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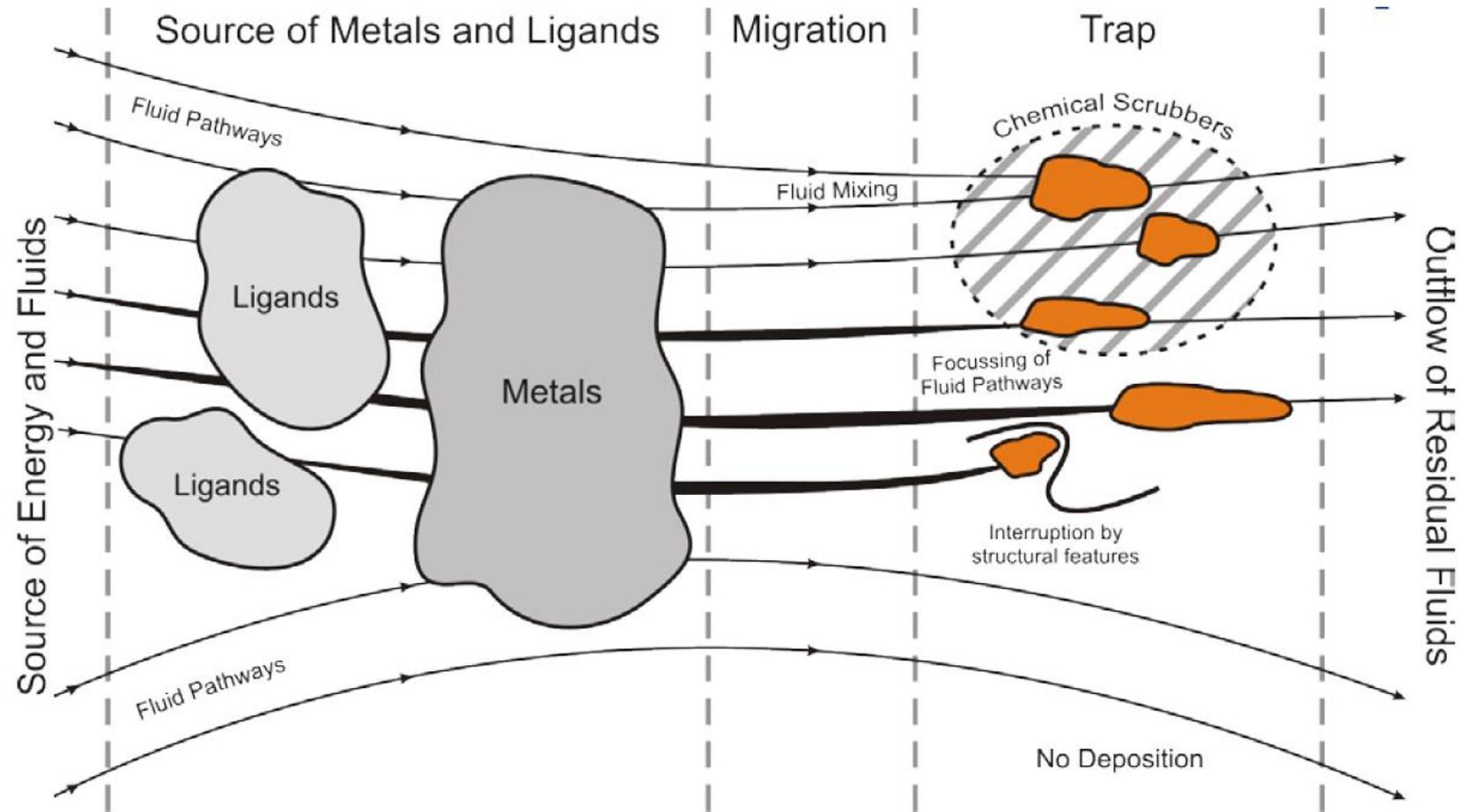
# Integrating Structural Geology to Understand Mineral Systems

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Consultant Geologist

20 August 2019

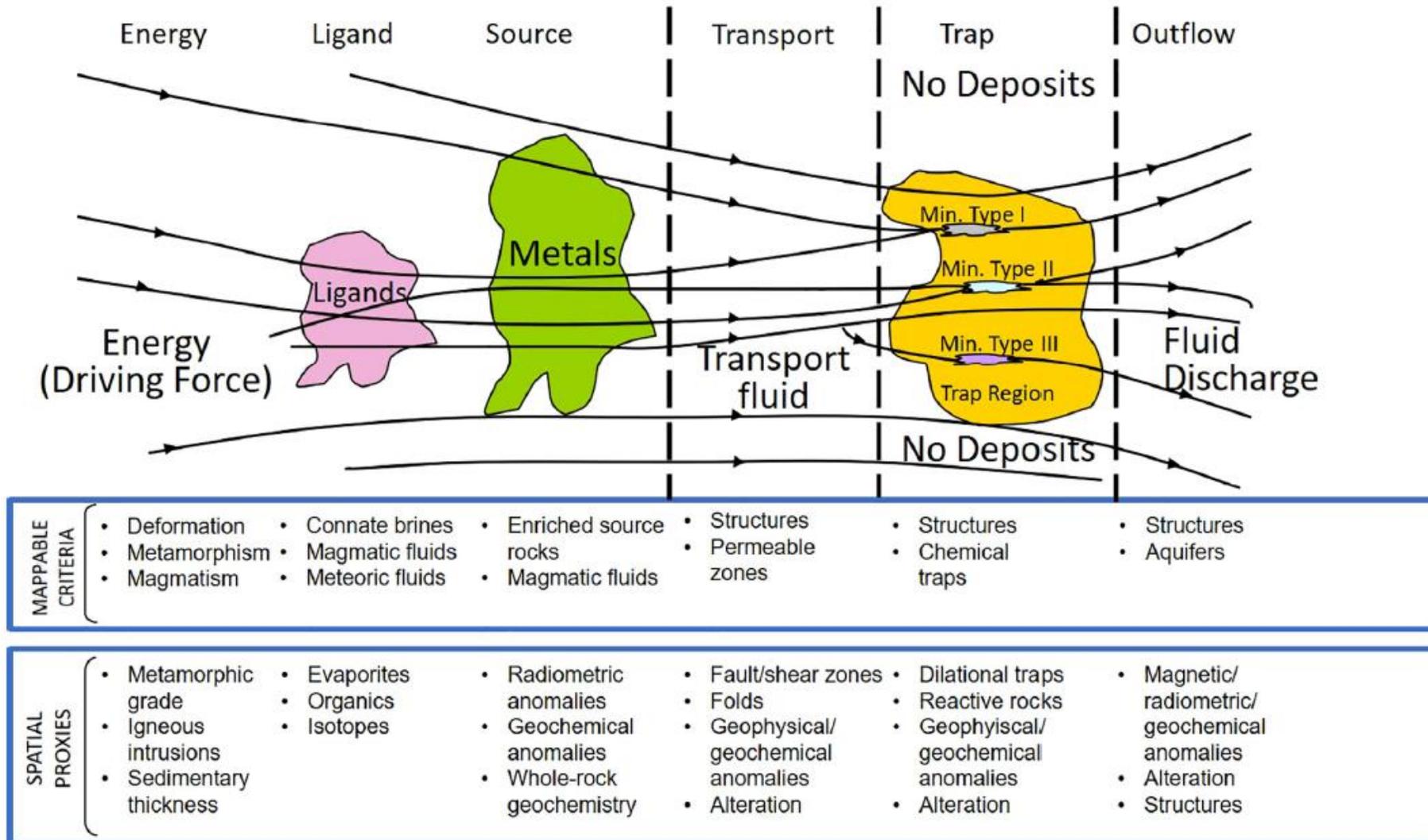


# Mineral Systems



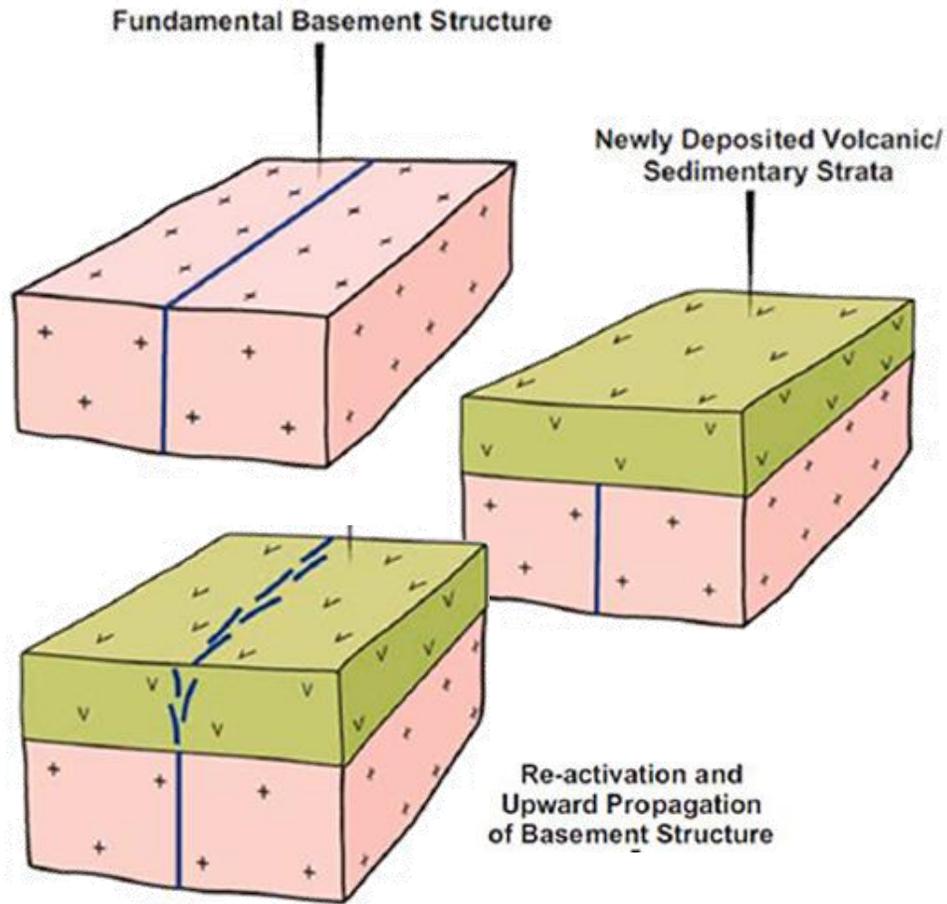
Peters et al., 2017; Knox-Robinson and Wyborn, 1997

# Components of Mineral Systems



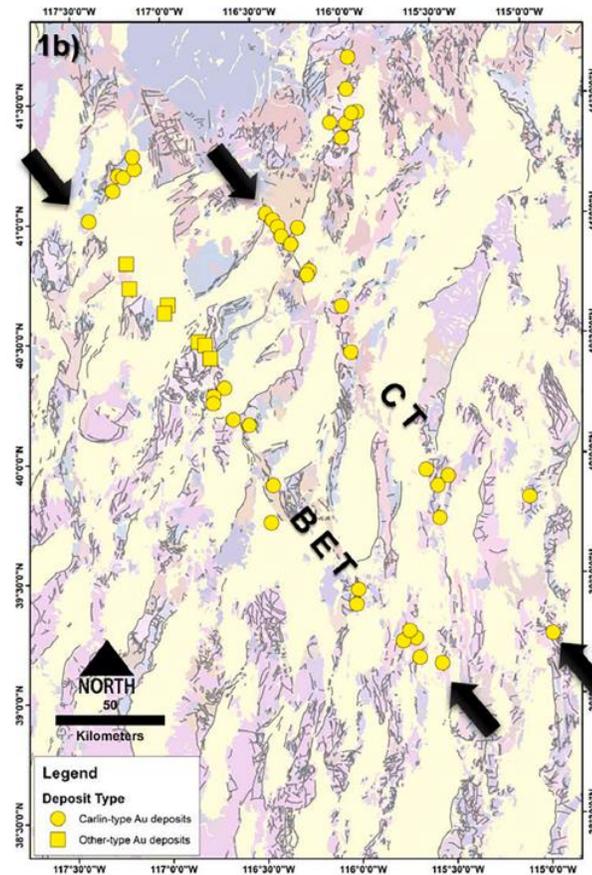
Ford et al., 2019; Knox-Robinson and Wyborn, 1997

# Lithospheric-Scale Structure and Fluid Migration

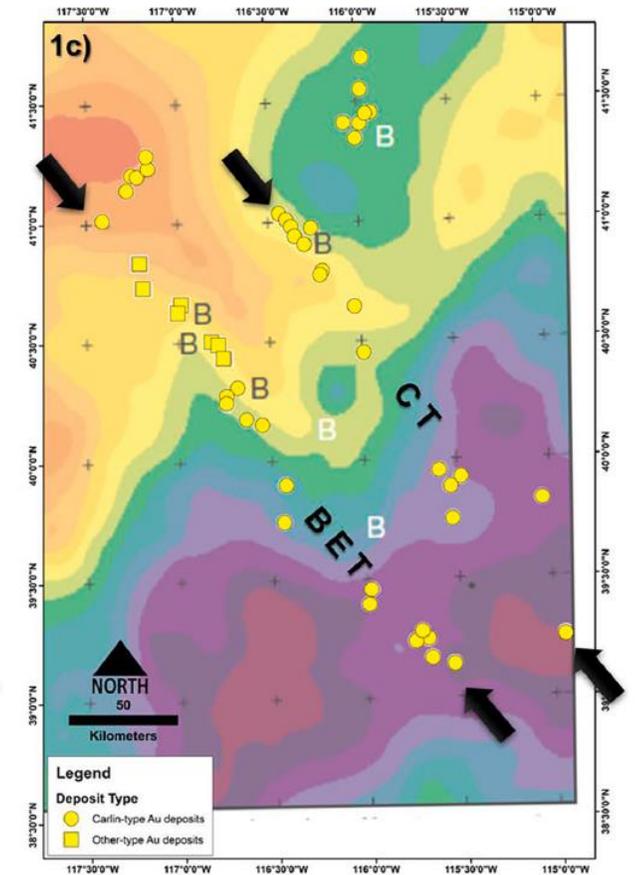


Hronsky and Kreuzer, 2019; McCuaig and Hronsky, 2014

e.g. Carlin province, Nevada

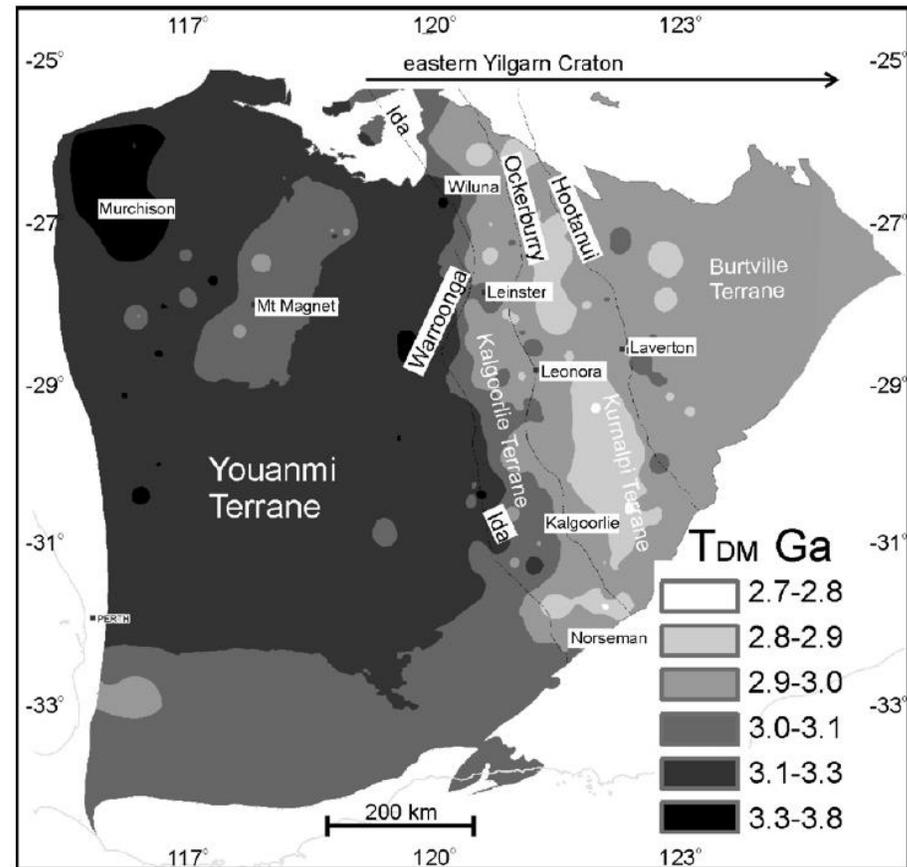
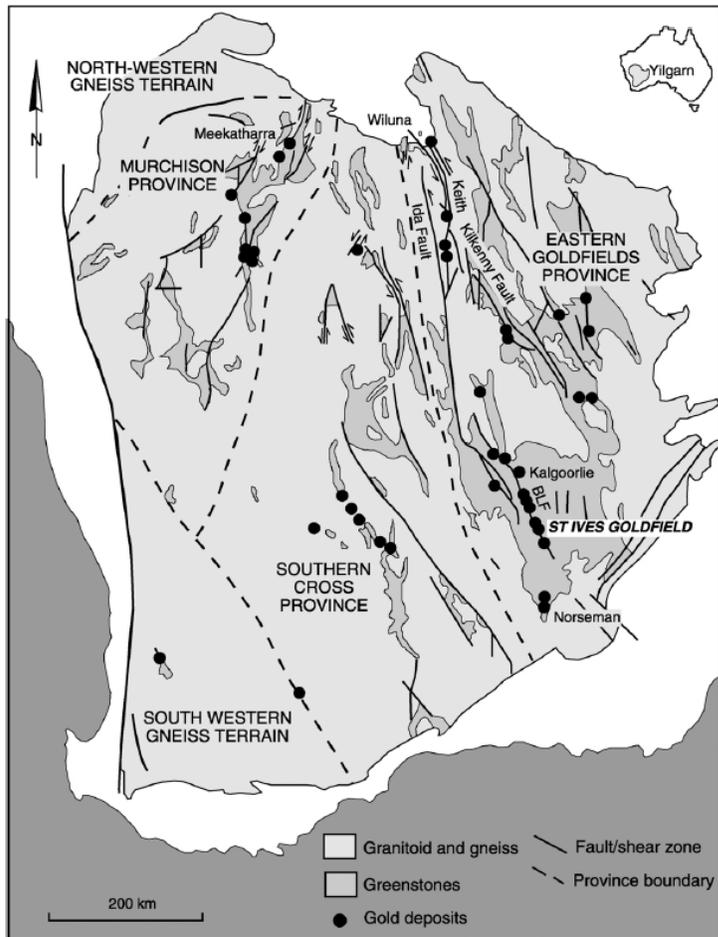


Bouguer Gravity

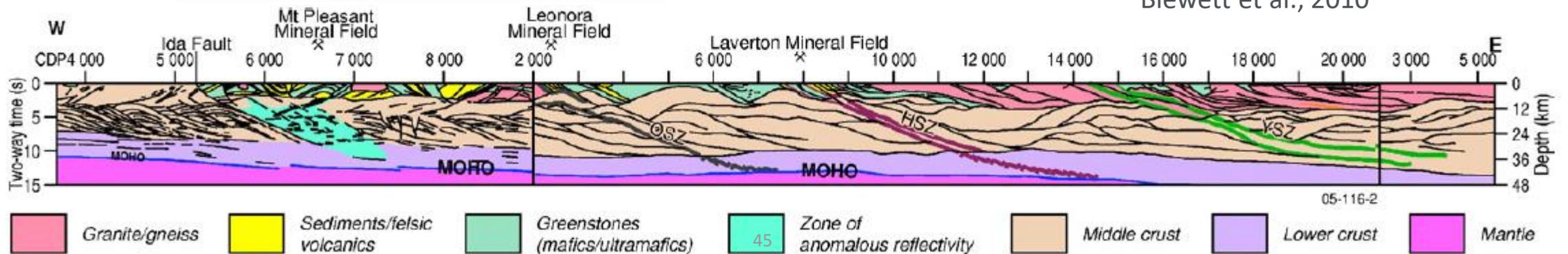


Hronsky and Kreuzer, 2019; Grauch et al., 2003

Cox & Ruming, 2004;  
Groves et al., 1989



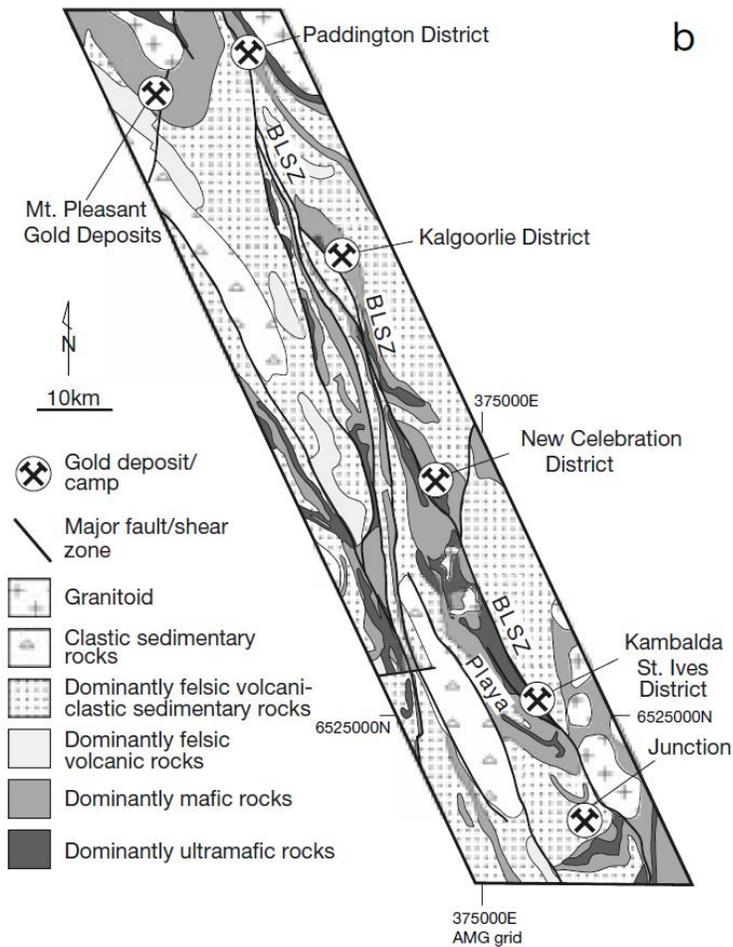
Blewett et al., 2010



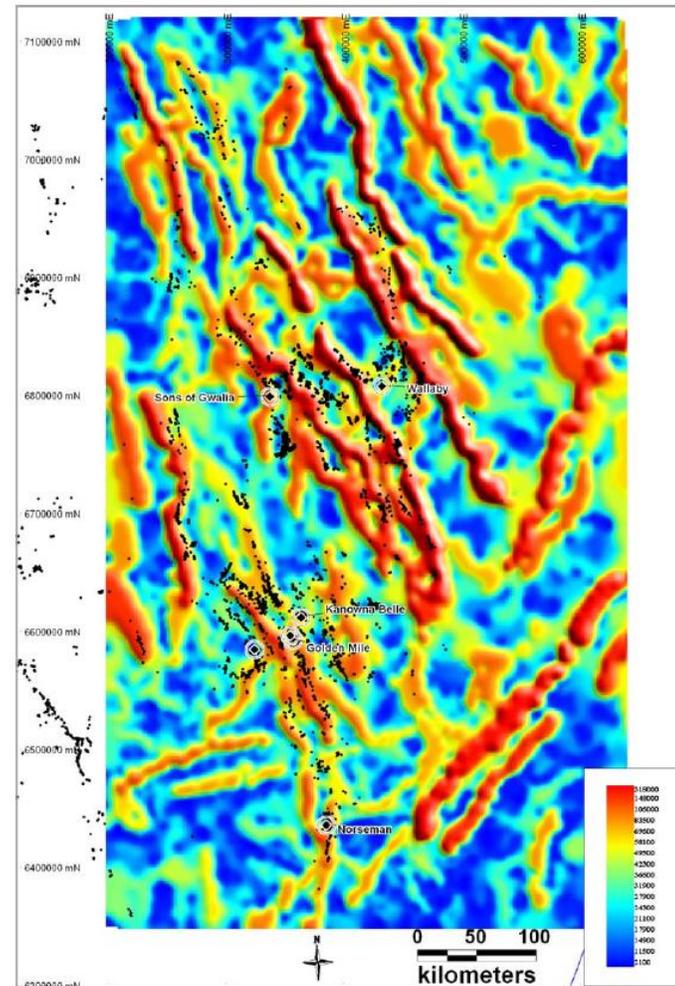
Blewett et al., 2010; Goleby et al., 2003



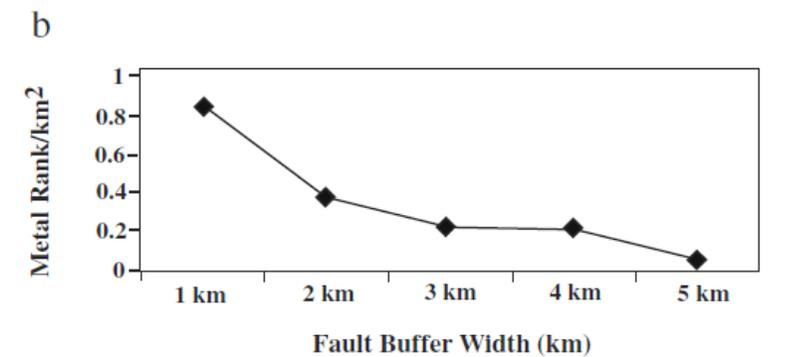
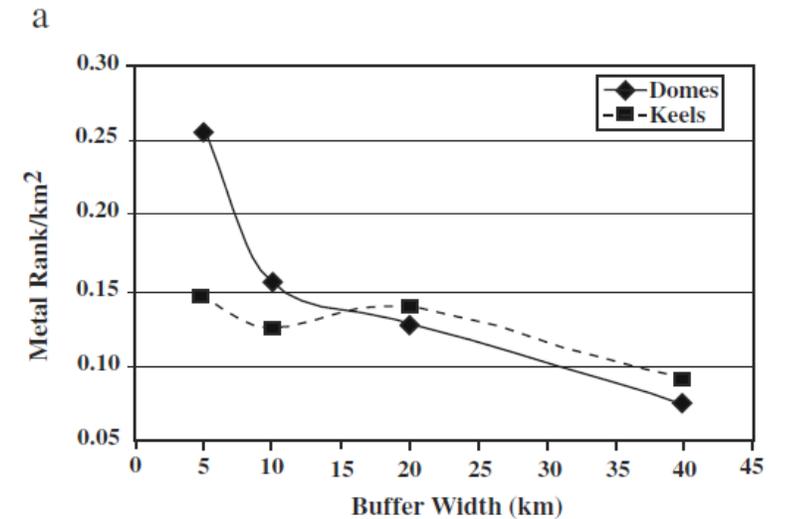
# Terrane to Local-Scale Fluid Migration and Trapping



Weinberg et al., 2005

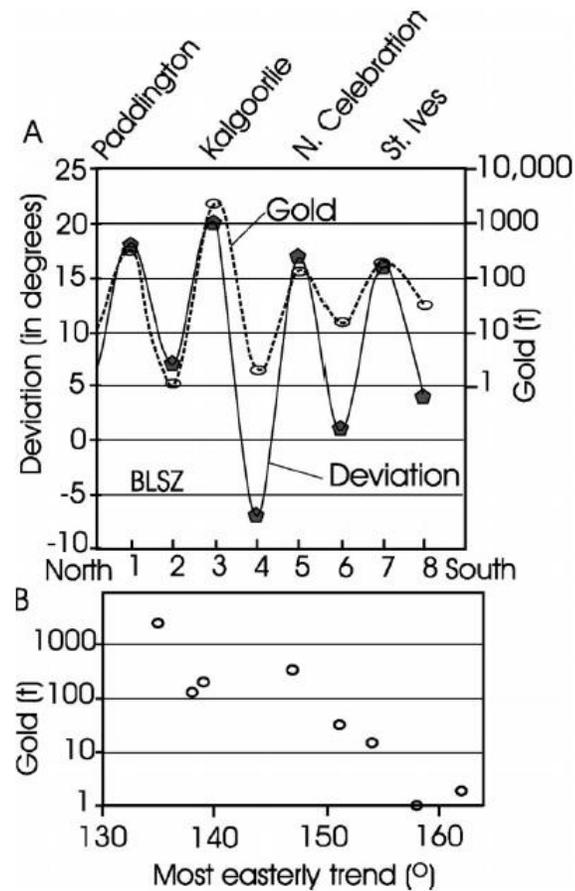


Bierlein et al., 2006

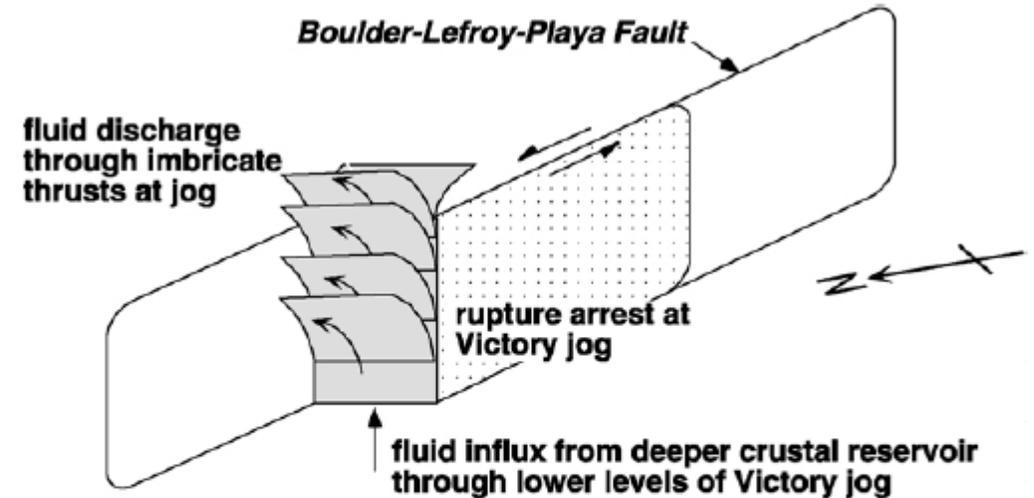
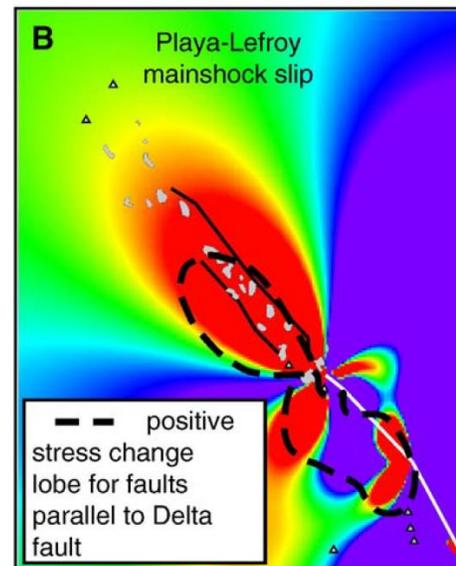
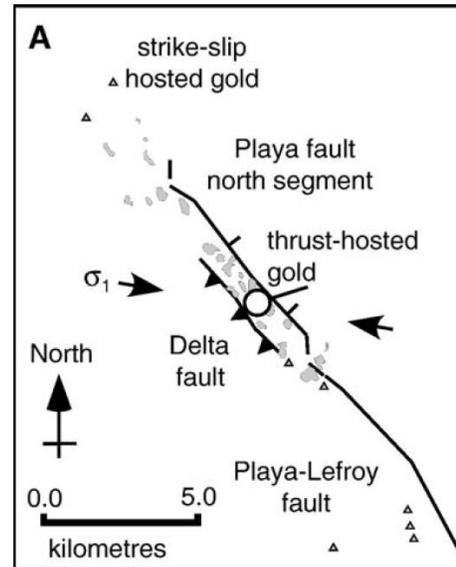


Bierlein et al., 2006

# Local to Deposit-Scale Fluid Migration and Trapping



Weinberg et al., 2004

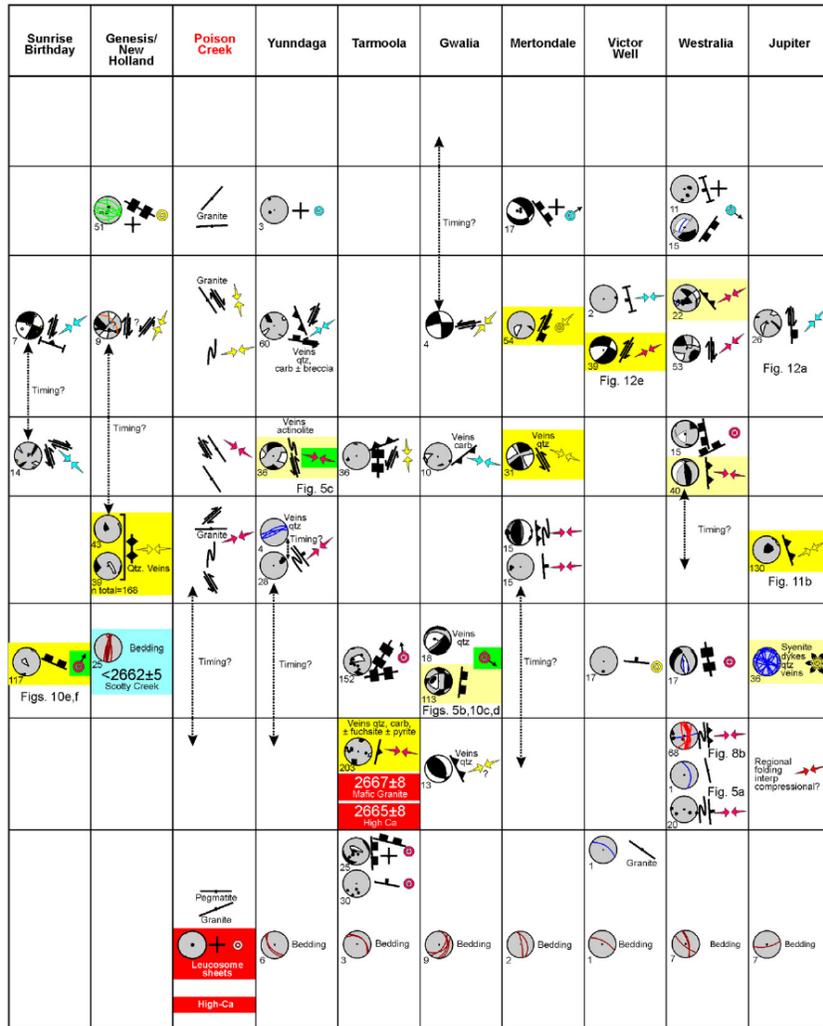


- low permeability unruptured fault segments
- moderate permeability ruptured planar fault segment
- high permeability imbricate thrust zone in jog

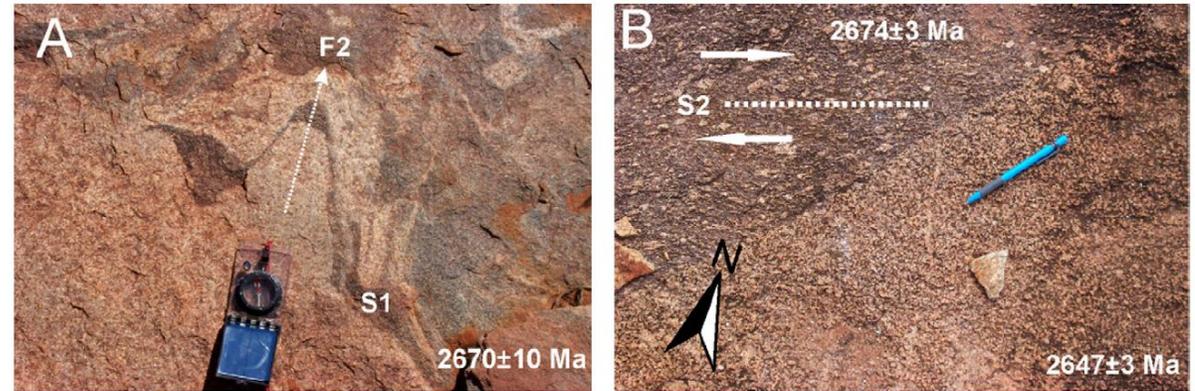
Cox and Ruming, 2004

Micklethwaite and Cox, 2006

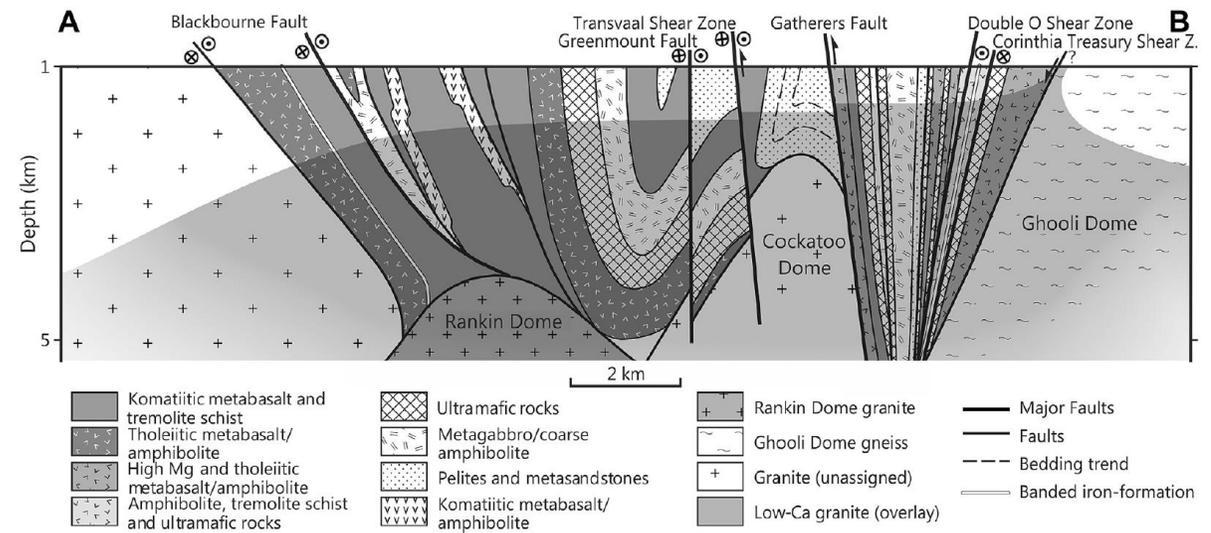
# Deposit-Scale Events and Traps?



Blewett et al., 2010



Blewett et al., 2010



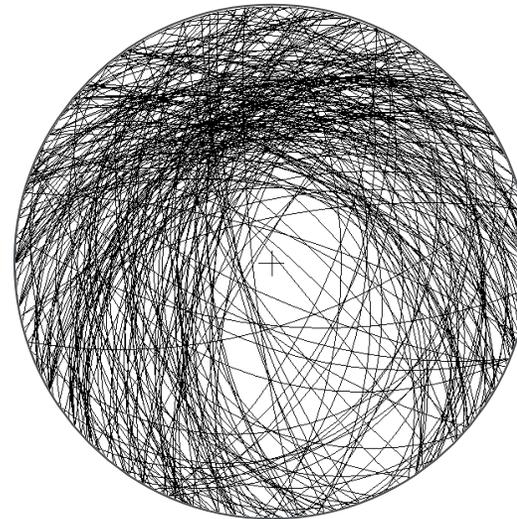
Doublier et al., 2014

# Deposit-Scale Events and Traps?

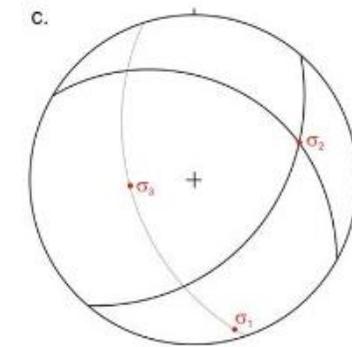
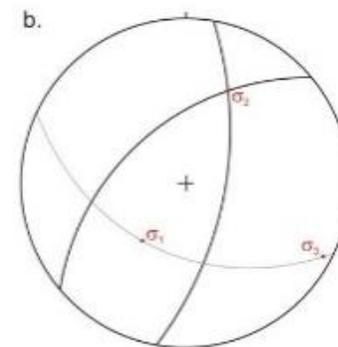
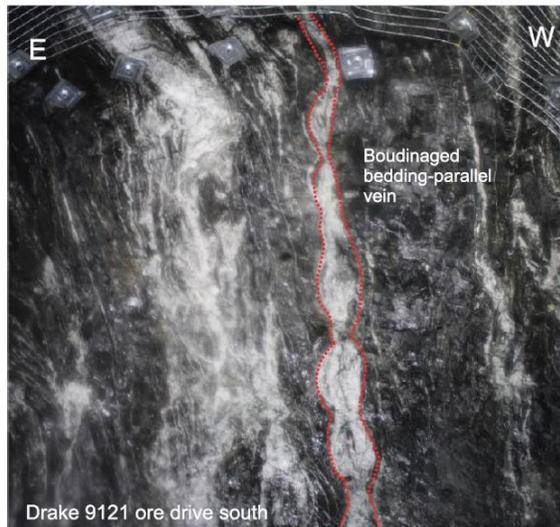
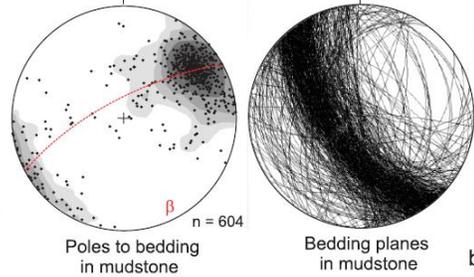
H1000	Hole_id	Depth From	Structure	SPATIAL	Alpha	Beta
D	ULDD019	105.3	BD	O	60	15
D	ULDD019	105.6	BD	O	55	20
D	ULDD019	105.7	BD	O	50	0
D	ULDD019	125.7	FO	O	35	350
D	ULDD019	133.6	FO	O	40	211
D	ULDD019	130.3	FO	O	50	355
D	ULDD019	133.1	VN	O	25	202
D	ULDD019	138.7	VN	O	35	170
D	ULDD019	149.1	FZ	O	55	5
D	ULDD019	149.5	FZ	O	60	35
D	ULDD019	149.7	FZ	O	55	15
D	ULDD019	162	FO	O	47	242
D	ULDD019	162.1	VN	O	70	174
D	ULDD019	163.9	VN	O	65	85
D	ULDD019	164.2	VN	O	50	127
D	ULDD019	163.4	FO	O	60	315
D	ULDD019	165.9	FX	O	35	310
D	ULDD019	164.8	VN	O	45	118
D	ULDD019	166.2	FO	O	15	137
D	ULDD019	166.2	JS	O	60	100
D	ULDD019	166.8	JS	O	50	225
D	ULDD019	169.4	FO	O	40	355
D	ULDD019	170	FZ	O	50	90

We cant rely on orientation alone to distinguish important structures and orientations.

We need more than this from our data collection.



# Deposit-Scale Structural Observations



# Deposit-Scale Structural Observations

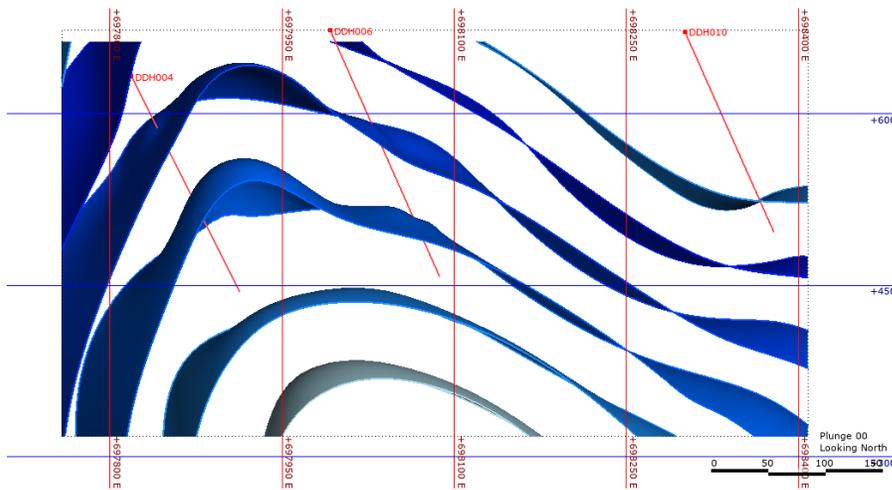
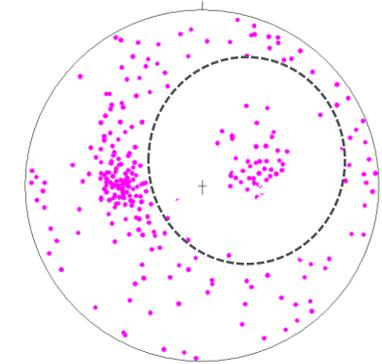
- Focus on observations rather than interpretation.
- What are the key characteristics of structures we can use to classify and interpret them.
- Make observations "Queryable".
- Get observations out of the comments field and into the data fields.
- Recording of cross-cutting relationships are key to interpret timing.



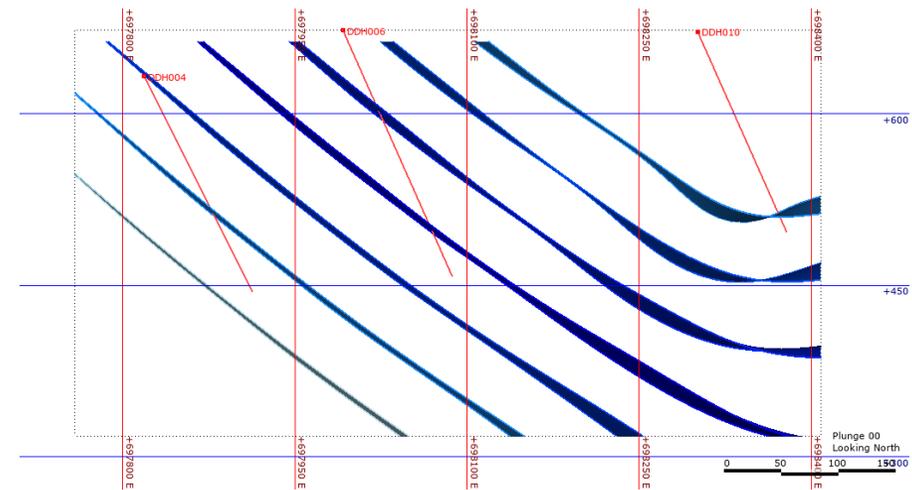
# Quality Control of Structural Observations

In all stages of core orientation, mark up and measurement, accuracy is key. Record the confidence associated with different workflows.

The accumulation of small errors over multiple stages can result in significant errors that can affect the quality of results.



Non filtered bedding data  
Apparent folding (which is not real!)



Filtered, good bedding data

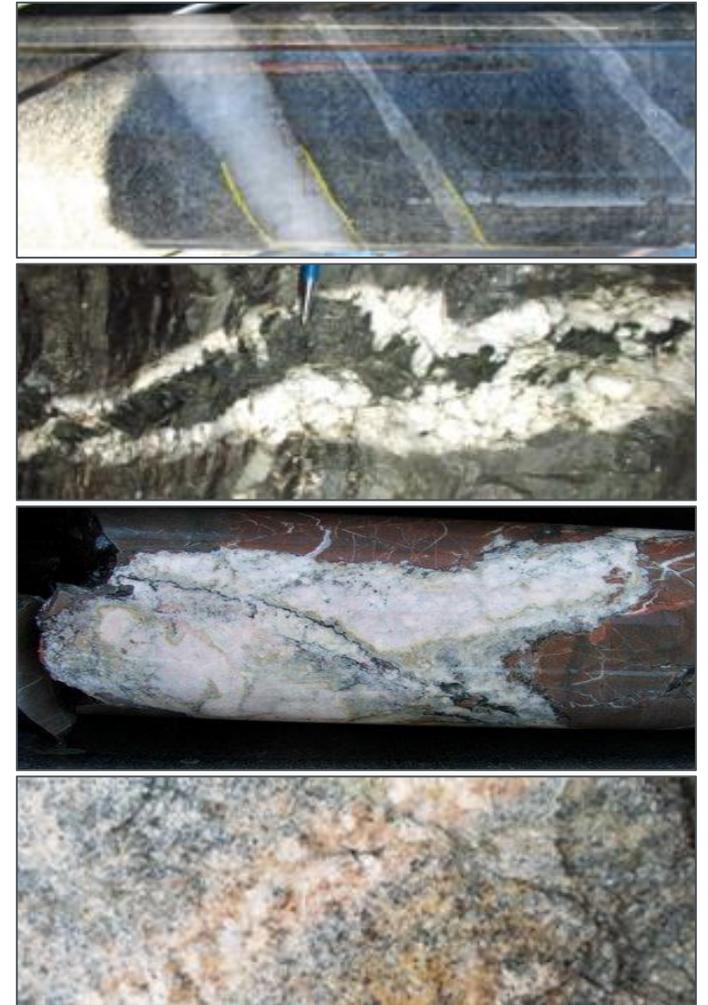
# Is a Vein Just a Vein?

Veins need to be separated for structural analysis by their characteristics, as well as their orientation and mineralogy.

For example, the vein characteristic could describe:

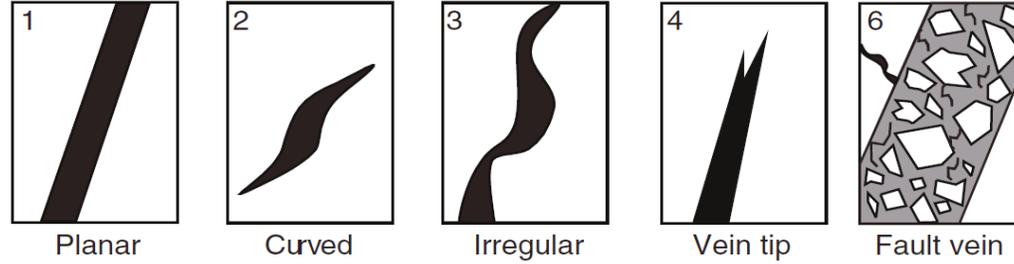
- What does the vein look like internally?
- What is the shape of the vein?
- How does the vein relate to other similar veins?

Vein abundance is important, but you don't have to measure every vein. Quantify similar veins by recording frequency.

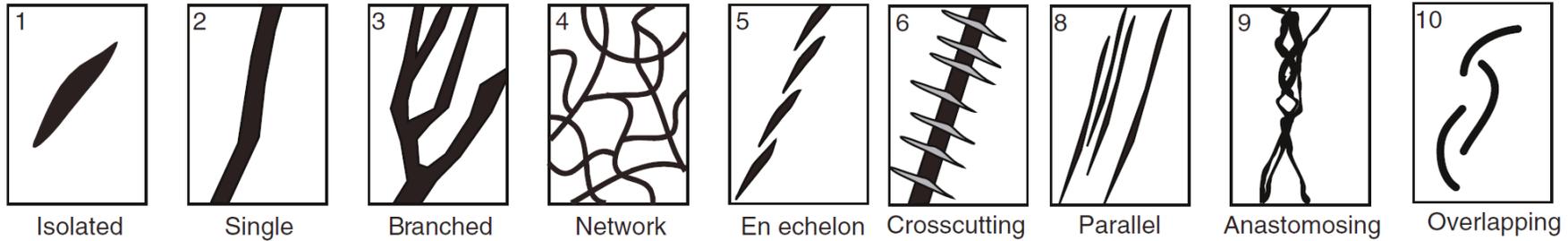


# Is a Vein Just a Vein?

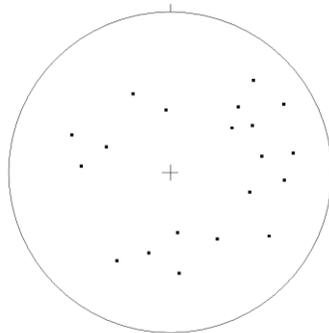
## Vein Morphology



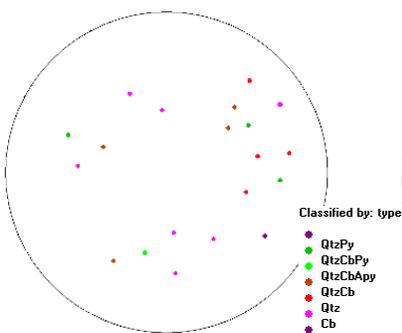
## Vein Connectivity



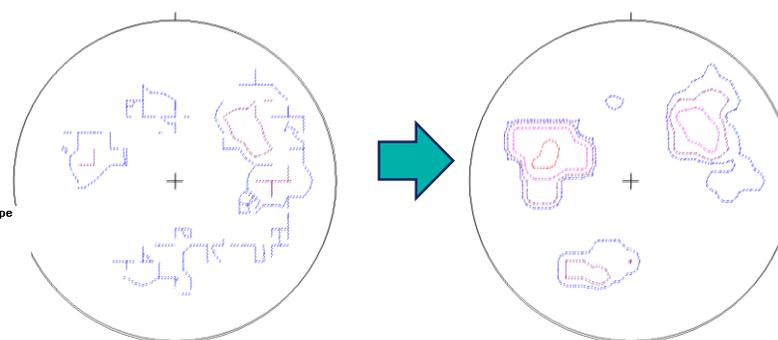
All Veins  
Not very helpful or useful



Veins by composition  
Helpful, but not statistically useful



Veins by composition + frequency  
Helpful, and statistically useful



# What About Other Structures? Faults, Folds, etc, etc

## Breccias

Angular



Sub-angular



Sub-rounded



Rounded

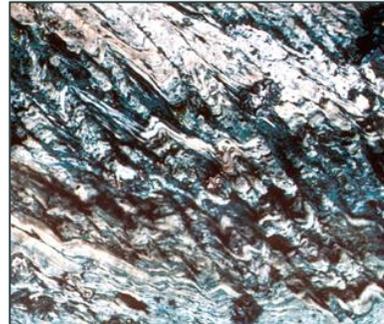


## Foliation

Slaty Cleavage



Crenulation Cleavage



Gneissic Banding



## Lineations

Structural Intersections



Fault Slickenfibres



Fold Axis

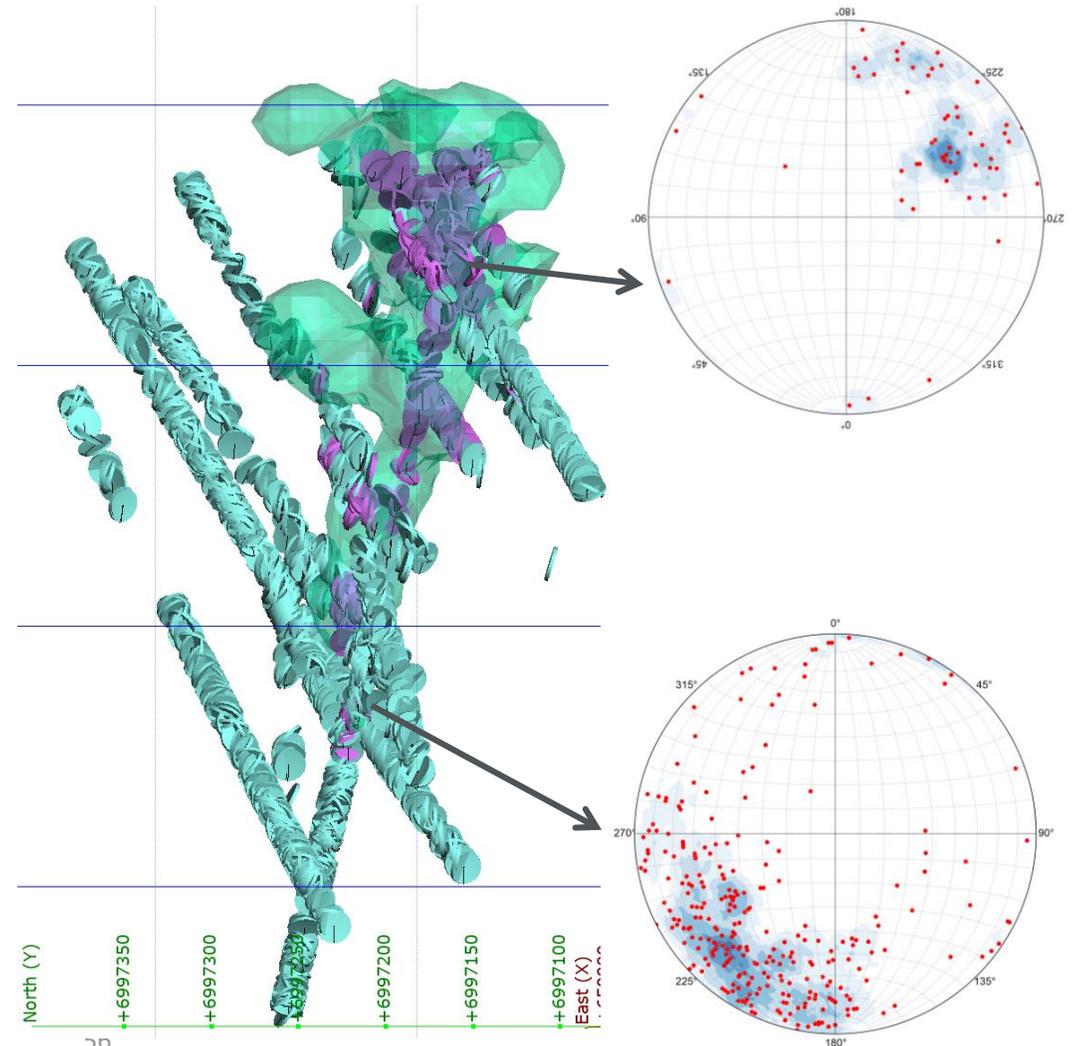


# Migration Pathways, Traps and Mineralisation

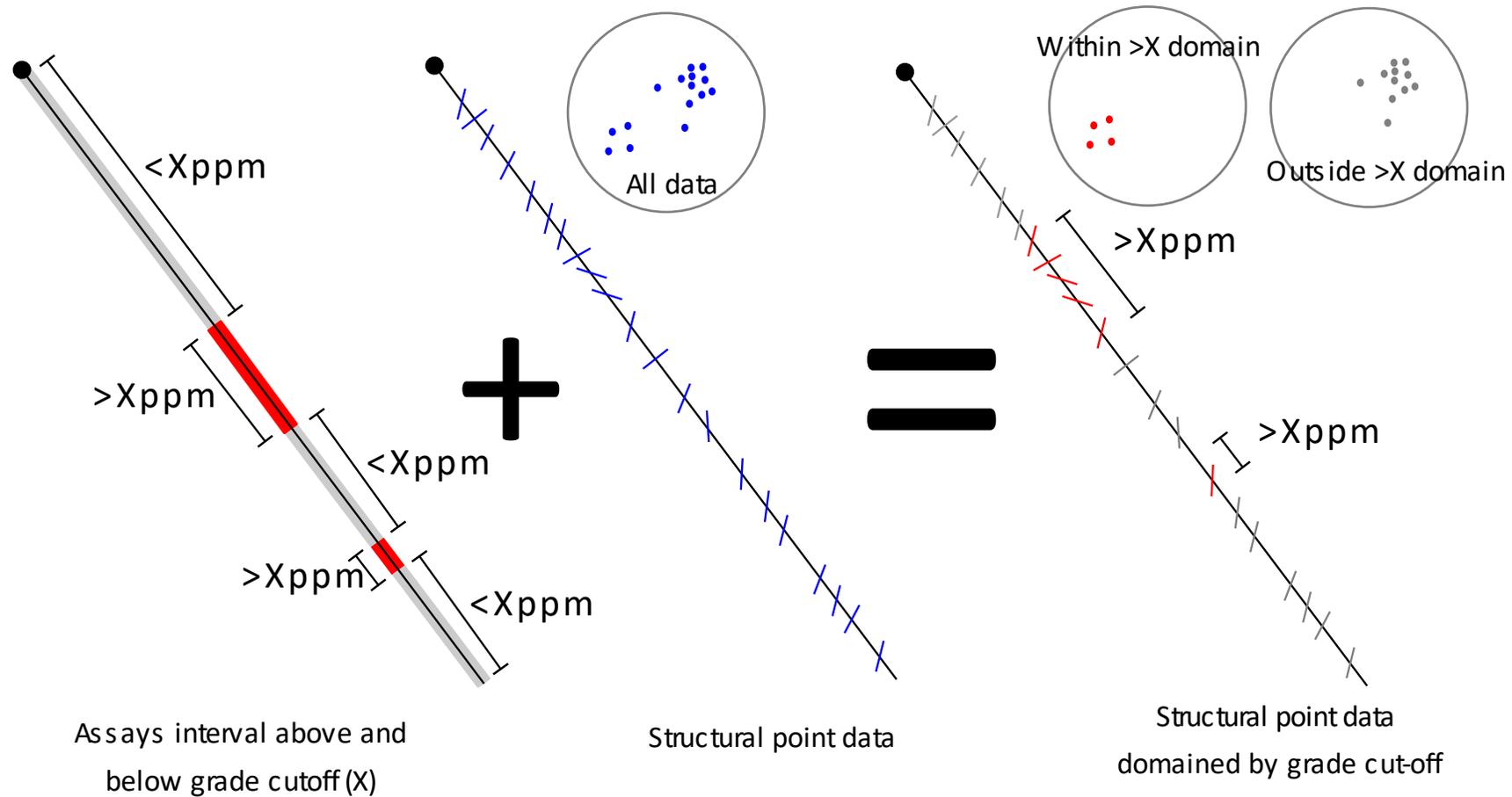
What is different about sites that host mineralisation compared to everything else around it?

Like any other data set (e.g. lithology, geochemistry, geophysics), we are looking for a structural anomaly that may help to predict sites of mineralisation.

Spatial domaining – domain by fault block, lithology, northing, easting etc. to recognise differences in statistical relationships between structures.



# Migration Pathways, Traps and Mineralisation



# Working Towards a Mineral System Understanding

Once you have a dataset interpretations can be undertaken for mineral systems understanding:

## Pre-Mineralisation Architecture

Fold architecture  
Fault architecture

## Syn-Mineralisation dilation/fluid focussing

Faulting/shearing  
Fault Bends  
Fault stepovers  
Structural intersections

## Post-Mineralisation deformation/ dismemberment

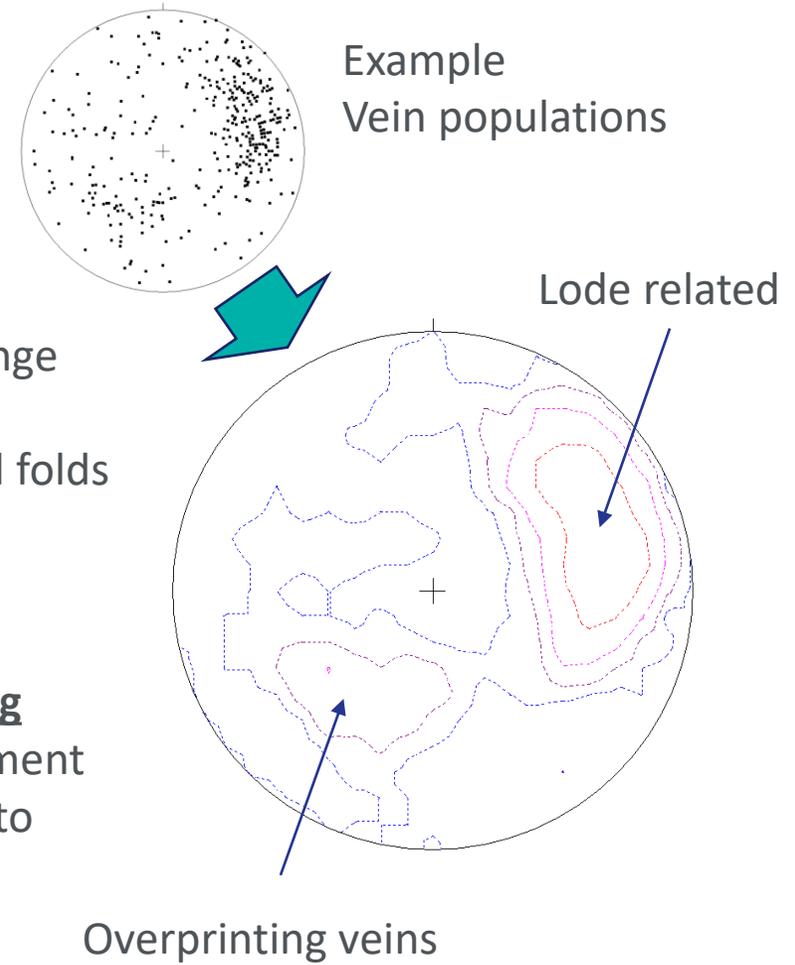
Folding  
Faulting/shearing

### Folds

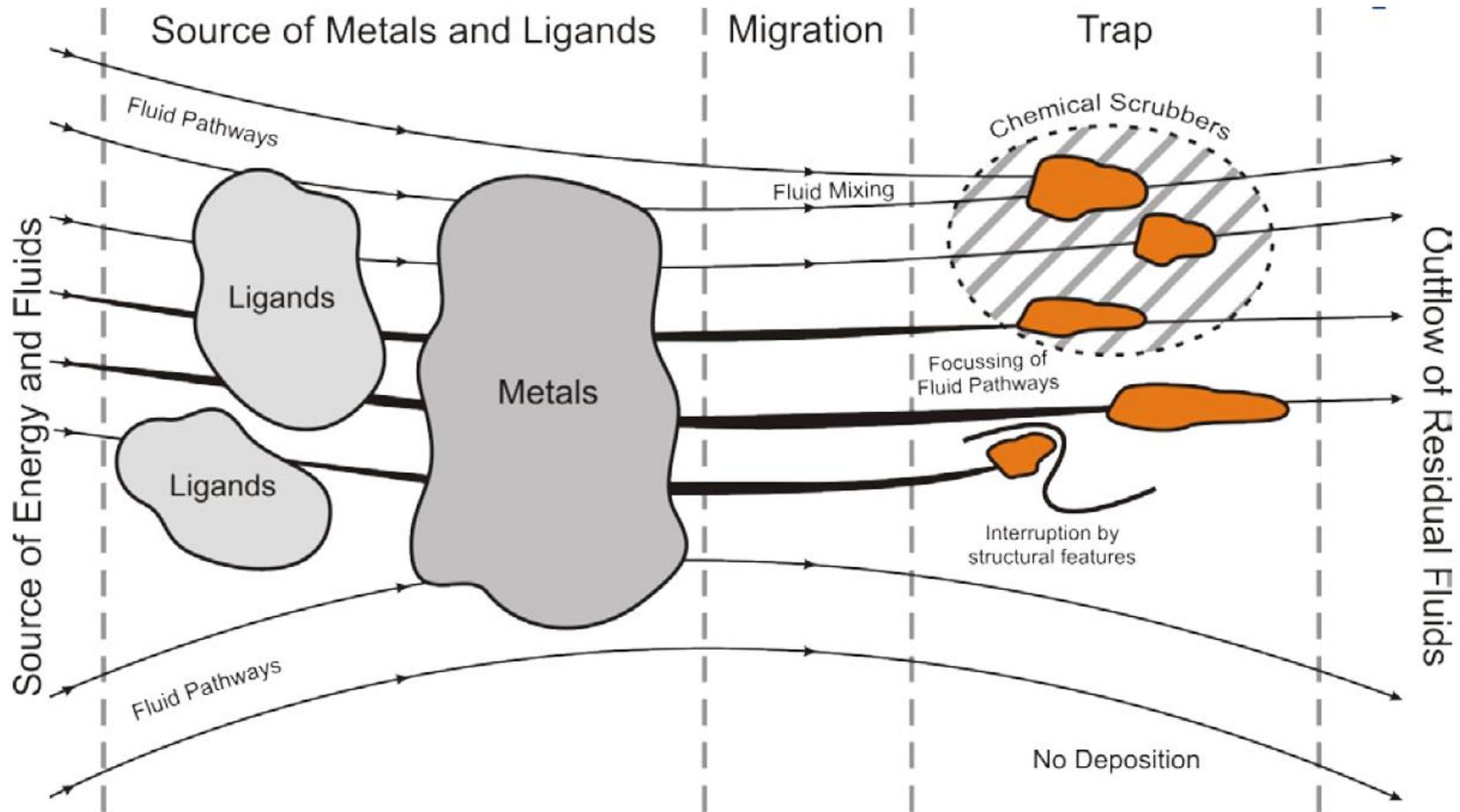
- Plunge and plunge direction
- Position around folds (vergence)
- Style of folding

### Faults and shearing

- Sense of movement
- Characteristics to recognise sets



# Structural Geology in Mineral Systems



Peters et al., 2017; Knox-Robinson and Wyborn, 1997



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# Principles of Structural Data Collection and Controls

Ask me about our  
CSA Global Short Course

