ePSPetroleum Hydrogeology of Southwestern Saskatchewan*

Anatoly Melnik[1] and Benjamin J. Rostron[1]

Search and Discovery Article #80189 (2011)
Posted October 17, 2011

*Adapted from ePoster presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011.

Note: Update your computer's Adobe Reader to the most current version to access all audio features of this presentation. Activate audio control by clicking the icon in the upper left-hand corner of the page.

[1]Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada. (amelnik@ualberta.ca)

Abstract

Petroleum migration, geothermal energy exploration and development, assessment of favourable locations for CO2 sequestration, and groundwater management and allocation all require the knowledge of regional hydrogeology. The Government of Saskatchewan initiated a project titled Saskatchewan Phanerozoic Fluids and Petroleum Systems Assessment (SPFPS) in order to investigate the movement of fluids in the Williston Basin portion of Saskatchewan. One of its objectives is to complete hydrogeological characterization of the area. As part of this task, this study has produced a suite of hydrogeological data and maps for southwestern Saskatchewan.

Twelve major hydrostratigraphic units (aquifers) have been identified: 7 Paleozoic; 1 Jurassic; and 4 Cretaceous aged units. Pressure and chemistry data obtained from Drill Stem Tests and water analysis reports were compiled for each aquifer. These data were culled for poor quality, production-influenced pressures and contaminated chemical data to ensure that only representative values were used to produce the final maps. Processed data were used to construct Potentiometric Surface and Total Dissolved Solids (TDS) maps.

Fluid flow in all Paleozoic aquifers is directed towards the north. Fluid flow in the Jurassic aquifer (Shaunavon) is also directed generally northwards. However, there is a prominent potentiometric low spatially associated with the producing Shaunavon oil and gas pools. In contrast to the deeper units, fluid flow in the Lower Cretaceous aquifers is directed towards the east and northeast, indicating the influence of inflow from the Alberta Basin to the west. Fluid flow in the Upper Cretaceous aquifer is controlled by local topography, with flow directed away from topographic highs towards low-lying subcrop areas.

TDS values in the Paleozoic aquifers range from 5 g/L in the south to over 300 g/L in the north. In the southern part of the study area, where TDS values are relatively low (< 50 g/L), the water's chemical concentration appears to be diluted by freshwater recharge from the Montana highlands. Overlying Jurassic and Cretaceous aquifers have relatively low TDS content ranging from 5 g/L to 30 g/L.

This study will be completed by construction of fresh water and density corrected driving force (DFR) maps and representative vertical hydraulic cross-sections. The combined results will be used to produce a complete regional characterization of subsurface fluid flow in southwestern Saskatchewan.

Reference

Hubbert, M. K., 1953, Entrapment of petroleum under hydrodynamic conditions: AAPG Bulletin, v. 37, p. 1954-2026.

click for audio

PETROLEUM HYDROGEOLOGY OF SOUTHWESTERN SASKATCHEWAN

A.Melnik and B.J.Rostron

click for audio

OUTLINE

1. Introduction – Project Overview
2. Geology and Hydrostratigraphy
3. Data Collection and Analysis
4. Results – Maps
5. Results – Cross-Sections
6. Applications: Case Study
7. Summary

click for audio

INTRODUCTION

The Project

Saskatchewan Phanerozoic Fluids and Petroleum Systems assessment

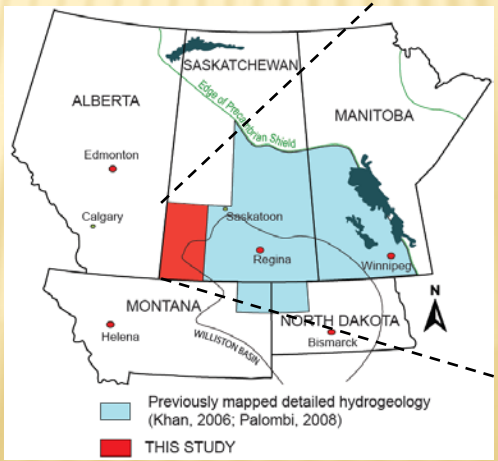
Study Objectives

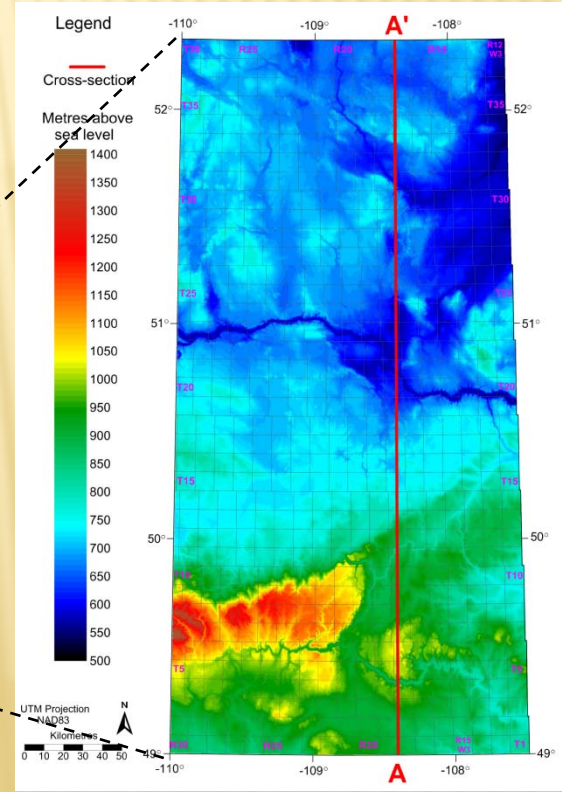
1. Detailed hydrogeologic characterization
2. Density-dependent flow
3. Hydrocarbon migration and entrapment

Applications

1. Petroleum exploration
2. CO2 sequestration
3. Groundwater management

Study Area





click for audio

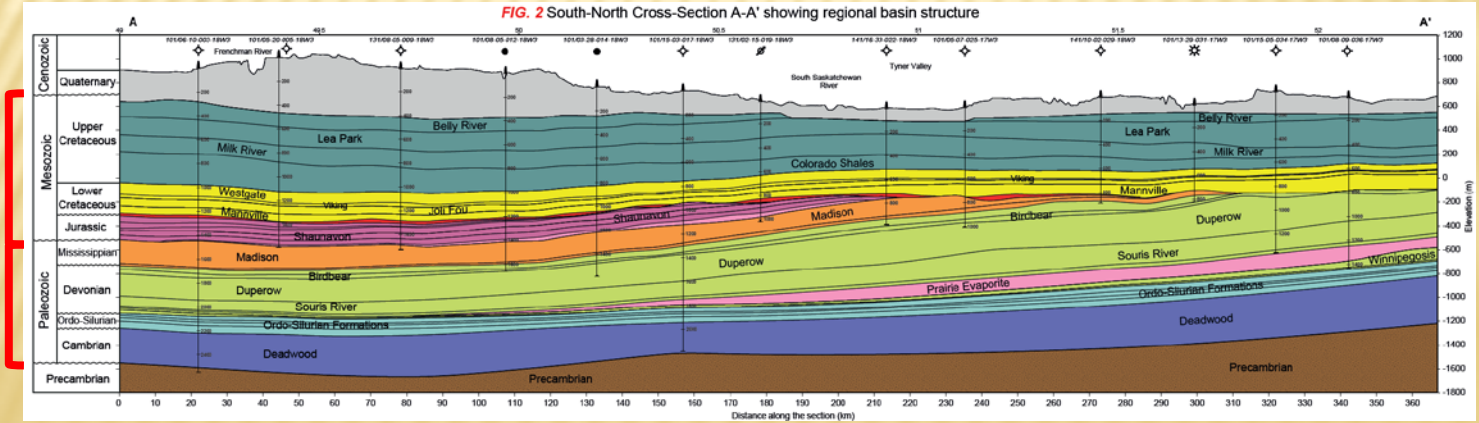
GEOLOGY – BRIEF SUMMARY

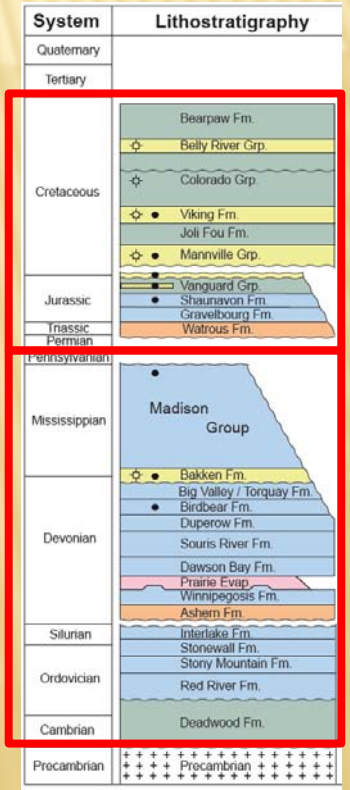
Paleozoic

- **Carbonate** and **evaporite** dominated sequences with minor siliciclastics.
- Dipping towards the south/southeast (Williston Basin center)

Mesozoic

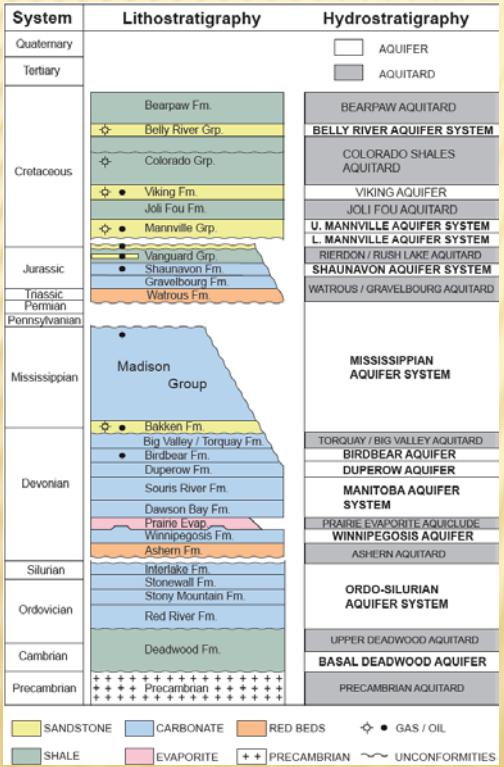
- **Siliclastic** rocks with several carbonate formations in Jurassic.
- Dipping towards the south
- Truncating Paleozoic sediments





click for audio

HYDROSTRATIGRAPHY



Upper Cretaceous

Lower Cretaceous

Jurassic

Mississippian

Lower Paleozoic

→ *Detailed Hydrostratigraphy*

Based on

1. Geology (SMER)
2. New data
3. Previous studies

→ *Aquifer Groups - Summary*

- Lower Paleozoic – 6 Aquifers
- Mississippian – 1 Aquifer
- Jurassic – 1 Aquifer
- Lower Cretaceous – 3 Aquifers
- Upper Cretaceous – 1 Aquifer

Total of 12 aquifers

click for audio

DATA COLLECTION AND ANALYSIS

Data Types

1. Formation **pressures** from Drill Stem Tests (DSTs)
2. Water **chemistry** reports

Data Collection

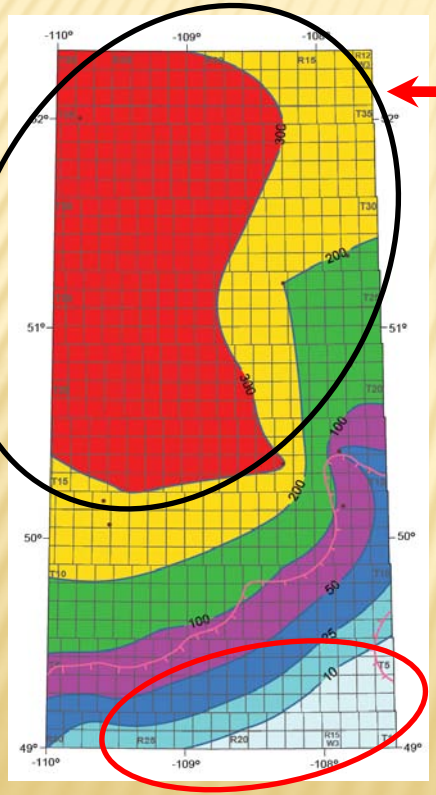
1. Exported data from commercial databases
2. **QUALITY CONTROL**

Data Analysis

1. **Total Dissolved Solids (TDS)** and water density.
2. Freshwater **hydraulic head** (potential)
3. Density-dependent **Water Driving Forces (WDFs)**

RESULTS - MAPS

Lower Paleozoic – Winnipegosis Aquifer

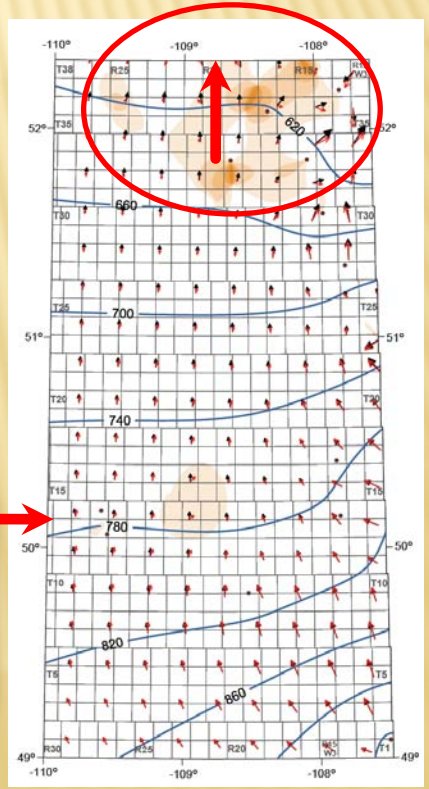


TDS (Salinity)

- Low TDS in the south (<10 g/L)
- Very high TDS in the central and northern areas (>300 g/L)
- Spatial correlation to Prairie Evaporite edge

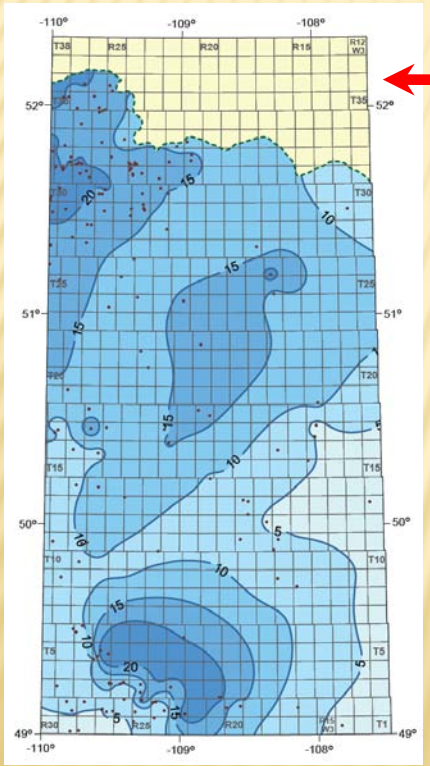
Fluid Flow

- Flow towards the north
- Low gradients
- Significant density effects



RESULTS - MAPS

Mississippian – Mississippian Aquifer

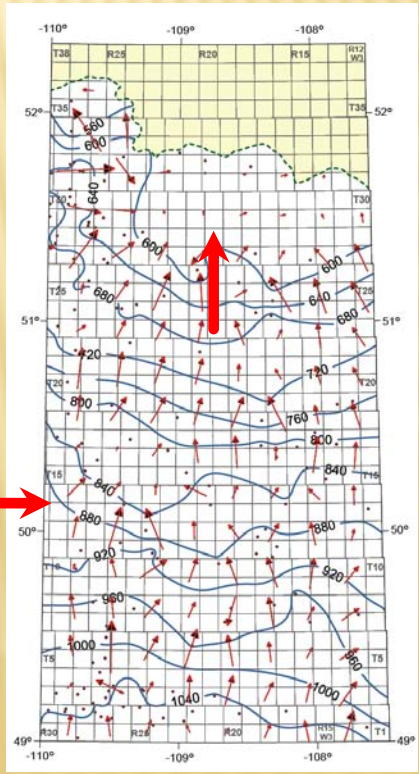


TDS (Salinity)

- Generally low TDS throughout the area (<30 g/L)

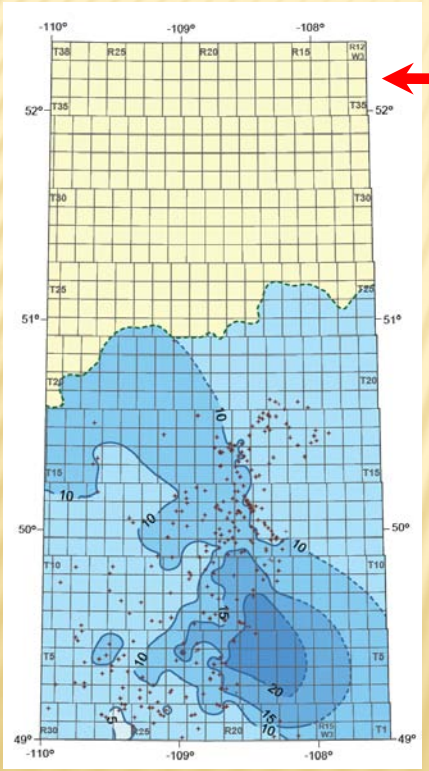
Fluid Flow

- Flow towards the north
- Very high gradients (active flow)
- No density effects



RESULTS - MAPS

Jurassic – Shaunavon Aquifer

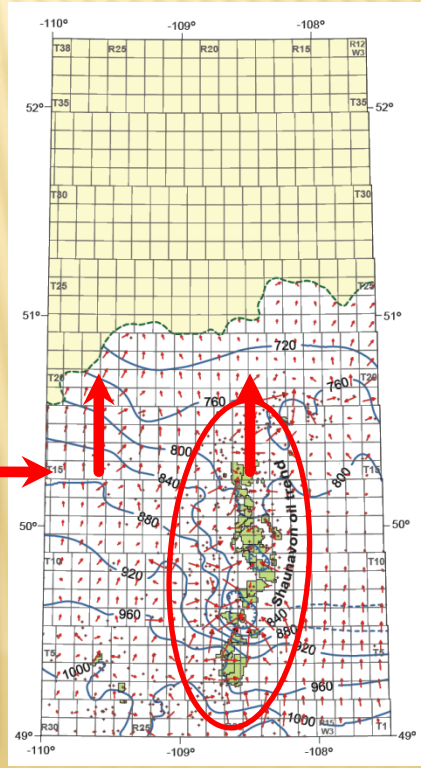


TDS (Salinity)

- Generally low TDS throughout the area (<20 g/L)

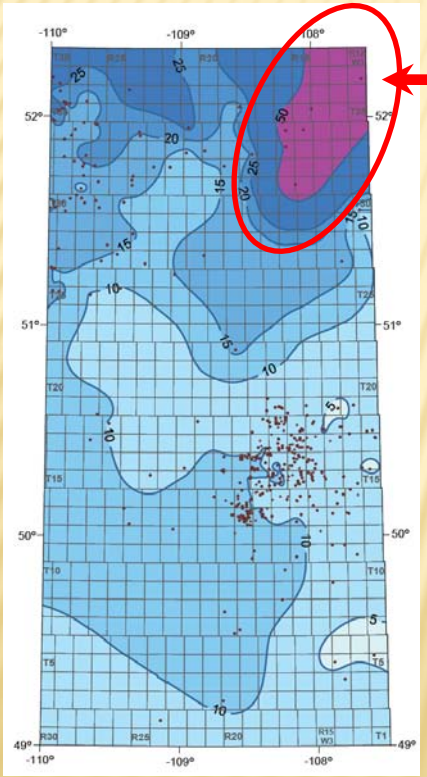
Fluid Flow

- Flow towards the north
- Large potentiometric low (sink) in central area
- Very high gradients (active flow)
- No density effects



RESULTS - MAPS

Lower Cretaceous – Lower Mannville Aquifer

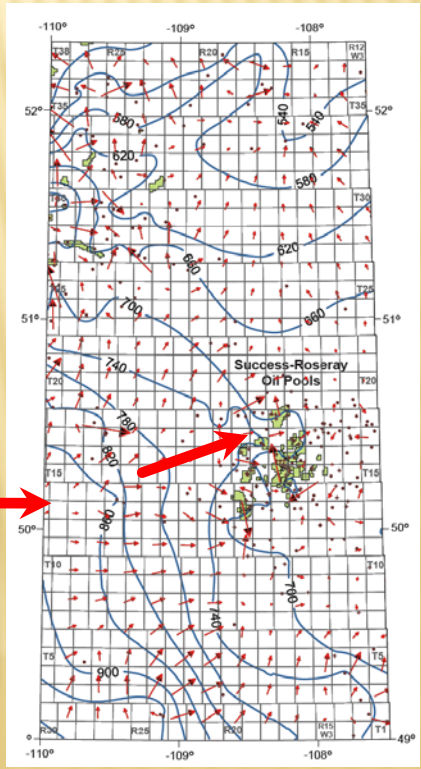


TDS (Salinity)

- Generally low TDS throughout the area (<25 g/L)
- Relatively high TDS in the north (>50 g/L):
- Cross-formational flow from Paleozoic aquifers

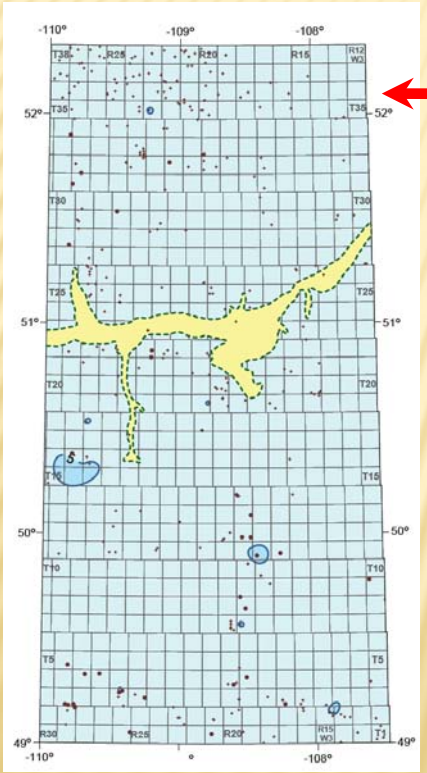
Fluid Flow

- Flow towards the east/northeast
- Moderate rates
- No density effects



RESULTS - MAPS

Upper Cretaceous – Belly River Aquifer

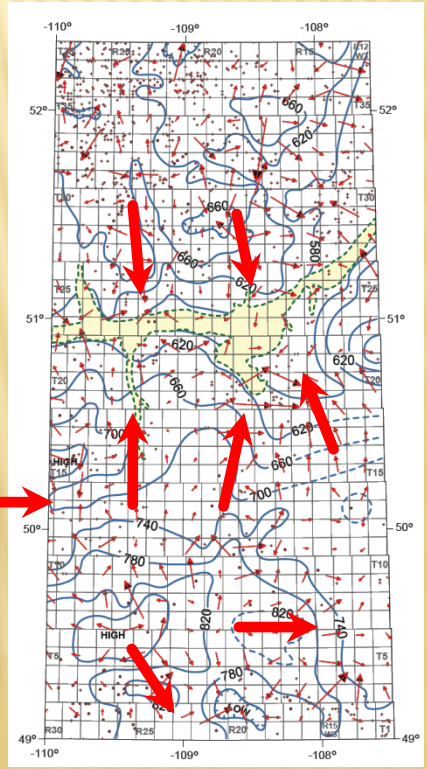


TDS (Salinity)

- Very low TDS (<5 g/L)

Fluid Flow

- Topographically controlled flow on a local scale
- Variable flow rates

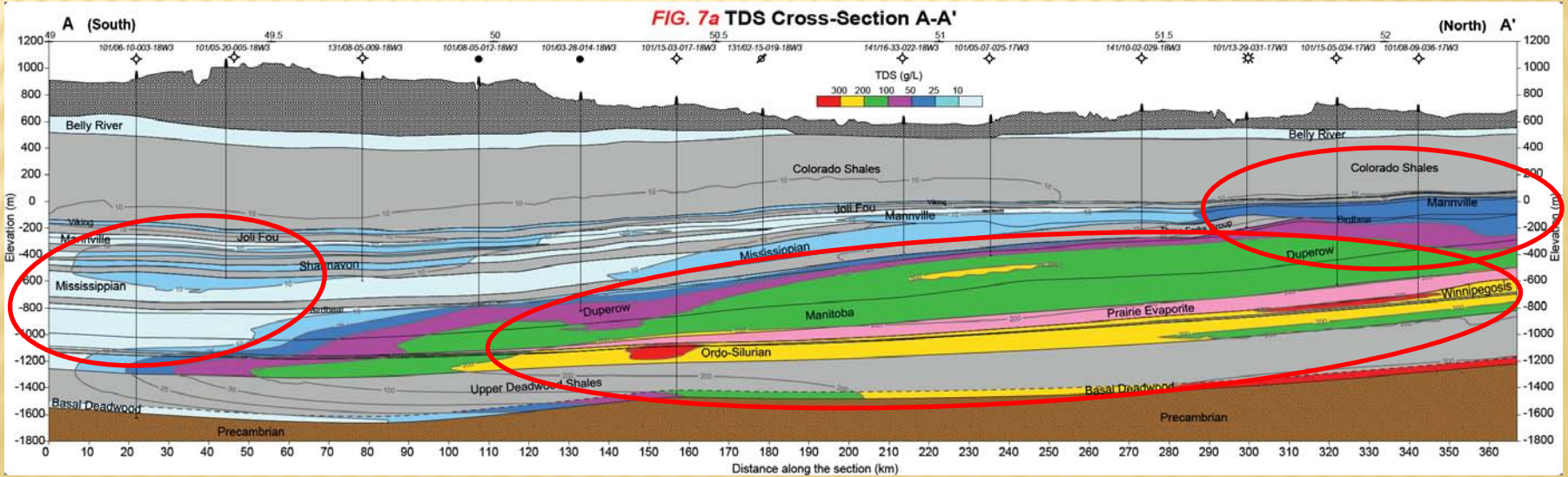


click for audio

RESULTS – CROSS-SECTIONS

TDS (Salinity)

- Freshwater input from south (<10 g/L)
- High TDS in Paleozoic formations adjacent to Prairie Evaporite
- Moderately high TDS in Mesozoic aquifers in the north: Cross-formational flow/mixing

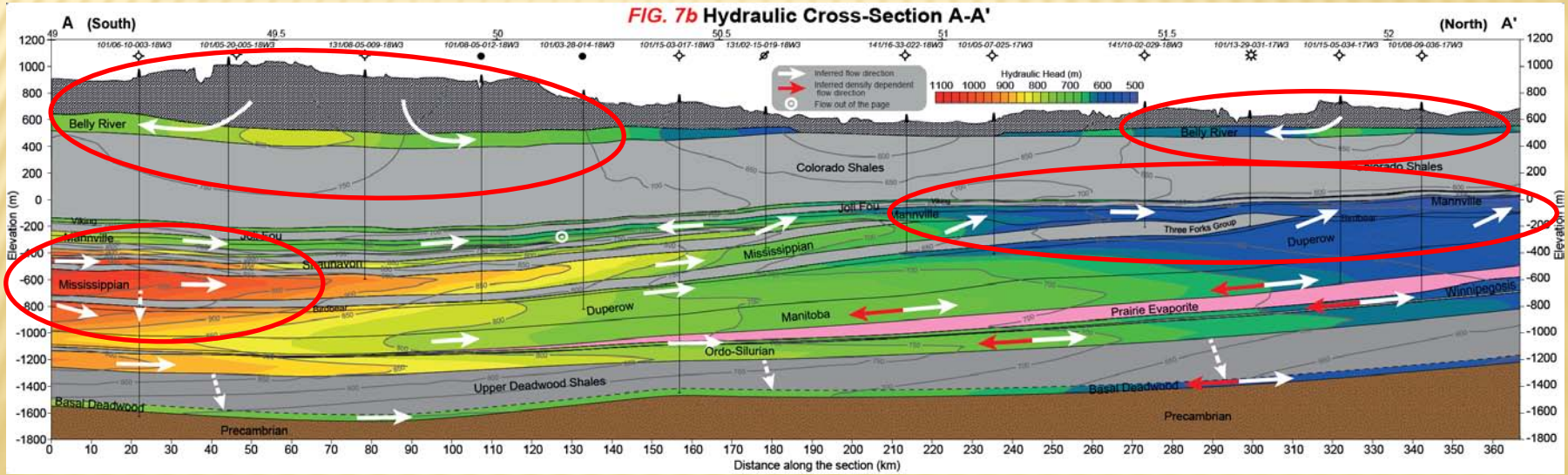


click for audio

RESULTS – CROSS-SECTIONS

Fluid Flow

- Flow is generally towards the north
- Highest hydraulic heads are observed in the Mississippian Aquifer (South)
- Paleozoic units discharge fluids into Lower Cretaceous Aquifers (North)
- Topography controlled flow in Upper Cretaceous Belly River Aquifer.



click for audio

APPLICATIONS

CASE STUDY: Hydrodynamic Entrapment in Shaunavon Formation

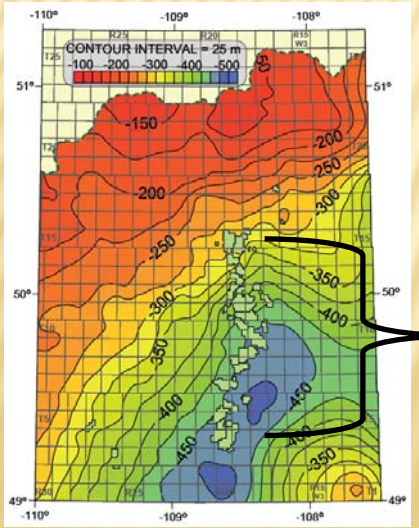
Shaunavon Formation (Jurassic)

- Carbonate cemented sandstones and shales
- Medium-heavy crude trapped along "Shaunavon Oil Trend"

Hydrodynamics

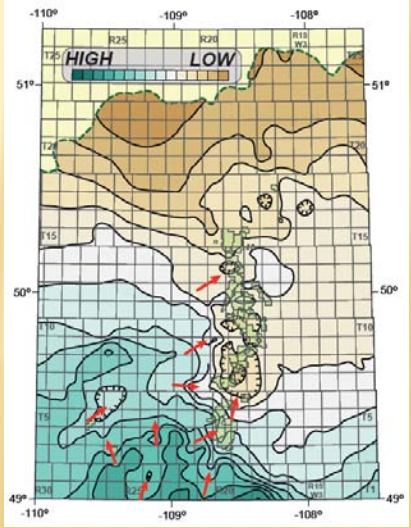
- UVZ method – Hubbert, 1953
- Shaunavon oil is trapped hydrodynamically
- Oil has migrated from south

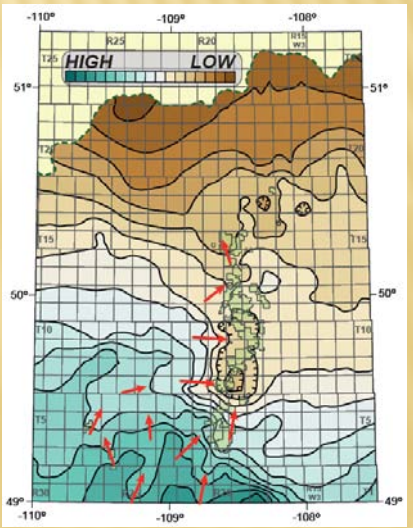
Shaunavon Structure Map



Oil is trapped DOWNDIP

22° API Oil Potential Maps 35° API





click for audio

SUMMARY

1. Twelve major aquifers or aquifer systems have been identified for southwestern Saskatchewan.
2. Lower Paleozoic aquifers have a wide range of TDS values; more than 300 g/L where Prairie Evaporite Formation is present. Mississippian and all Mesozoic aquifers have low TDS values; less than 30 g/L.
3. Fluid flow in Paleozoic and Jurassic aquifers is generally towards the north. Fluid flow in Lower Cretaceous aquifers in towards east and northeast. Upper Cretaceous aquifer has local scale topographically driven flow from high to low elevation areas.
4. Significant density-related flow effects are present in Lower Paleozoic aquifers.
5. Hydrodynamic trapping conditions have been identified in Shaunavon and other aquifers.

Reference
Hubbert, M. K., 1953. Entrapment of petroleum under hydrodynamic conditions. American Association of Petroleum Geologists Bulletin, v. 37, p. 1954-2026.

click for audio

THANK YOU FOR ATTENTION

- Questions?
  - Contact Information
  - Anatoly Melnik: amelnik@ualberta.ca
  - Benjamin Rostron: ben.rostron@ualberta.ca