Water Source and Disposal

for Unconventional Gas Plays in N.E. British Columbia

Presentation to
CSUG Water Workshop
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Introduction

- Unconventional gas plays have changed the face of exploration and development in NEBC
  - Huge gas resources over very large areas
  - Intensive development – horizontal drilling, multi-frac stimulations
- Environmental impacts must be addressed
  - Access to new, undrilled areas
  - Roads, pipelines, materials
  - Water is the most critical issue

Why is Water so Important?

- Large water volumes required to make up frac fluids
  - Horn River Basin – up to 4000 m^3 per frac, up to 28 fracs per horizontal leg
- Contaminated flowback / produced water must be disposed of safely
- Recycling can reduce volumes of new water required and disposal capacity required, but –
  - Substantial amount of water stays in the ground during each frac operation
  - Chemistry of flowback waters necessitates some disposal

Addressing Water Issues

- Producers in WCSB are acutely aware of importance of addressing water issues early, before large-scale development begins
  - Prefer to use deep saline groundwater to avoid conflicts with domestic and agricultural use of potable water
  - Producer groups have enlisted technical support from Geoscience BC and provincial government
    - Also provided confidential data and financial support
- Provincial government has worked to fine-tune the regulatory framework to support water access and disposal needs

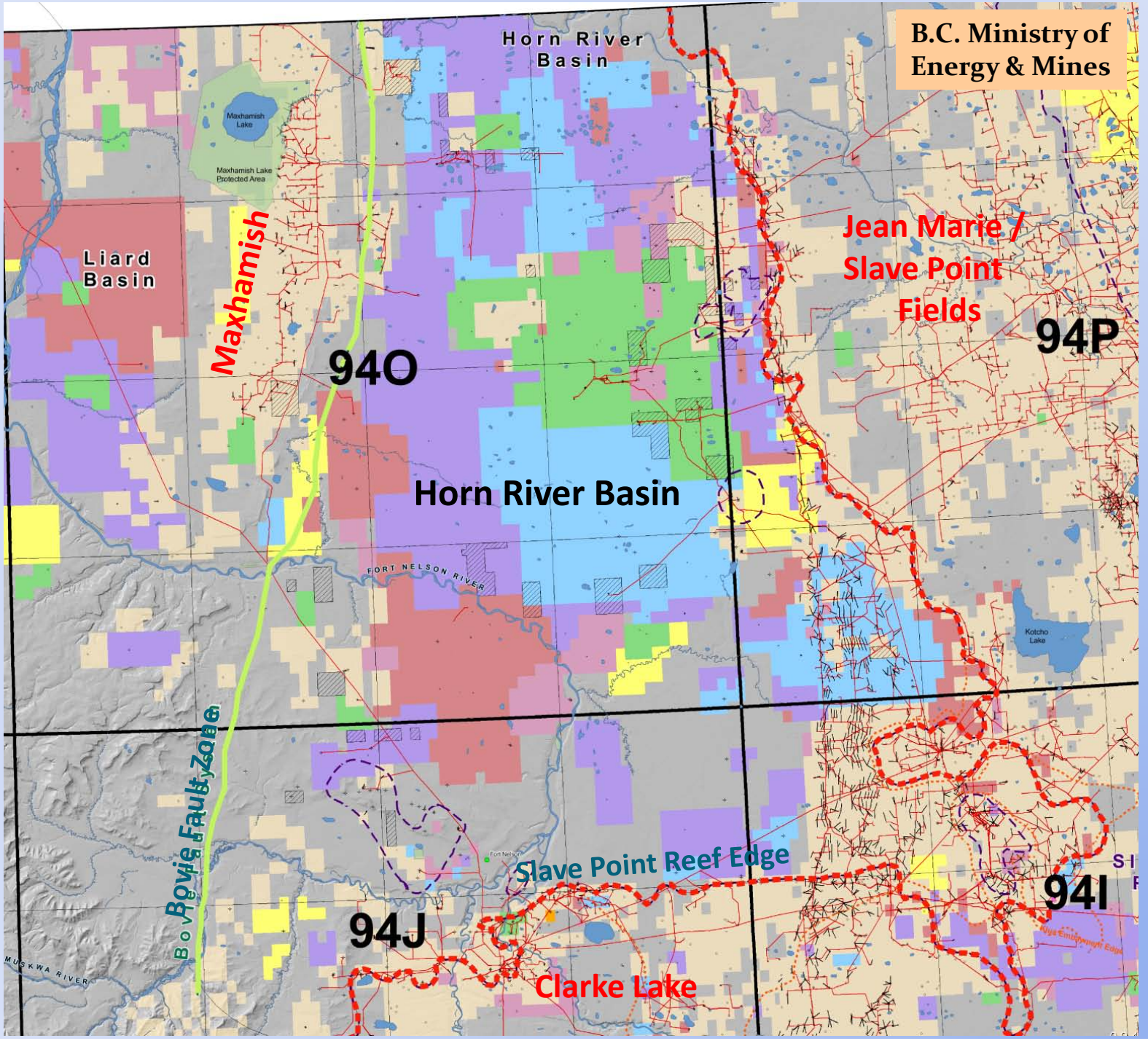
Horn River Basin

Horn River Basin – EnCana Two Island Lake 63-K pad

Photo courtesy EnCana

Horn River Basin – Overview

- Devonian Muskwa Formation – true shale gas target
- Shale gas play in a shale-dominated basin
  - Drilling for conventional targets on southern and eastern basin flanks
  - Play area practically undrilled prior to Muskwa discovery
- Large, water-based fracs were established early as essential to economic success of the play


B.C. Ministry of Energy & Mines
Horn River Basin
Maxhamish Lake
Maxhamish Lake Protected Area
Liard Basin
Maxhamish
Jean Marie / Slave Point Fields
94P
94O
Horn River Basin
FORT NELSON RIVER
Kotcho Lake
Bovie Fault Zone
Slave Point Reef Edge
94I
94J
MUSKWA RIVER
Clarke Lake

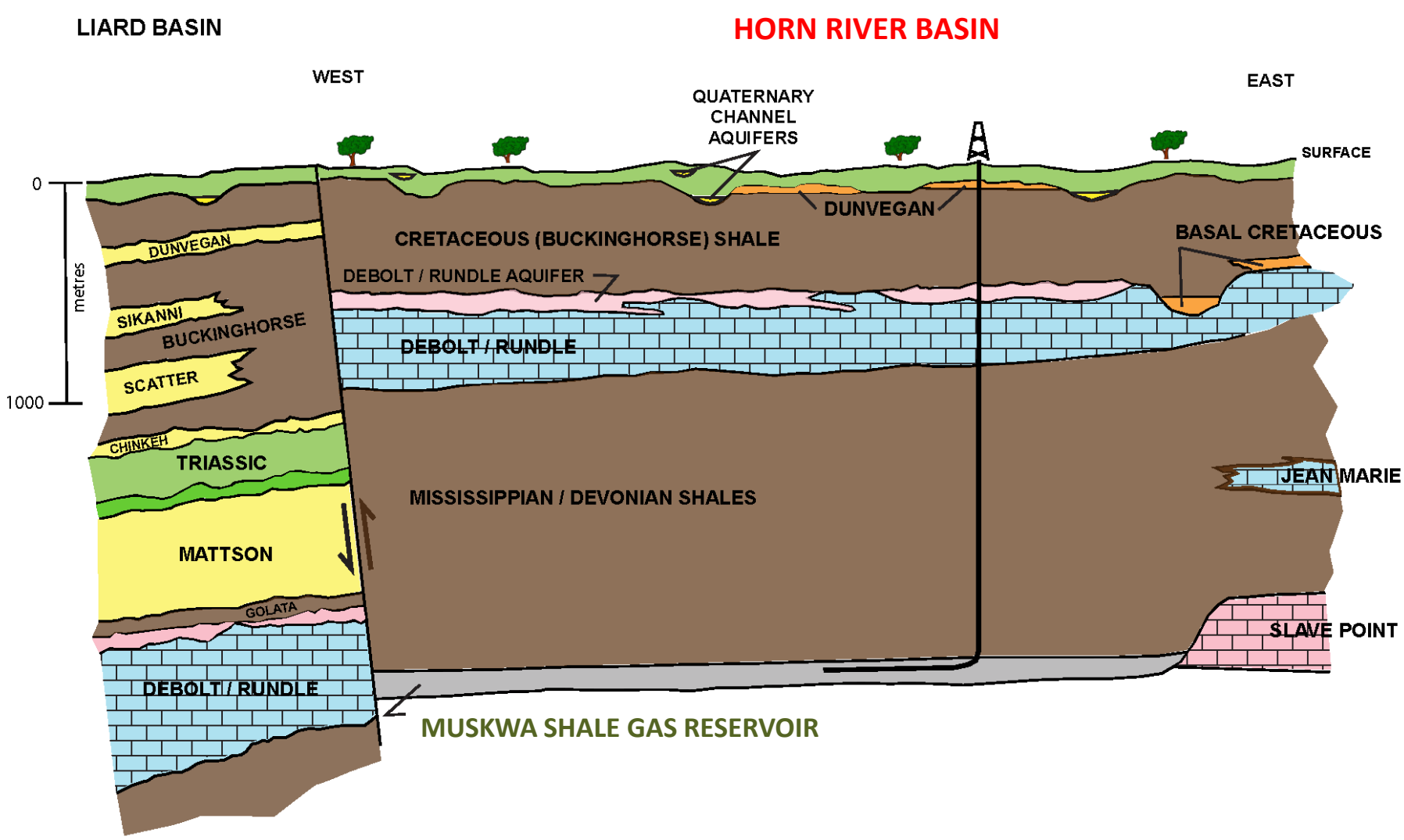
HRB – Water Issues

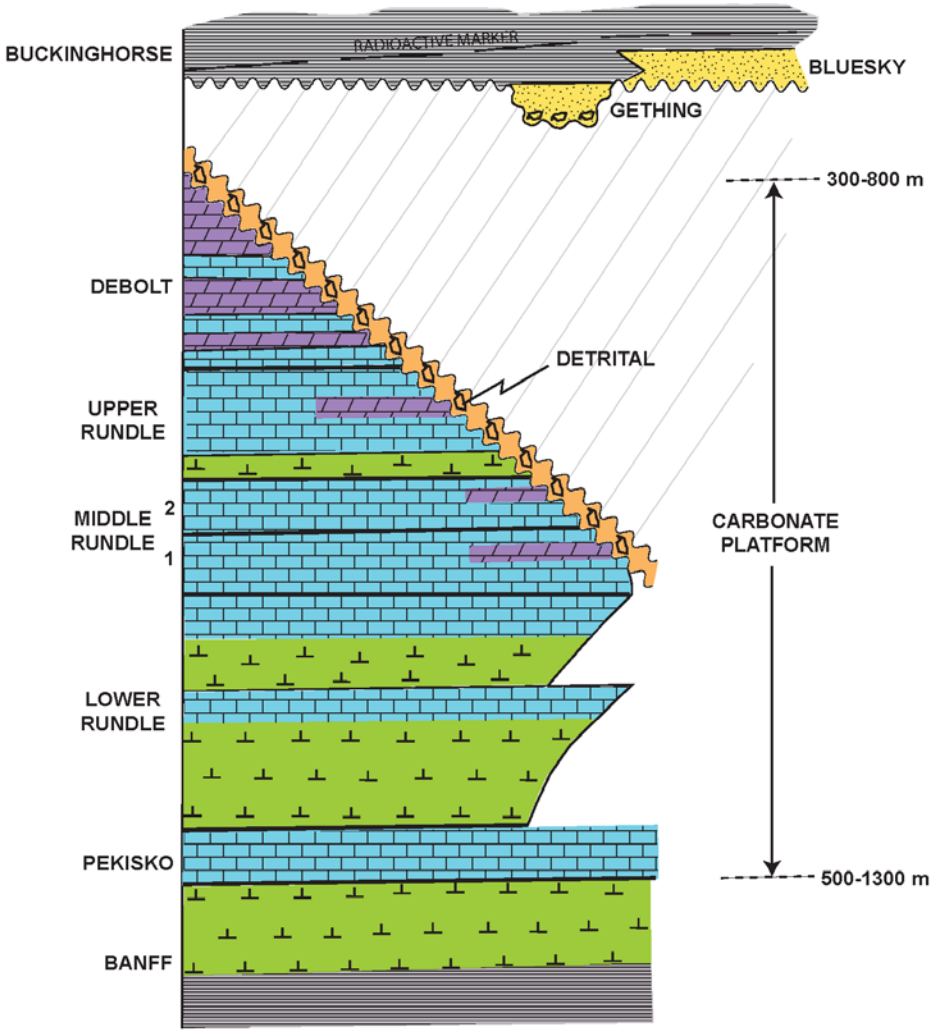
- Lacks large through-flowing rivers or large lakes
- Surficial geology and aquifers not mapped
- Deep subsurface aquifers not mapped
  - Well control lacking over most of basin
- Horn River Basin Producers Group recognized issues during initial delineation work
  - Enlisted technical support from Geoscience BC

Geoscience BC – HRB Aquifer Project

- Geoscience BC is a not-for-profit technical organization, originally funded by provincial grant
  - Tasked with undertaking geoscience-based projects to promote minerals and petroleum exploration in B.C.
  - Received large grant, targeted at HRB, in 2007
- HRB Producers Group identified water sourcing and disposal as primary geoscience-related issue for shale gas development
- Phase I program set up in 2009
  - Determine distribution and capacity of deep subsurface, non-potable aquifers in the HRB as:
    - Potential sources of water for shale gas completions
    - Potential disposal sites for water produced during shale gas completions and production

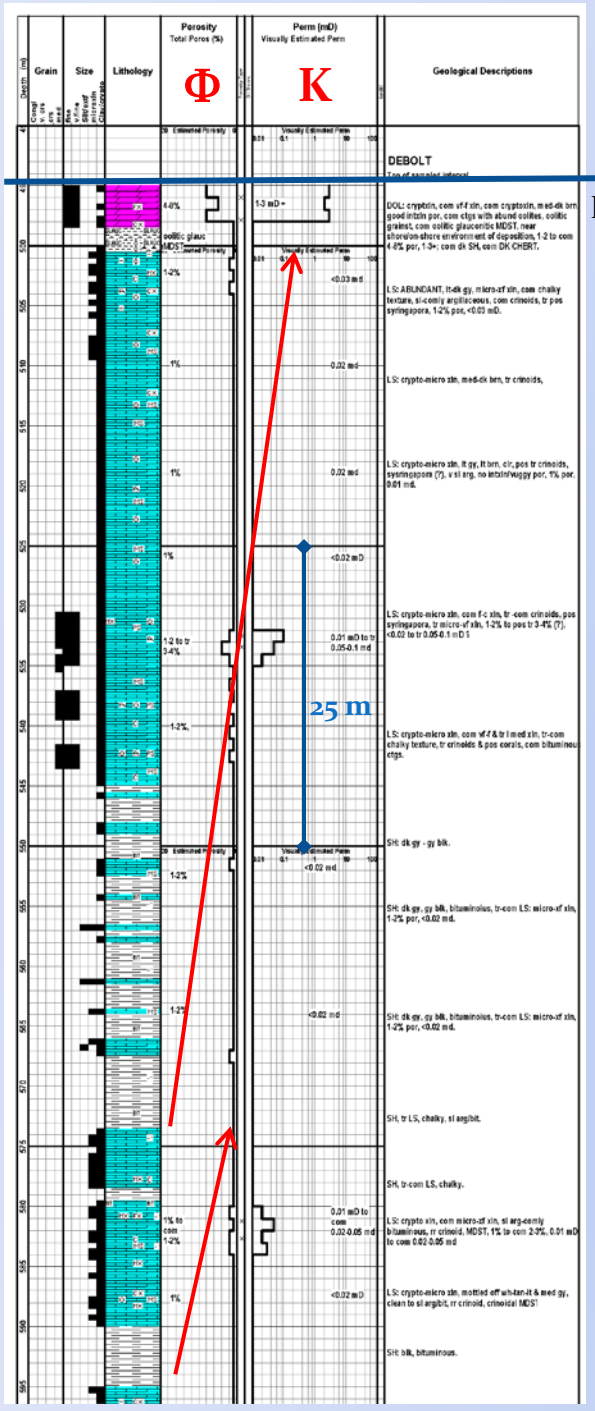
HRB Schematic Cross-section





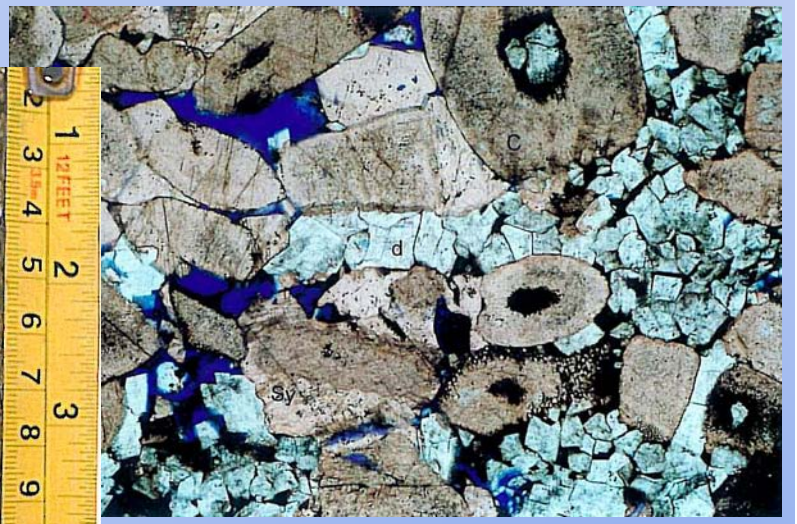
Horn River Basin
Primary Reservoir Units

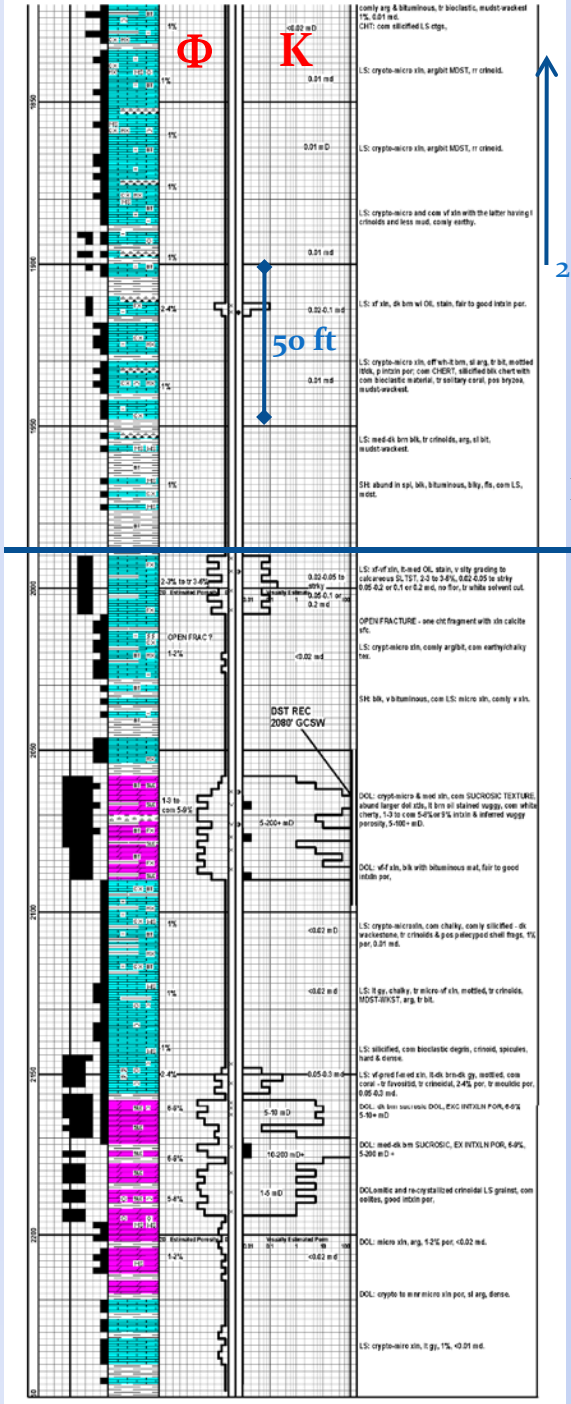
- Mississippian carbonate platform
  - Local reservoir development within cycles
  - More consistent and higher-quality reservoir at upper surface in “Detrital” zone
- Mattson sandstones (not shown)
  - to west in Bovie Fault Zone and Liard Basin
- Cretaceous sandstones
  - Gething to east
  - Bluesky to southeast
  - Chinkeh (not shown) in Liard Basin



Rundle / Debolt Aquifer

- Correlated on flooding surface markers in Horn River Basin
- Stacked shoaling-upward carbonate cycles form carbonate platform
  - dominantly mudstones to wackestones / packstones; little primary porosity
  - upper parts of cycles are dolomitized in middle of platform, in isolated wells





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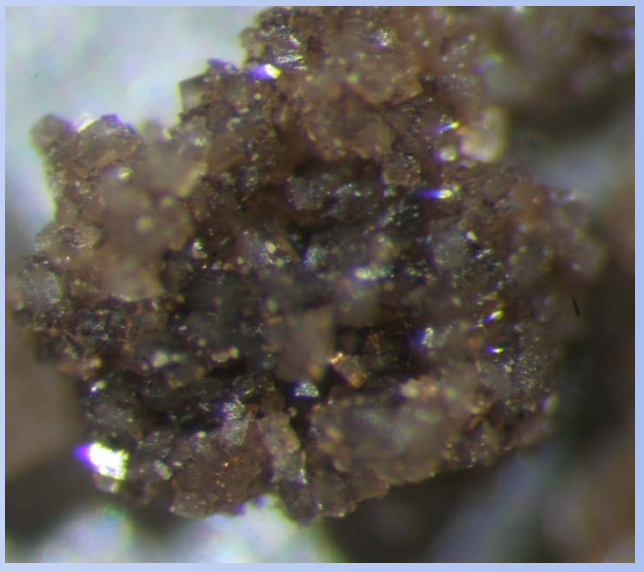
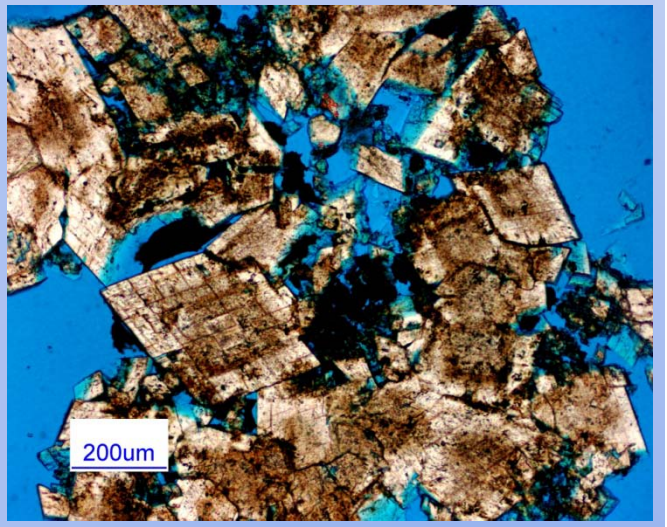
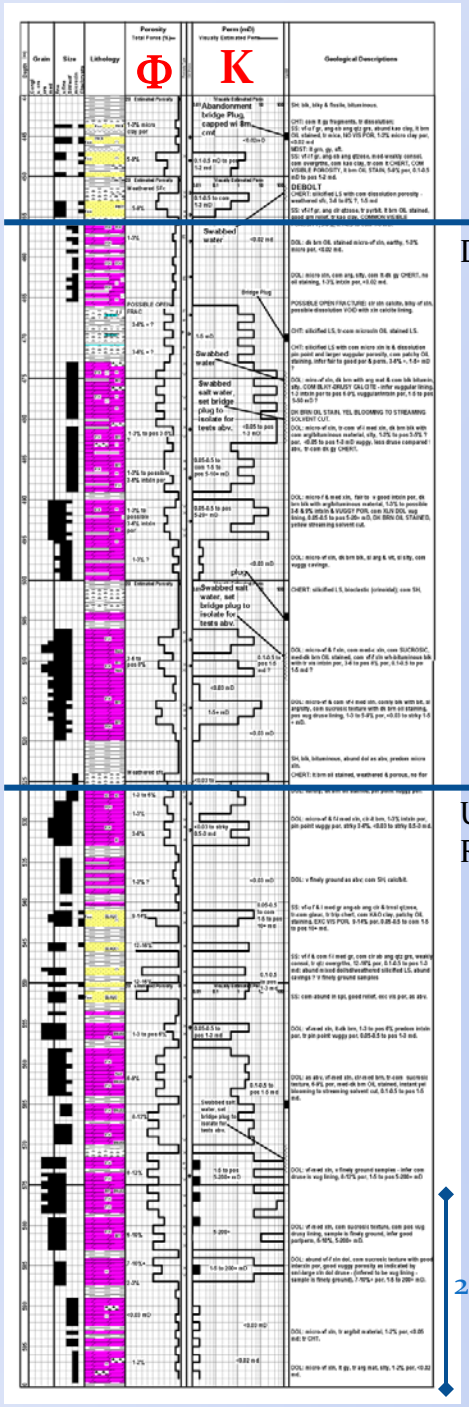
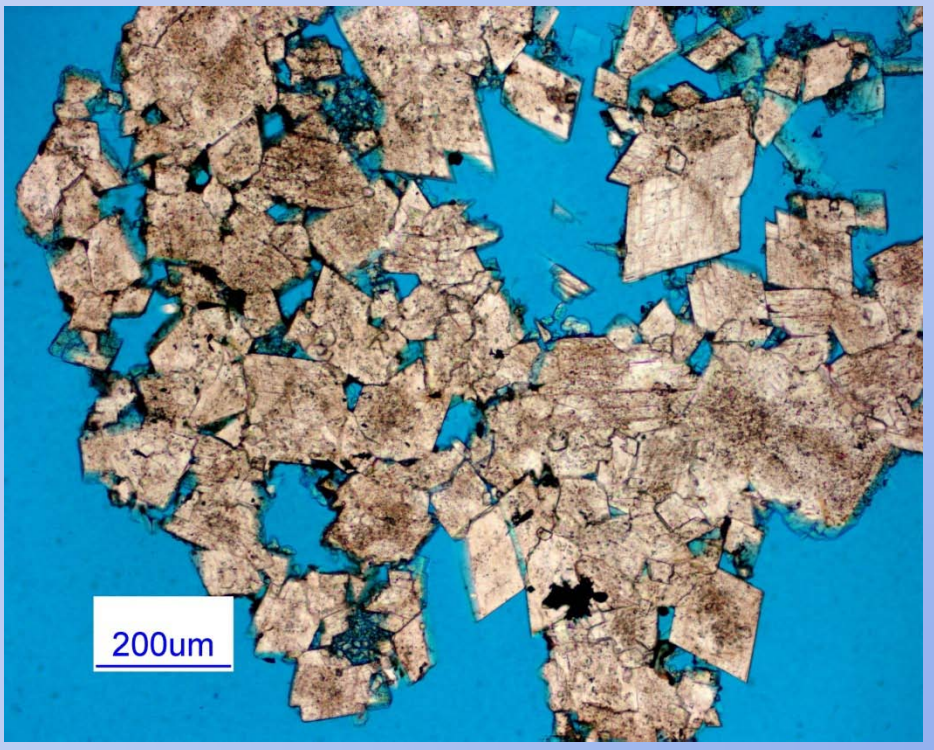






Detrital Zone

- Extensive and intensive dolomitization at pre-Cretaceous unconformity
- Poor core and sample recovery
- Poor log characterization – washed out



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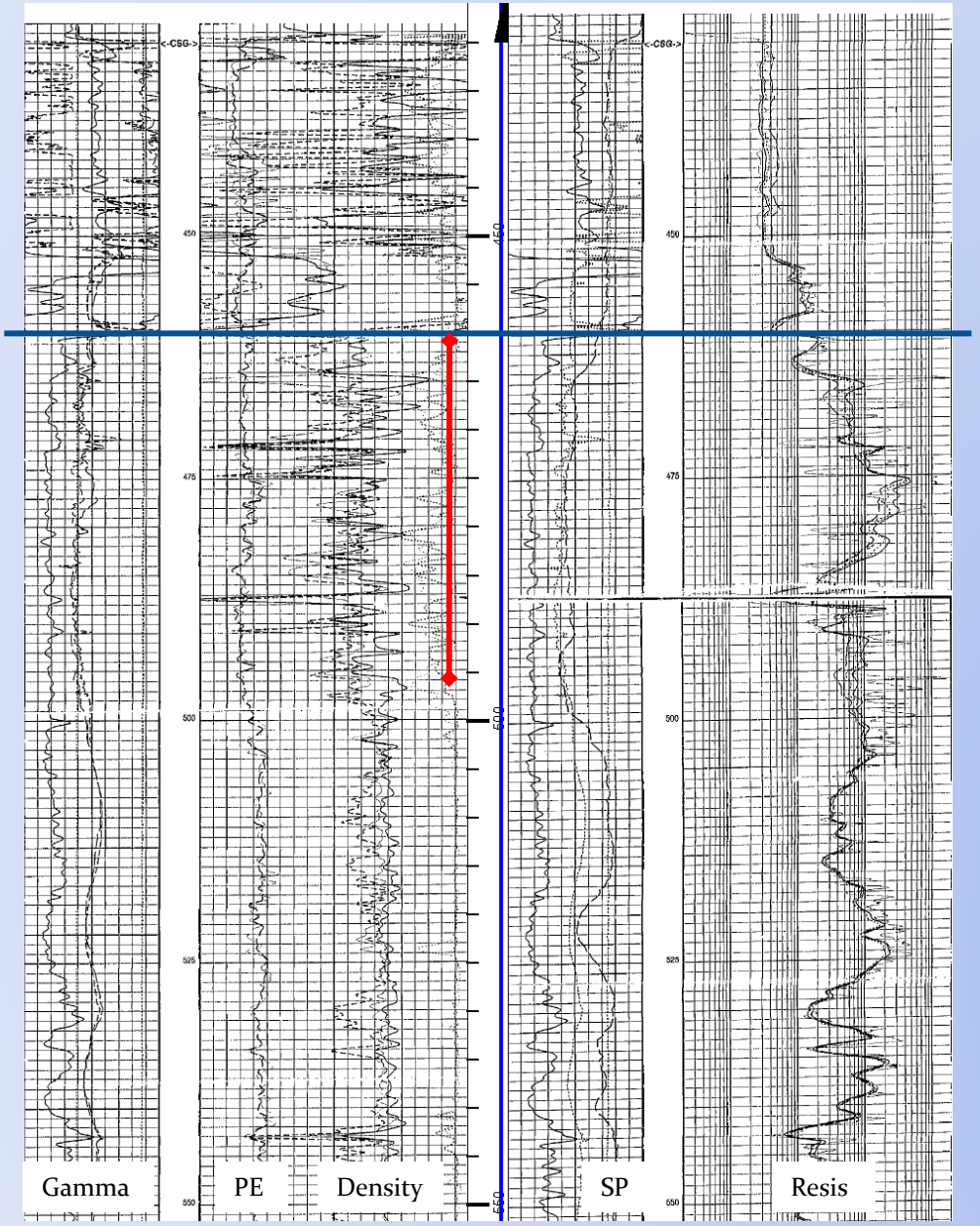

Detrital Zone

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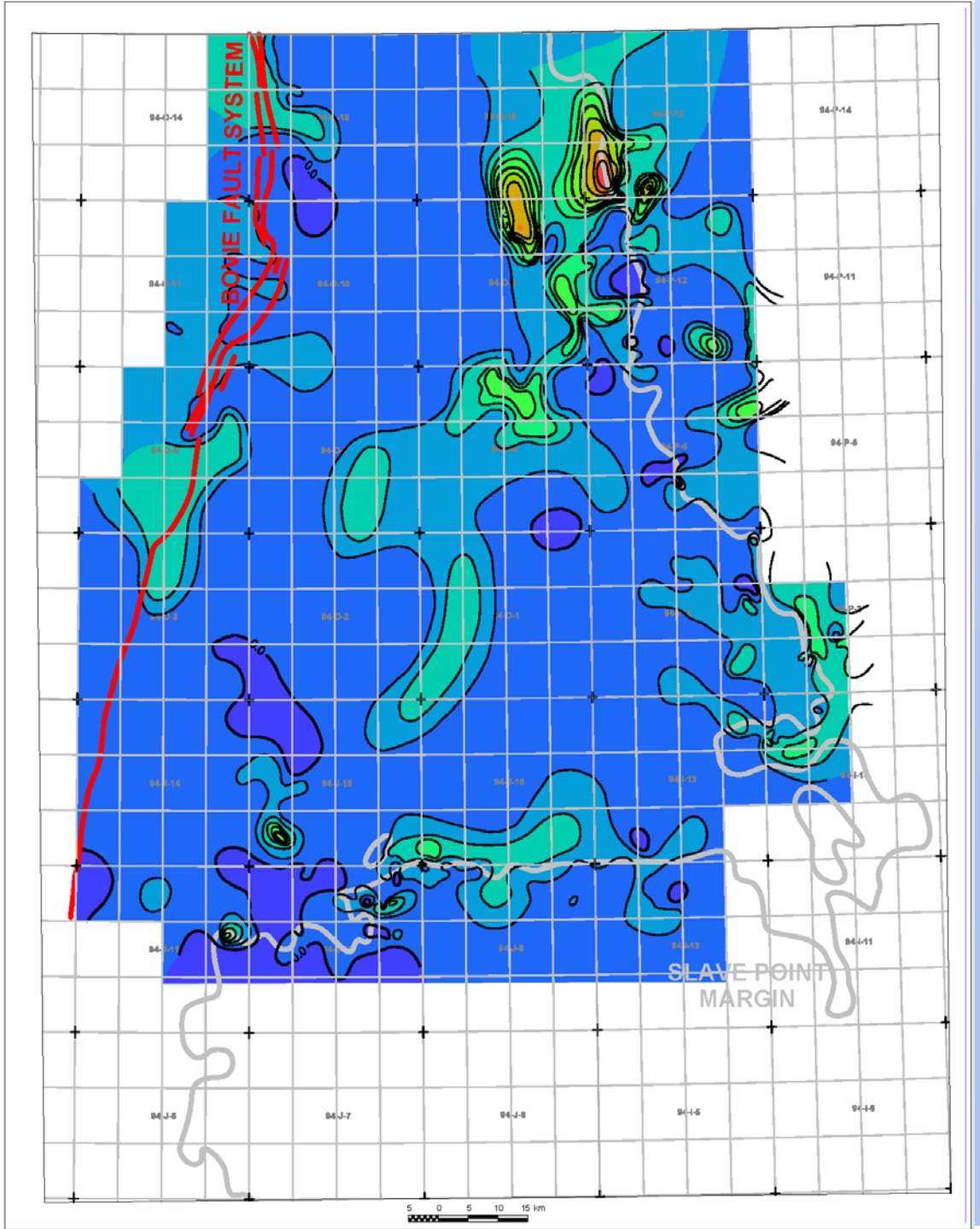
Detrital Zone Outcrop Analogue

Madison Group, Northern Montana

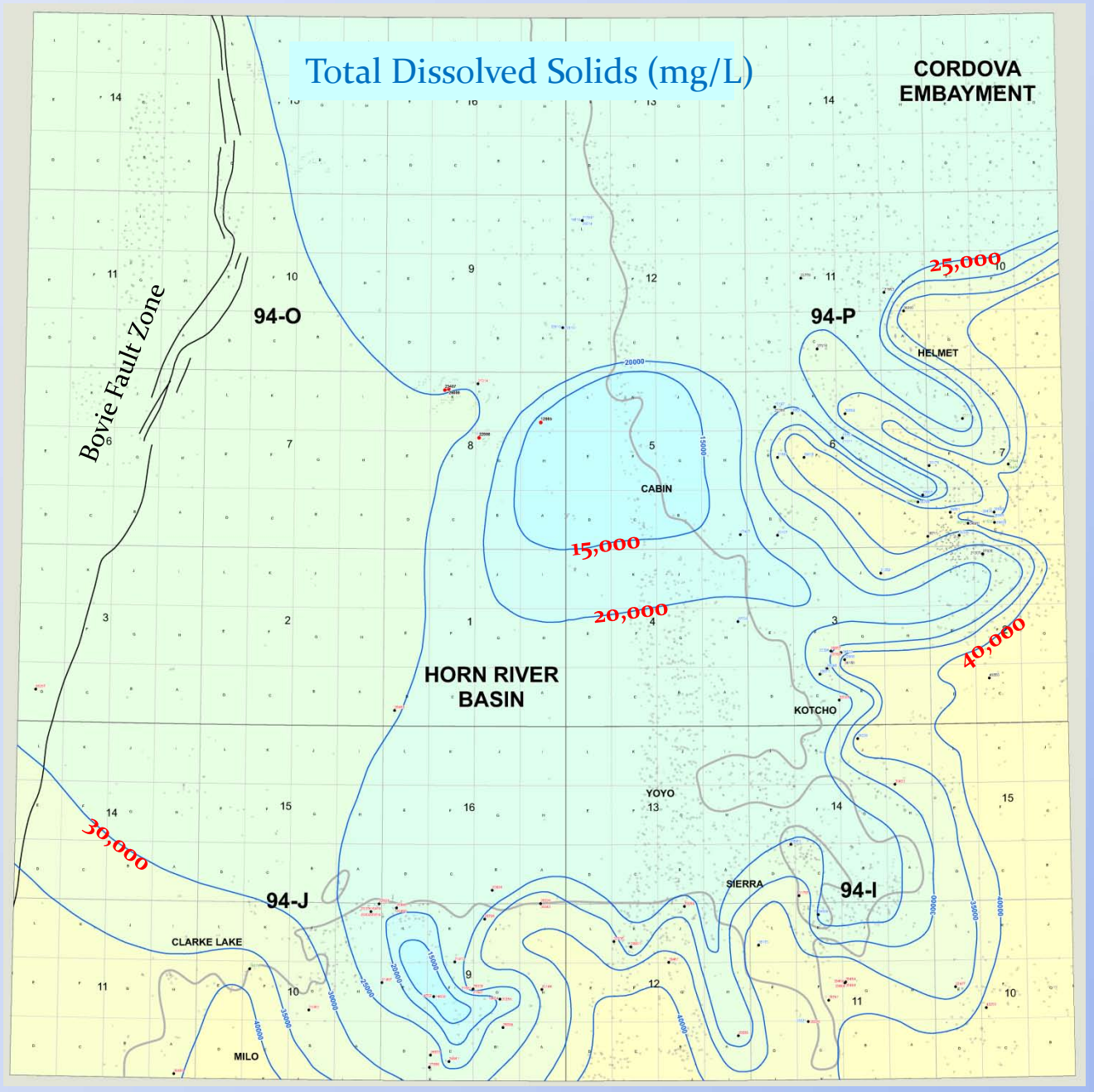
Regional fracturing
(Giant Springs, Great Falls)

Solution breccia, dolomitization, recrystallization



Porosity-Thickness
Carbonate Platform
(Total enhanced reservoir)

- "Detrital" zone reservoir dominates, but good reservoir in lower zones is locally important

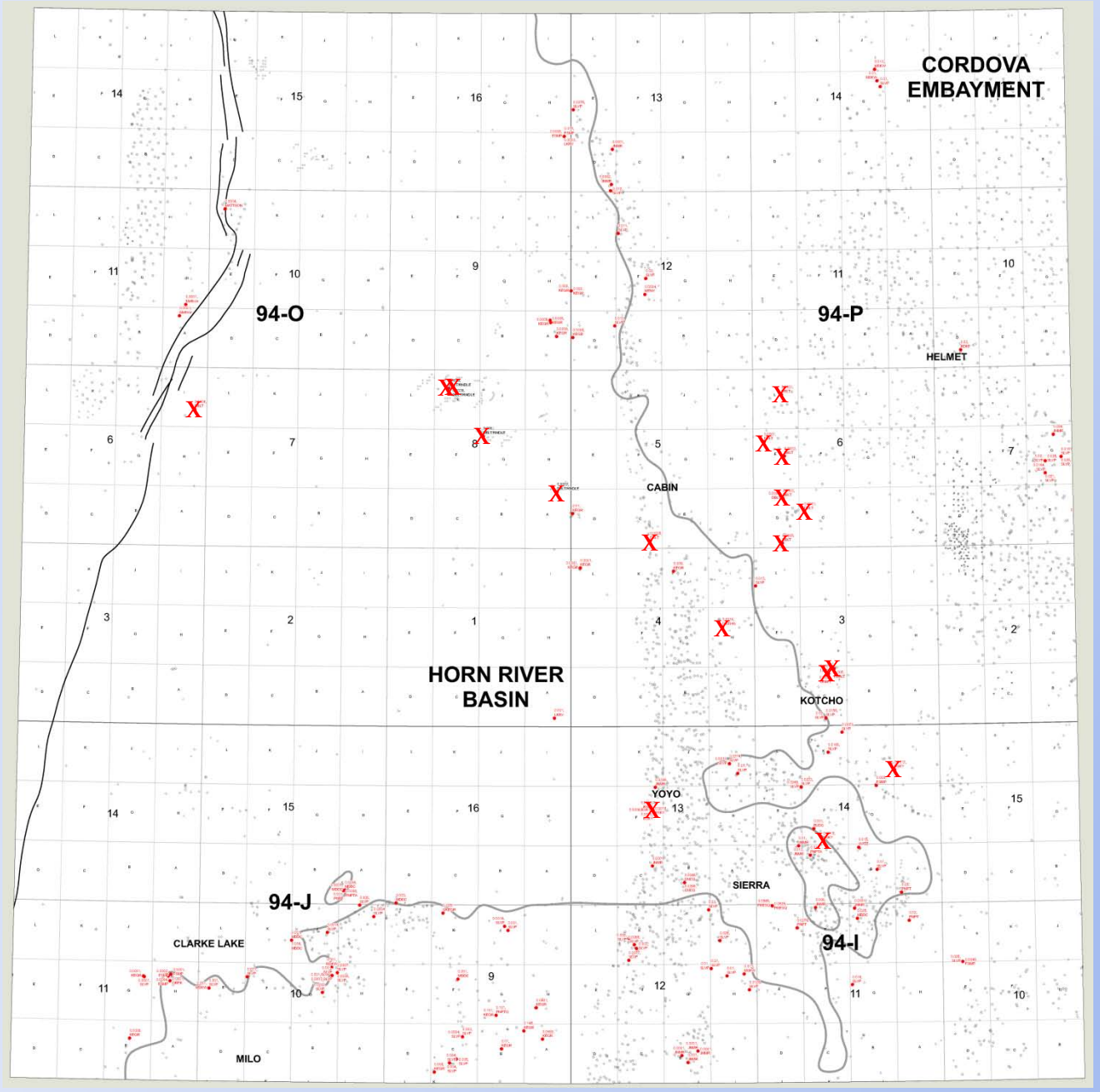


Cretaceous – Rundle Hydrostratigraphic Unit

Water Salinity

Formation water TDS
15,000 – 40,000 mg/l

- Much too saline to be potable, but still OK for use as completion fluid
- Values similar across entire vertical section



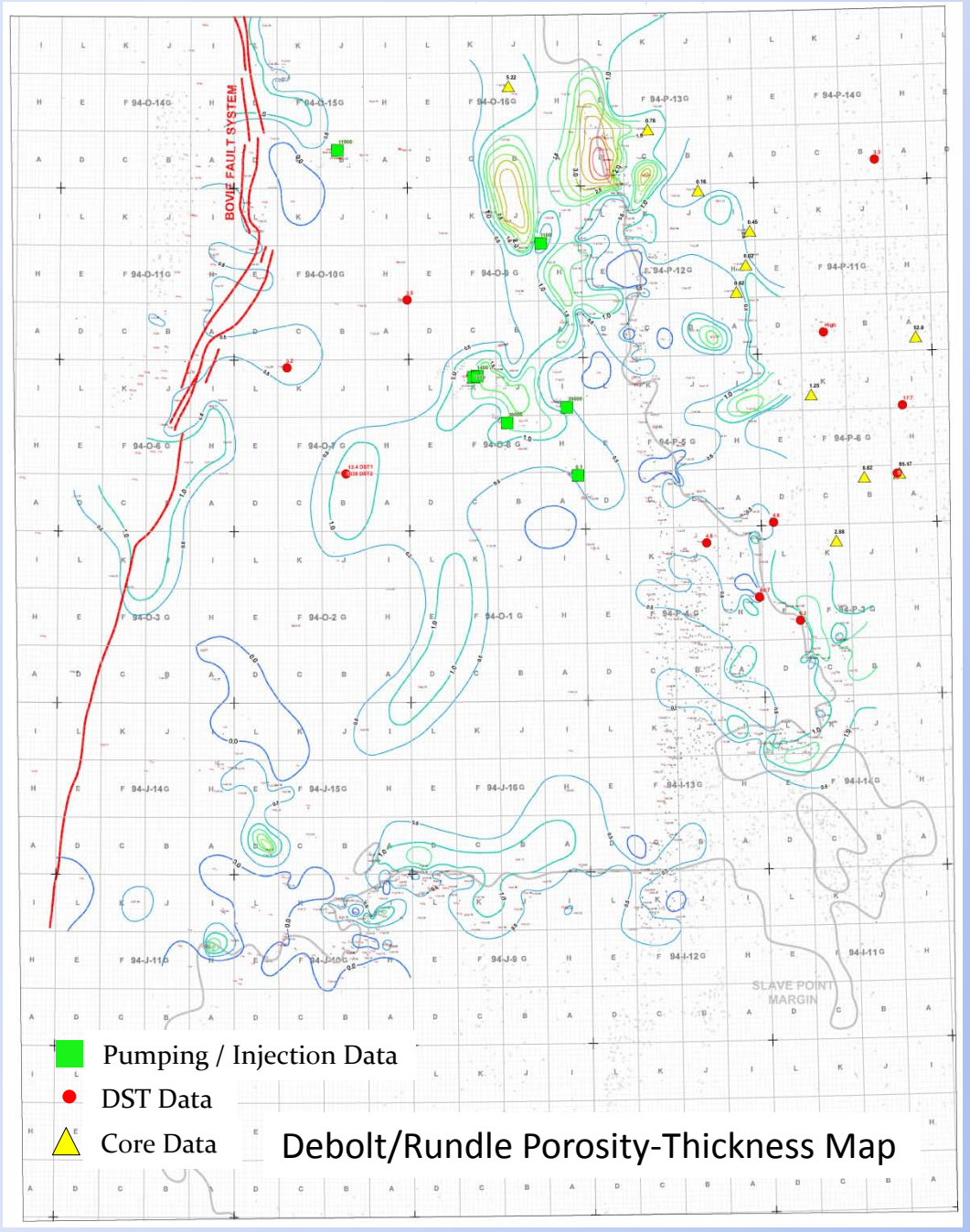
Cretaceous – Rundle Hydrostratigraphic Unit

H_2S Concentration

Very low H_2S concentrations in Rundle / Debolt

- Most <0.001 mole %
- Highest 0.006 mole % (60 ppm)

X – H_2S in Cret / Miss



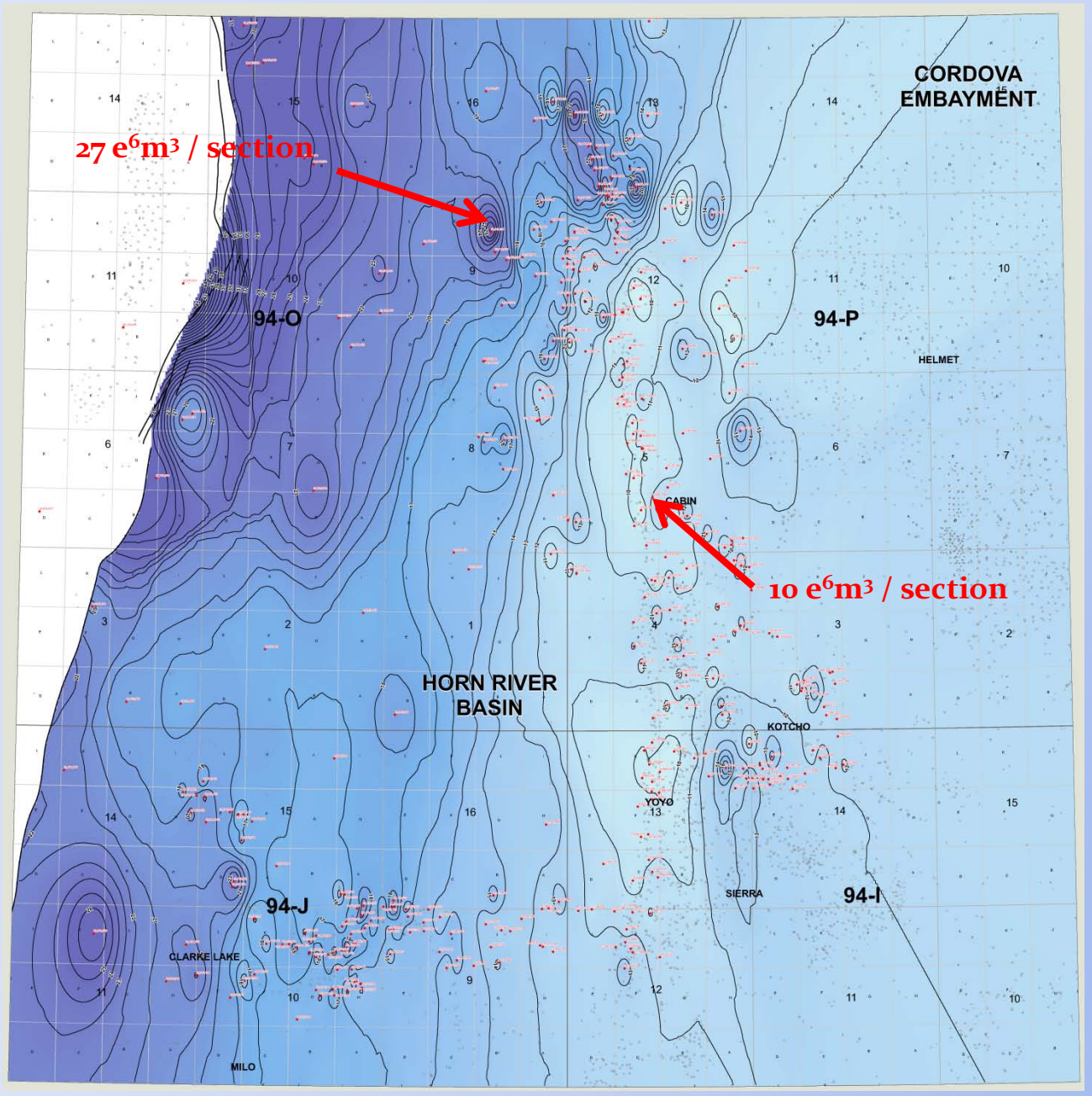
Debolt – Rundle Aquifer

Permeability

P/I tests all located where "enhanced" reservoir exists

- All except one show K > 1000 mD
- Maximum 39,800 mD

Core and DST results show K < 10 mD in regional strata



Debolt–Rundle Aquifer

Water Volumes in Place

Assumptions:

- Average porosity = 2%
- "Enhanced" porosity = 9%

Total water volume – 95 e^9m^3
- 15 e^9m^3 in "enhanced" rock

Horn River Basin Aquifer Characterization Project

Conclusions (1)

- Stratigraphic analysis shows three subsurface units with aquifer potential:
  - Mississippian carbonate platform
  - Mattson Formation
  - Cretaceous sandstones
- Best quality and most continuous reservoir in “Detrital” unit capping Mississippian carbonates, particularly associated with Debolt subcrop edge
  - Very little well control in western half of HRB – is the “Detrital” more widespread?
  - Existing data support only semi-quantitative reservoir quality assessment

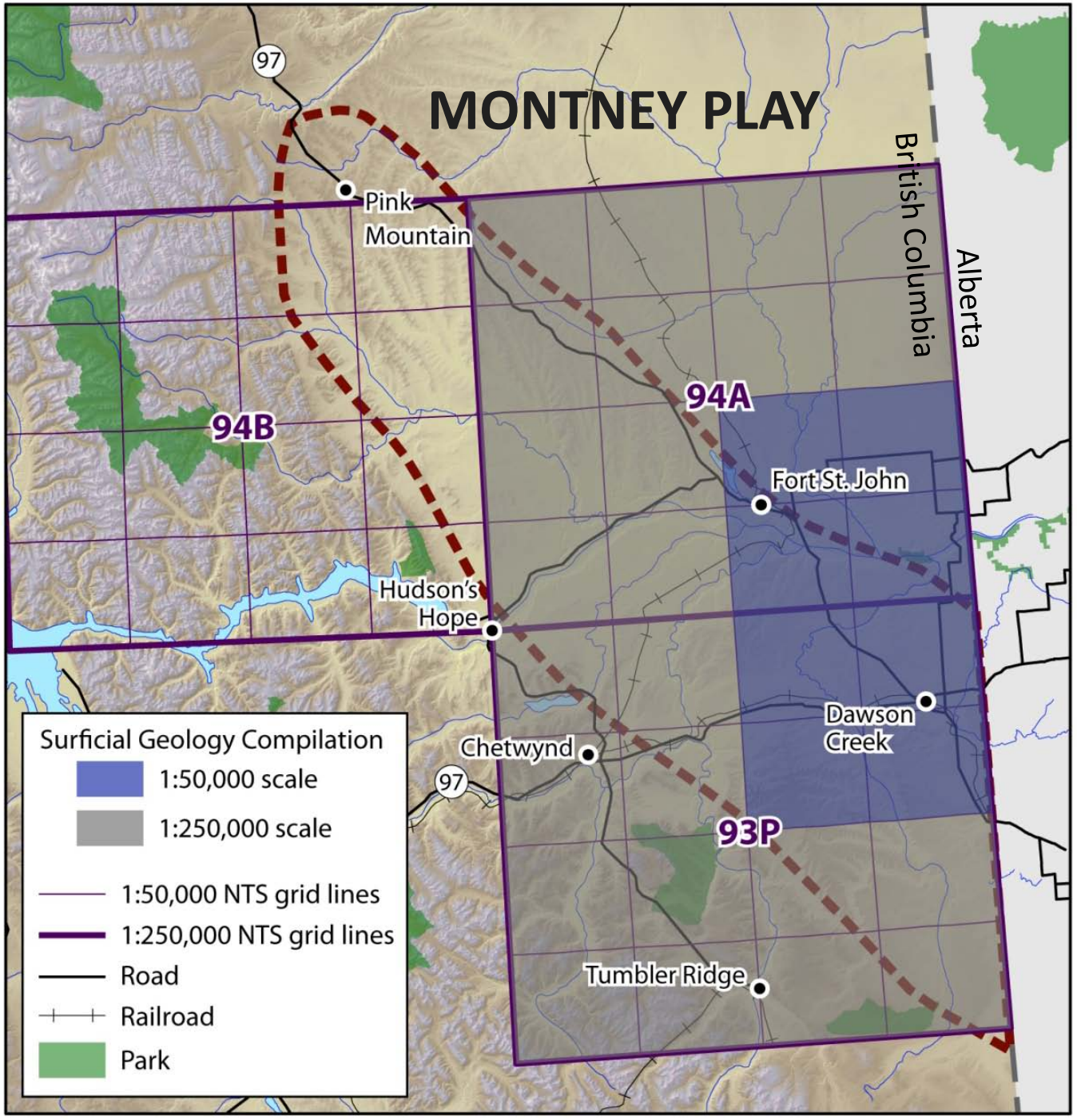
Horn River Basin Aquifer Characterization Project

Conclusions (2)

- Waters are saline, but suitable for use as completion fluid
  - Low concentrations of sour gas seen in Mississippian waters – requires some treatment
- Extremely high permeabilities occur in Mississippian "Detrital" unit
  - Flow/injectivity tests, DST's, cuttings samples, well logs
  - Mappable along Φ-h fairways
- Relatively limited reservoir potential in sandstone aquifers
  - Potential local "sweet spots" in Mattson and Chinkeh
- Aquifer opportunities are not evenly distributed across the basin

Horn River Basin Aquifer Characterization Project
Phase 2 Study (In Progress)

- More advanced mapping of surface geology and unconsolidated sediment cover
- Remote geophysical methods to delineate shallow channel aquifers
  - Proposals for Airborne Electromagnetic Survey Pilot Study under consideration
- Update subsurface mapping with new well data
  - Particularly additional test and flow / injectivity results


MONTNEY PLAY
97
Pink Mountain
British Columbia
Alberta
94A
94B
Fort St. John
Hudson's Hope
Dawson Creek
Chetwynd
97
93P
Tumbler Ridge
Surficial Geology Compilation
1:50,000 scale
1:250,000 scale
1:50,000 NTS grid lines
1:250,000 NTS grid lines
Road
Railroad
Park

Montney Play – Overview

- Triassic Montney Formation
- Tight gas (siltstone) Deep Basin play in Peace River Plains
  - Initial development at Dawson with downspaced vertical wells
  - First horizontal multi-frac completion in 2005; now the preferred development strategy
- Recent development in Peace River Foothills
  - More argillaceous westward – grades to a shale gas play
- Variety of completion strategies and fluids – but all require large water volumes

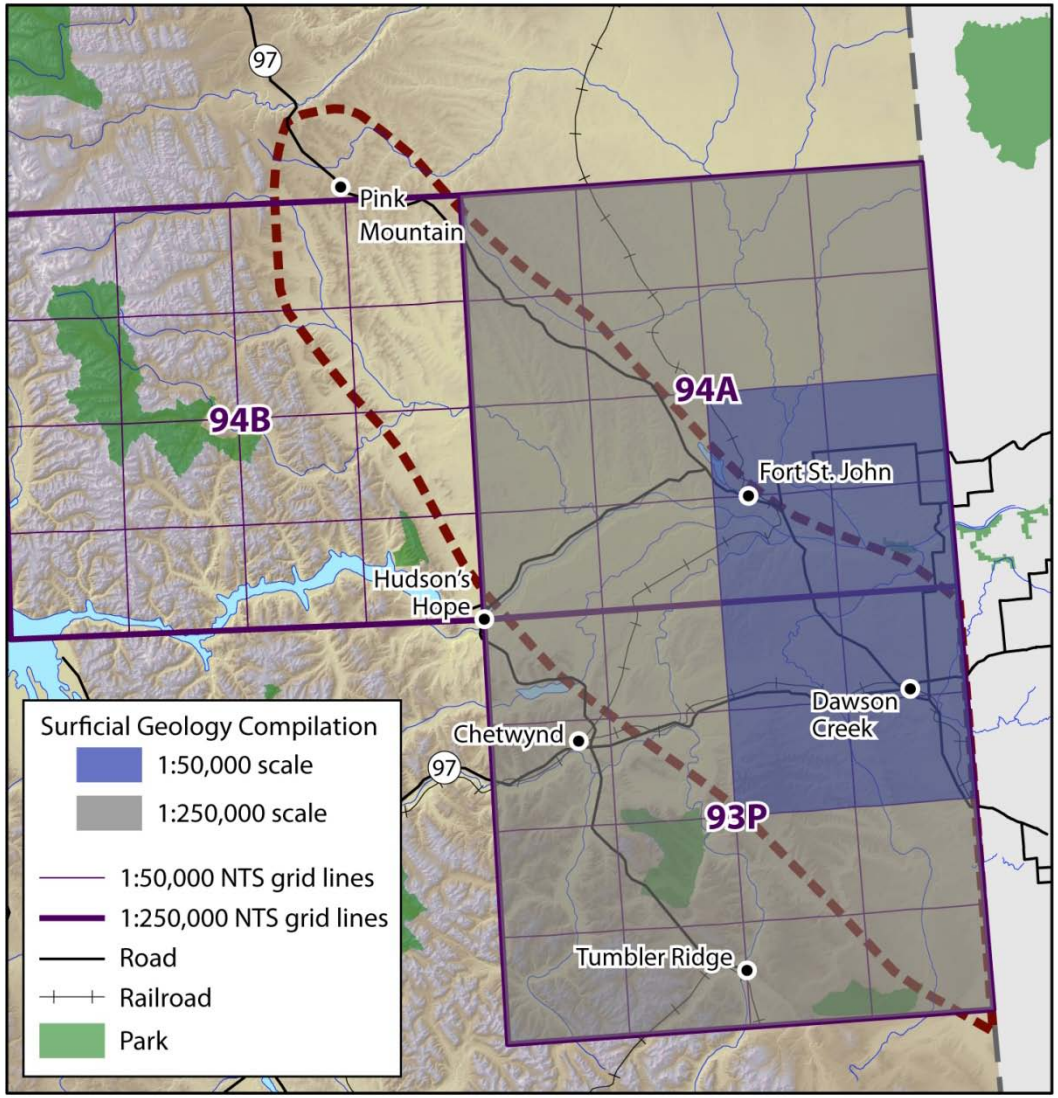
Montney Play Area – Water Issues

- Several major rivers flow through area
  - Seasonal flow variations are considerable
  - Hydroelectric developments – existing and planned
- Substantial domestic and agricultural water demands
  - Dawson Creek, Fort St. John
  - Urban and rural water wells
  - Abundant shallow well data for surficial and shallow bedrock aquifers
- Abundant deep well control from oil and gas operations
  - Some water injection wells exist, but few water source wells
  - Deep aquifers have not been assessed regionally
- Producers have come to appreciate scope of water source and disposal issues as individual pools have been developed

Geoscience BC – Montney Water Project

- Geoscience BC guided initiation and development of Montney Water Project, modeled on work in HRB
- Comprehensive assessment of surface, shallow groundwater, and deep saline aquifers
  - Collaborative effort with industry, provincial government, universities, and communities
- Phase I program set up in 2010; completion Q2 2011
  - Data gathering and database creation are key activities for surface and shallow bedrock assessment
  - Comprehensive regional deep saline aquifer mapping based on existing well and test data

Montney Water Project – Surface Water



Montney Water Project – Surface Water

- Montney play area encompasses parts of several major watersheds – including Peace, Pine, Halfway, Kiskatinaw
- Each has particular issues and demands
  - Seasonal / variable water flow – some recent droughts
  - Agricultural / domestic demands
  - Hydroelectric developments
- Studies are designed to better characterize and understand hydrology of each watershed
  - Acquiring additional stream flow data is critical
  - Support for academic projects

MWP – Surficial Geology and Shallow Aquifers

Bedrock Topography

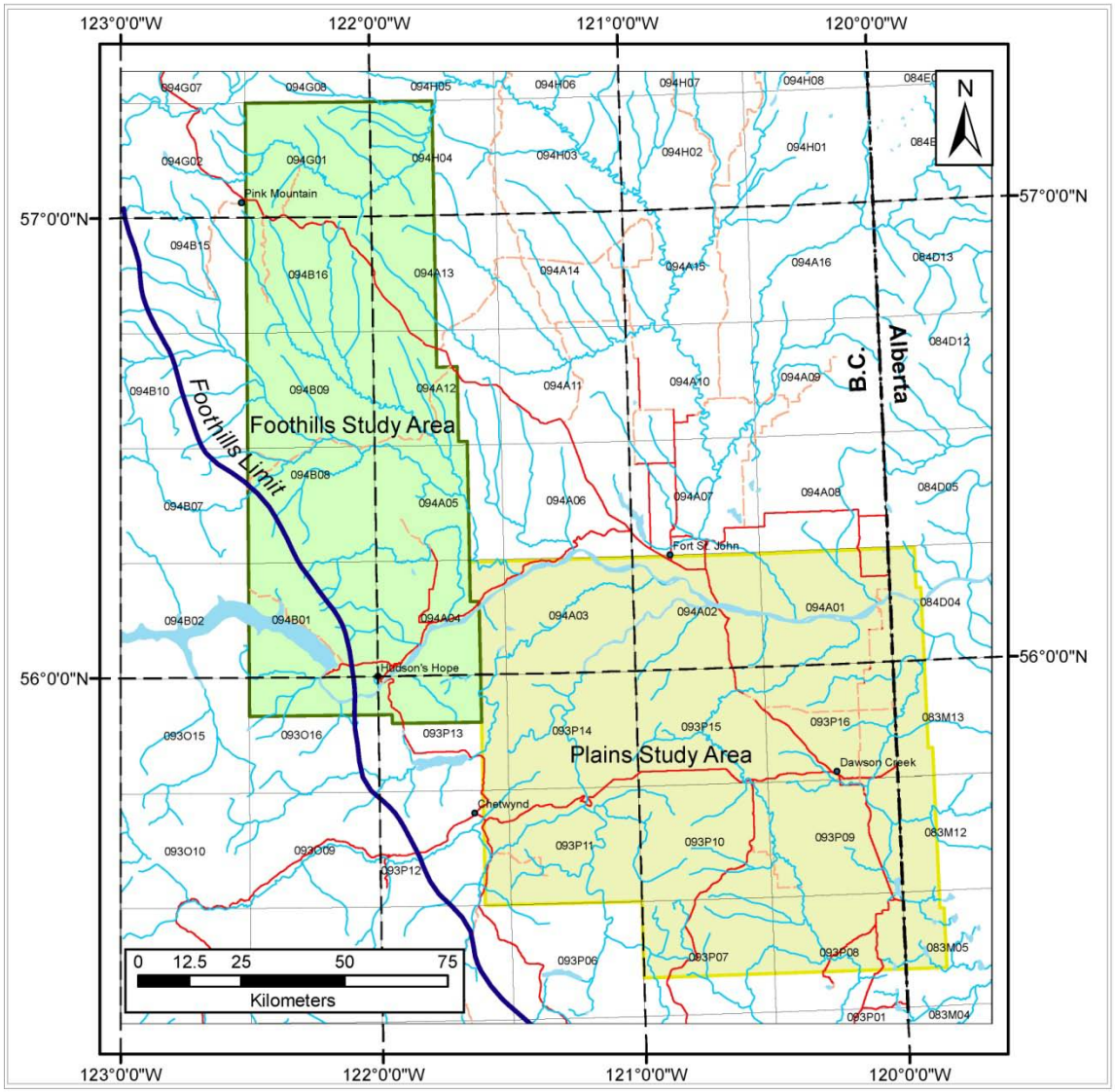
Drift Thickness

BRITISH COLUMBIA
www.gov.bc.ca

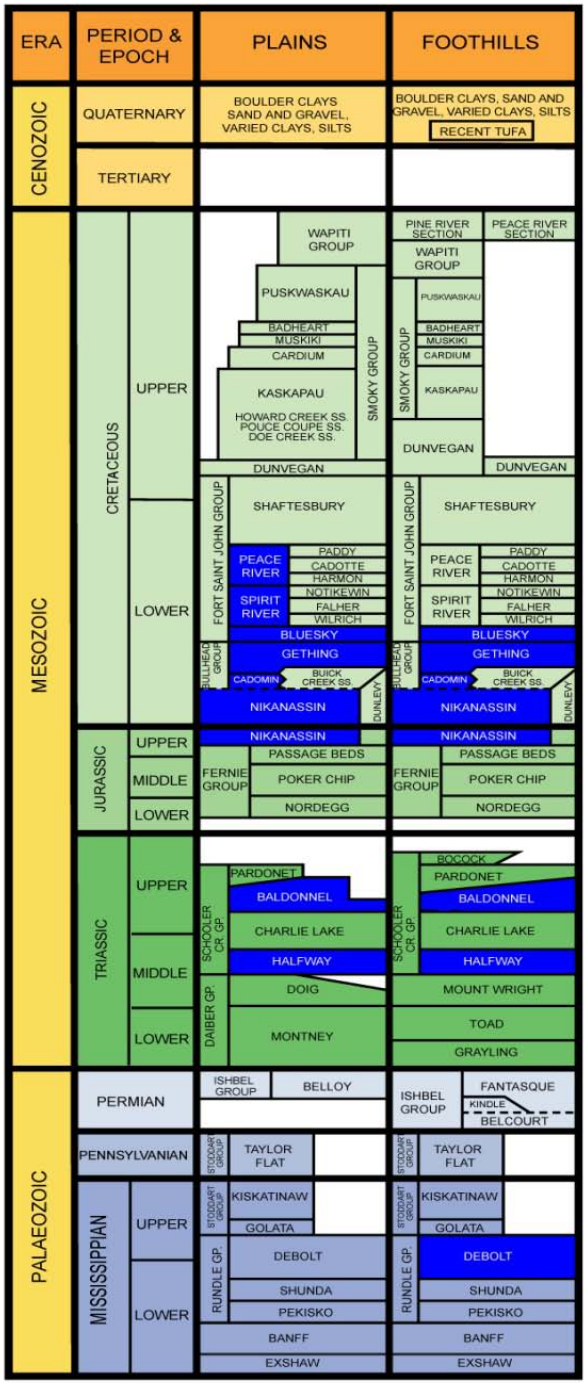
MWP – Surficial Geology and Shallow Aquifers

- Compile existing maps and databases on shallow bedrock and unconsolidated sediment cover
- Create comprehensive databases of shallow well data, identifying usage, water quality, and volumes
- Consistently identify and map shallow aquifers
- Compile all information into spatial data model

Montney Deep Aquifer Study Areas



- Montney play fairway subdivided into Plains and Foothills study areas
- Aquifer characteristics distinct in each area



Montney Deep Bedrock Aquifer Stratigraphy

- Plains – several potential aquifer zones in Lower Cretaceous and Triassic
- Foothills – less Cretaceous potential, possible Debolt carbonate aquifer?

Plains
Cadomin

- Peace River alluvial fan source area
- Deep Basin (non-aquifer) area to south
- Best aquifer potential to north and east

Plains
Bluesky

- Chamberlain Delta to south
  - Poor aquifer potential – fine-grained, Deep Basin
- Broad shoreface to north
  - Substantial aquifer potential, increasing to east

Foothills
Gething

- Confluence of Spirit River and Edmonton valley systems
  - Thick basal sands with good continuity
- Substantial aquifer potential only in southeast
  - Degradation of reservoir quality westward

Foothills
Bluesky

- Thick estuarine valley fill in northwest
  - Dominantly fine-grained, Deep Basin
- Stacked shorefaces in south
  - Some aquifer potential – good porosity, wet on logs

Deep Subsurface Aquifer Characterization

- Regionally significant aquifers mapped
  - Gross isopach, net porous reservoir, average porosity
- Test and production data assessed to characterize potential reservoir performance
  - Regional hydrogeology
  - Fluid chemistries – suitability as frac fluids
  - Model long-term productivity and injectivity rates
- Final outputs will be like Horn River Basin study

Montney Water Project - Summary

- Collaborative effort, led by Geoscience BC
  - Industry, provincial government, community support
  - Identify secure long-term water sources; minimize potential conflicts with existing water users
- Comprehensive assessment of surface, shallow groundwater, and deep saline aquifers as water sources
- Wastewater disposal – deep saline aquifers
- Alternative solutions – e.g., Shell using Dawson Creek municipal wastewater

Other Unconventional Play Areas

- Cordova Embayment
  - Devonian shale gas potential – earlier stage of development than Horn River Basin
  - More developed infrastructure, but faces similar water source and disposal issues
- Liard Basin
  - Thicker shale section with unconventional potential
  - Chinkeh tight oil play at Maxhamish
  - May be most challenging area for water – most deep subsurface aquifers have shaled out

Conclusions (1)

- Unconventional gas plays have changed the face of exploration and development in NEBC
- High-capacity water sources and safe wastewater disposal are key issues to successful development
  - Careful planning is required to identify appropriate sources and disposal sites, while minimizing environmental and community impacts
- Joint Geoscience BC and Horn River Basin Producers Group Aquifer project identified deep saline aquifers in the Horn River Basin that are now important water sources supporting the HRB shale gas play

Conclusions (2)

- Geoscience BC Montney Water Project, undertaken with support from industry, provincial government, and universities, will better define scope and potential solutions for industry water needs in the Montney play fairway
- Additional (Phase 2) work will be required in both HRB and Montney to address issues more comprehensively
- Other NEBC unconventional play areas – Liard Basin and Cordova Embayment – will face similar water issues as prospectivity is defined and development ramps up