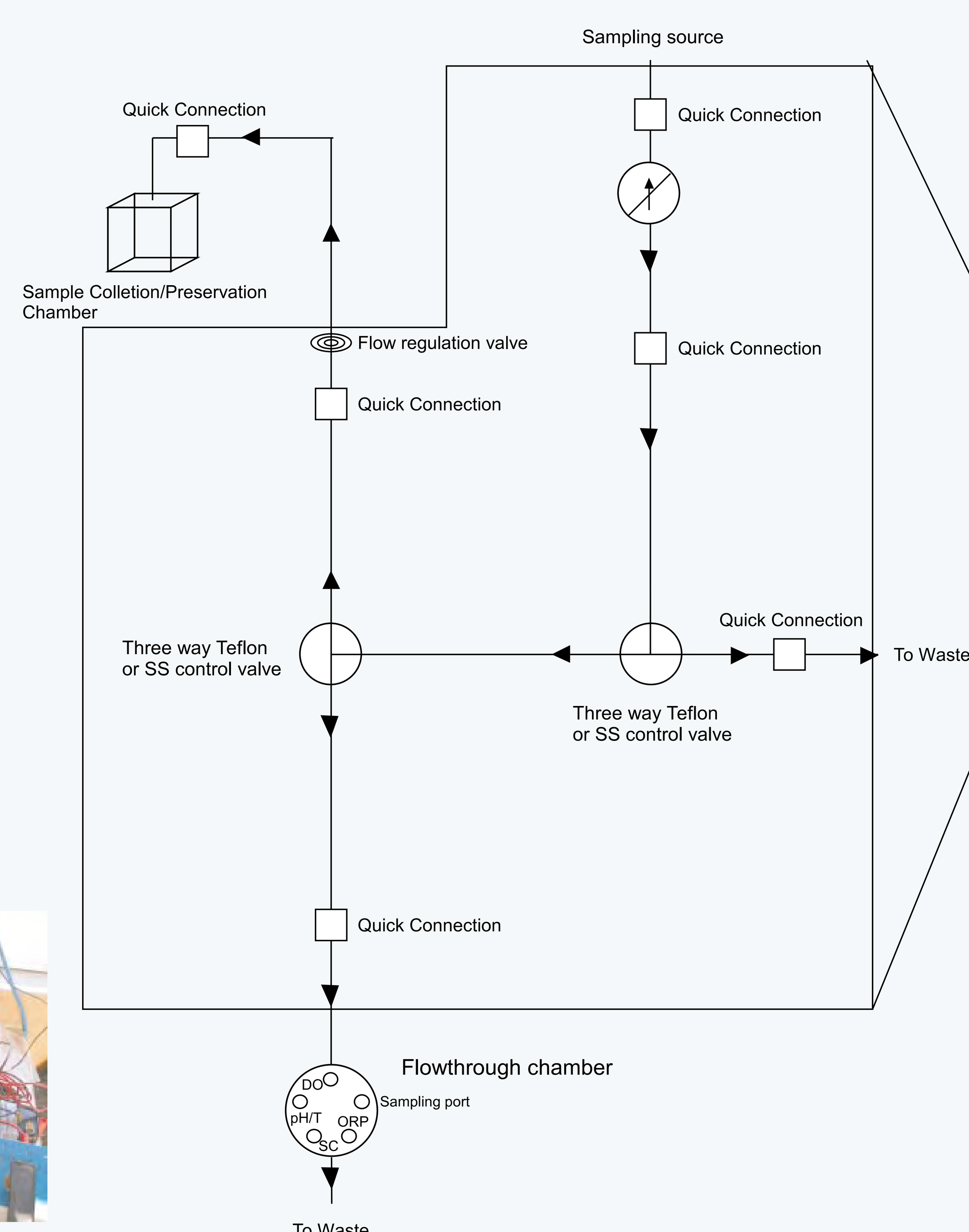
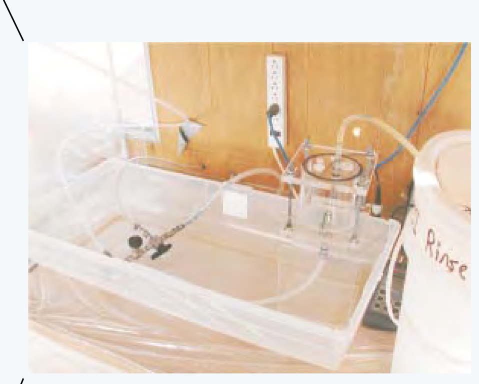
$\delta^{87}Sr$	Process identification (i) mixing of waters (ii) dissolution of carbonates (iii) weathering of continental crust or volcanic rocks Water source
NORMS	Health concerns Process identification (i) mixing waters

The groundwater sampling protocols used in this program were developed from the combined practices of the United States Geological Survey, United States Environmental Protection Agency, University of Calgary, University of Alberta and University of Saskatchewan. A sampling system utilized by the USGS was implemented and adapted for use during our field sampling investigations

The inflow portion of the system is connected as closely to the pump as possible

A sample processing chamber is used to minimize the chance of sample contamination from outside sources





A manifold system directs the flow of water from inflow to the flow through cell where field measurements are taken, to the sample processing chamber were samples are collected and to waste.

Field measurements are taken to verify that a sufficient volume of groundwater has been purged from the well as well as to help characterize the groundwater.

Groundwater Field Sampling Setup (modified from Koterba and others, 1995)

High quality groundwater samples were collected from domestic, industrial and observation wells, as well as from springs discharging from an exposed section of a Quaternary/Tertiary buried channel aquifer. High quality formation water samples were collected from oil and gas wells that are completed in important water bearing formations within the study area. Sample duplicates, splits and blanks were processed in order to monitor QA/QC. Additional historical chemical information was gathered from analyses performed by the Alberta Research Council and Alberta Environment as well as produced water analyses collected by the Alberta Energy and Utilities Board. The additional sample points were selected based on well completion quality and charge balance criteria.

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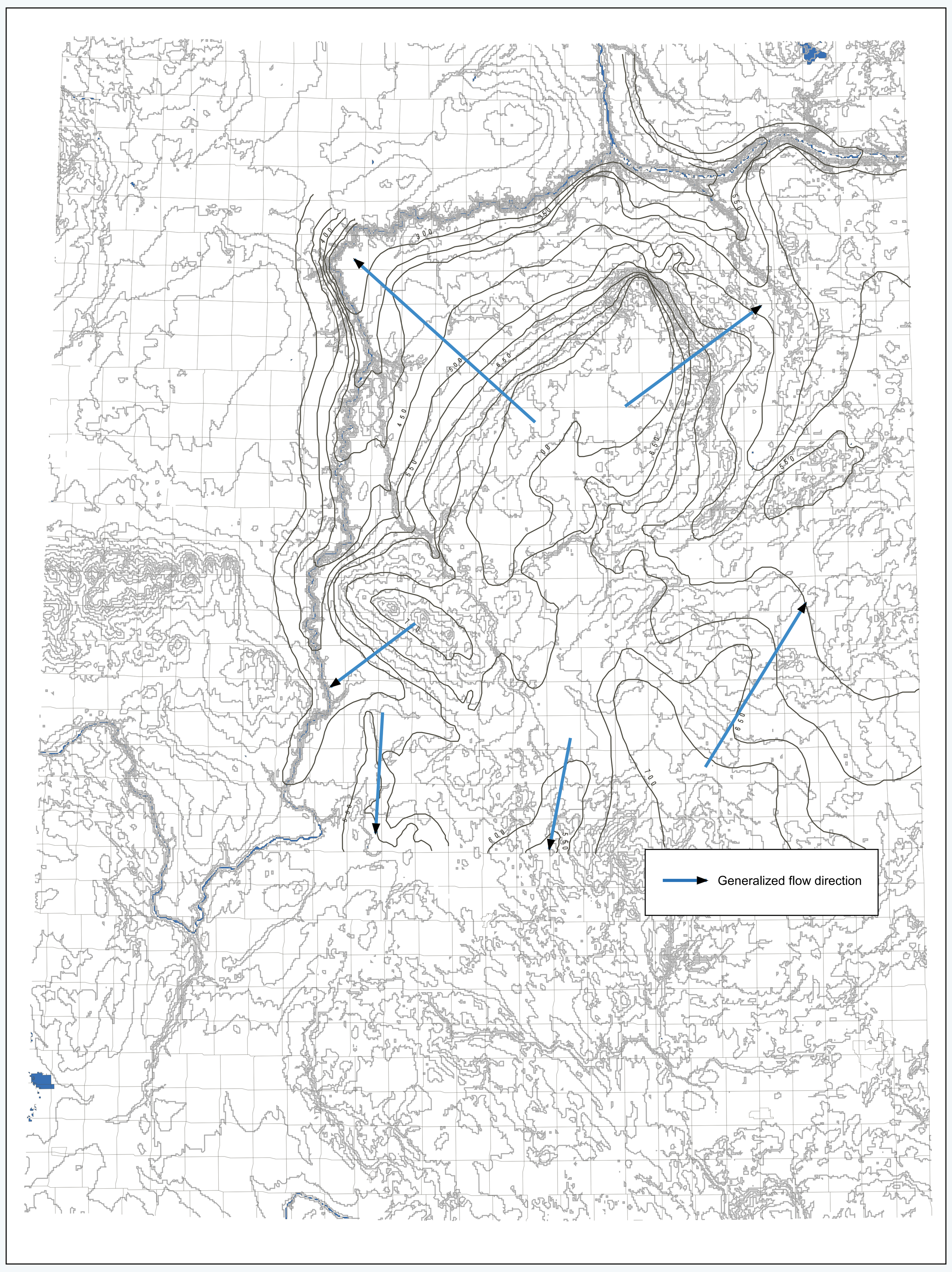
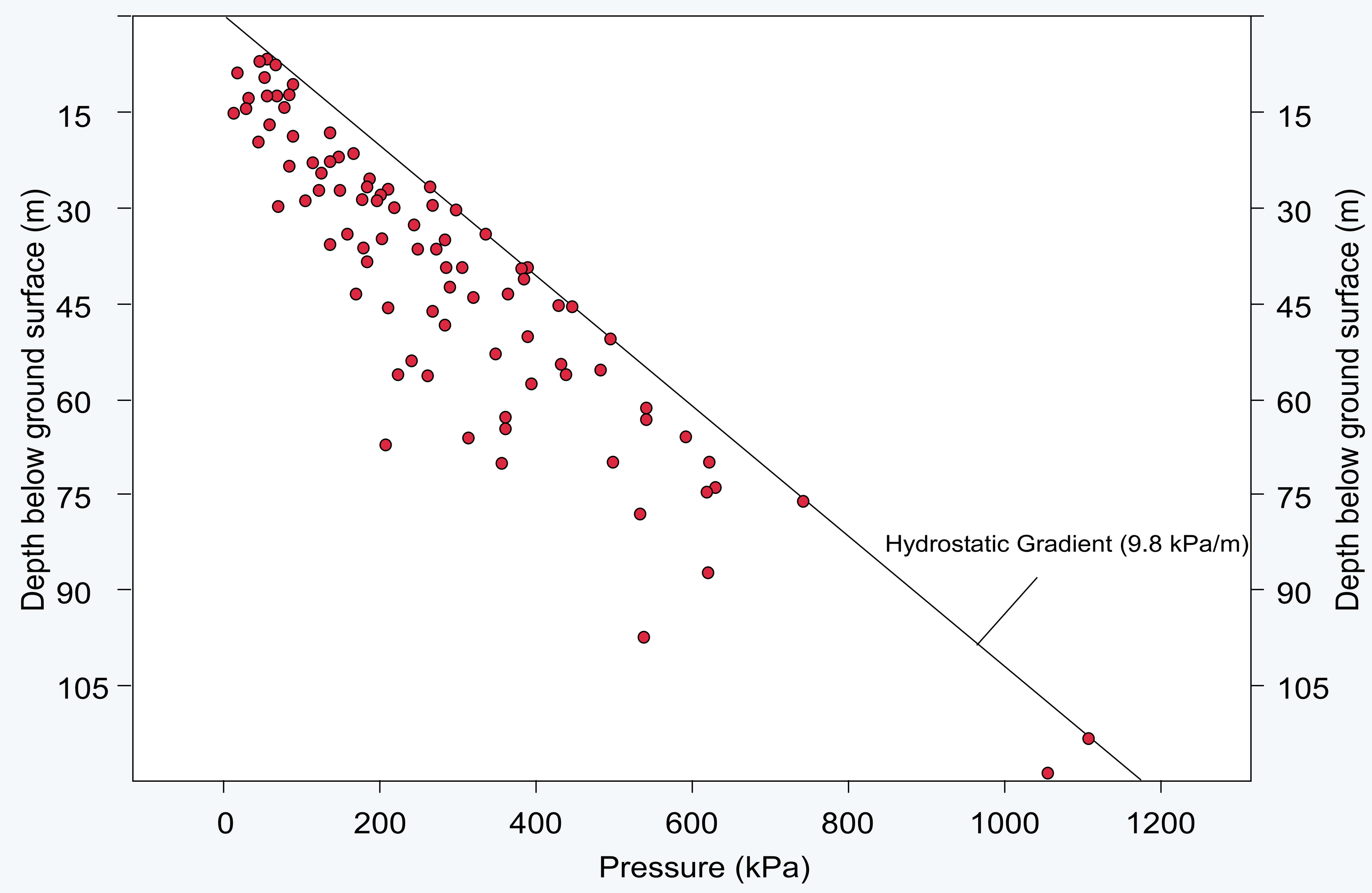
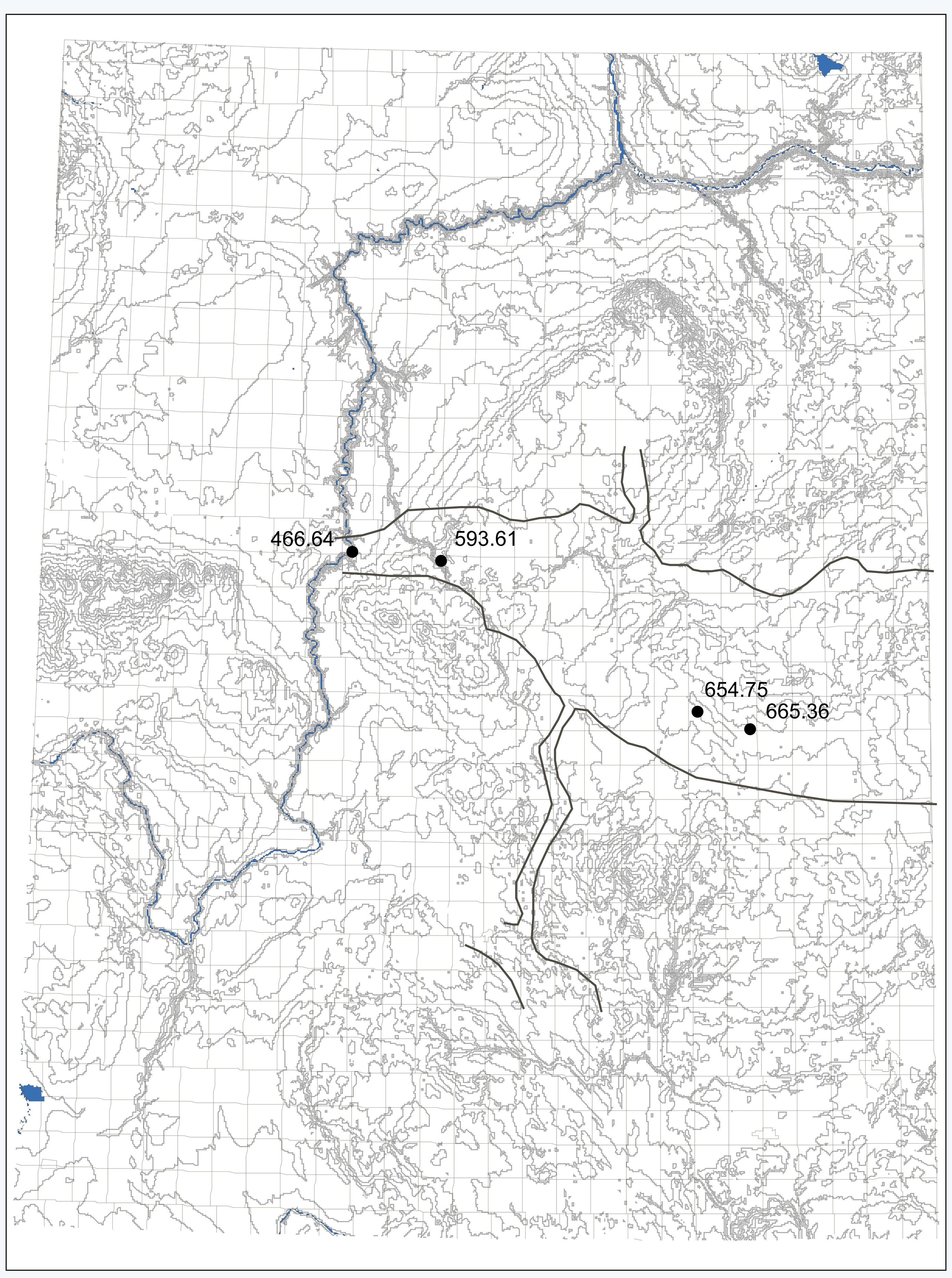
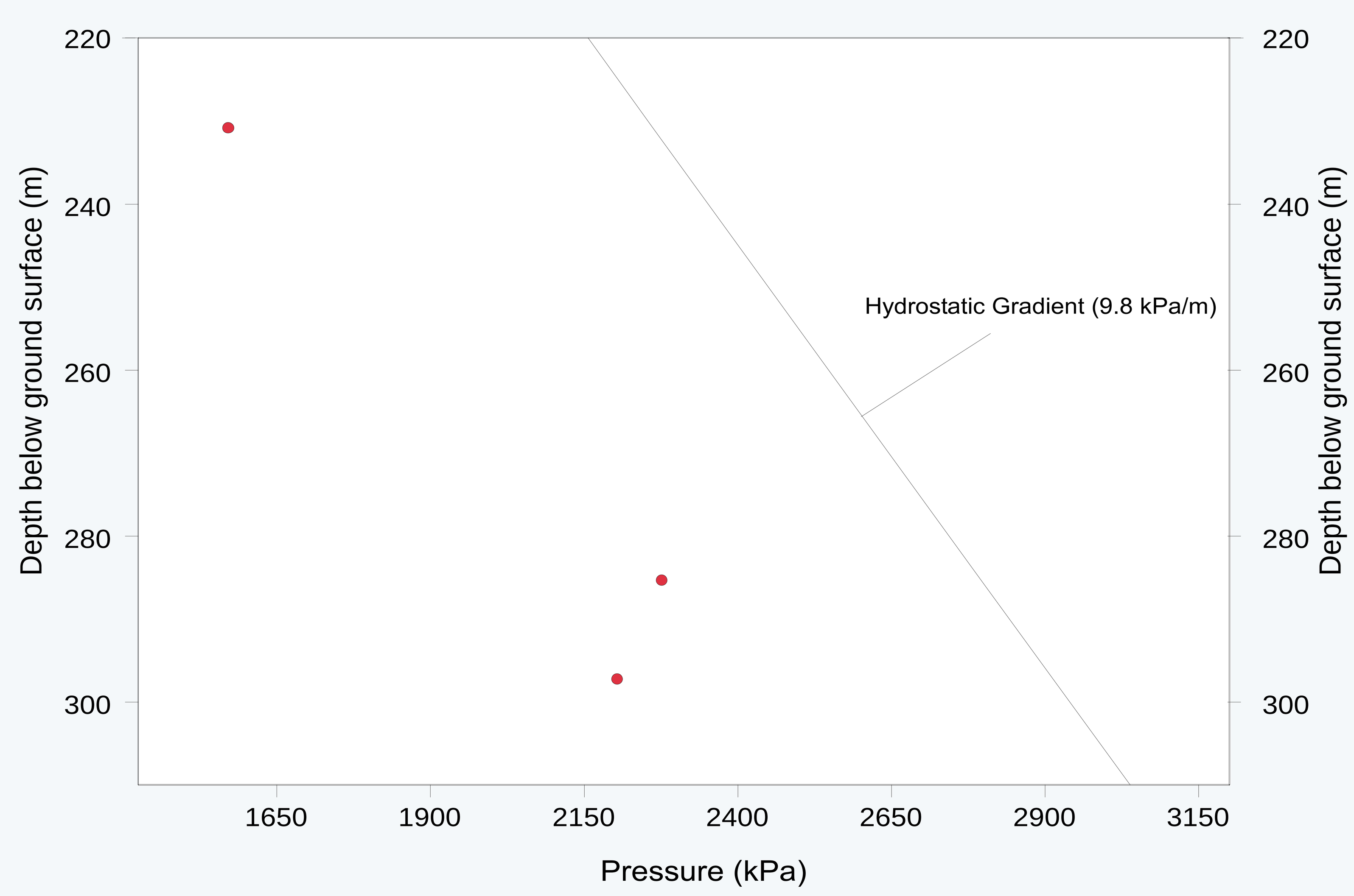


Quaternary Drift Aquifer Wells

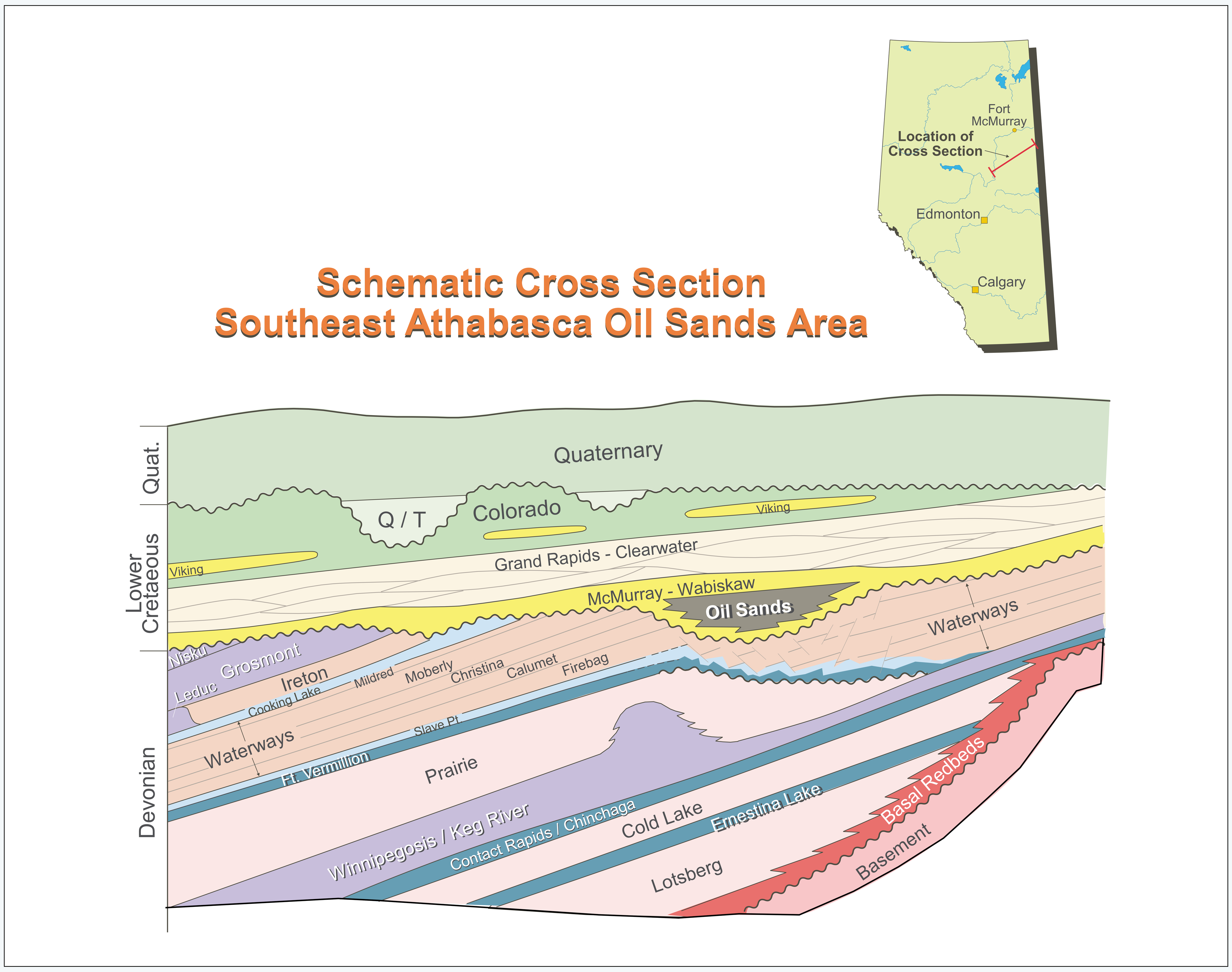




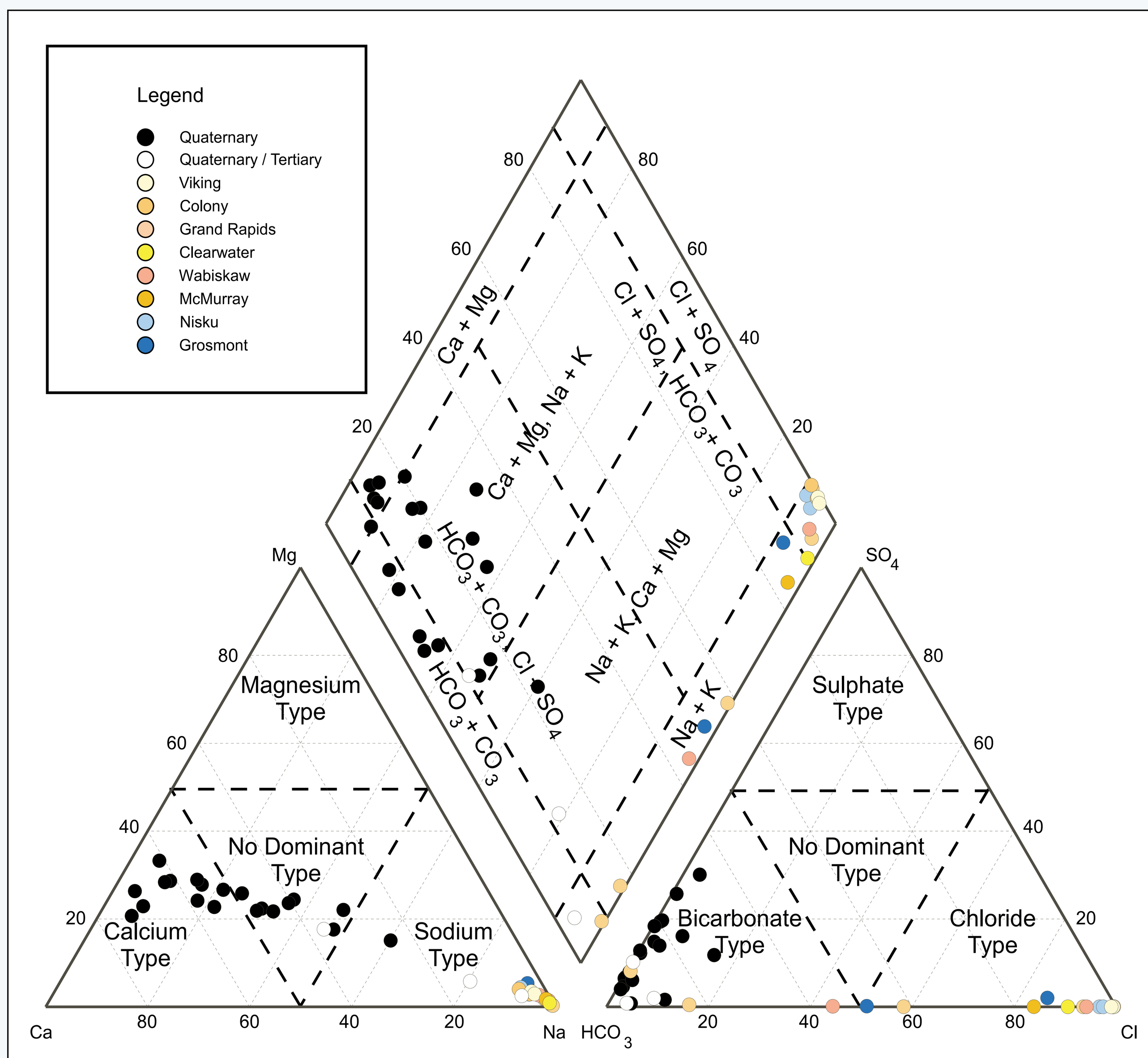
Buried Channel Aquifer Wells



The production of in situ oil sands requires substantial volumes of water for steam generation and oil sands processing. Estimates over the lifetime of extraction activities range from 3 barrels of water per barrel of bitumen to 1 barrel of water per barrel of bitumen. The most likely sources of water are: Quaternary drift aquifers, Quaternary/Tertiary buried channel aquifer systems, and Cretaceous sandstones such as those in the Viking, Grand Rapids, Clearwater, Wabiskaw and McMurray. The water used in the extraction and processing operations is recycled many times, but eventually must be disposed of. Likely targets for disposal include the McMurray Formation, and Devonian formations such as the Winnipegosis / Keg River Formation.

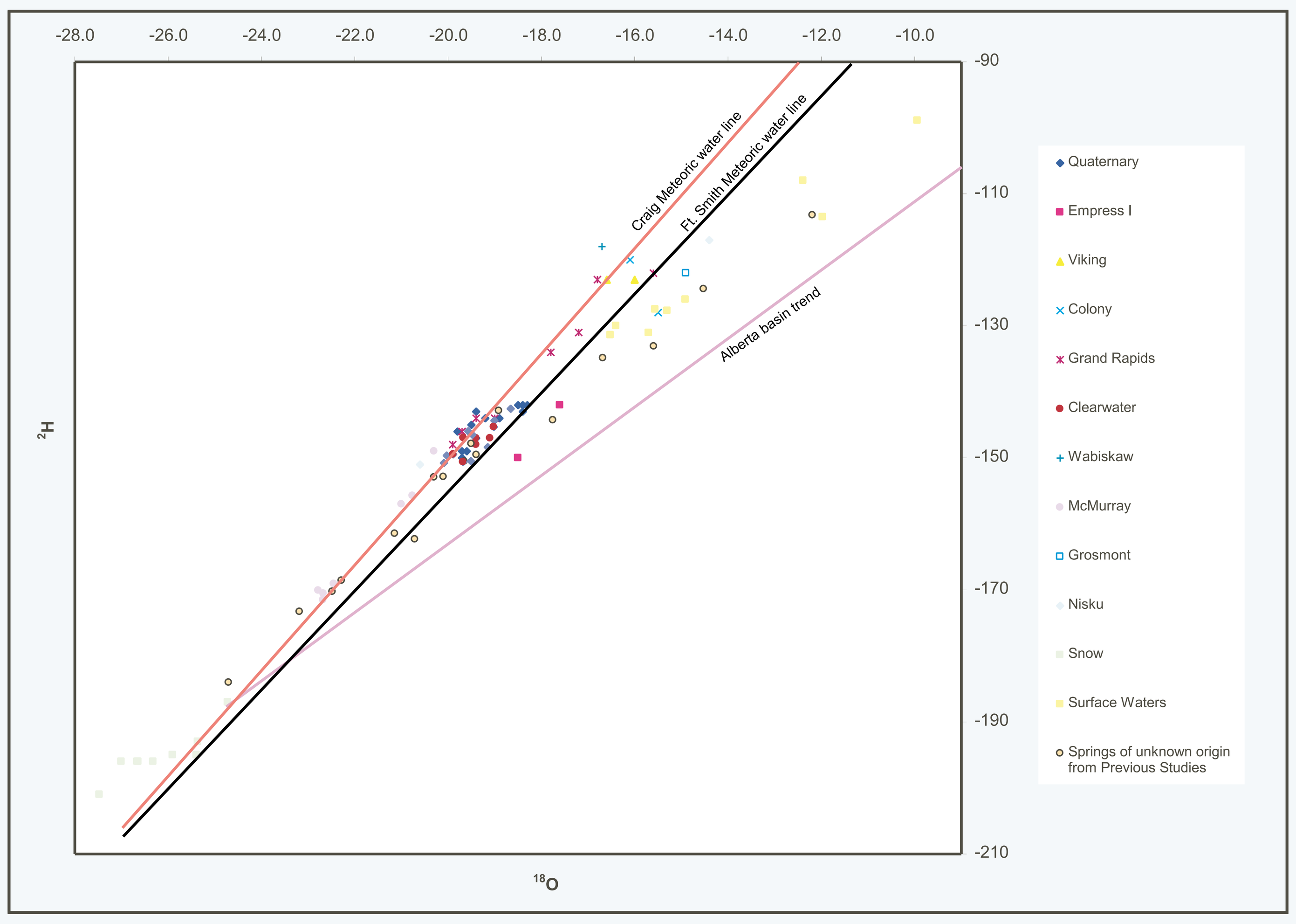


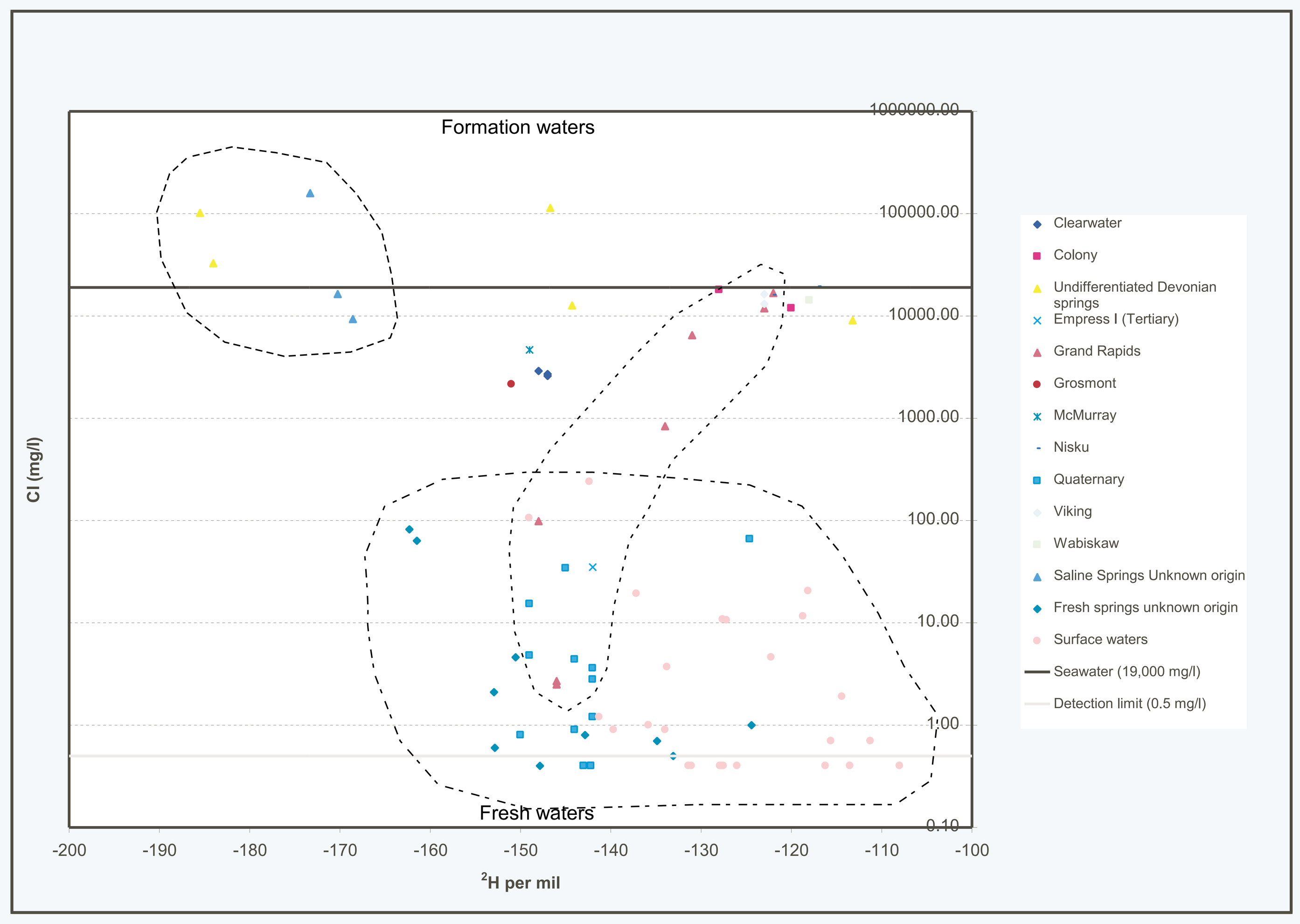
The water needed for steam generation and processing applications must meet certain chemical criteria. As can be seen in the Piper diagram below, the various waters have different chemical signatures. The table below lists the post-processing chemical constraints for steam generation as defined for a recent in situ oil sands project. The bolded text indicates chemical concentrations of water from various formations or intervals that meet the post-processing chemical constraints for steam generation criteria.

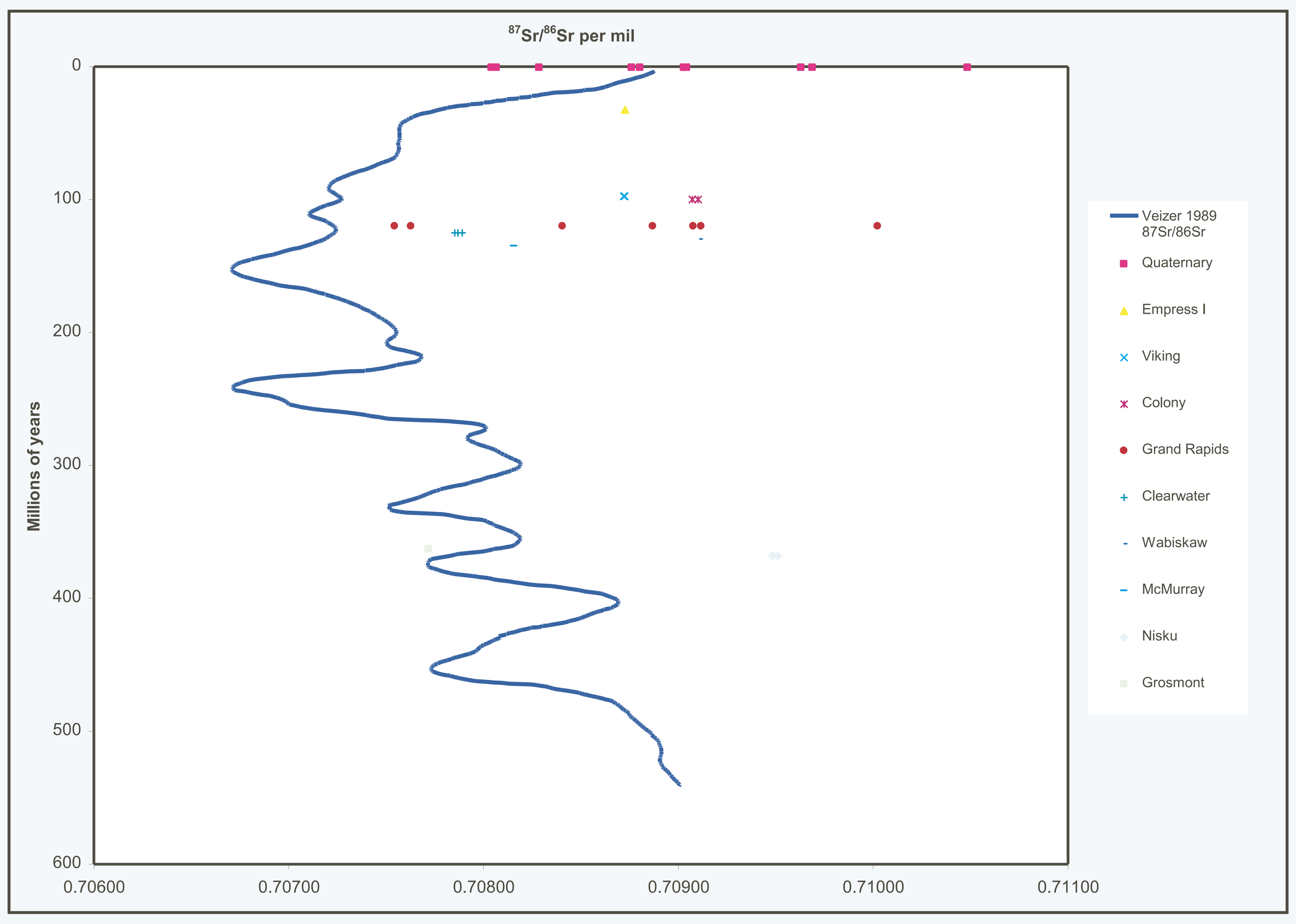


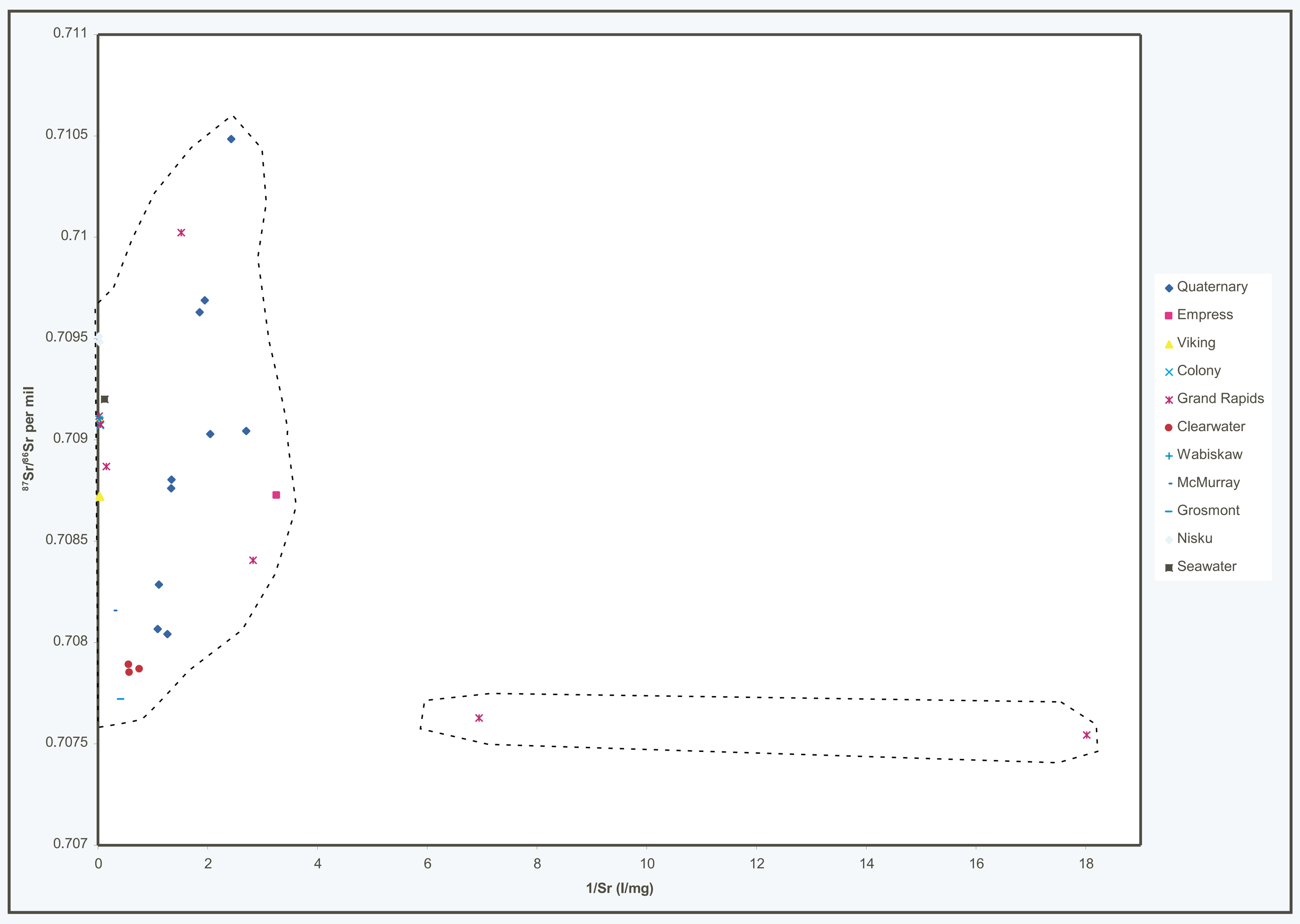
Summary of Chemical Parameters

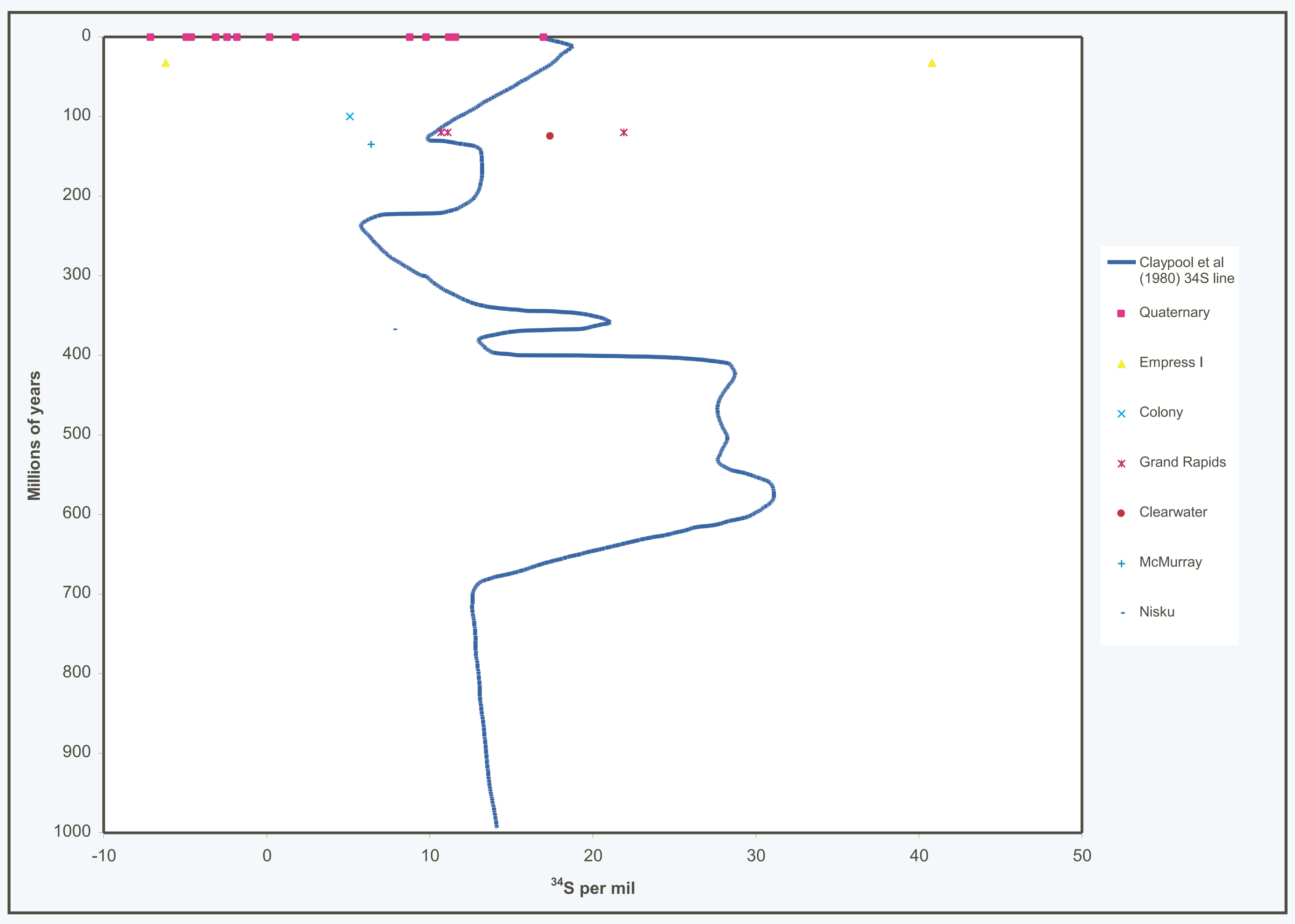
Parameter	Chemical Constraints for Steam Generation	Quaternary Drift Aquifers n = 18	Quaternary/Tertiary Buried Channel Aquifers n = 3	Viking n = 2	Colony n = 2	Grand Rapids n = 6	Clearwater n = 3	Wabiskaw n = 2	McMurray n = 1	Nisku n = 2	Grosmont n = 2
Ca		84.8	16.3	246.5	396	110.8	11.7	90.5	28	428	62
Mg		25.4	6	170	188	68.6	9.9	80.5	30.2	244	70.4
Na		105.6	193	9390	9245	3520.7	1953.3	6035	3190	11000	3200
K		5.8	2.6	42.8	42	17.8	5.8	60.5	14.7	82	33.3
Fe	< 0.25 ppm	2.38	0.72	**0.024**	**0.12**	**0.15**	**<0.03**	**<0.03**	**0.006**	0.26	**0.062**
Mn	Negligible	0.237	0.04	0.19	0.79	0.22	0.018	0.0085	0.11	0.30	0.044
Ba	Negligible	0.009	0.15	15.8	17.65	5.16	0.66	7.6	2.5	23.7	1.82
Extractable Silica	Less than 30 ppm	73	63.1	**25.5**	34.3	31.3	47.9	42	**29.3**	53.2	33.9
S	Negligible	21.4	2.78	0.59	1.91	3.06	0.08	1.4	0.41	0.65	29.0
TDS	< 8000 ppm	**563.2**	**526.5**	24650	24900	9213.9	5016.7	15380	8680	30300	8320
Hardness	< 1 ppm	351.5	65.5	1315	1550	472	63	554	194	2070	443
Dissolved oxygen	Negligible	0.57	0.83								
Cl	Negligible	32.3	25.8	14700	14950	6021.6	2733.3	7850	4660	17600	4660
Oil	< 0.5 ppm										
pH	7.5 to 9.0	7.30	**7.87**	7.44	7.28	**8.34**	**8.26**	**8.09**	**8.03**	7.11	7.2

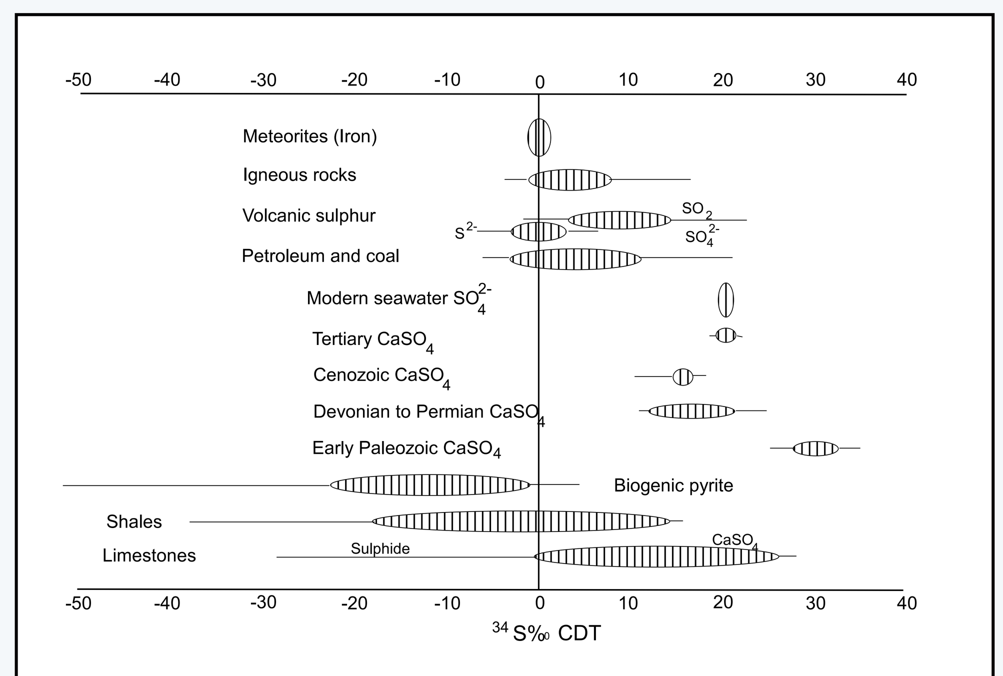




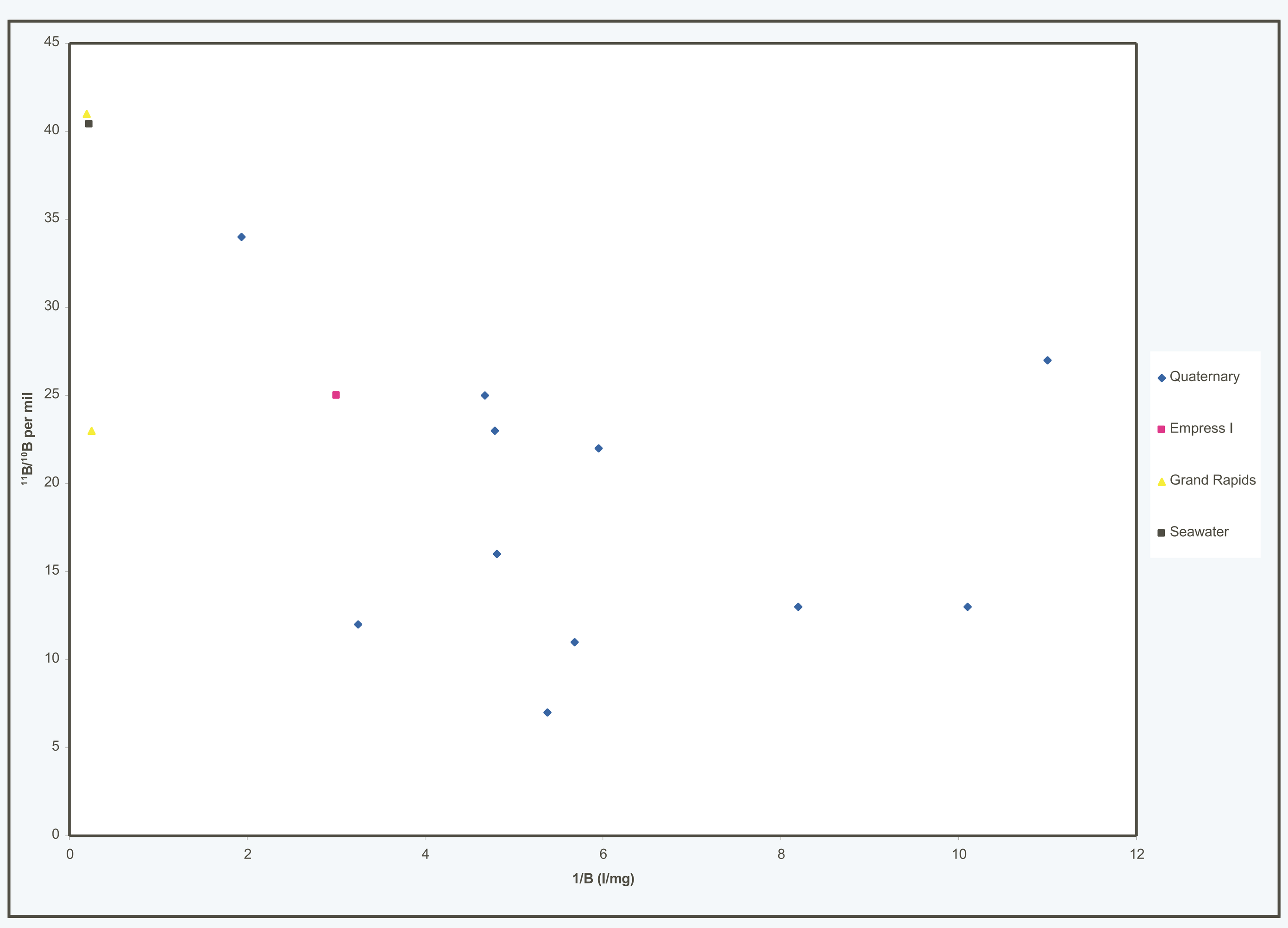








Ranges in ^{34}S contents of sulphur and sulphur compounds in different materials and environments (modified from Krouse, 1980)



Isotopic measurements of formation waters from northeast Alberta have been made covering a stratigraphic range from Devonian to Quaternary aged aquifers. The stable isotopes of O, H, S and B as well as radiogenic Sr indicate mixing between meteoric water and formation water.

The majority of the ^{18}O and ^{2}H data plot along the meteoric water line except those that fall along evaporation trend lines above the Alberta basin line. Although the ^{2}H vs Cl^- plot shows a general lack of mixing between meteoric and deeper formation water, waters from the Grand Rapids Formation, which subcrops in the study area, show significant mixing. The contradictory results based on these two plots suggest varying degrees of connection between Cretaceous and Devonian formation waters with Quaternary water. Possible means of mixing include local flow of meteoric water through channels incised through till sheets and into Cretaceous formations. More data is required for conclusive evaluation.

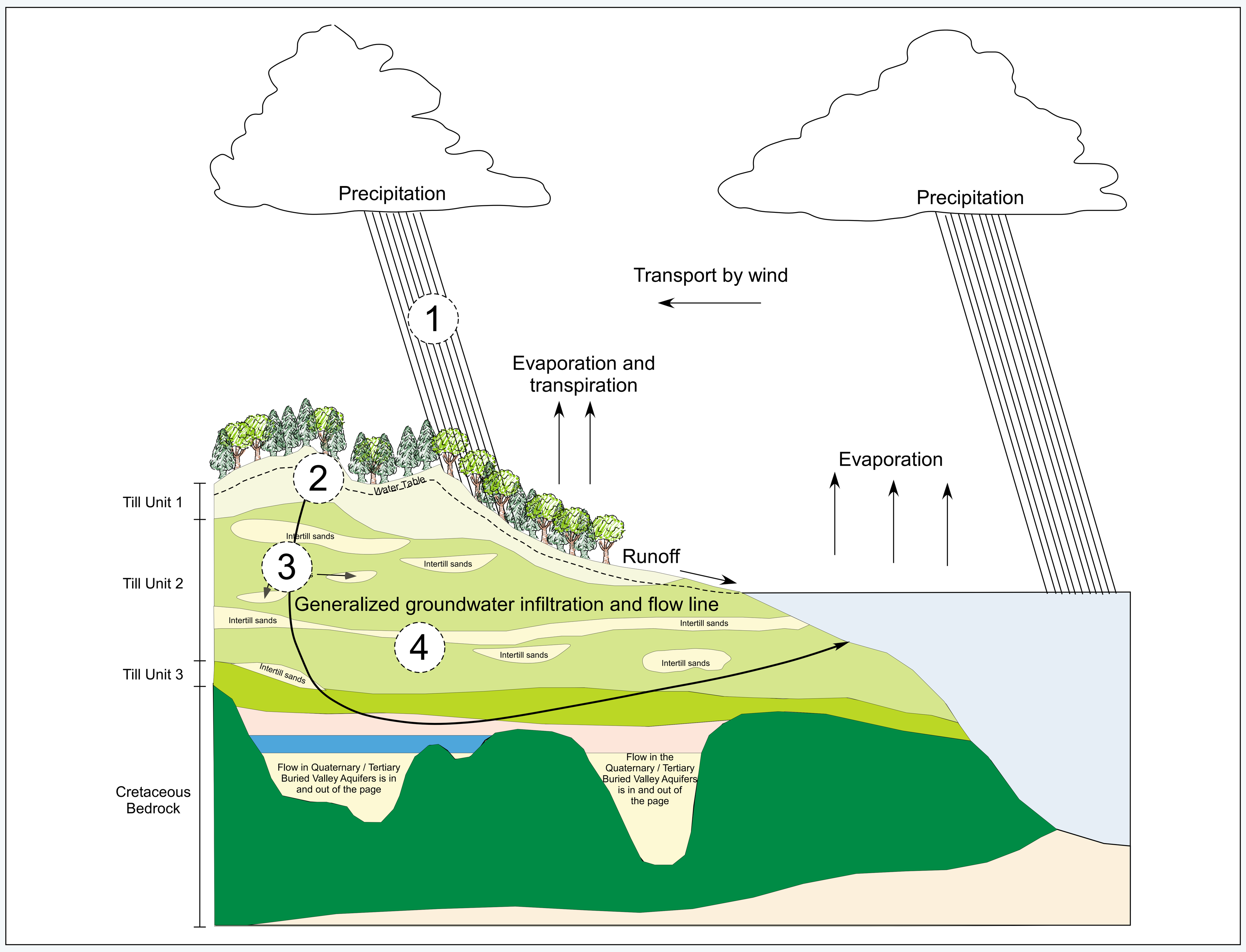
^{87}Sr data plotted against the seawater Sr ratios from the Phanerozoic (Veizer, 1989) show significant deviations from the seawater curve with the exception of the Grosmont formation. Continental K+ rocks are higher in Sr than sea water and this is reflected in the ^{87}Sr/^{86}Sr ratio of the water with which they have equilibrated. The ^{87}Sr/^{86}Sr vs 1/Sr plot tests the mixing relationship showing a moderate positive trend typical of clastic sediments. Two Grand Rapids points show dilution and depletion reflecting mixing. The departure of the Nisku samples from the line is most easily explained through diagenesis.

The ^{11}B/^{10}B vs 1/B plot shows significant scatter in the Quaternary data with no discernible trend. More data is required to adequately determine mixing regimes between the Quaternary, Cretaceous and Devonian formations.

^{34}S data plotted against the ^{34}S of marine sulphate through time (Claypool et al, 1980) show considerable variation from the marine sulphate line. ^{34}S values from the Quaternary water samples are typical of a number of S sources including igneous rocks, petroleum and coal, seawater SO_4^{2-}, $CaSO_4$, shales, limestones and sulphide minerals. This is based on chemical equilibrium calculations as well as sedimentological and petrological oxidation of sulphide minerals from shales incorporated into the tills with a minor contribution from limestones and $CaSO_4$.

Based on the Piper plot of the major ion chemistry of water from the Quaternary drift sequence and water from the Quaternary / Tertiary buried valley aquifers, differences between the waters are evident. However, there are some striking similarities. What then is controlling water chemistry in the study area?

The simple answer is water rock interactions, with perhaps some bacterial influence. The figure below shows a generalized cross section through the study area. Represented on the cross section are Quaternary drift aquifers and Quaternary /Tertiary buried valley aquifers.



1. The oxygen and hydrogen isotopes from well samples suggest that the drift and buried valley aquifers were recharged by meteoric water that has the same isotopic composition as present day precipitation.

2. As the water enters the hydrogeological system, it reacts with soil CO_2 to form aqueous CO_2 or carbonic acid.

3. As the water continues to infiltrate into the soil, it interacts with the matrix materials. Tills in the study area have between 2 to 10 wt% carbonate content. Dolomite is the dominant carbonate mineral type present. As the carbonic acid reacts with the carbonates, carbonate dissolution begins to occur. Predominantly, these processes release Ca, Mg, and HCO_3 into the groundwater, but also release Ba and Sr. As the aqueous CO_2 mixes with the carbonate derived C, the $\delta^{13}C$ ratio of the dissolved inorganic carbon changes and is expected to follow one of the paths below (Figure 1). The range of $\delta^{13}C$ values found in the samples is within the range for groundwater DIC (Figure 2). The $\delta^{13}C$ of the buried channel aquifer is different than those found in the drift aquifers (Figure 3). It has yet to be determined if this value is significant. If it is, it suggest one of many possibilities including: the recharge pathway in the buried channel aquifers is different than the recharge pathway in the drift aquifers, or perhaps there is another source of DIC being introduced in the buried channel aquifers to change the ratio, such as bacterial oxidation of organic matter.

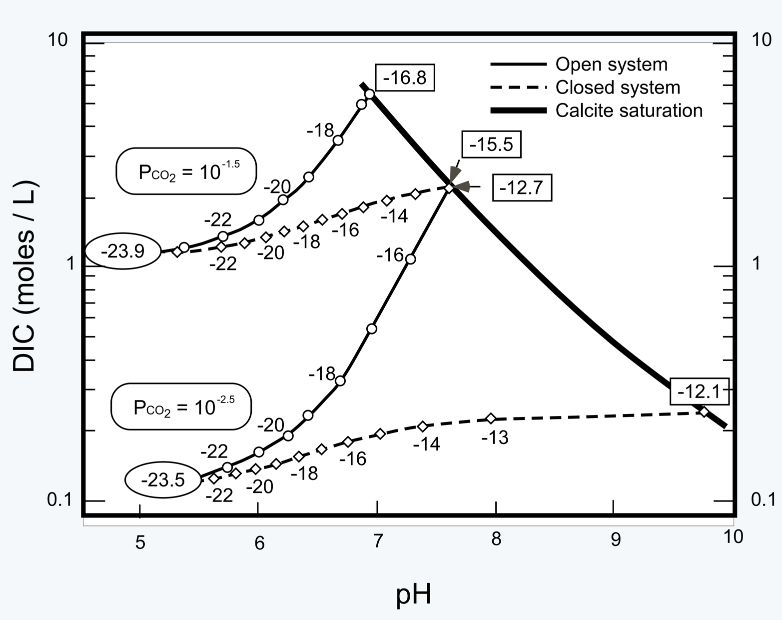


Figure 1 - The evolution of DIC and $\delta^{13}C$ DIC in groundwaters (modified from Clark and Fritz, 1997, Environmental Isotopes in Hydrogeology)

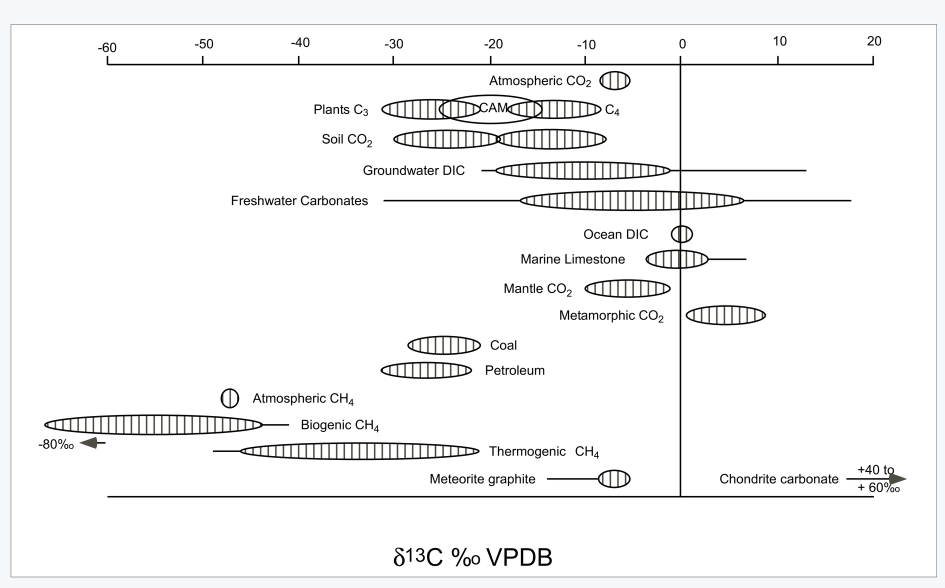


Figure 2 - Ranges of $\delta^{13}C$ values in selected natural compounds (modified from Clark and Fritz, 1997, Environmental Isotopes in Hydrogeology)

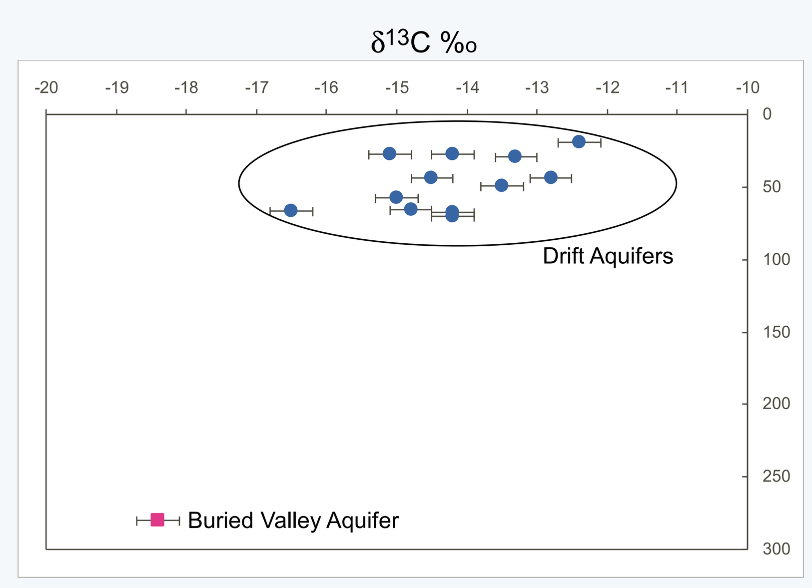
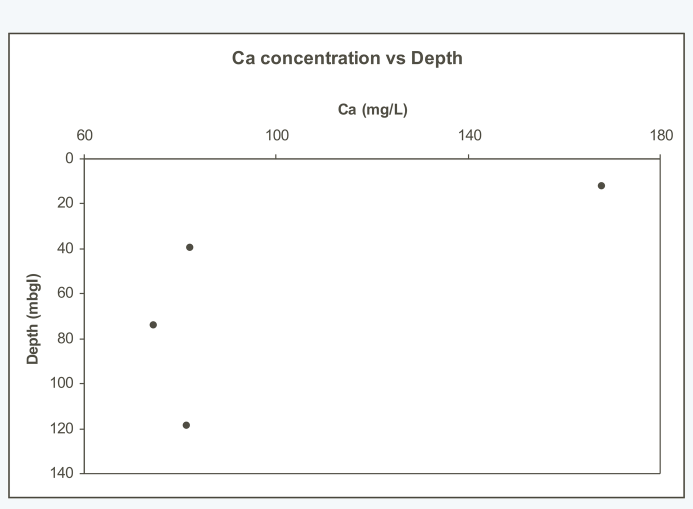
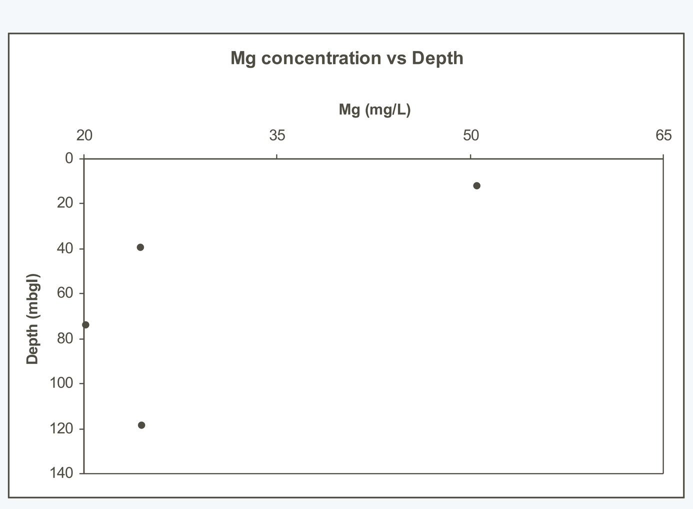
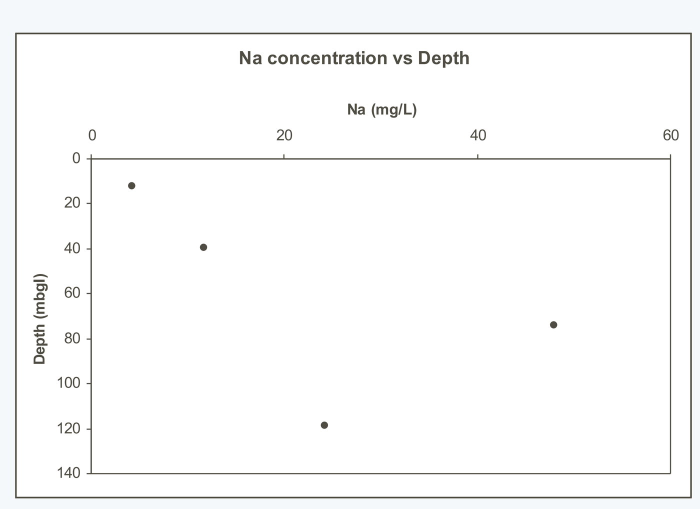


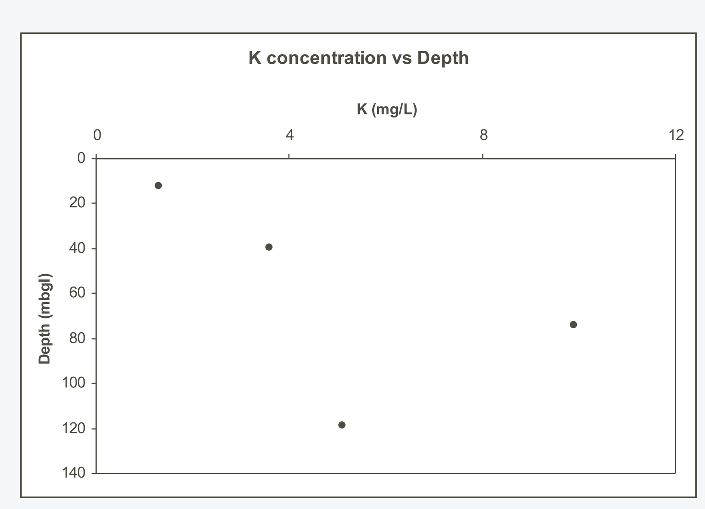
Figure 3 - $\delta^{13}C$ vs Depth in the Drift and Buried Valley aquifers

4. Continued exposure to the geologic materials, most importantly the tills, during groundwater flow further changes the chemistry of the water. If we assume that the till composition is similar in this study area to that of tills in the Sand River area (Andriashek and Fenton, 1989) the tills in this study area will contain between 22 to 43% clay. The clays are composed of approximately 53% illite, 23% kaolinite, 17% smectite and 7% chlorite. Cation exchange on the clays results in the exchange of Ca and Mg for Na (with the smectites) and K (with the illites). These exchange reactions occur both as water flows downwards through the Quaternary materials and as it flows laterally from high to low hydraulic head. An example of these exchange reactions can be seen from a nested piezometer site (see the figures below).









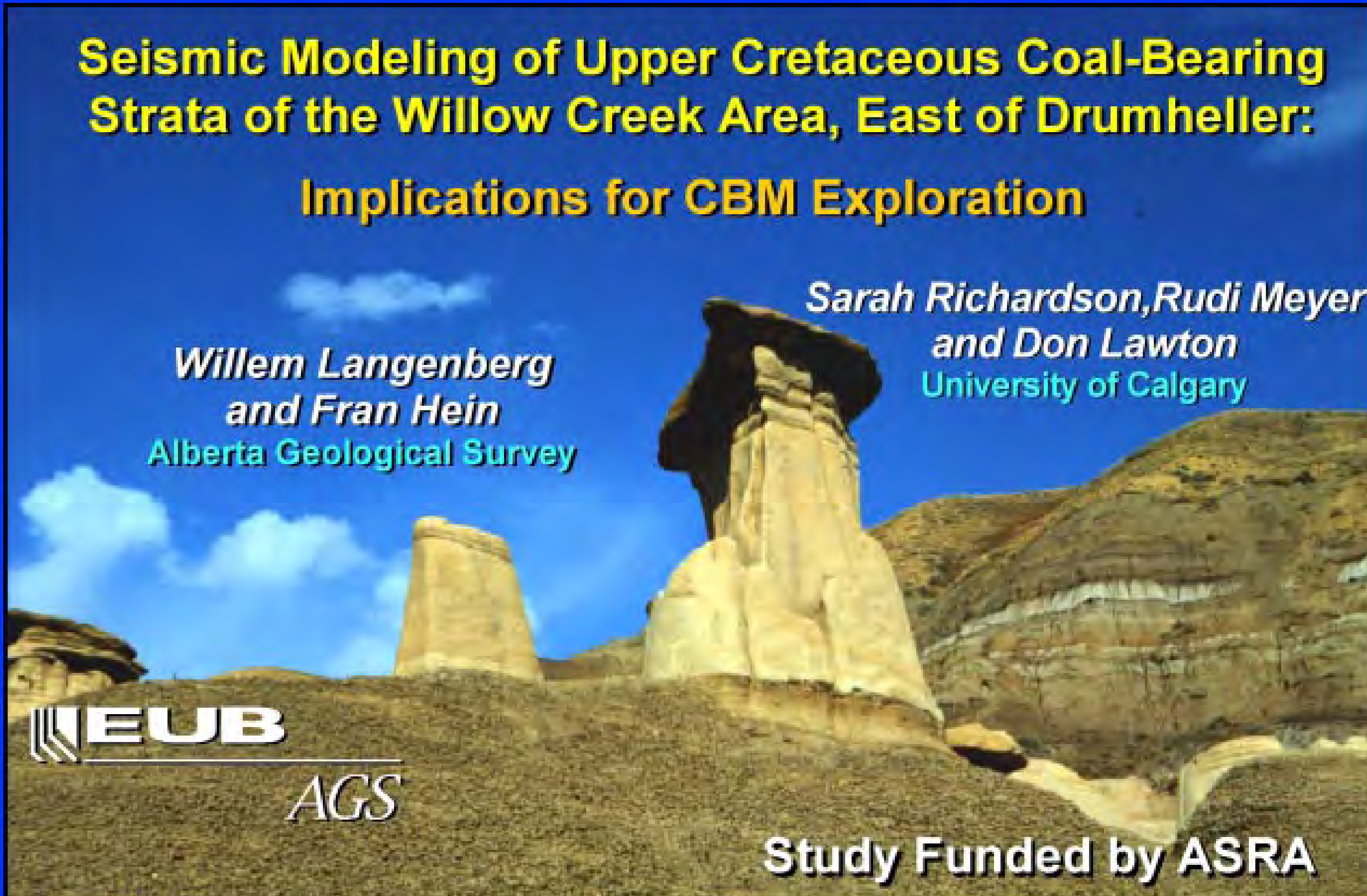
The dominant processes controlling water chemistry are generation of carbonic acid, carbonate dissolution and subsequent cation exchange. Other water rock interactions are occurring, but those previously listed affect water chemistry to the greatest extent.

Seismic Modeling of Upper Cretaceous Coal-Bearing Strata of the Willow Creek Area, East of Drumheller:

Implications for CBM Exploration

Willem Langenberg and Fran Hein
Alberta Geological Survey

Sarah Richardson, Rudi Meyer and Don Lawton
University of Calgary



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Study Funded by ASRA

wICSPG01.1

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Outline

- Location and geological setting
- Delta complex of Lower Horseshoe Canyon Formation
- Geometry of coal bearing strata in cross section
- Seismic models
- Conclusions

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Location of Study Area

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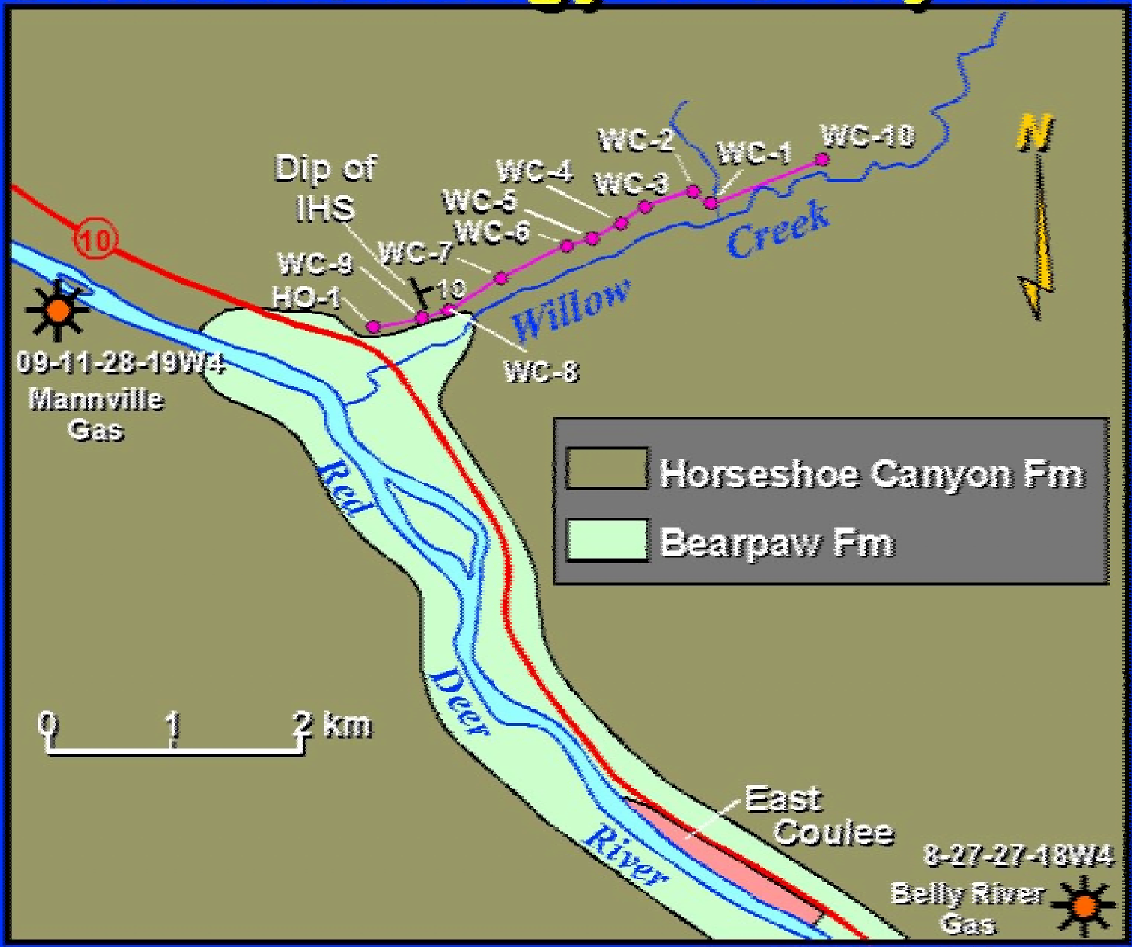
Surface Geology of Study Area



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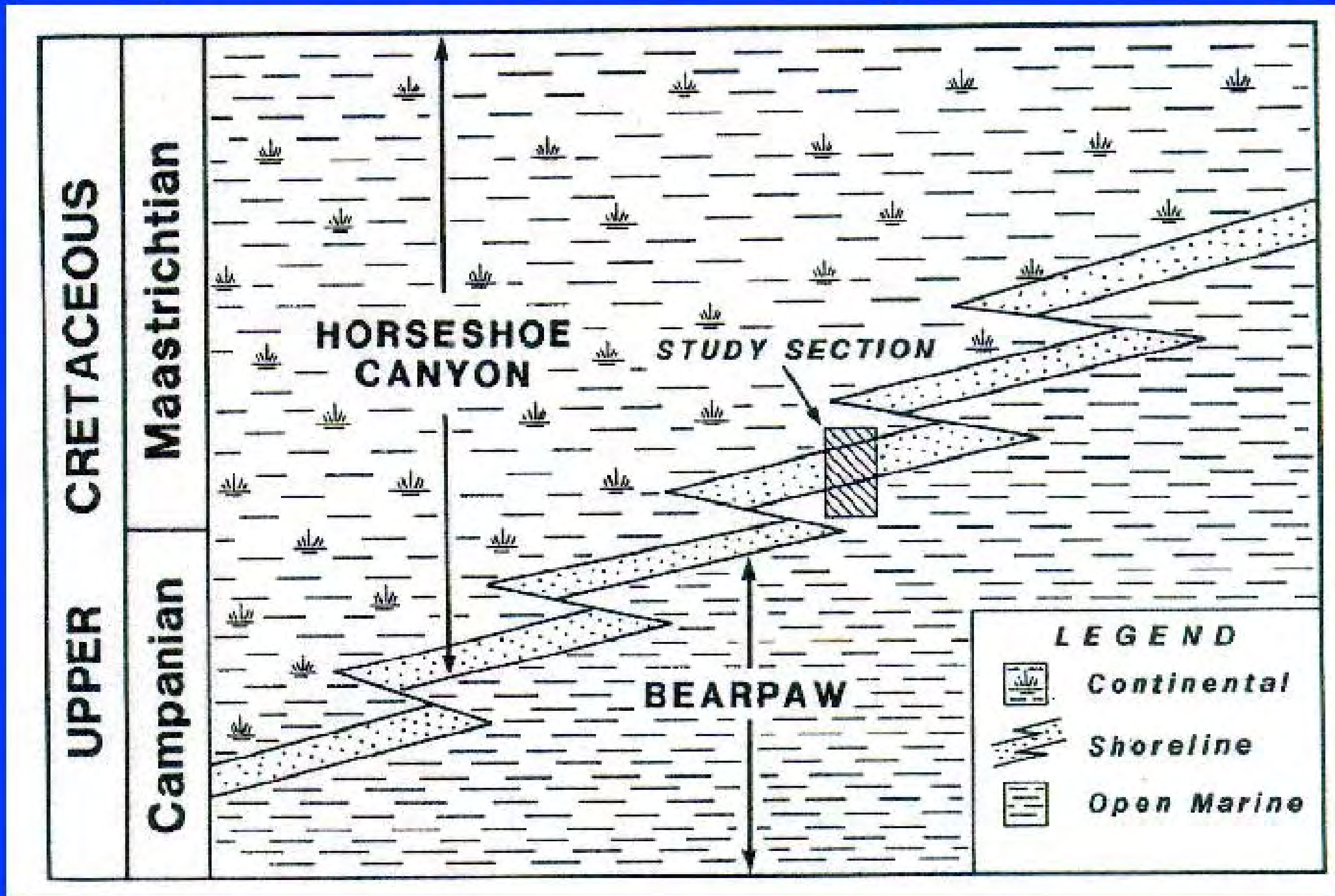
Inclined Heterolithic Stratification (IHS) Westside Willow Creek

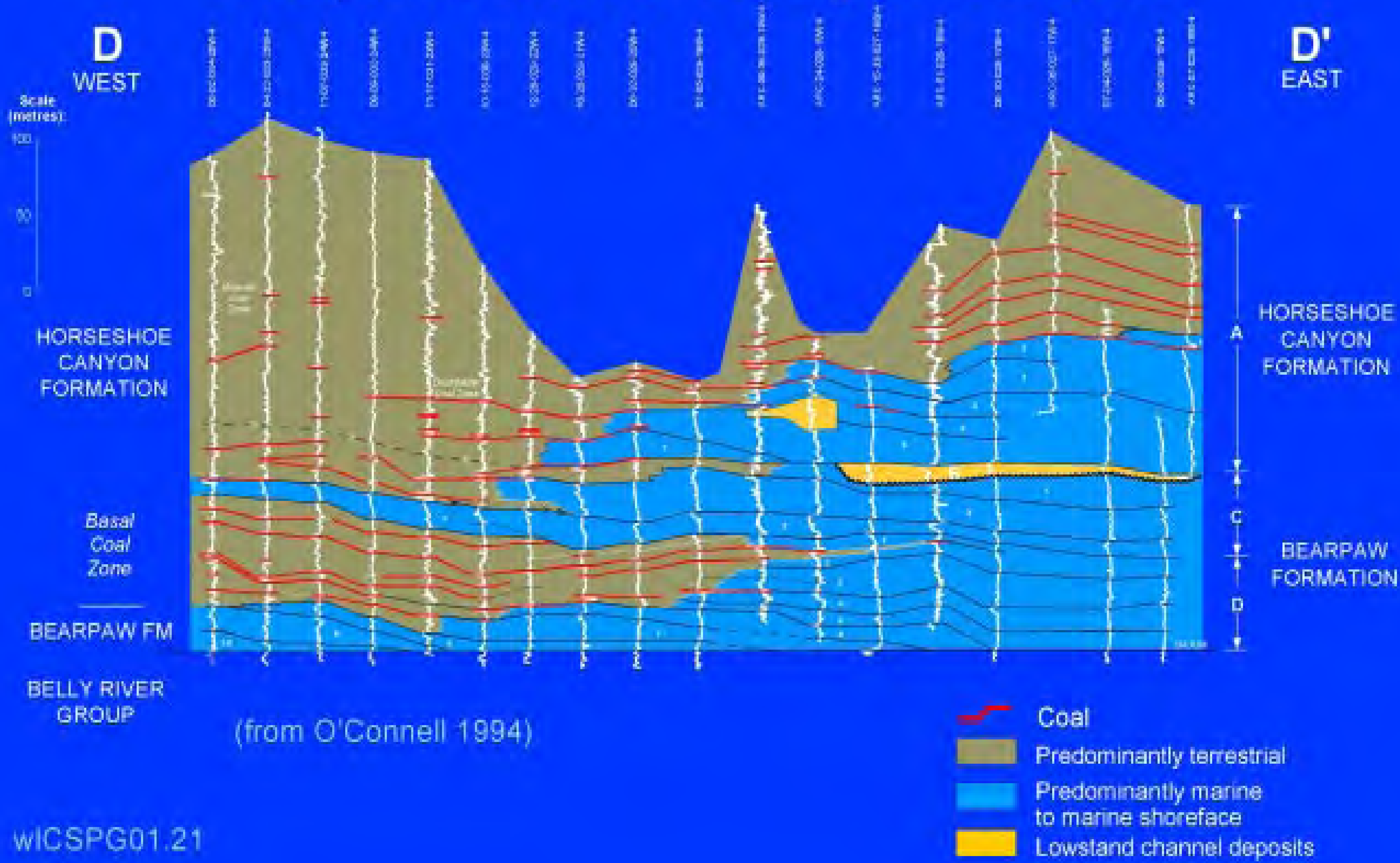
W E

Bearpaw - Horseshoe Canyon Transition



(from Rahmani, 1980)

Bearpaw-Horseshoe Canyon Transition



(from O'Connell 1994)

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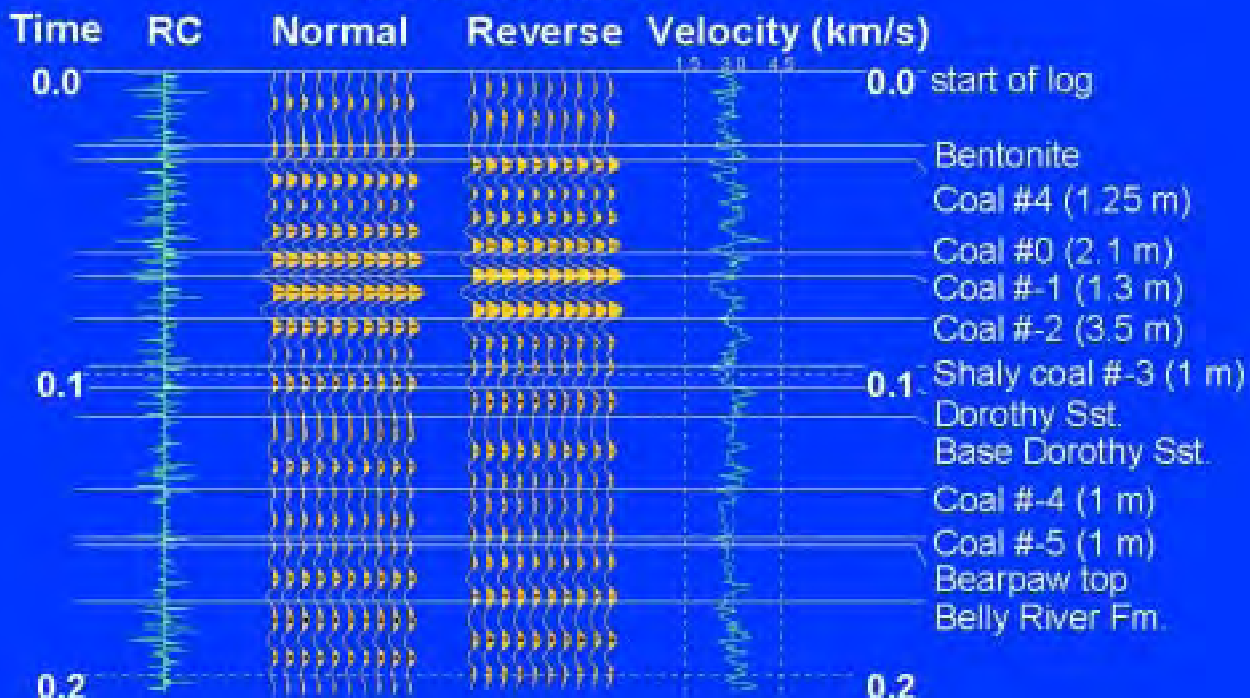
Synthetic

02-13-28-22W4



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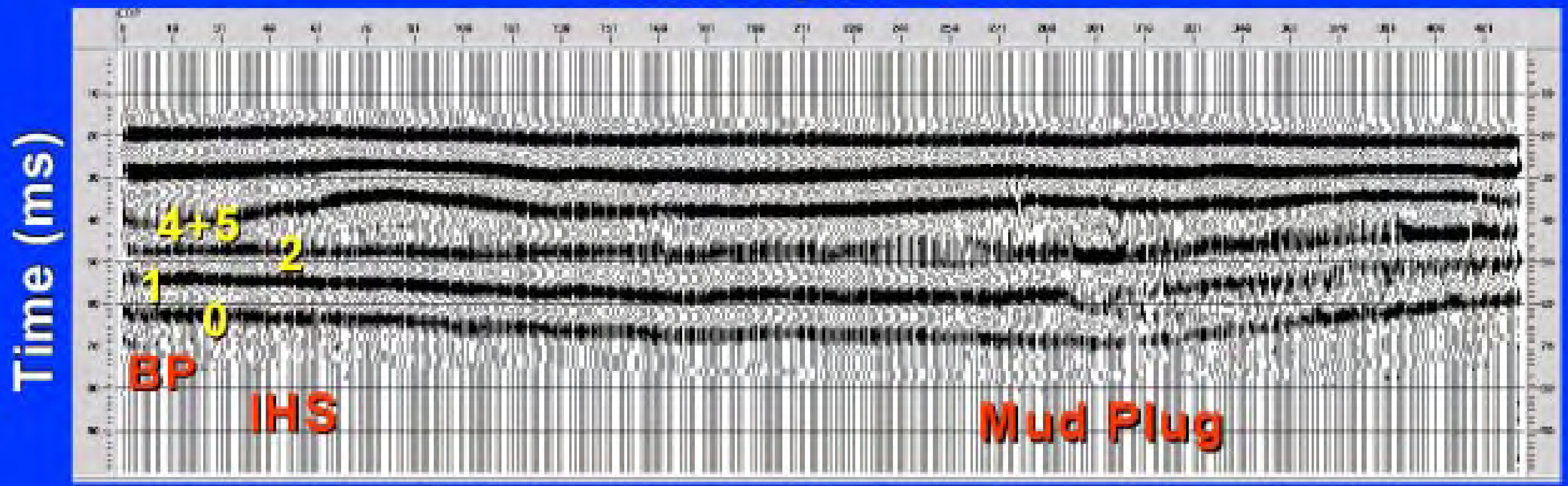
Normal Incidence Ray Tracing

Outcrop, 100Hz



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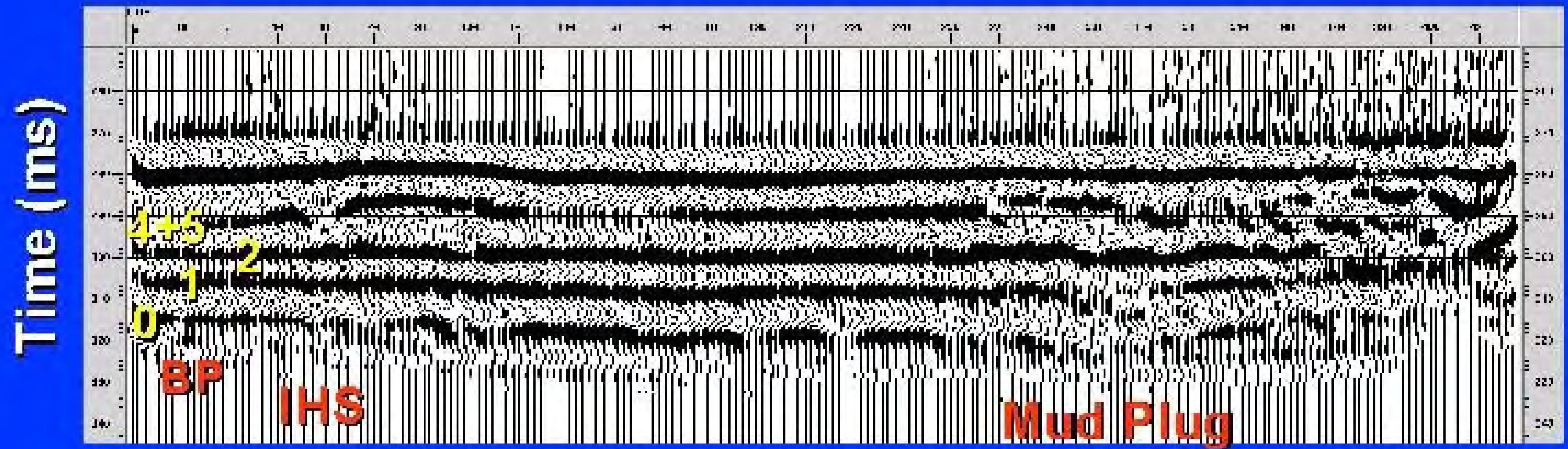
Common Mid Point Ray Tracing

400m 100Hz



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Conclusions

- Southeasterly prograding delta complex fed by rivers flowing from the Northwest
- Coal zones are mappable on seismic images
- Thick coal seams will be mappable up to 400 m depths, but thin coal seams are not resolvable
- Velocities are higher than in the Athabasca Oil Sands
- Low velocity contrast between sandstone and thin mudstone layers in IHS
- IHS only mappable as zone
- Shear waves in combination with Vertical Seismic Profiling (VSP) may detect fractured "sweet spots"

Coalbed Methane Potential of Selected Alberta Coal Deposits

(A review of coal geology, distribution and characterization as related to coalbed methane potential)

A.Beaton, D.Chen and R.Richardson, Alberta Geological Survey, and
J. Campbell, Jaycon Reconnaissance

EUB Alberta Energy and Utilities Board

AGS Alberta Geological Survey

Abstract

The Alberta Plains area contains significant coal resources within strata ranging in age from Cretaceous to Tertiary. Shallow coal deposits are a traditional source of energy for power generation, but increasing demand for energy has led to a renewed interest in the coalbed methane potential within Alberta.

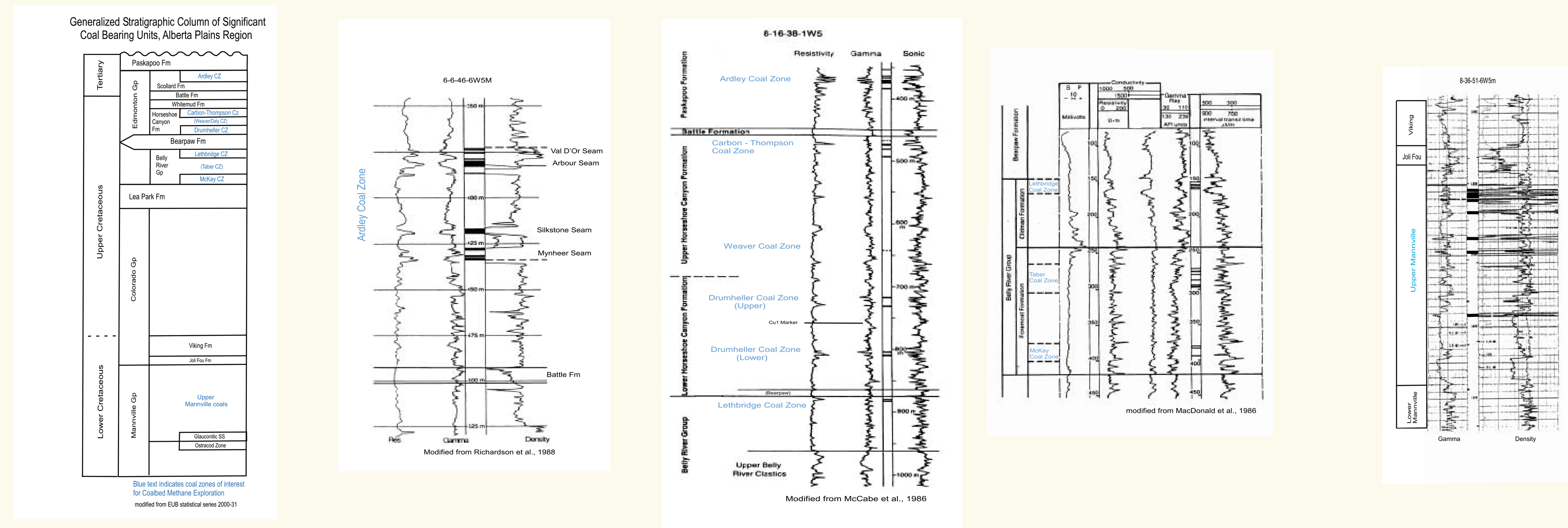
Coal characterization is an essential component of any coalbed methane project evaluation. Rank, composition, seam continuity, thickness and distribution are critical parameters in predicting gas generation and production potential.

The Cretaceous upper Mannville contains several thick, continuous coal seams that are potential coalbed methane targets. Cores and cuttings were sampled across the Alberta Plains, providing detailed coal rank and compositional data relevant to gas potential. Some shallow rank anomalies were observed suggesting favorable coalbed methane potential in selected areas of central Alberta.

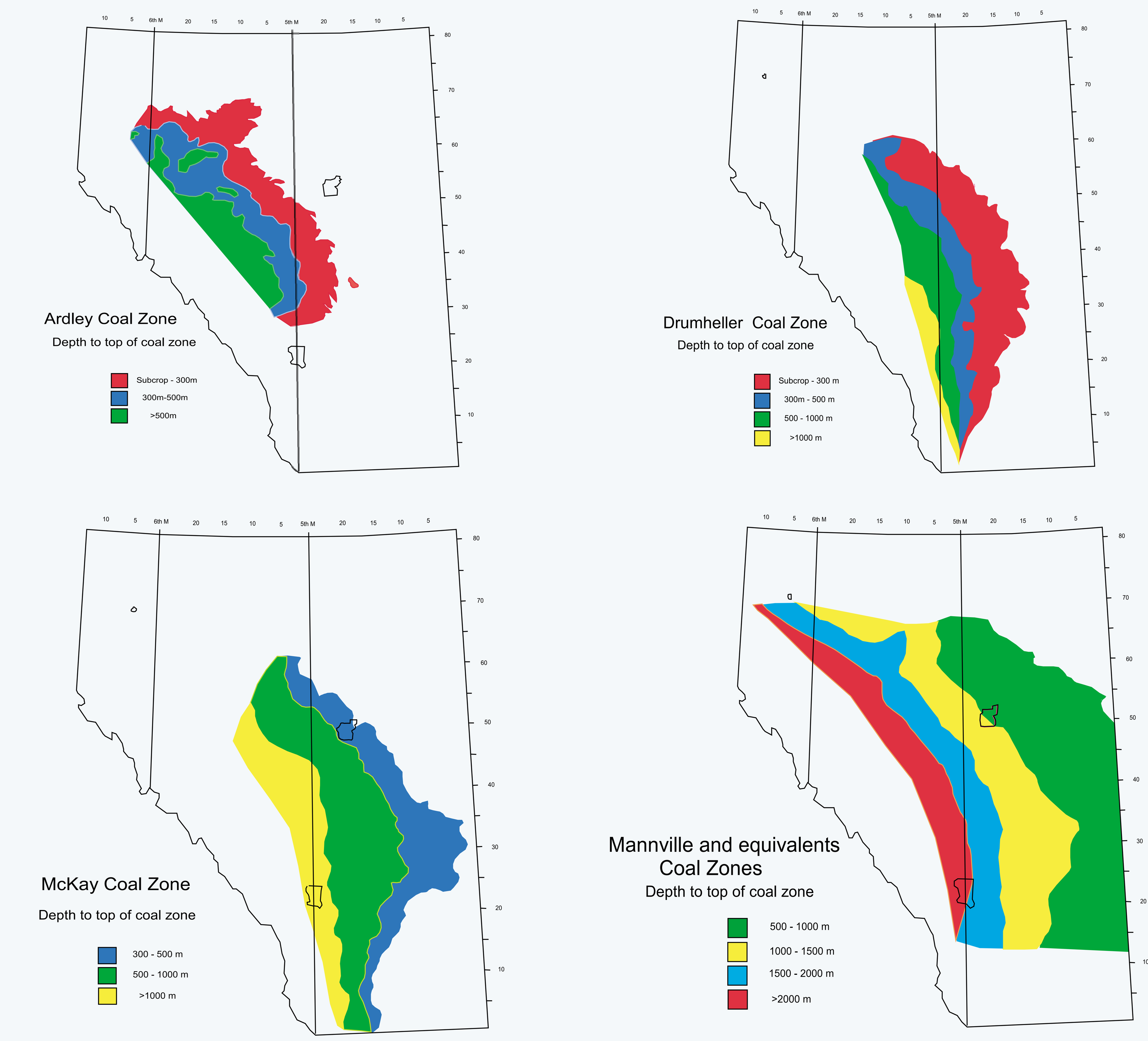
Coalbed methane potential across Alberta is being assessed by the Alberta Geological Survey. Detailed regional and local cross-sections across the Alberta Plains are being constructed to examine the geology, distribution and character of Cretaceous coals associated with the above mentioned rank anomalies. Overlying coal zones within the Belly River Formation and Edmonton Group are being examined and their coalbed methane generation potential is currently being assessed. A detailed coalbed methane database including stratigraphy, lithology, coal quality and predicted gas potential is in preparation.

Acknowledgements: Funding for the coalbed methane evaluation of Alberta is in part provided by ASRA, the Alberta Science and Research Authority

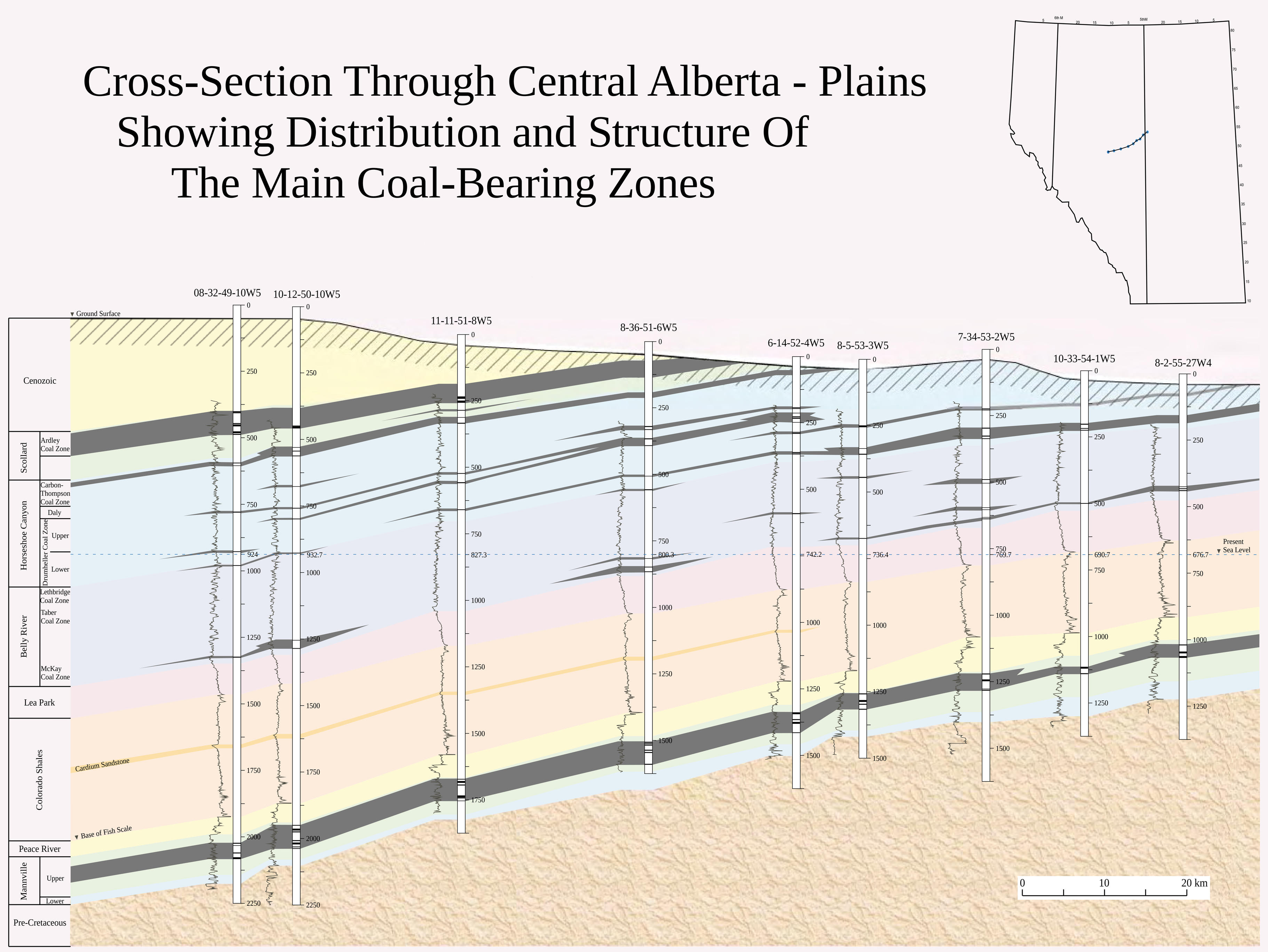
Stratigraphy and Typical Geophysical Log Signatures of Main Coal Bearing Strata of Alberta Plains



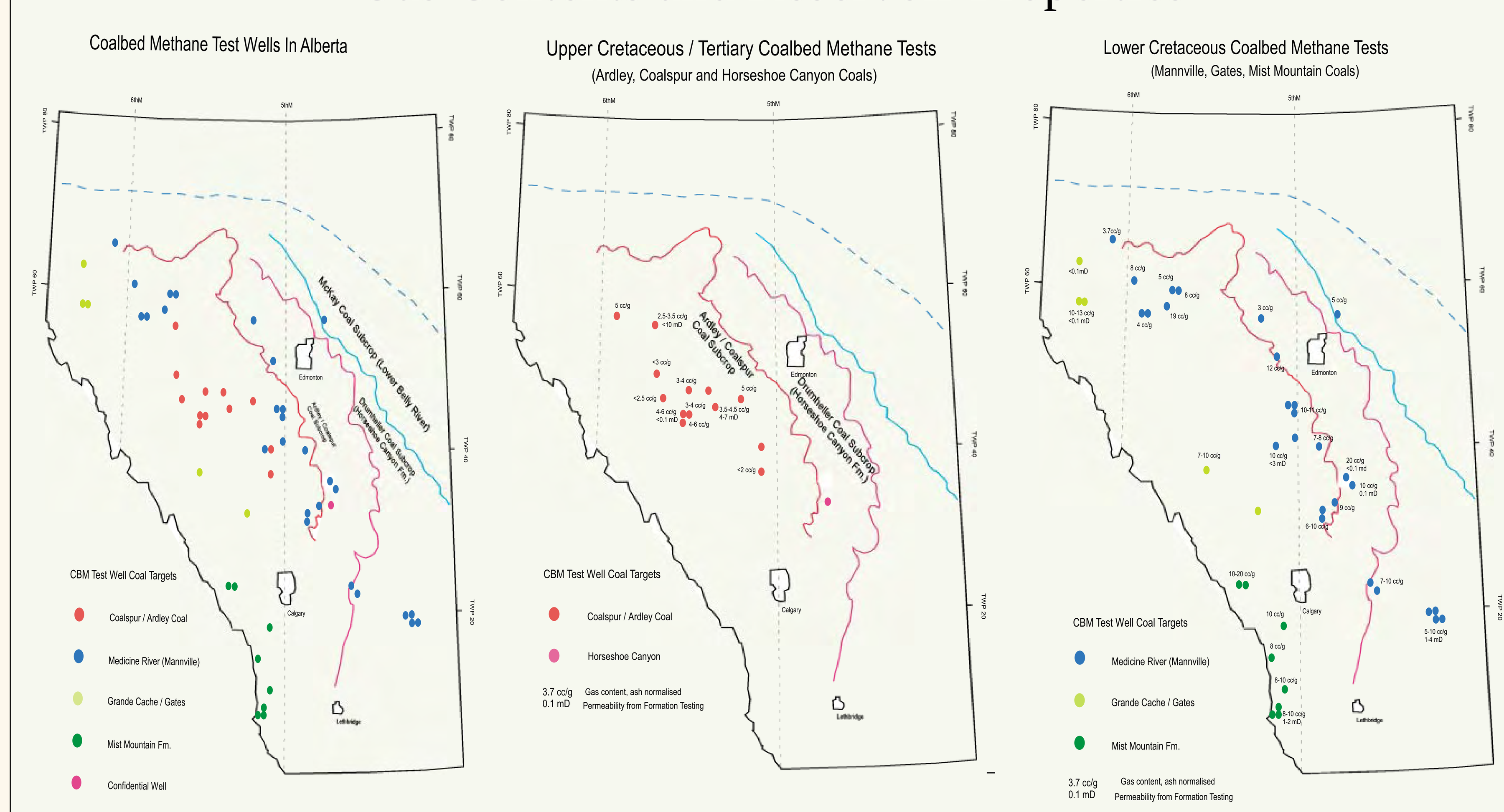
Distribution and Depth of Coal Bearing Strata in the Alberta Plains



Cross-Section Through Central Alberta - Plains Showing Distribution and Structure Of The Main Coal-Bearing Zones

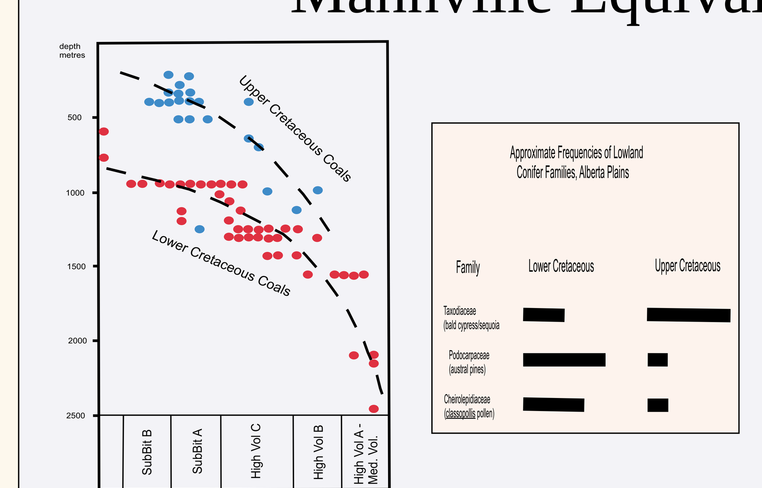


Coalbed Methane Test Wells Gas Contents and Reservoir Properties



To date, coalbed methane testing is limited. Main targets of exploration have been the Ardley coal zone and Upper Mannville coals. Gas content data suggest Ardley coals average 3-5 cc/g, whereas Mannville and equivalent coals average 8-10 cc/g. Permeability, a key factor to CBM produceability, is not well understood, however limited test data suggest low permeability, ranging from 0.1mD -to 4 mD for Mannville and equivalent coals, and in the range of 4-6mD for Ardley coals. Public data is not available on Horseshoe Canyon or Belly River coals.

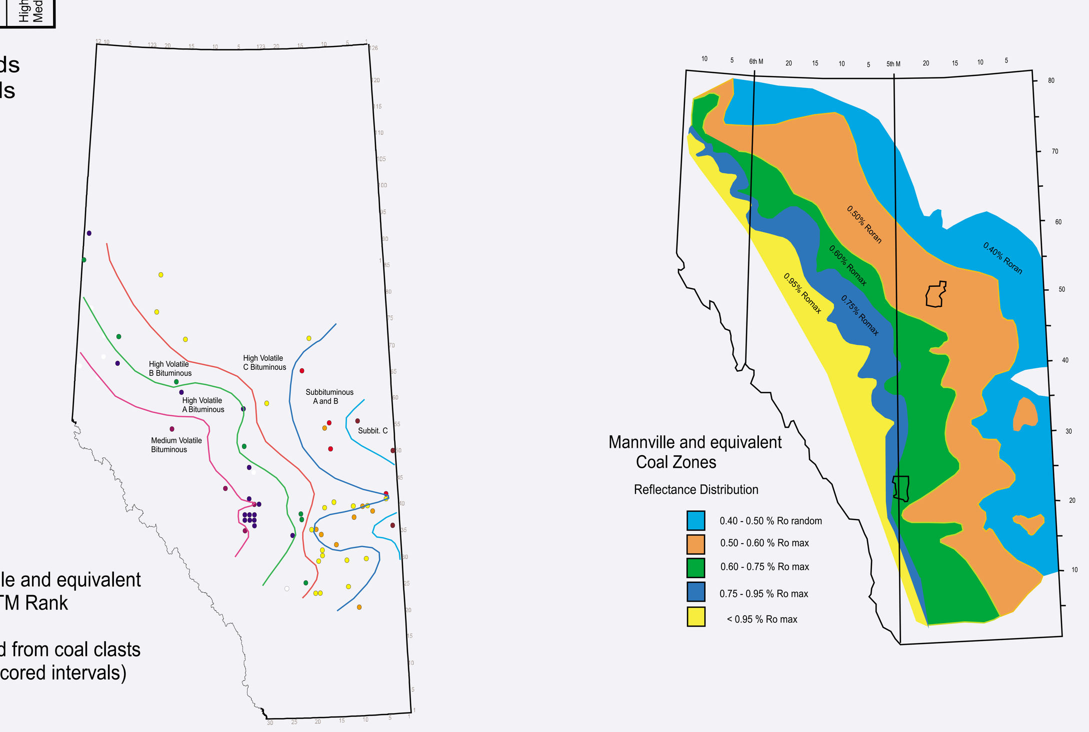
Coalification Trends and Rank Distribution Mannville Equivalents and Basin Trends



Depth / Rank Trends
Alberta Plains Coals

Rank based on vitrinite reflectance from coal seams within the Mannville and equivalents agrees with ASTM rank derived from coal clasts and thin seams below the main Mannville seams.

Mannville rank commonly is lower than expected based on depth. The plot at right indicates different coalification tracks for Upper vs. Lower Cretaceous coals. Typically suggested as suppressed reflectance owing to bitumen saturation, there may be a botanical contribution to rank trends with coals of differing ages.



Bedrock Topography and Drift Thickness, Athabasca Oils Sands (in situ) Area and Adjoining Regions

Laurence D. Andriashek, P.Geol., John G. Pawlowicz, Mark M. Fenton, P.Geol., and Ilona M. Ranger

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Abstract

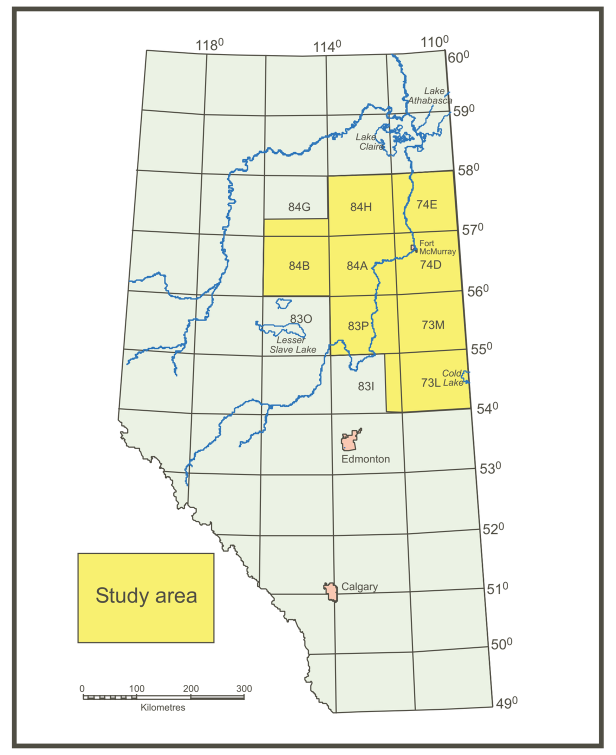
Bedrock topography and drift thickness maps provide valuable information to the energy industry on such aspects as: depth to bedrock, thickness and nature of drift cover, occurrence of buried aquifers for groundwater supply, potential for boulder or gravel horizons that may impede drilling operations, aberrations in airborne geophysical exploration surveys, and drill casing depths for groundwater protection. This poster consolidates the interpretations of previous bedrock topography studies in the region. In addition, the poster highlights the results and interpretations that are the outcome of 1) new projects that the AGS conducted in support of regulation of the energy development in the Oil Sands areas, and 2) initiation of the new AGS Minerals Program to support both exploration and development.

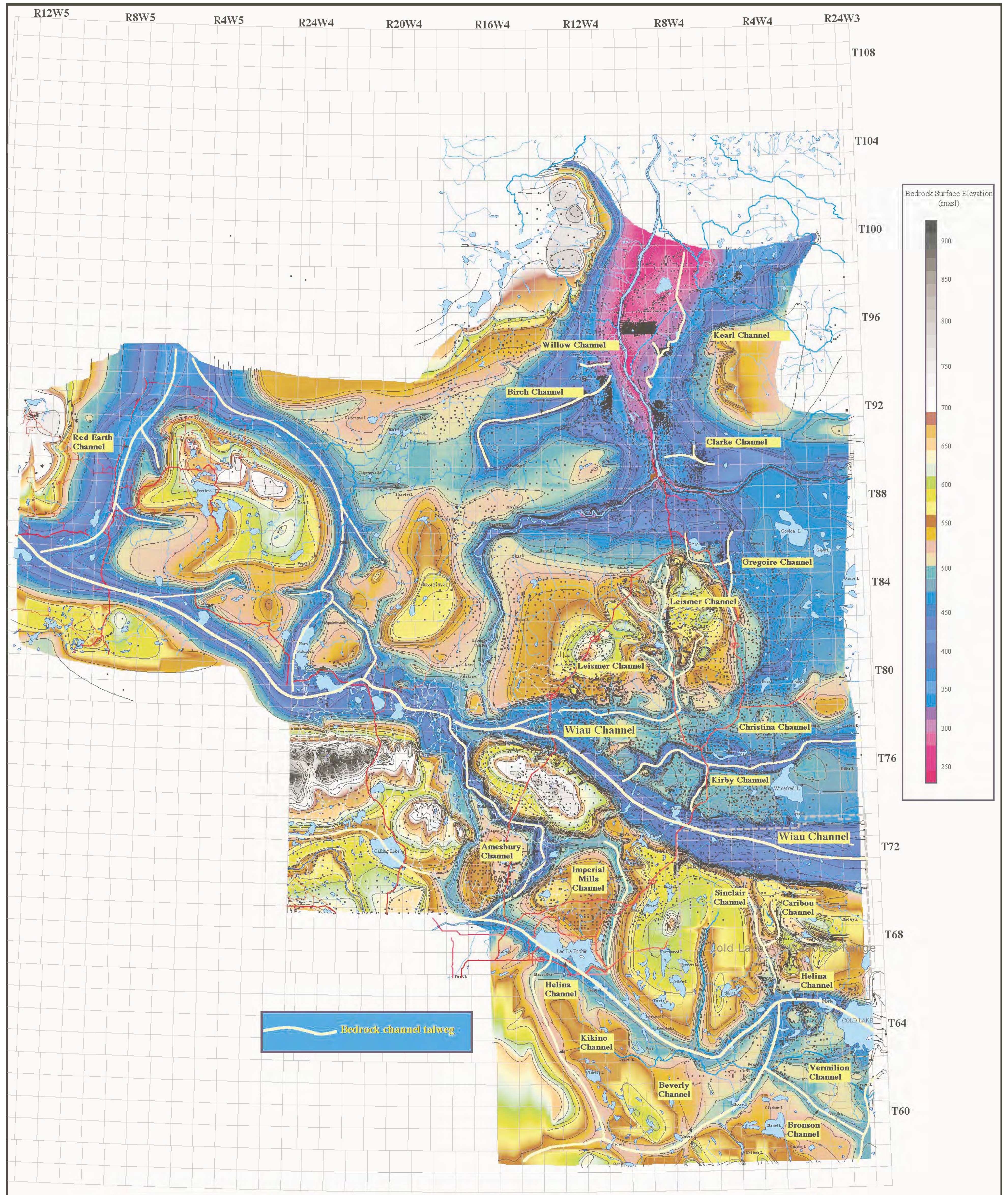
Landscape features that record the erosion and deposition from multiple glacial advances and retreats during the past 1.5 million years or more characterize the present-day topography of northern Alberta. Masked by these glacial sediments is a bedrock surface which displays a markedly different appearance - one that records a history of major fluvial channel systems that modified the bedrock landscape during the Tertiary, and later overprinted by deep channels scoured into the bedrock surface by glacial meltwater during Quaternary glacial periods.

This poster presents the Alberta Geological Survey's current understanding of the bedrock topography and buried fluvial channel features in the parts of northern Alberta defined by longitude 110^0 to 116^0 W and latitude 55^0 to 58^0 N (see figure). This area encompasses the Athabasca Oil Sands (in situ) Area as well as the Athabasca Oil Sands (surface mineable) Area, the northern part of the Cold Lake Oil Sands Area, and the western part of the Athabasca Oil Sands Area overlying the Grosmont and Wabasca oilsand deposits. Each of these areas has, is, or will be undergoing intensive oilsands development.

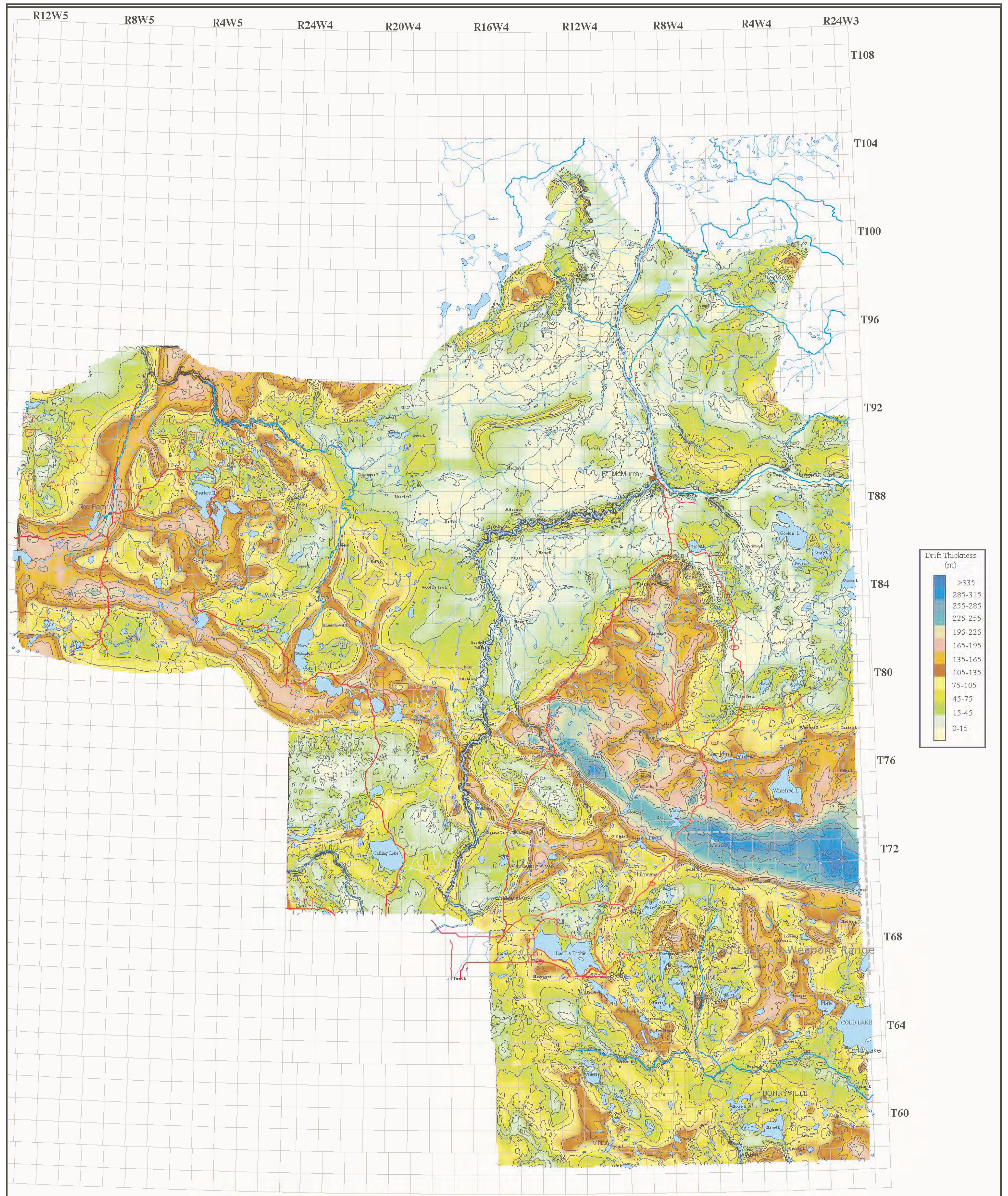
Buried channels form the most dramatic aspect of the bedrock topographic surface. Two major channel morphologies emerge from the interpretation of borehole logs in the region. The first consists of broad, shallow-walled channels or valleys that are interpreted to represent regional drainage systems formed during the Tertiary. In a few locations where the fluvial sediment resting on the floor of these channels has been sampled, the clast petrology is consistent with a preglacial source from the Cordillera west of the region. Rock types from the Laurentide Shield to the northeast (granite, gneiss) are conspicuously absent in the clast composition. The general trend of these channel, or valley, systems is north and east toward the Arctic Ocean. In some cases, opposing ends of channels display reverse gradients, indicative of headwall erosion and stream capture of older drainage systems. Stream piracy and subsequent channel abandonment is also indicated by abrupt, hanging wall confluences with other channel systems. All attest to the evolutionary degradation of the exposed bedrock surface during the late Cenozoic. Because of their broad width, preglacial valleys serve as depositional basins for subsequent geological events. In this regard, preglacial valleys are the foci for thick accumulations of both stratified glaciofluvial, and nonstratified glacial diamict (till). Accumulations of more than 250 m of drift are not uncommon in this region.

The second type of buried-channel form consists of deep, narrow, and steep-walled channels that are interpreted to have been scoured into the bedrock surface by catastrophic releases of glacial meltwater during any one of several glacial events that have occurred in the region. The composition of the clasts on the floors of these channels includes a significant component of Laurentide Shield rock types from northeast of the region, which could only have been transported into the area by glacial advances from that direction. The orientations of glacial meltwater channels are influenced as much by the position of glacial ice margins as they are by the underlying regional topography. As such they do not necessarily follow the same drainage direction as preglacial channels. The fact that some meltwater channels are incised onto the highest parts of the local bedrock surface, or exhibit shallow U-shaped longitudinal profiles, indicates that some were probably formed in a subglacial rather than subaerial environment.



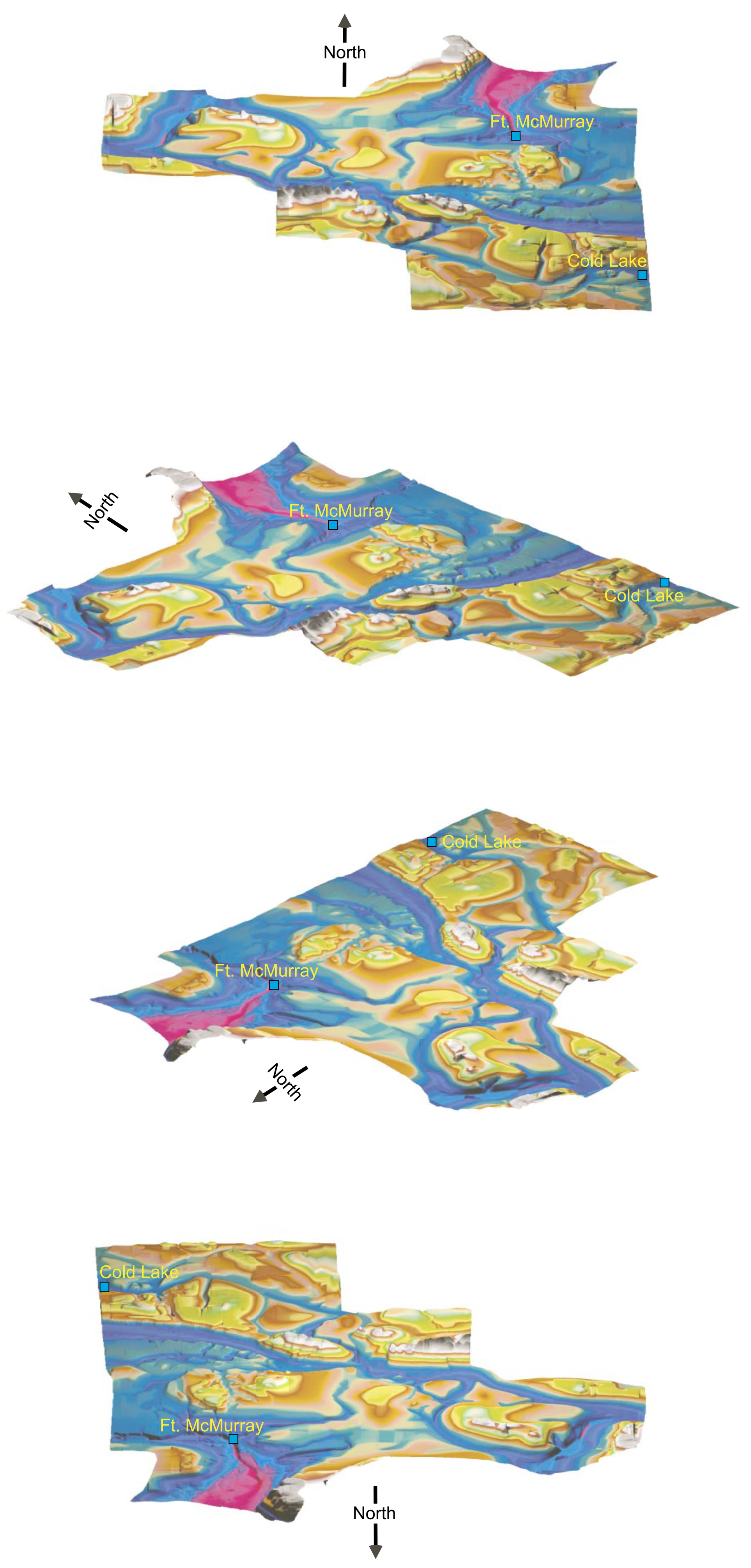


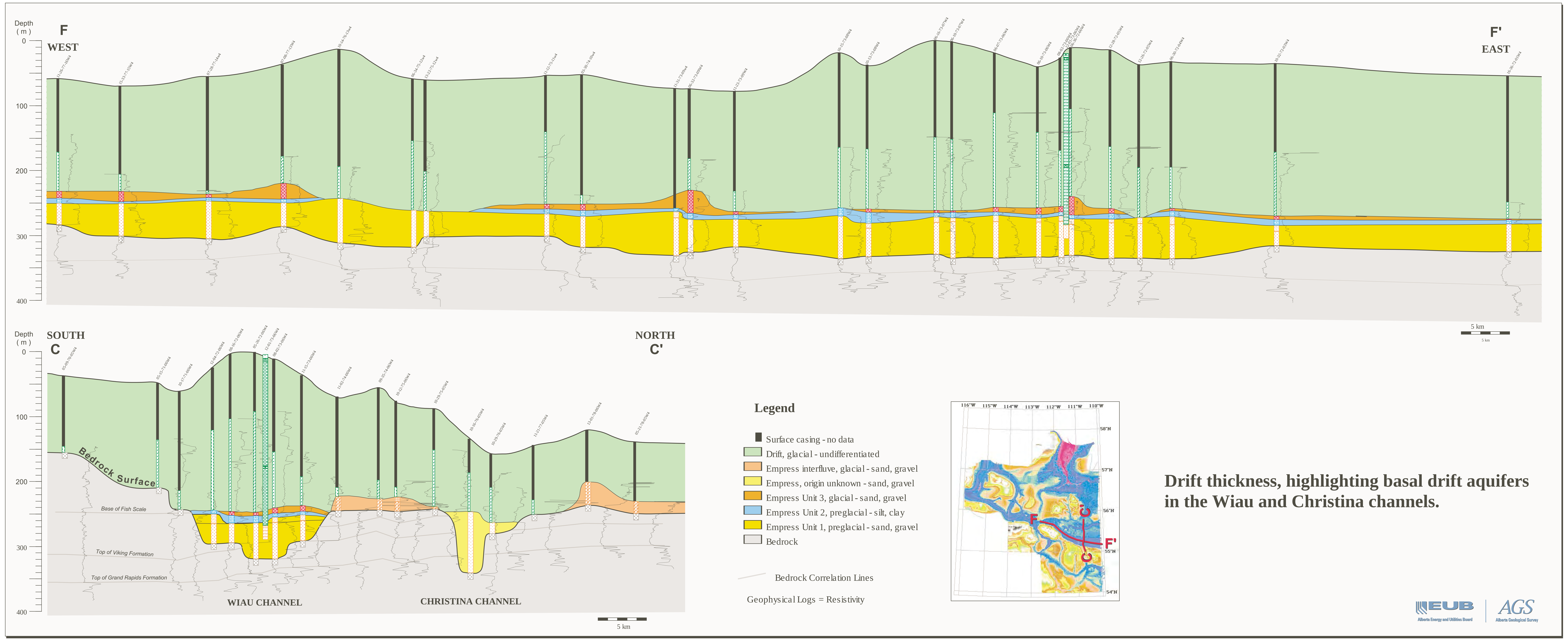
Bedrock Topography, NE Alberta



Drift Thickness, NE Alberta

Perspective Views of Bedrock Topography




Depth (m)
F
WEST
F'
EAST
SOUTH
C
NORTH
C'
Bedrock Surface
Base of Fish Scale
Top of Viking Formation
Top of Grand Rapids Formation
WIAU CHANNEL
CHRISTINA CHANNEL
5 km
Legend
Surface casing - no data
Drift, glacial - undifferentiated
Empress interfluve, glacial - sand, gravel
Empress, origin unknown - sand, gravel
Empress Unit 3, glacial - sand, gravel
Empress Unit 2, preglacial - silt, clay
Empress Unit 1, preglacial - sand, gravel
Bedrock
Bedrock Correlation Lines
Geophysical Logs = Resistivity
Drift thickness, highlighting basal drift aquifers in the Wiau and Christina channels.
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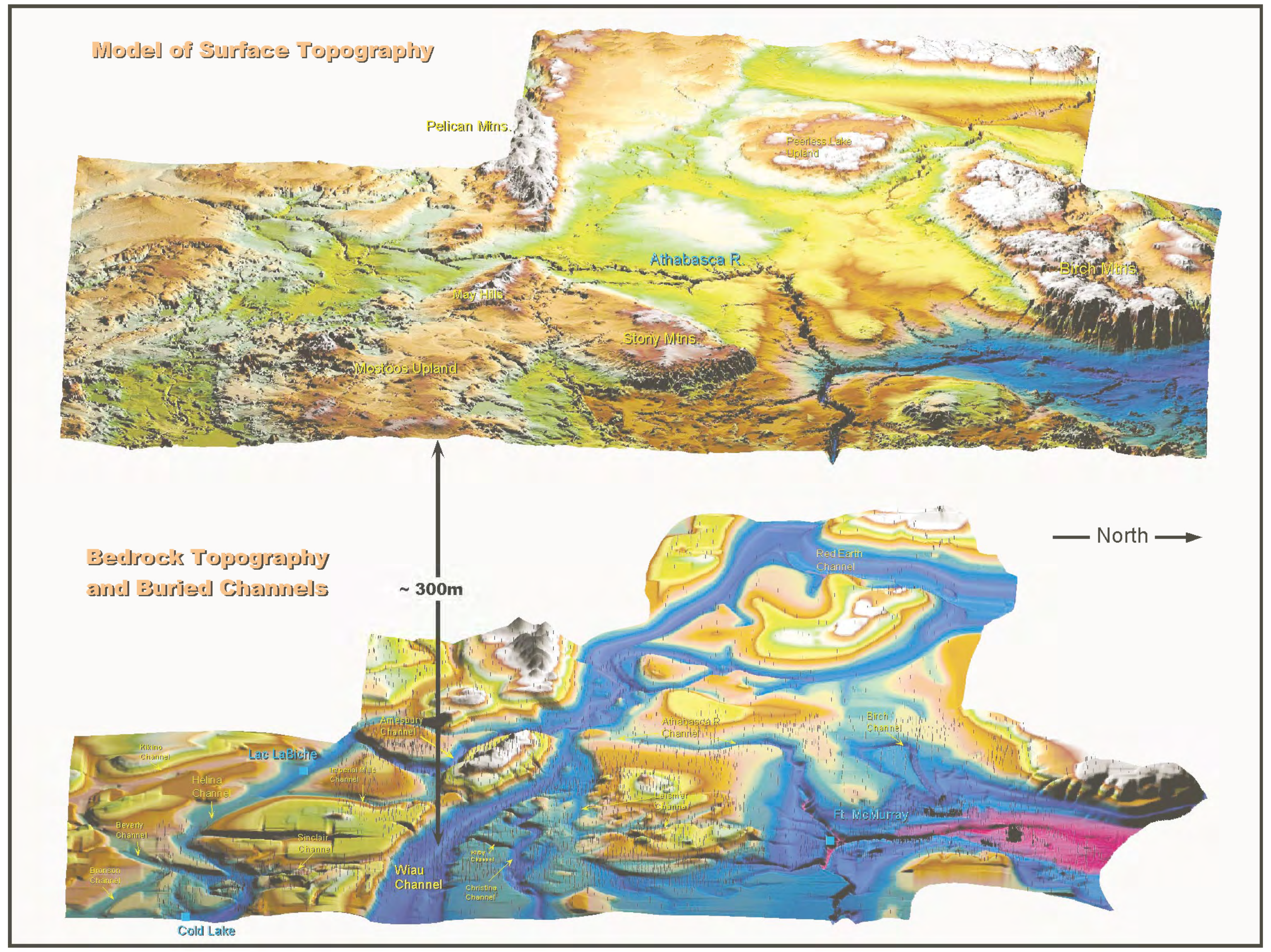
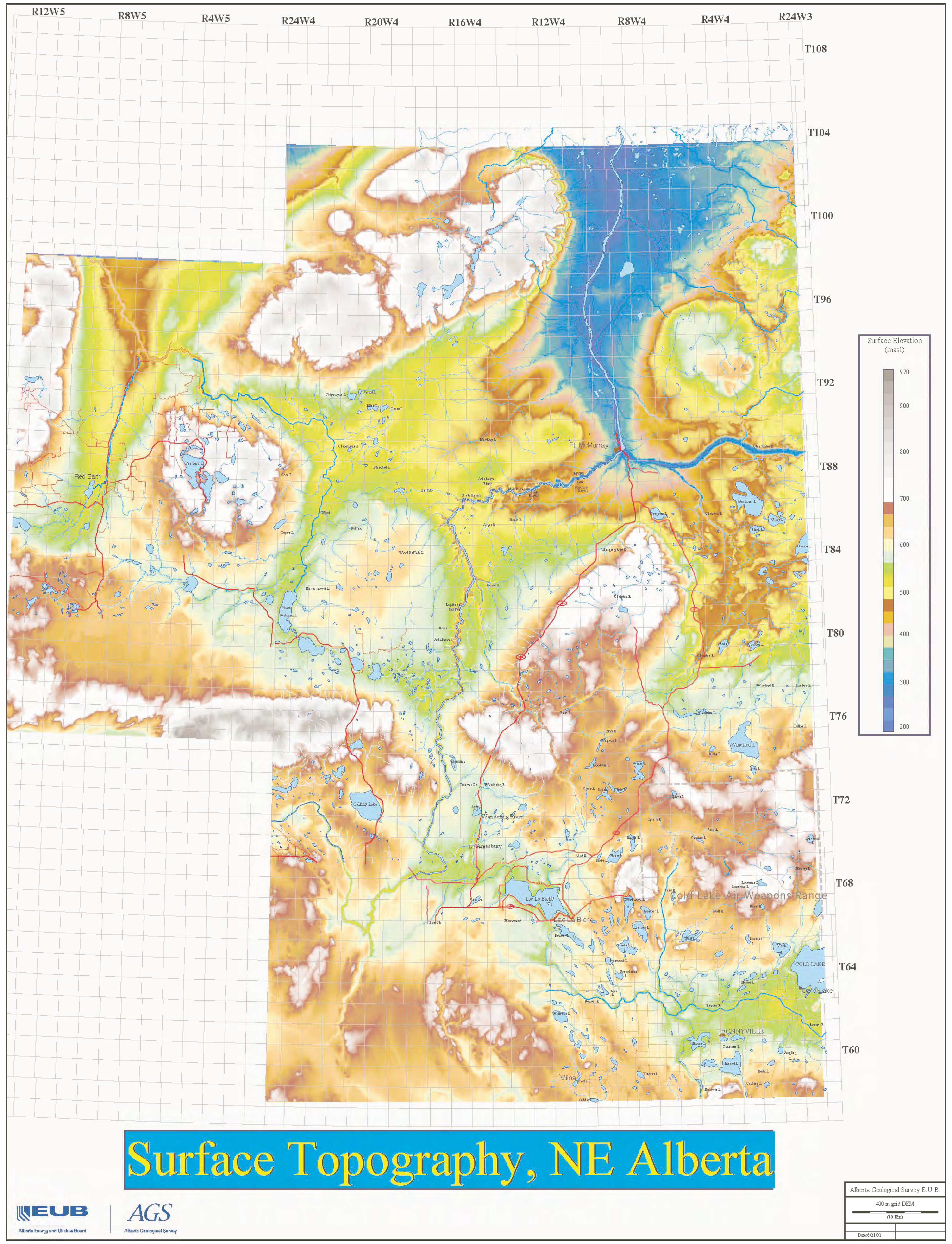

Model of Surface Topography
Pelican Mtns.
Athabasca R.
Stony Mtns.
Bedrock Topography and Buried Channels
~ 300m
North
Lac La Biche
Wiau Channel
Cold Lake

R12W5
R8W5
R4W5
R24W4
R20W4
R16W4
R12W4
R8W4
R4W4
R24W3
T108
T104
T100
T96
T92
T88
T84
T80
T76
T72
T68
T64
T60
Surface Elevation (masl)
Ft. McMurray
Surface Topography, NE Alberta
EUB
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The Drumheller Coal Zone, Lower Horseshoe Canyon Formation: Sedimentology and Sequence Stratigraphic Analysis for Coal Bed Methane (CBM) Exploration

Cristina Pana, Frances J. Hein, C. Willem Langenberg and Andrew Beaton

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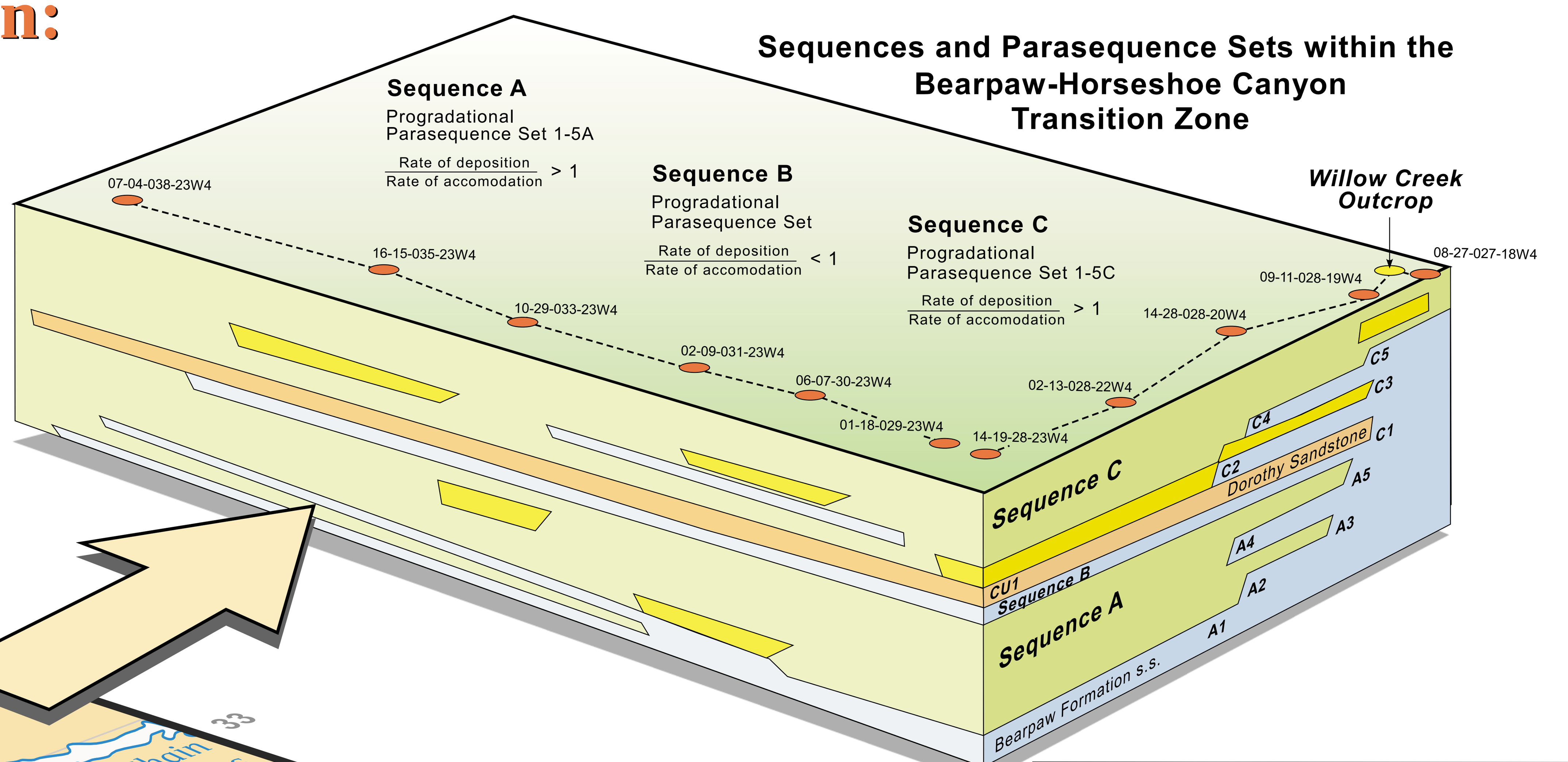

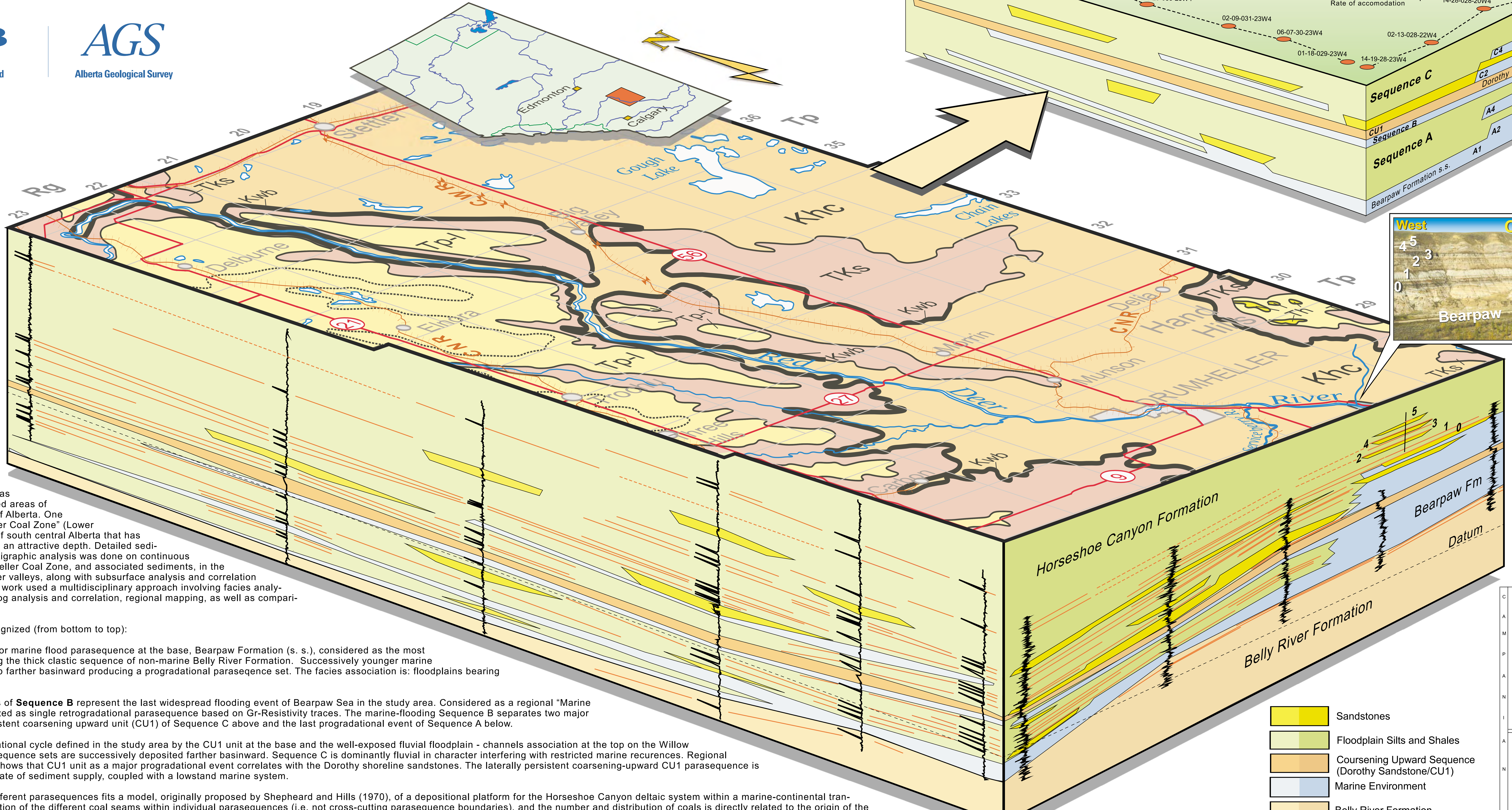

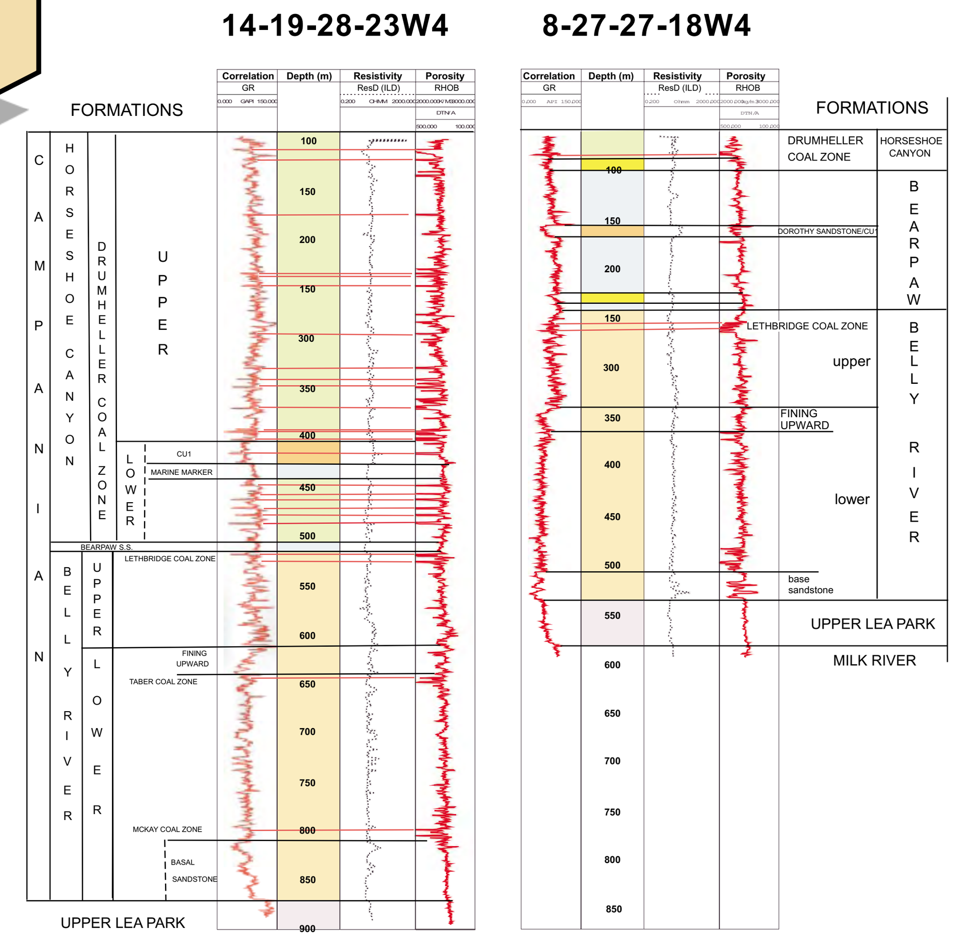

Sandstones

Floodplain Silts and Shales

Coursening Upward Sequence (Dorothy Sandstone/CU1)

Marine Environment

Belly River Formation

Upper Lea Park Formation

Coal

Abstract

Renewed government interest in the coal-bed methane (CBM) potential of Alberta has led to geologic studies in targeted areas of the Plains and Foothill regions of Alberta. One area of interest is the "Drumheller Coal Zone" (Lower Horseshoe Canyon Formation) of south central Alberta that has large reserves of coal present at an attractive depth. Detailed sedimentological and sequence stratigraphic analysis was done on continuous outcrop exposures of the Drumheller Coal Zone, and associated sediments, in the Willow Creek and Red Deer River valleys, along with subsurface analysis and correlation of oil/gas well logs. Much of this work used a multidisciplinary approach involving facies analysis of outcrops and cores, well-log analysis and correlation, regional mapping, as well as comparisons with modern analogues.

Three major sequences are recognized (from bottom to top):

Sequence A is defined by a major marine flood parasequence at the base, Bearpaw Formation (s. s.), considered as the most important transgression following the thick clastic sequence of non-marine Belly River Formation. Successively younger marine paraseqences southeasterly step farther basinward producing a progradational paraseqence set. The facies association is: floodplains bearing coals and channel fills.

The interbedded silts and shales of **Sequence B** represent the last widespread flooding event of Bearpaw Sea in the study area. Considered as a regional "Marine Marker", Sequence B is recognized as single retrogradational parasequence based on Gr-Resistivity traces. The marine-flooding Sequence B separates two major progradational cycles, the consistent coarsening upward unit (CU1) of Sequence C above and the last progradational event of Sequence A below.

Sequence C is the last progradational cycle defined in the study area by the CU1 unit at the base and the well-exposed fluvial floodplain - channels association at the top on the Willow Creek valley. The coarser parasequence sets are successively deposited farther basinward. Sequence C is dominantly fluvial in character interfering with restricted marine recurences. Regional outcrop-subsurface correlation shows that CU1 unit as a major progradational event correlates with the Dorothy shoreline sandstones. The laterally persistent coarsening-upward CU1 parasequence is thought to be a result of a high rate of sediment supply, coupled with a lowstand marine system.

The spatial distribution of the different parasequences fits a model, originally proposed by Shepheard and Hills (1970), of a depositional platform for the Horseshoe Canyon deltaic system within a marine-continental transition zone. The regional correlation of the different coal seams within individual parasequences (i.e. not cross-cutting parasequence boundaries), and the number and distribution of coals is directly related to the origin of the facies preserved within the different parasequences.

The present study shows that sequence stratigraphic analysis provides a realistic framework for deciphering the 3-D architecture of individual coal seams within the Drumheller Coal Zone. Such a framework, coupled with coal rank, cleat - orientation, structural and petrographic data, is useful for characterization of the coal-bed methane potential of the Alberta Plains.

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