SPE-198331-MS
Assessment of Fault Zone Properties for CSG Development Areas

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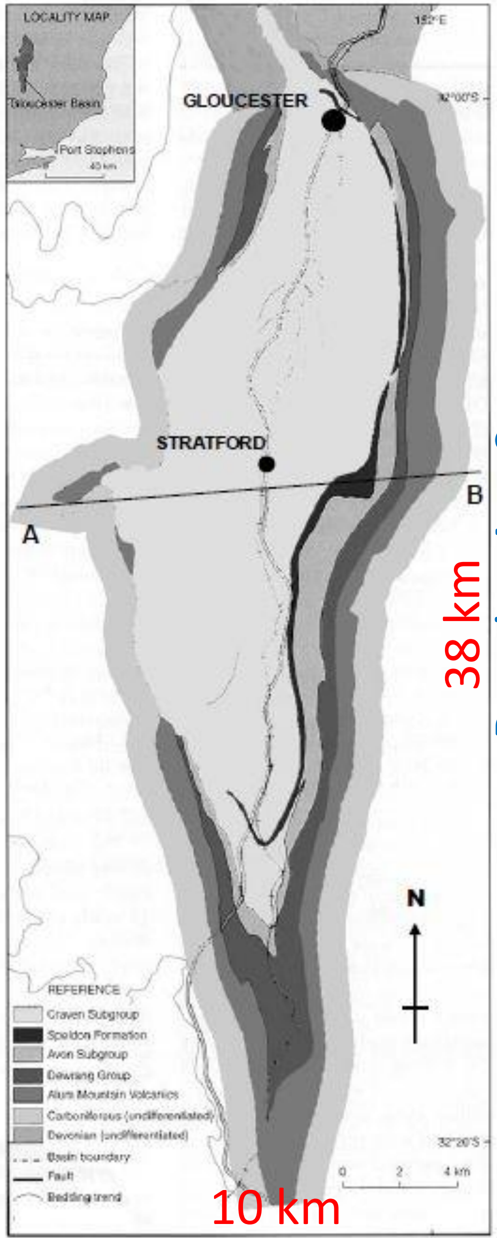
Gloucester Basin Overview



Group	Subgroup	Formation	Approx Thickness	Coal seams
Gloucester Coal Measures	Craven Subgroup	Crowthers Road Conglomerate	350 m	
		Leloma or Woods Road Formation	585 m	Linden Bindaboo Deards
		Jilleon or Bucketts Way Formation	175 m	Cloverdale Roseville Fairbairns Lane
		Wards River Conglomera		
		Wenha Forma		Road
	Speldon Formation			
	Avon Subgroup	Dog Trap C Formation		nview
		Waukivory Creek Formation	326 m	Avon Triple Rombo Glen Road Valley View Parkers Road
Dewrang Group		Mammy Johnsons Formation	300 m	Mammy Johnsons
		Weismantel Formation	20 m	Weismantel
		Duralie Road Formation	250 m	
Alum Mountain Volcanics				Clareval Basal coal seam

after Ward et al., 2001; Ogier-Halim, 2010

CSG potential

Devonian and Carb volcanics and sed

Alluvium (100’s mD)

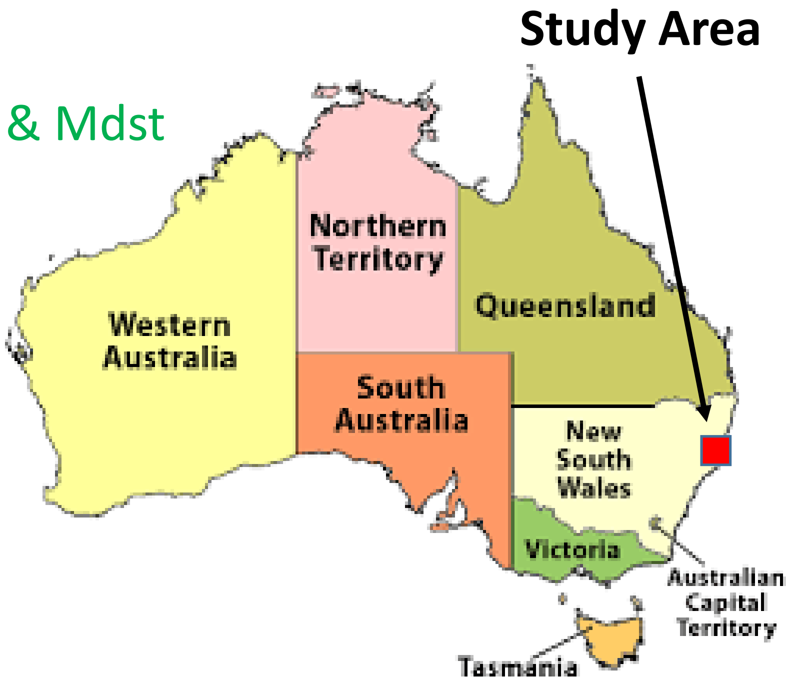
Fractured bedrock (10’s mD)

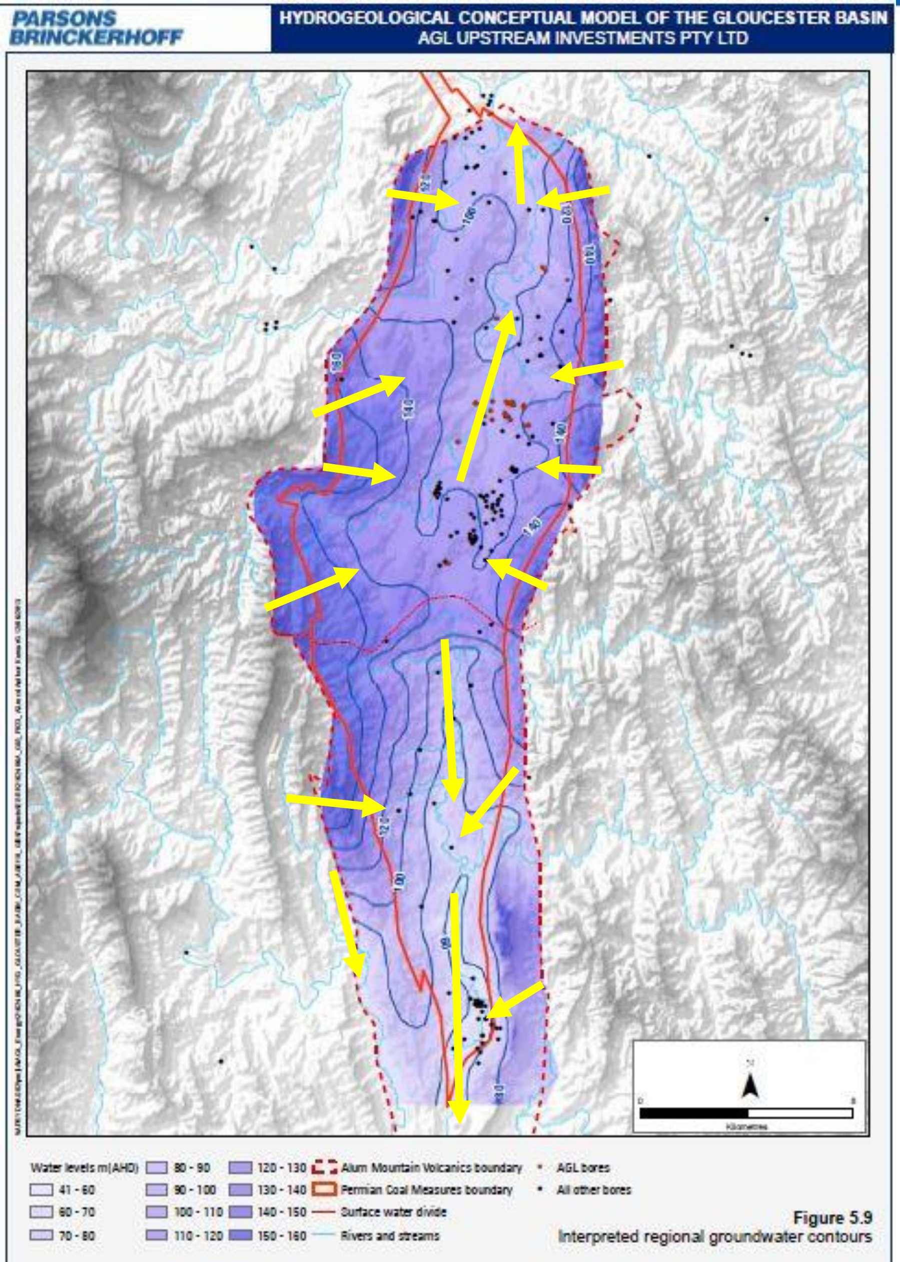
Bedrock (< 1 mD)

250m CSG

Marine SSt & Mdst

200m CSG





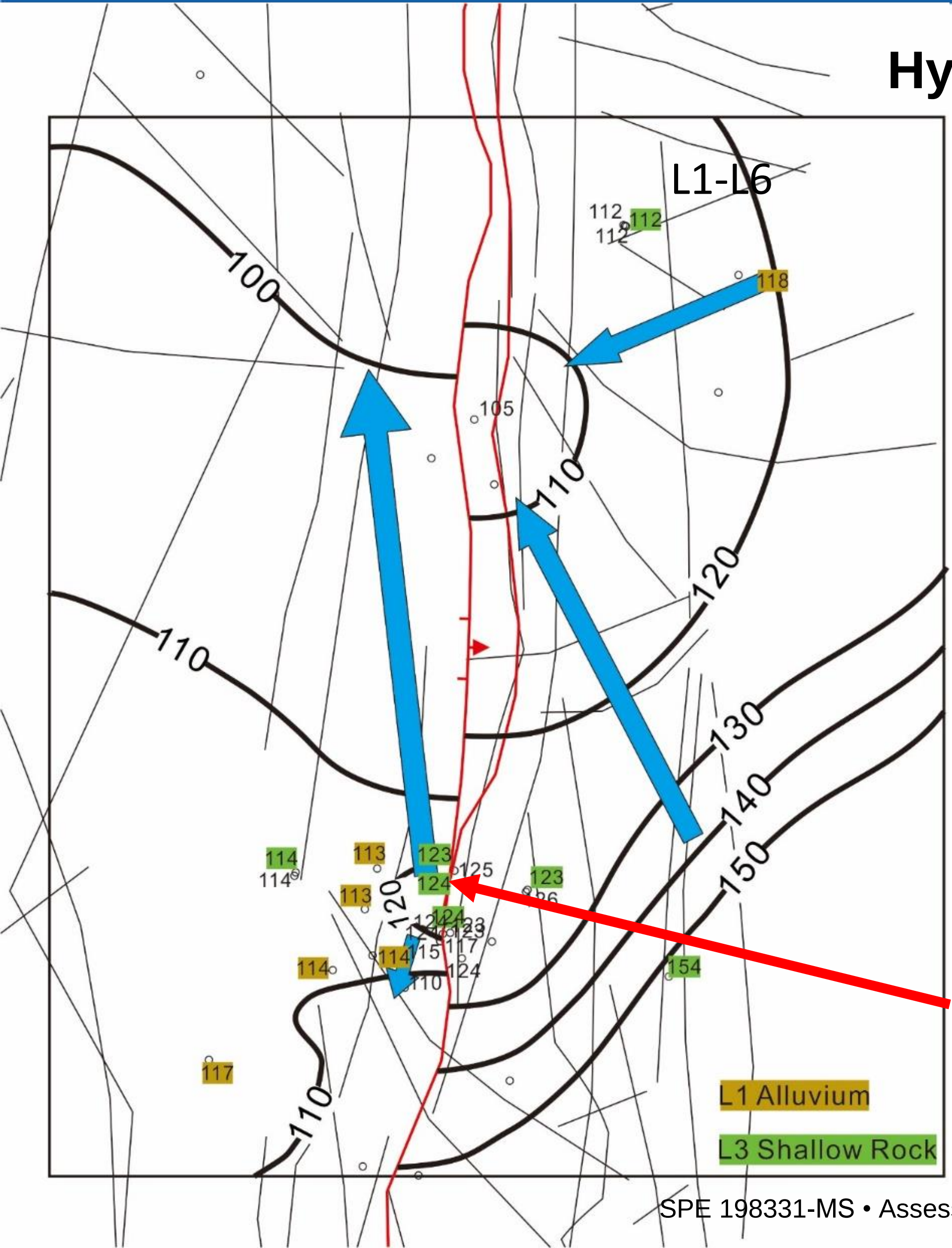
Gloucester Basin Overview

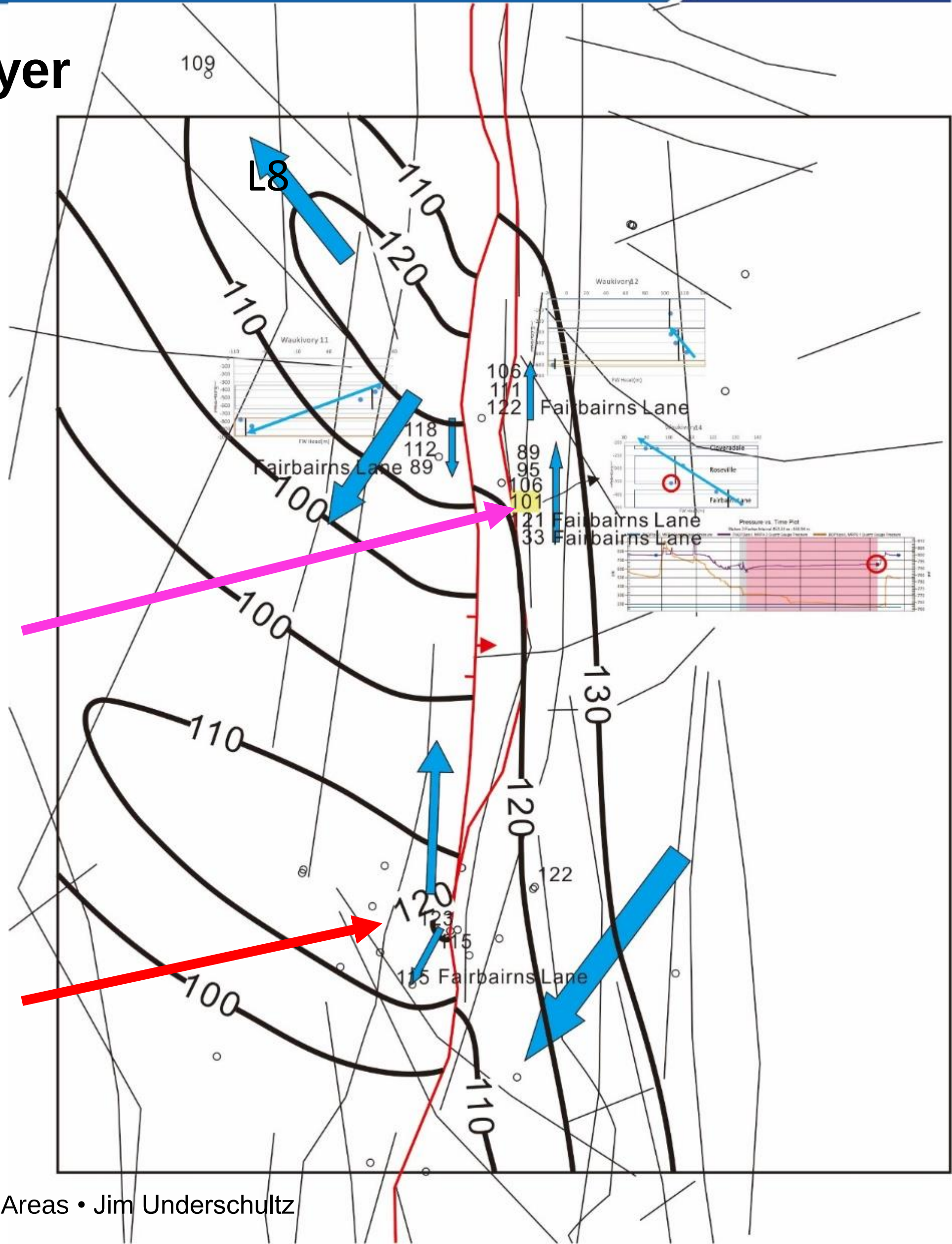
Gloucester Hydrogeology upper aquifer system?

Note that the shallow aquifer flow system is driven by high topography on the eastern and western edges of the basin with an axial drainage to the north and south coincident with surface drainage

From Parsons-Brinkerhoff (2013)

Hydraulic Head Data per Layer

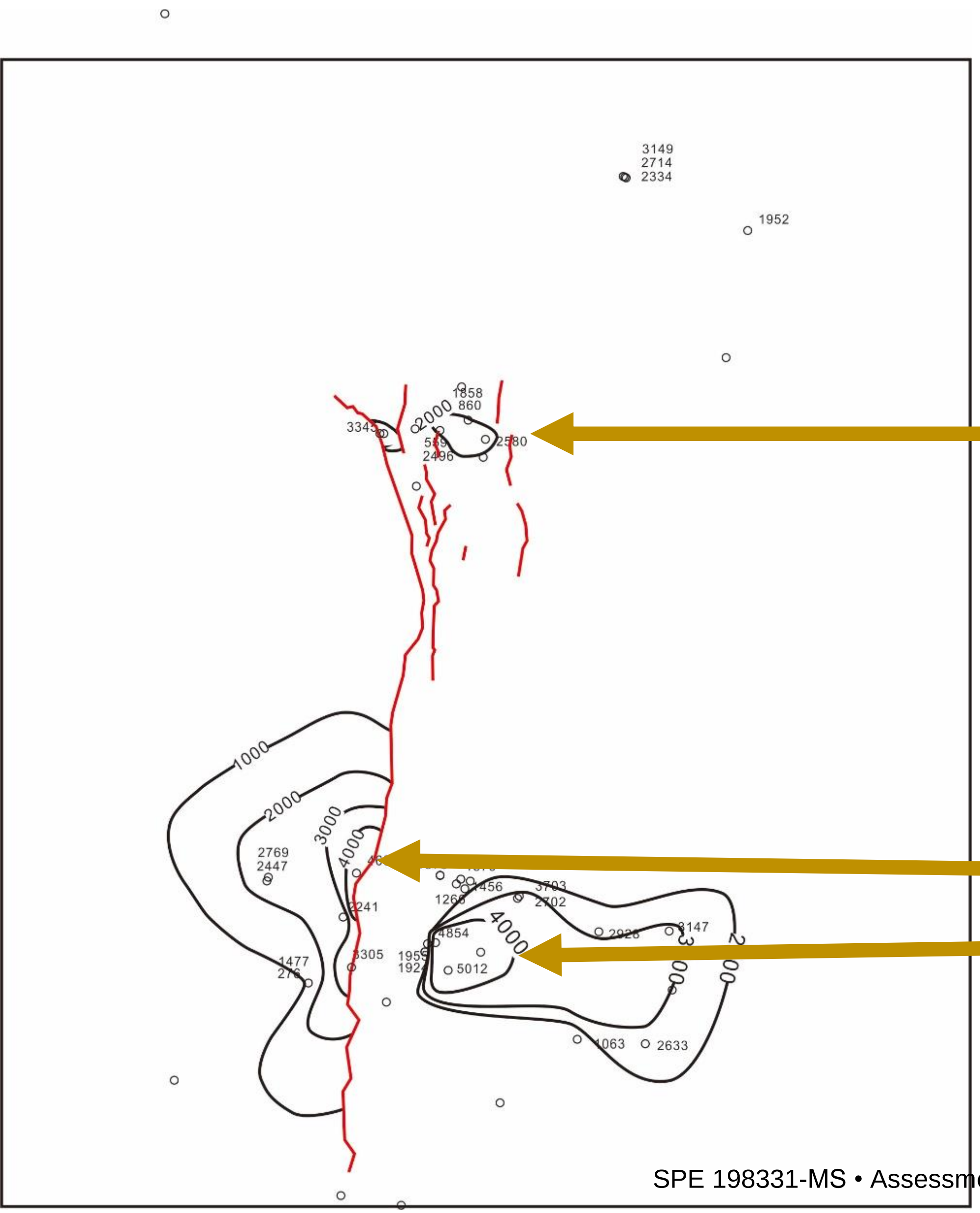




Vertical hydraulic head gradient @ WK12

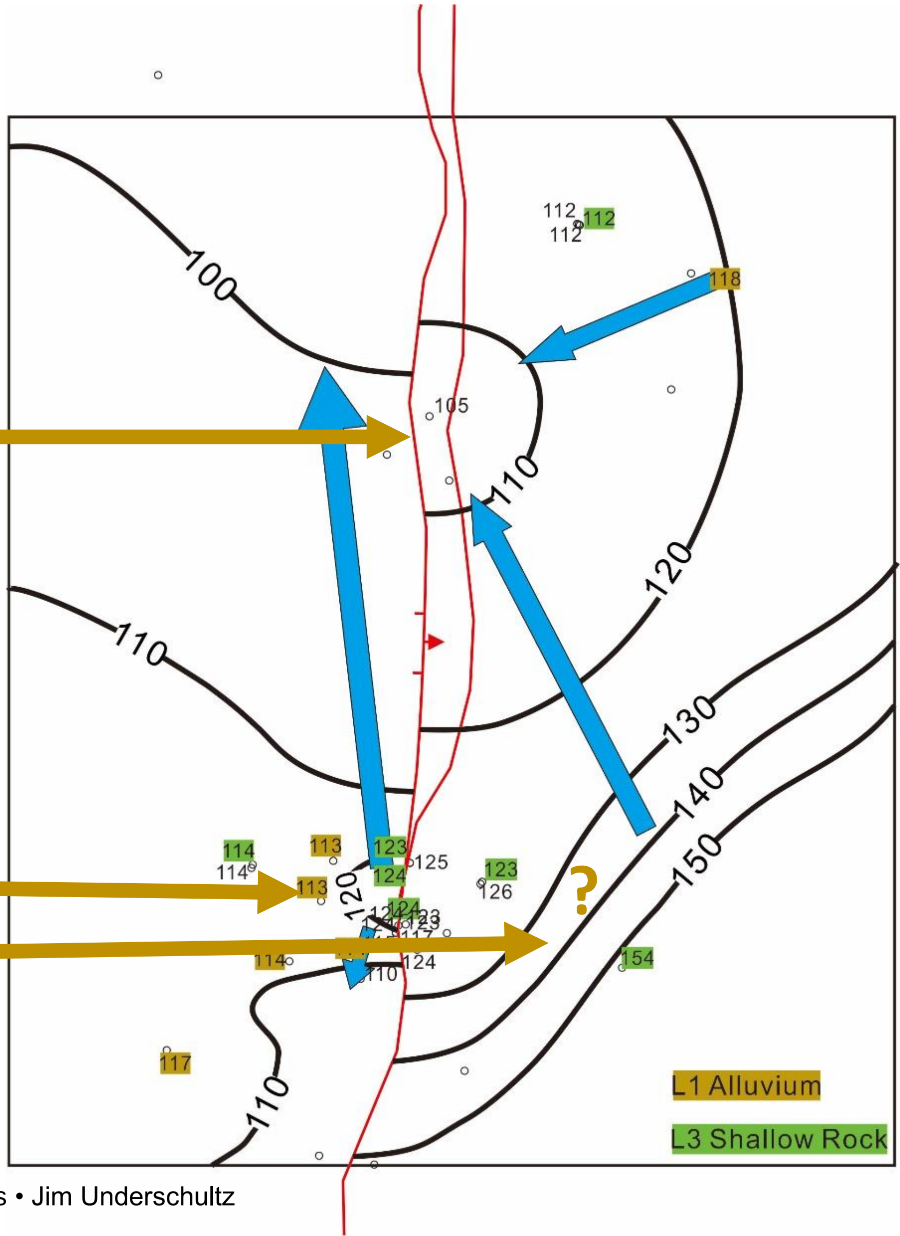
Hydraulic head discontinuity

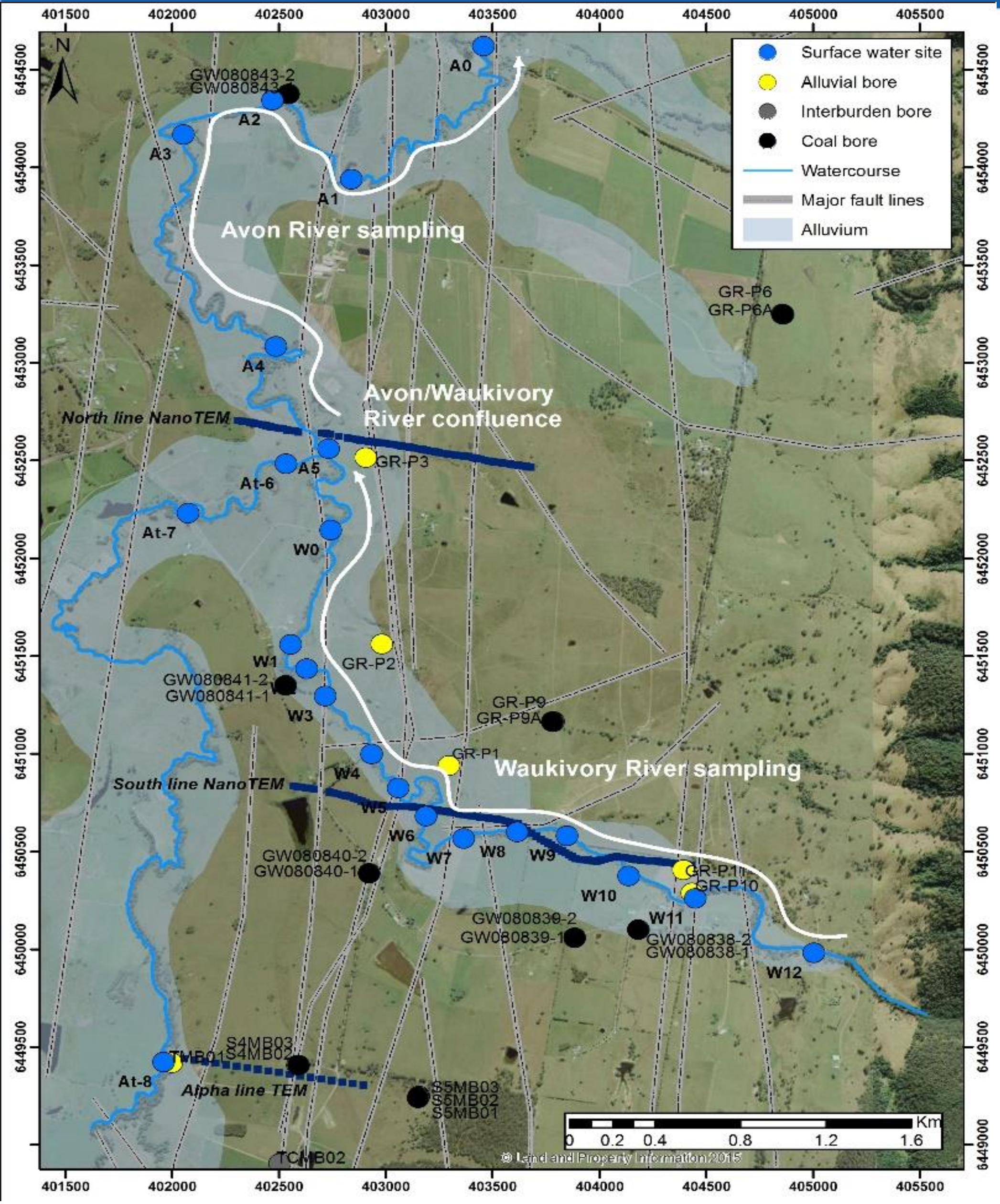
L1-6 Salinity Contour and Hydraulic Head Reminder



Note the correlation between TDS anomalies and hydraulic head signature

No correlation here?



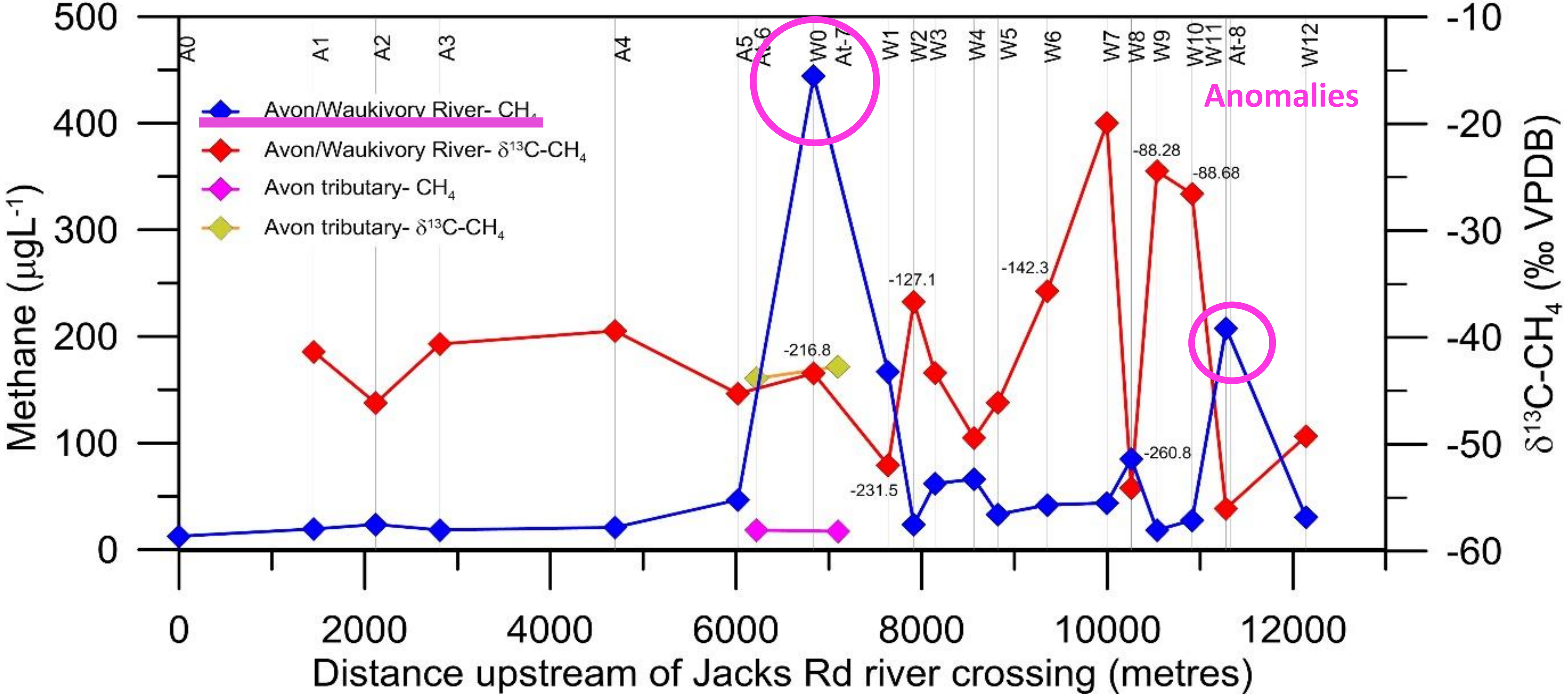


Field Sampling Program

- Surface water sampling:
  - T, pH, DO, radon 222, ^{4}He, ^{14}C, ^{3}H, CH_4 major ions and stable isotopes of water
- Groundwater sampling:
  - Ne, Xe, Kr, Ar, ^{4}He, radon 222, CH_4, major ions and stable isotopes of water
- Time Domain Electromagnetic (TEM) surveys
- Atmospheric CH_4 sampling

^{4}He, CH_4 and TEM proved to be most diagnostic

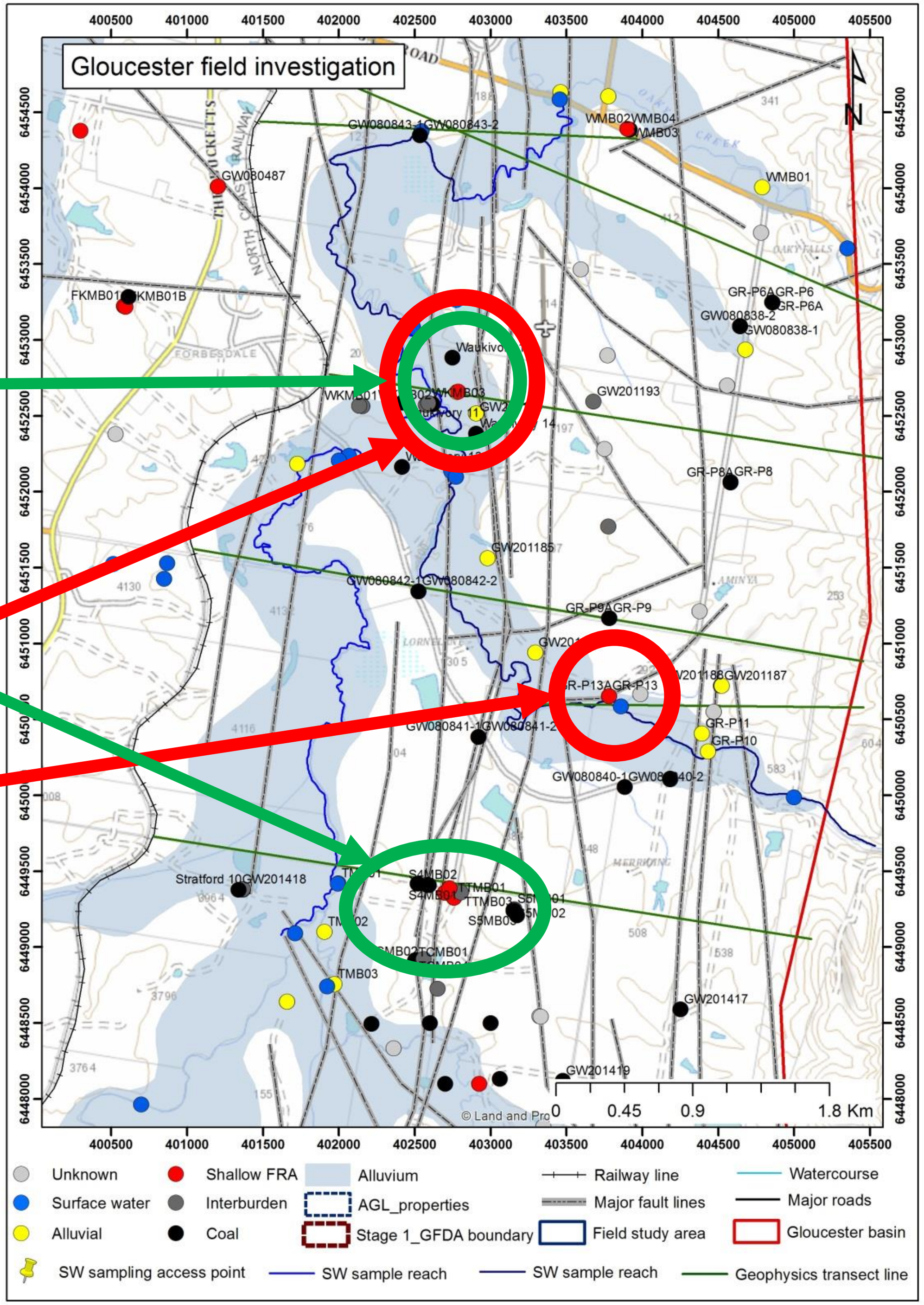
Selected Field Sampling Results

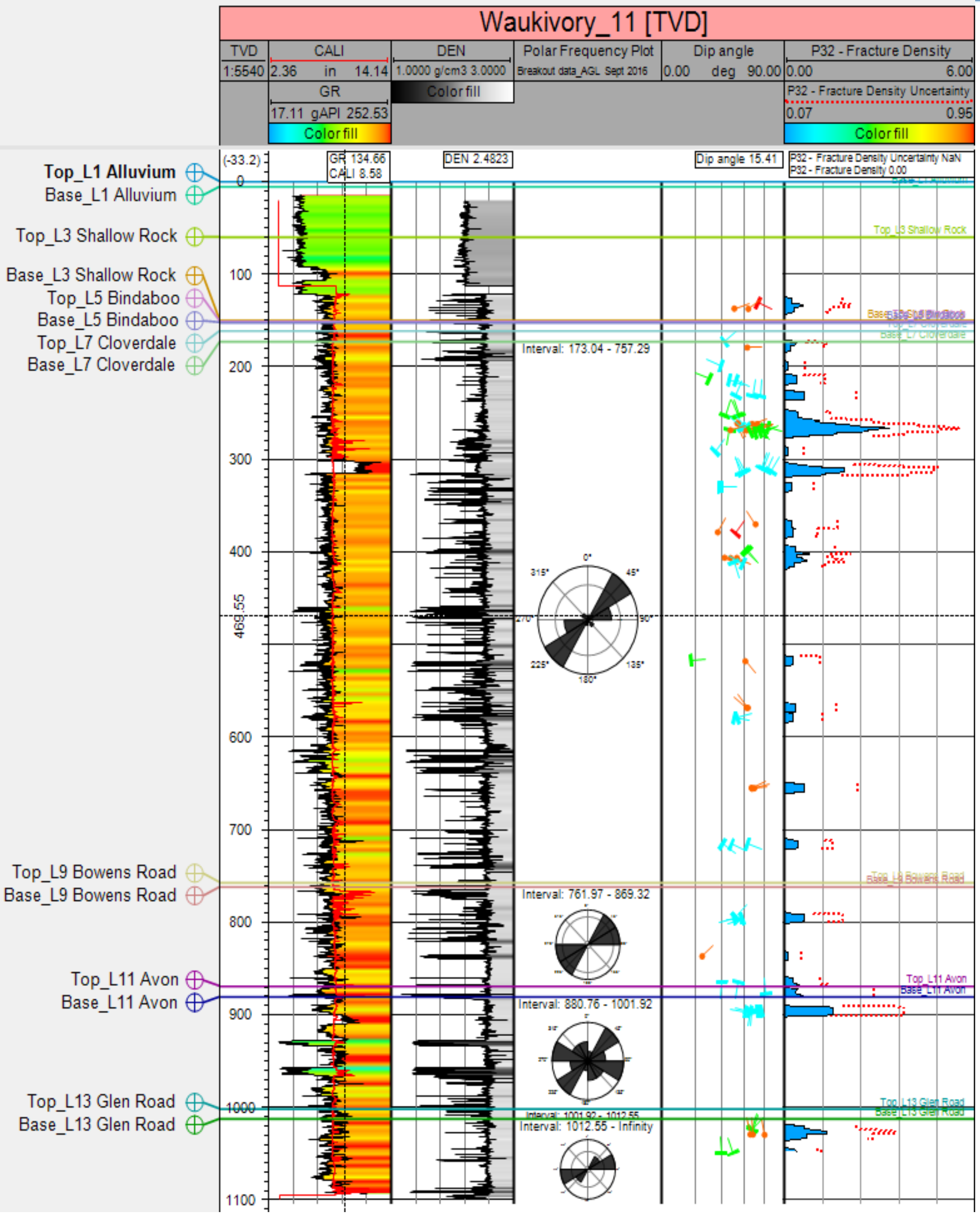


Field Site and Subsurface Results Overlain

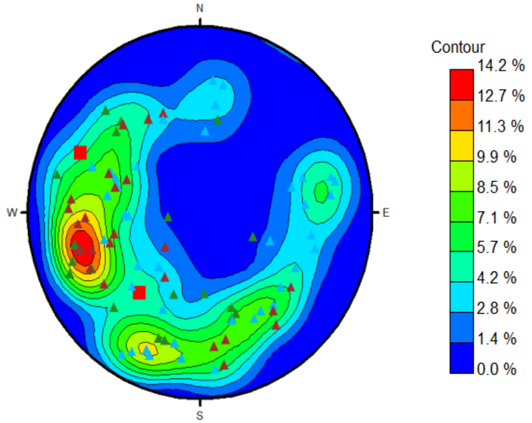
Sub-Surface Anomalies
- TDS
- Head

Surface Anomalies:
- He
- CH_4



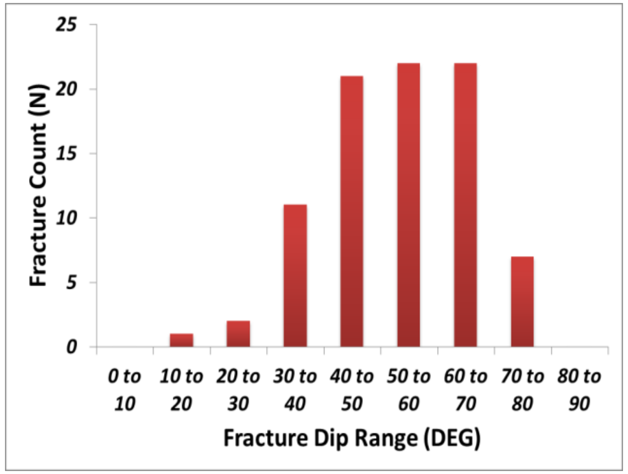


Waukivory11 Shmax and fracture distribution along depth



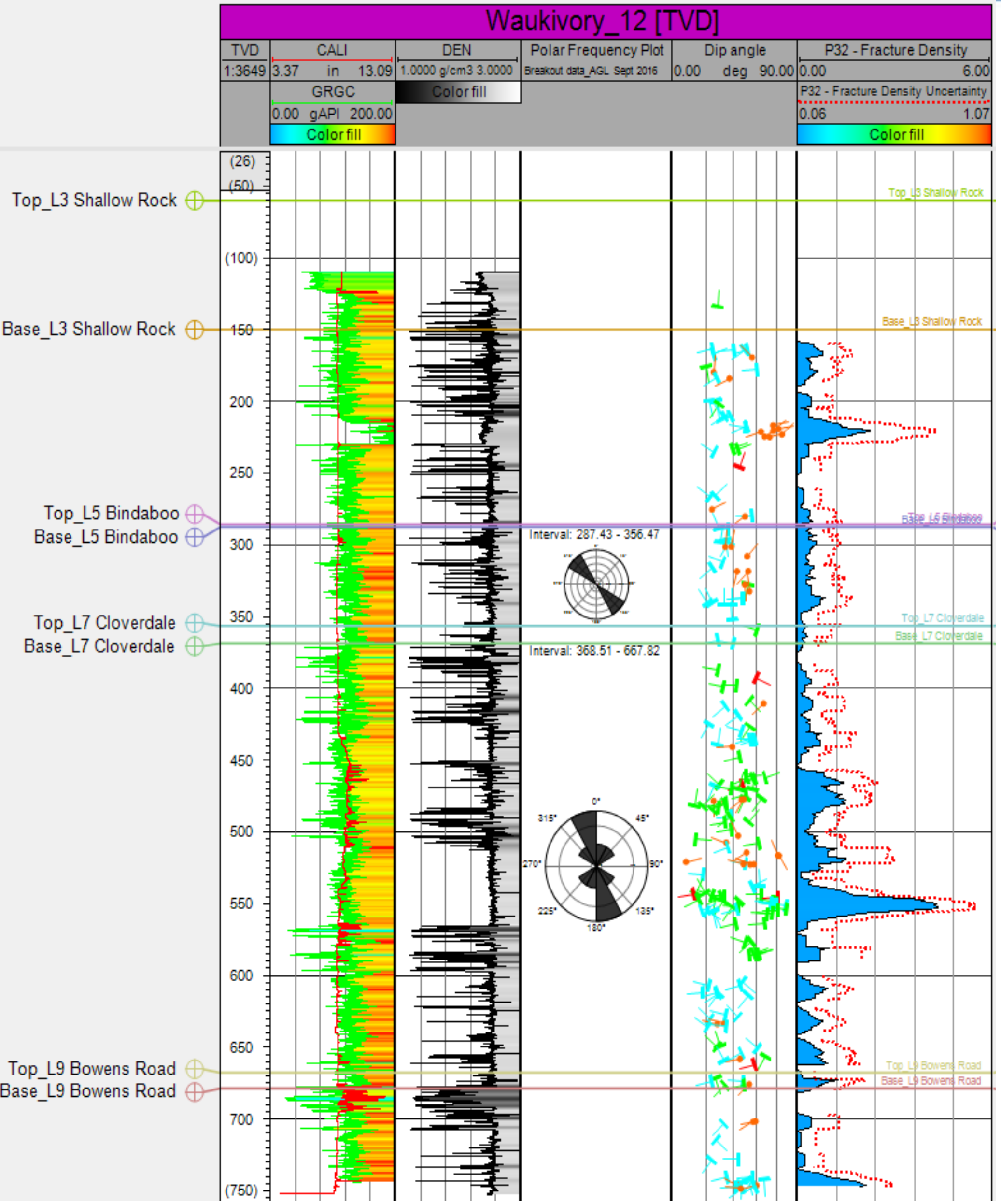
Stereonet contour of faults and fractures dip azimuth in Waukivory11 well

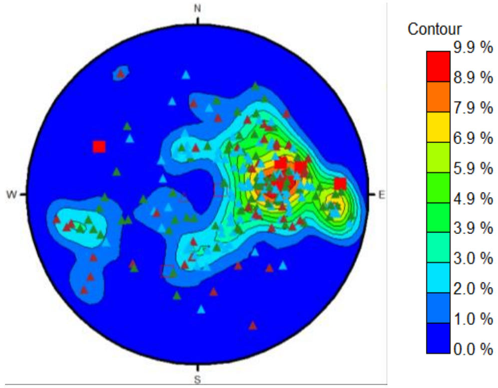
- Conductive Fracture (19/19)
- Fault (2/2)
- Mixed Fracture (26/26)
- Resistive Fracture (40/40)



Waukivory11 fracture dip range vs fracture count

Compression and Low Fracture Density: no anomaly





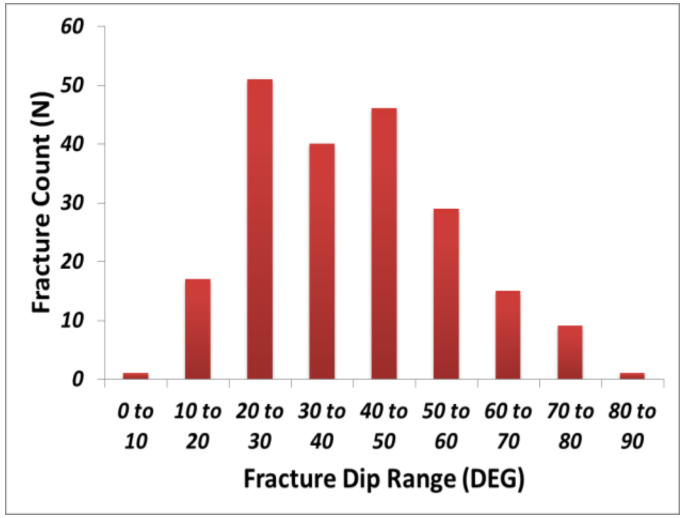
(b) Stereonet contour of faults and fractures dip azimuth in Waukivory12 well

▲ Conductive Fracture (77/77)

■ Fault (6/6)

▲ Mixed Fracture (44/44)

▲ Resistive Fracture (96/96)

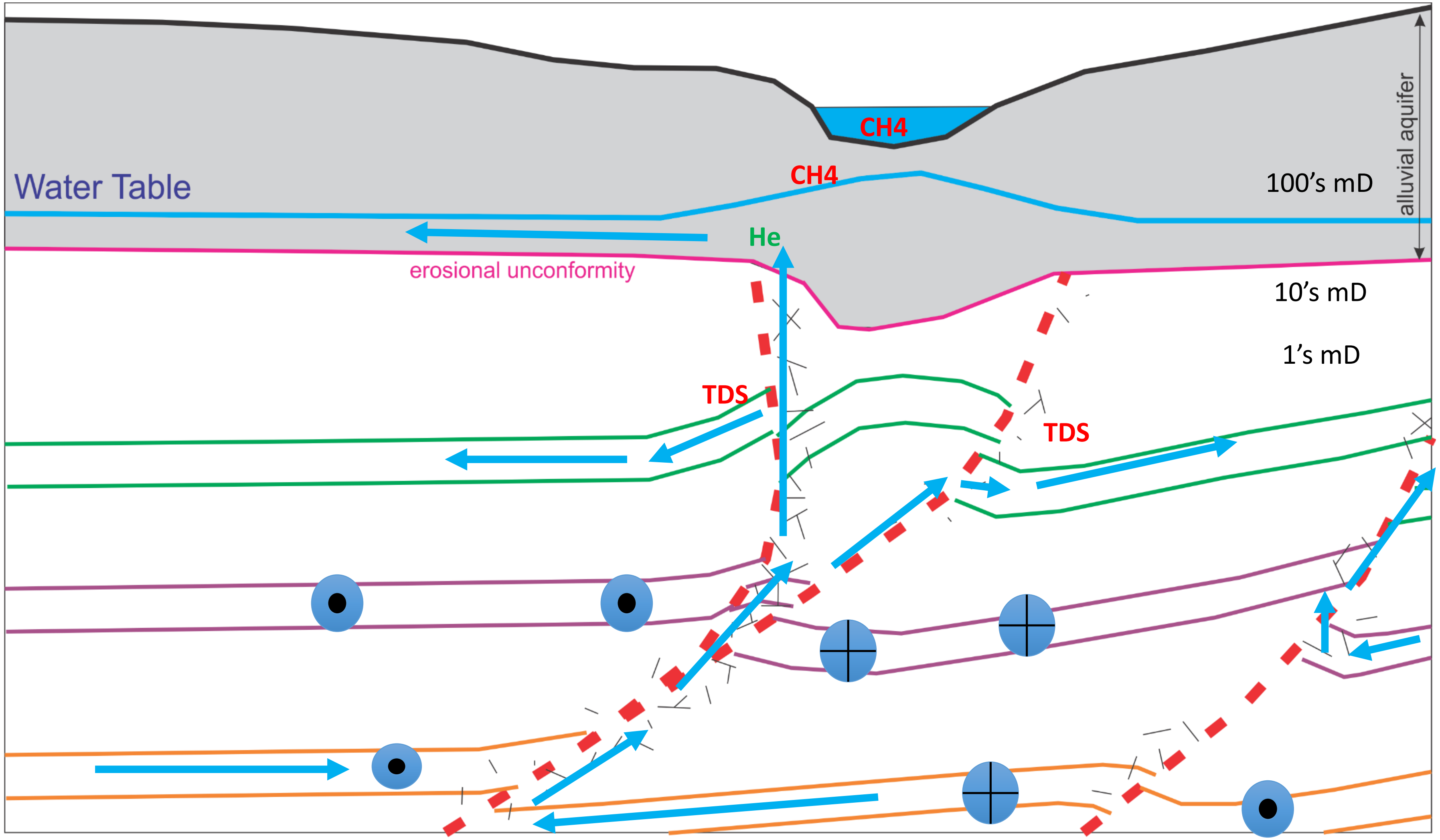


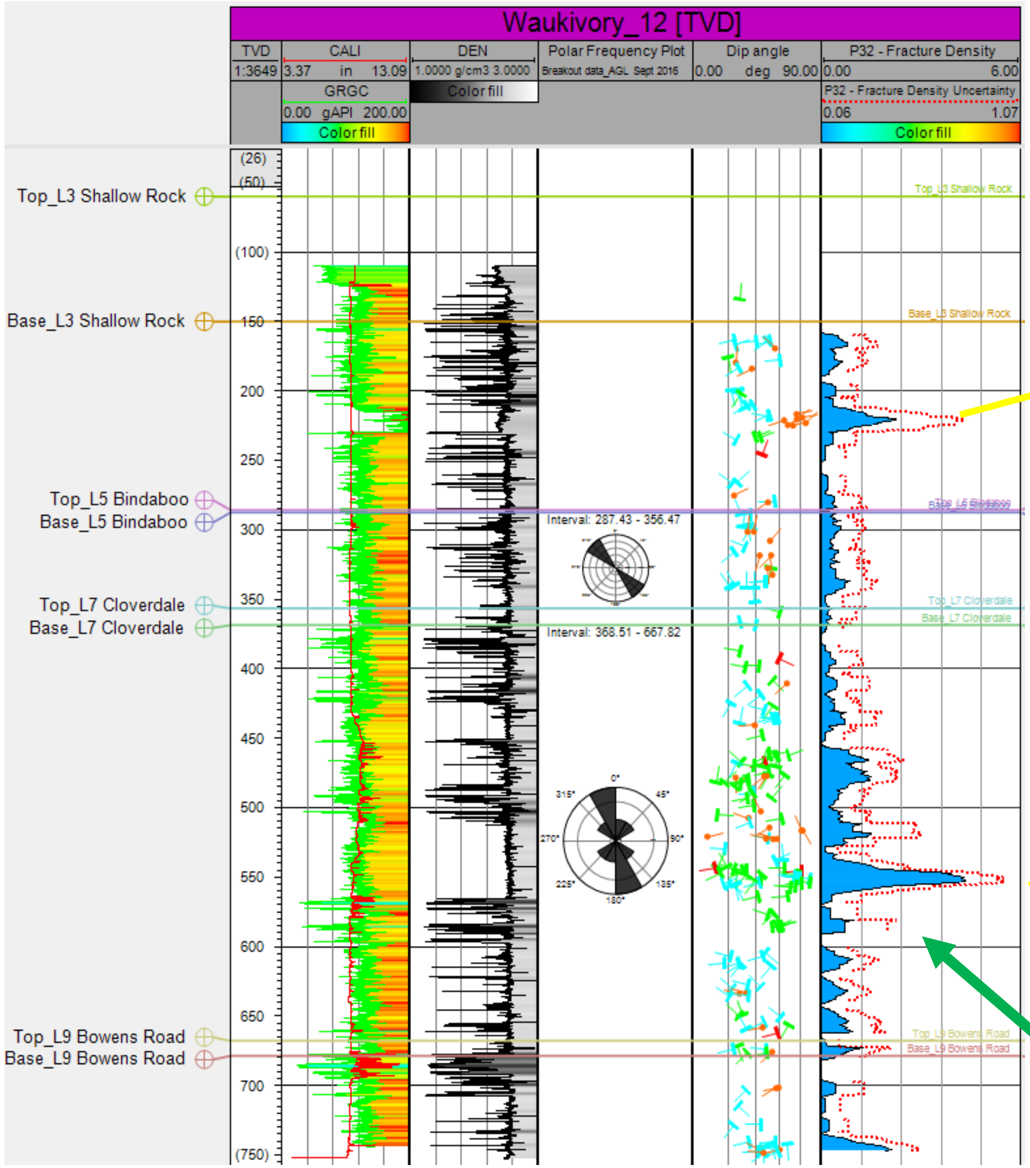
(c) Waukivory12 fracture dip range vs fracture count

(a) Waukivory12 Shmax and fracture distribution along depth

Dilation and High Fracture Density near an anomaly

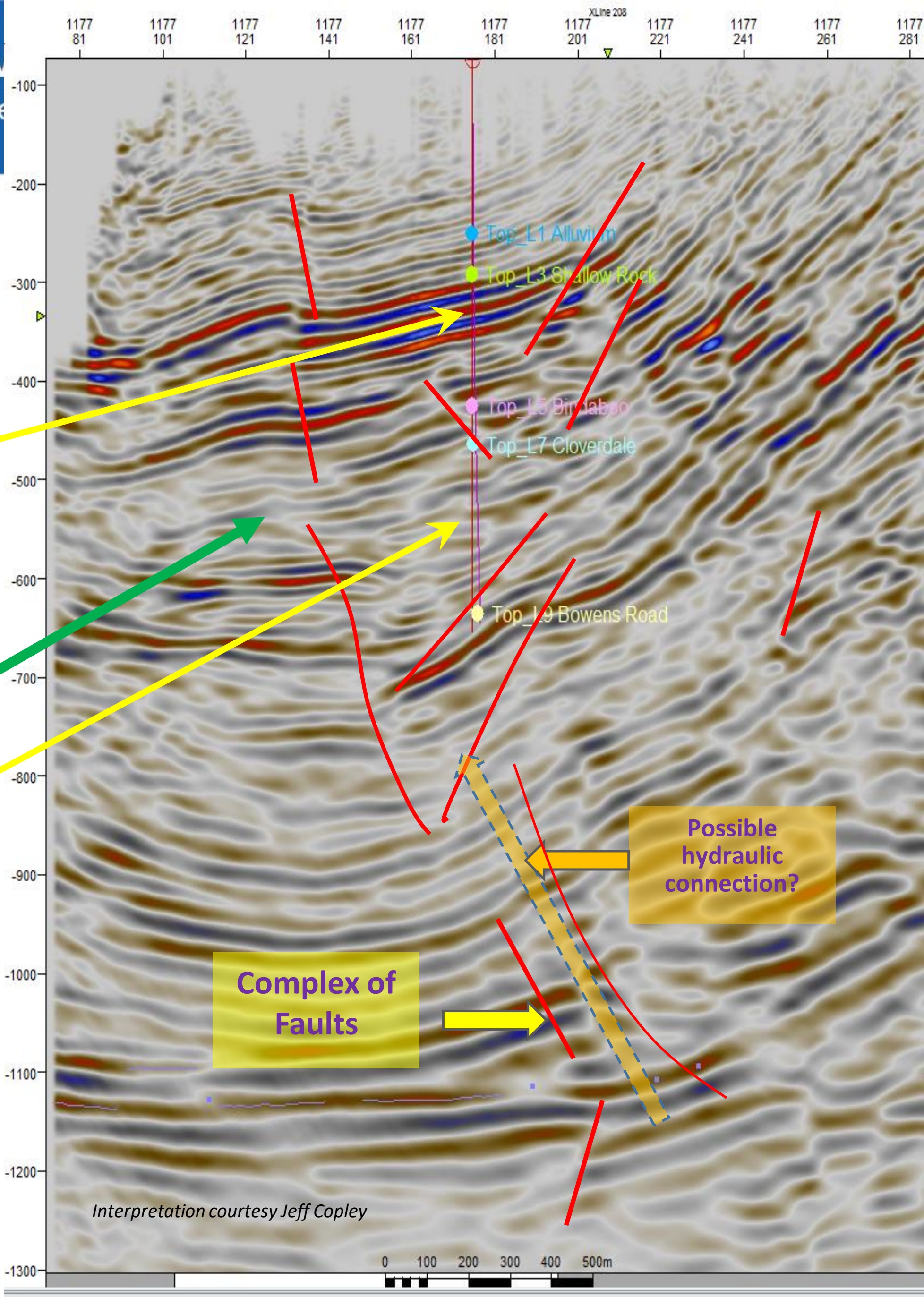
Conceptual Hydrogeological Model



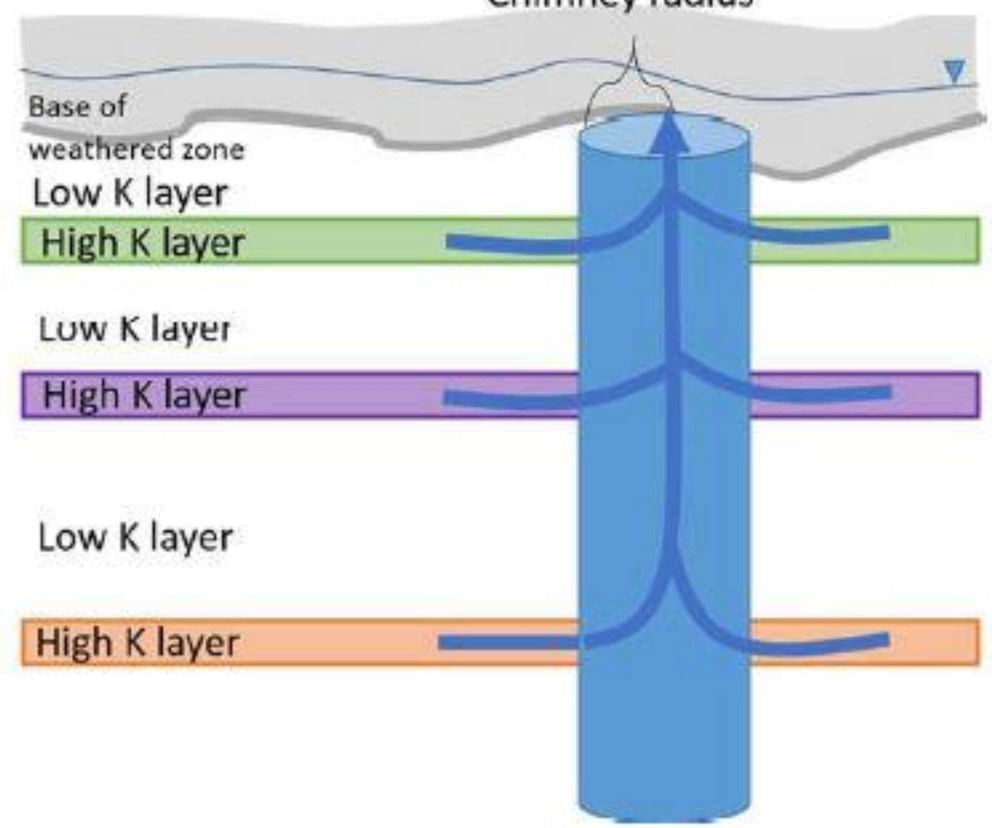


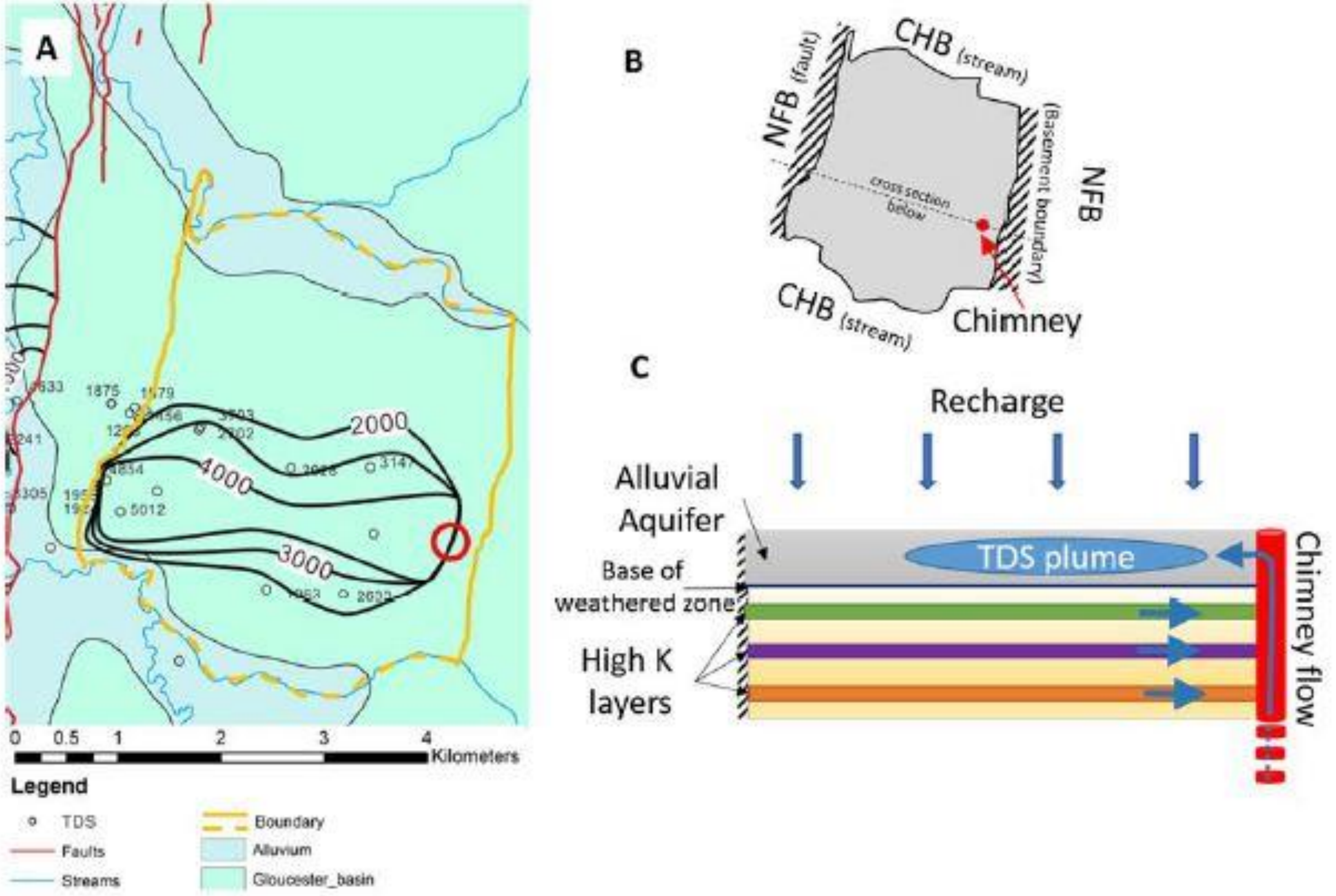
Northern Anomaly: shallow Strick slip flower structure

Northern Anomaly: corresponds to high density dilatant fractures



Total Dissolved Solids Modelling





Calibration with Chimney k = ~13mD
Or ~ 13x host rock k.

Take Away Messages

What we saw:

- Changes in water chemistry are subtle
- Upward hydraulic gradients and hydraulic head discontinuities help identify fault zone hydraulic character
- TDS can help characterise the flow systems near faults e.g. previous slide.
- Damage zone enhanced permeability is key to locating up fault fluid flow in a block of 1 mD permeability rock volume

What we deduced:

- With subsurface hydro, surface hydro, and in-situ stress and strain we believe we know what to look for in the seismic expression for vertical leakage conditions
- We included these characteristics in a groundwater flow model to calibrate a permeability to be enhanced by about 1 order of magnitude in dilatant faults.

This gives us some measure of predictability for fault zone permeability from just the seismic volume in areas devoid of other data

Acknowledgements / Thank You / Questions

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