Mapping Formation-Top Offsets in Southwest Alberta: Methodology and Results

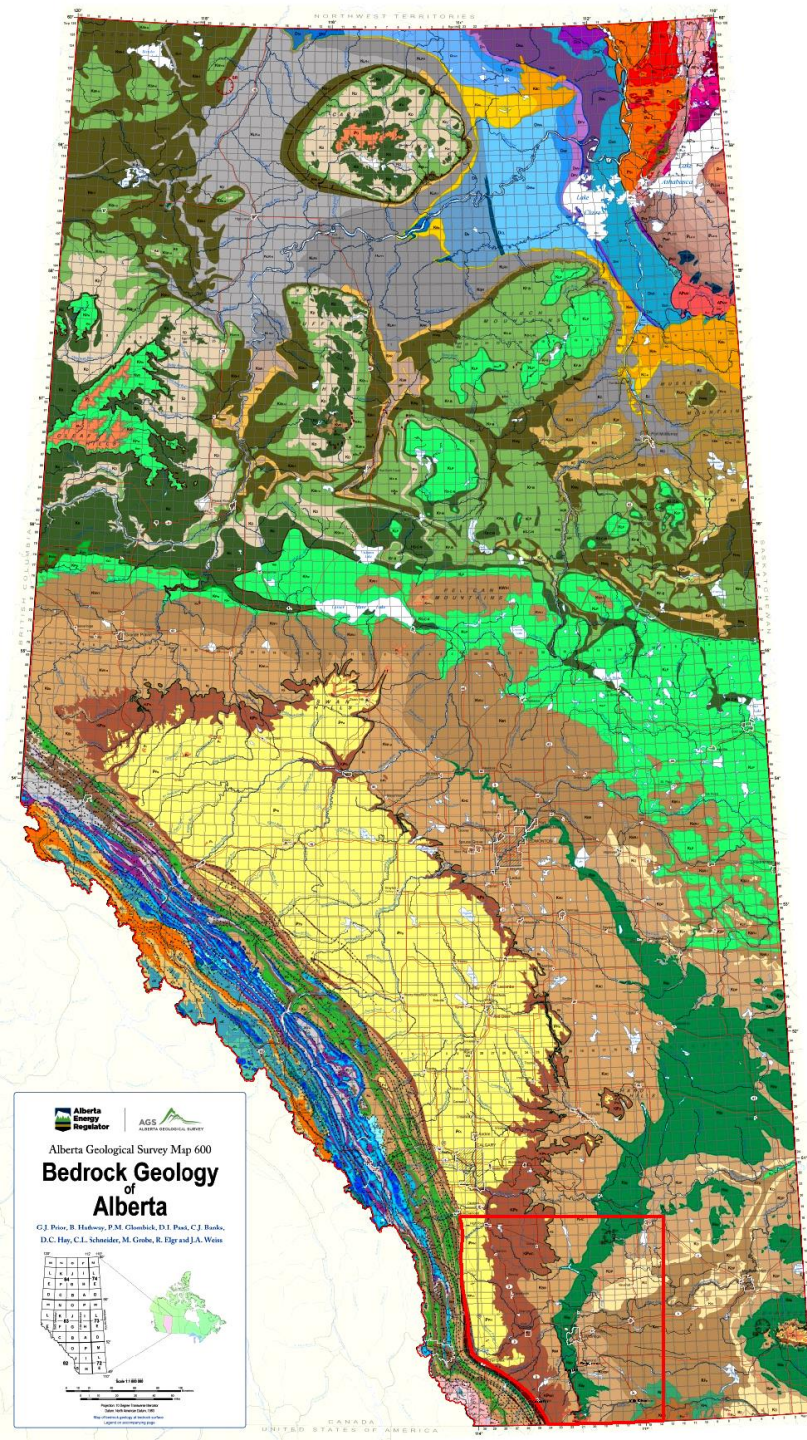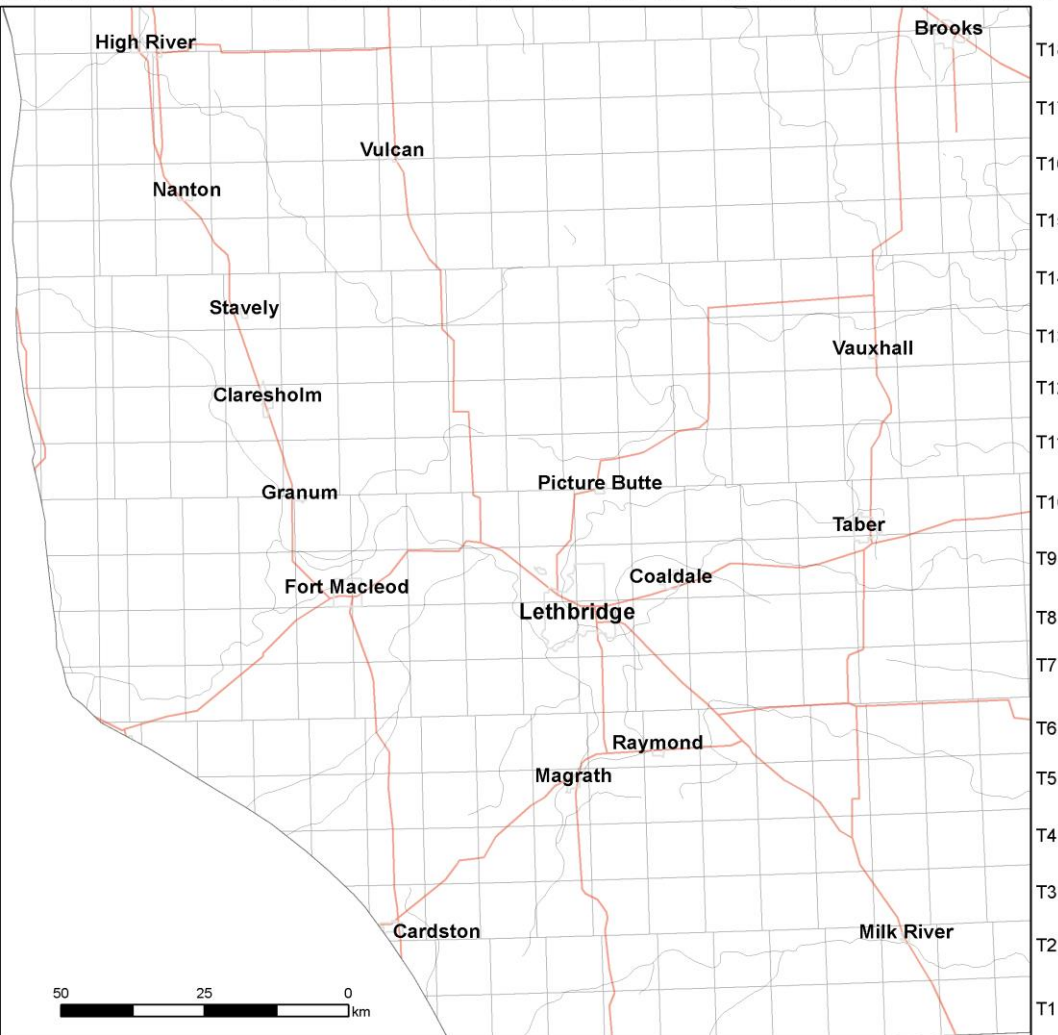**Shilong Mei, Dinu Pana and Ryan Schultz**

May 4, 2015

Outline

- **Introduction**

- **Data and Error**

- **Methodology**

  - **Quality Control**

  - **Refined Trend Surface Analysis**

- **Results**

Study Area

Study Area

(from Jerzykiewicz, 1997)

What is a Formation-Top Offset ?

- Defined as any vertical displacement of a formation top that can be detected using well log data and/or geostatistical analysis

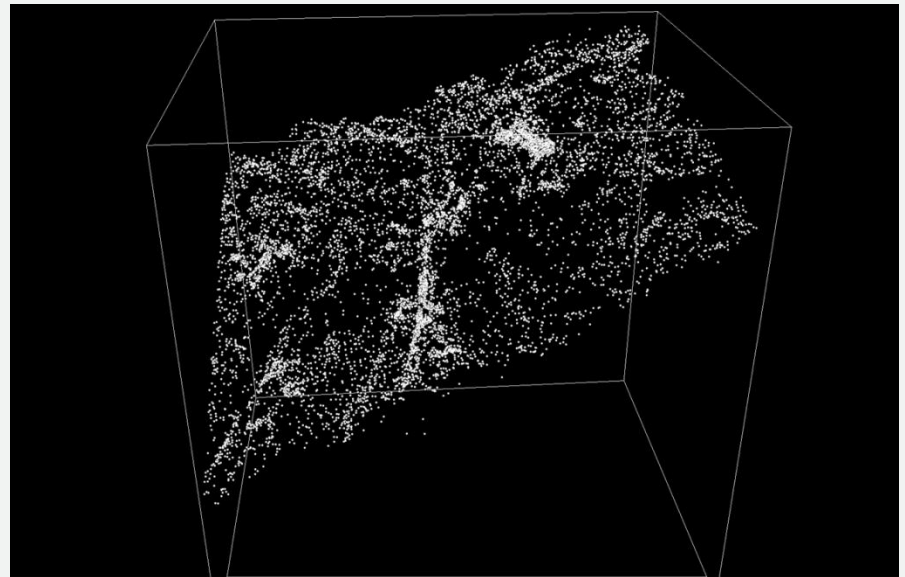- Represents local structures, e.g., faults, when confirmed

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What are contained in the data?

- Data used are formation-top picks

- All picks available are used; the more the better

- Data contains:
    - Trend
    - Errors
    - Structures

- Trend dominates the interpolated surface

- Erroneous data mask or blur local structures

- Both trend and error need to be reduced so as to highlight local structures
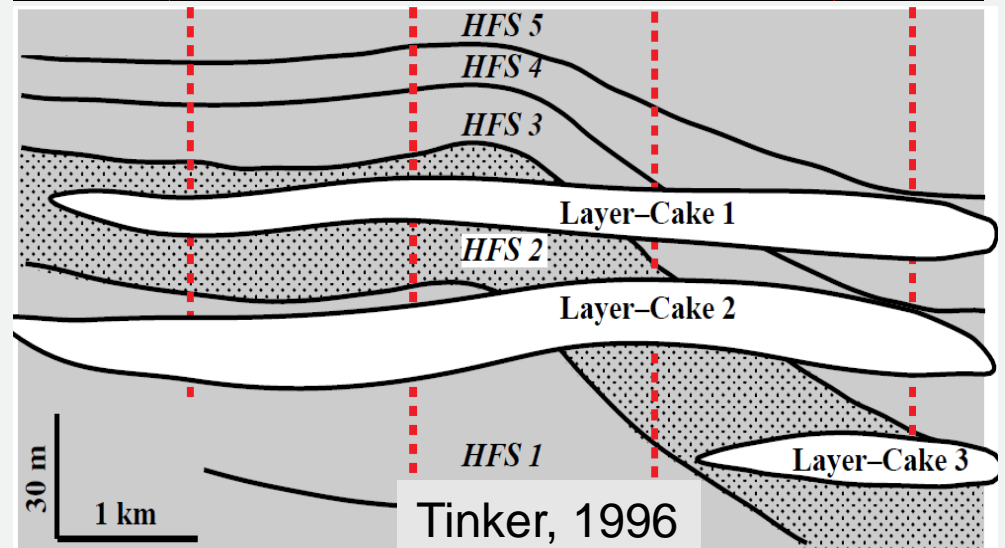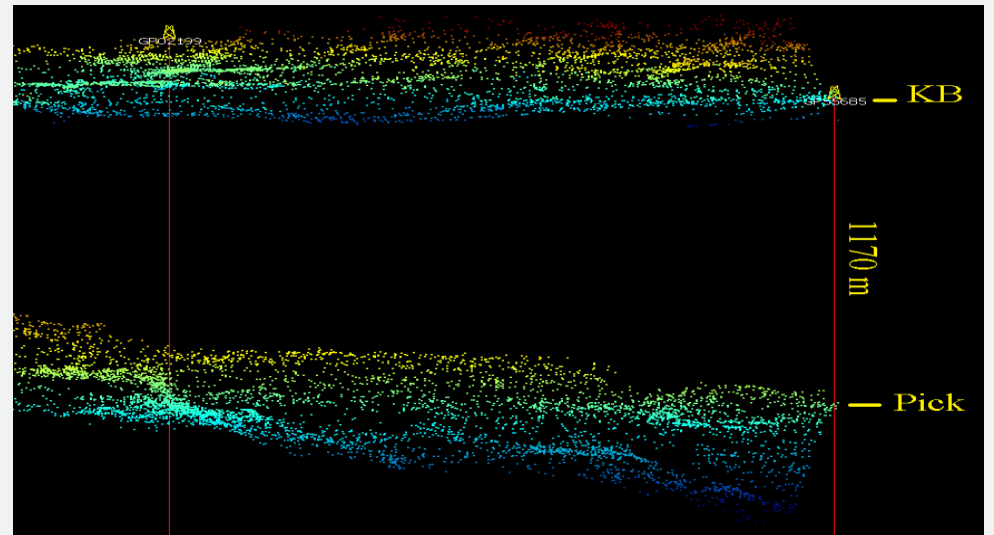

Data, data error/uncertainty and interpolation

What are the sources of error in the data?

Error in Formation-Top Picks

- Error in KB

- Mixing of vertical and deviated wells (without survey data)

- Error in picking (e.g., inconsistency)

- Other errors: data entry mistakes, incorrect well log calibration, etc.

Tinker, 1996

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What is the methodology trying to achieve ?

- Methods were published in

  CJES, 46(5): 309-329 (Mei, 2009)

- Data contain trend, errors and structures

- Goal is to highlight local structures:

  - **Faults**

  - **Salt dissolution structures**

  - **River valleys**

  - **Astrobleme**

- Achieved by:

  Reducing the error

  Removing the trend
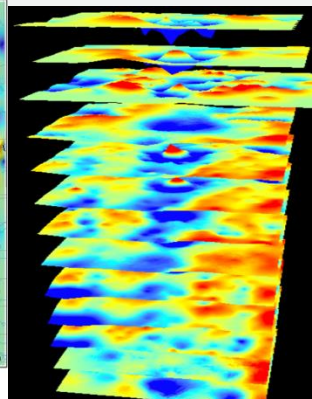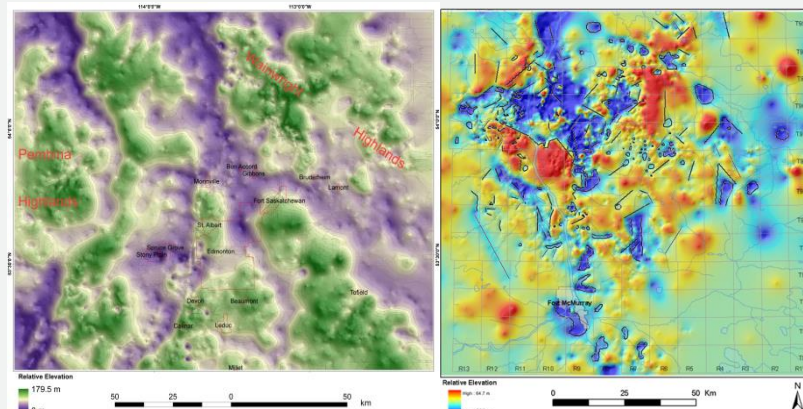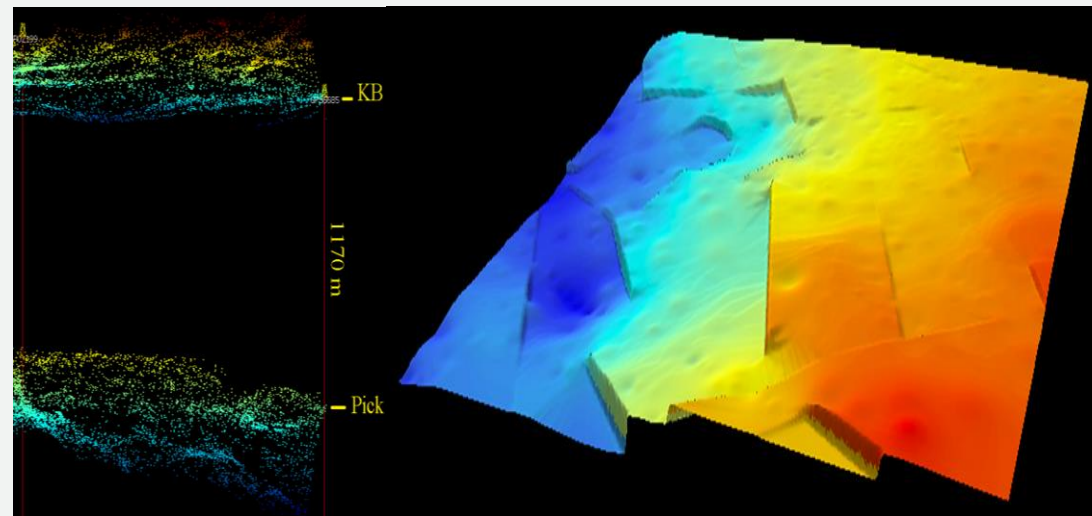
How to locate erroneous picks?
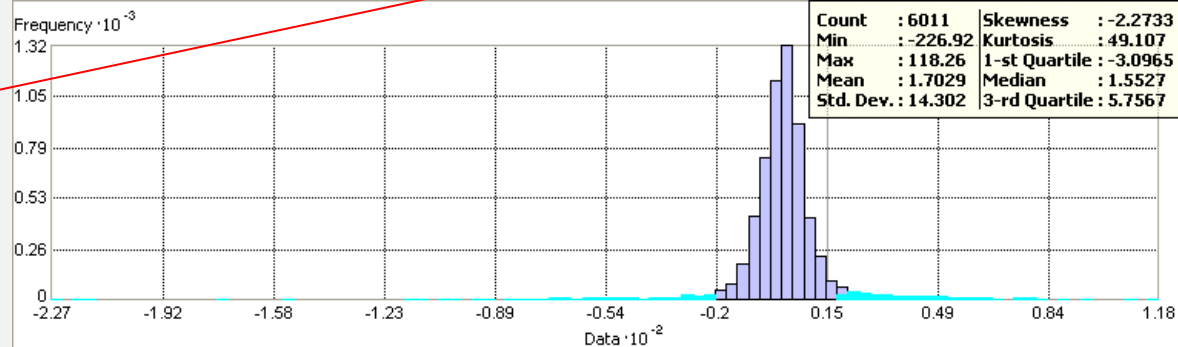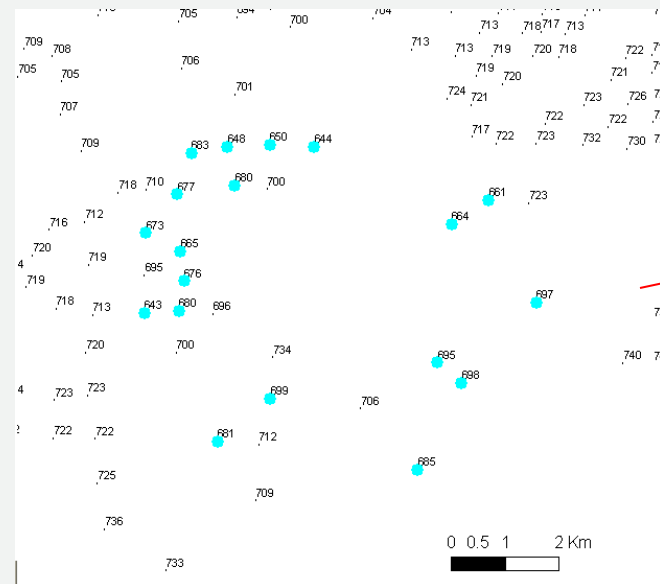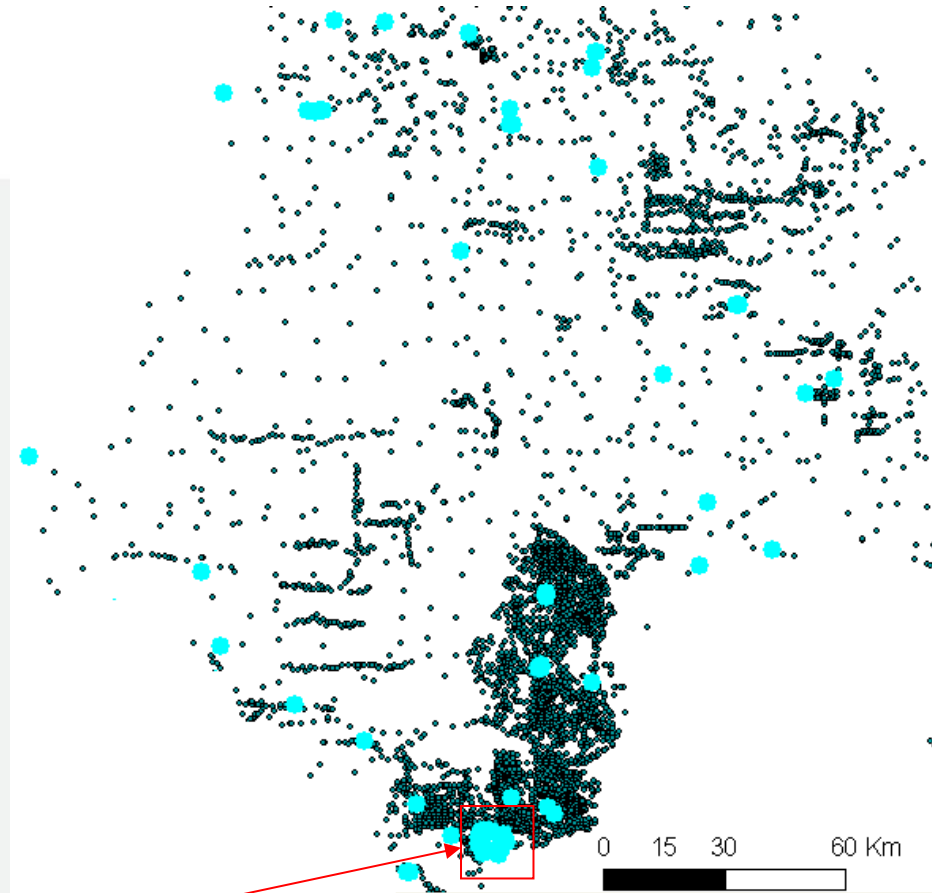

Geostatistical Outliers: deviated from expected value by more than 20m

- A local trend surface was generated around each data point using the surrounding data points

- The deviation of the data point from the local trend was calculated

- The data points with deviations larger than an expected threshold were identified as outliers
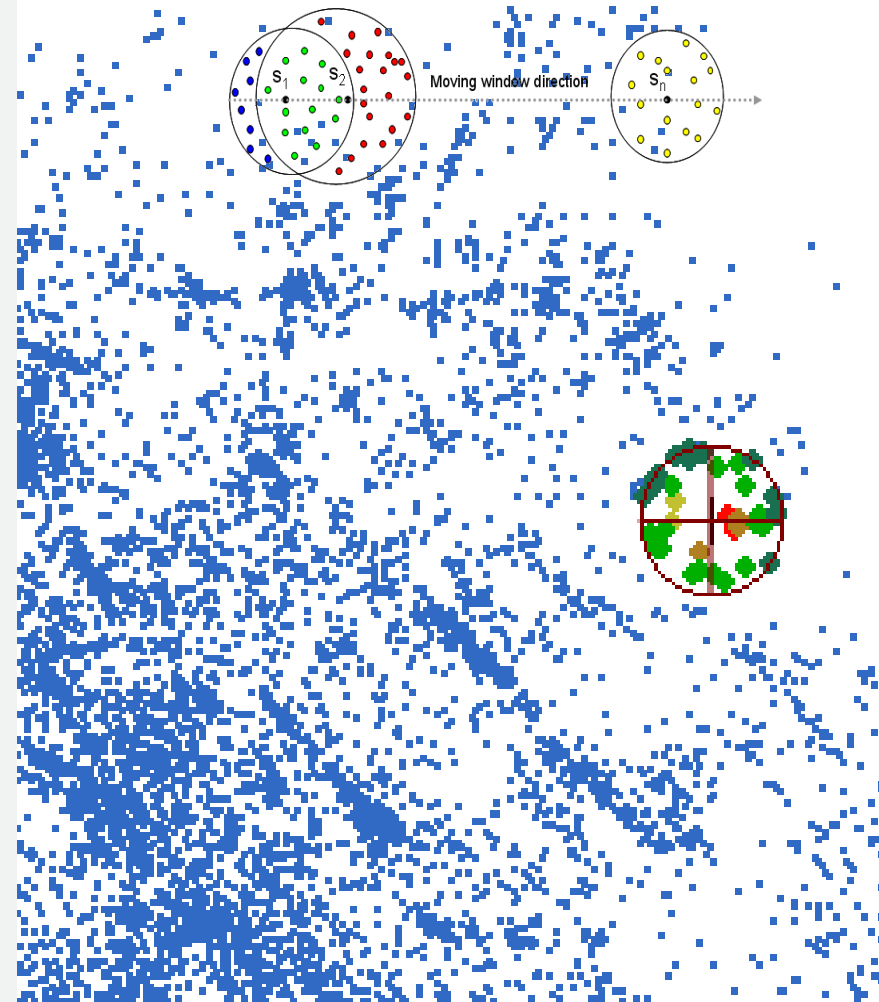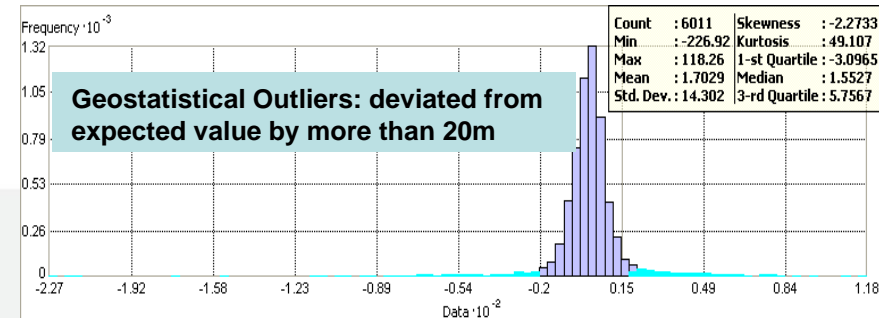
Not all outliers are erroneous picks!
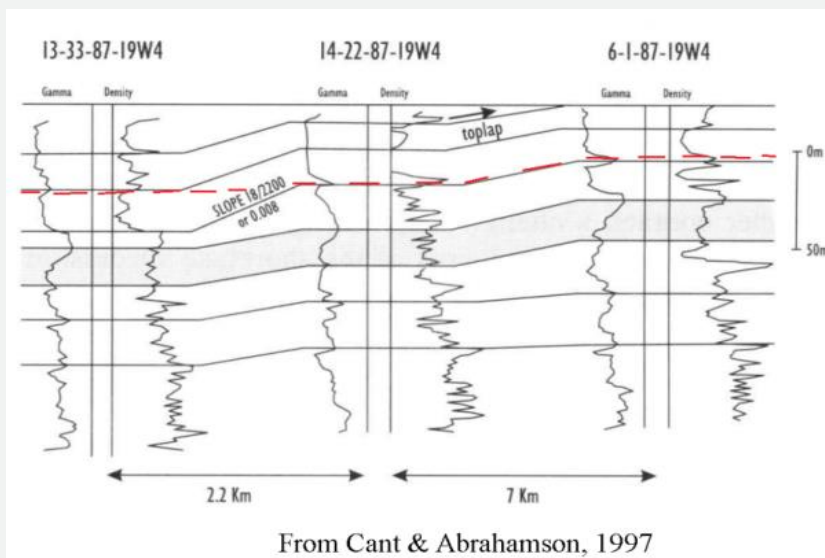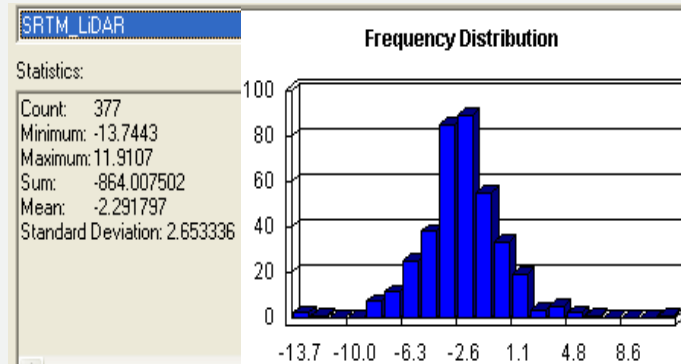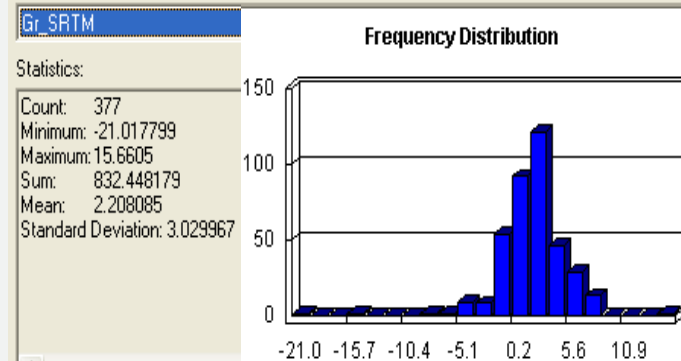
- The outliers were grouped into two categories

  - Clustered?

    - Real local structures

  - Randomly distributed?
    - errors

Count : 6011	Skewness : -2.2733	
Min : -226.92	Kurtosis : 49.107	
Max : 118.26	1-st Quartile : -3.0965	
Mean : 1.7029	Median : 1.5527	
Std. Dev. : 14.302	3-rd Quartile : 5.7567	

Geostatistical Outliers: deviated from expected value by more than 20m

How to correct erroneous picks?

- KB error
  corrected using LiDAR and SRTM DEM, offset well KBs in a flat area

- Picking error
  Re-picking using a consistent correlation model

- Error of unknown source
  Remove it!

From Cant & Abrahamson, 1997

Gr_LiDAR

Statistics:

Count: 377
Minimum: -23.862301
Maximum: 15.7373
Sum: -31.55928
Mean: -0.083712
Standard Deviation: 2.340754

Frequency Distribution

Gr_SRTM

Statistics:

Count: 377
Minimum: -21.017799
Maximum: 15.6605
Sum: 832.448179
Mean: 2.208085
Standard Deviation: 3.029967

Frequency Distribution

SRTM_LiDAR

Statistics:

Count: 377
Minimum: -13.7443
Maximum: 11.9107
Sum: -864.007502
Mean: -2.291797
Standard Deviation: 2.653336

Frequency Distribution

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Alberta
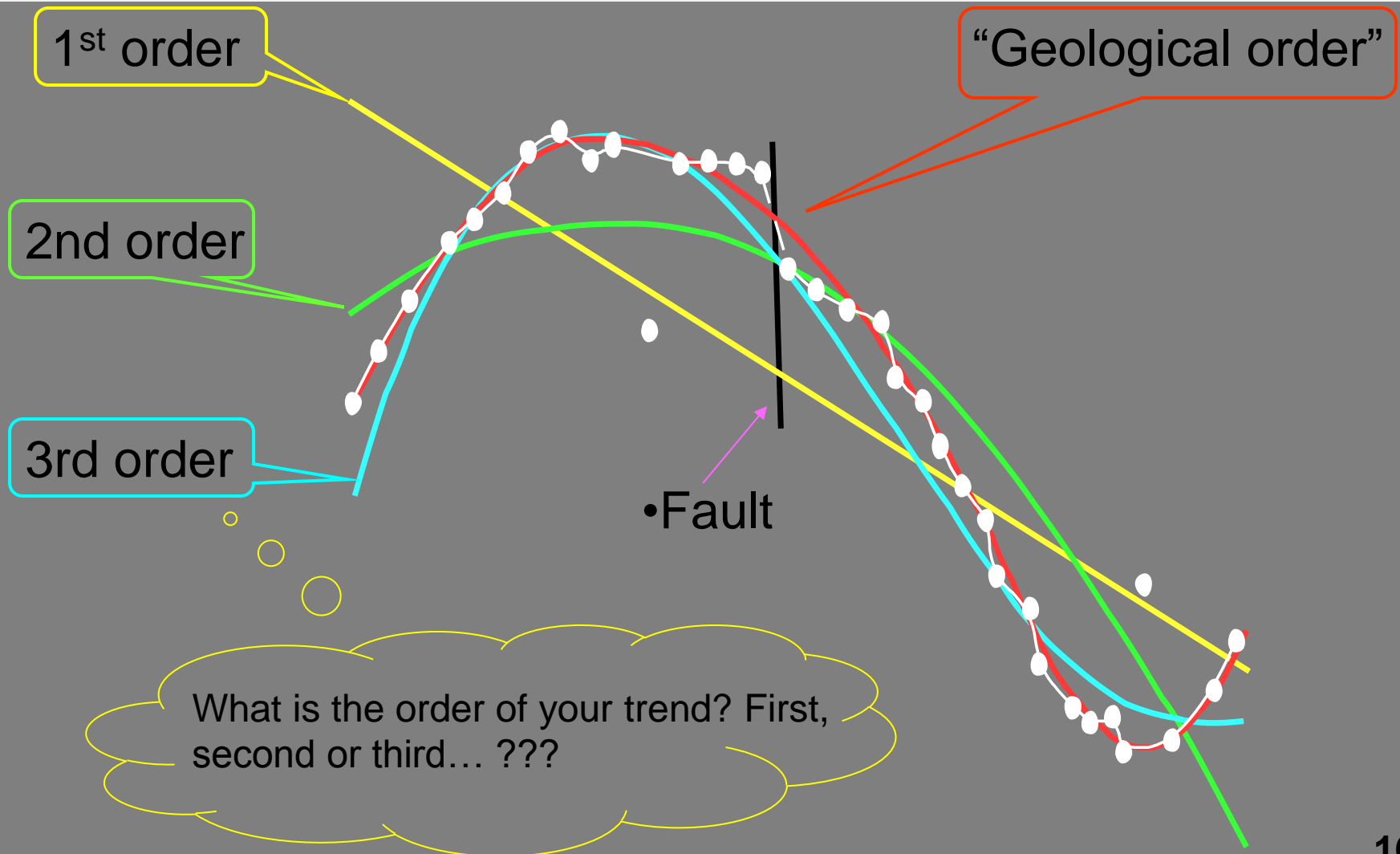Energy
Regulator

AGS
ALBERTA GEOLOGICAL SURVEY

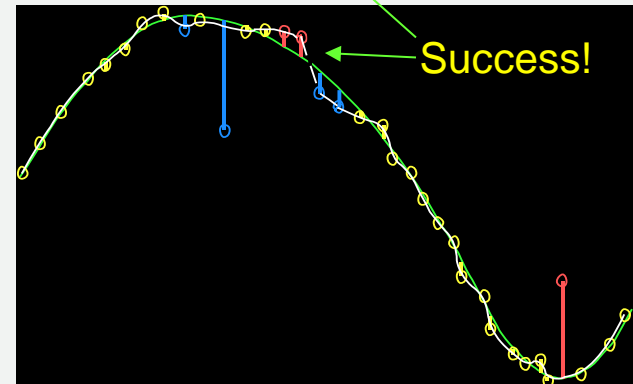# Consistently a question: How much trend needs to be removed?
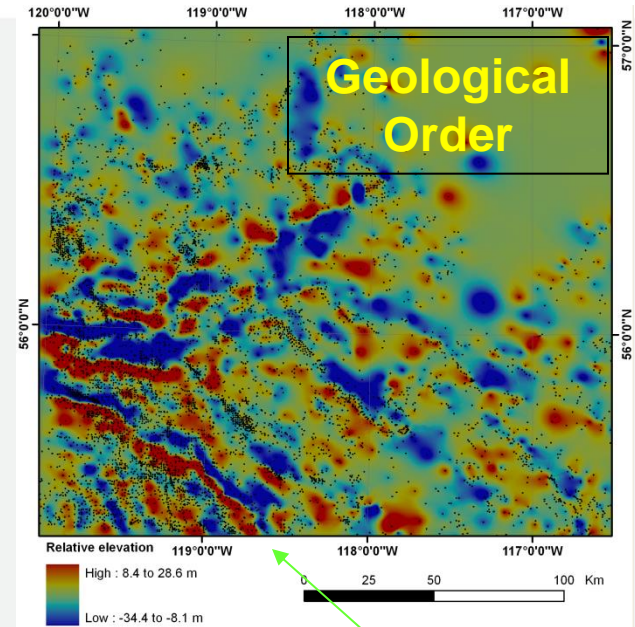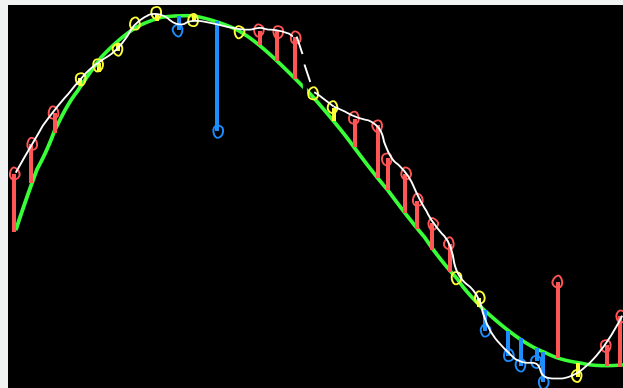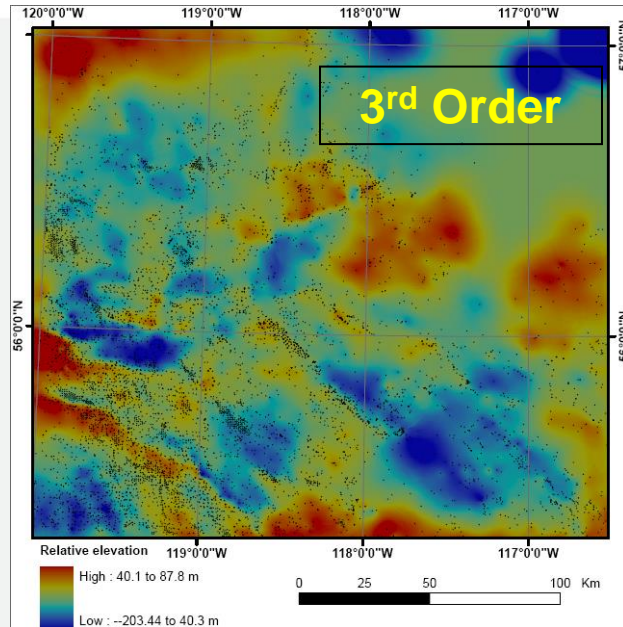
Peace River Arch example

Geological or Mathematical?
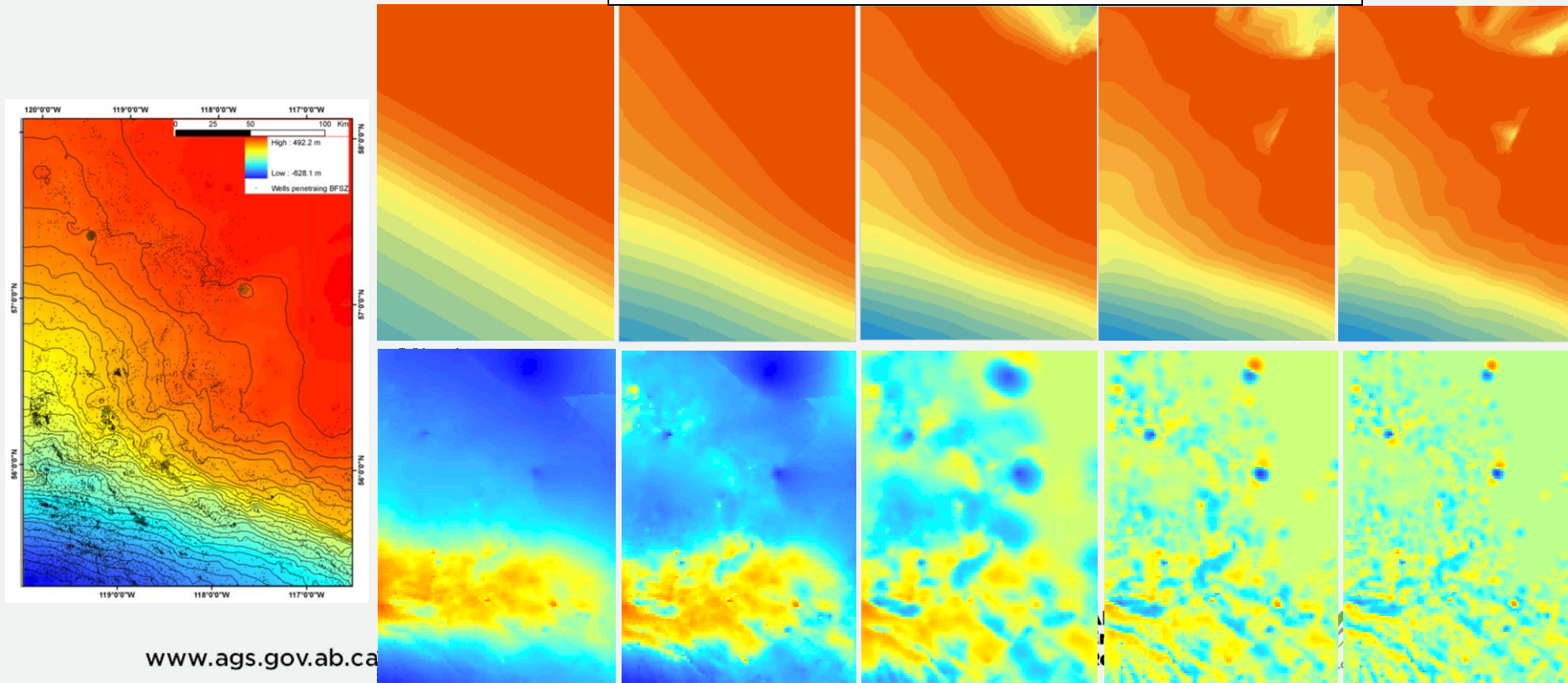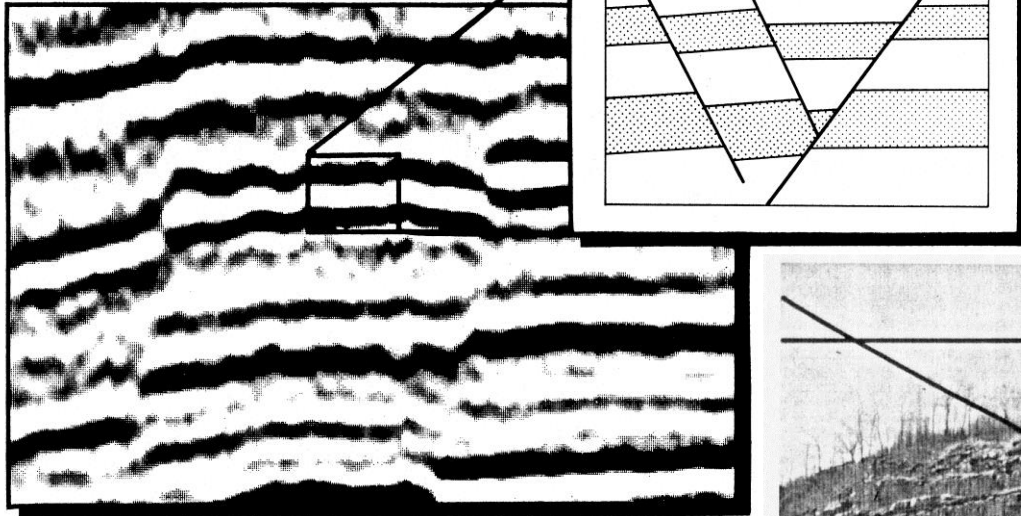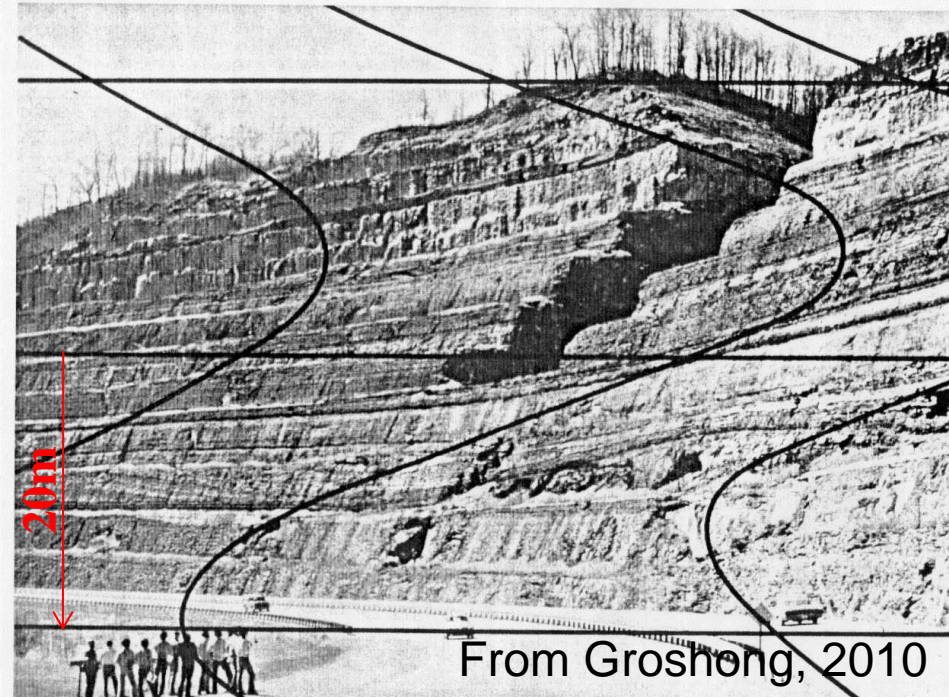
What is the order of your trend?

Comparison

Comparison with Seismic Profile

(Yielding and others, 1992)

- Highest resolution: 25m
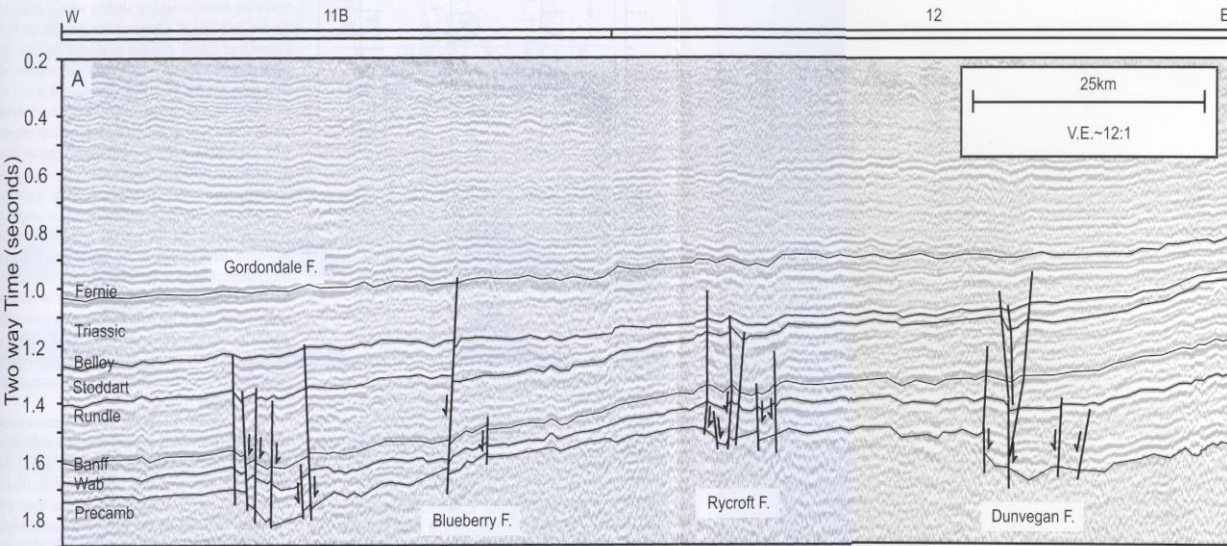
- Offsets detectable: >50m

From Groshong, 2010

20m

Scale of a typical seismic wave form as compared to an outcrop (based on an idea from A.E. Pallister and A. E. Wren)
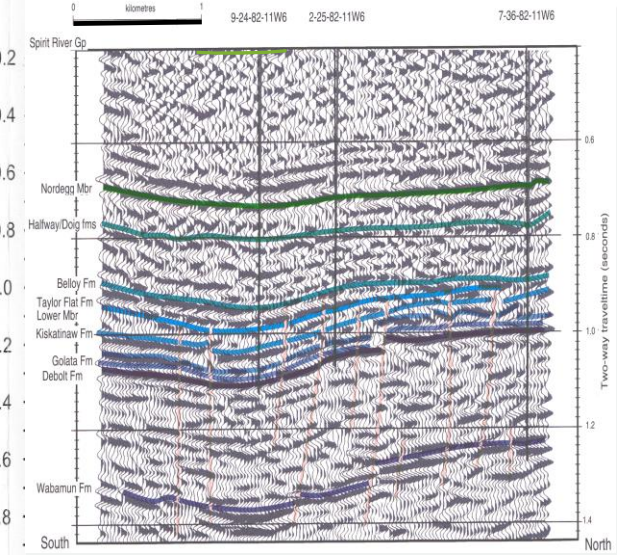
Comparison with Seismic Profile
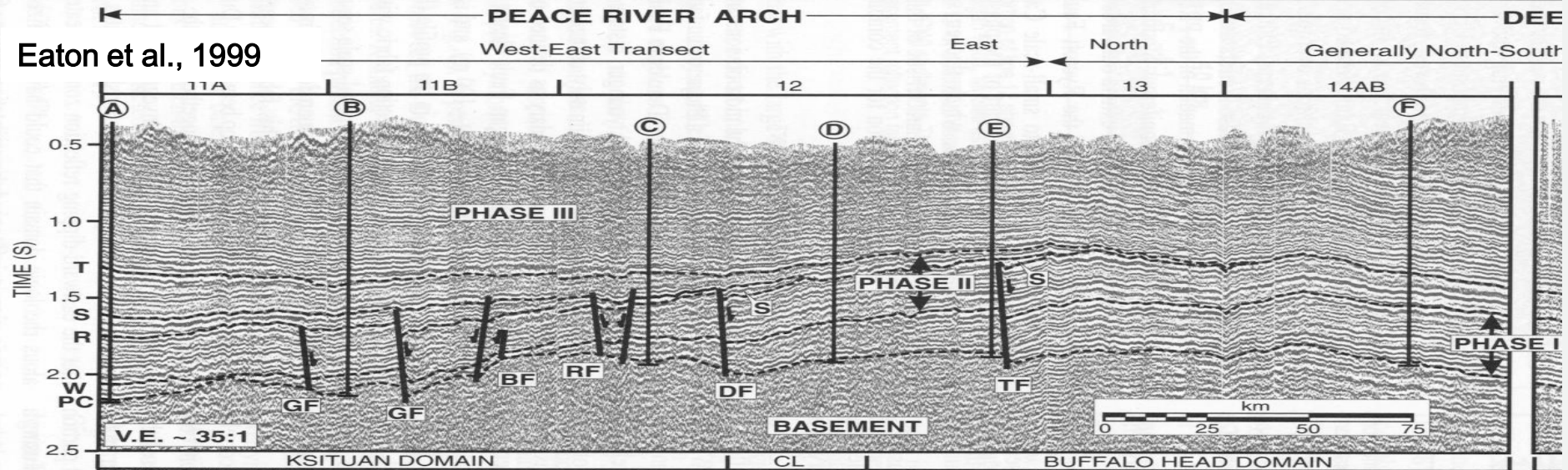## Do these faults extend into Cretaceous?

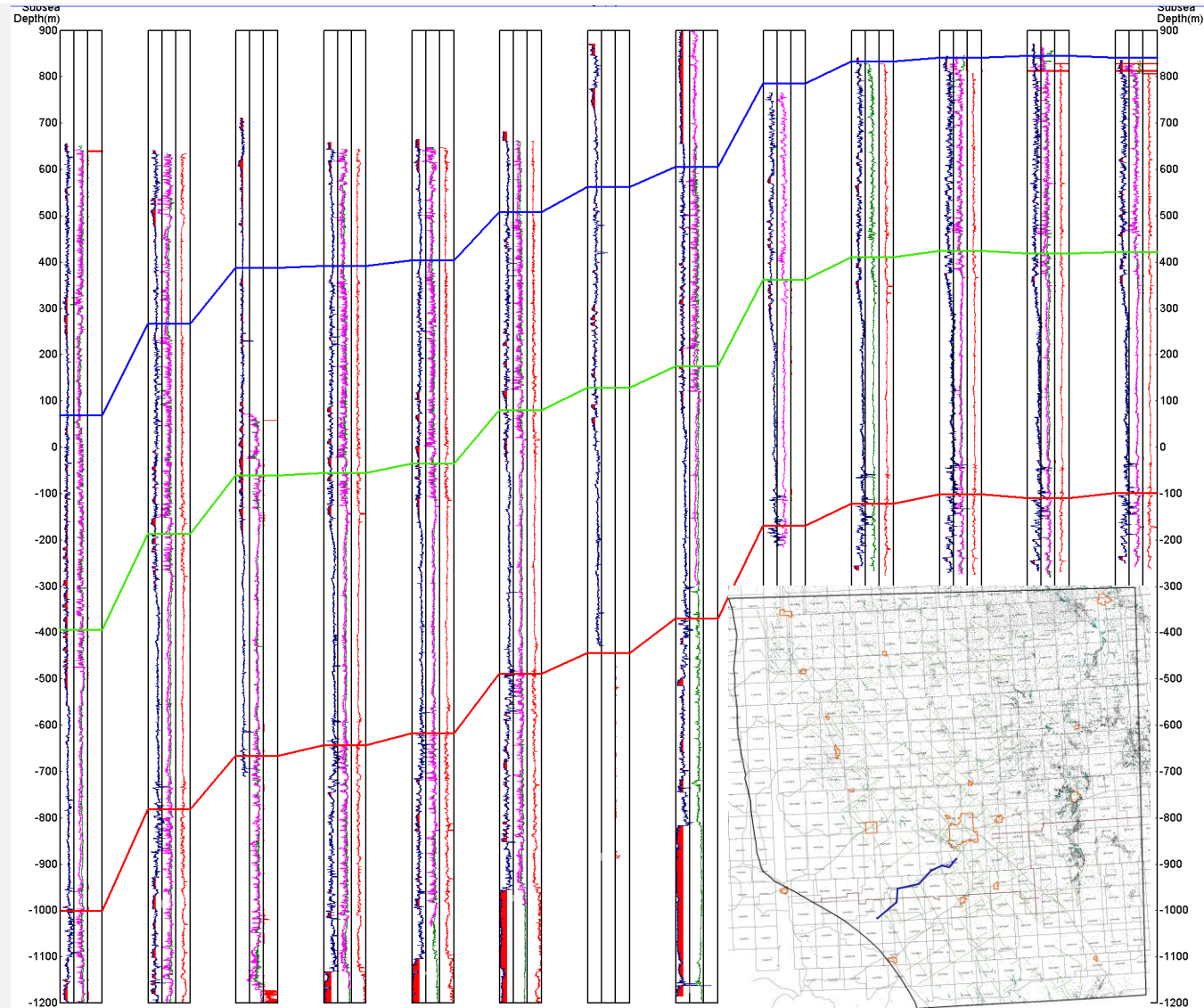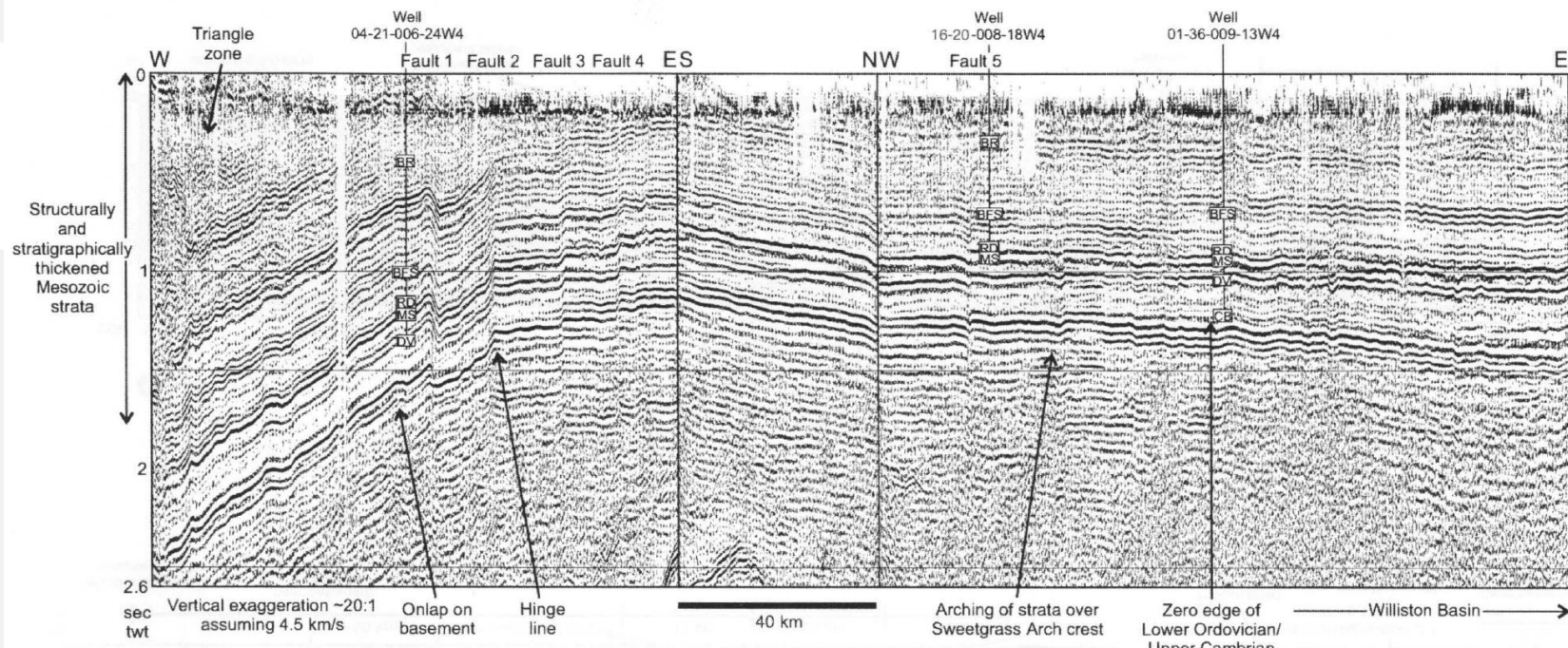Hope et al., 1999

Richards et al., 1994

Eaton et al., 1999

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What are the three Formation-tops used ?

Formation-top	Total picks	#/per TWP
Lower Bearpaw Flooding Surface	4480	1-190
Milk River	9591	1-370
BFSZ	17553	1-467

SALT Line 30   SALT Line 29   SALT Line 31

Well
04-21-006-24W4

Well
16-20-008-18W4

Well
01-36-009-13W4

Triangle
zone

W

Fault 1 Fault 2 Fault 3 Fault 4   ES   NW   Fault 5   E

Structurally
and
stratigraphically
thickened
Mesozoic
strata

Vertical exaggeration ~20:1
assuming 4.5 km/s

Onlap on
basement

Hinge
line

40 km

Arching of strata over
Sweetgrass Arch crest

Zero edge of
Lower Ordovician/
Upper Cambrian

Williston Basin

**Complementary
to seismic line**

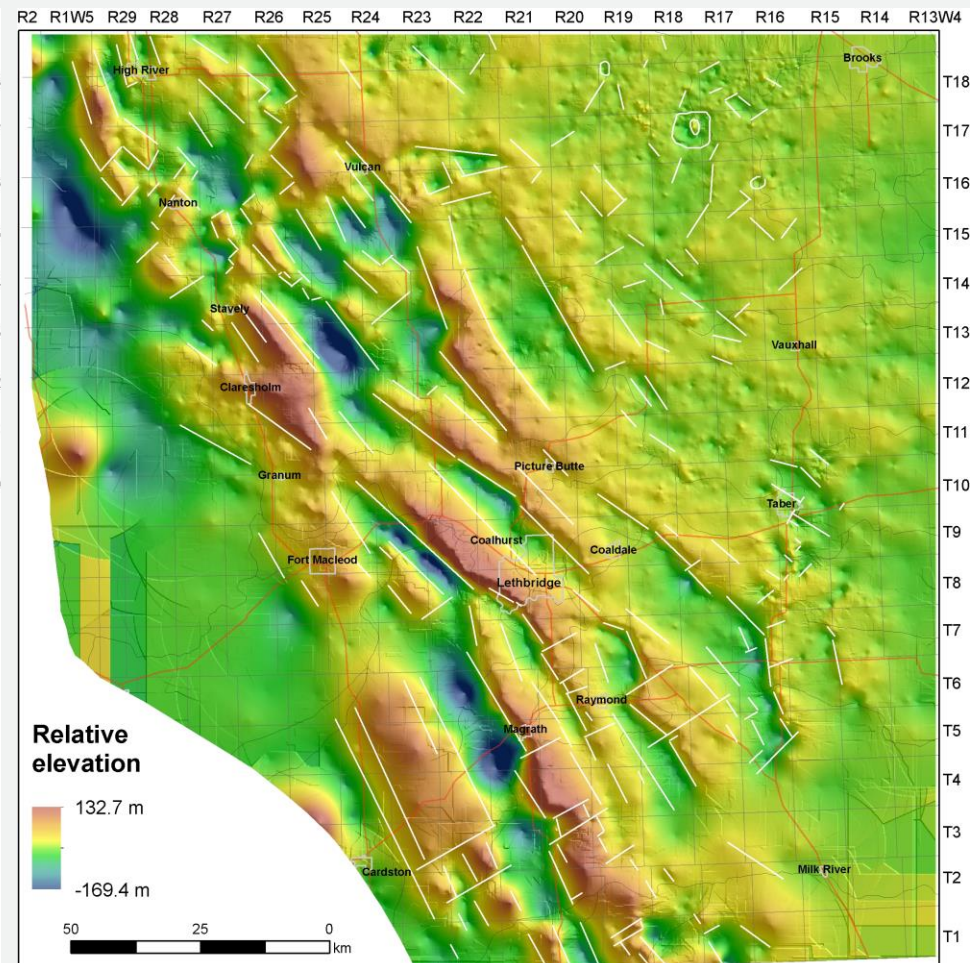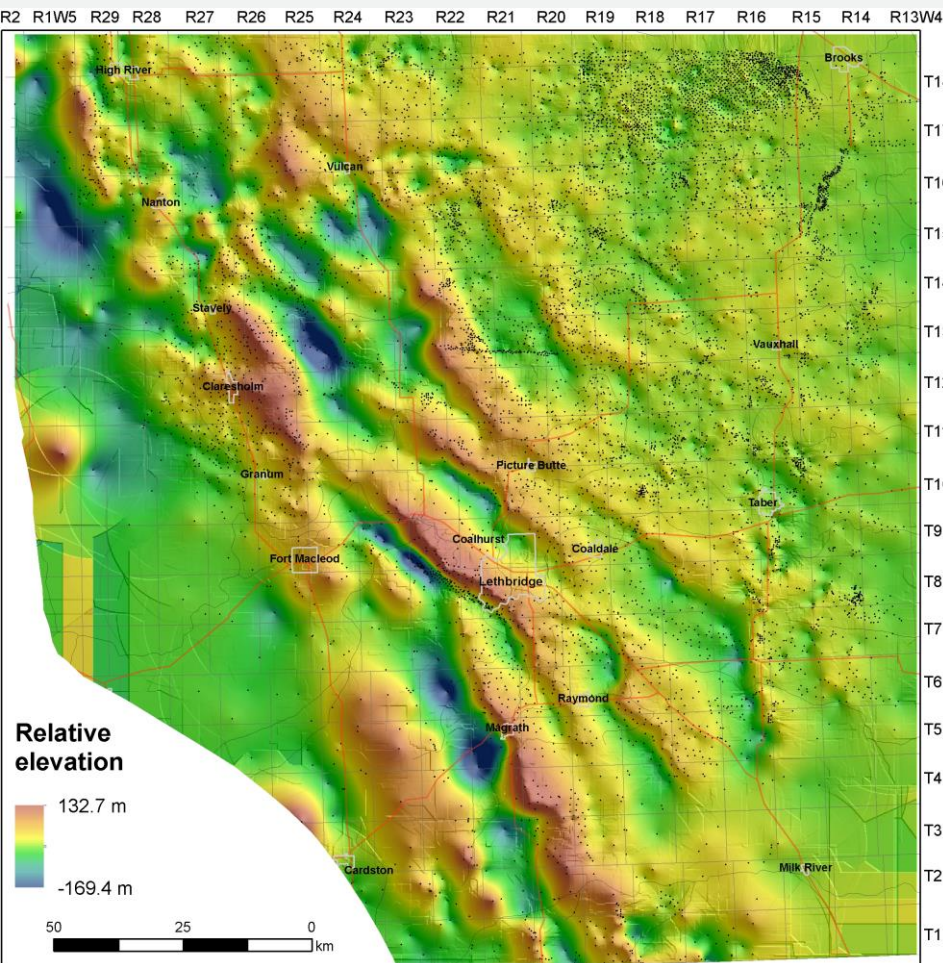22
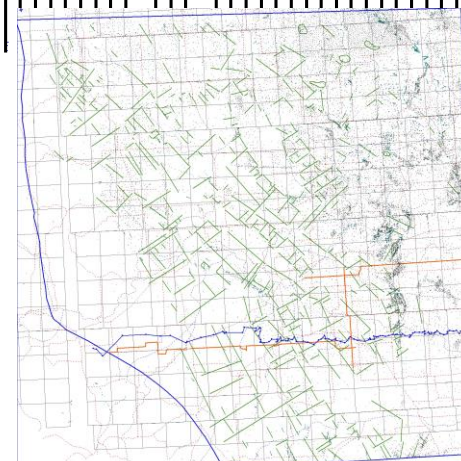
Formation-top Offsets from Lower Bearpaw Flooding Surface

LBP, 4880 picks in total, ranging from 1-190 points per township
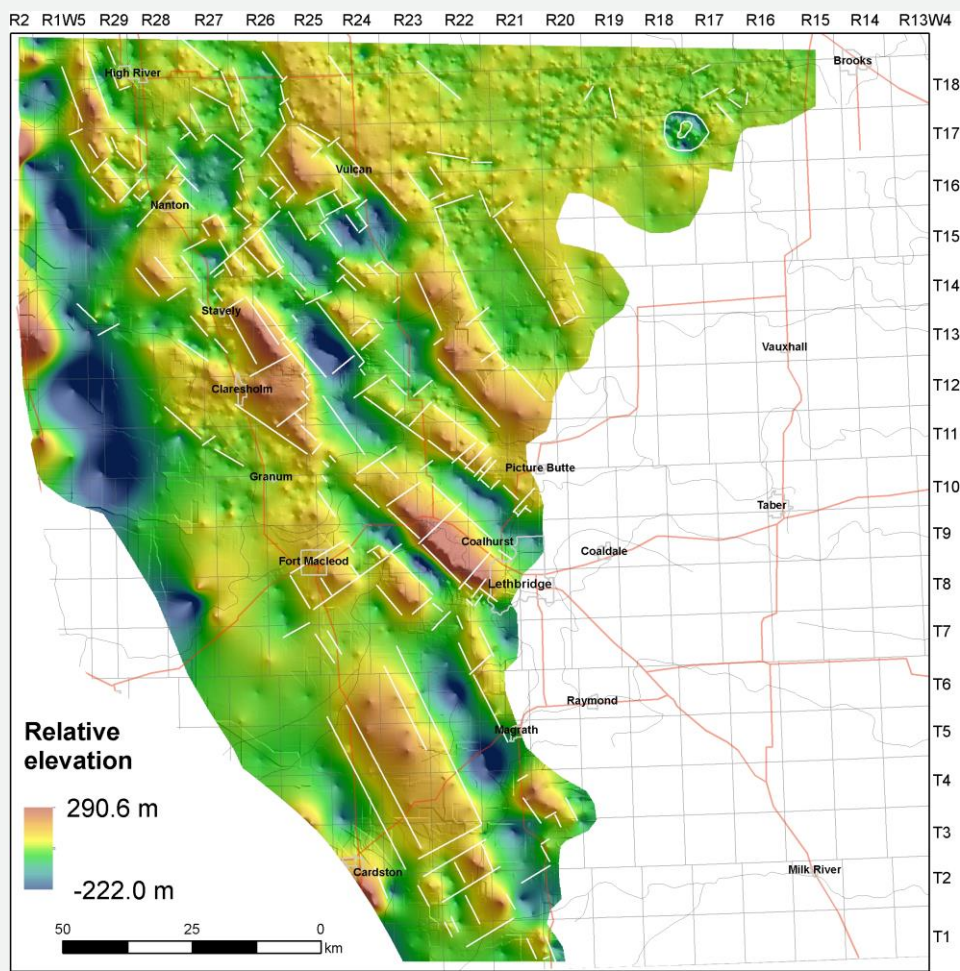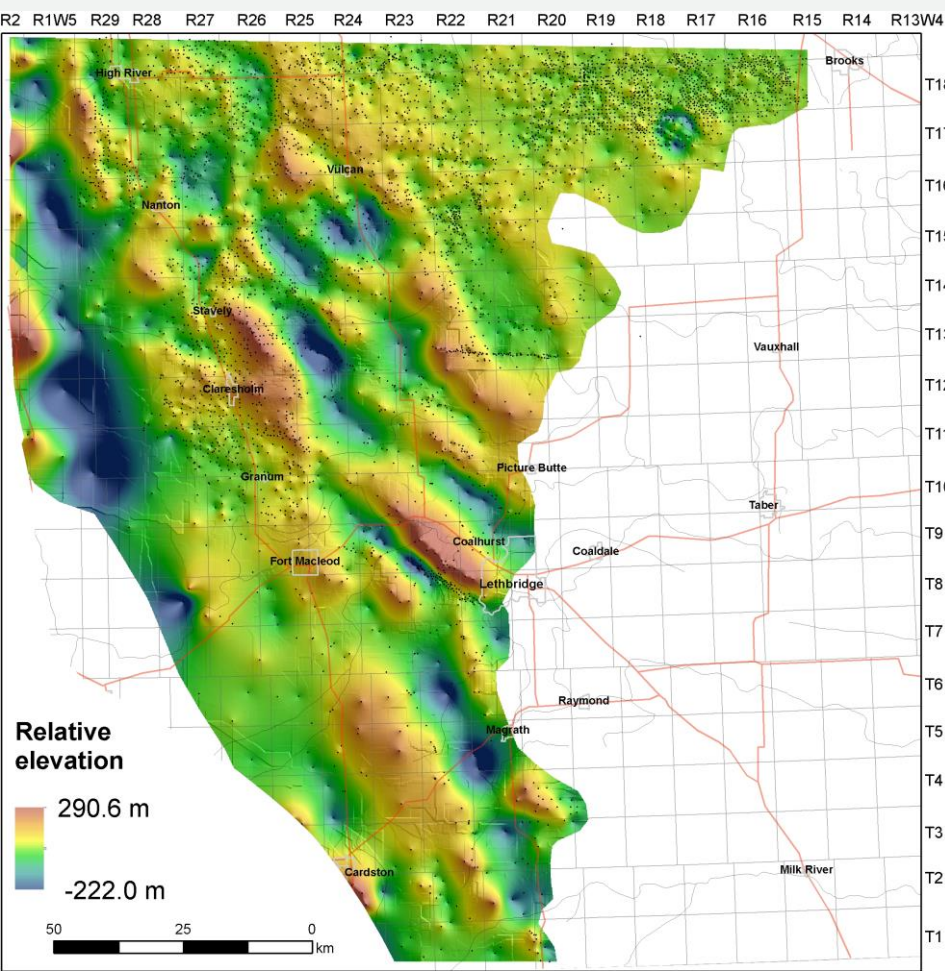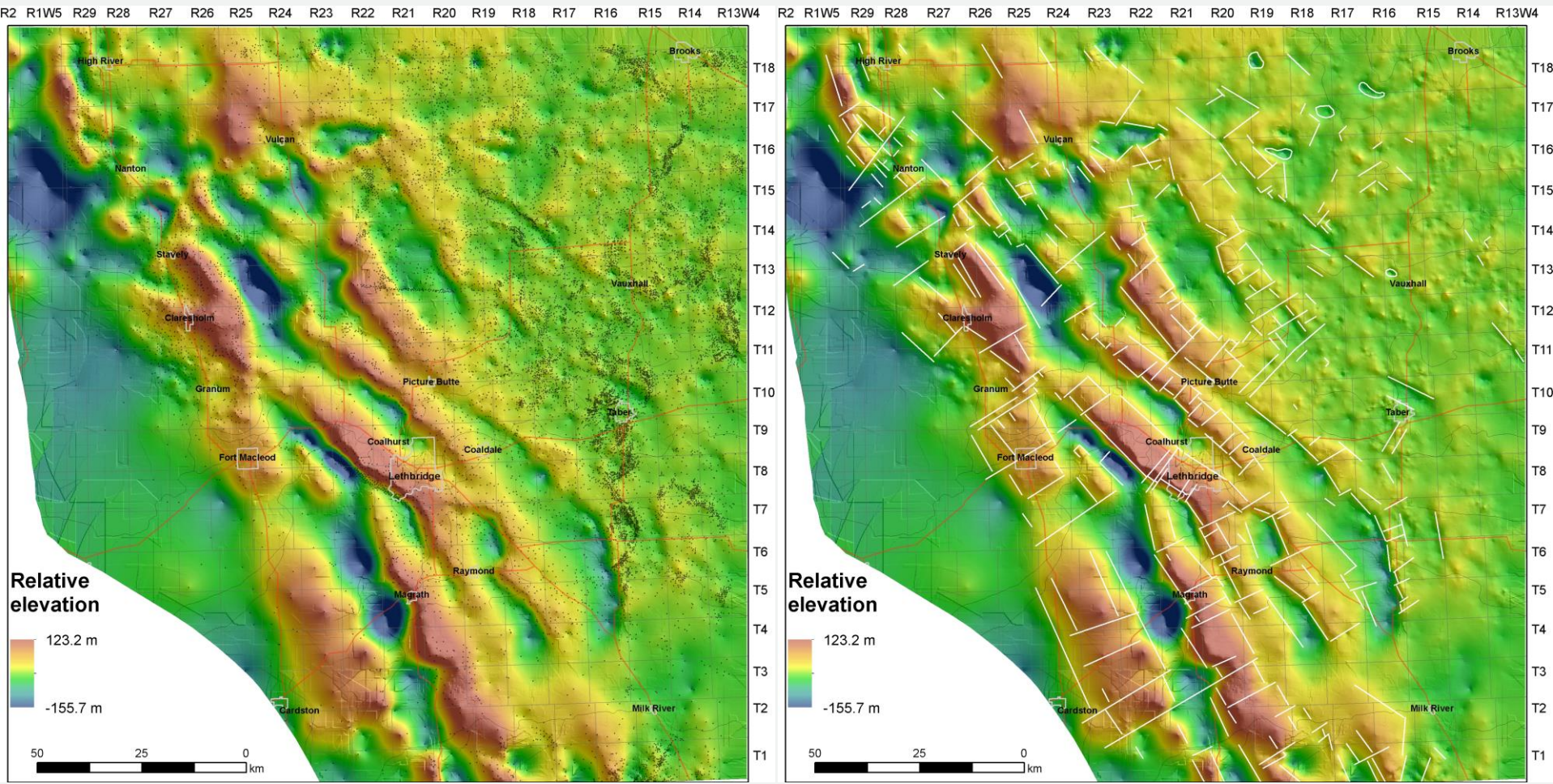
Formation-top offsets from Milk River Fm

Milk River, 9591 picks in total, ranging from 1-370 points per township
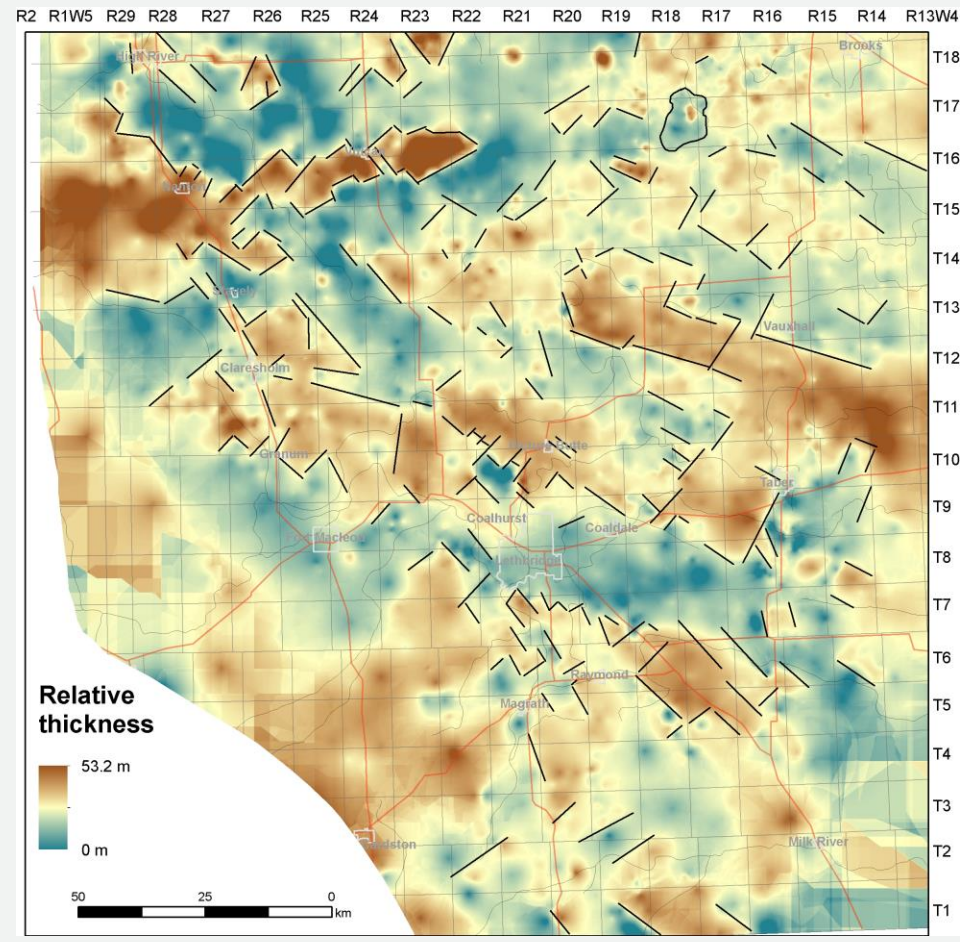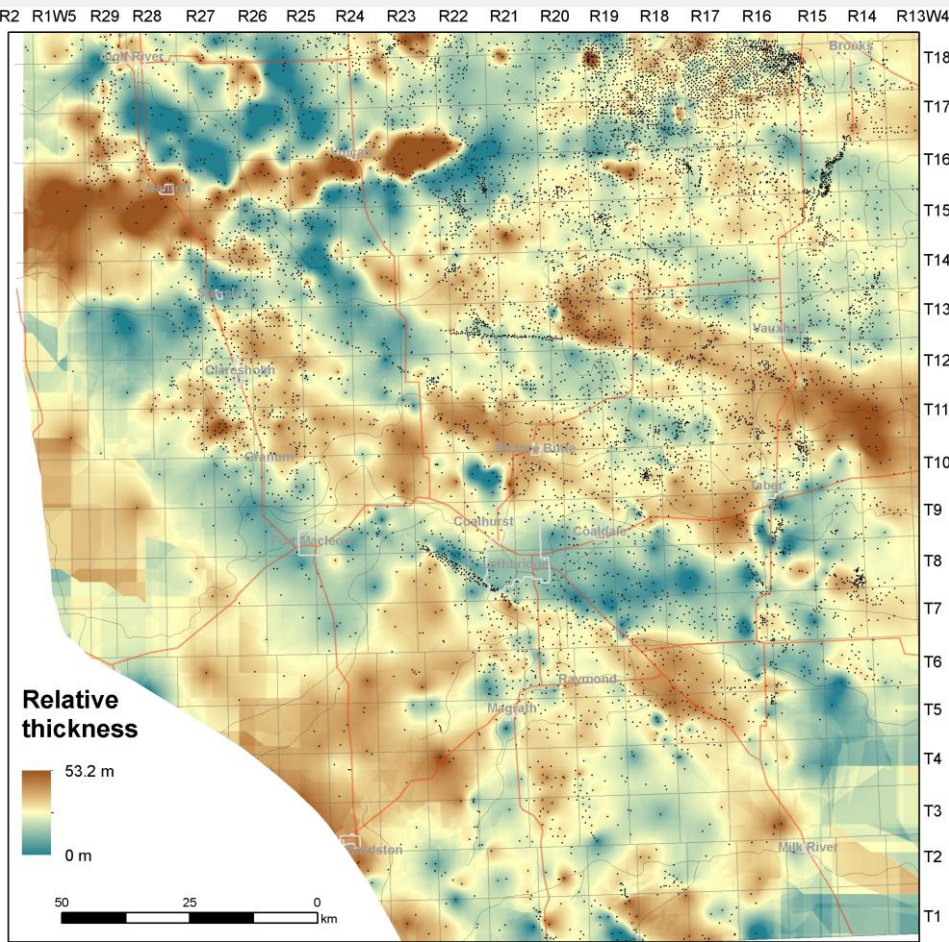
Formation-top offsets from BFSZ

BFSZ, 17553 picks in total, ranging from 1-467 points per township

Isopach of the Interval from BFSZ to Milk River Top

9544 picks in total, ranging from 1-460 points per township

Comparison of Offsets and Isopach

- Overlapping linear offsets indicates multiple geological units affected

- Overlapping with isopach trend indicates syn-depositional or growth faults

- Influence of the Vulcan Zone

www.ags.gov.ab.ca
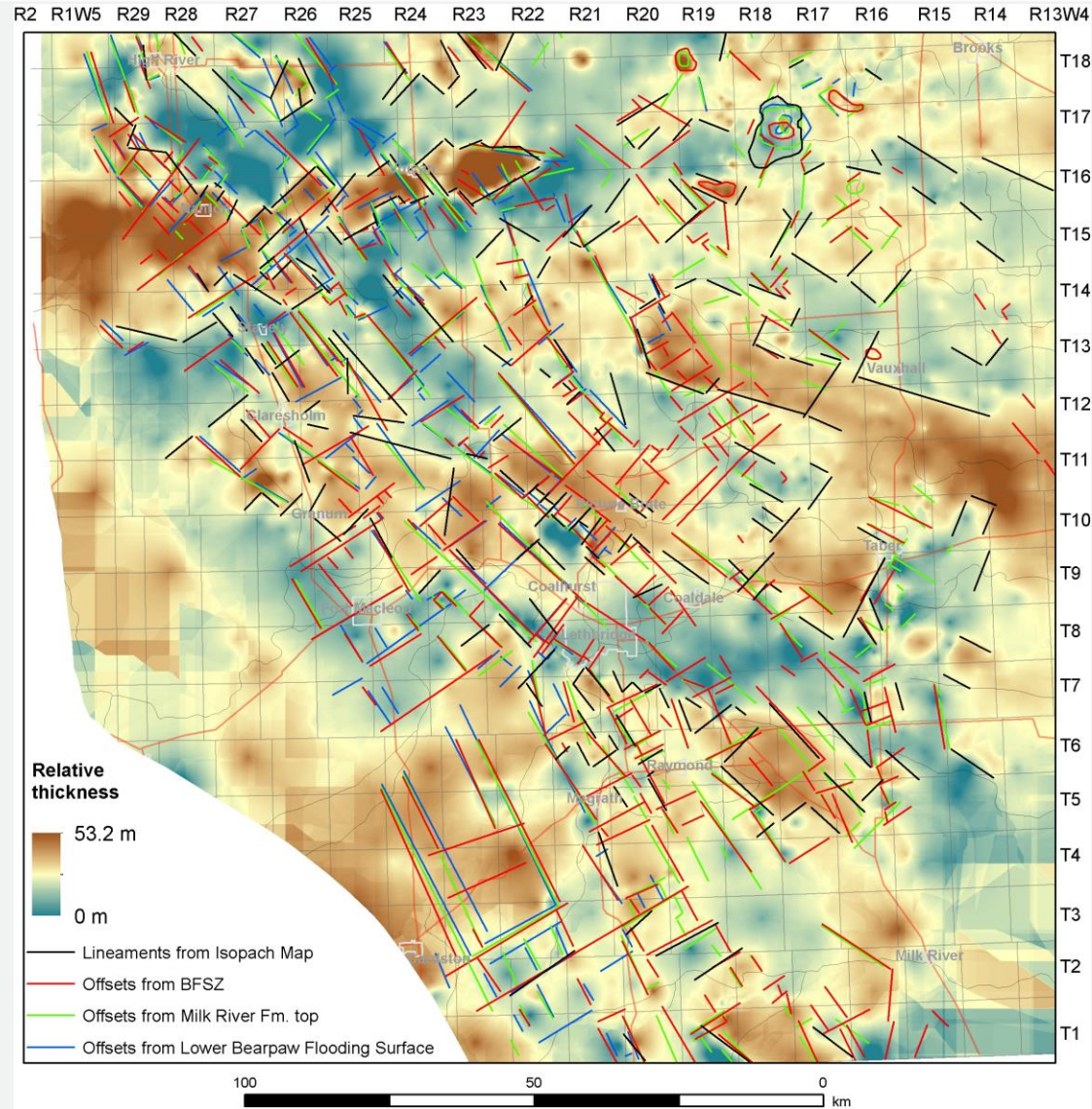
Compared to known faults

- Previously, faults were identified at isolated locations at riverbank outcrops and along the seismic reflection lines

- Coincide with the offsets mapped in this study

- Offset maps have revealed the orientation and extent of these faults in 3D

www.ags.gov.ab.ca
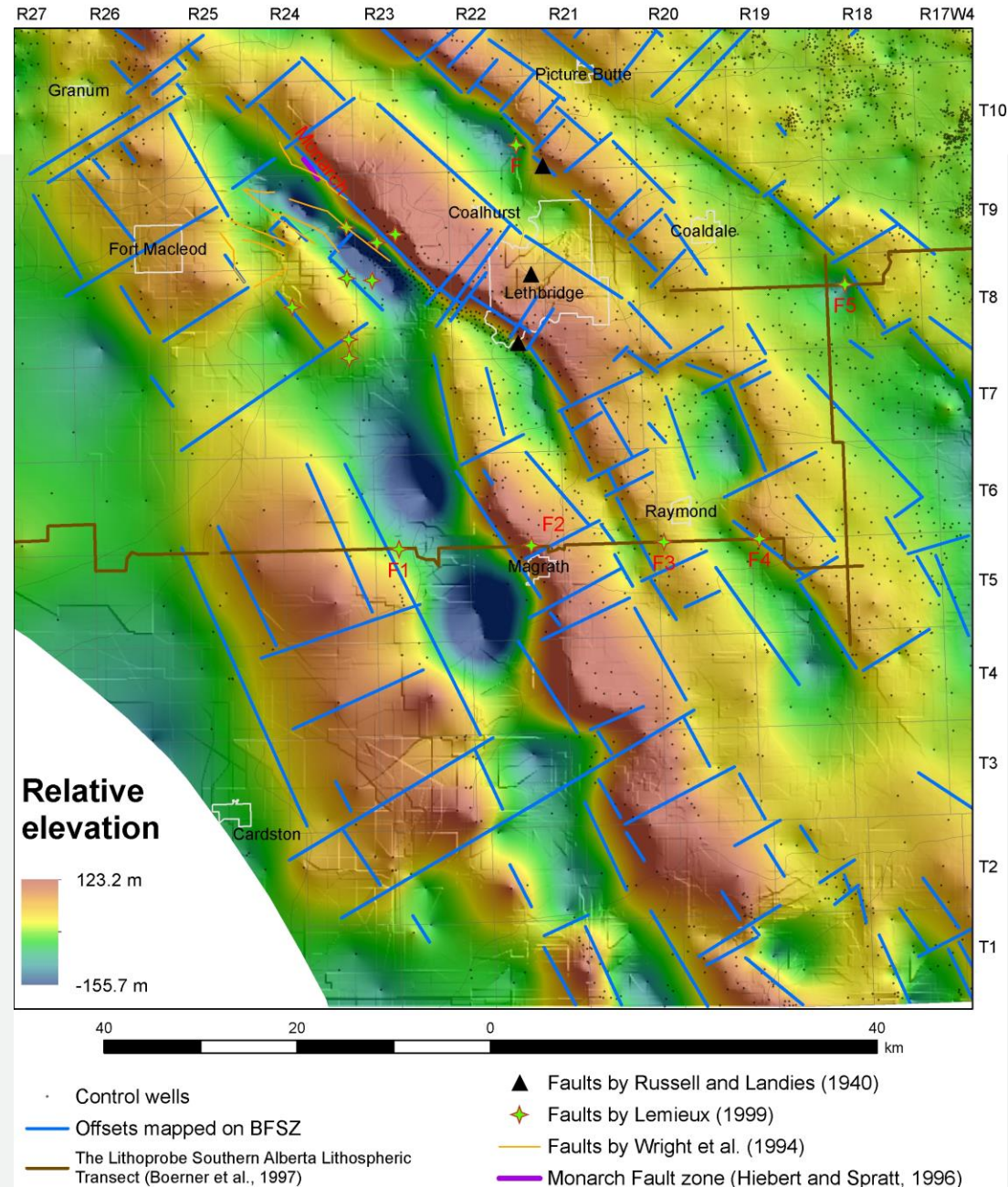
Compared to Basement Fabrics
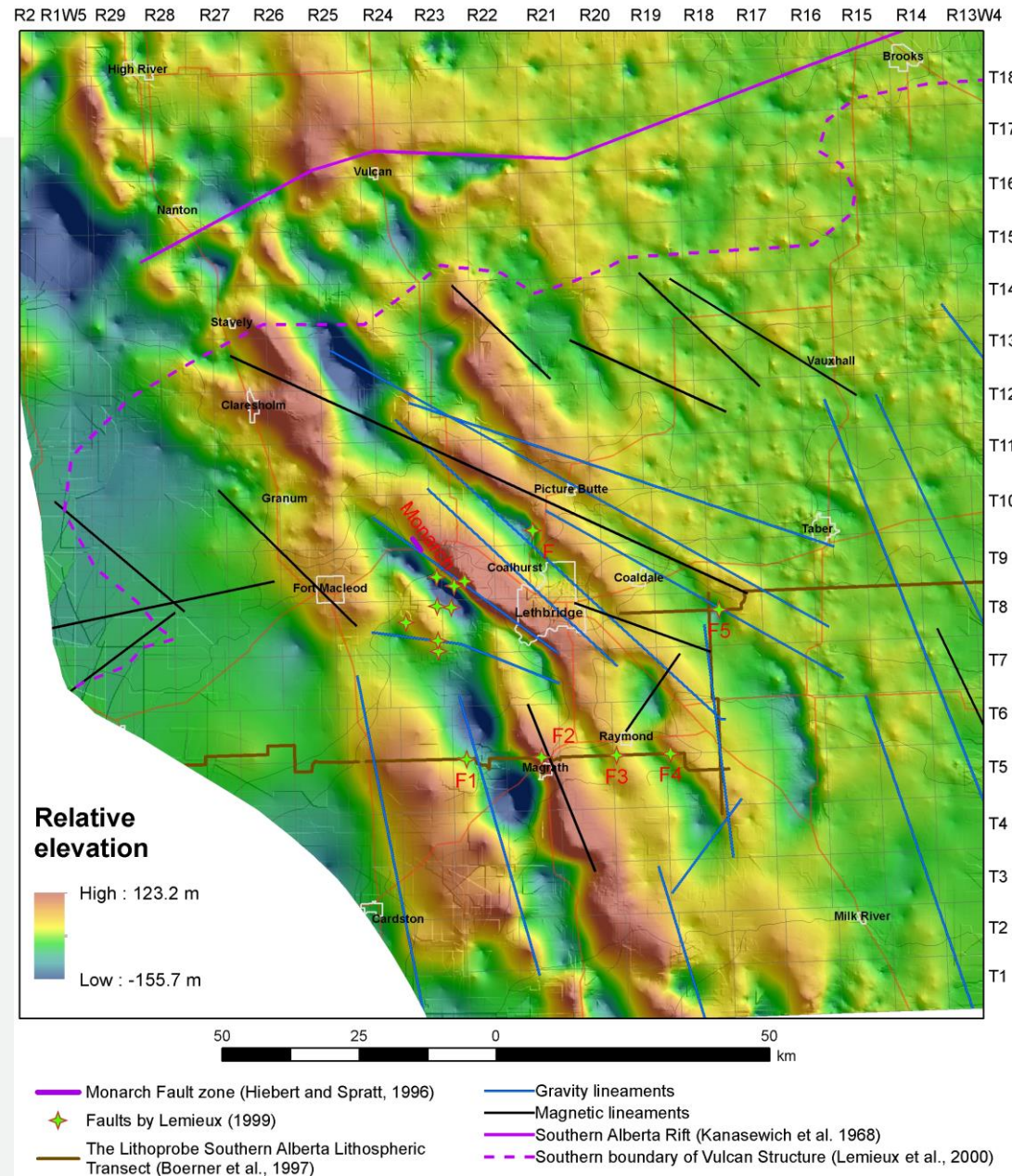
- NW-SE fabric appears crosscut/displaced by NE trending lineaments/zones

- Offset lineaments mimic the fabric of the potential field maps and locally coincide with the gravity and/or magnetic lineaments

  - the Vulcan Low

  - NW-SE strike changes to NNW-SSE strike near Lethbridge

  - F1, F2, Monarch fault zone

Relative elevation

High : 123.2 m

Low : -155.7 m

— Monarch Fault zone (Hiebert and Spratt, 1996)
✦ Faults by Lemieux (1999)
— The Lithoprobe Southern Alberta Lithospheric Transect (Boerner et al., 1997)
— Gravity lineaments
— Magnetic lineaments
— Southern Alberta Rift (Kanasewich et al. 1968)
--- Southern boundary of Vulcan Structure (Lemieux et al., 2000)

Thank you