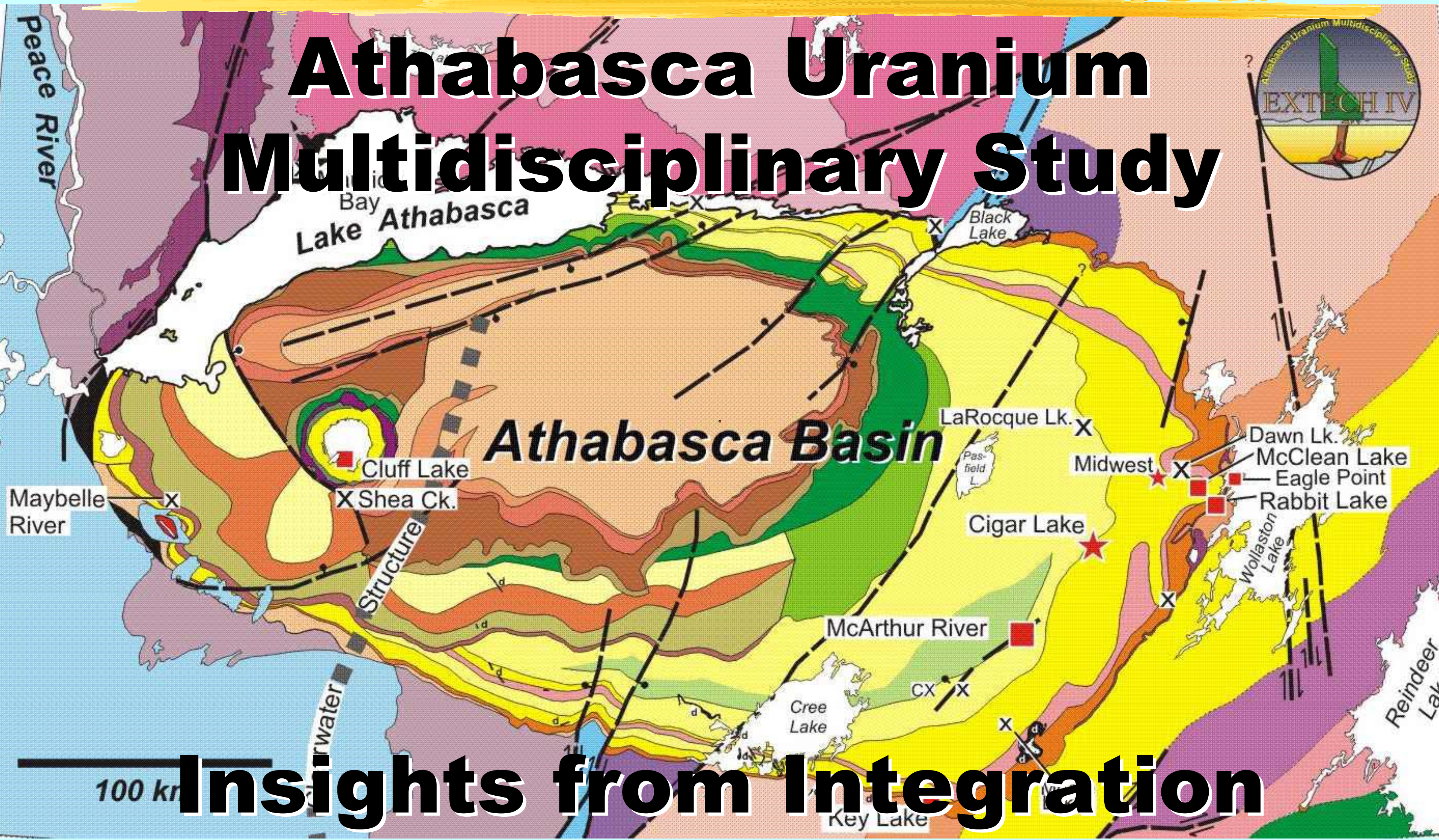
EXTECH IV

Athabasca Uranium Multidisciplinary Study

Insights from Integration



Charlie Jefferson, Gary Delaney, Reg Olson, Dave Thomas, Craig Cutts

The EXTECH IV project spanned three years from April 2000 to March 2003, and is now a sub-Project under Western Churchill Metallogeny Project, Northern Resources Development Program. This talk presents insights from the write up and integration process of this project.

EXTECH IV - PARTNERSHIPS & ACKNOWLEDGMENTS

Sub-Project research teams (>80)
Industry and Provincial partners
GSC colleagues, managers
NSERC, University profs, students
Final Volume Committee & Peer revs

www.uic.com.au, www.cpg.ca, www.can.ca

EXTECH IV is a partnership funded by the GSC under the Earth Sciences Sector Project System and Targeted Geoscience Initiative, by Saskatchewan and Alberta geological Surveys, Cameco and COGEMA (now part of AREVA), and enhanced through university-industry-NSERC partnerships involving the universities of Alberta, Laurentian and Saskatchewan. It is now part of a partnership of very similar composition under the Western Churchill Metallogeny Project. Most of the ideas presented here have been more or less known by the experienced exploration geologists who guided the project from its inception. The new insights presented here are based on the combined efforts and new data developed by fourteen sub-project teams who have updated the geoscience framework, advanced and clarified previous exploration concepts, and demonstrated new or improved existing exploration tools for unconformity-associated uranium deposits in the Athabasca Basin.

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Athabasca Uranium Multidisciplinary Study
EXTECH IV

Cameco

Saskatchewan Geological Survey 1948

Canada 1842 Geological Survey - Commission Géologique

AGS
Alberta Geological Survey

AREVA

Natural Resources Canada | Ressources naturelles Canada

Canada

Final Volume in Preparation

These results and insights are being compiled into a final volume whose publication is co-sponsored by the Saskatchewan Geological Society, Mineral Deposits Division of the Geological Association of Canada, and Geological Survey of Canada (through the Earth Sciences Sector of Natural Resources Canada). Planned launch is at Vienna 2005 International Uranium Conference. We are soliciting images for the cover, two possibilities being shown here.

EXTECH IV
Athabasca Uranium
Multidisciplinary Study
Northern Saskatchewan and Alberta

Collected papers and DVD of data reporting on the results of a collaborative project funded by the Geological Survey of Canada (Earth Sciences Sector, NRCan), Saskatchewan Industry and Resources, Alberta Geological Survey (Alberta Energy Utilities Board), Cameco Corporation, COGEMA Resources Incorporated and Natural Science and Engineering Research Council, with contributions from University of Saskatchewan, Laurentian University, the University of Alberta, Geomatics Canada (NRCan) and Geosystems Canada Inc.

Goals of this project were:
1) enhance the geoscience data base for exploration
and
2) develop and enhance EXploration TECHnology for shallow to deep unconformity related uranium deposits.

Cameco AGS Alberta Geological Survey AREVA

Saskatchewan Geological Society
Mineral Deposits Division
Geological Survey of Canada

EXTECH IV

EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta

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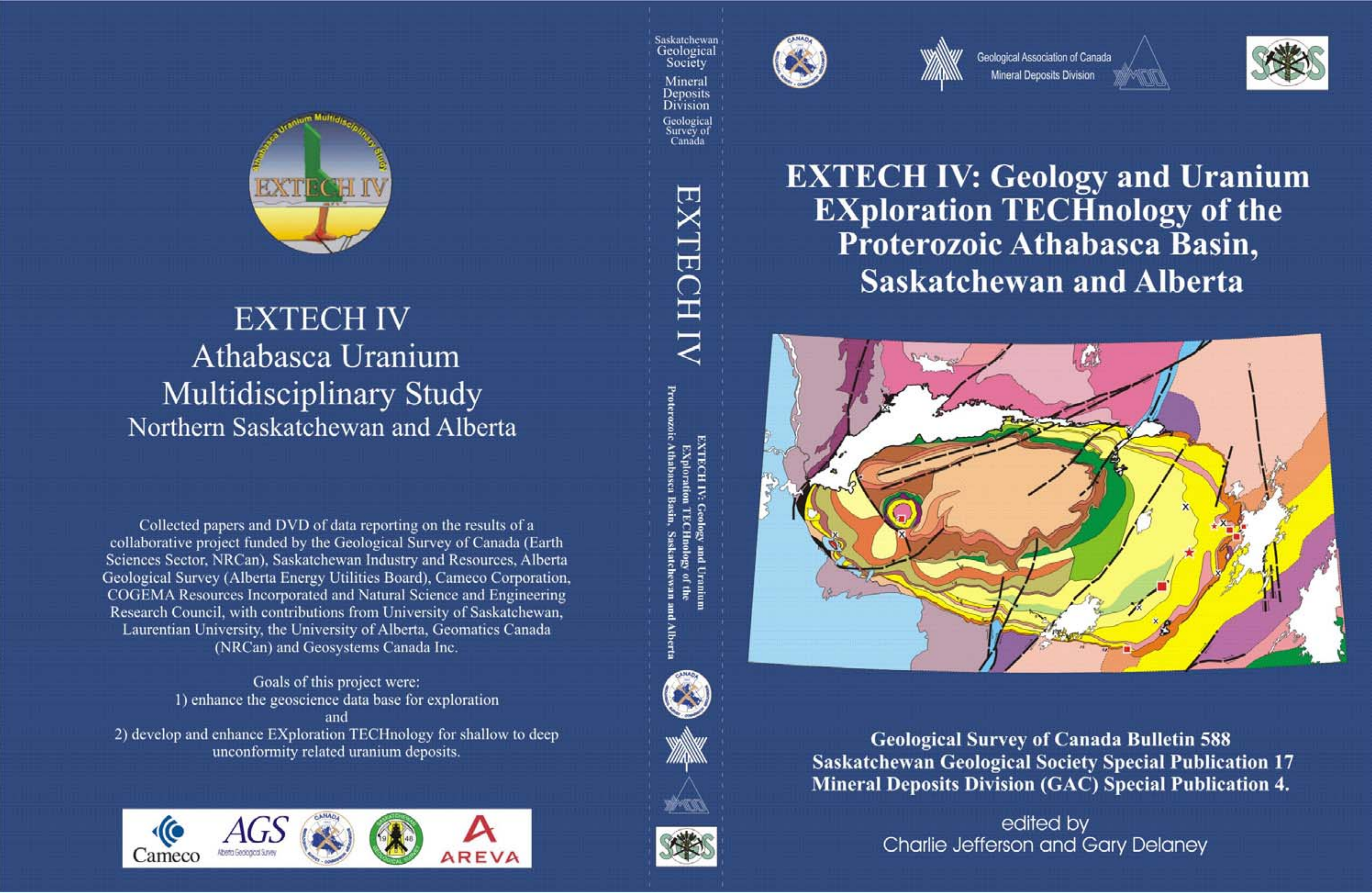
Geological Survey of Canada Bulletin 588
Saskatchewan Geological Society Special Publication 17
Mineral Deposits Division (GAC) Special Publication 4.

edited by
Charlie Jefferson and Gary Delaney

Final Volume in Preparation



Athabasca Uranium Multidisciplinary Study

EXTECH IV

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Objectives and Insights

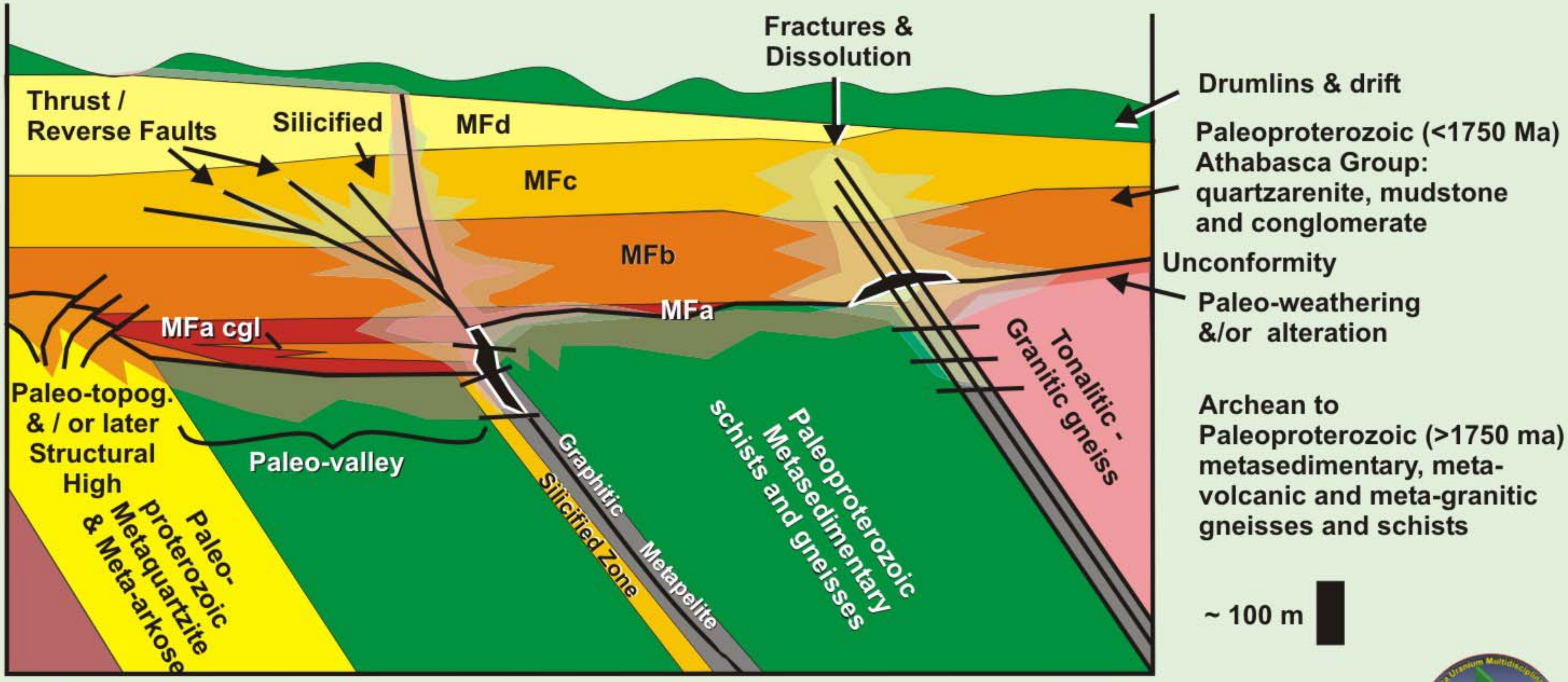
- Enhance & preserve 4-D geoscience data
- New exploration methods / tools
- Sustain Development, Employment, Training

✓ Insights:

- Favourable Basement Features
- Growth Faults & Basin Development
- Growth Faults & Ore Systems
- Questions for the Future

Unconformity U Deposit Types

Generalized geological elements of simple and complex unconformity-associated uranium deposits in the eastern part of the Paleoproterozoic Athabasca Basin.

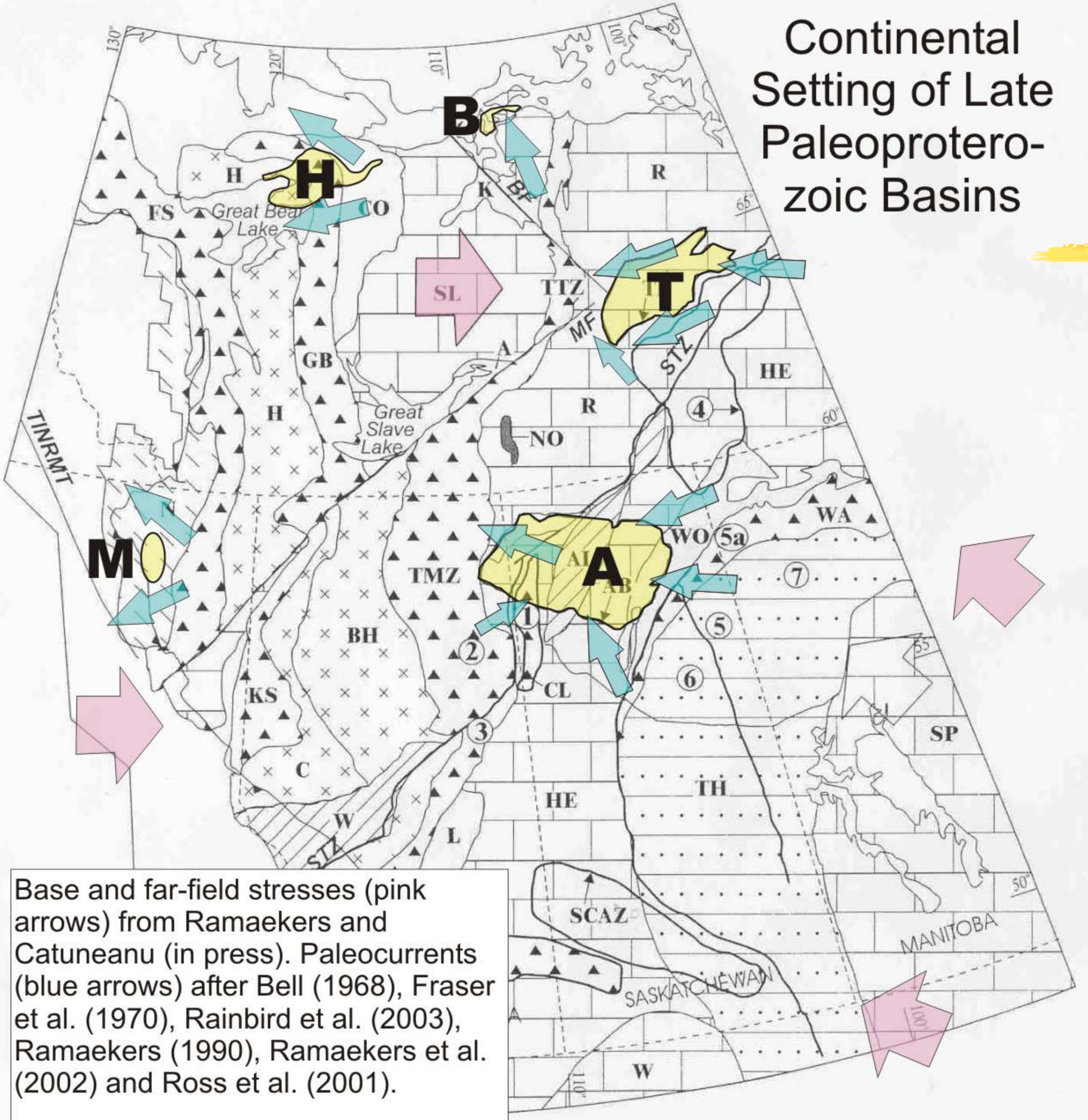


Simple Type:
- lower total REE
- HREE/LREE >1
- basement hosted

Complex Type:
- high total REE
- HREE/LREE ~1
- U, Ni, Co, Cu, As
- sandstone hosted

After Sibbald-Hoeve, Thomas et al., Ruzicka, McGill et al., and EXTECH IV team

Regional Setting

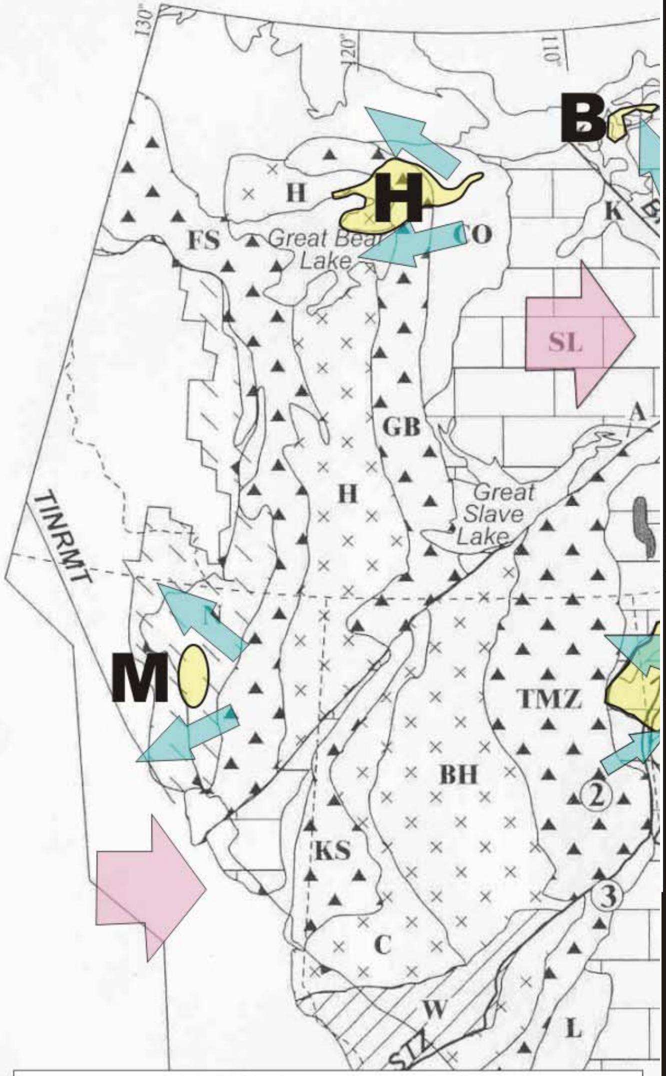


Continental Setting of Late Paleoproterozoic Basins

Base and far-field stresses (pink arrows) from Ramaekers and Catuneanu (in press). Paleocurrents (blue arrows) after Bell (1968), Fraser et al. (1970), Rainbird et al. (2003), Ramaekers (1990), Ramaekers et al. (2002) and Ross et al. (2001).

Athabasca Basin is one of 4 Paleo- to Mesoproterozoic siliciclastic sedimentary basins in the northwestern Canadian Shield that were deposited by overall westerly-flowing rivers (but see detail later this talk). This study focuses on the Athabasca Basin, but the others have similar setting and gross stratigraphy, so it is hoped that lessons from the Athabasca can be applied or at least compared and contrasted with what we know of the others.

Regional Setting



Base and far-field stresses (pink arrows) from Ramaekers and Catuneanu (in press). Paleocurrents (blue arrows) after Bell (1968), Fraser et al. (1970), Rainbird et al. (2003), Ramaekers (1990), Ramaekers et al. (2002) and Ross et al. (2001).

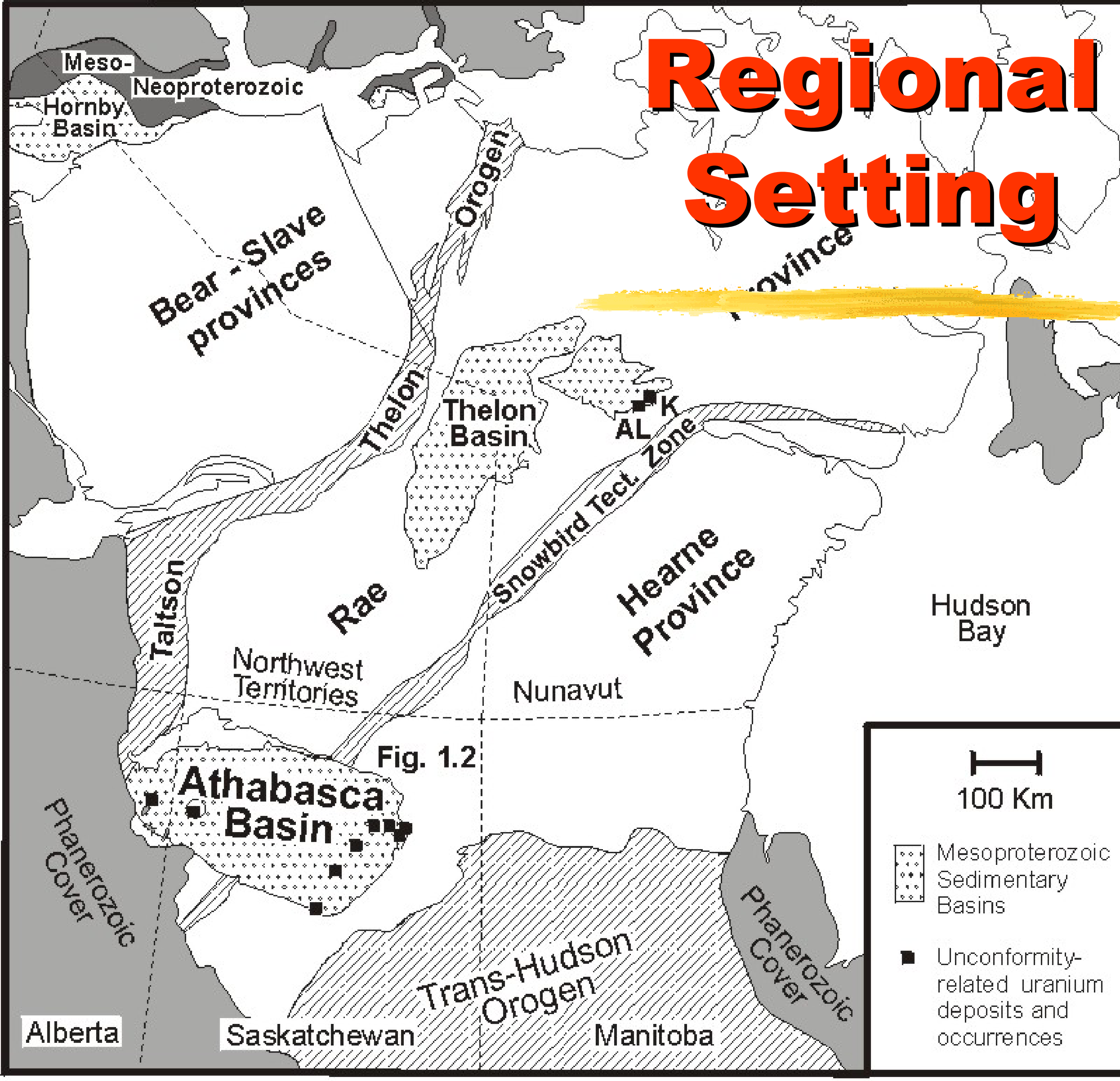
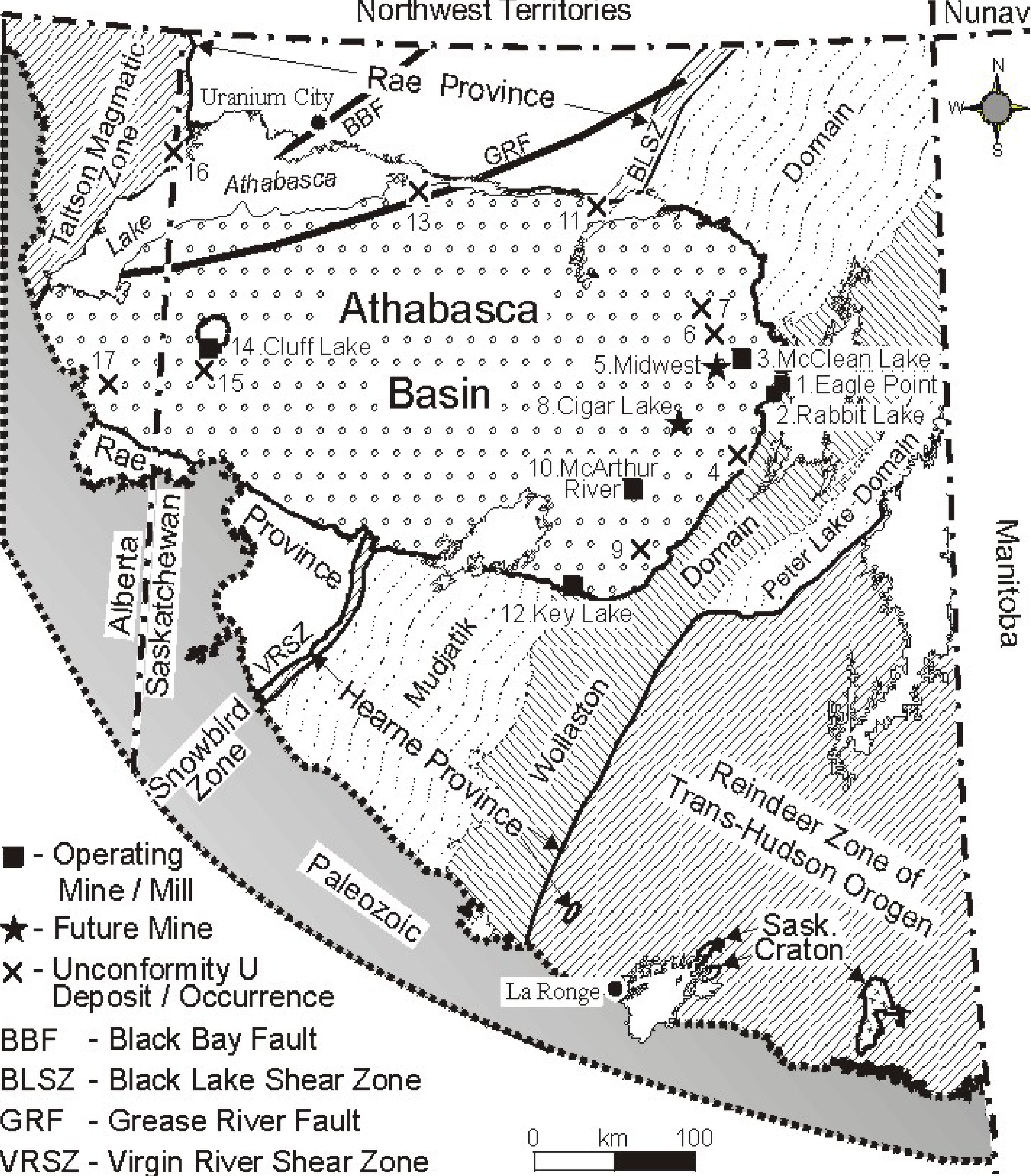
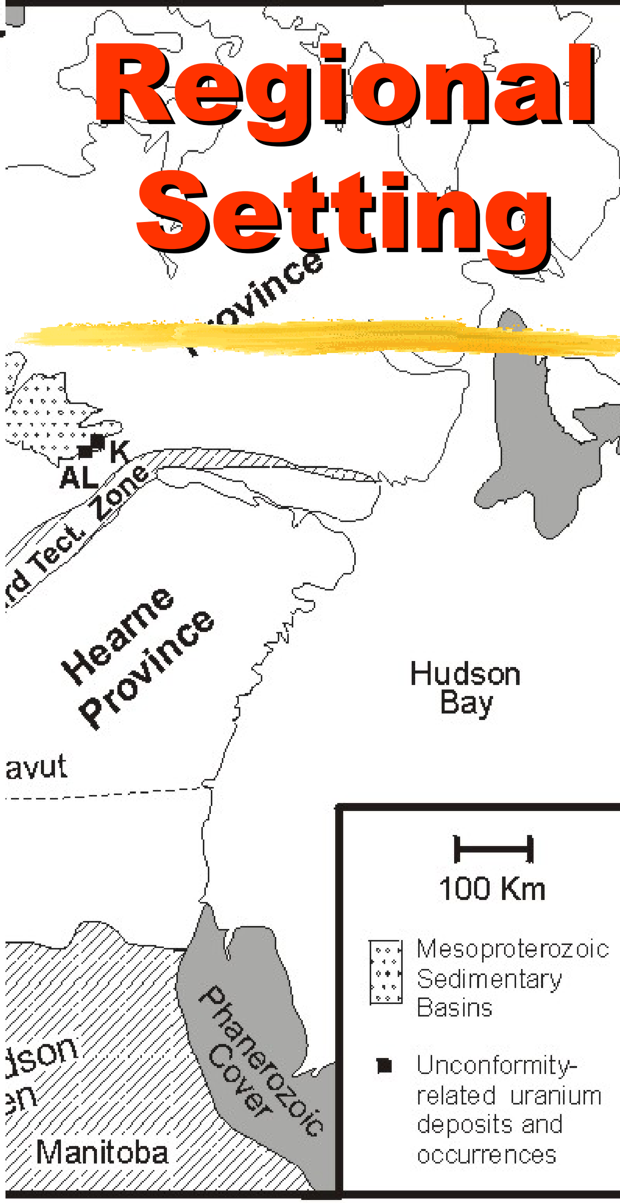


Figure 1.1. Athabasca Basin relationships to major tectonic elements of northwestern Canadian Shield, after Thomas et al. (2000), Ruzicka (1996) and Card (2001). Thelon deposits are Kiggavik (K) and Andrew Lake (AL). Athabasca deposits are detailed in Fig. 1.2 and Table 1.1.

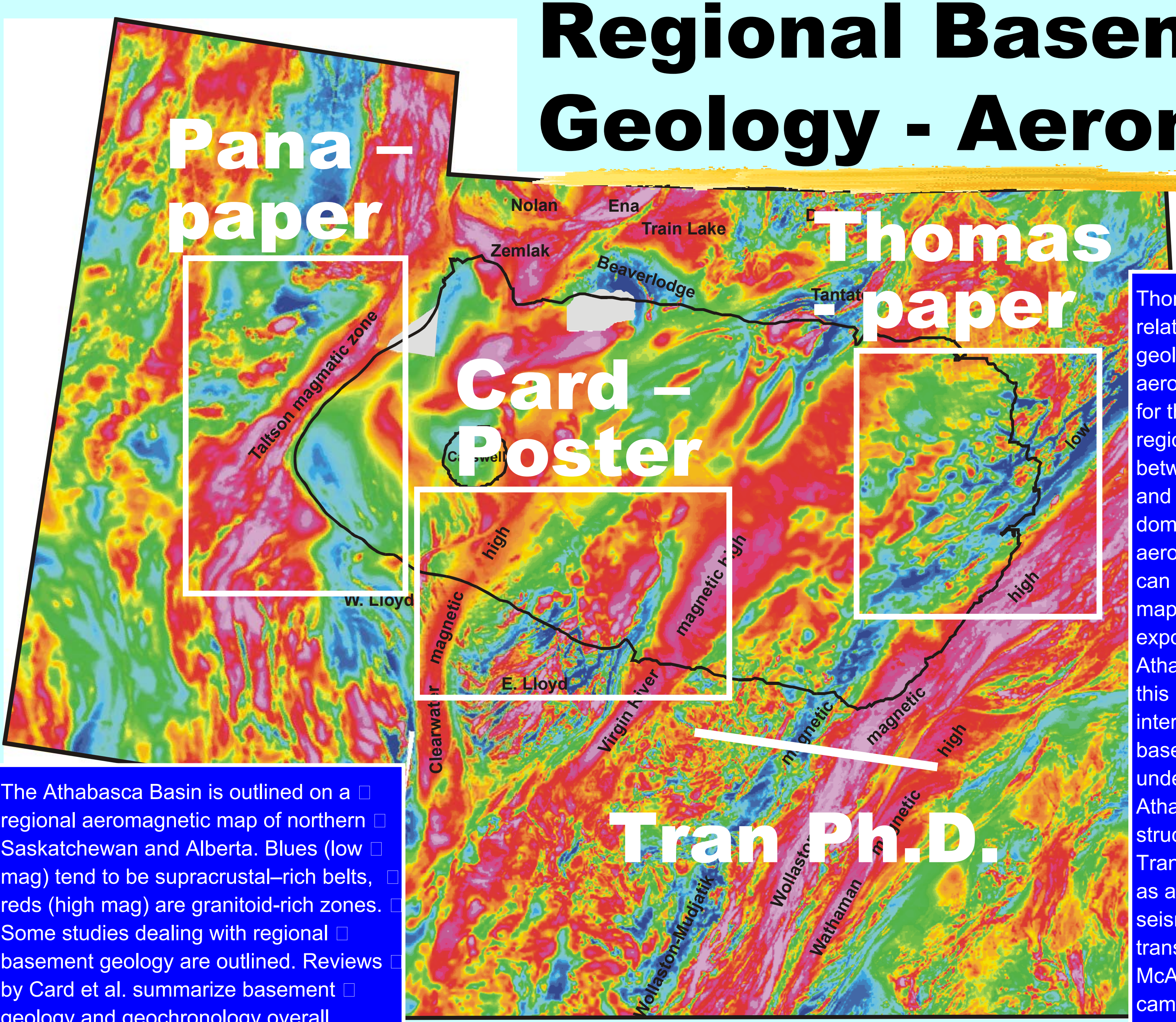
Regional Setting





ps to major tectonic elements of
omas et al. (2000), Ruzicka (1996) and
vik (K) and Andrew Lake (AL).
.2 and Table 1.1.

Regional Basement Geology - Aeromag

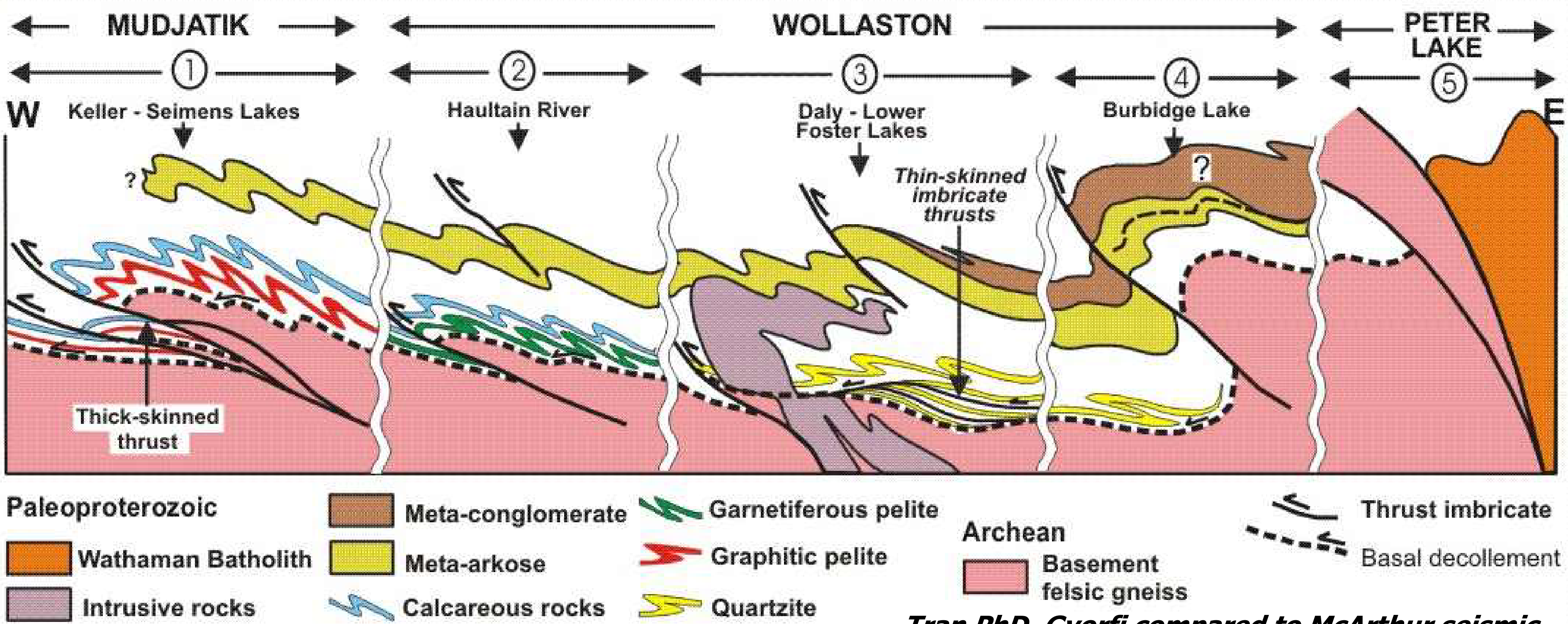


The Athabasca Basin is outlined on a regional aeromagnetic map of northern Saskatchewan and Alberta. Blues (low mag) tend to be supracrustal–rich belts, reds (high mag) are granitoid-rich zones. Some studies dealing with regional basement geology are outlined. Reviews by Card et al. summarize basement geology and geochronology overall.

Thomas reviews the relationships between geology and aeromagnetic signatures for the most prospective region – the transition between the Wollaston and Mudjatik basement domains – and how aeromagnetic signatures can be correlated with mapped geology exposed outside the Athabasca Basin, then this knowledge used to interpret geology of basement rocks underlying the Athabasca basin. The structural transect by Tran was used by Gyorfi as an aid to interpreting seismic reflection transects across the McArthur River mining camp.

Hudsonian Basement Structure and Stratigraphy Prepare the Ground

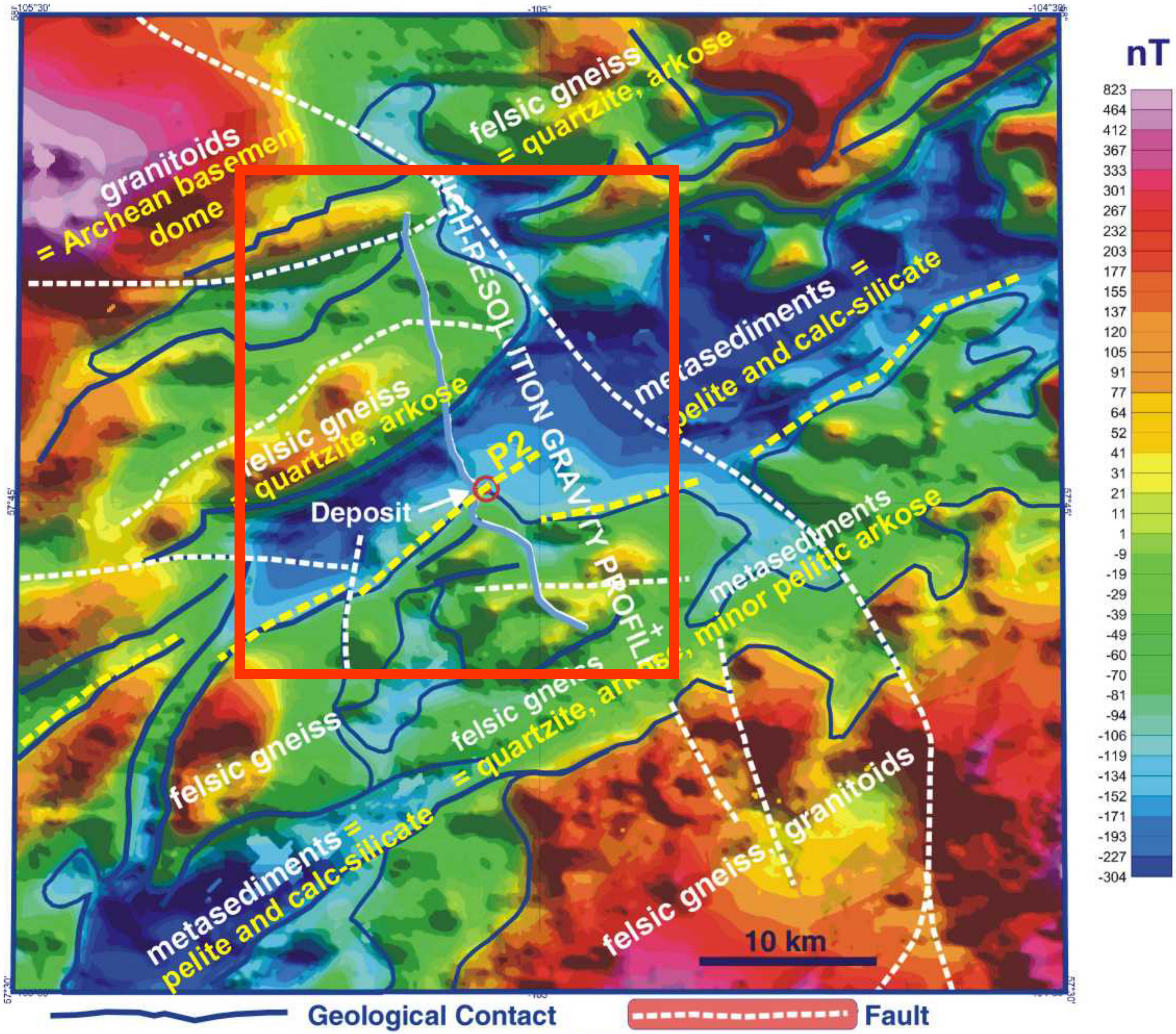
W E



Tran PhD, Gyorfi compared to McArthur seismic

This schematic down-plunge projection was interpreted by Hai Tran from detailed field mapping in collaboration with Gary Yeo, from south of Cree Lake (W) to across the Needle Falls Shear Zone and the Wathaman Batholith (E). This transect was in turn used by Gyorfi as a model for interpreting seismic data from basement structures beneath the Athabasca Basin. A key supracrustal unit associated with unconformity associated uranium deposits is the basal pelitic gneiss of the highly metamorphosed Paleoproterozoic Wollaston Supergroup. This basal metapelite records a stratigraphic facies change in subunits, from quartzite in the east through garnetiferous to graphitic pelite in the west. The graphitic pelite is specifically spatially assocated with reactivated basement faults and ore deposits. Scale is not specified, and stratigraphic thicknesses are uncertain due to extreme strain, however the meta-arkose unit in the Wollaston Group (AKA quartzofeldspathic gneiss now termed Burbage Lake Formation by Yeo and Delaney, 2005) is in the order of 500 m thick, and 3-5 kilometres in mapped thickness of Wollaston Supergroup paragneiss are represented above the basement gneiss.

SHADED TOTAL MAGNETIC FIELD



ILLUMINATED FROM NORTHEAST

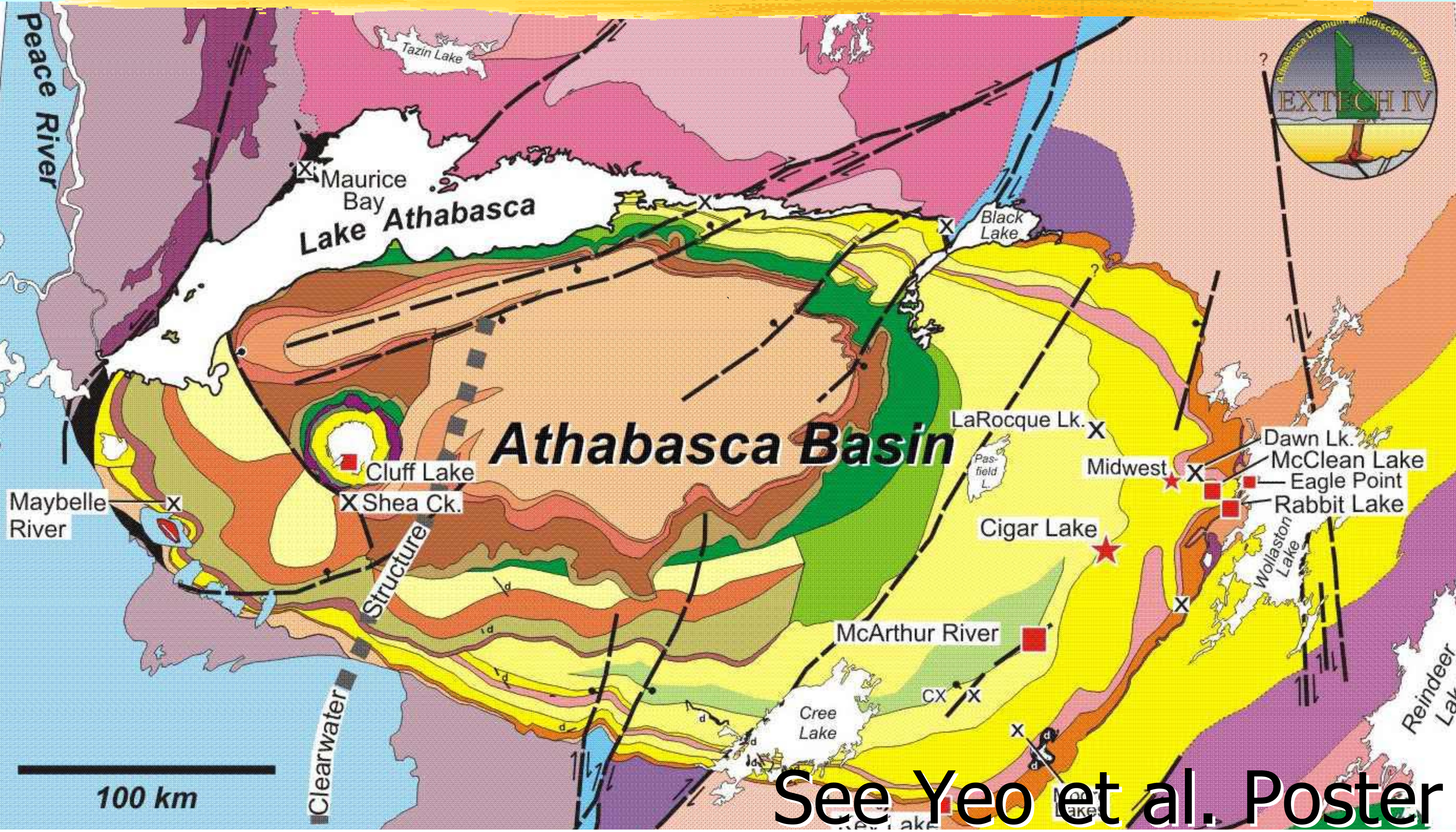
Contacts and Faults interpreted mainly from aeromagnetic data, and extended from geological information in McGill et al. (1993) in the style of Baudemont and Rafini (2000).

Thomas, Wood

Modelling Magnetics for Gravity and everyone else

This is an example of interpreted basement geology by Thomas and Wood. Construction of this map repeats unpublished similar interpretations that have been made by industry geologists, but is necessary to determine rock types and thereby rock properties that are required to interpret high-resolution gravity profiles along the McArthur River transect, shown as a blue line inside the red rectange. Sharp gradients in magnetism are use to infer faults and lithologic changes, for example granitoid domes (intense red) , arkosic metasediments (green to orange) and pelitic metasediments light to dark blue). Offsets of these gradients indicate cross faults, and particularly sharp gradients trending northeasterly are also interpreted as faults.

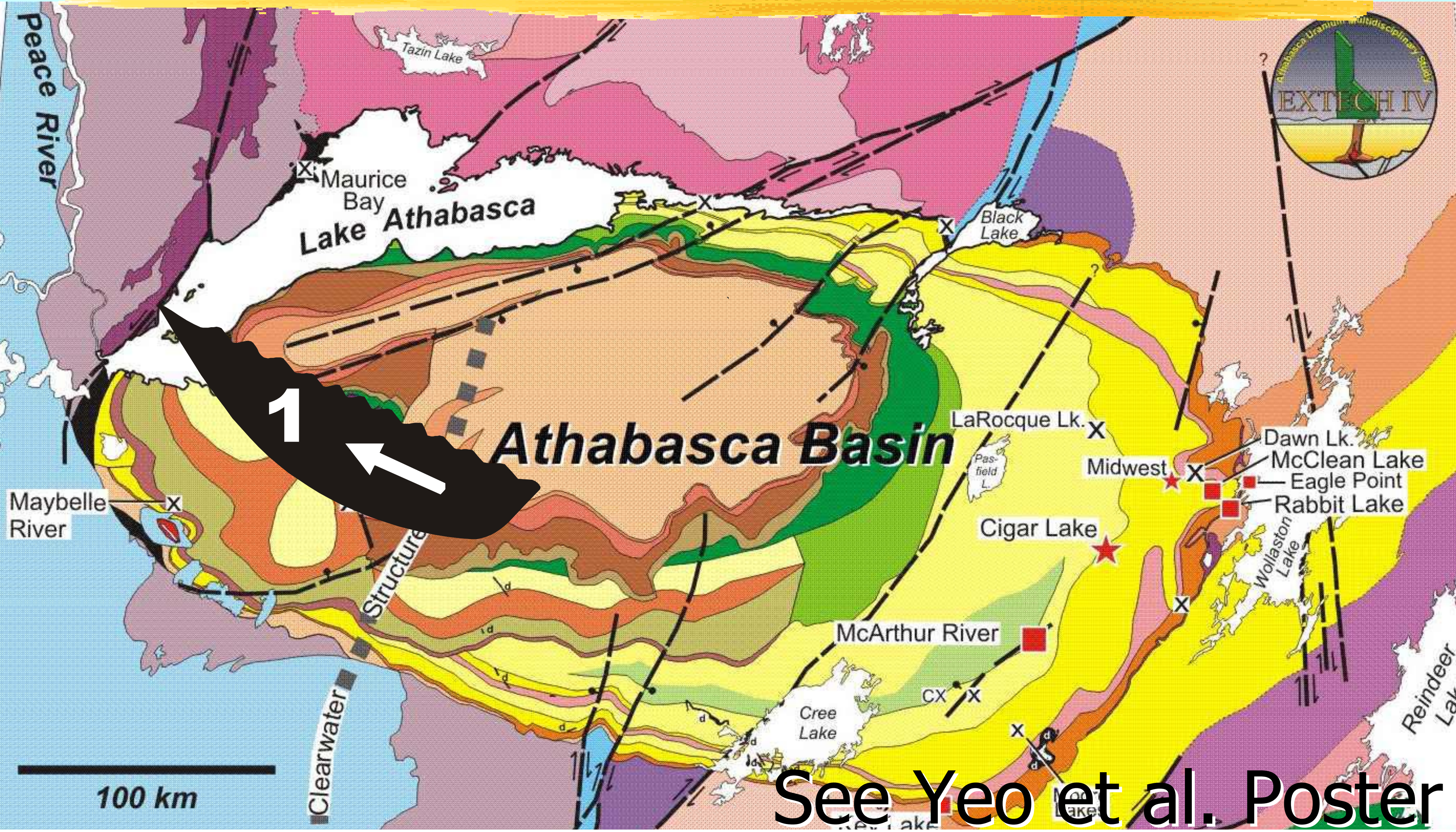
Basin Development from Regional Stratigraphy



See Yeo et al. Poster

The way the Athabasca Basin developed is related to growth faulting, development of accommodation space, subsidence generated by transpressional and transtensional tectonism, and broader crustal subsidence generated by mantle processes, possibly related to descending shallow subduction slabs. The lithostratigraphic and paleocurrent record shows that the basin developed in four major stages, each with its own regional configuration.

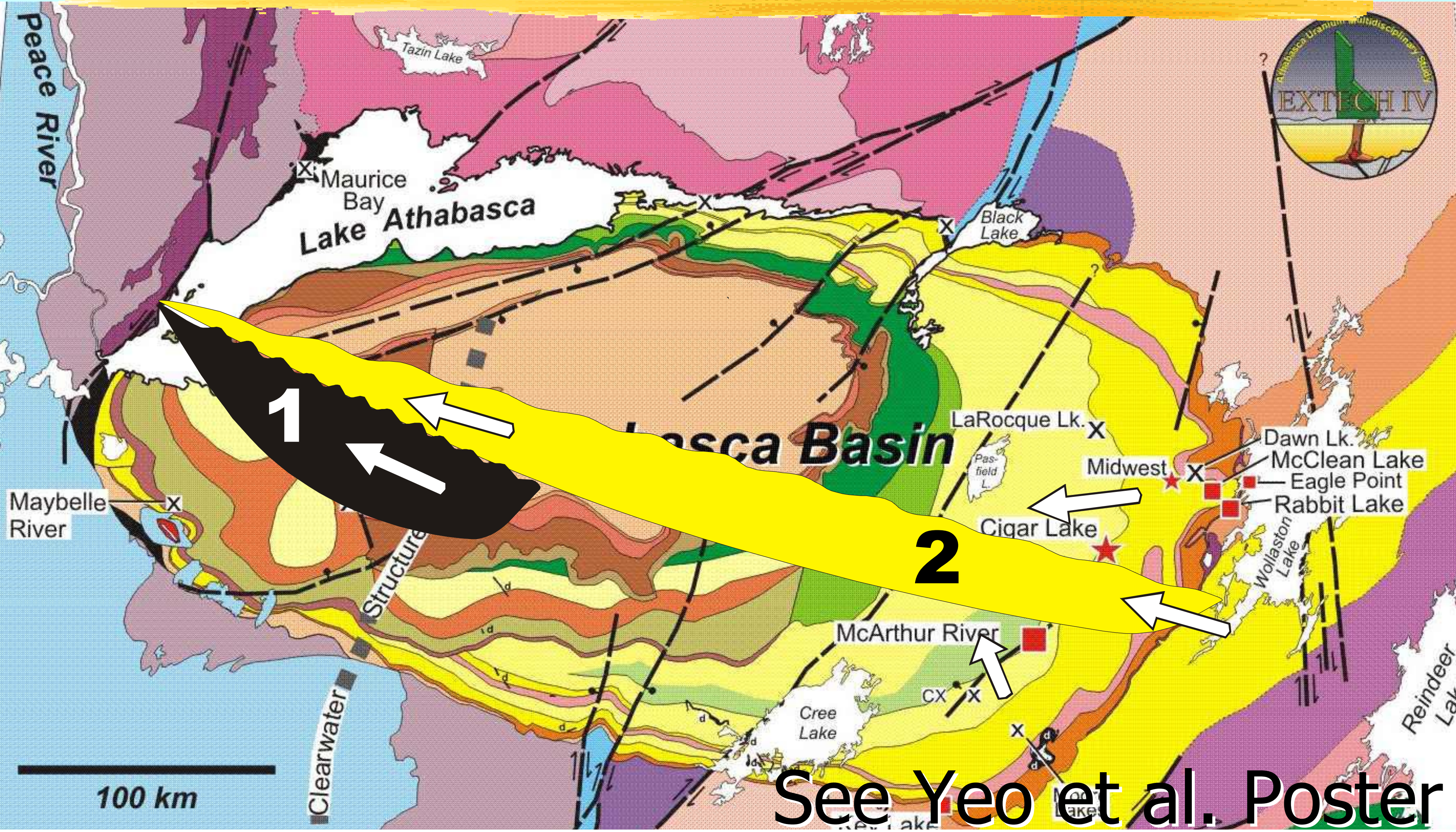
Basin Development from Regional Stratigraphy



See Yeo et al. Poster

Sequence 1, Fair Point, was probably only deposited in and around its western area of preservation, and was probably much thicker before uplift □ and erosion prior to deposition of Sequence 2. Westerly rivers derived sediment from the south and east of where Sequence 1 is preserved.

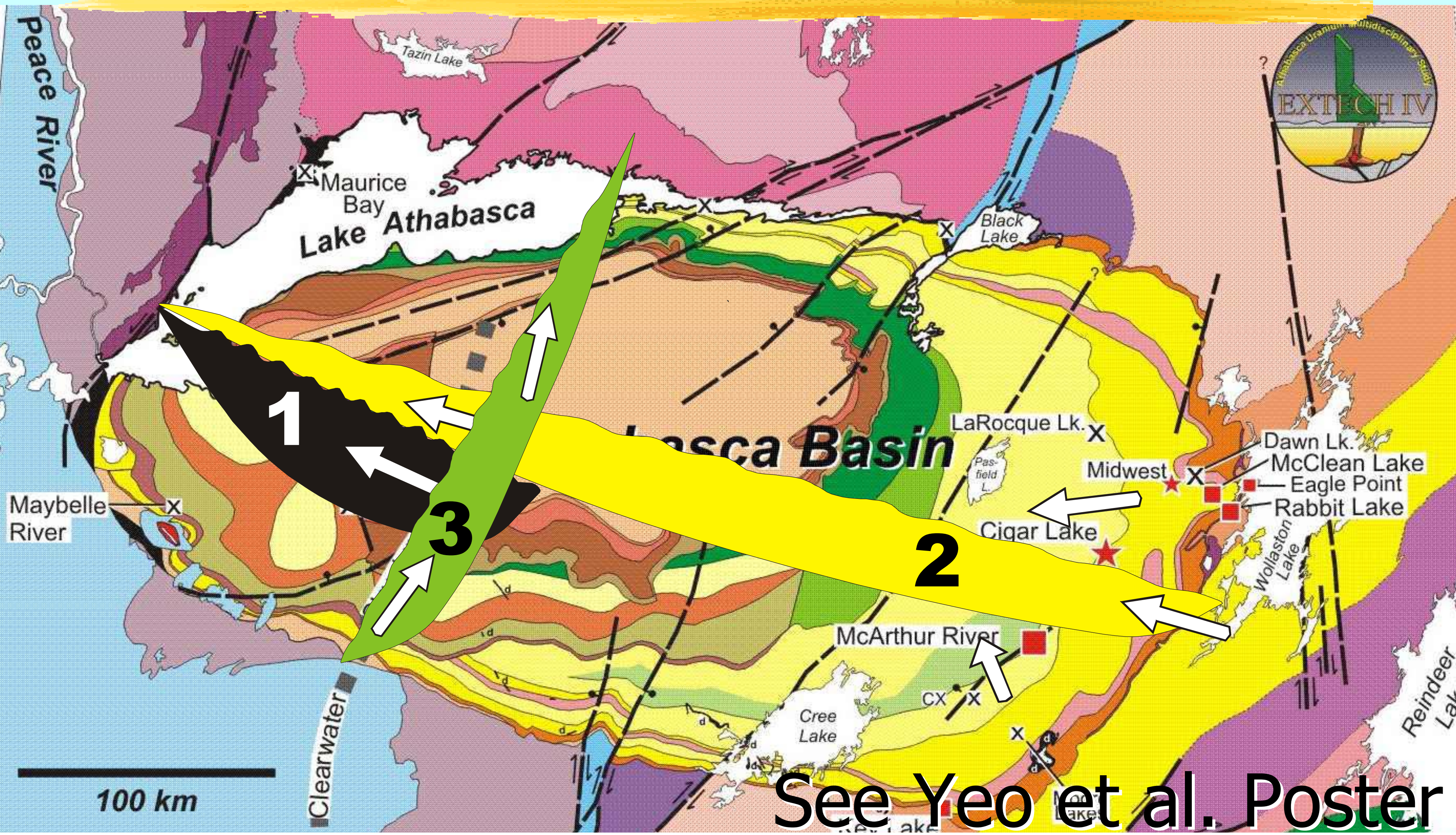
Basin Development from Regional Stratigraphy



See Yeo et al. Poster

Sequence 2 was deposited as a westward-tapering and –fining wedge with rivers transporting detritus from the east, southeast and northeast.

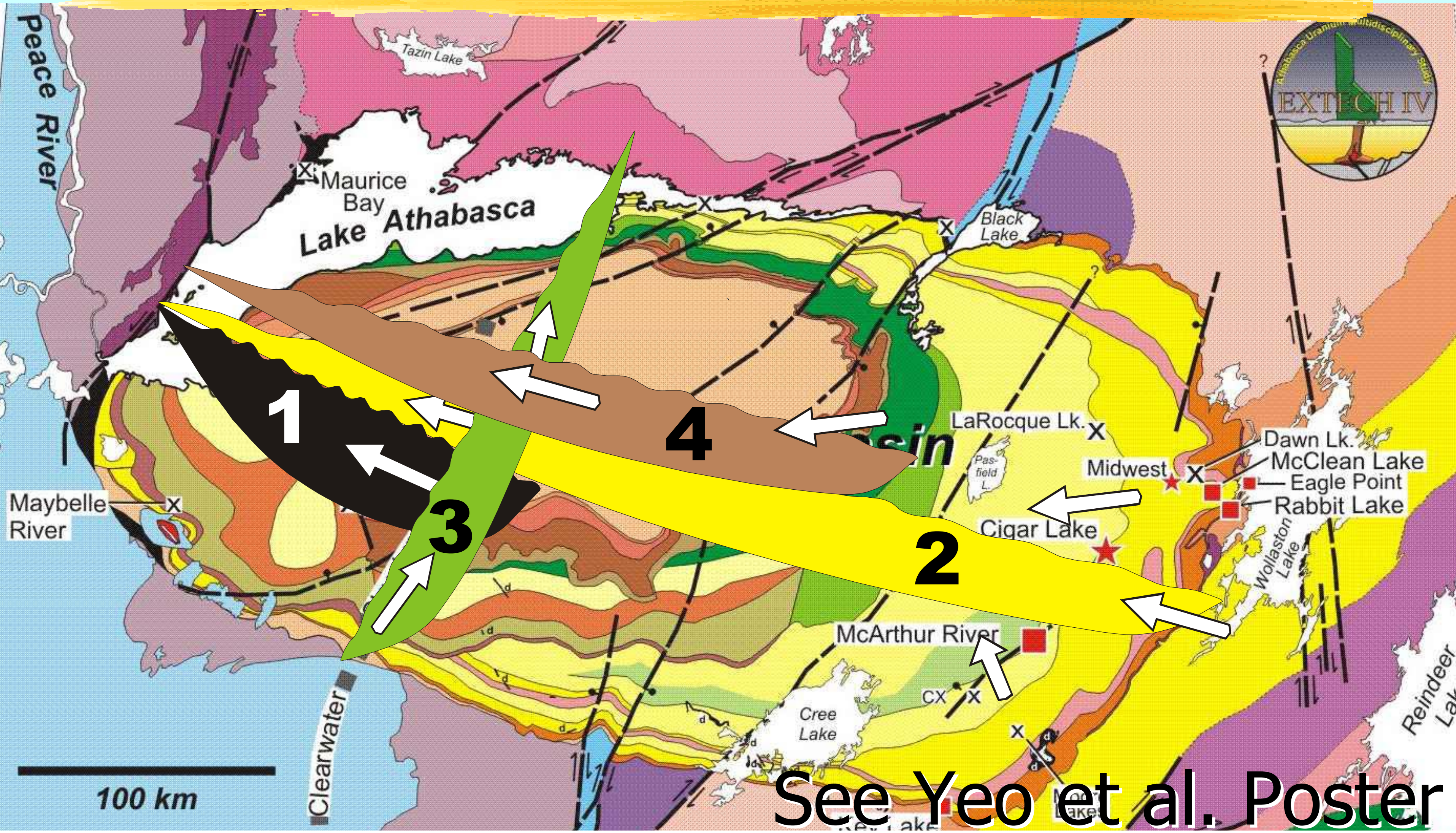
Basin Development from Regional Stratigraphy



See Yeo et al. Poster

Sequence 3 was the lithostratigraphic unit that cause the most difficulty in mapping until we finally realized that it is a northerly tapering and fining wedge derived mainly from the south and southwest

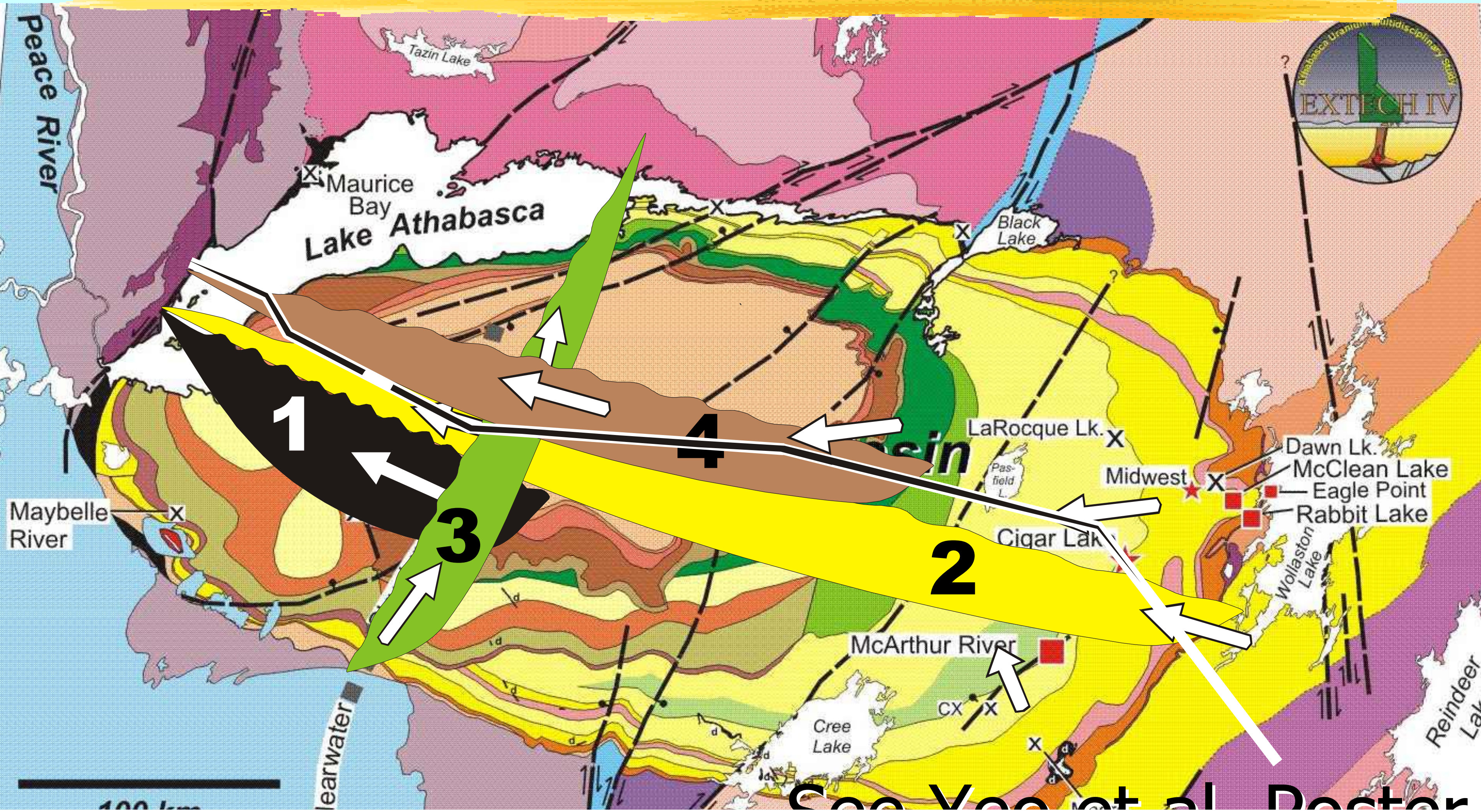
Basin Development from Regional Stratigraphy



See Yeo et al. Poster

Sequence 4 was again derived from the east, and we are uncertain as to how far east it originally extended. Note that these and subsequent cross sections are strongly expanded vertically so that we can see the stratigraphy

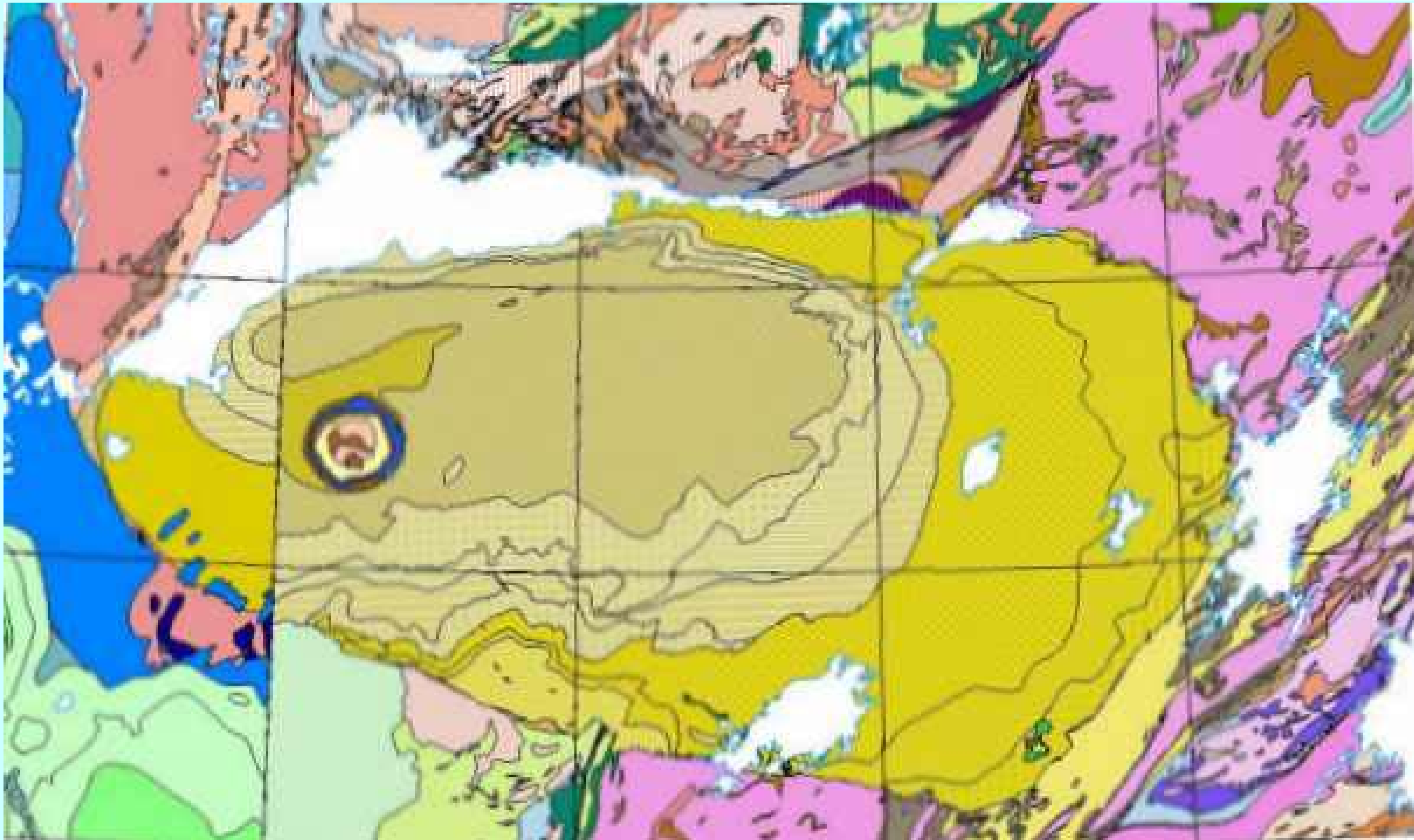
Basin Development from Regional Stratigraphy



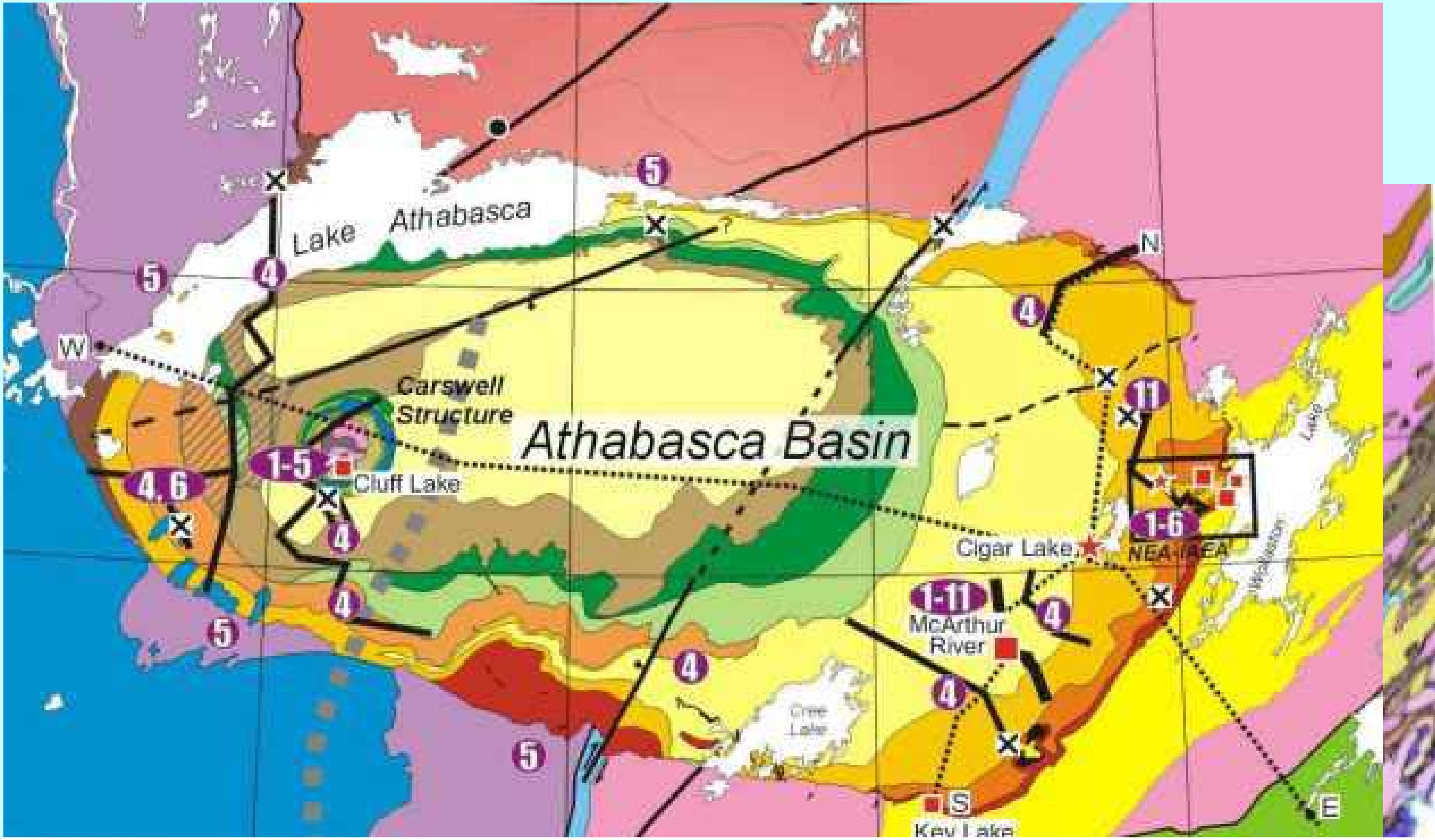
Actual thickness of the entire preserved Athabasca Group is shown to scale by the doubly tapered black line – the Athabasca and sister intracontinental basins were relatively quite thin, and had anomalous geothermal gradients to account for diagenetic temperatures in the order of 200-240º that persisted for hundreds of millions of years. Papers by Ramaekers et al.,Yeo et al. and a poster by Yeo et al at this Open house illustrate some of the regional stratigraphic framework that was determined by EXTECH IV. This was bolstered by a number of university –based detailed stratigraphic – sedimentological studies.

Evolving map Reflects Basin Development

First map: When we started EXTECH IV the Athabasca Basin had much the same formations that we know today but there were great uncertainties regarding their regional and local distribution, highlighted by a provincial border "fault".

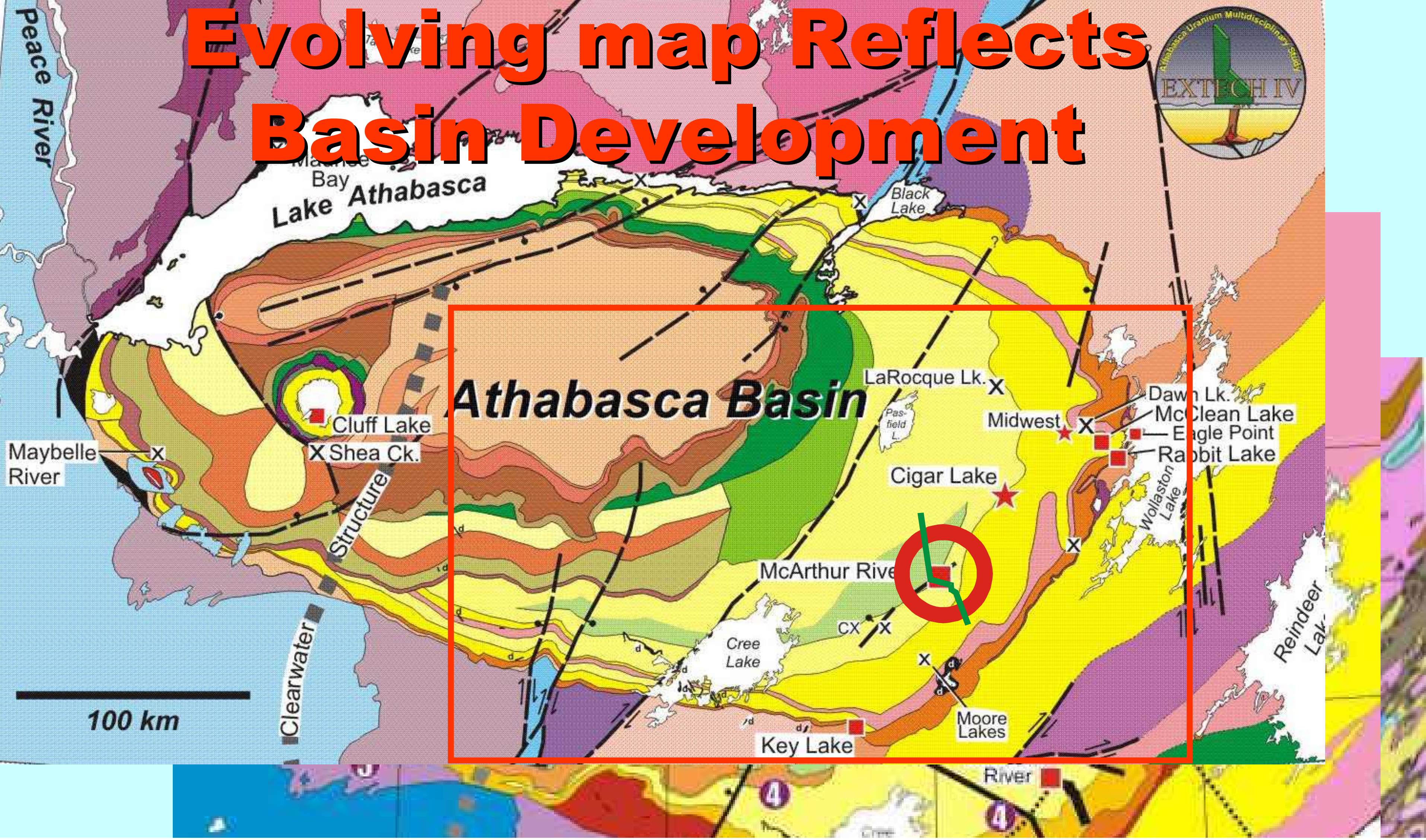


Evolving map Reflects Basin Development



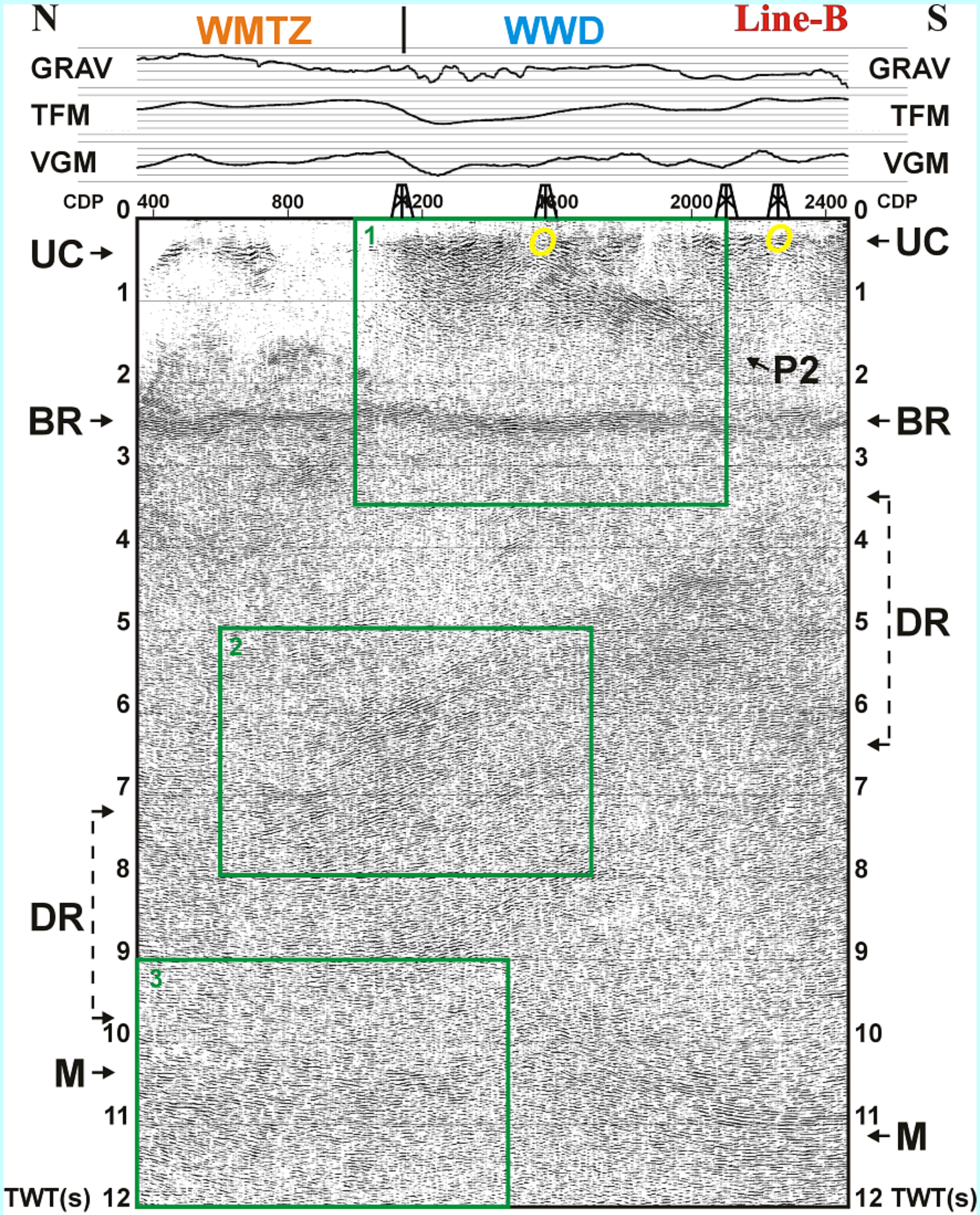
Second map: after two years of mapping, logging core and recompiling archived data, we had started to resolve the border fault, but internal controversy had developed regarding east-west stratigraphic relationships, and we were still uncertain of the relationships between the Virgin River area (large red lenticle south central basin, then mapped as MFa) and other parts of the basin.

Evolving map Reflects Basin Development



Third map, upper left: four years after project inception, the stratigraphic units had been resolved based on a better understanding of the sequence relationships shown in the previous slide. The Virgin River area is now understood in terms of interfingering relationships between units derived from the east (the Read Formation, previously known as MFa and most of Manitou Falls Formation) and units derived from the south (MFw, new member interfingered with MFb). Also the improved understanding of the relationships between growth faults and sedimentation led to the interpretation of a growth fault on the southwest side of the Carswell Structure, at approximately the same position as the previous “boundary fault” located along the Alberta-Saskatchewan border.

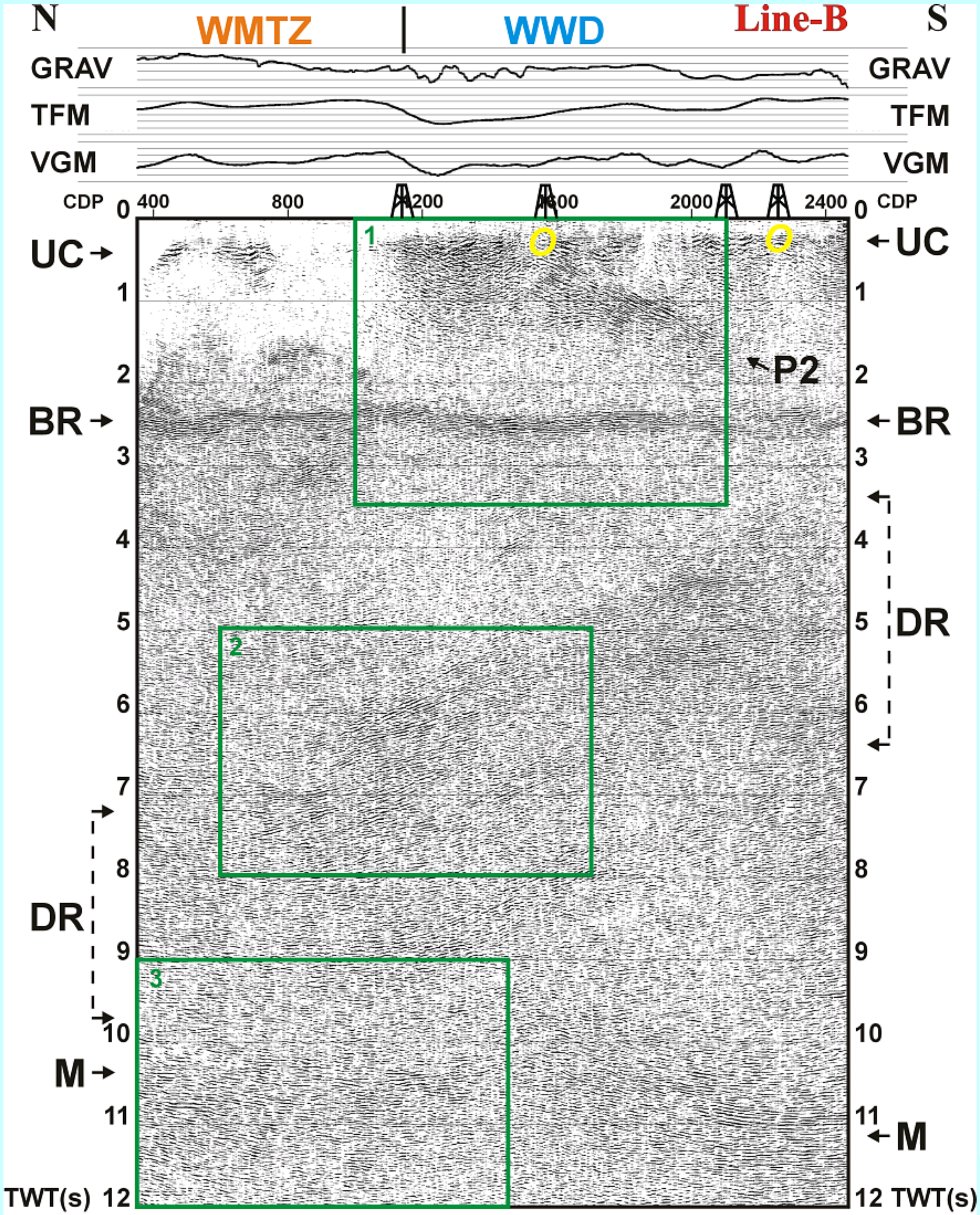
The large red rectangle and circle at McArthur River show the area of the next slide.



Basin Framework from Regional Seismic

- Unconformity
- P2 structure
- Bright zone
- Deep structures

Takacs, Hajnal et al.



Basin Framework from Regional Seismic

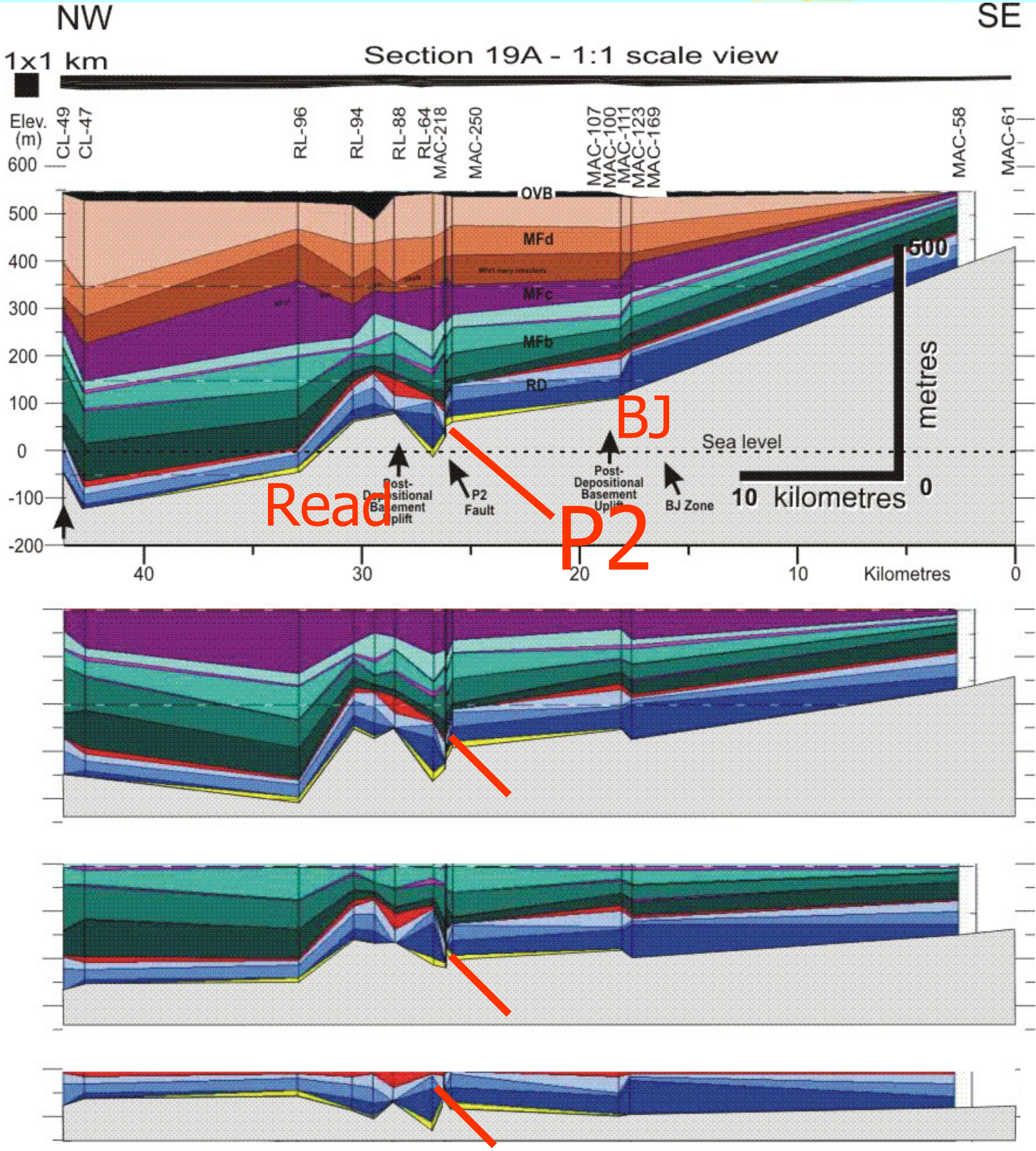
Regional seismic data were acquired in order to better understand the deep structural context of the Athabasca Basin and the moderately deep expression of the P2 and other structures known in the local exploration area. These data were coordinated and processed by E. Takacs through a post-doctoral fellowship with Zoli Hajnal and colleagues. The basal Athabasca Group unconformity (UC) is clearly identified and deepens gently toward the west. The P2 structure can clearly be seen to extend deep into the upper crust, and a similar structure comes in from the western edge of the transect. These terminate at a bright reflector (BR) that has been hypothesized to be a regional intrusion, or a rheological boundary along which a major structural discontinuity is located (Gyorfi, pers. com. 2004-12-29). Structures below the bright reflector have opposite orientations to those above. M = Moho. See the papers by Hajnal et al and White et al., and the poster by Gyorfi et al at the Open House for specific results.

Takacs, Hajnal et al.

Basin Evolution McArthur R. Area

A NW-SE stratigraphic transect of the McArthur River area was measured in numerous drill holes over a three-year period, under Sub-Project 4, as part of a multidisciplinary examination of this exploration and mining camp. Location of transect is green line over heavy circle.

Basin Evolution McArthur R. Area



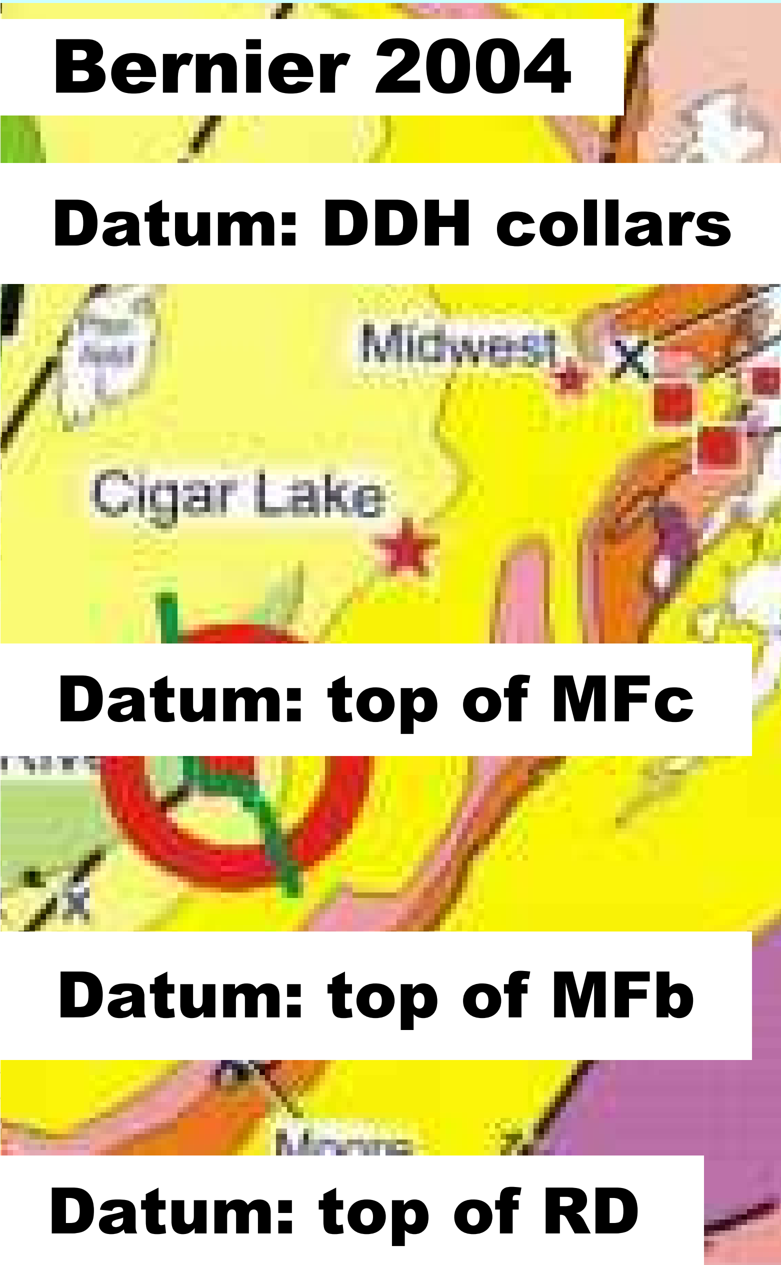
Bernier 2004

Datum: DDH collars

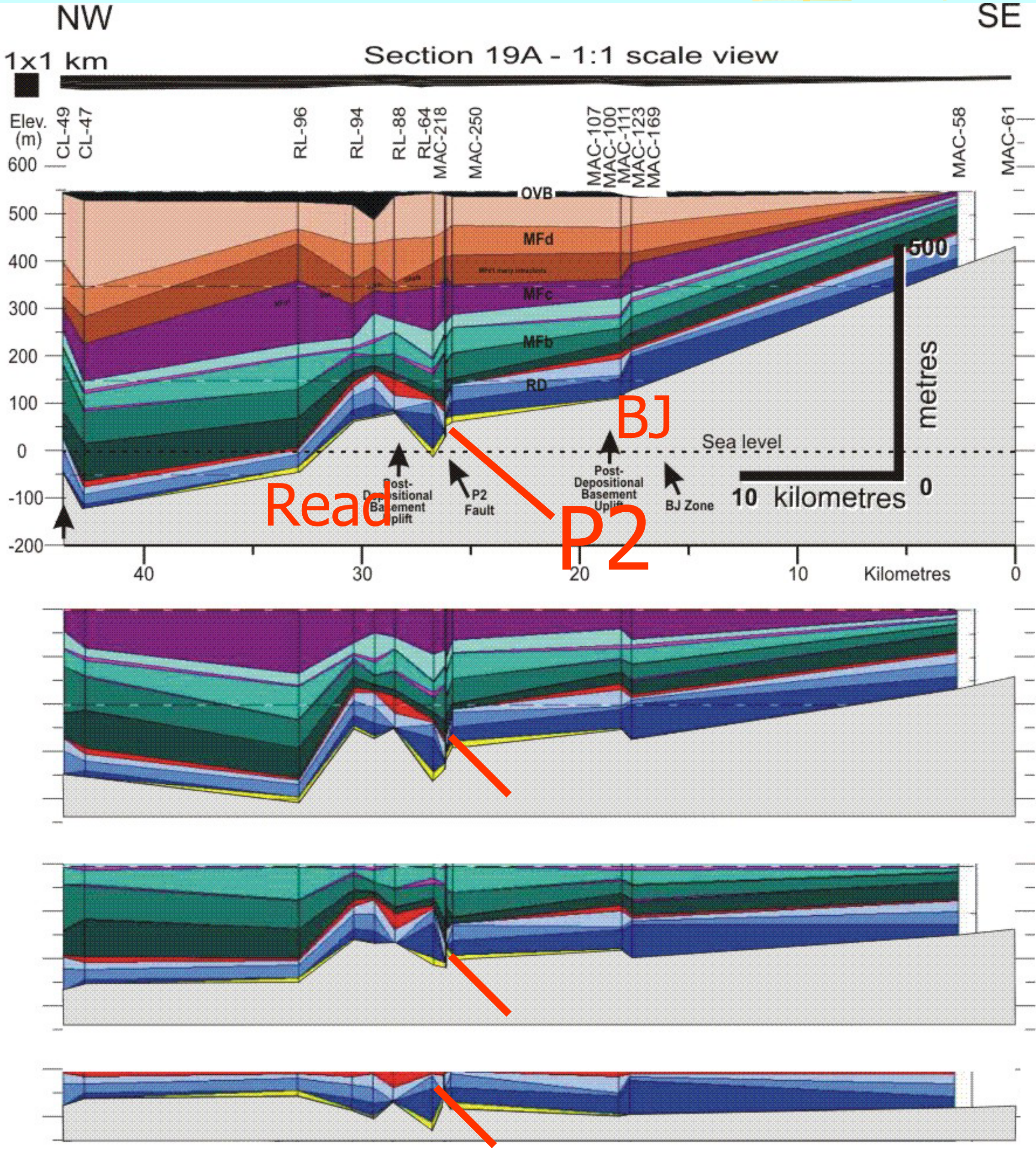
Datum: top of MFc

Datum: top of MFb

Datum: top of RD



Basin Evolution McArthur R. Area

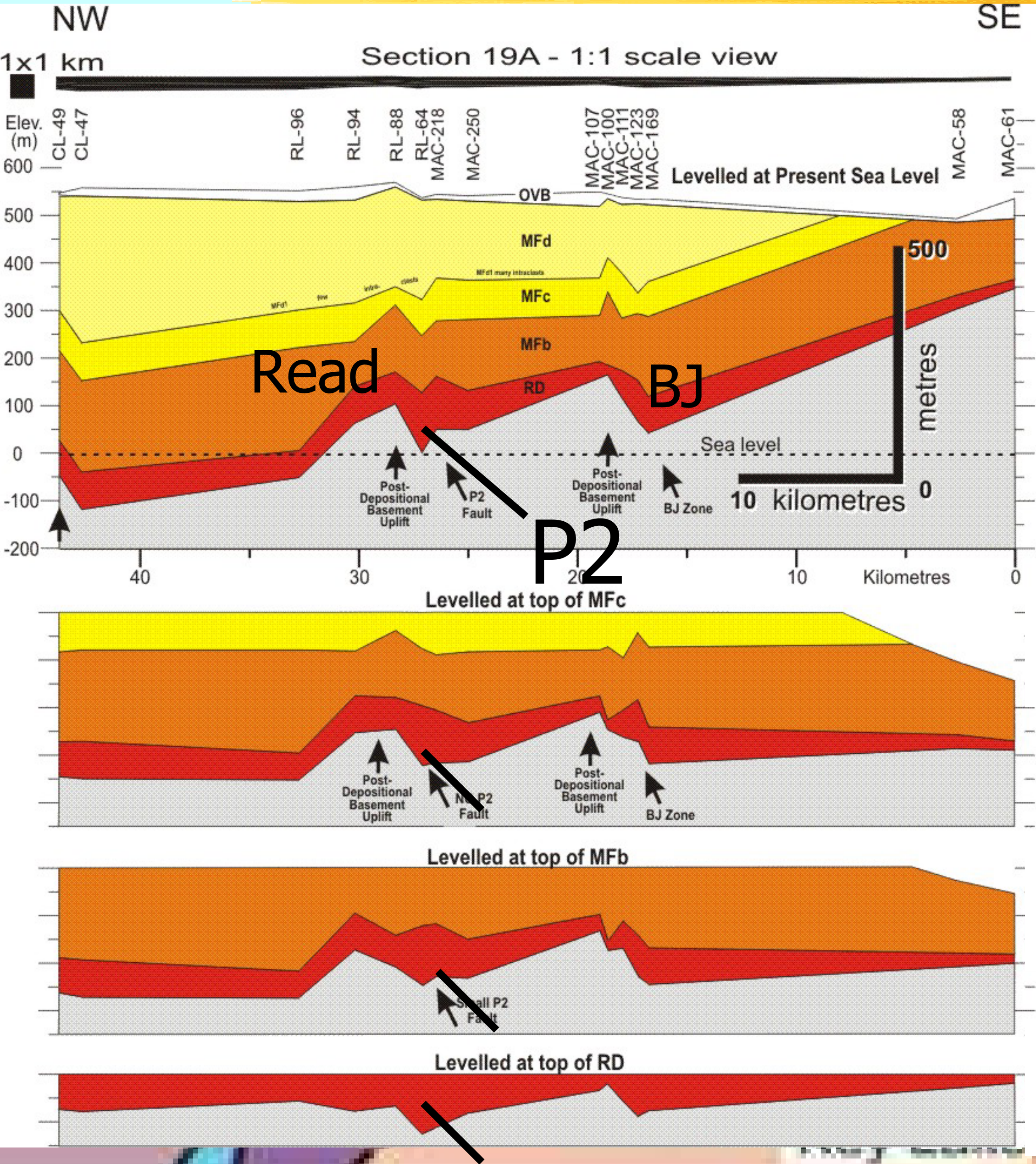


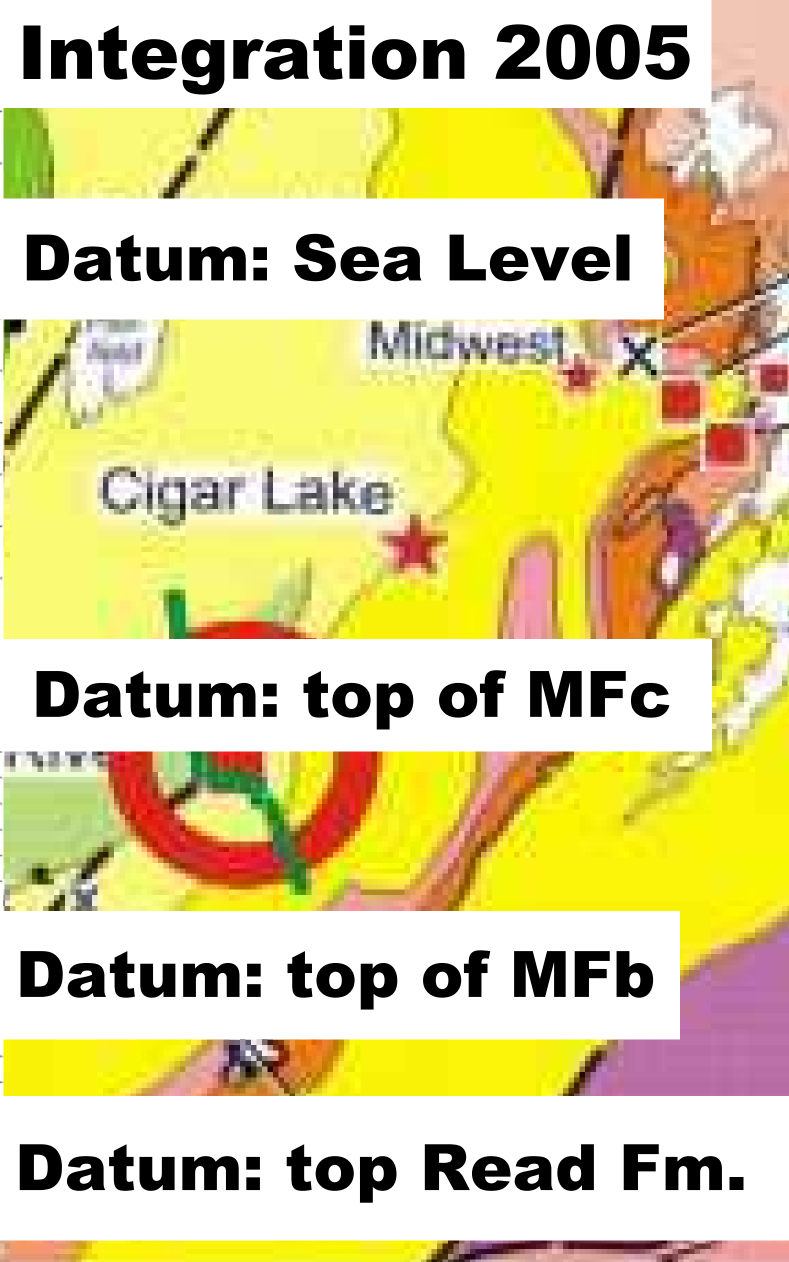
Bernier 2004

Datum: DDH collars

Initial figure shows a series of cross sections in blues and reds (Manitou Falls Formation) overlying pale grey (basement gneiss) along the same line of section. The cross sections are built one member at a time from bottom to top, flattened along the tops of each successive member to approximate time slices during sedimentation. Caveat: these are lithostratigraphic units, so are very likely to be time-transgressive and thus the “time” component is very crude. Nonetheless, it is apparent that basement structural elements such as the P2 fault and uplifts of quartzite ridges were not only active before sedimentation but also during deposition of each sub-unit. Due to the lack of constraints on units eroded in the eastern part of the study, these were simply connected at the eastern end of the transect, resulting in an apparent progressive tilting of the basal unconformity plane toward the west as each successive unit was deposited.

Basin Evolution McArthur R. Area





Integration 2005

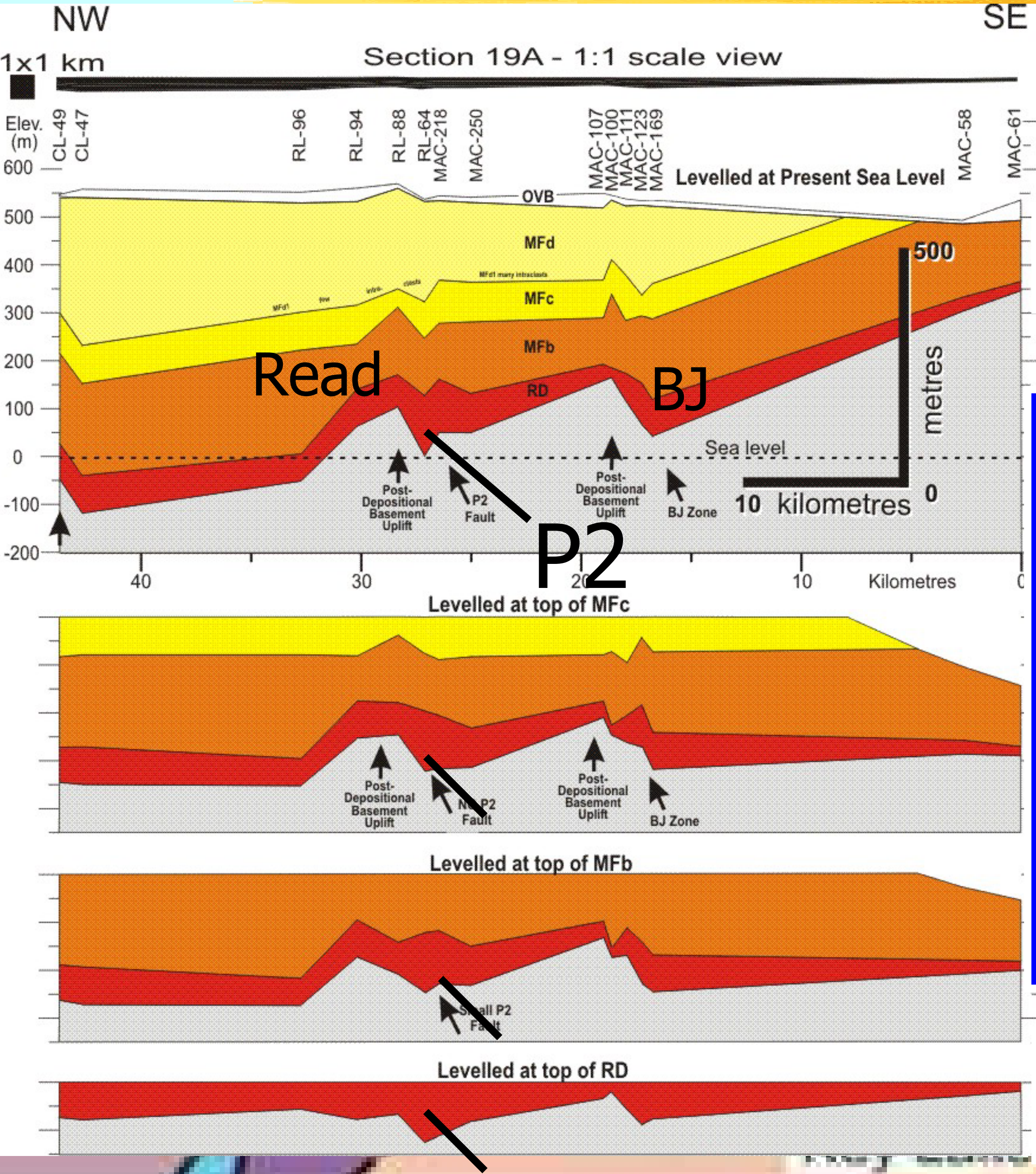
Datum: Sea Level

Datum: top of MFc

Datum: top of MFb

Datum: top Read Fm.

Basin Evolution McArthur R. Area



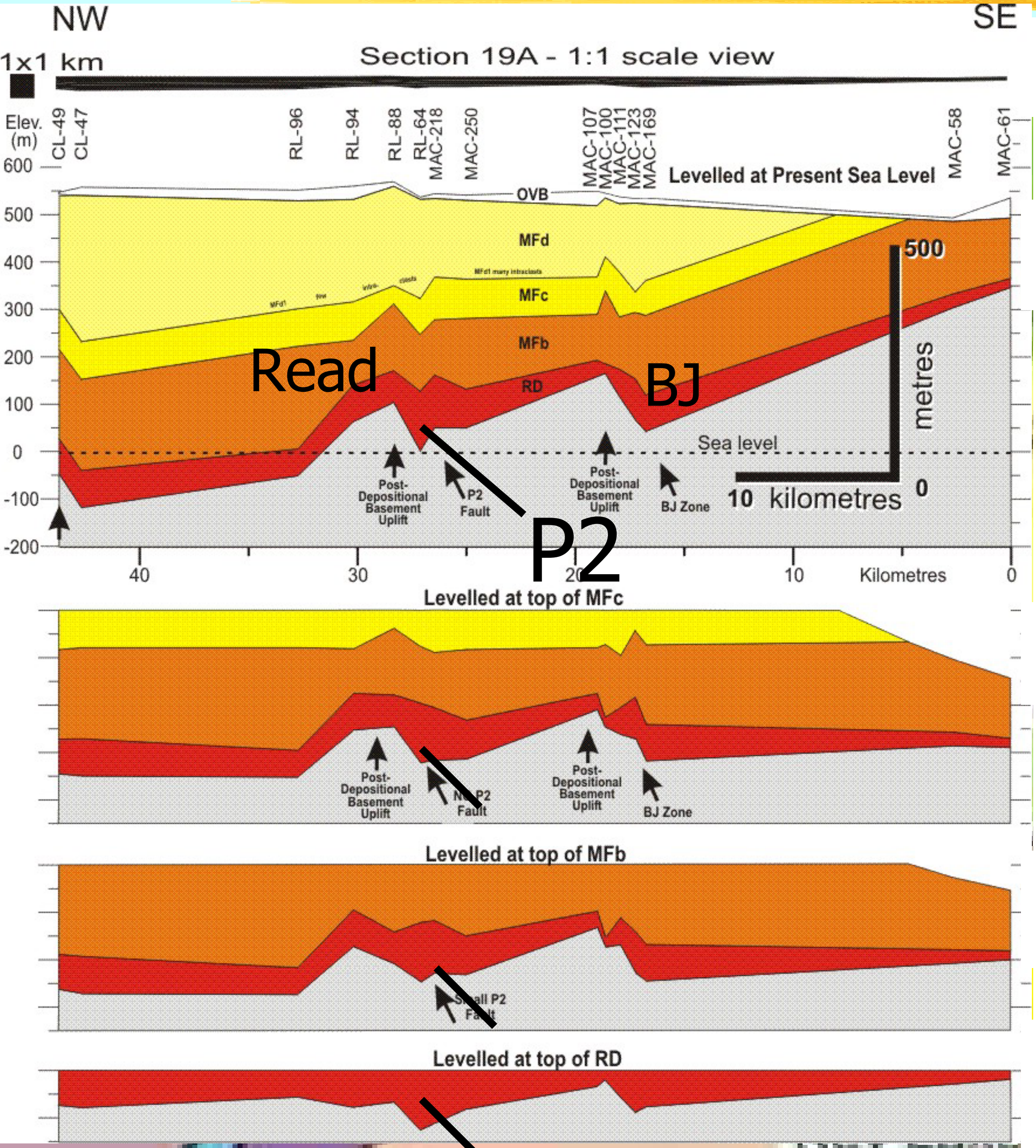
Integration 2005

Datum: Sea Level

The second set of transects retain grey for basement, with red = Read Formation, orange = MFb, yellow = MFc and pale yellow = MFd. In this version of the same transect the following changes affect the data: (a) logs of more drill holes were included for the BJ zone, (b) unit picks were based on integrated assessment of one or more multiparameter statigraphic logs with geophysical logs, particularly gamma ray, and (c) the eastern extensions of eroded stratigraphic units are assumed to maintain approximately the same present-day dips toward the east. The resultant series of flattened sections suggests no increase in basinward tilt through the time of deposition of Read Formation, MFb and MFc. The time at which the much steeper westerly dip was attained cannot be constrained by the preserved strata in the eastern area.

Datum: top Read Fm.

Basin Evolution McArthur R. Area



Other disciplines involved in this transect and whose results are represented in the following slides include:

Sub-Project 1. Regional to high resolution seismic reflection (the position of the transect was defined by consideration of key geological questions in the area vis-à-vis where the vibroseis vehicles could travel along a winter road);

Sub-Project 2. Multiparameter borehole geophysics that provides a “Rosetta Stone” of geophysical parameters linking geological data with the various geophysical transects.

Sub-Project 3. Organic geochemistry (this was one of many sites examined) presented toward the end of this presentation

Sub-Project 5. Structural and Basement Geology

Sub-Project 6. Gamma Ray and Quaternary Geology (this site was studied by ground gamma ray transects only)

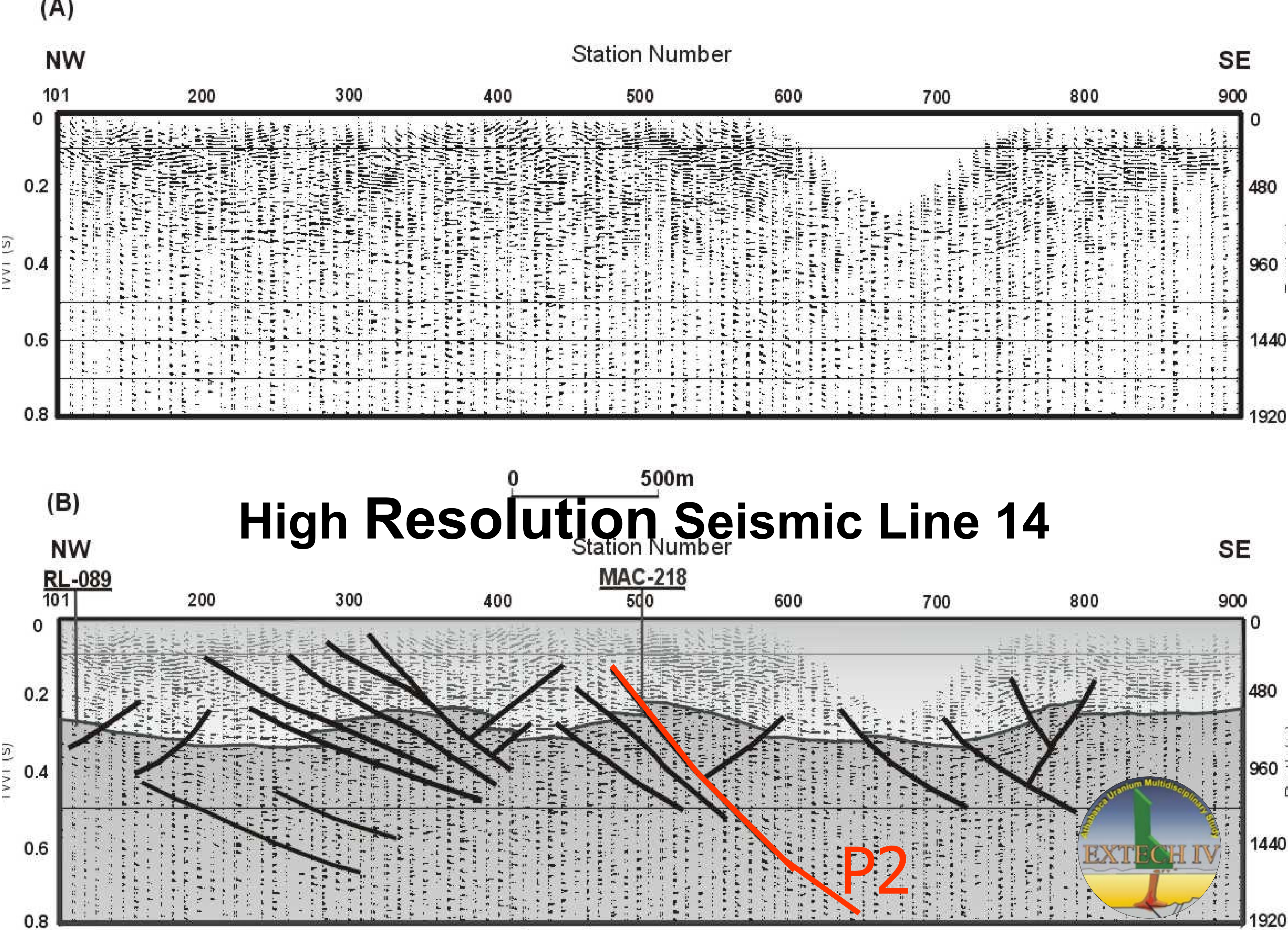
Sub-Project 7. Mineralogy (this was integrated with and provided support mainly to Sub-projects 2 & 4.

Sub-Project 9. Audiomagnetotelluric transect along the same line as seismic, with follow-up detailed survey grid over much of the exploration and mine workings

Sub-Project 10. Gravity transect along the same regional line as seismic.

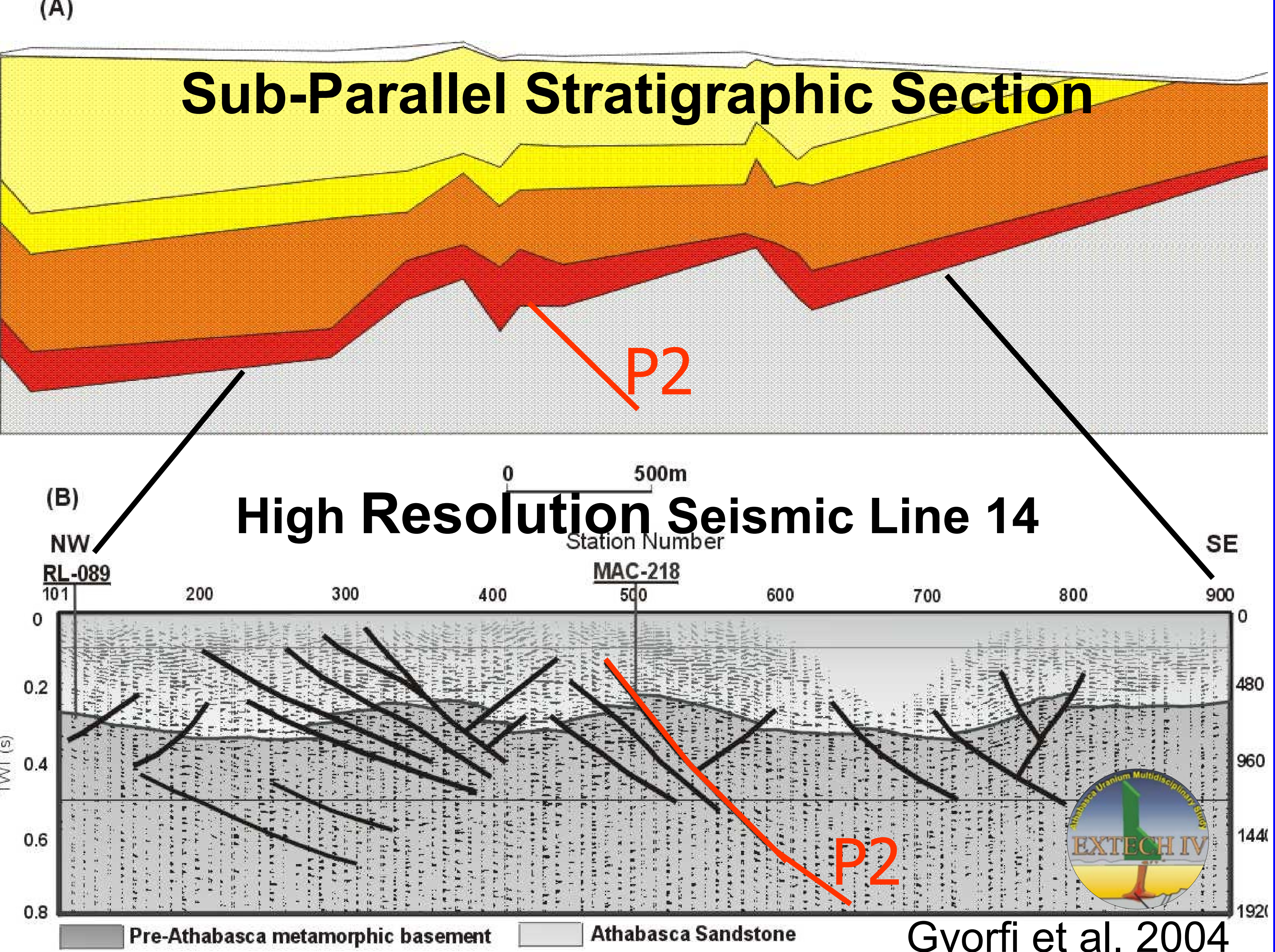
Datum: top Read Fm.

High Resolution Seismic Line 14



▨ Pre-Athabasca metamorphic basement ▨ Athabasca Sandstone

Gyorfi et al. 2004

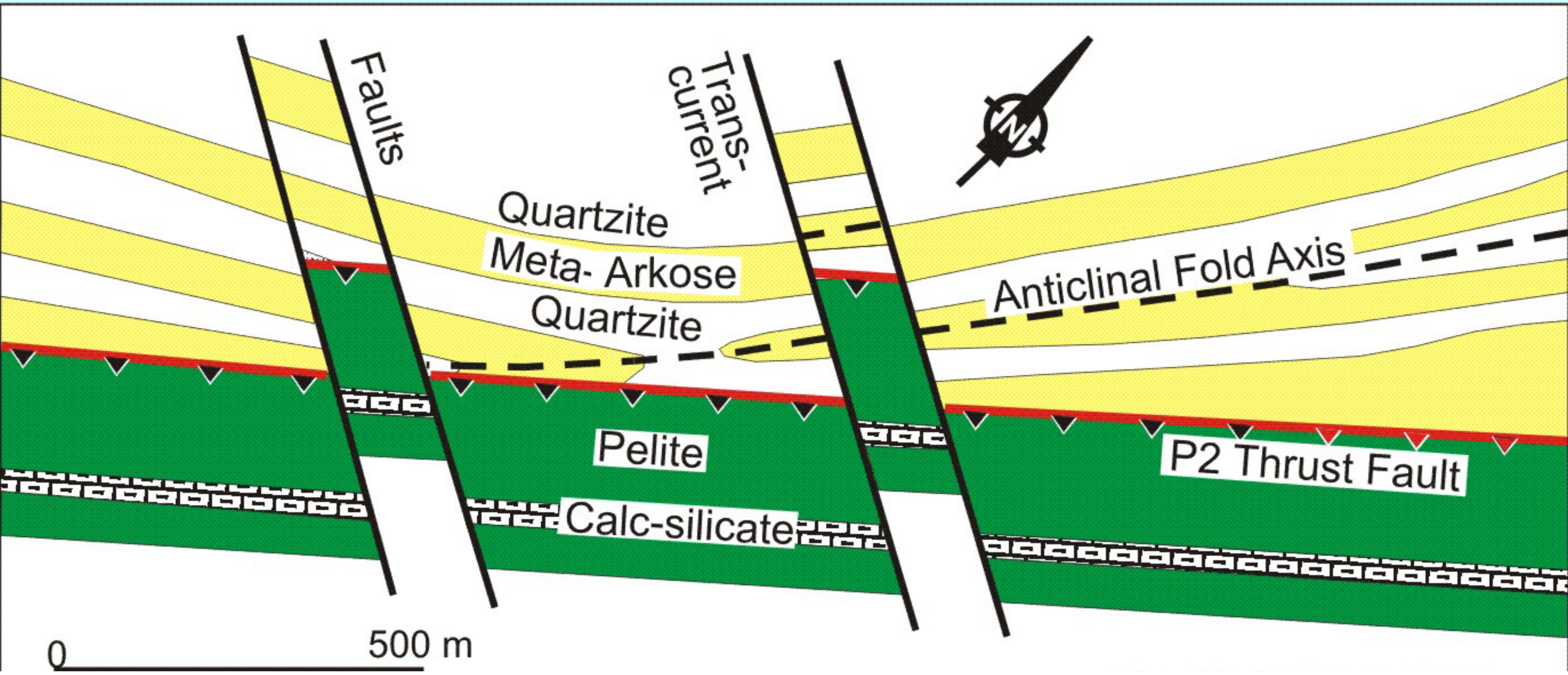


Sub-Parallel Stratigraphic Section

High Resolution Seismic Line 14

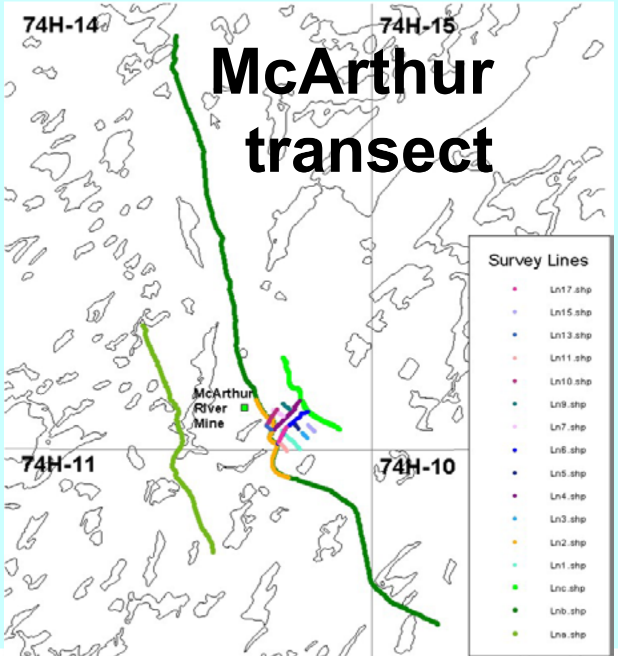
Gyorfi et al. 2004

The role of cross faults at McArthur River



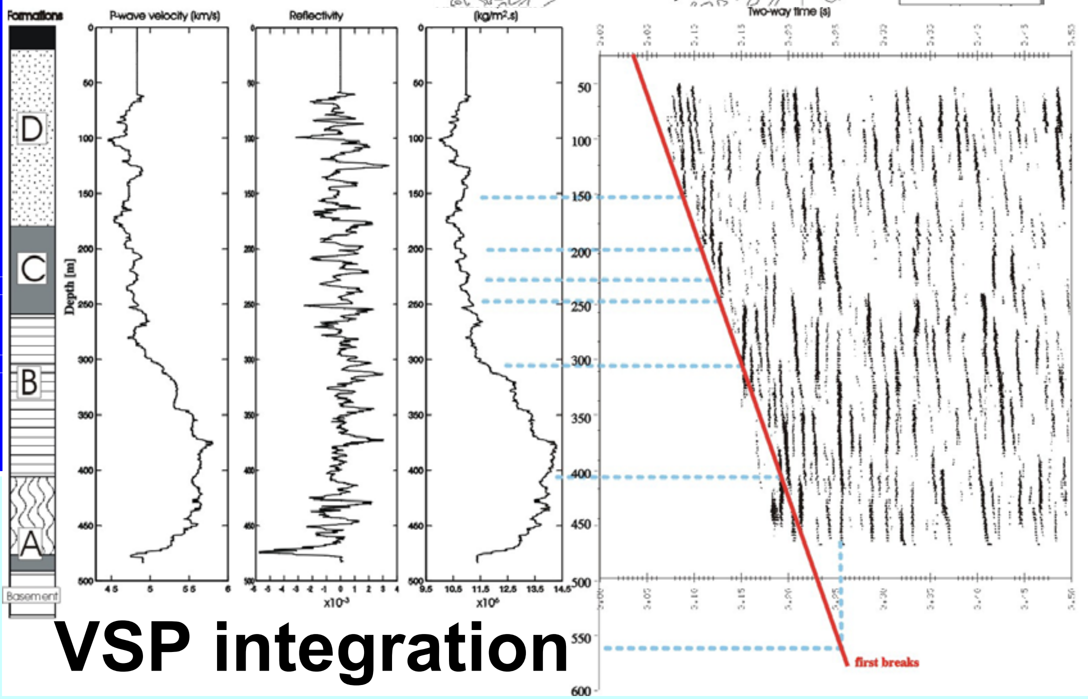
This is a plan view cartoon of the basement geology at the level of the basal Athabasca unconformity. Early work by McGill et al. demonstrated the relationship between the P2 fault and massive super-high-grade uraninite ore through a series of drill holes located across and along the strike of the P2 fault. In addition, McGill et al. discussed the concept of transcurrent faults intersecting and offsetting the P2 fault, suggesting that cross structures may be important for mineralization. Such cross structures also account for the strong variation of structural and stratigraphic style in all three dimensions. This is analogous to Sedex and VMS deposits where intersections of growth faults are key to focusing ore-forming hydrothermal processes. This leads us to the next slide regarding high-resolution and high-density seismic reflection data.

High Resolution Seismic



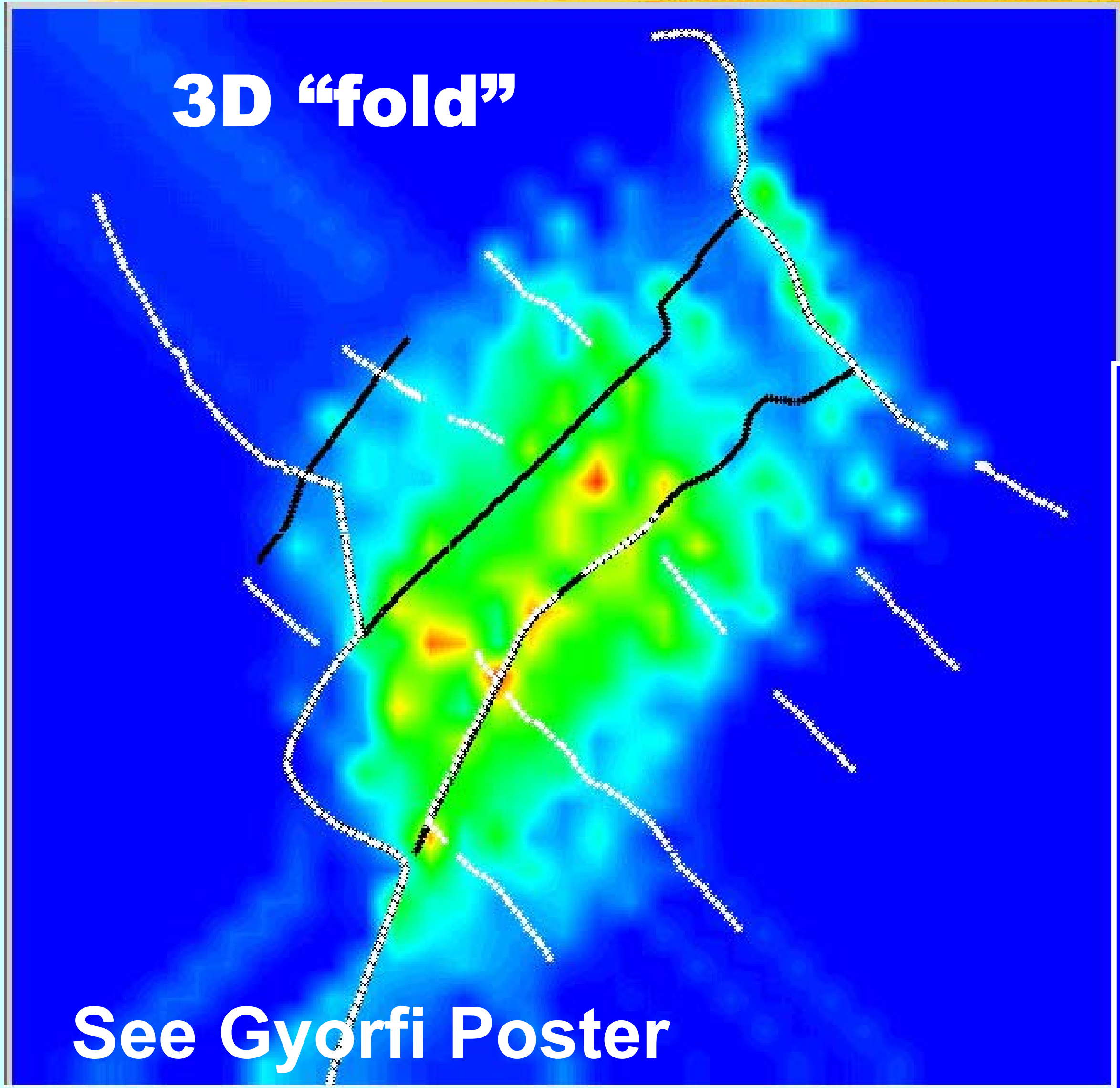
McArthur transect

This slide illustrates more of the variations in seismic reflection applications. The upper right map shows the plan view of seismic data acquisition, with the two longest lines (totalling ~ 50 km) being regional and deep (past the Moho) and the cluster of shorter lines locating high-resolution data. At lower right is an illustration of vertical seismic profiling where seismic reflections are tracked back to the source drill hole where they can be correlated with geological units and other borehole geophysical parameters. One question that has been resolved is whether or not the silicification front associated with the ore body can be imaged seismically. Although a large increase in density and sonic velocity is associated with the silicification, it appears to be too gradual to cause a reflection, although it is reflected by overall velocity regimes. Instead, individual reflections within the Athabasca Group appear to be related to the bedding fabric, although no reflective packages are characteristic of any of the members recognized by lithostratigraphic methods.



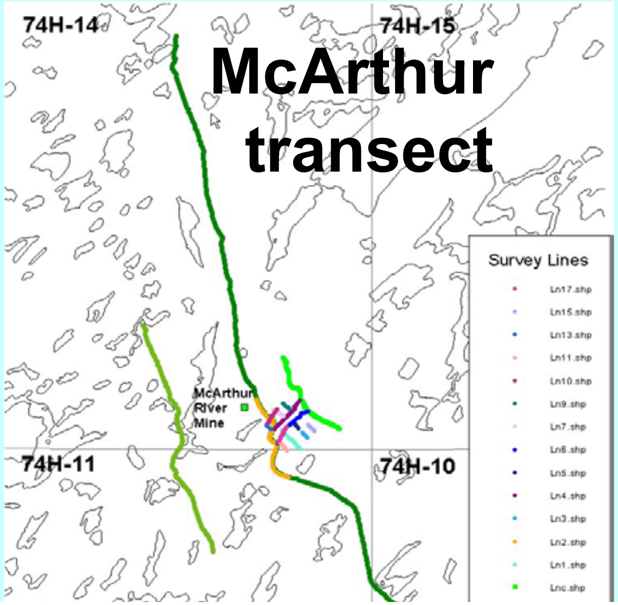
VSP integration

High Resolution Seismic



3D “fold”

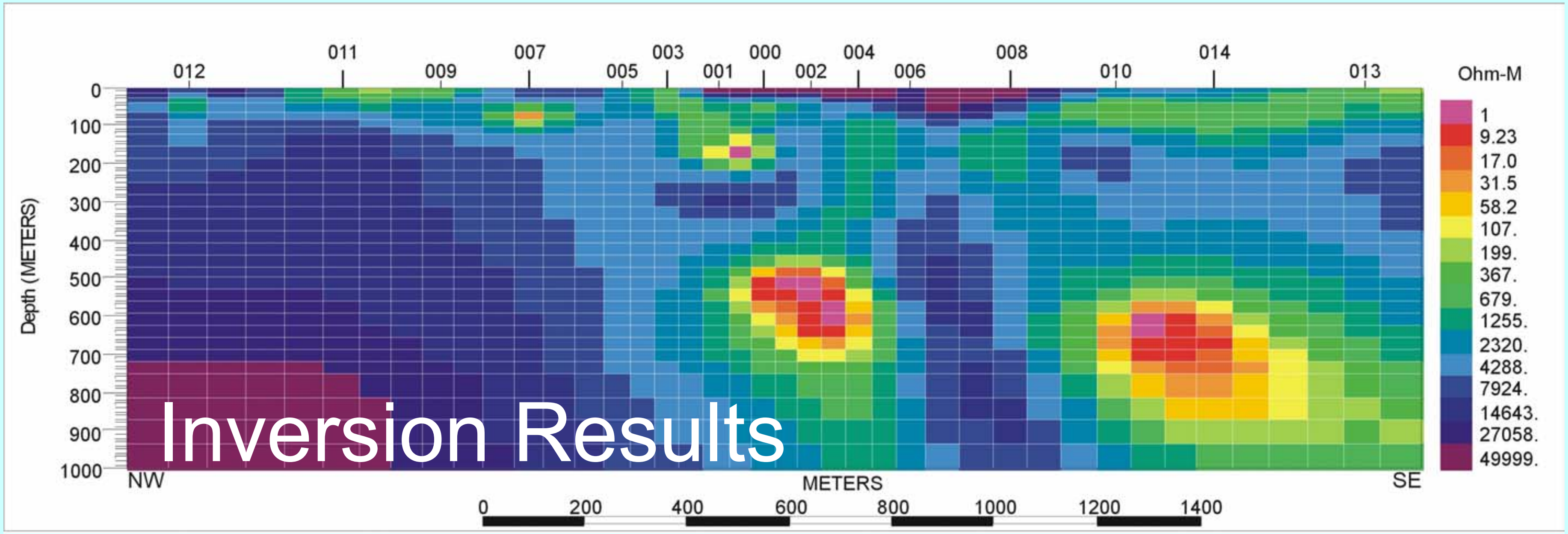
See Gyorfi Poster



McArthur transect

Last slide component “dissolving in” shows the density of seismic reflection data acquired in the highest resolution pseudo-3D study. A normal 3D array for petroleum exploration is rectilinear and has uniform density of overlapping (“fold”) data, usually in the yellow to red colour indicating 50 to 80 data points in each 10-m-square column of data. Because of the cultural barriers to seismic data acquistion related to an active mine site, this represents the best data that could be acquired under the circumstances. Not shown here is an interpretation of these data by Steve Gyorfi, as a late addition to his Ph.D. thesis, and presented as a poster at this Open House (Nov 29 - Dec 1, 2004). It is a remarkably successful component of the overall seismic sub-project, documenting a complex polygonal array of minor fault blocks as defined by the position of the basal unconformity. These results and their relationship to property scale exploration strategies will be discussed by Gyorfi in his thesis.

Magnetotellurics



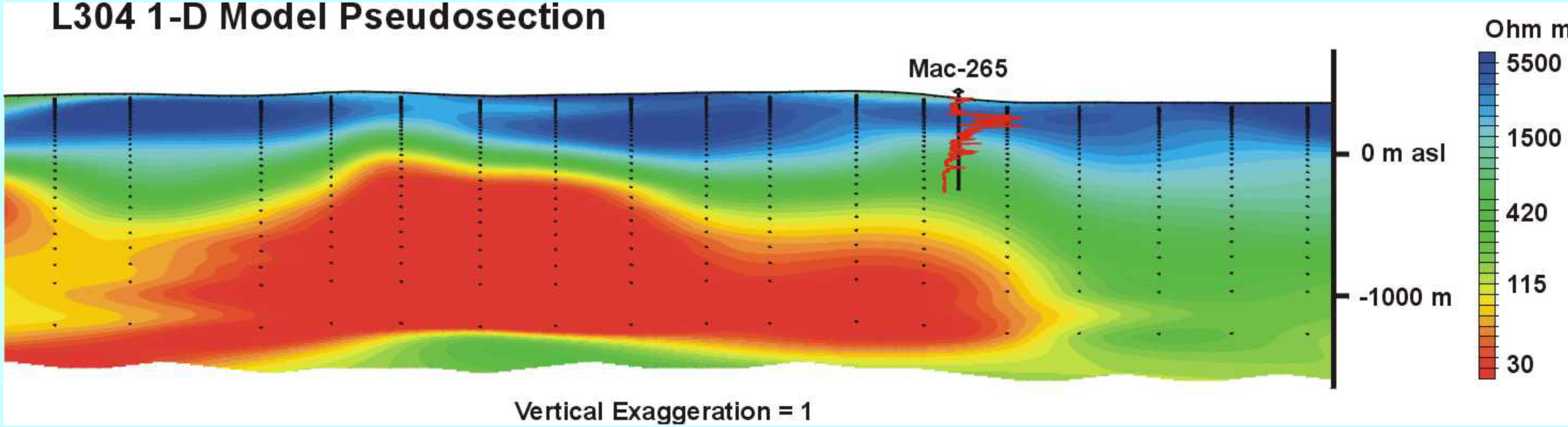
- **First line along Seismic short line A-A′**
- **Strata <500m more resistive to the west**
- **Conductive bright spots <350 m**
- **Conductive basement features dip SE, resistivities compatible with graphite**

Craven, McNeice

In the McArthur area there were two AMT surveys consisting of a preliminary 15 site survey in 2001 followed by a much larger survey in 2002 consisting of one hundred and thirty five AMT stations over the P2 and P2 North mineralized zones.

Initial slide: The inversion of the 15 site survey detects subsurface features to 500+ m depth related to basement graphitic and sulphidic conductors and post-Athabasca faults

Magnetotellurics



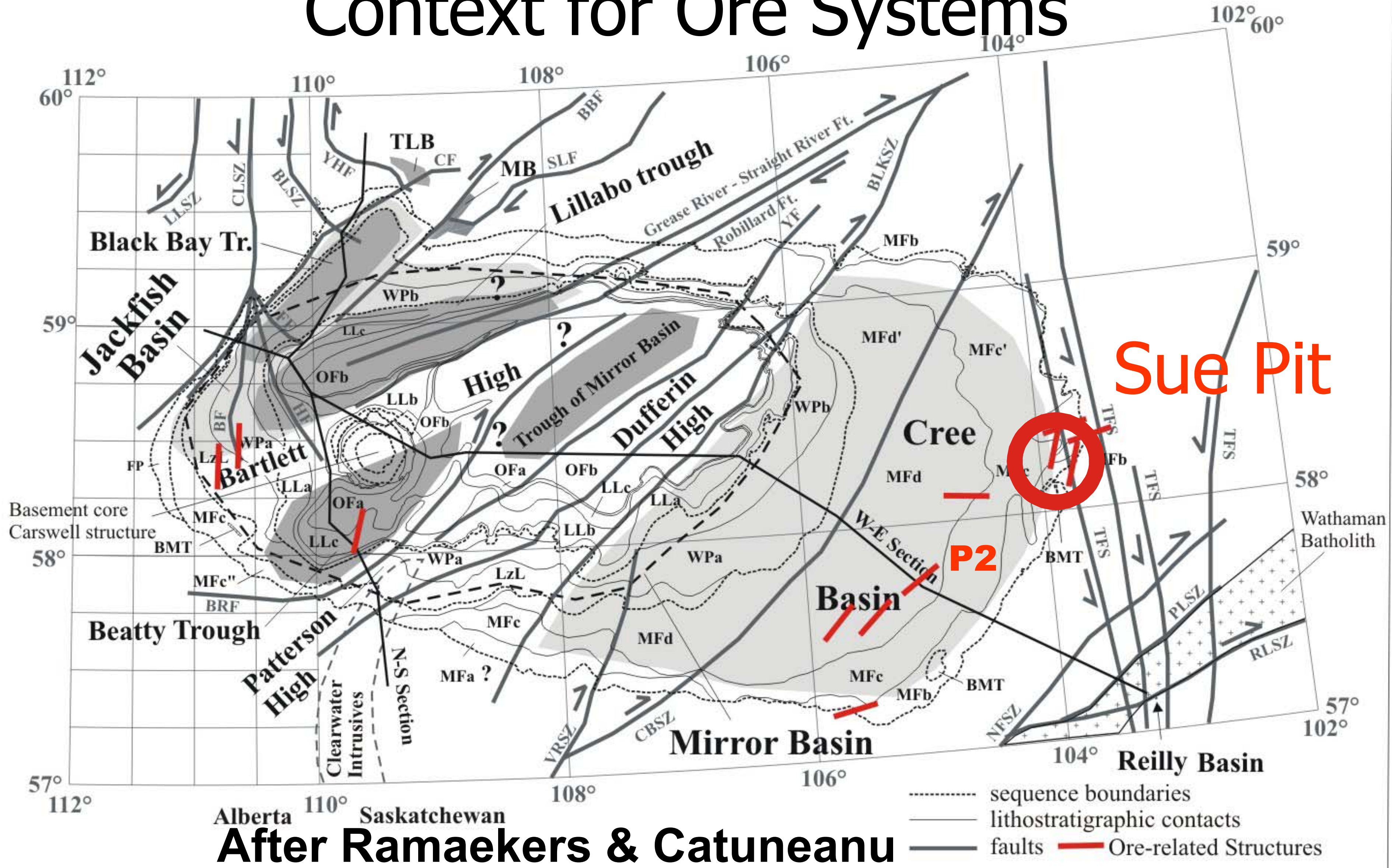
- **Line northeast of power line, transects airport**
- **Undulating surface between low and high resistivity corresponds to borehole geophysics conductivity spike, may relate to silicification front**

Craven, McNeice

Second image: Exploration attributes in the overlying Athabasca Group include fracture zones and argillic alteration (= de-silicification = increased conductivity) and silicification (= decreased conductivity). The low-conductivity=high-resistivity zone is calibrated with borehole geophysical data from Mwenifumbo et al. (MAC-265). All of these features are related in varying ways to the mineralization process at the basal unconformity.

Regional Structural Framework

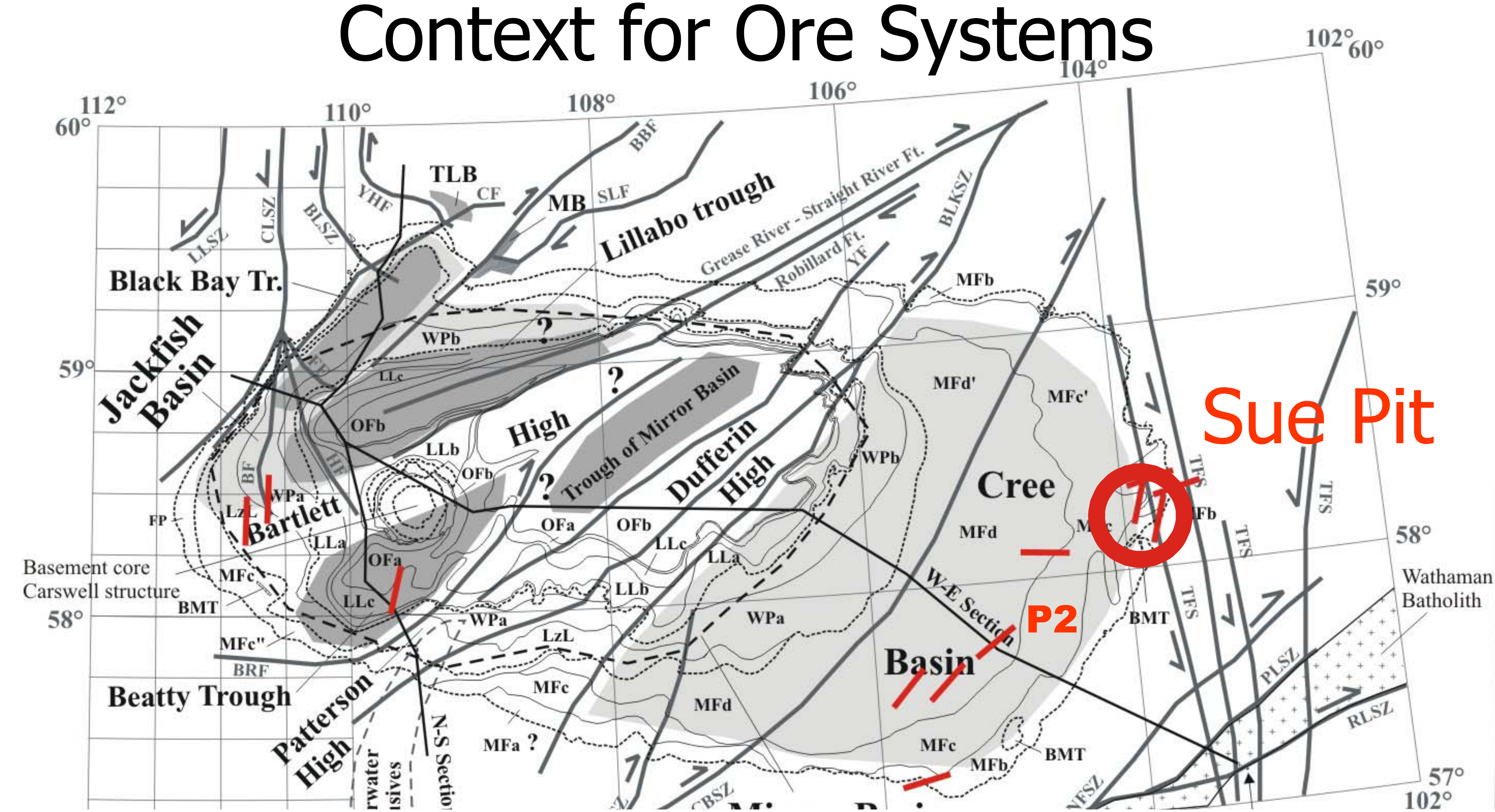
Context for Ore Systems



After Ramaekers & Catuneanu

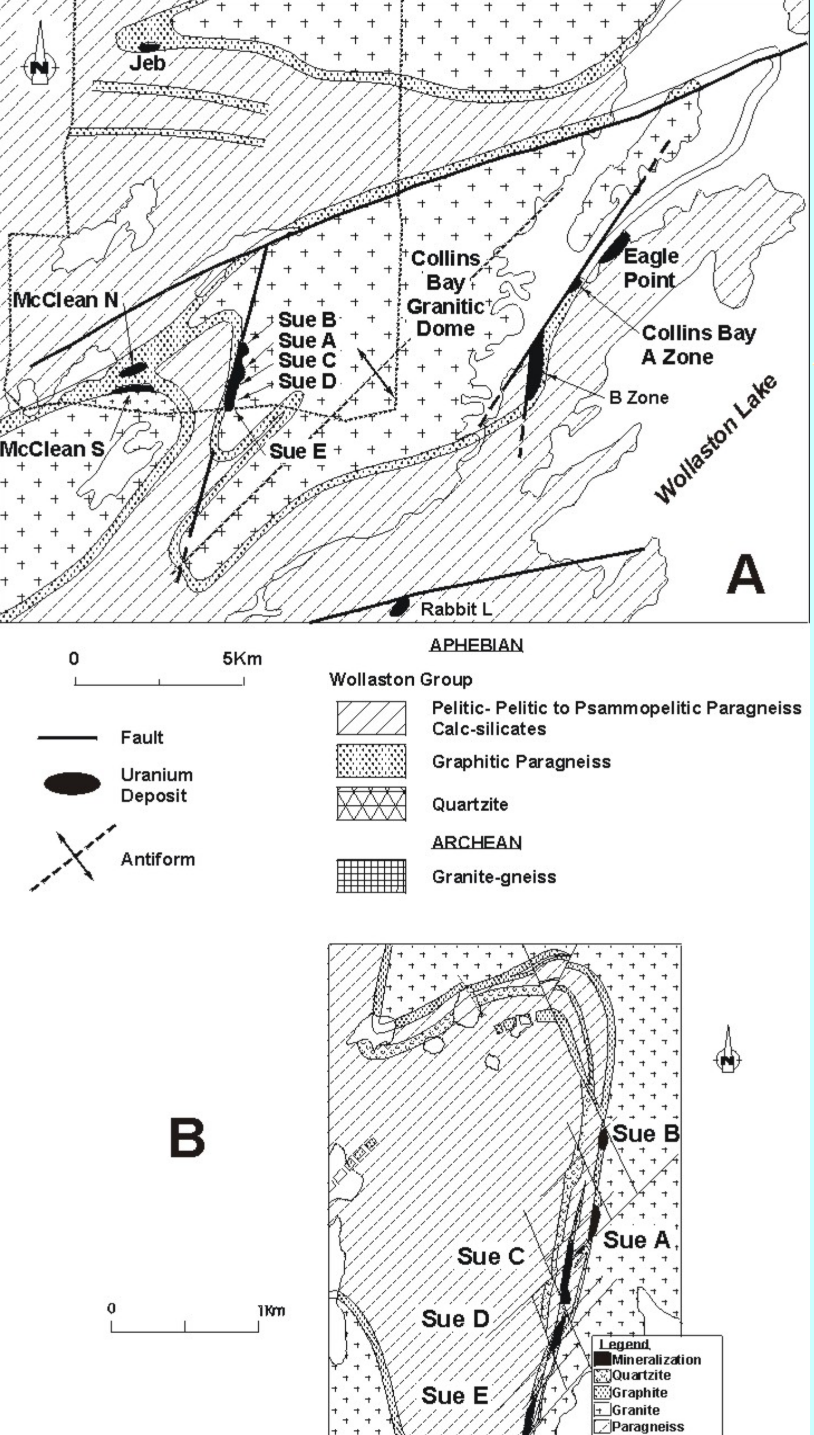
The previous slides have documented the existence, long-term development and some new technology to detect and define growth faults. Here we explore the linkages between these faults, basin development and hydrothermal systems that deposited world class unconformity-associated uranium deposits. In this slide we see regional fault systems that have long been known as ductile shear zones during pre-Athabasca Group time, and were re-activated as brittle structures immediately before, during and after deposition of the Athabasca Group. Isopach data are interpreted to show that these faults were active at different times and many served as hinge lines bounding successive depositional basins.

Context for Ore Systems



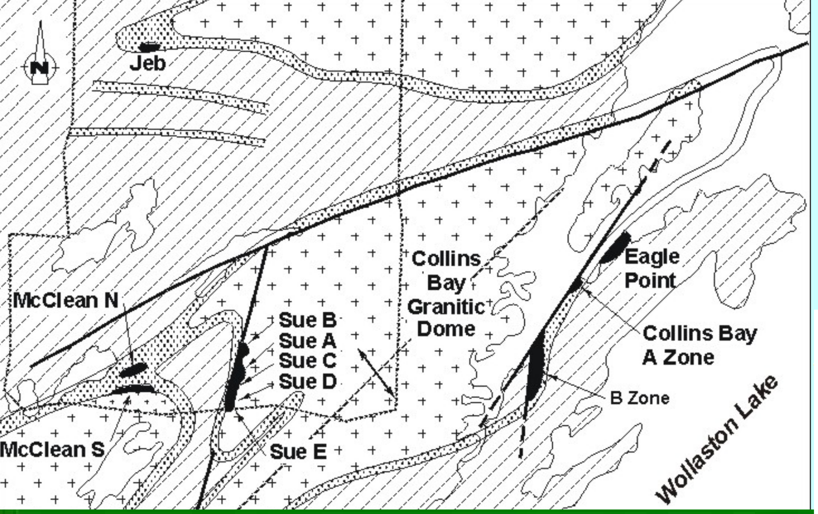
Specific relationships are detailed in Ramaekers et al. 2005 (in prep.). Subsidiary faults from these large structures and structures of many other orientations influenced local depositional patterns and later provided conduits and foci for fluid flow. Only a few of these faults are shown here in red. The red cirdle shows the location of detailed mapping by Ghislain Tourigny during mining of the Sue C open pit, where he documented explicit relationships between such faults and ore deposition.

Growth Faults & Ore – Sue Pit

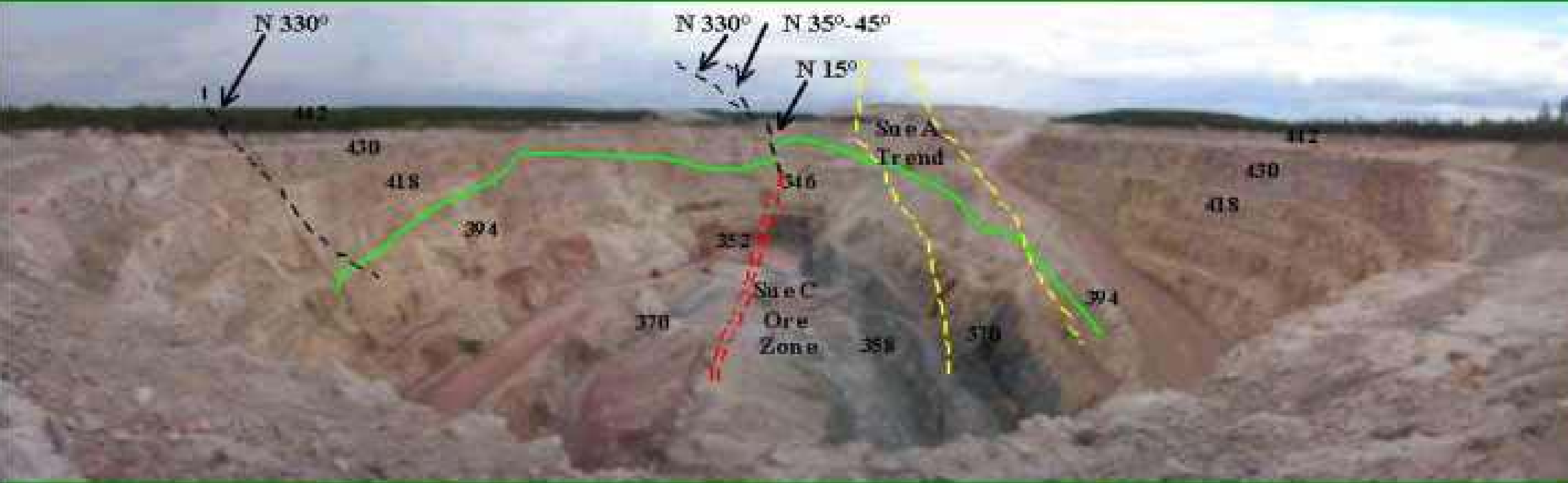


This series of slides briefly summarizes detailed mapping and interpretations of basement structures and their relationship to ore deposits by Tourigny et al. (2002, 2005). The regional geology of the basement rocks with the Athabasca Group figuratively stripped off is that of Archean granitoid gneiss domes surrounded by Wollaston Group metasedimentary gneiss. As you will recall from the basement structural cross section shown previously, these are are interference structures formed by re-folded thrusts involving interleaved basement-cover thrusts. The thrusts are broken folds such that basal Wollaston Group graphitic metapelites wrap around the Archean basement domes. Faults associated with these structures trend east-northeasterly. North-northeasterly and are intersected by northerly trending faults of the Tabbernor fault array. Ore deposits and prospects in this region are located along such mesoscopic fault zones where they intersect and occupy the graphitic metapelite units.

Growth Faults & Ore – Sue Pit



The next portion of this slide shows the Sue C Open Pit as of the summer of 2000. The ore zone, associated fault and shear zone, the offset of the sub-Athabasca Group unconformity are outlined



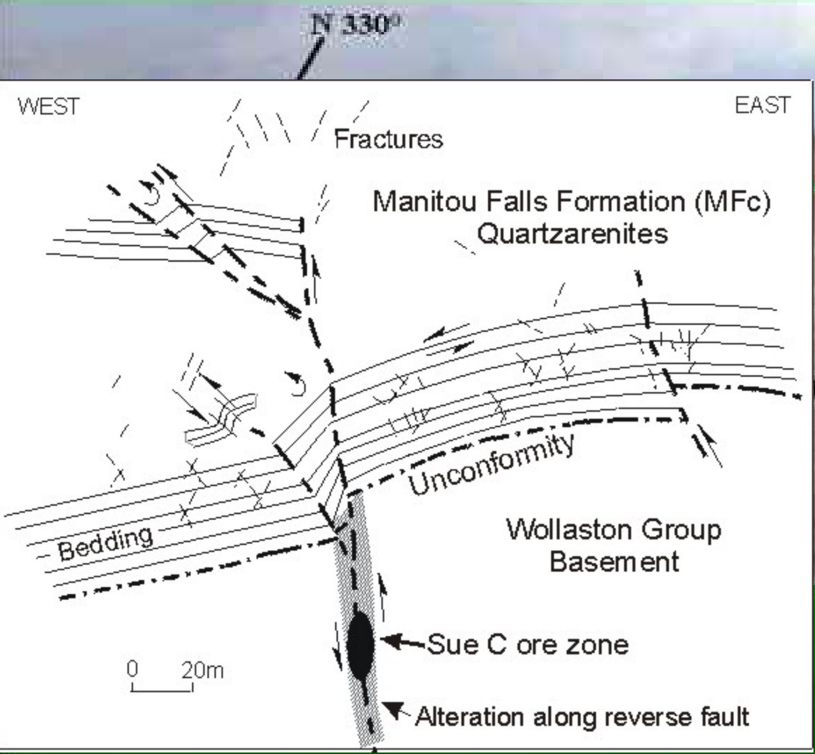
SUE C PIT - FACING NORTH

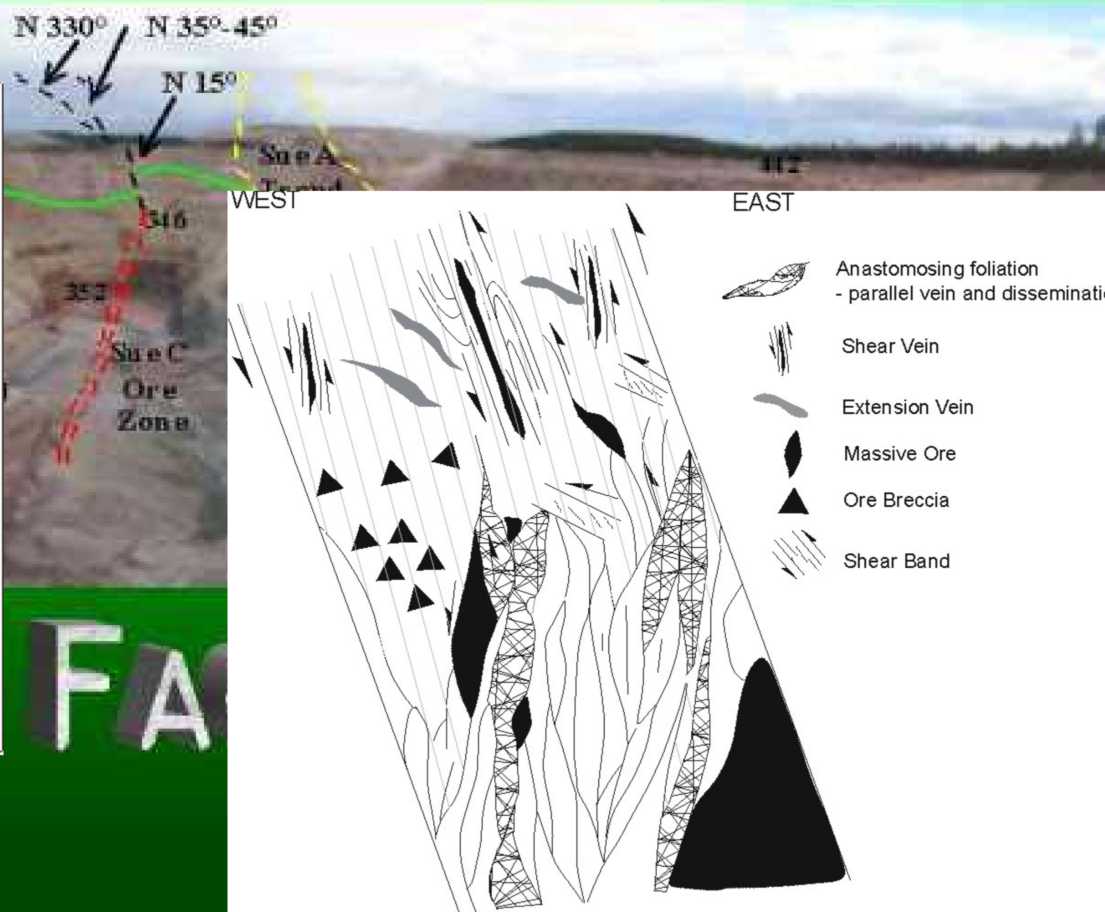
Ghislain Tourigny, Steve Wilson, Guy Breton, Philippe Portella

AUGUST 20, 200

The cartoon on lower left illustrates the degree of offset of the unconformity, and how the reactivated basement fault zone splays out into the overlying Manitou Falls Formation, terminating in kink folds and intrastratal shear zones. In detail (lower right), the ore zones are seen to be complex structures with massive uraninite ore lenticles occupying dilatant zones in sheared, crushed and milled graphitic metapelite. The ore lenticles are also sheared and reworked, documenting multiple ore-forming deformation events. The rake of individual ore lenses plunges southeasterly, similar to the rake and plunch of the overall Sue C ore zone.

Growth Faults & Ore – Sue Pit

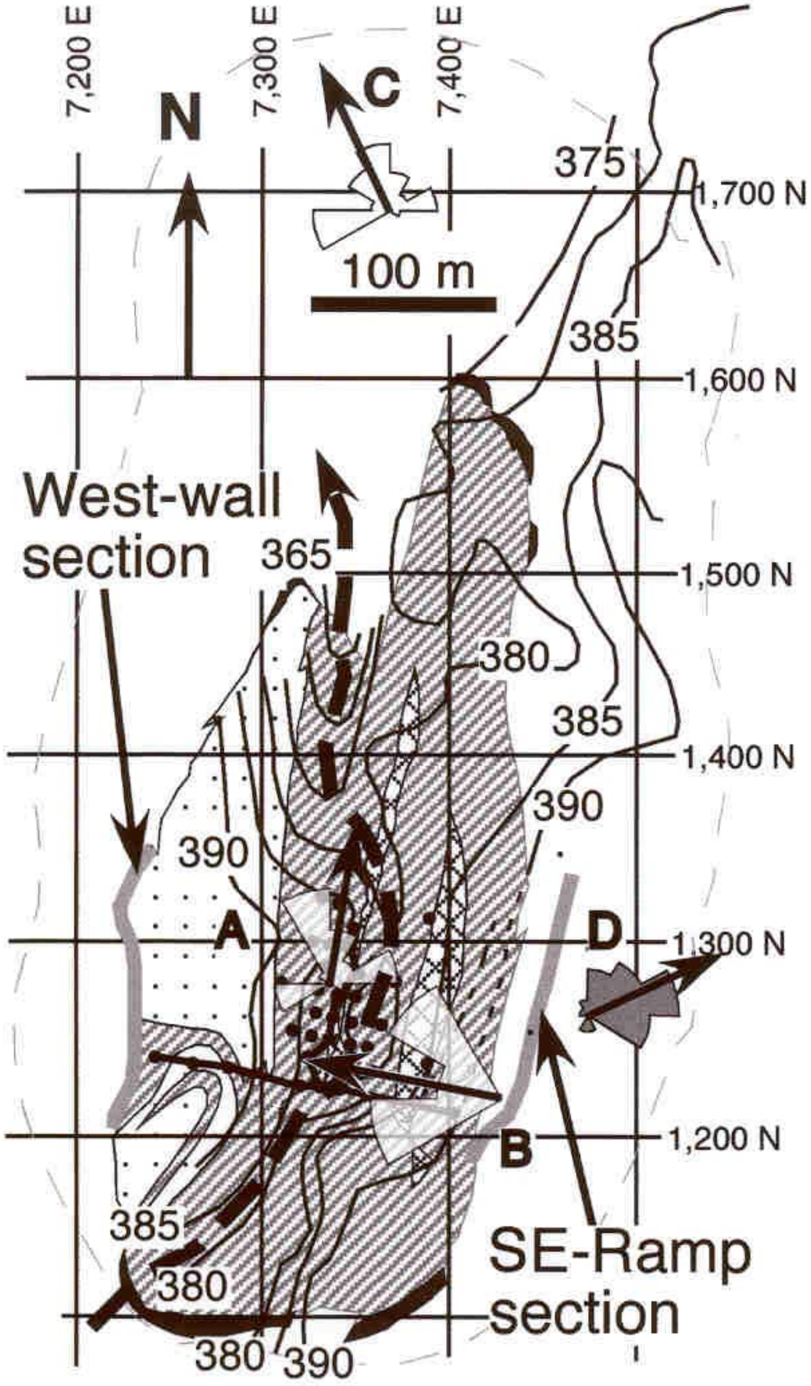




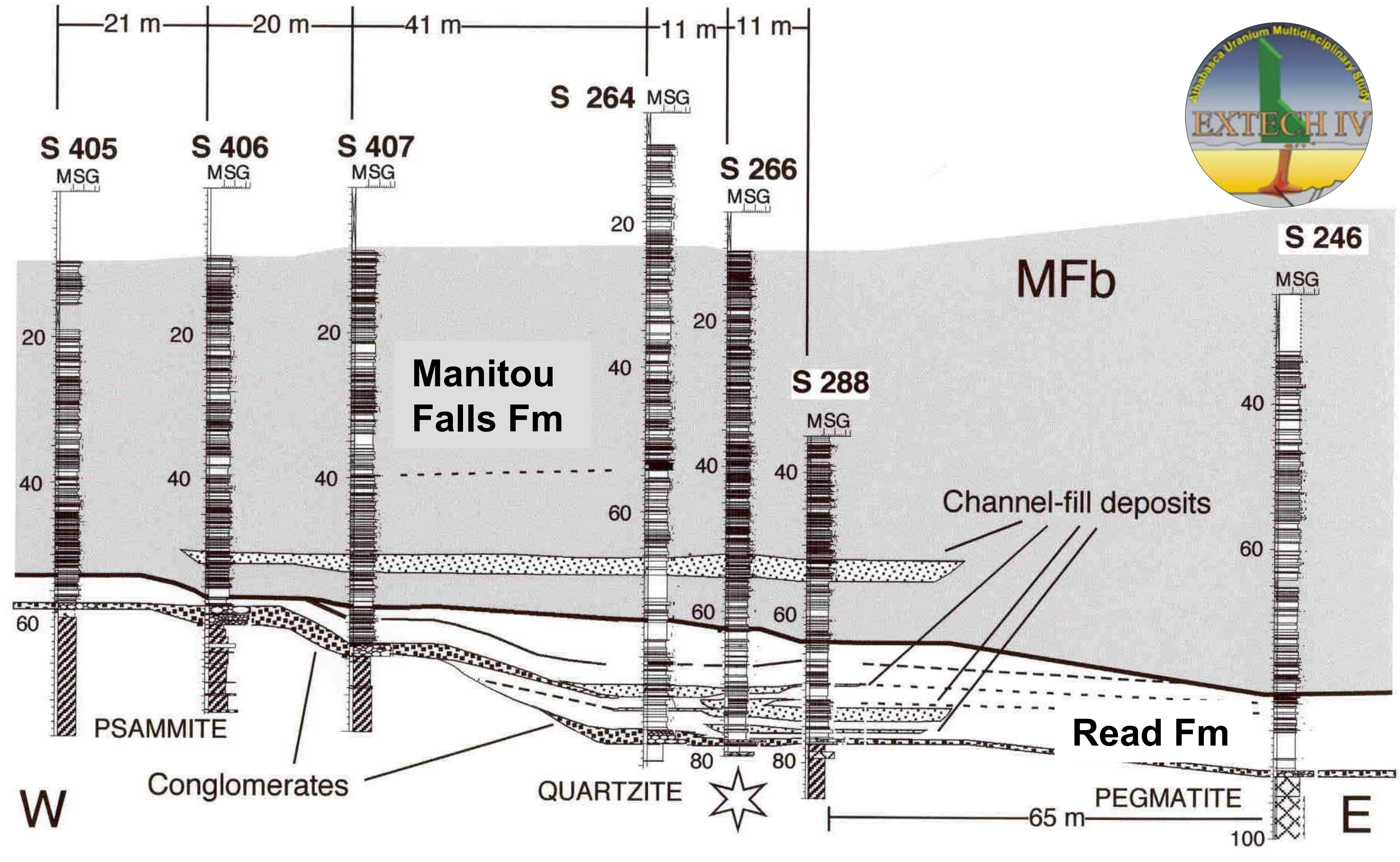
Ghislain Tourigny, Steve Wilson, Guy Breton, Philippe Portella

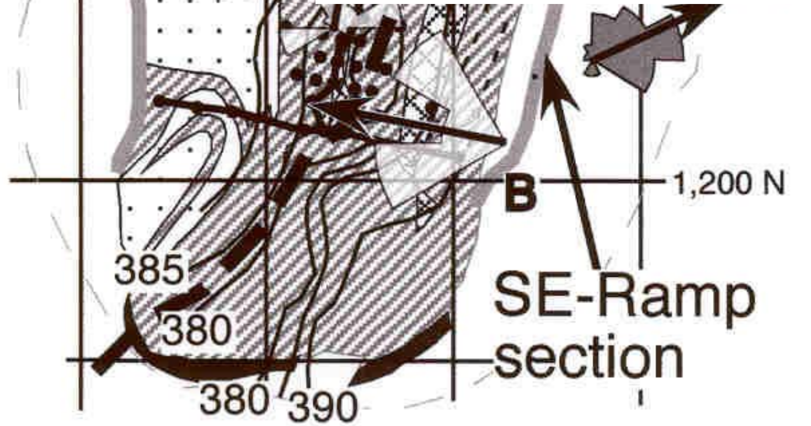
Detailed Fluvial Architecture and paleovalleys

Long, Bernier, Collier, Wallis



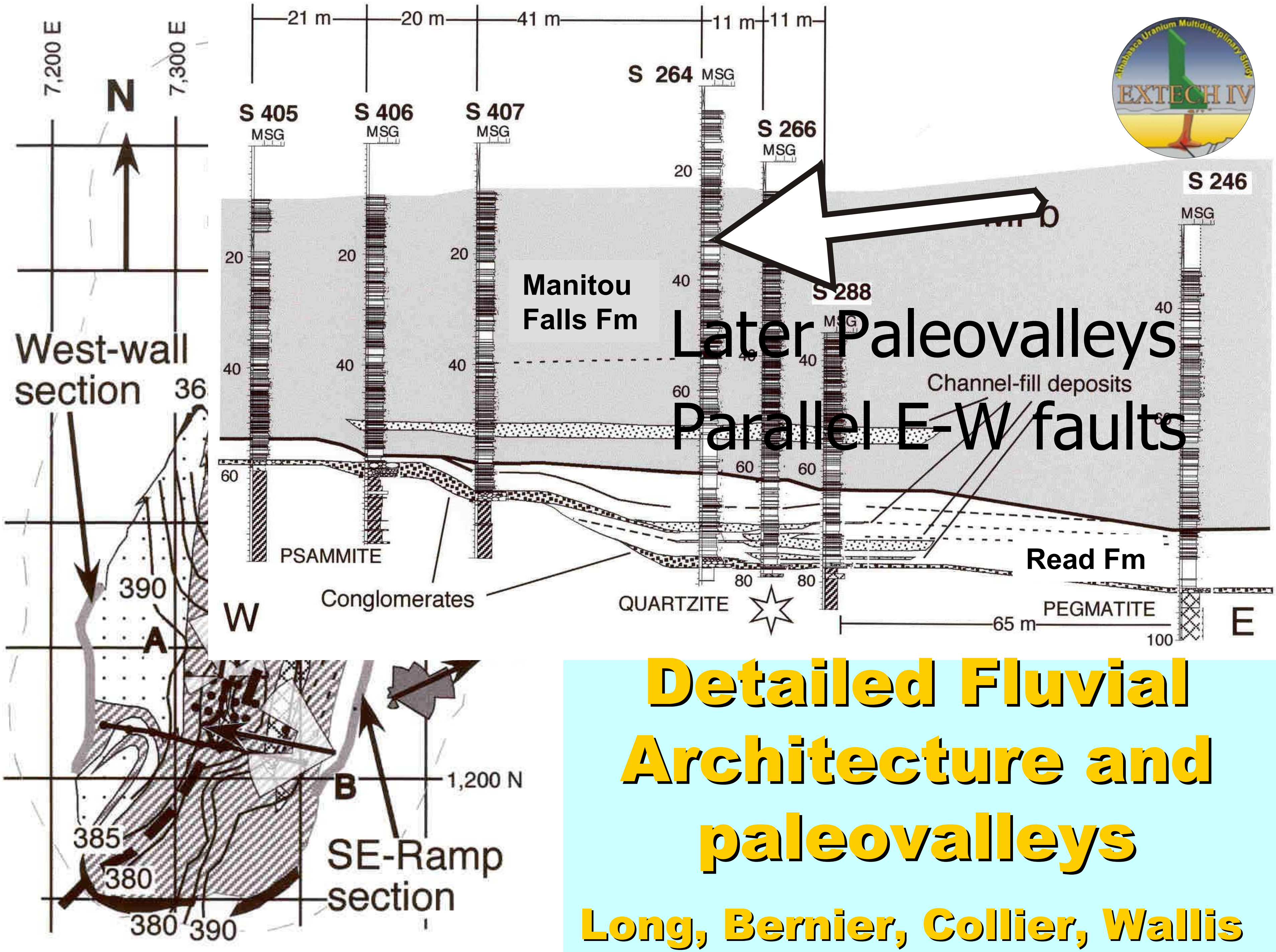
The paleovalley concept not new, but little has been published, and now we better understand that paleovalleys were there before and during deposition of the Athabasca Group. Darrel Long's detailed mapping of sedimentary facies architecture at the same time as Tourigny was mapping basement structure helped to show the relationships between the two. A small north-south paleovalley clearly existed and was filled by onlapping fluvial siliciclastic strata during initial sedimentation. Small escarpments (5-30 m high) were draped by small talus cones of angular proximally derived basement clasts. Later on, basement topography developed along northeast-southwest trending fault zones, such as the Rabbit Lake Fault (Wallis et al. 1985). These faults were active during sedimentation, but their growth would have been hardly visible at surface because paleocurrent patterns suggest that rivers flowed right across them and deposited Manitou Falls Formation without deviation of paleocurrents – ie. any paleotopography was rapidly filled by sediment and the fluvial braid plain remained at grade across the region. Thus these growth faults were probably very similar to those documented by EXTECH IV at McArthur River and Wheeler River.





Detailed Fluvial Architecture and paleovalleys

Long, Bernier, Collier, Wallis



Later Paleovalleys

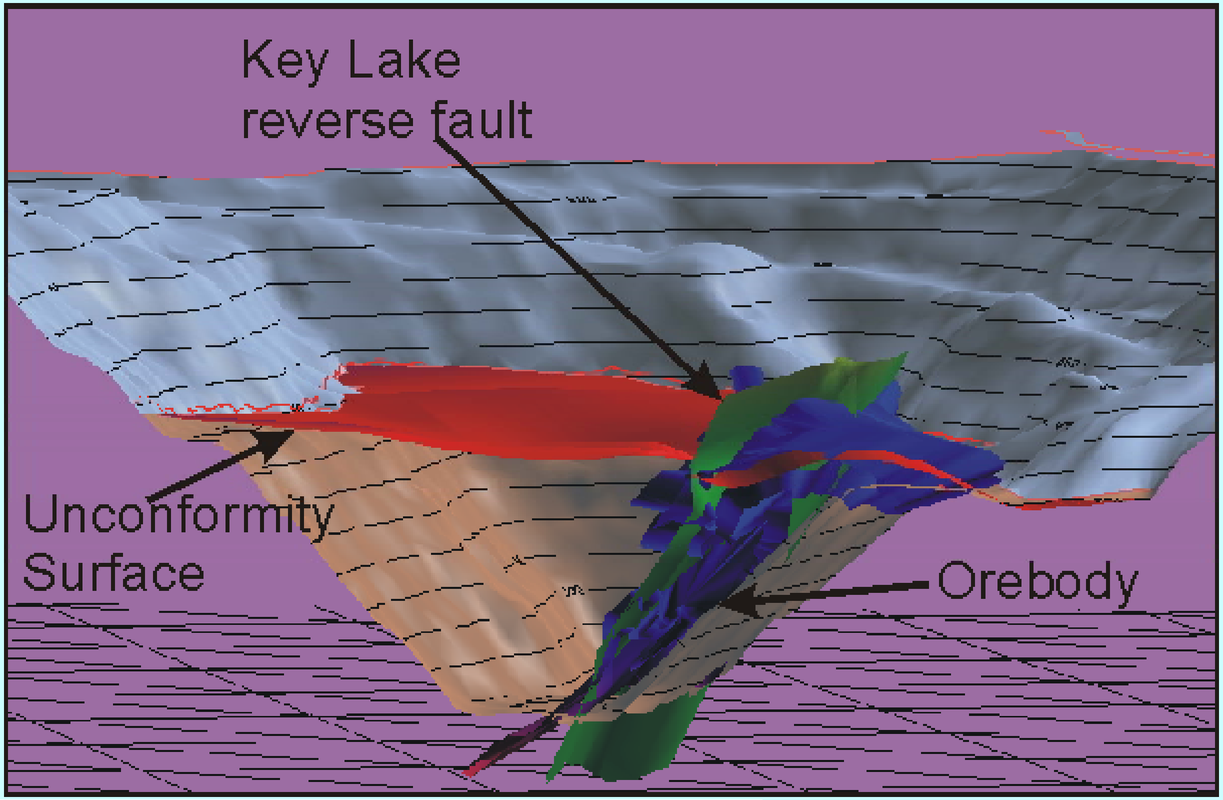
Parallel E-W faults

Detailed Fluvial Architecture and paleovalleys

Long, Bernier, Collier, Wallis

Property Scale Basement – Key Lake

- E-W trending brittle-ductile faults
  - reactivated
  - Ore at unconformity and to depth

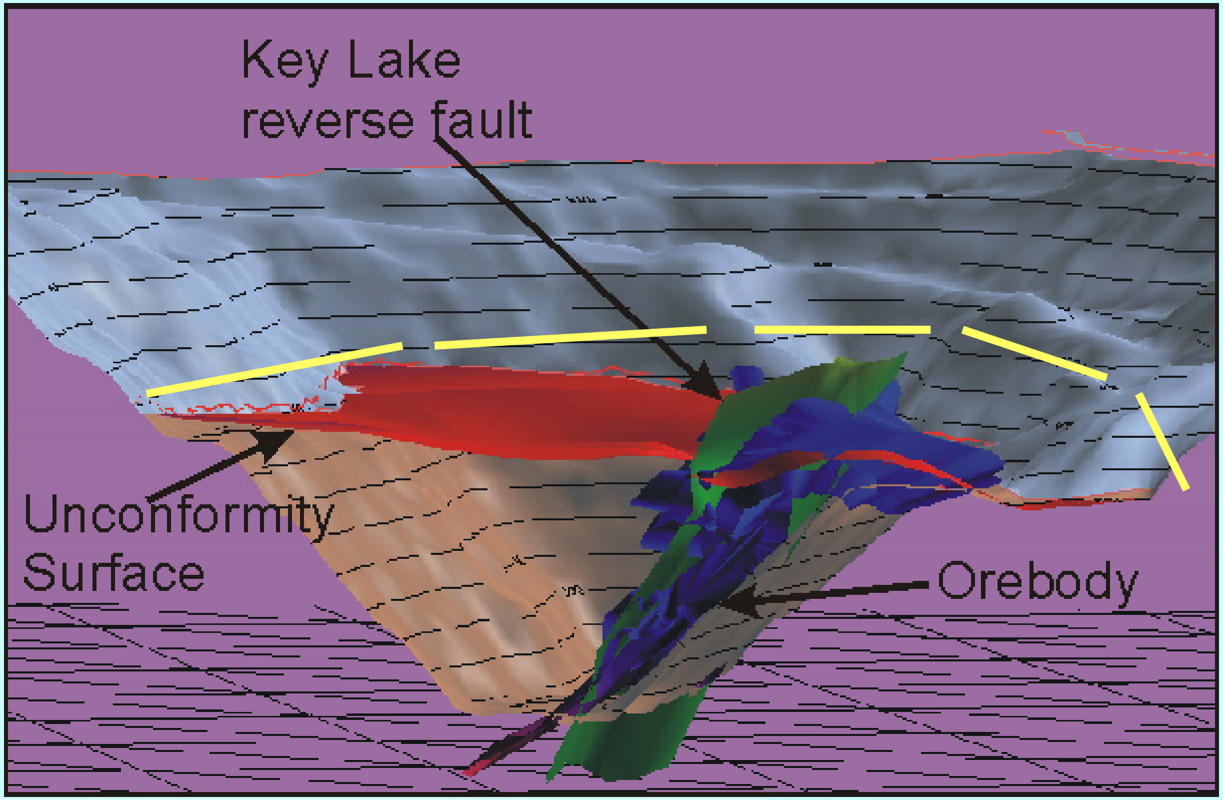


Shawn Harvey compiled isopachs at Key Lake that, combined with his basement structural mapping, indicate similar interplays between reactivated basement faults, paleotopography, and ore deposition in reactivated structures. Again, much of this was known but very little documented before EXTECH IV, and Harvey's work together with sedimentological studies by Collier, Yeo and Long, provide a coherent integrated linkage between growth faults, basin development and later mineralization.

Harvey

Property Scale Basement – Key Lake

- E-W trending brittle-ductile faults
  - reactivated
  - Ore at unconformity and to depth
- Paleo-valley from isopachs



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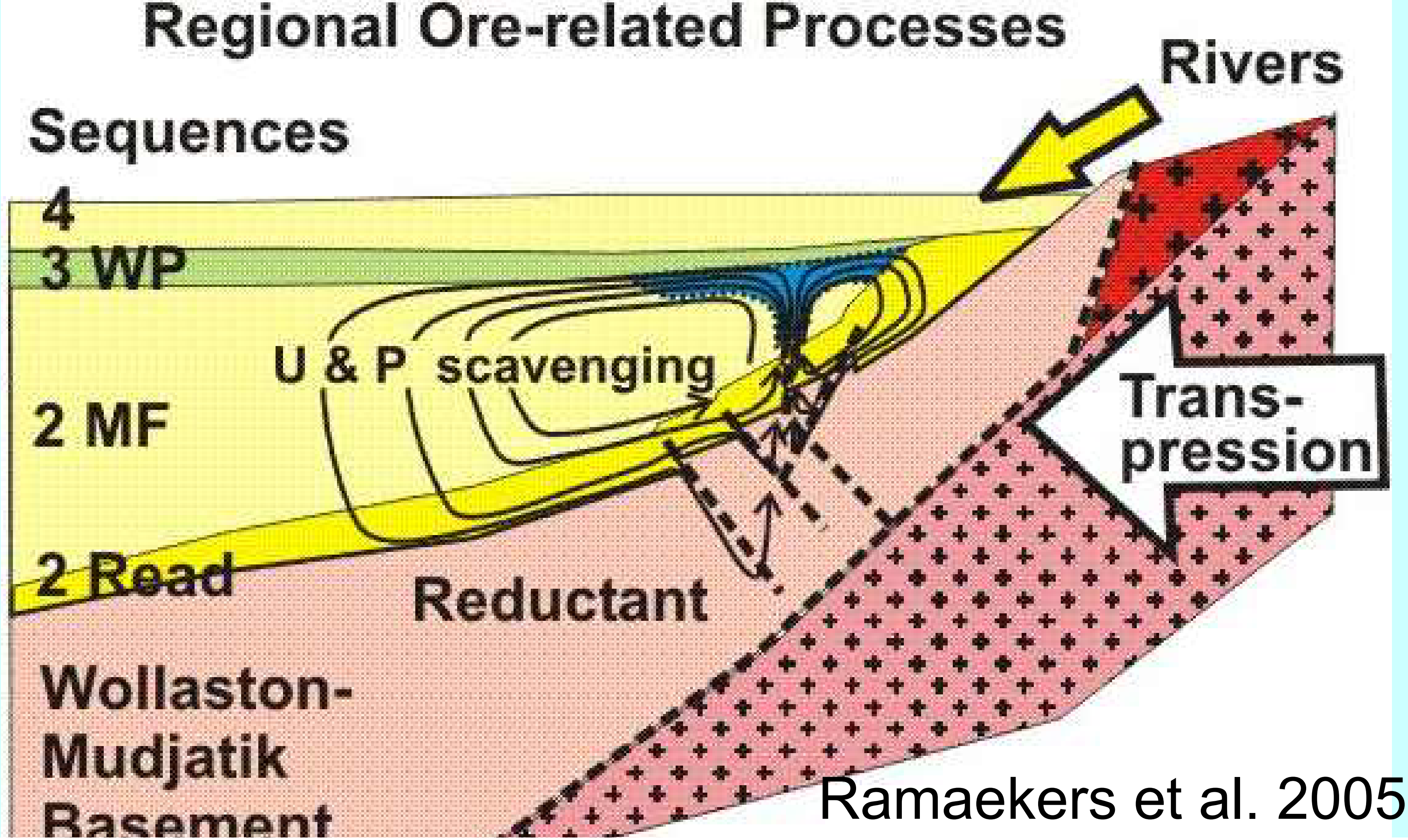
Harvey

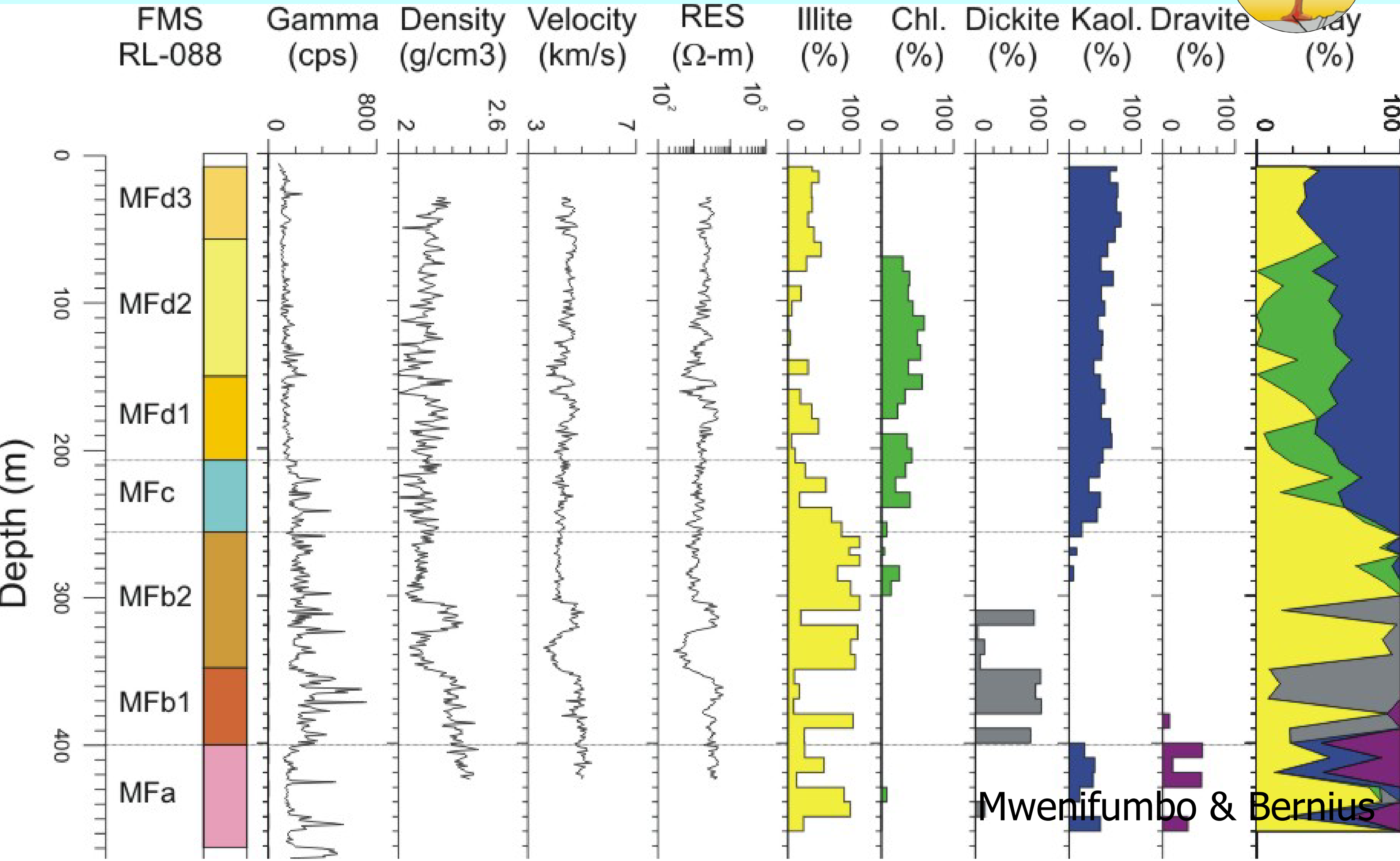
Sources and transport of U



Ramaekers et al. 2005

Ramaekers et al. 2005 pull the fault-basin development-ore deposition framework together on a regional scale. Note this is vertically exaggerated, with dominant flow lines being parallel to bedding, and short vertical hydrothermal transit along fault zones (squashed section below is getting close to true scale). Ore deposits formed at both ingress and egress sites, with the bulk of geochemical scavenging of uranium being along the longest flow lines – within the basin fill.

Crandallite Story (Monazite?)



Mwenifumbo & Bernius

Mwenifumbo et al. identified crandallite as the source of thorium anomalies in Manitou Falls Formation, likely resulting from alteration of monazite during peak diagenesis, releasing uranium quantitatively.

Crandallite Story (Monazite?)

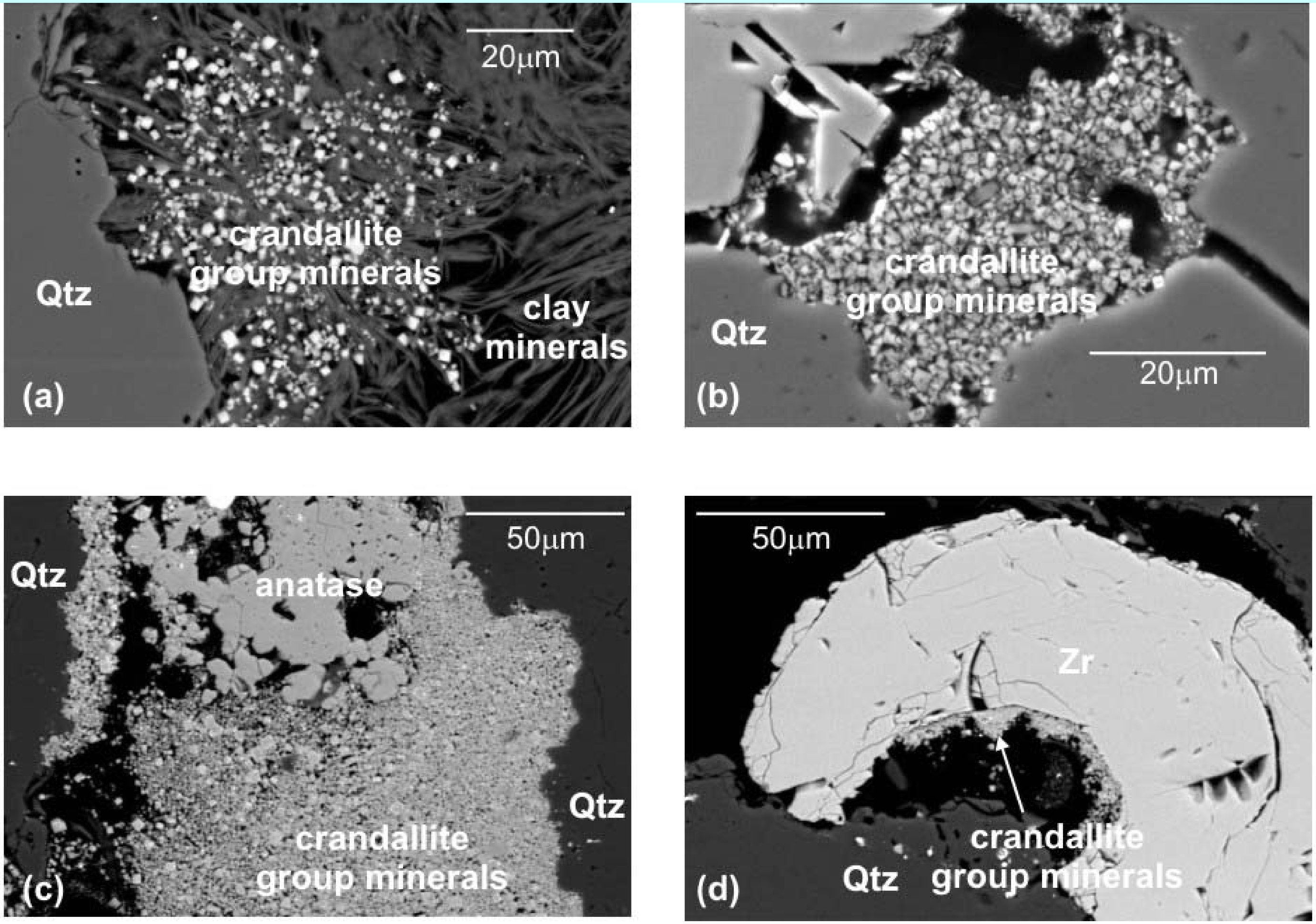
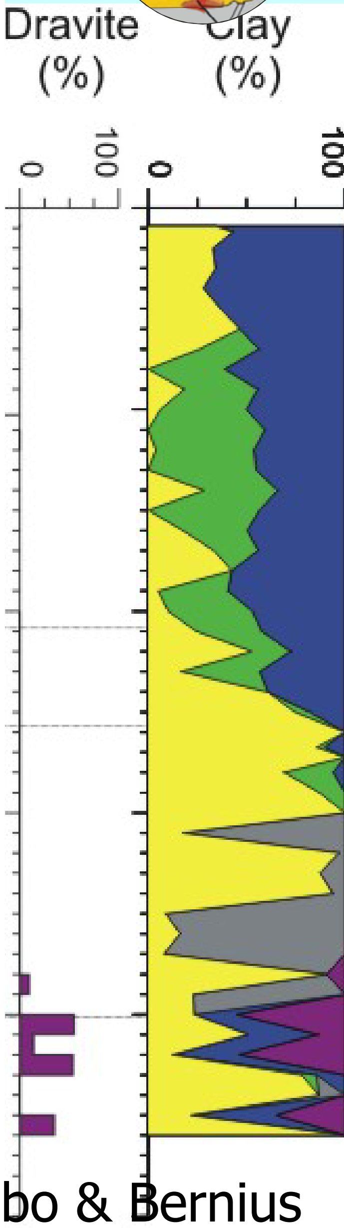


Figure 5: SEM photomicrographs of crandallite group minerals occurring in various habits. (a) Loose clusters of crandallite group minerals in close association with clay minerals, (b) and (c) dense tight clusters of crandallite group minerals associated with a secondary TiO2-mineral (anatase). (d) crandallite group minerals lining solution cavity around zircon (Zr) crystal.



Mwenifumbo & Bernius

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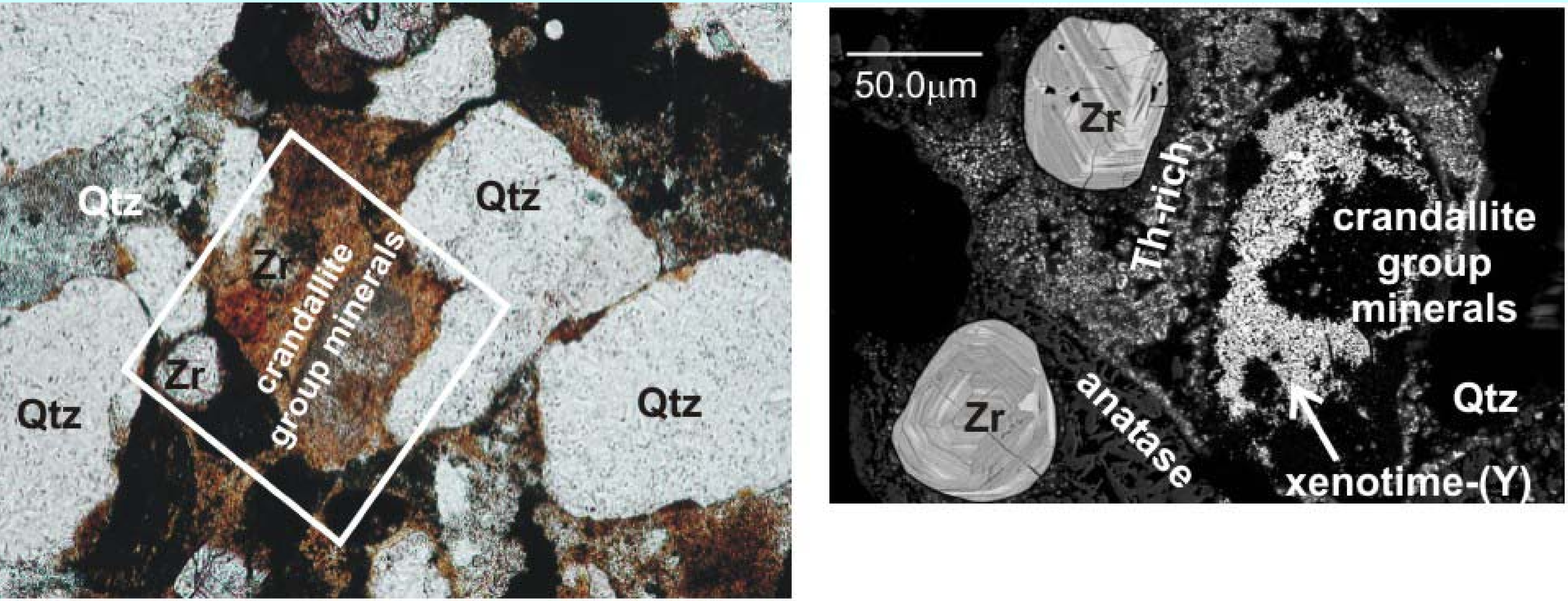


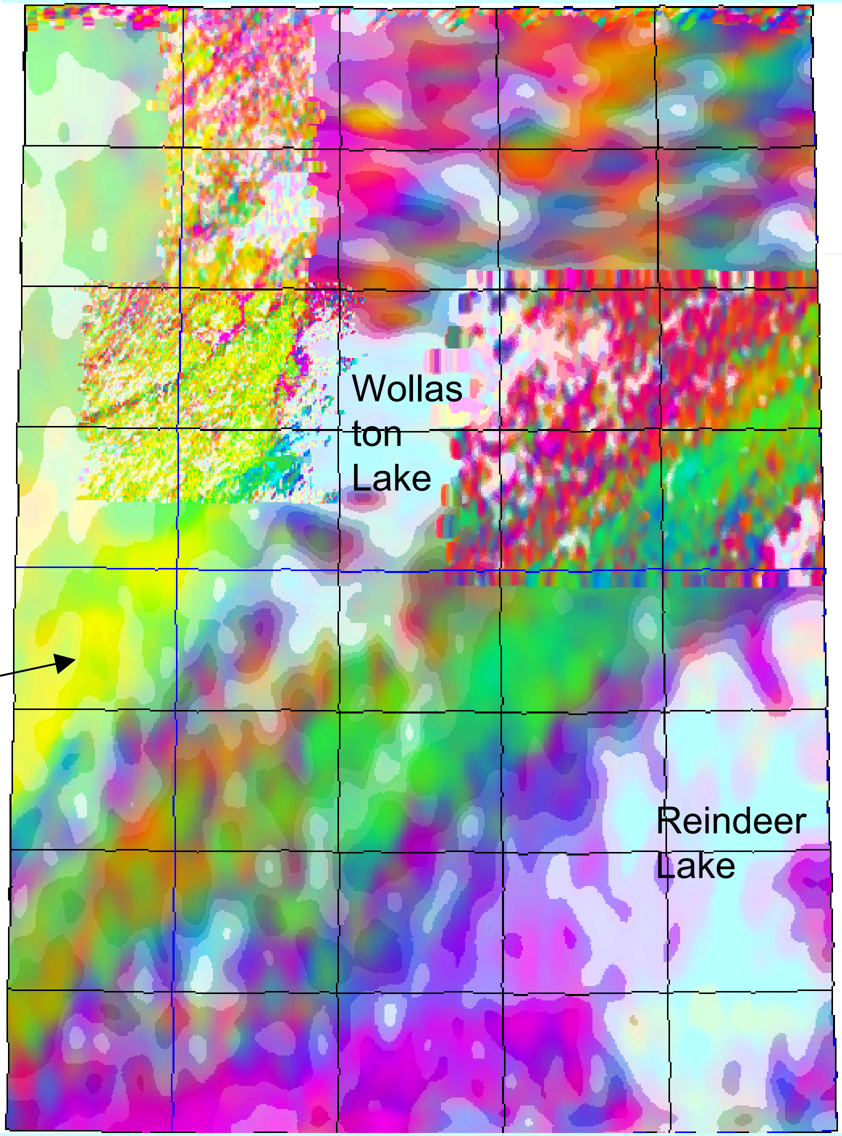
Figure 7. (a) Photomicrograph of a polished thin section of conglomerate showing crandallite and xenotime-(Y). Relic mineral is replaced by crandallite group minerals and xenotime-(Y). (b) SEM image showing zoned zircons, crandallite, xenotime-(Y) and anatase (rutile). Zircons show as white subrounded grains

Mwenifumbo & Bernius

Gamma Ray insights - Uranium Sources

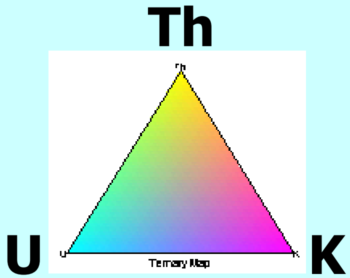
This gamma ray map shows the thorium anomaly in Manitou Falls Formation on the left (west), with basement rocks on the right (east) showing greater abundance of uranium and potassium. The basement rocks quantitatively represent the source of sediment for the Athabasca Basin, indicating that in qualitative terms, an enormous amount of uranium has been removed from the Manitou Falls Formation. It is suggested that this uranium found its way to the world class deposits at the base of this basin.

maps Bird (MFb) & Collins (MFc) members of Manitou Falls Fm.



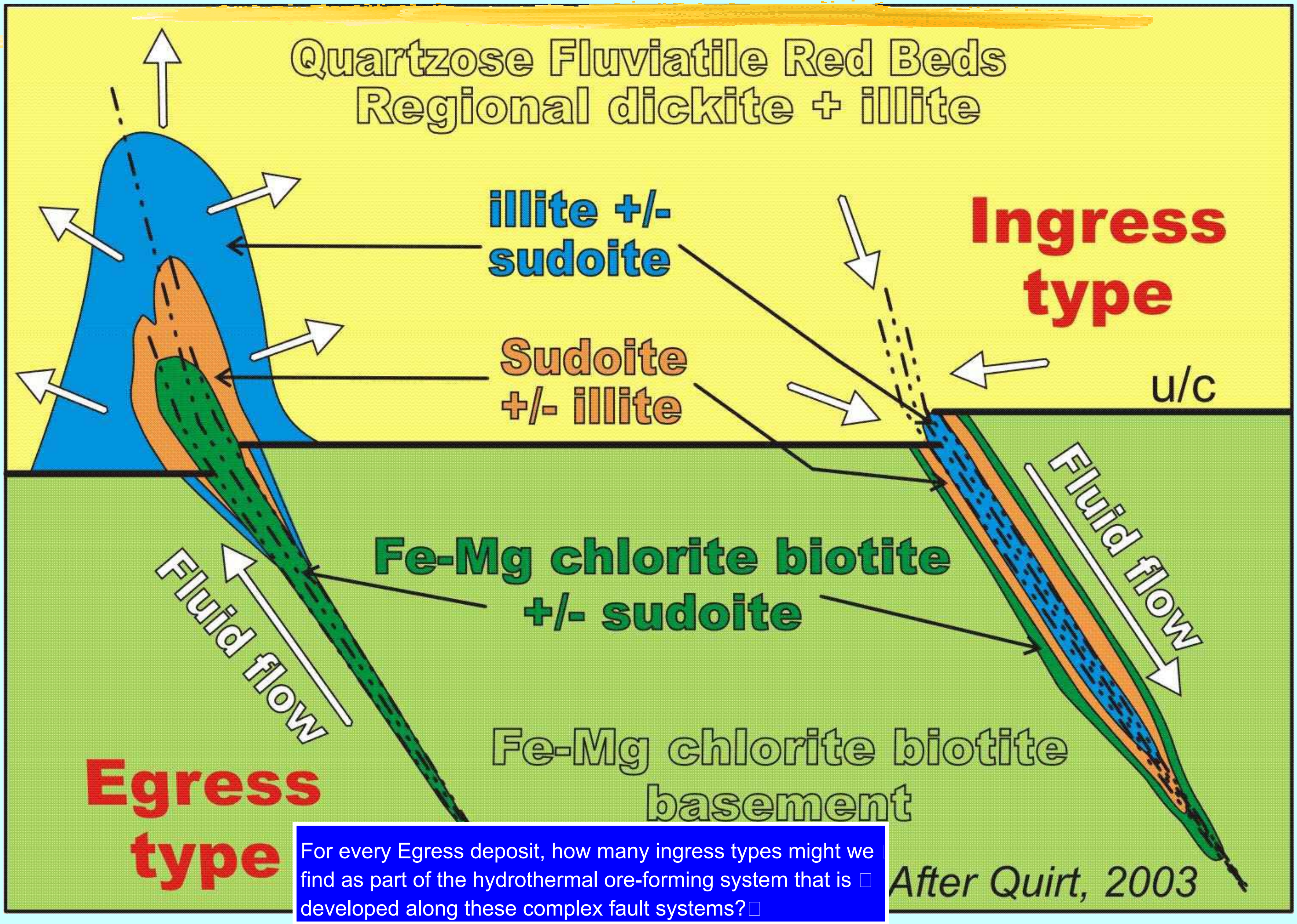
Source Basement Domains

elevated Uranium & potassium represent primary sediment composition



Ford, Carson et al.

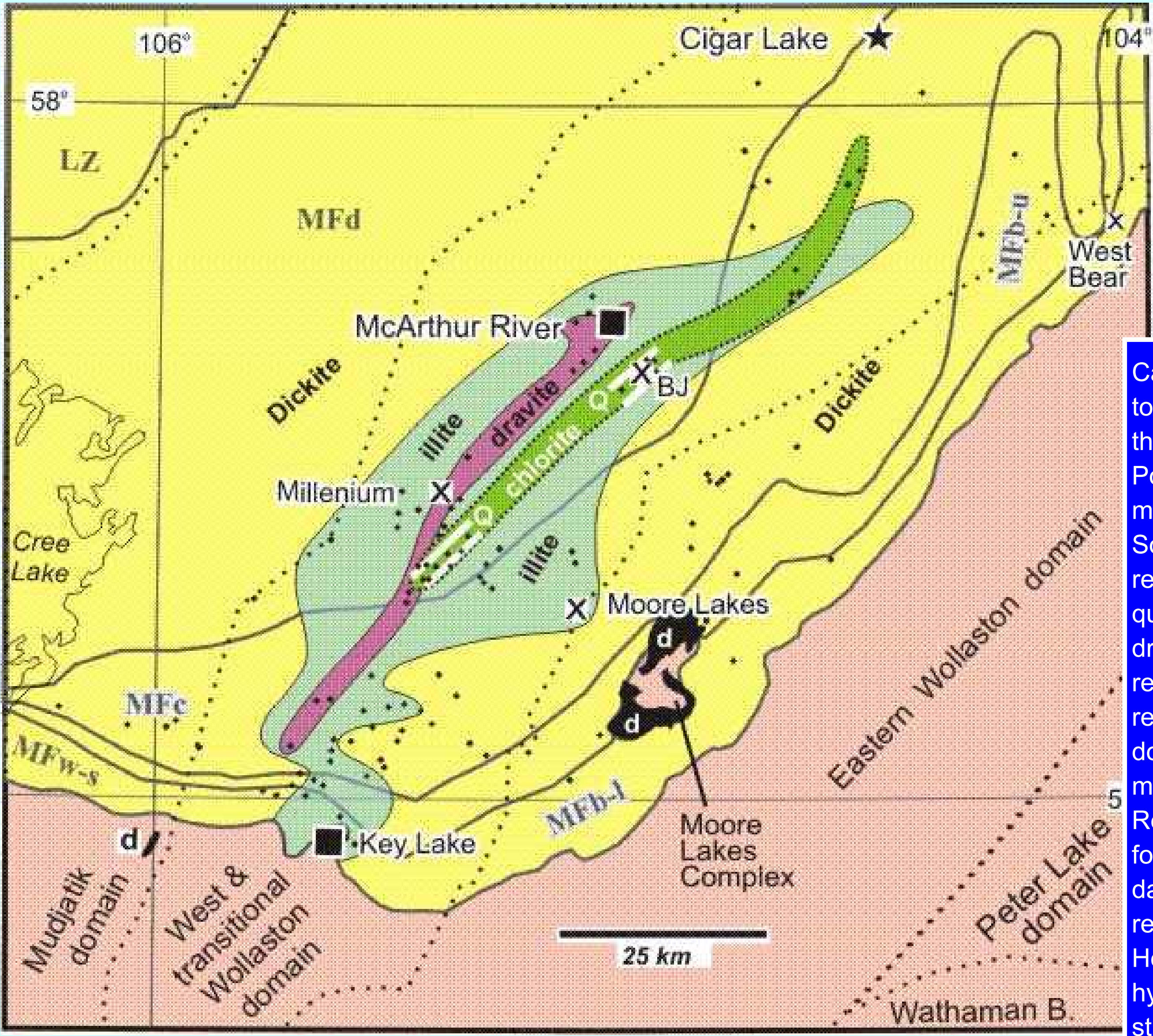
Deposition of U and Alteration



After Quirt, 2003

For every Egress deposit, how many ingress types might we find as part of the hydrothermal ore-forming system that is developed along these complex fault systems?

Ingress – Egress Ore Systems

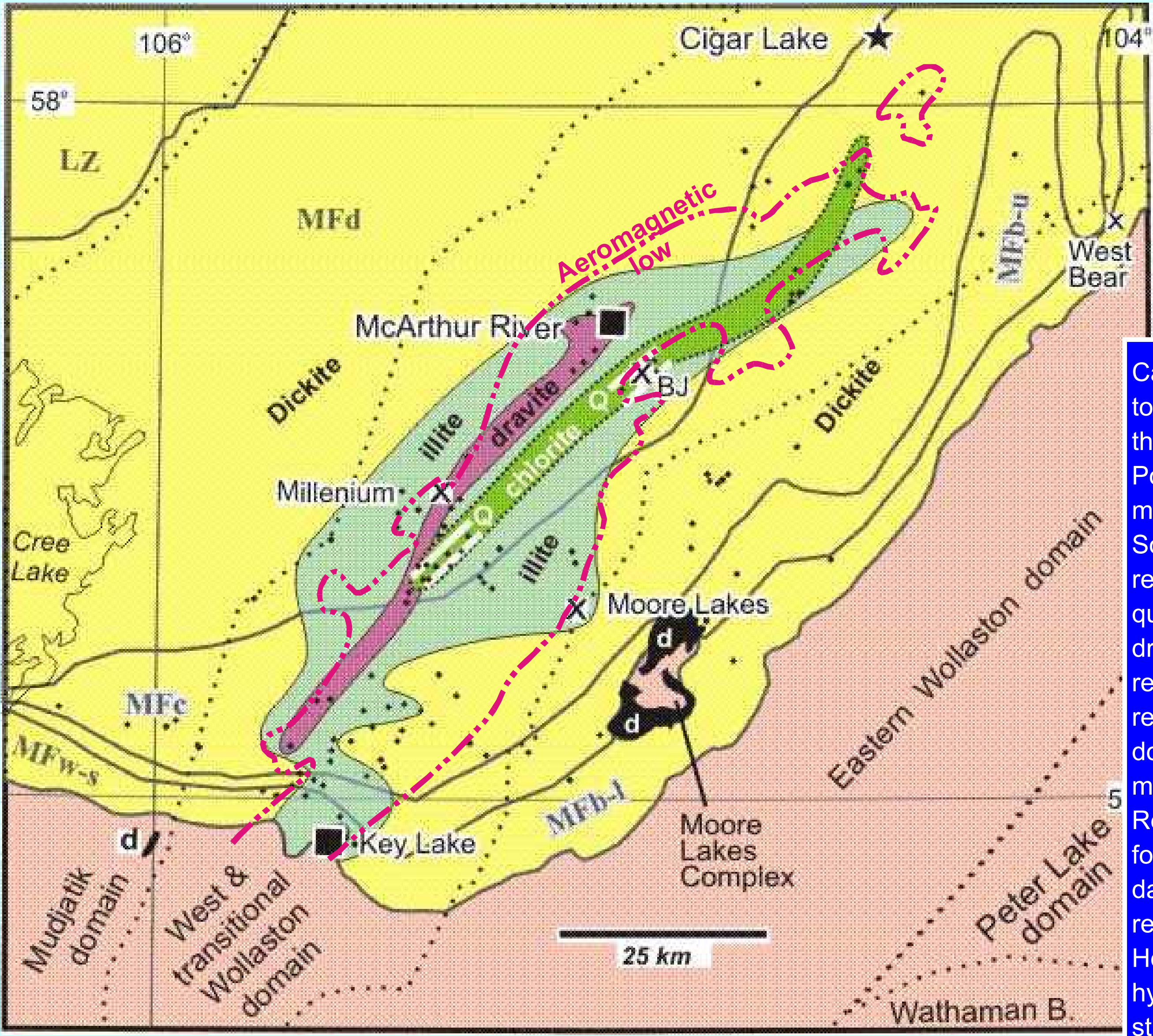


For every Outie how many Innies, where and How far out-side the basin?

After Earle & Sopuck

Can we apply some of what we learned above to previously published data? Can we integrate the complex fault assemblage compiled by Portella and Annesley with geochemical and mineralogical mapping presented by Earle and Sopuck? Is chlorite alteration specifically related to tectonic pop-ups of basement quartzite (well known "quartzite ridges")? Is dravite more characteristic of the P2 and related structures? The faults shown here are represented on more and more detailed scales down to small polygonal mosaics only 100's of metres on a side (Gyorfi, 3-D seismic poster). Resolving such relationships at a scale suitable for drilling will require enormous amounts of data, possibly only available through 3-D high resolution seismic, or many many drill holes. How much do we understand about the hydrothermal flow systems that followed such structures? For every egress deposit, how many ingress deposits might there be nearby?

Ingress – Egress Ore Systems



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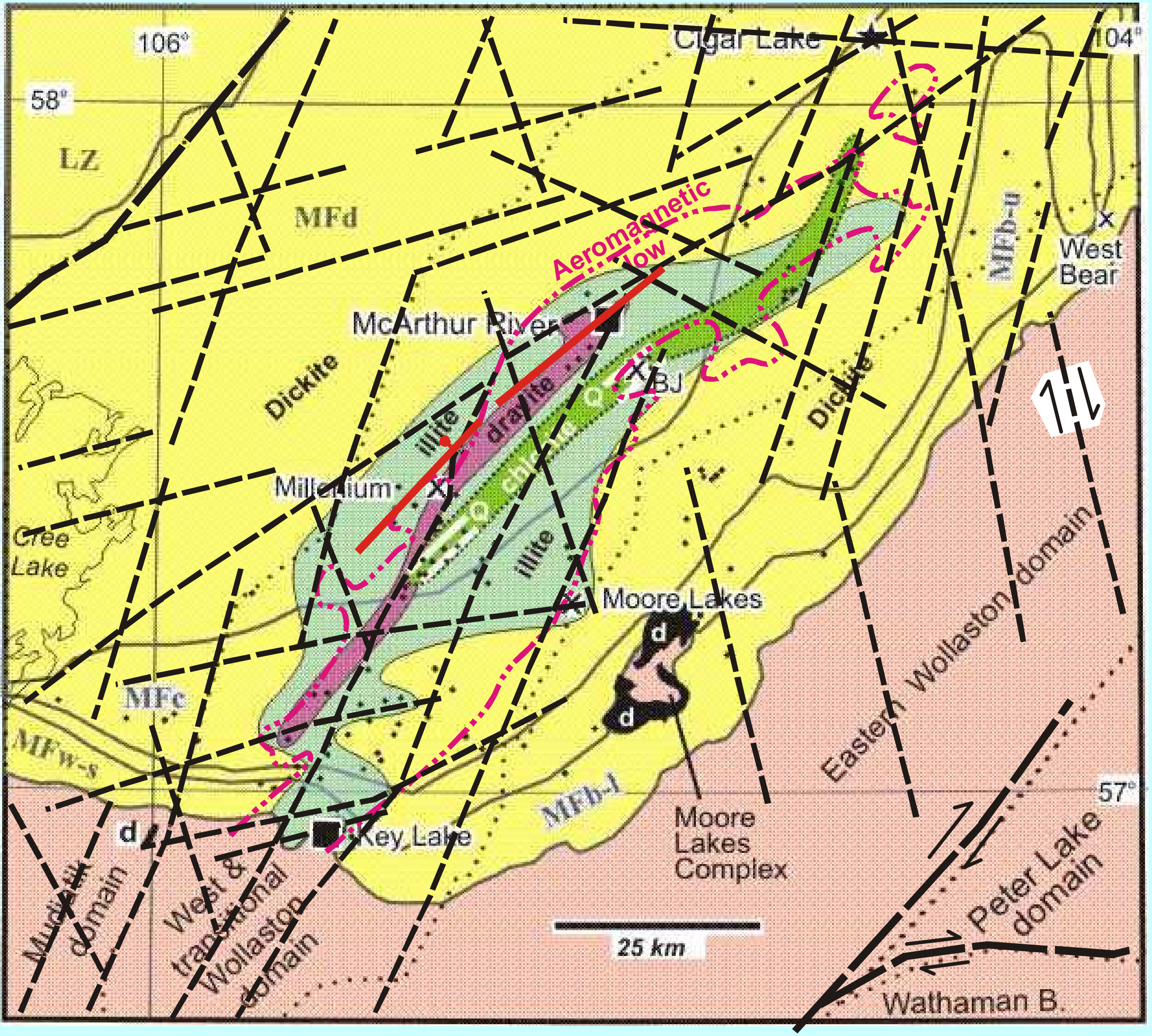

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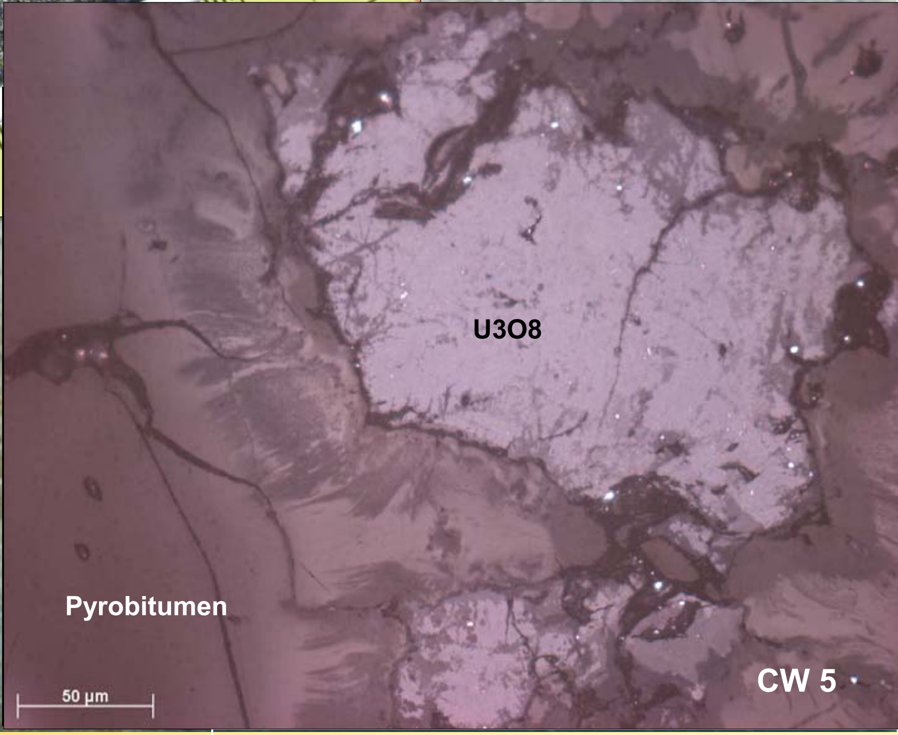
After Earle & Sopuck + Portella & Annesley

Bitumens & Hydrocarbons post-ore

Recent focus has been on basement graphitic zones as sources of organic reductants to precipitate uraninite. Work by Wilson, Stasiuk et al. indicate that hydrocarbons post-date ore and could have been derived from both Proterozoic (Douglas Formation) and Phanerozoic (e.g. Cretaceous tar sands) that infiltrated the basin. It is suggested that the long-known sulphidic component has been overlooked here, and may be a very important factor, possibly distinguishable geophysically. i.e. there may be graphitic shear zones and graphitic-sulphidic shear zones each with different prospectivity.

Cluff Lake, Claude waste pile

Maybelle River, AB



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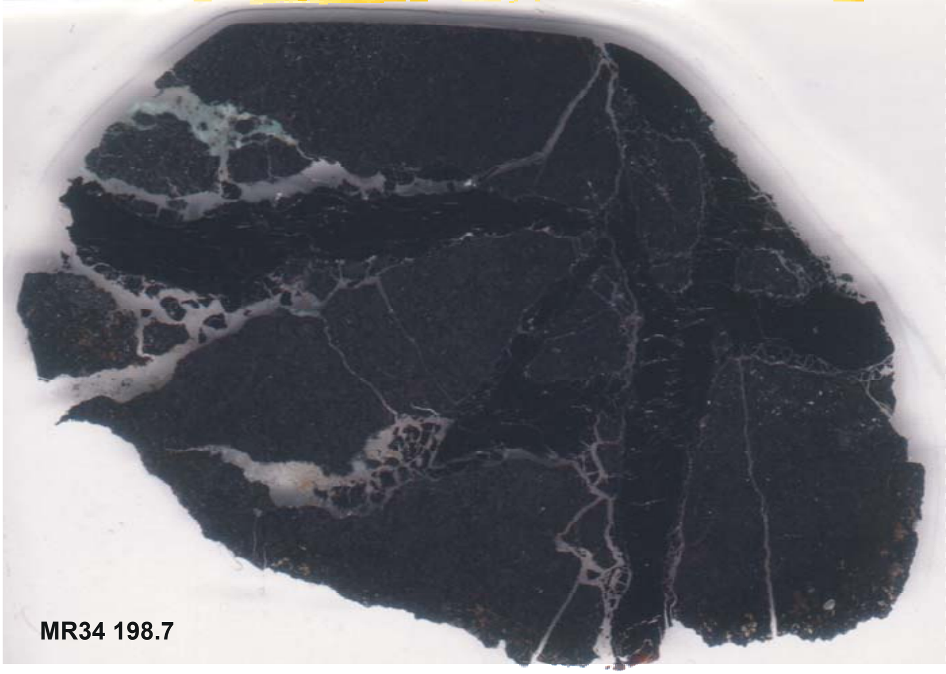

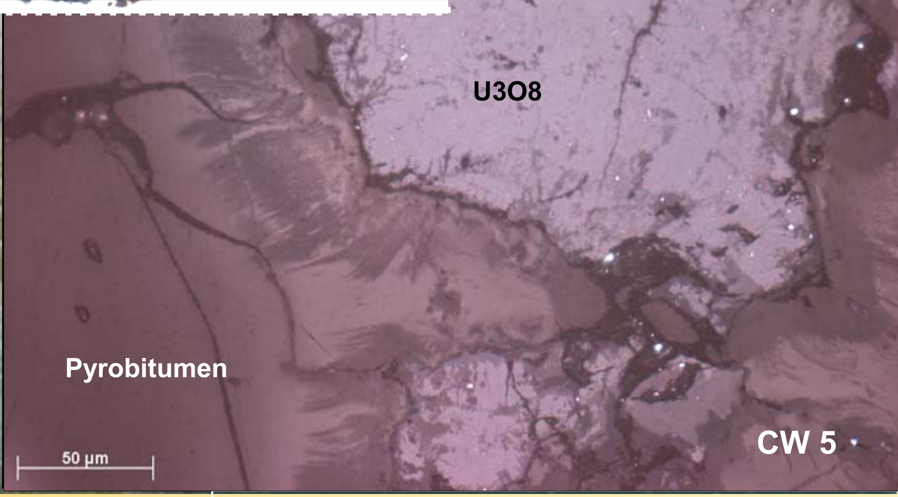

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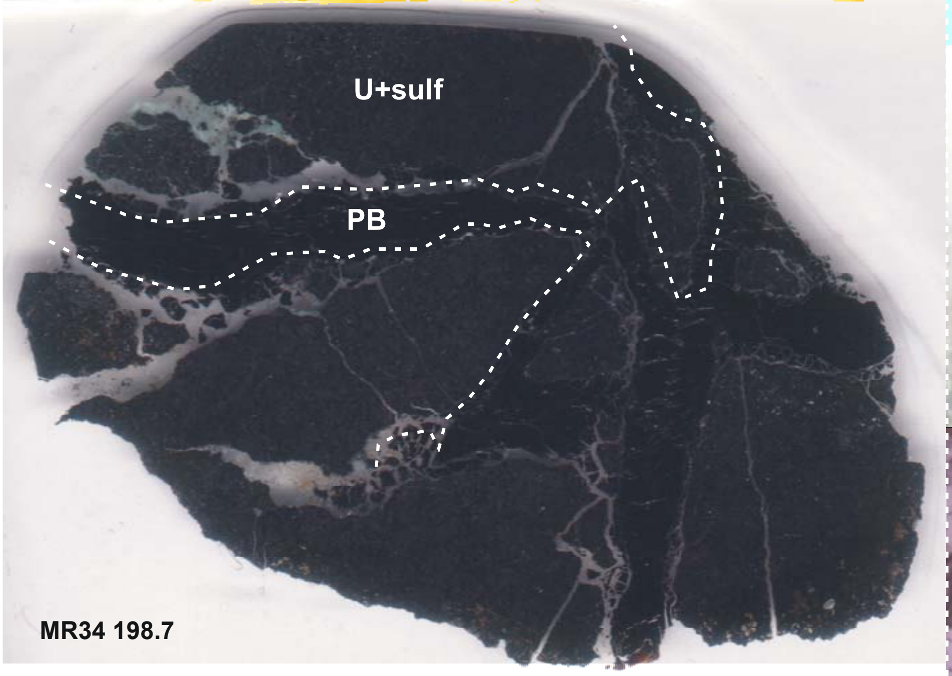

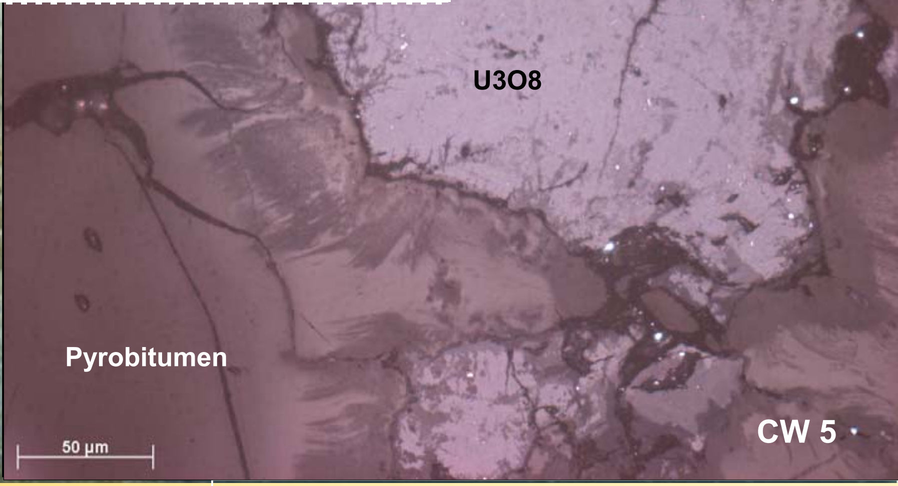

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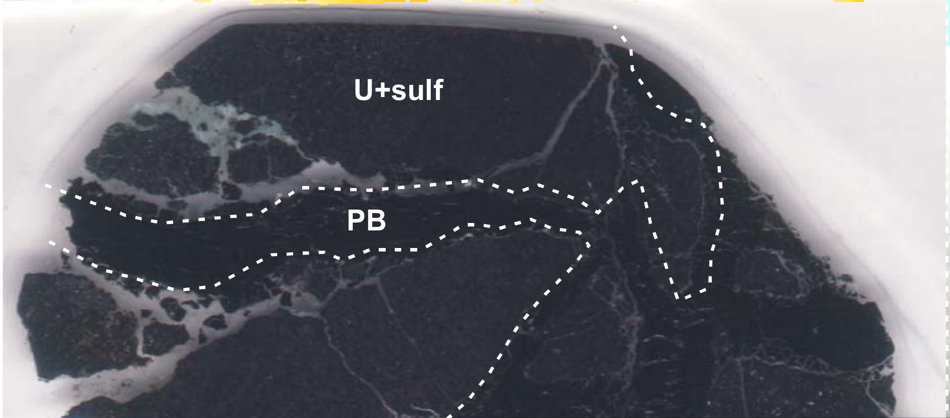

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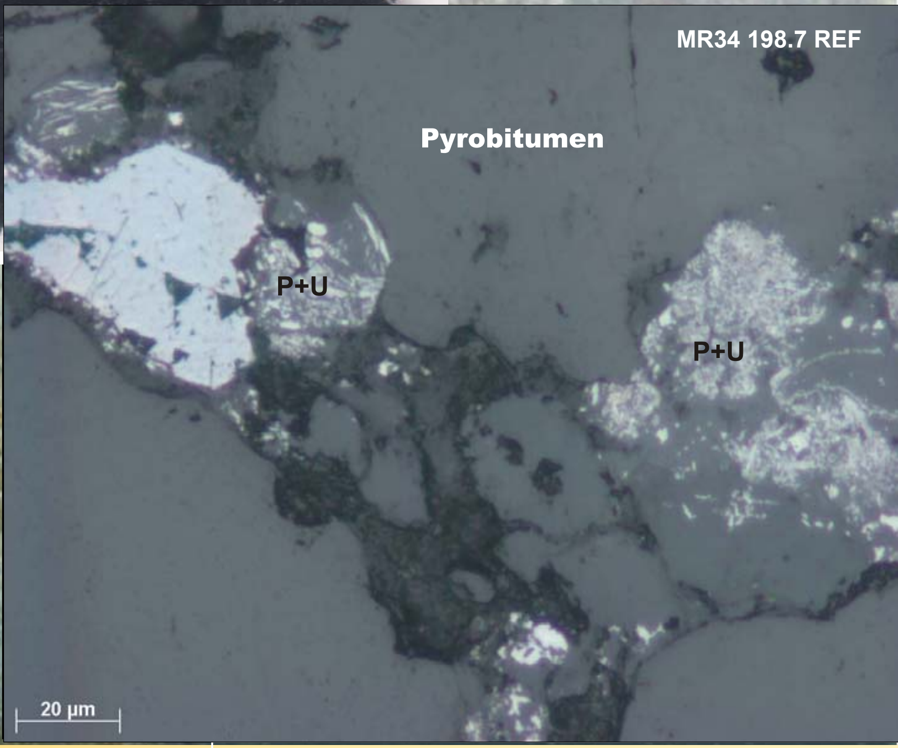

Maybelle River, AB

Wilson, Stasiuk et al.

Insights and Questions

- Basement preparation, Basin development and ore systems are linked
- Growth faults reactivated basement structures active before and during sedimentation
- Link ingress and egress types through fault \ ore systems?
- Can we develop better tools for detecting ingress deposits?