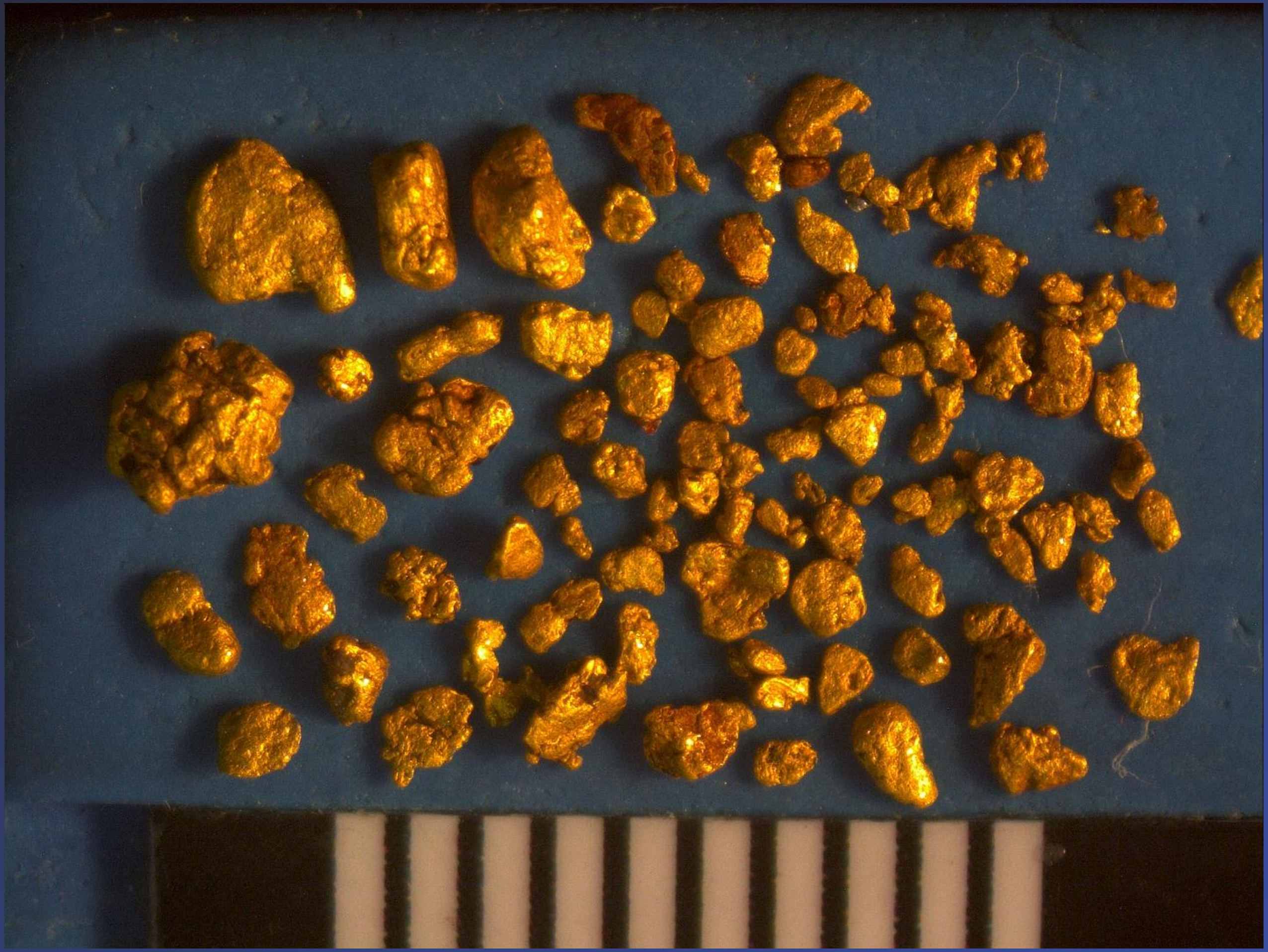
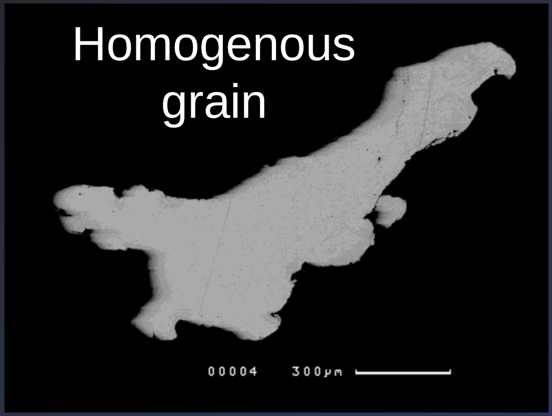
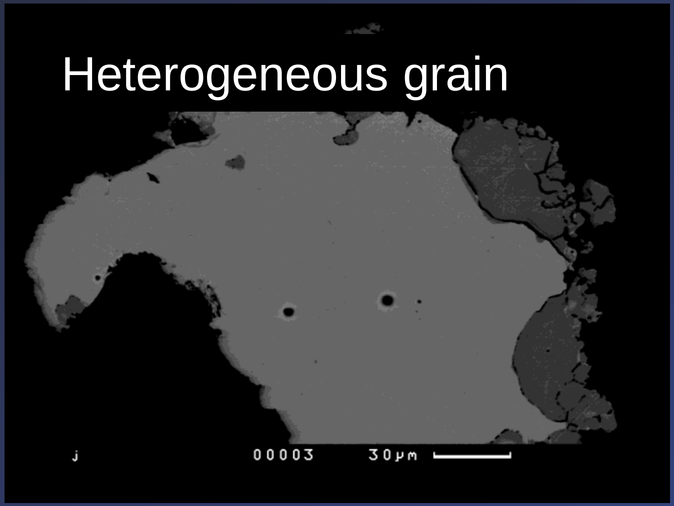
Gold grain studies



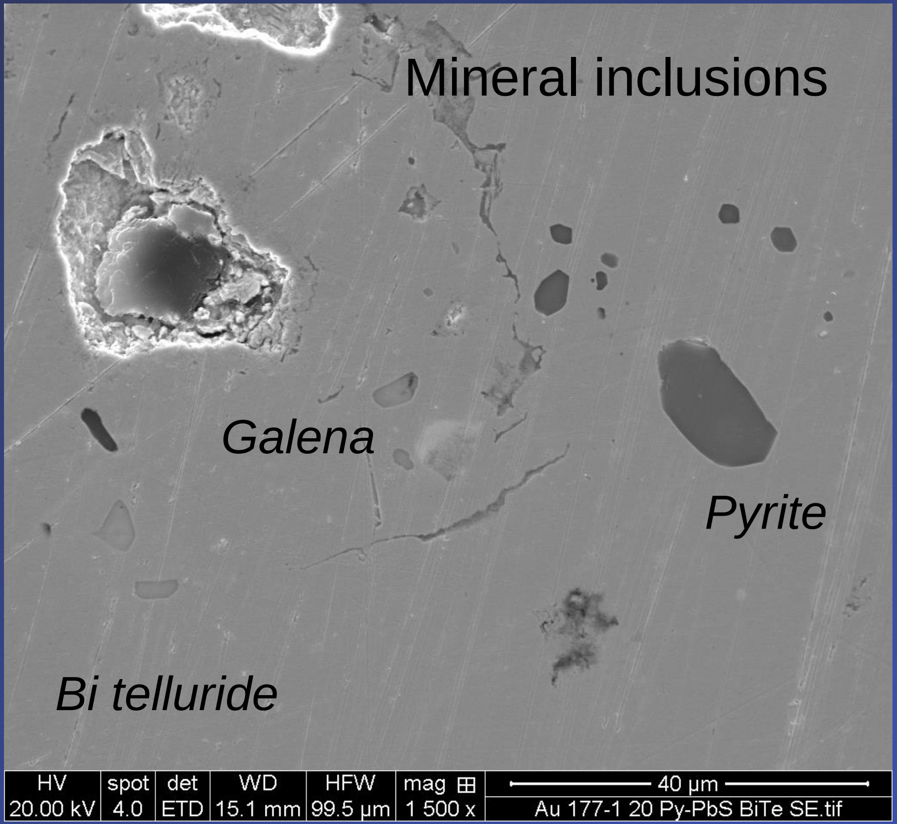
Gold grain characteristics

Alloy compositions



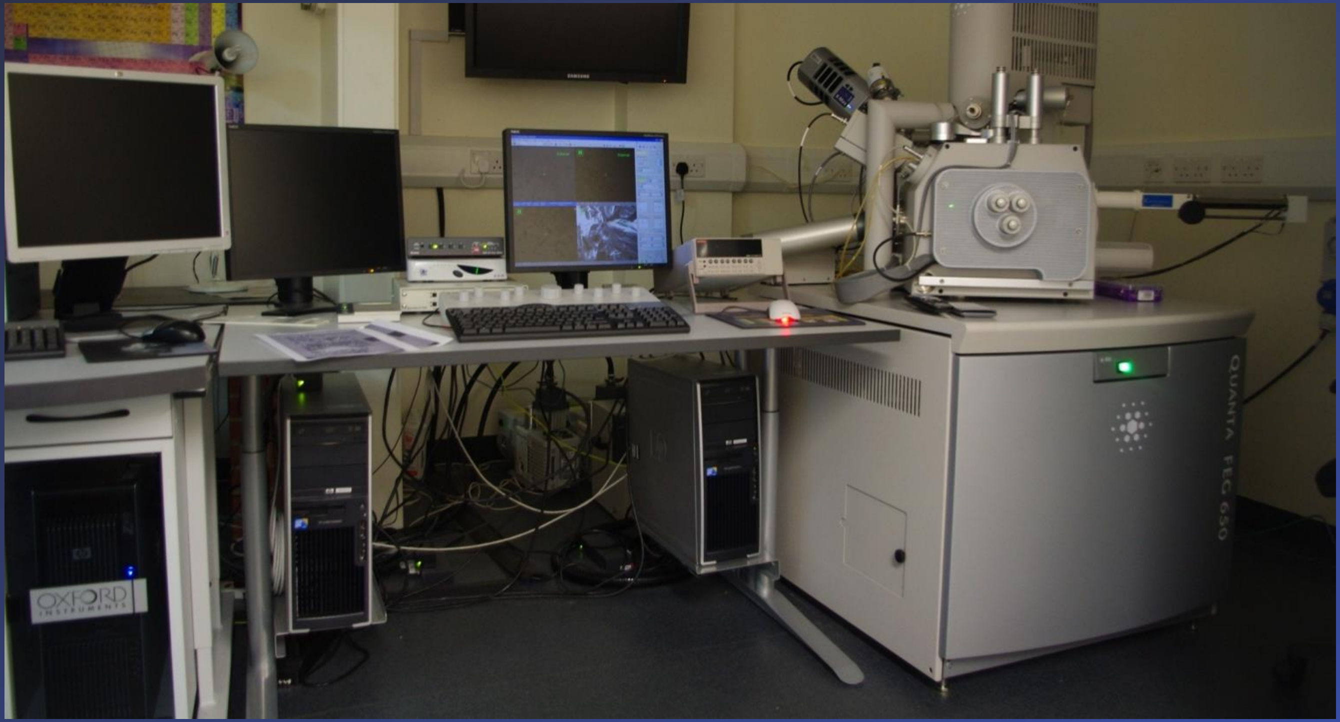


BSE images of sections:



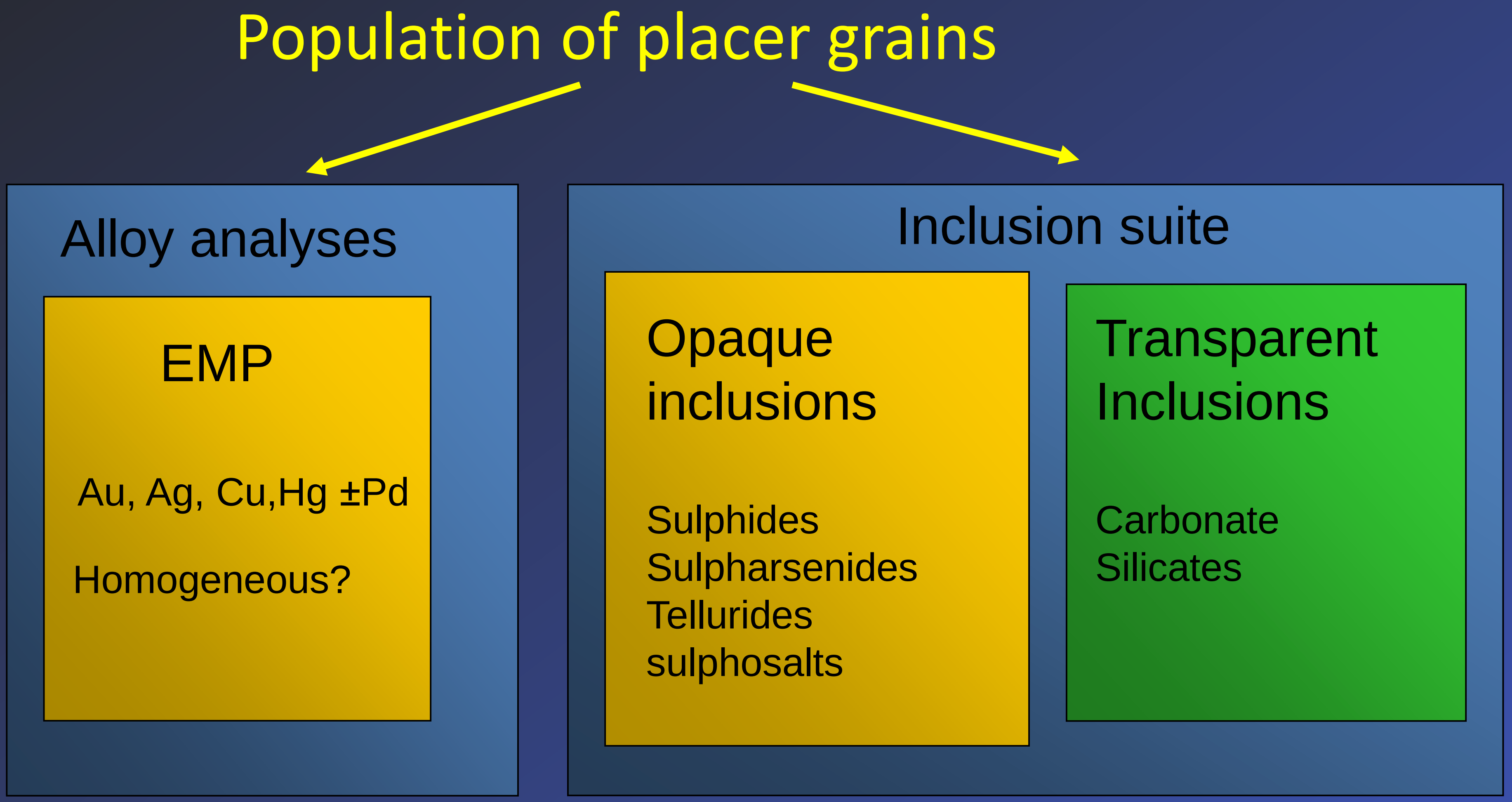
Analysis

Alloy compositions:
Joel Superprobe



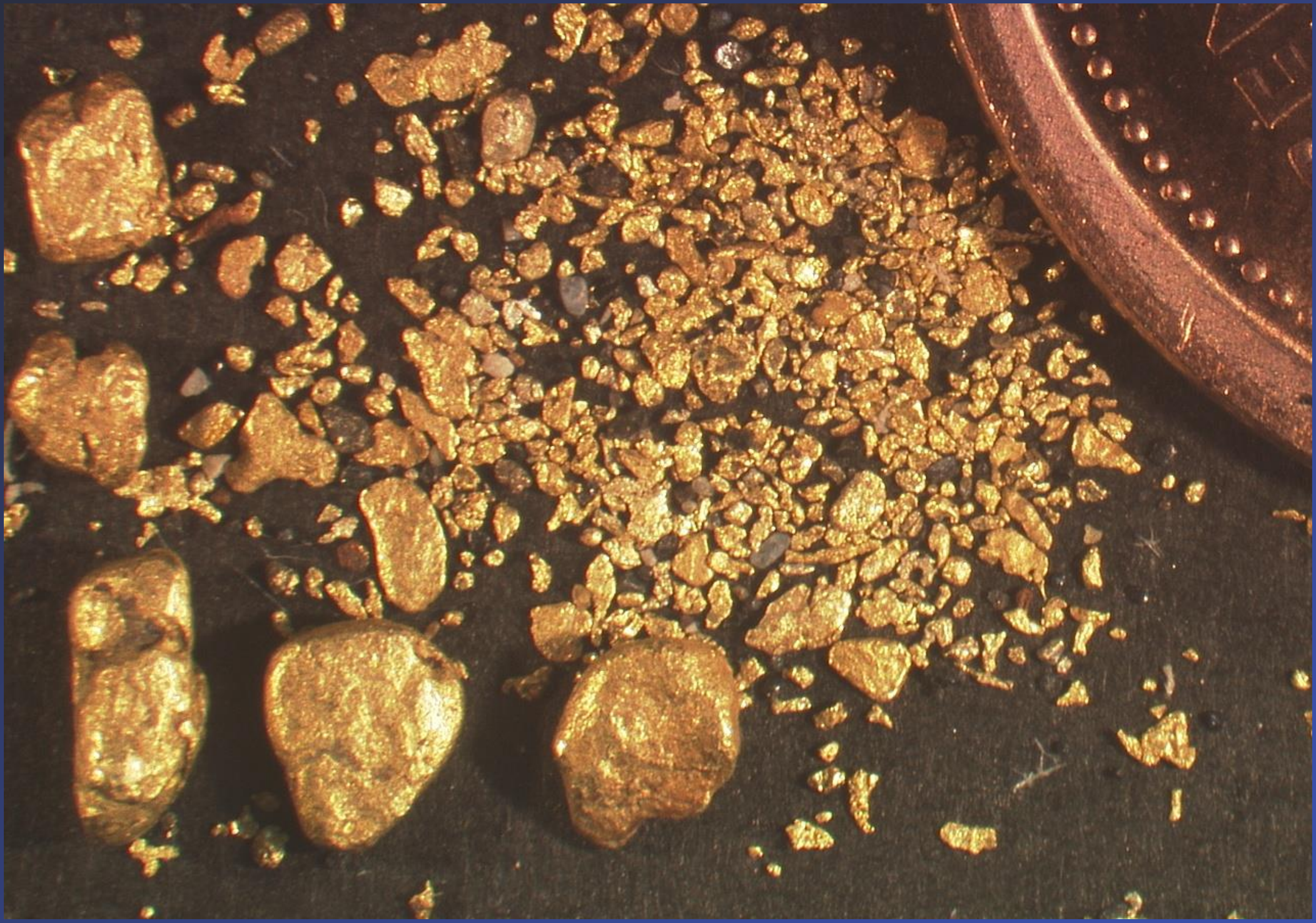
Inclusions:
SEM

Gold alloy chemistry and inclusion mineralogy

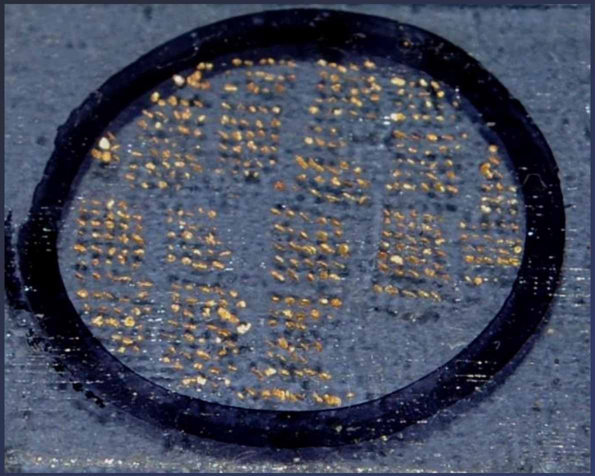


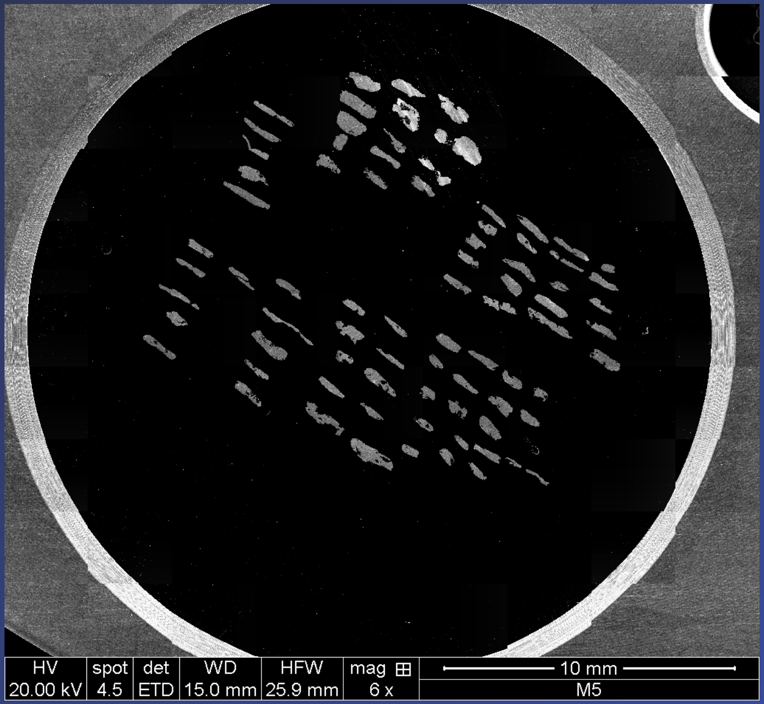
Sample collection

Particle size in the population will vary:



Samples mounted in 1” blocks: according to grains size





BSE collage of 1” polished block containing gold grains after polishing

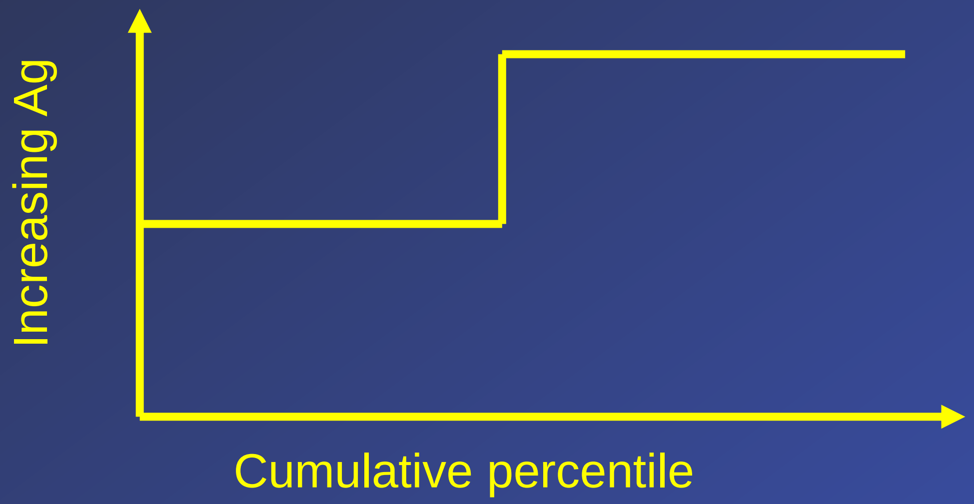
Also mount according to shape

Raw data

	grain	feature	inclusion	Au	Ag	Cu	Hg	Sum
Glencurry,Omagh	7a			81.7	17		1.01	99.71
Sperrins	7b	Au rim		87.5	13.2		0.08	100.78
WRS 421i	7c			92.4	7.5		0.13	100.03
32 grains	7d	Ag/Au tracks		74.8	22.8		2.22	99.82
Leeds sample	7e			75	24.3		1.89	101.19
Leeds analyses	7f			79.3	21.7		0.1	101.1
	7g			75.7	25		0.26	100.96
	7h			82.5	17.3		0.47	100.27
	7i	porous area		80.8	19		0.92	100.72
	7j	Ag-rich areas		75.3	23.4		1.83	100.53
	7j			75.3	23.8		1.76	100.86
HG	7k	Au rim		79.6	20.5		1.07	101.17
1.264848485	8a		galena	82.4	17.2		1.03	100.63
	8b		CaFeMgMnCO3	88.2	11.6		0.06	99.86
	8c	#NUM!		79	19.9		1.26	100.16
	8d			75.4	25.2		0.76	101.36
	8e			82	18.5		0.06	100.56
	8f		FeCO3	77.6	20.7		2.07	100.37
	8g	Au/Agpattern	pyrite	73	25.9		2.39	101.29
	8h			78.7	20.7		1.18	100.58
	8i			84.3	15.9		0	100.2
	8j	Au rim		80.7	17.7		1.71	100.11
	8k			53.3	43.3		4.01	100.61
	9a			71.9	25.2		2.88	99.98
	9b		pyrite	78.9	19.8		1.95	100.65
	9c			85.1	14.8		0.33	100.23
	9d		arsenopyrite	74.7	23.1		2.1	99.9
	9e			81.1	17.9		0.81	99.81
	9f		arsenopyrite	82.3	16.7		0.68	99.68
	9g			74.3	24.5		1.43	100.23
	9h			79	19.8		2.02	100.82
	9i			74.7	24.6		1.62	100.92
	9j	Au rim	pyrite	69.8	30		1.65	101.45

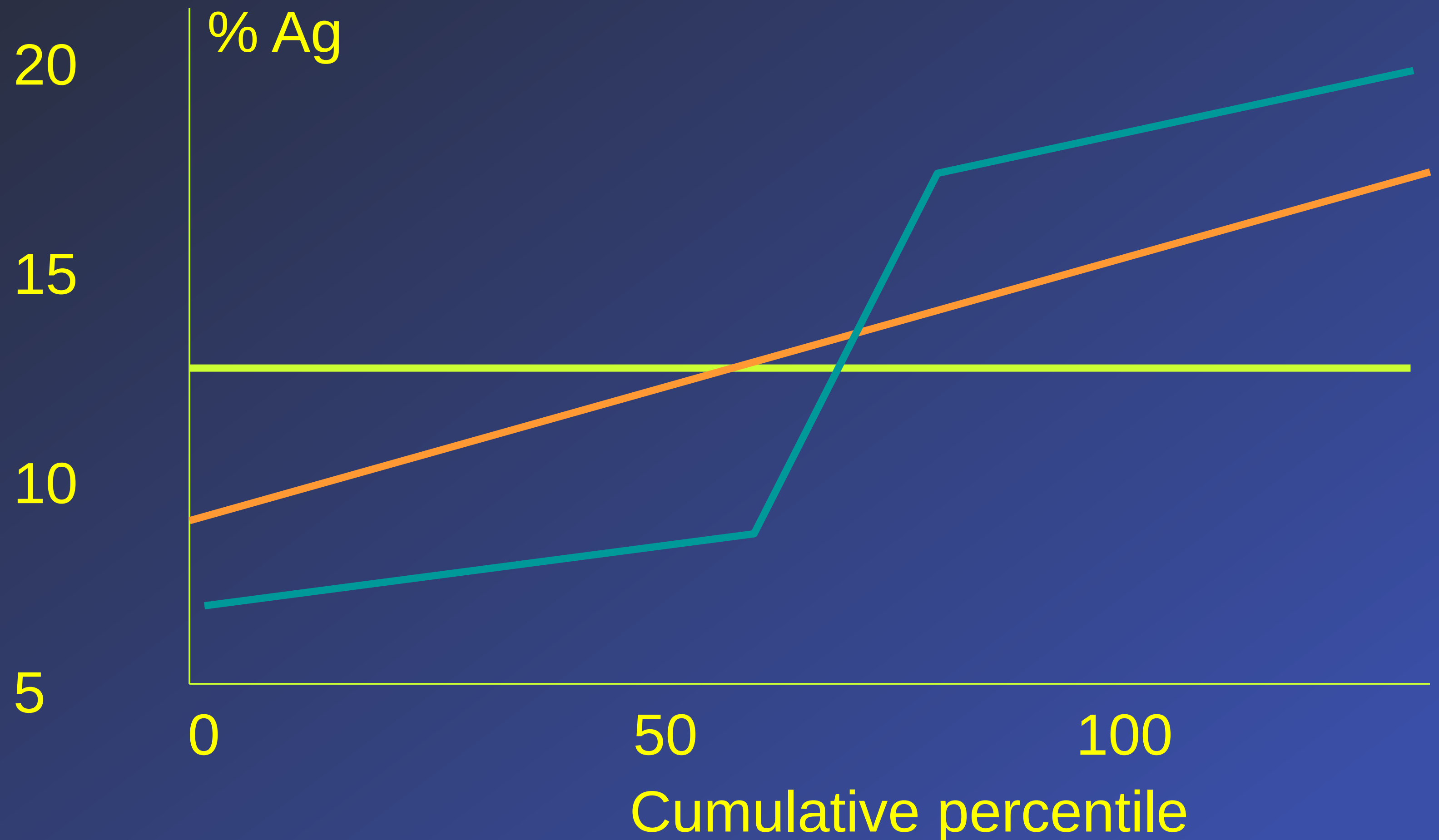
Comparing the silver content of different populations

Grain no	%Ag	Cumulative percentile	Increasing % Ag
1	5	10	5
2	10	20	5
3	10	30	5
4	10	40	5
5	5	50	5
6	5	60	10
7	5	70	10
8	10	80	10
9	5	90	10
10	10	100	10

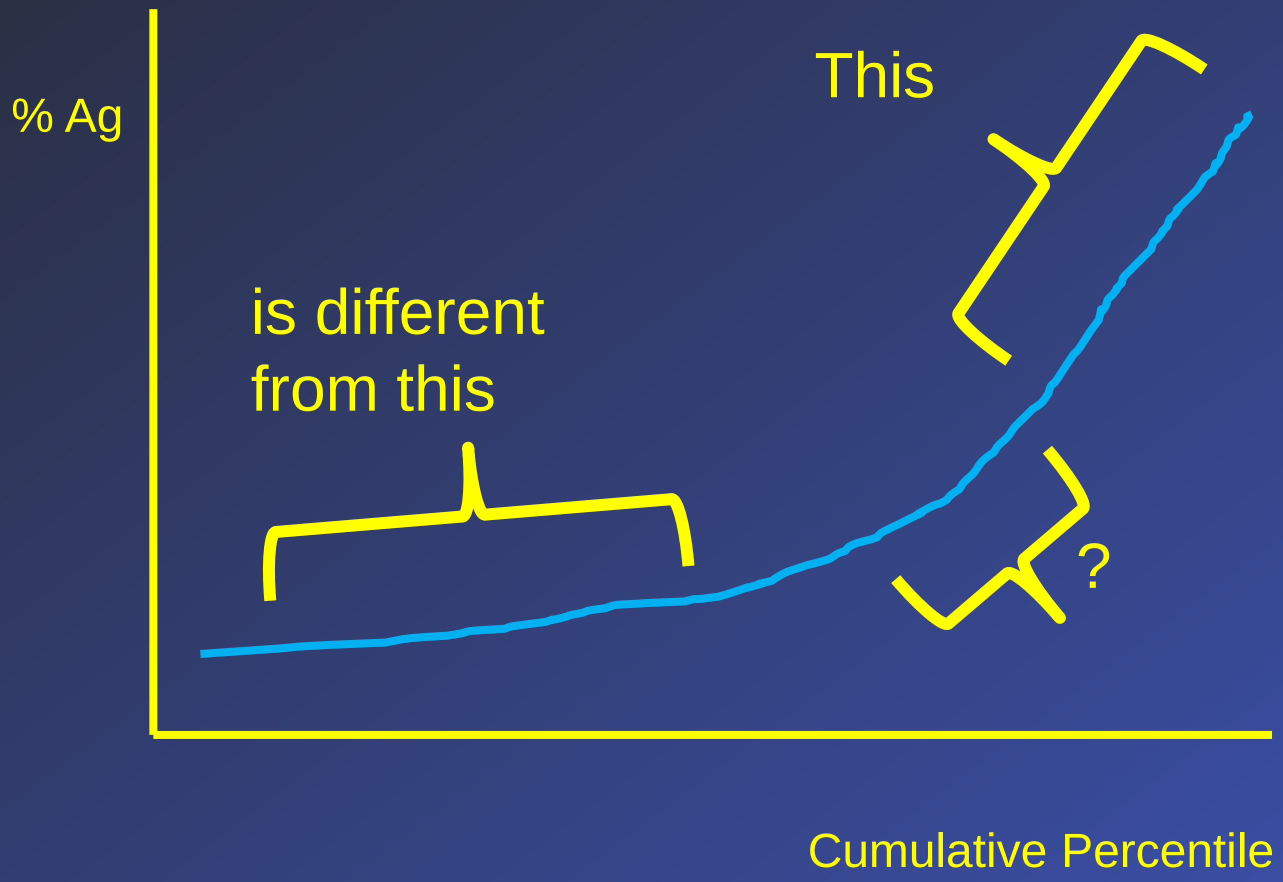


Interpreting the plot shape

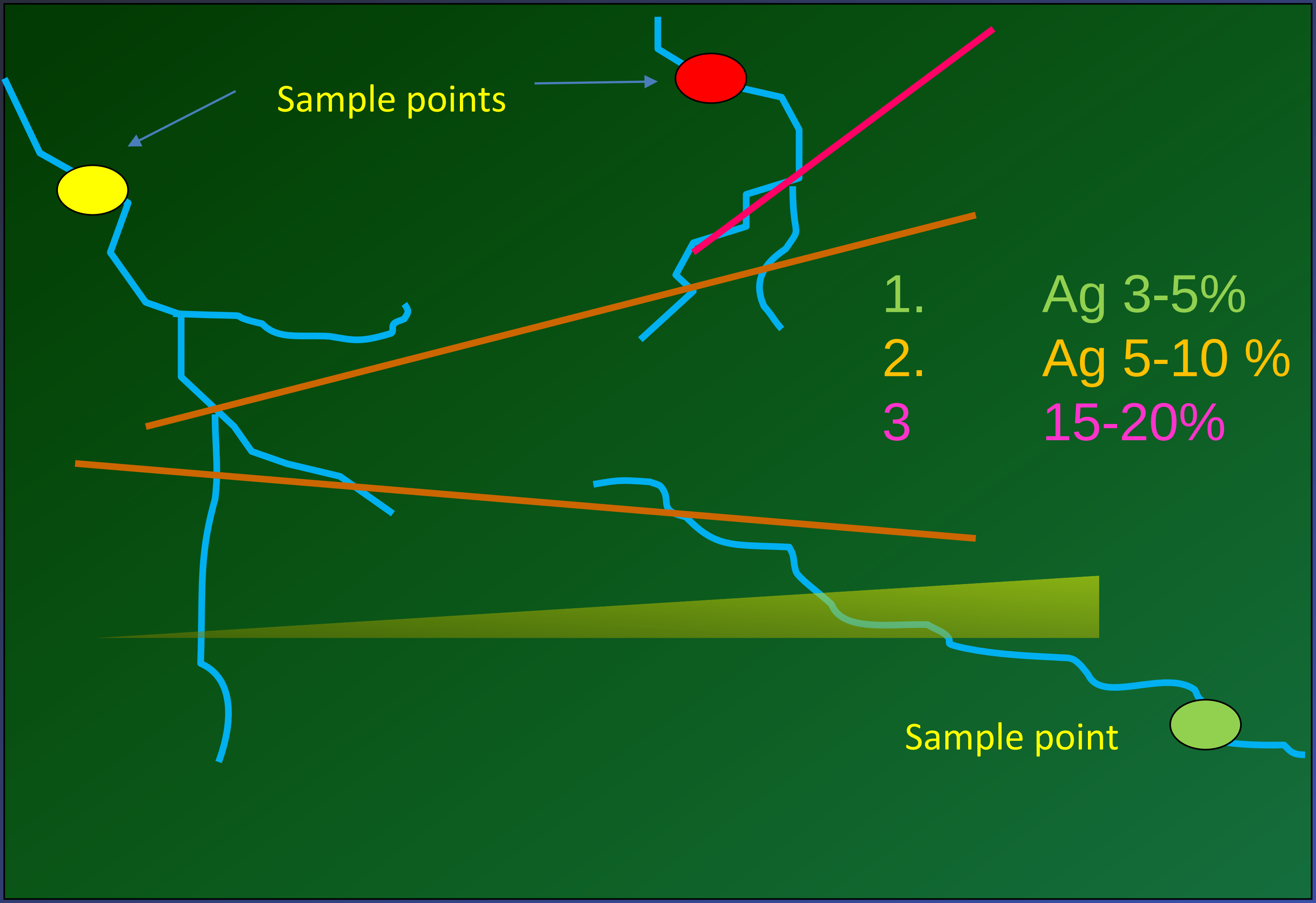
1: All grains same Ag- typical of grains from an ore sample
2.Typical simple placer population
3. Complex placer population



More common plot form: two populations but possibly overlap in Ag ranges

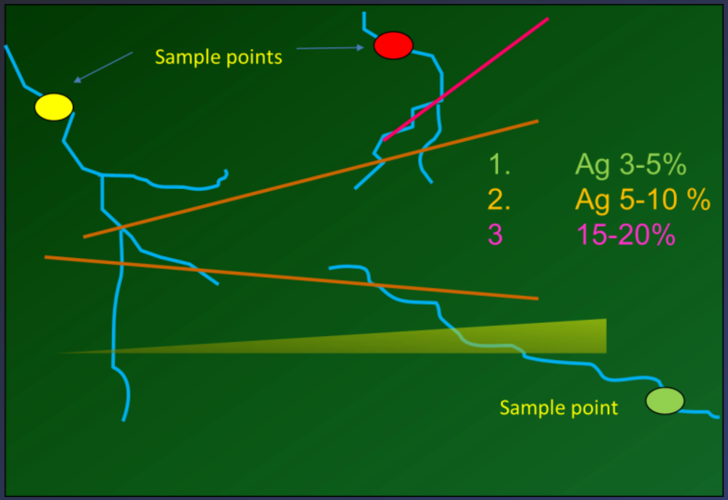


Example How complex signatures originate in placer gold



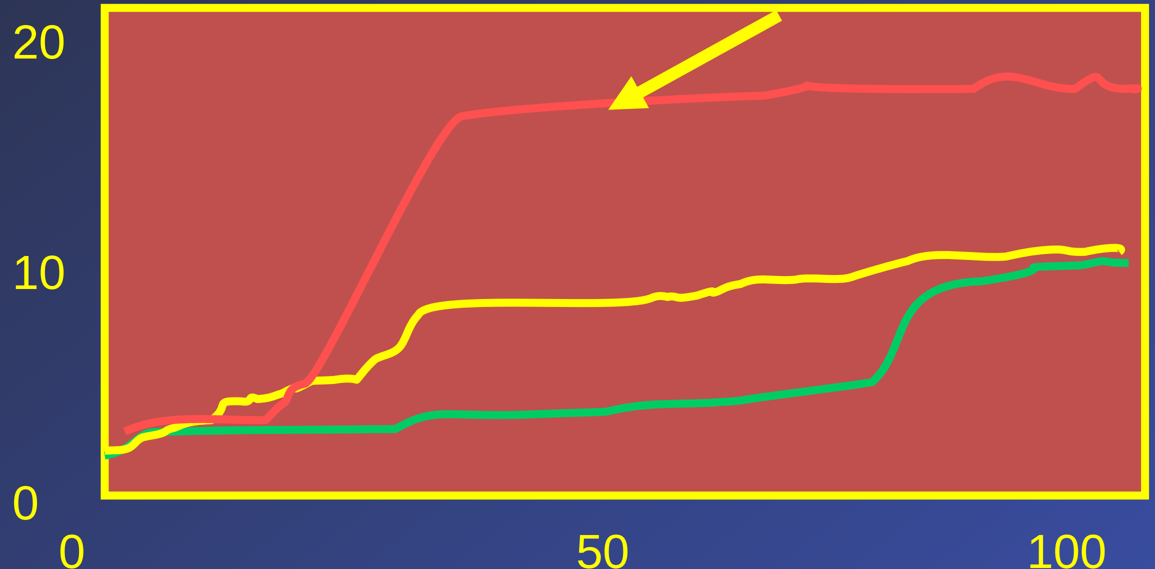
3 drainages intersect mineralization containing Au with different Ag ranges

Generation of complex signatures



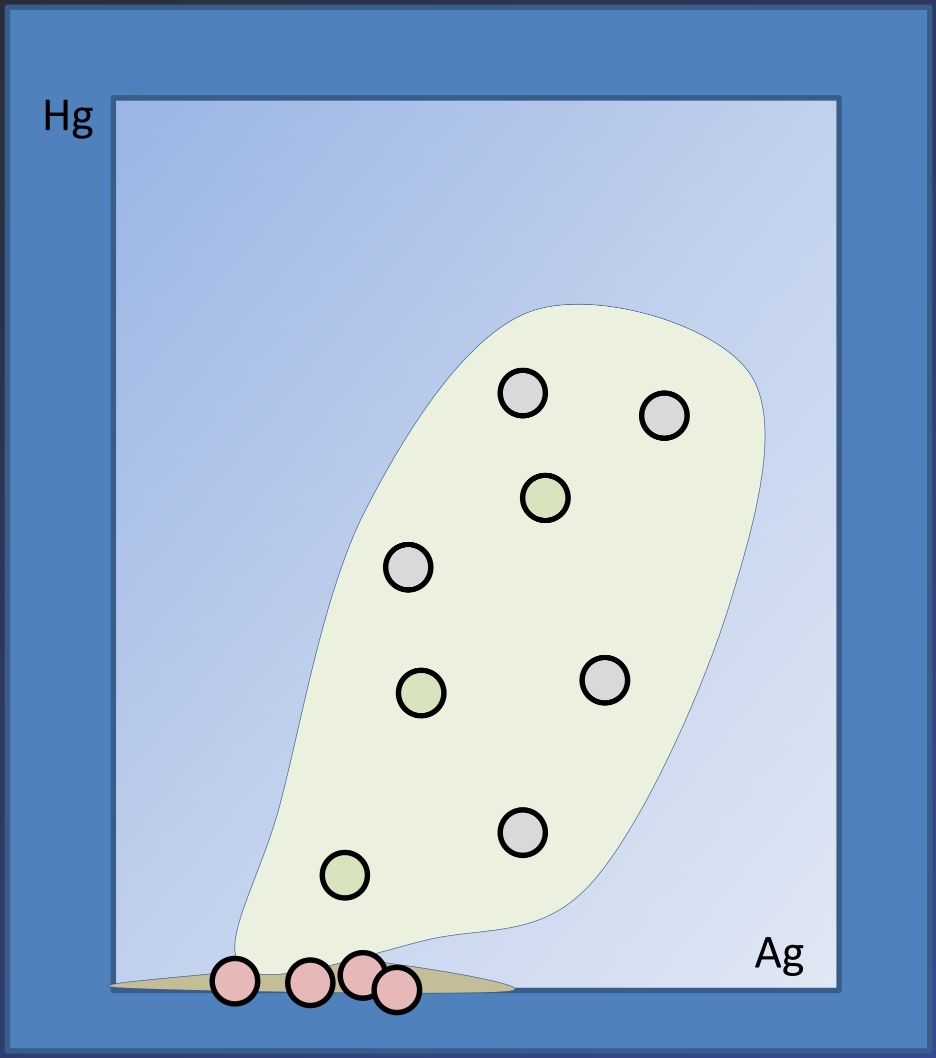
1. Ag 3-5%
2. Ag 5-10 %
3 15-20%

Why isn't the cusp here?



Orientation of mineralization to valley influences amount of placer gold

Covariance plots



Retain actual data

Build compositional fields with inclusions

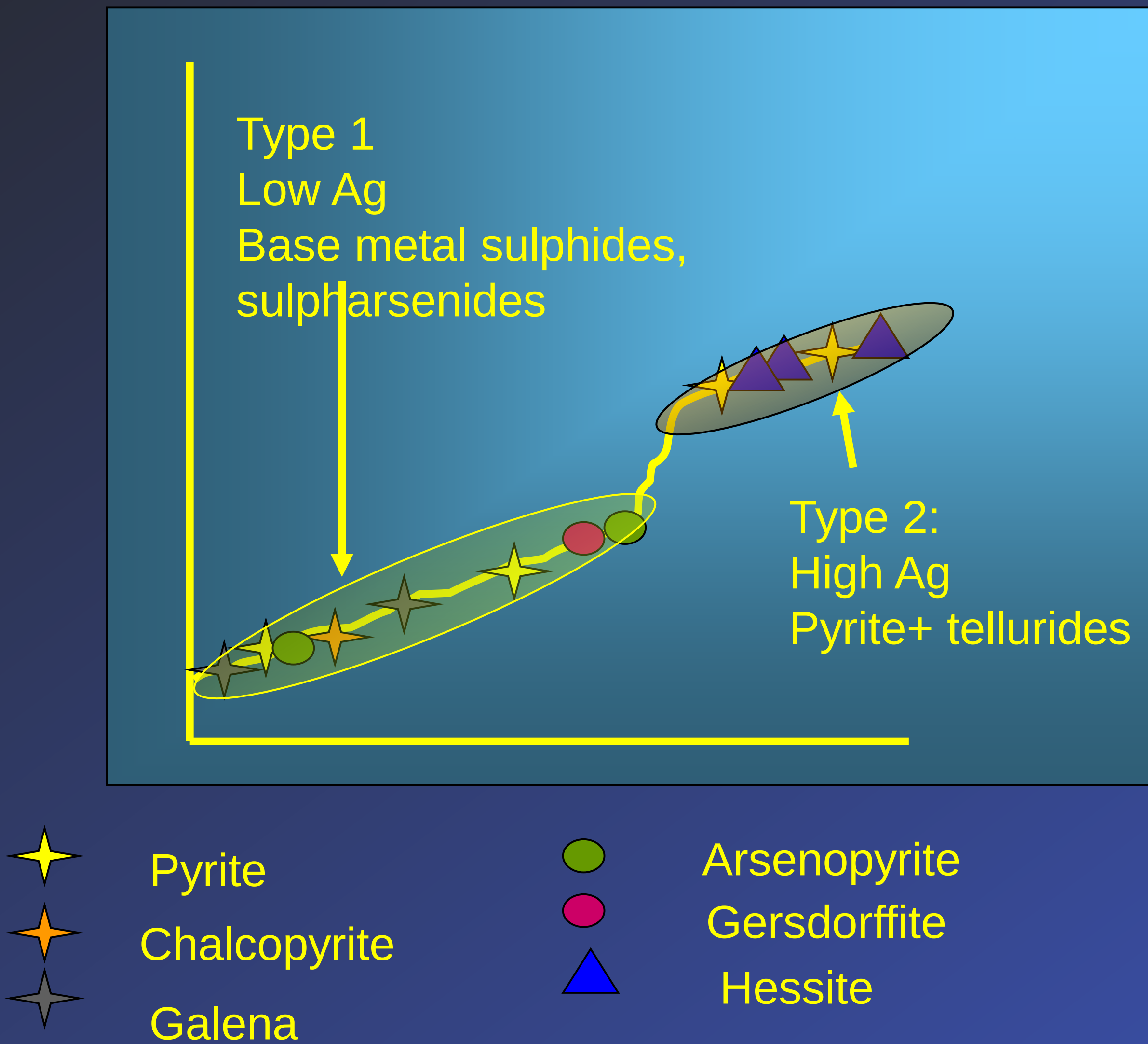
Quantifying the inclusion assemblage

Inclusion assemblage reported using a scoring method which defines the assemblage in terms of abundance of key chemical elements.

Inclusion spotting

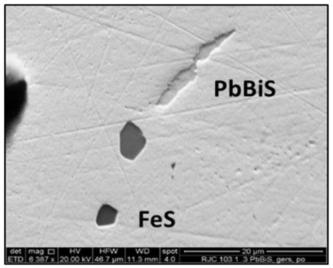
Grain	Inclusions
1	
2	FeS_2
3	
4	FeAsS
5	FeAsS, FeS_2
6	
7	
8	$CuFeS_2$
9	PbS
10	NiAsS
11	
12	AgTe
13	
14	
15	AgTe
16	
17	
18	FeS_2
19	PbS
20	
21	FeAsS
22	
23	FeS_2
24	AgTe

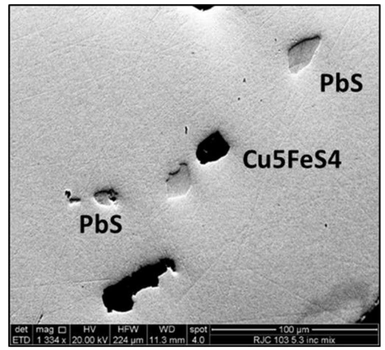
Maybe we have 2 distinct populations?

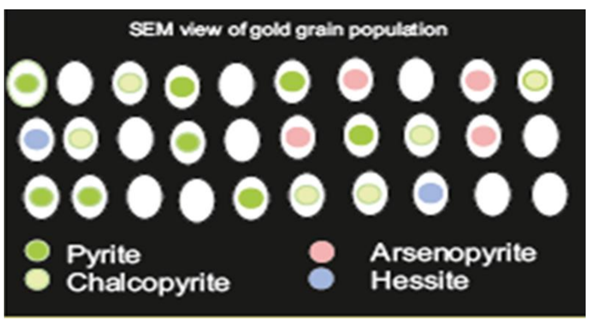


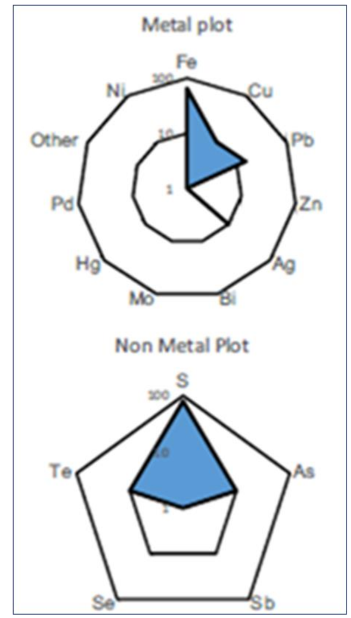
4. CHARACTERIZATION OF INCLUSION SIGNATURES

Identification of gold signatures, represented by the alloy composition and suites of mineral inclusions of a particle, allows discrimination among populations from different localities. Alloy composition reflect differences in the conditions of gold precipitation, whereas the inclusion suite represents mineralogy of the phase of mineralization coeval with gold.







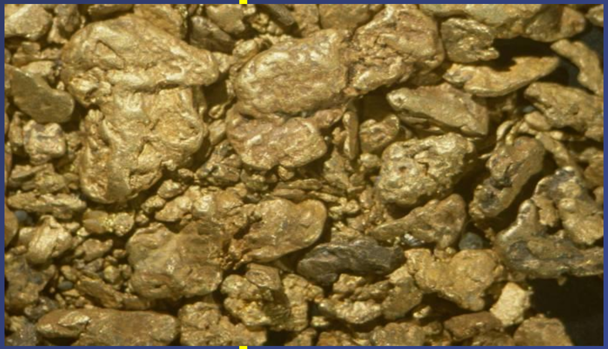


Inclusion	Number
Pyrite	8
Chalcopyrite	6
Arsenopyrite	4
Hessite	2
TOTAL	20

Metal score				Total	Percentage
Fe	8	3	4	15	75
Cu	3			3	15
Ag	2			2	10
Non Metal score					
S	8	6	2	16	80
As	2			2	10
Te	2			2	10

Placer gold grain morphology

Rough- quartz attached- very little transport



Thin flakes- PROBABLY travelled

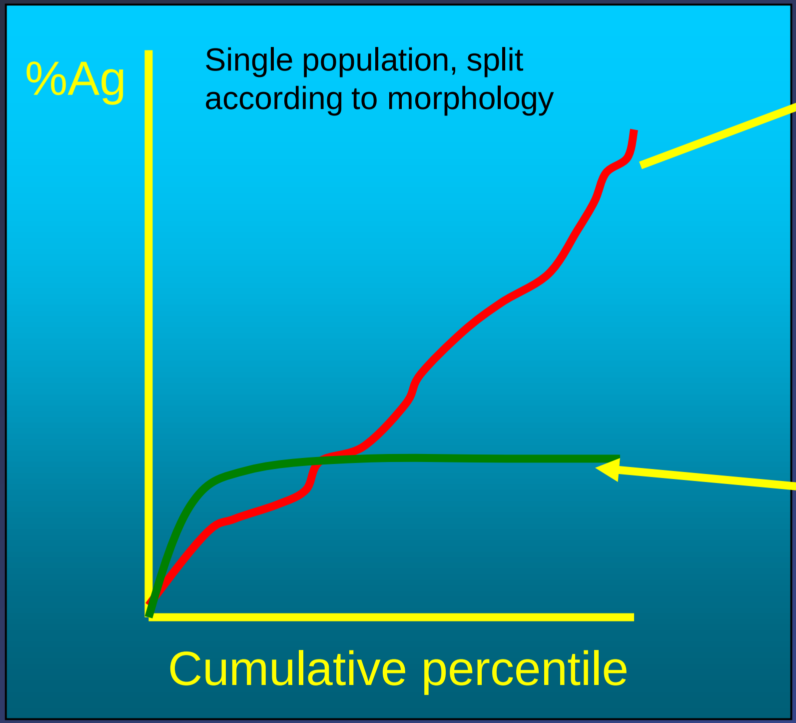
Linking morphology with microchemistry

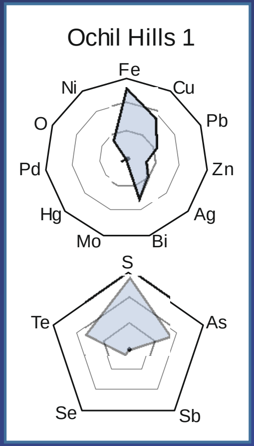
If both morphological extremes are present in the same placer sample what does it tell us? Example: Ochil Hills Scotland LS Epithermal:

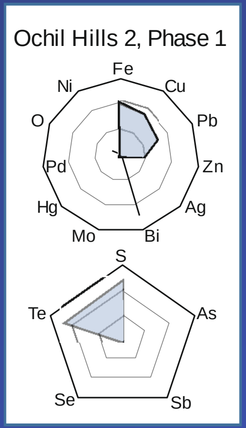
Either: 2 sources

or one geographically large source

How can we unpick this?







So morphology , alloy chemistry and inclusion assemblages are distinct

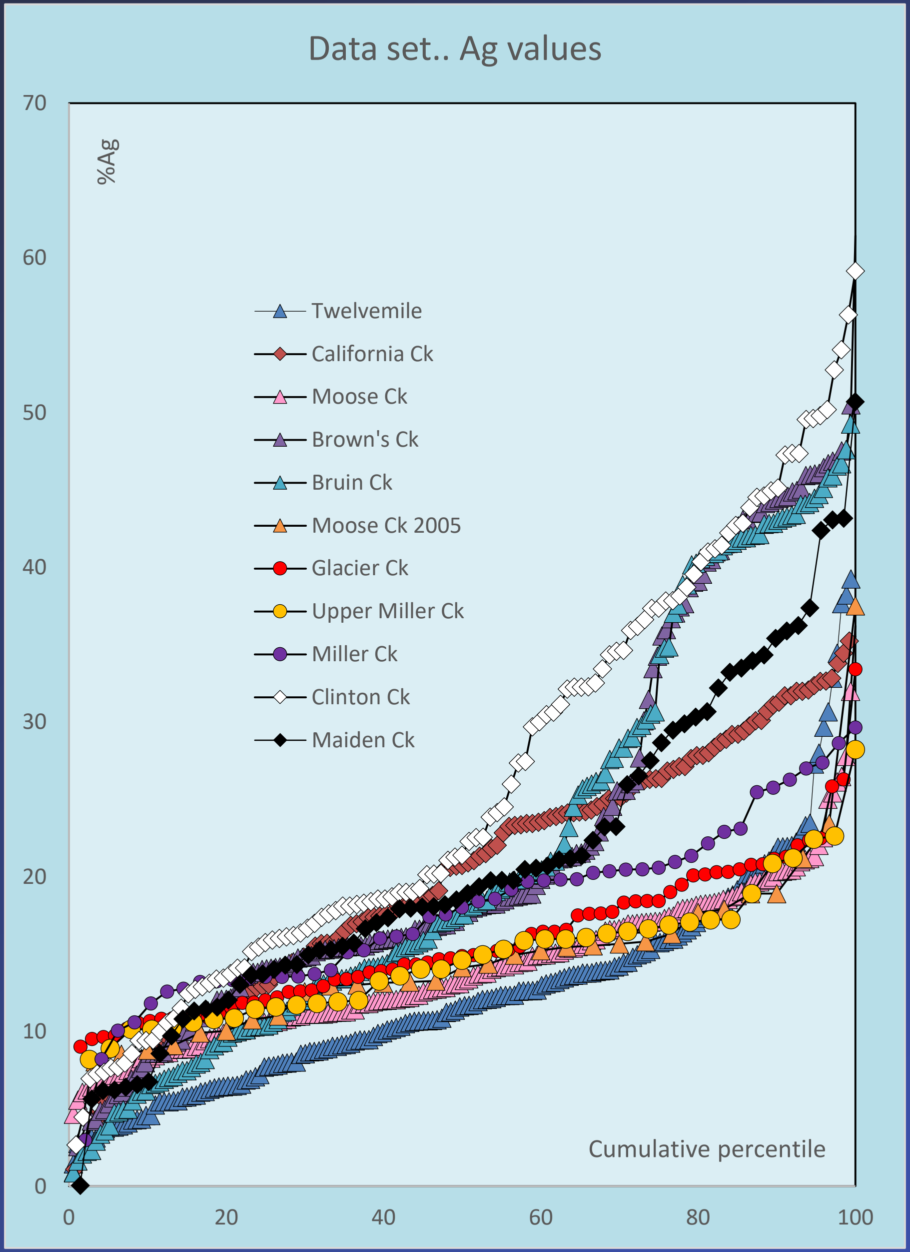
And Now- Sandro's Gold

This is the whole data set for Ag with comparitors for other Sixtymile and Fortymile localities I had already

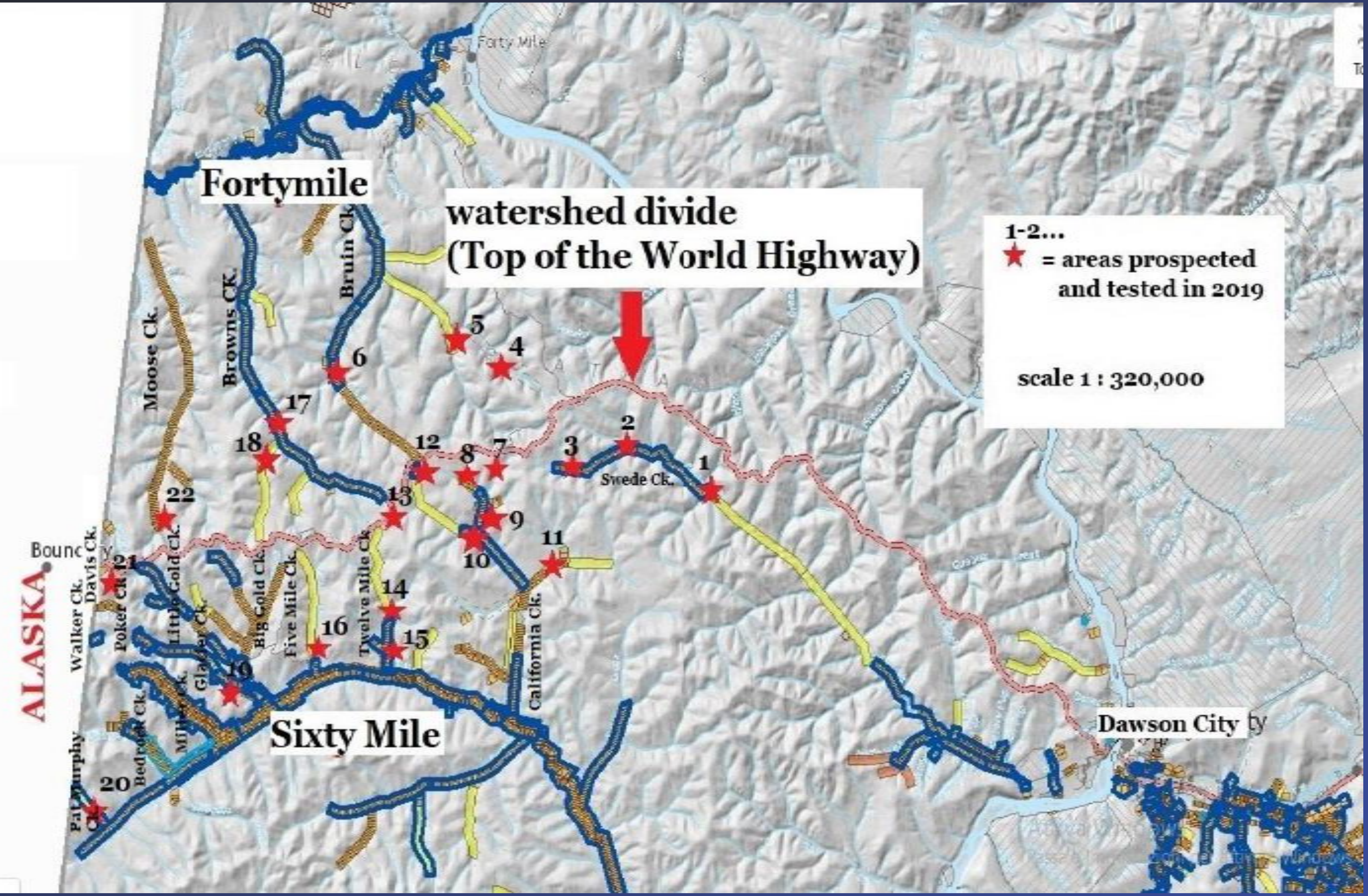
I'll look at specific comparisons more closely in following slides

I start off with Ag plots, then consider other metals in the alloy then inclusions.

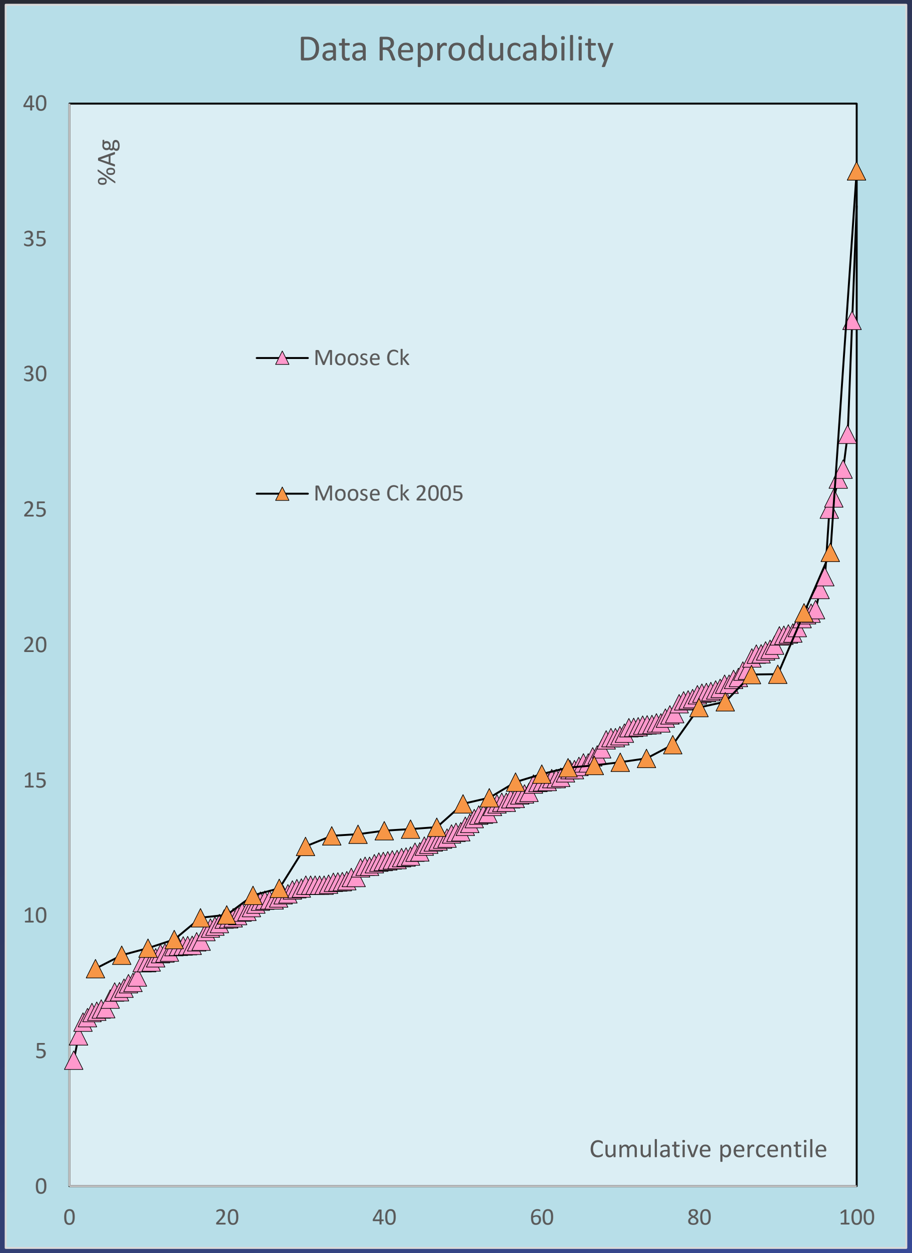
Locality	Particles analysed	Inclusions recorded
Moose Ck	173	4
Bruin Ck	173	7
BrownsCk	175	19
Twelvemile Ck	172	12
California Ck	134	15



Geographical considerations

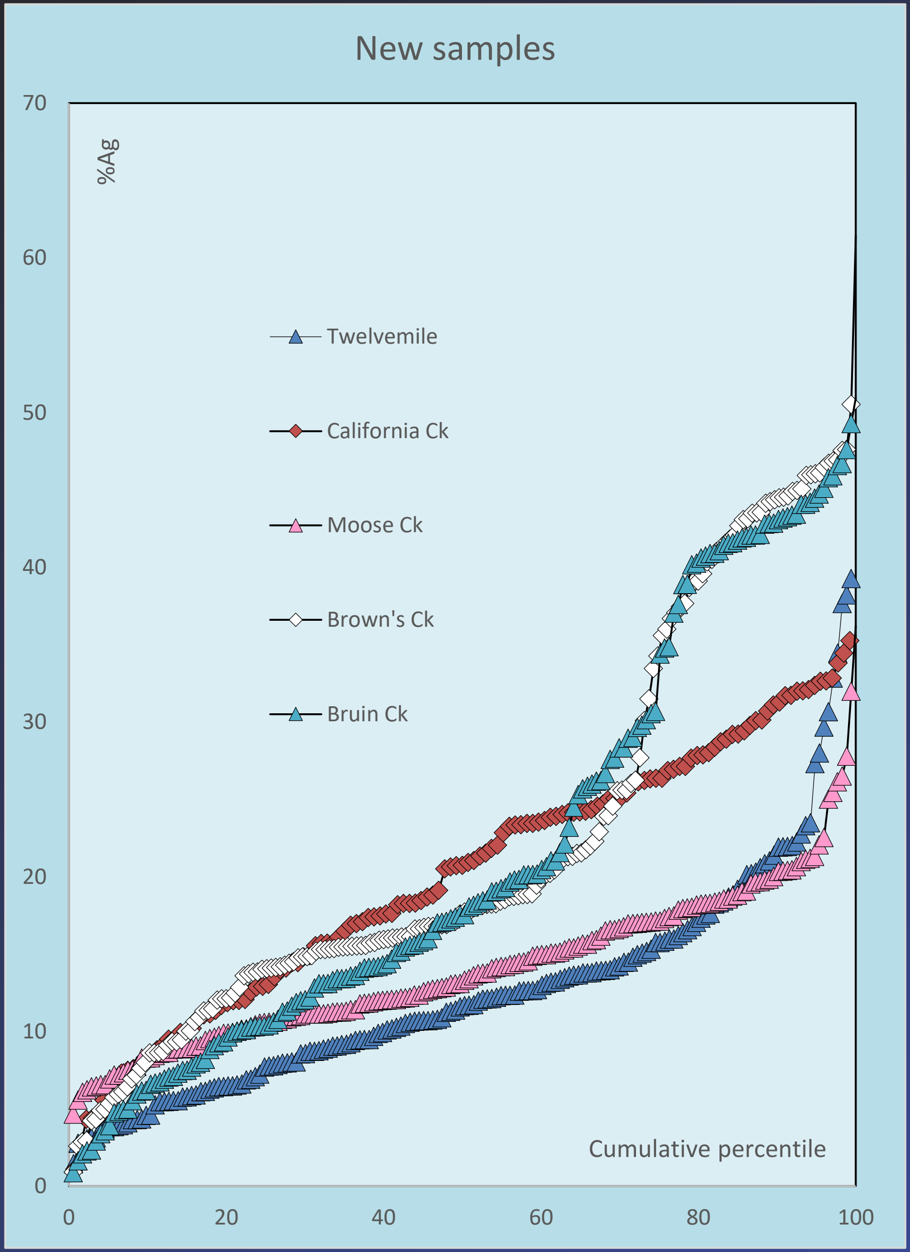


Useful (for me) to get a feel for sampling locations. I'm not sure if some fo the samples you sent are composites from different localities on the same creek



These are plots form a Moose Ck sample collected by me in 2005 (I remember some very scary Alaskans…) and your sample.

My sample is not large, but the coincidence of plots is pretty good- and variation far less than for plots between Moose and other creeks, so we seem to be in good shape.

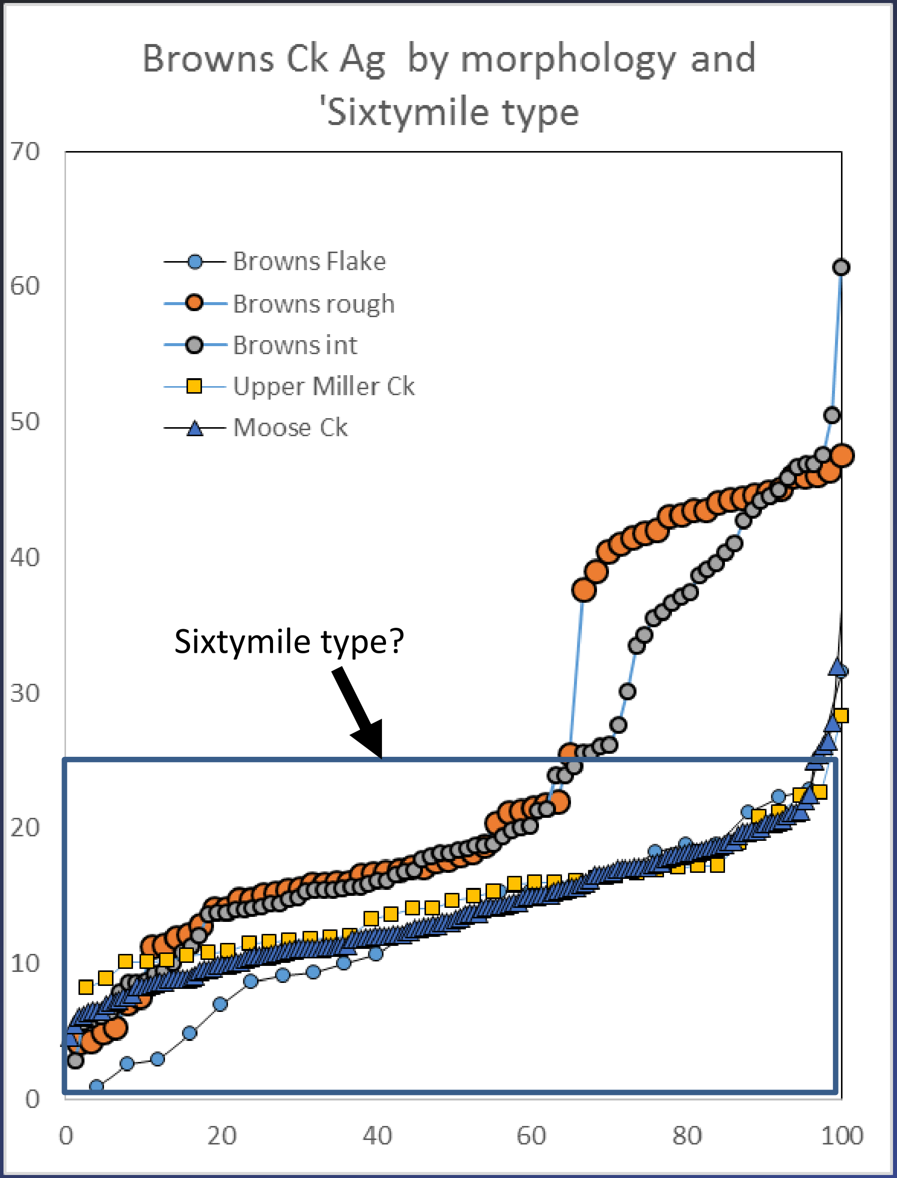


Comments

1. Browns Ck and Bruin Ck very similar Ag range
2. Gold from Moose Ck Au looks like gold from Twelvemile Au
3. Potential for Browns Ck and Bruin Ck to comprise two populations.
4. California Ck gold looks different…

I use Ag plots as a first pass.

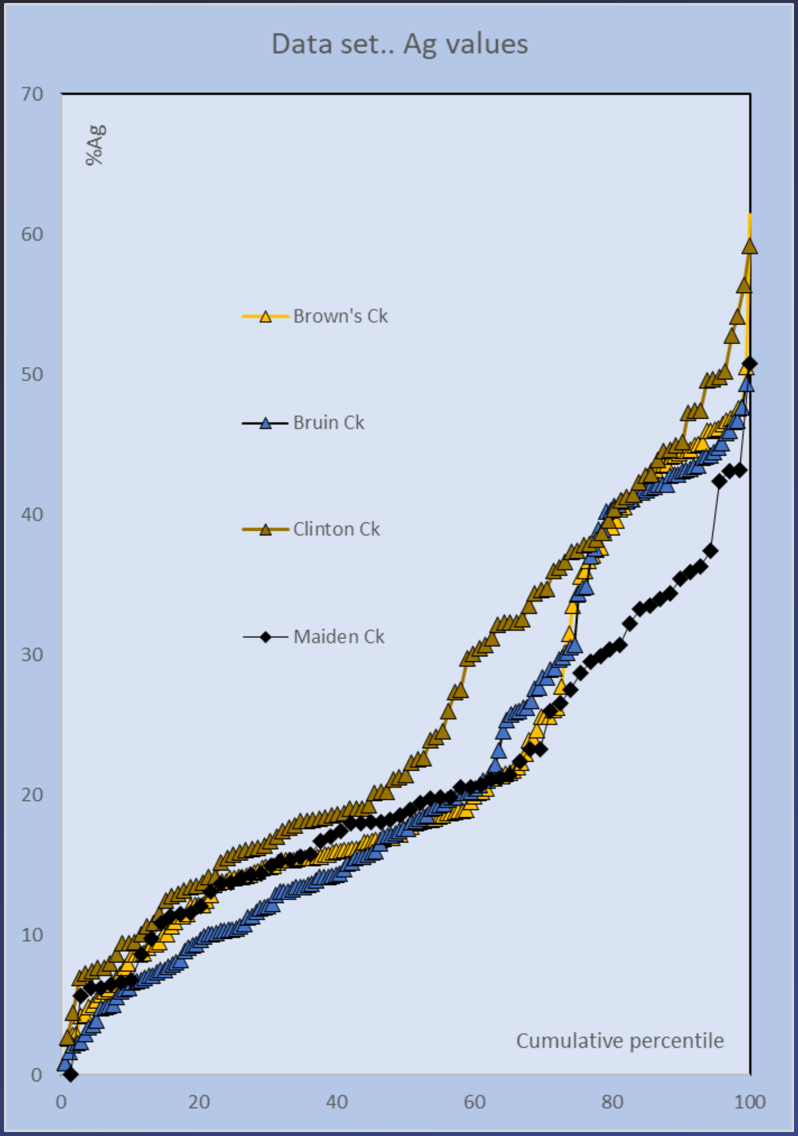
They tell me ‘same or different’- up to a point: it works for ‘different’ but ‘same’ needs another independent validation.



I'm starting to find similarities now between gold in different locations. There is a population in Brown's Ck that has travelled further than the 'rough' gold particles and it is compositionally very similar as gold from Moose Ck and Upper Miller Ck- (chosen here to represent the Sixtymile signature).
I've left Twelvemile off, for reasons that will become clear in a few sides time.

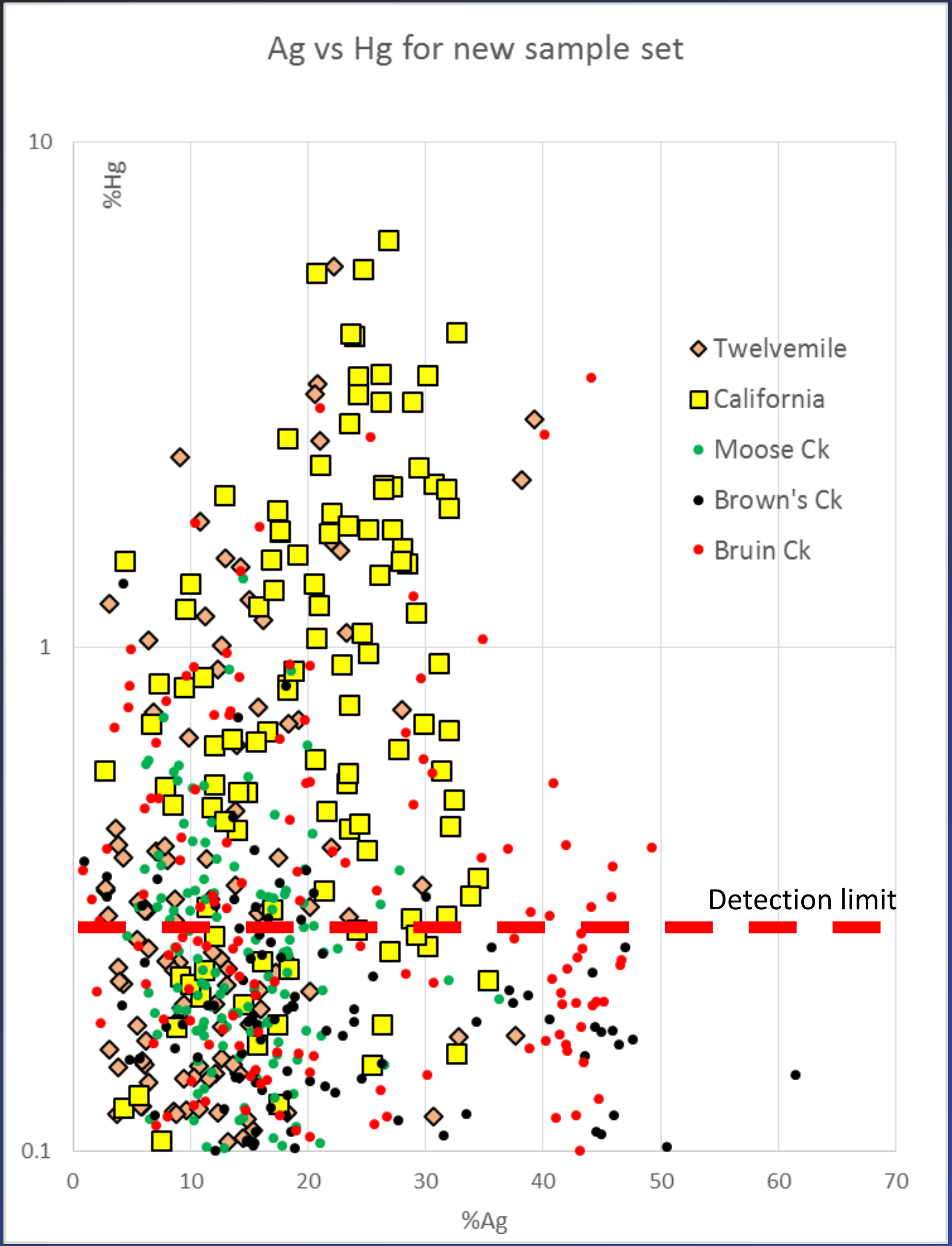
Take away messages form this plot is that the source of Au in Moose Ck is consistent with Sixtymle type and some of this type probably contributes to the Browns (and maybe Bruin) placer. However in Brown and Bruin there is something else going on as well (the high Ag signature) .

Browns/Bruin and Fortymile localities



This is interesting- there is a sympathy on curve shape between these localities both show similar proportions of the same sub ranges – with a common break in slope at around 20%Ag

I don't have the geological background in the area to take this particular analysis much further- it might be worth talking to YGS about it.



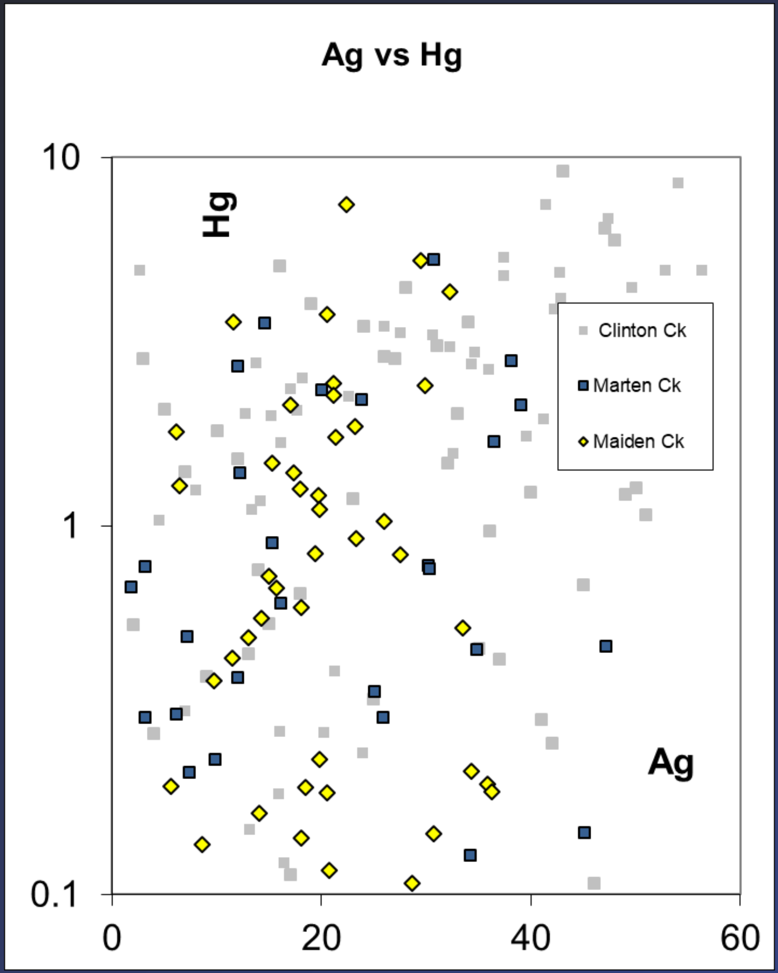
I've plotted the Hg on a log scale to accentuate the spread.

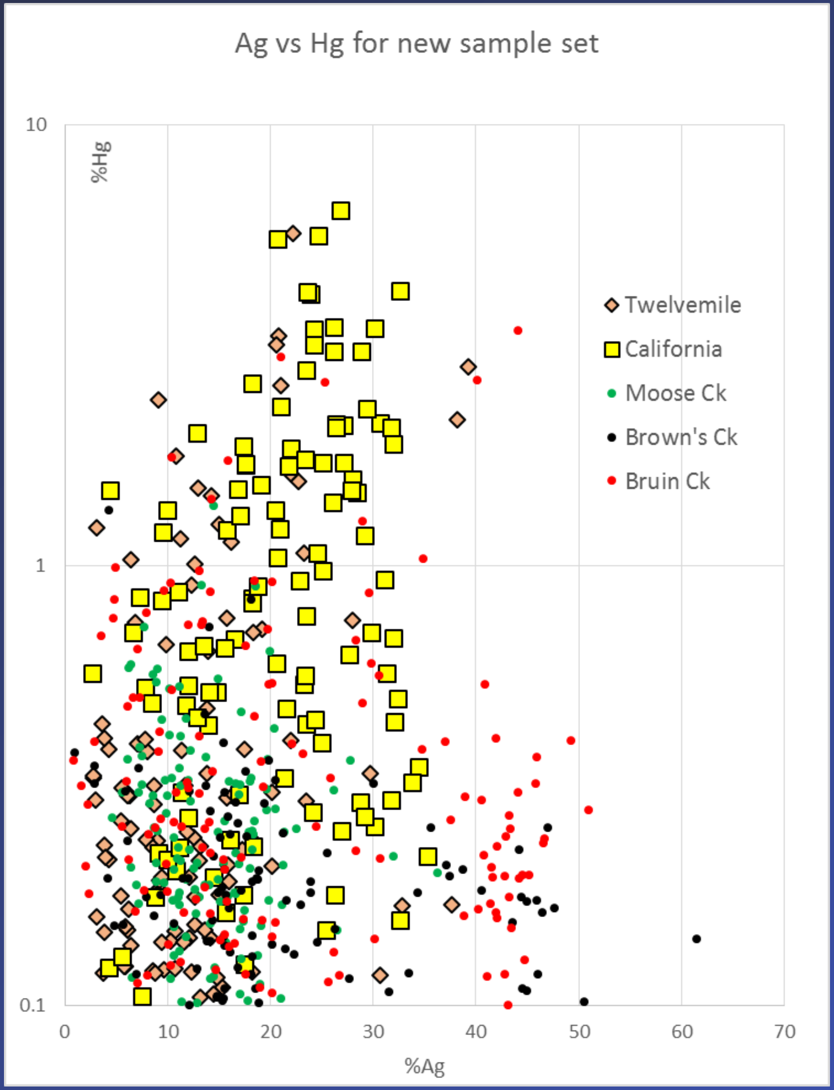
I don't know how experienced you are with this kind of data- but we don't generally use values for elements until they are 3x LOD

So at LOD we can say 'there is some Hg- but we don't know how much') 0.3-0.9% - 'definitely Hg, probably close to reported at the top end and >0.9% = the true value.

Here gold from California stands out as a Hg rich population. Most other high values are Twelvemile gold, but there is a large spread in that data set.
Values from other creeks are too low to support interrogation

Hg is always confusing.

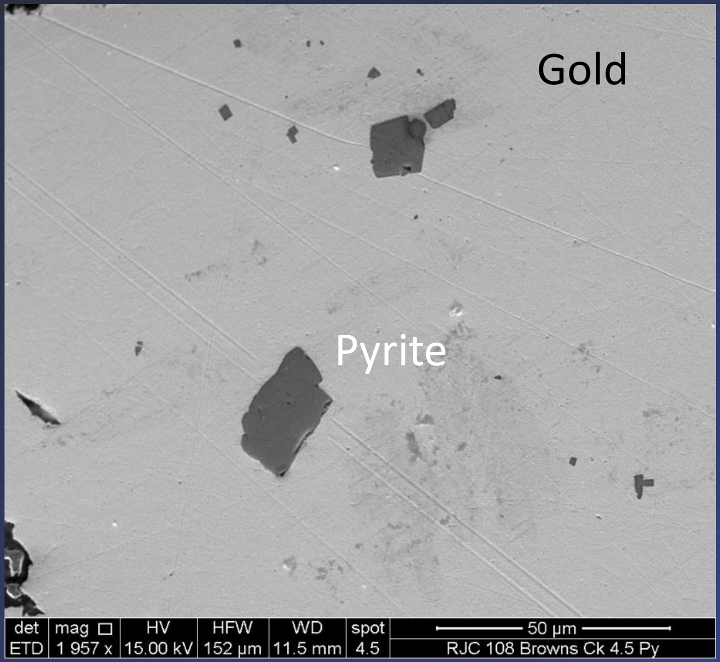


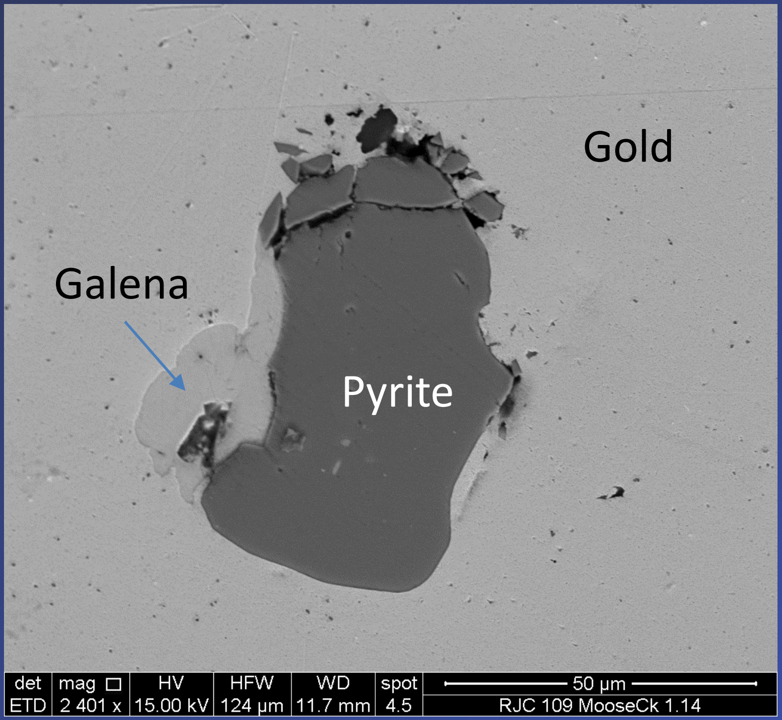


Gold from Clinton Ck, Maiden Ck and Marten Ck all shows VERY high Hg, in terms of the population, far higher than Brown's/Bruin. Interpreting the meaning of Hg distributions is never straightforward- but it does act as a discriminant.

Inclusions

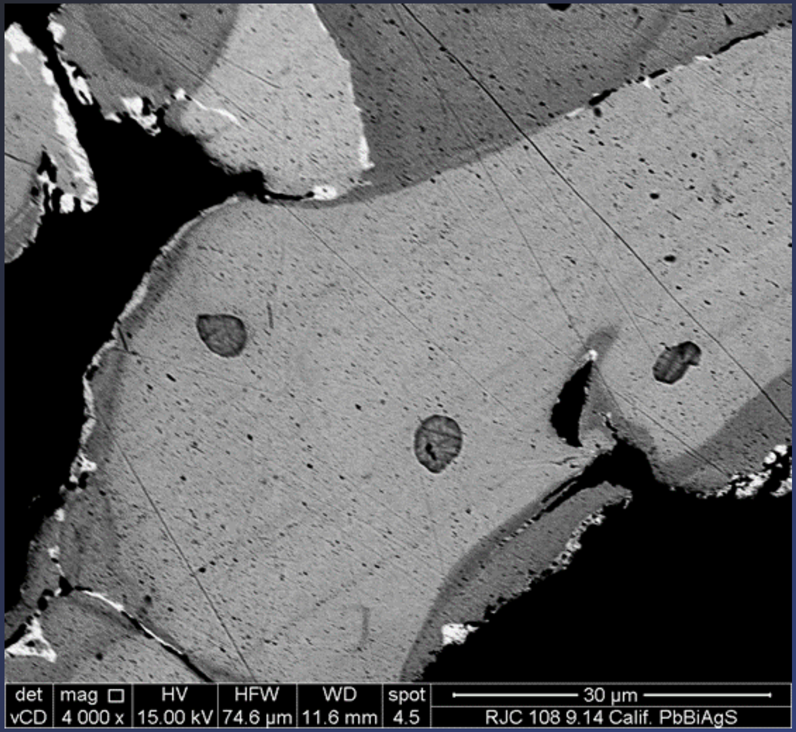
I'll start off with a few images- then move on to what (I think) it all means

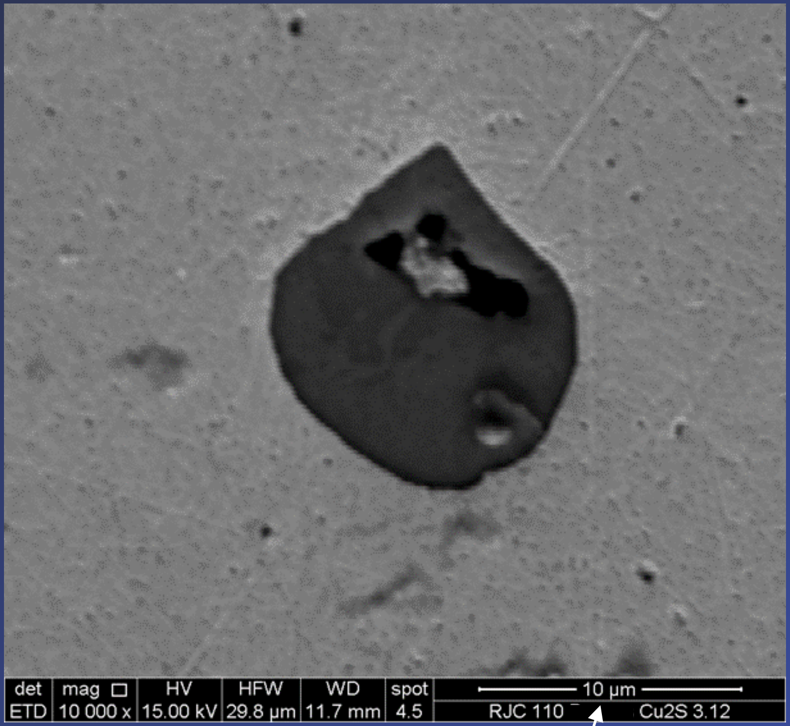




Examples of inclusions from 'Sixtymile type' gold- simple sulphides, typical of gold form orogenic settings.

Different things…

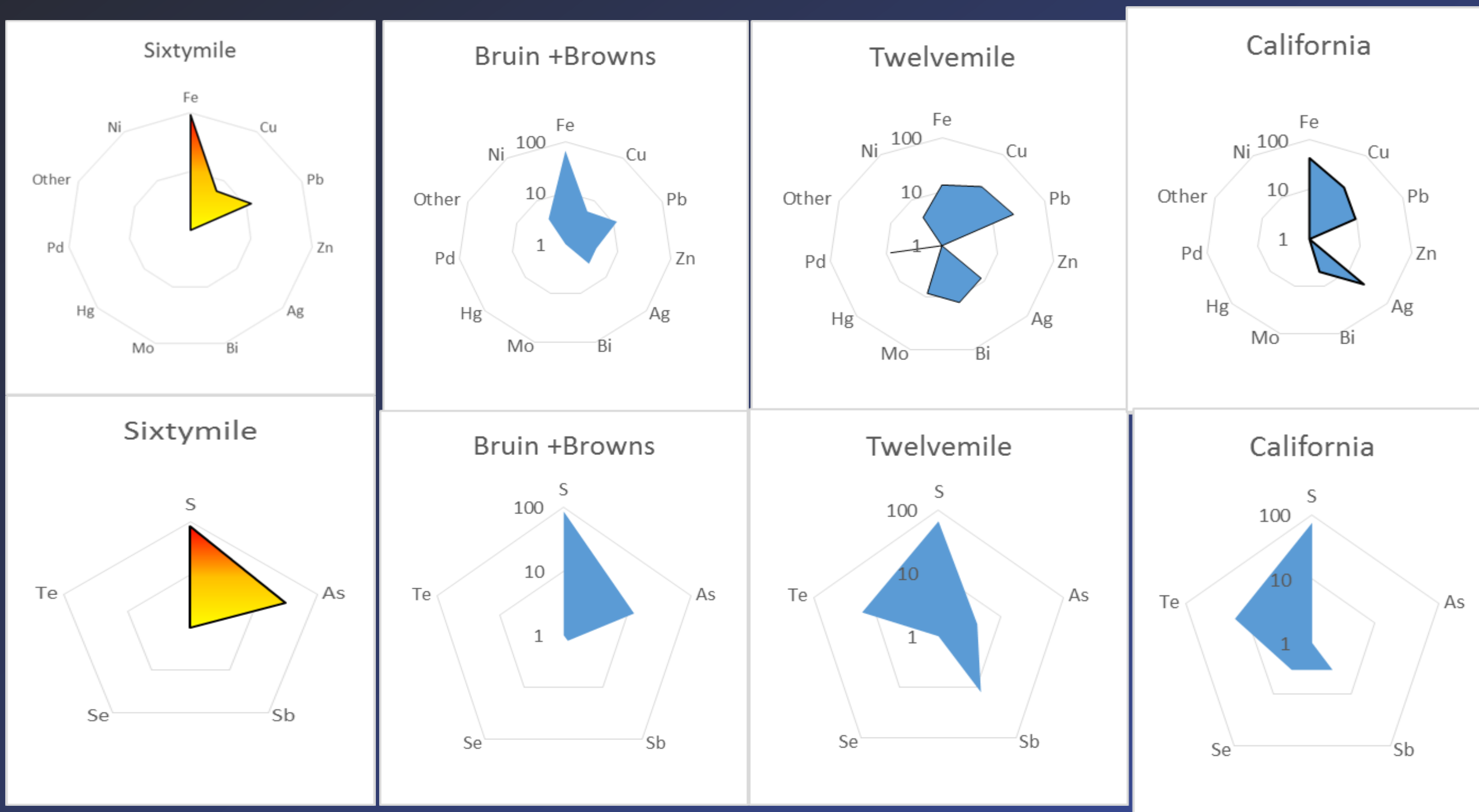




The inclusions here are a Pb- bearing matildite The Pb-Bi-Ag-S signature is often associated with a magmatic fluid.

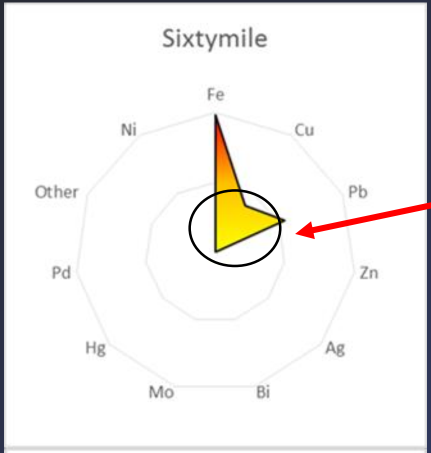
Copper sulphide inclusions are interesting – I have never found them in gold from orogenic settings. They are common in gold from porphyry settings and also associations with ultramafic rock

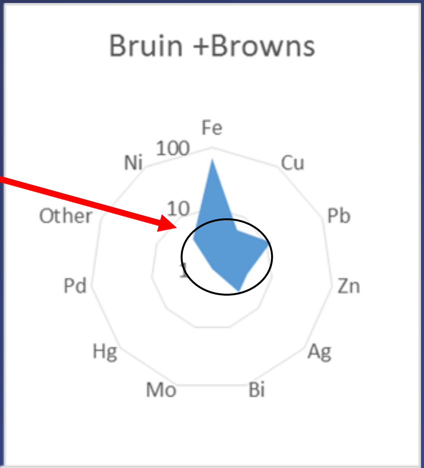
Inclusion radar plots



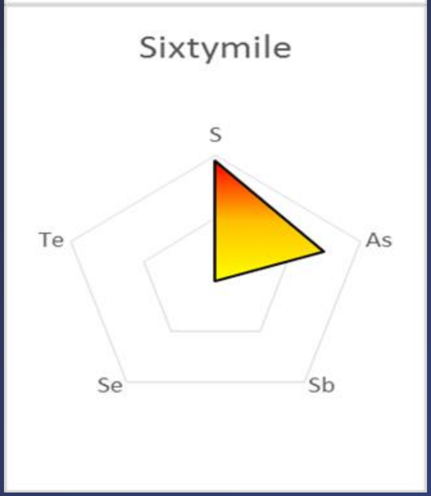
The problem I have with data sets such as these is that inclusions are VERY scarce. Even though I looked at c 170 particles from each population, I still don't have enough data to make a meaningful diagram for Moose Ck. The similarity in Ag plot for Browns and Bruin enabled me to combine inclusion data from those two localities- to give a meaningful characterization. We'll look at this lot a bit more closely....

Are Bruin+ Browns and Sixtymile compatible?

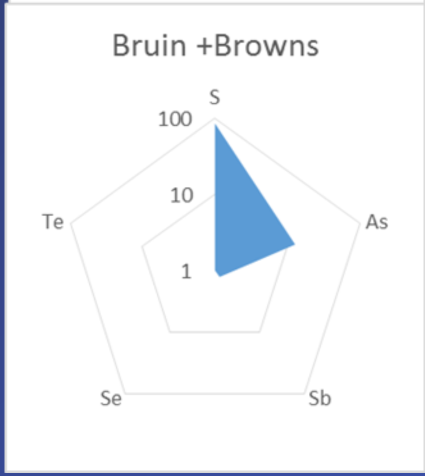




More complicated metal signature

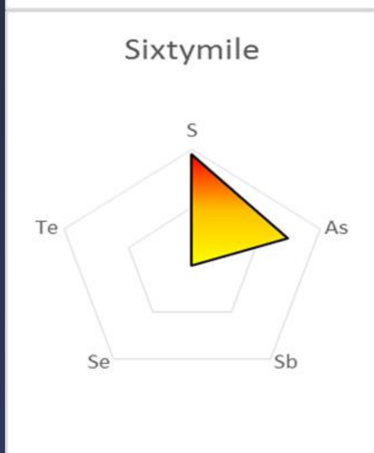


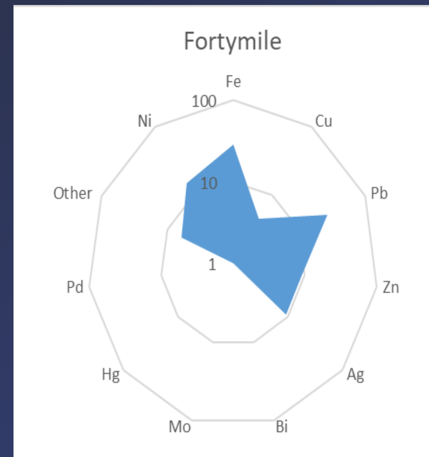
Non metal signature similar- sulphides and sulfarsenides

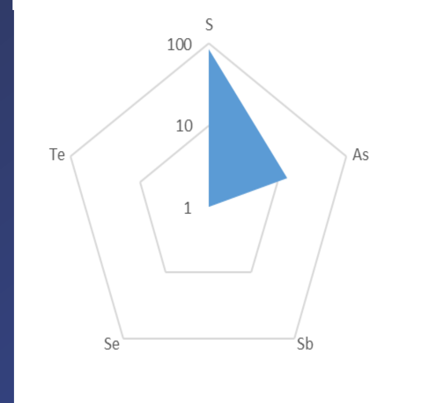


They may share similar gold particles but some of the Brown- Bruin gold is more complicated mineralogically.

Browns/Bruin vs Fortymile



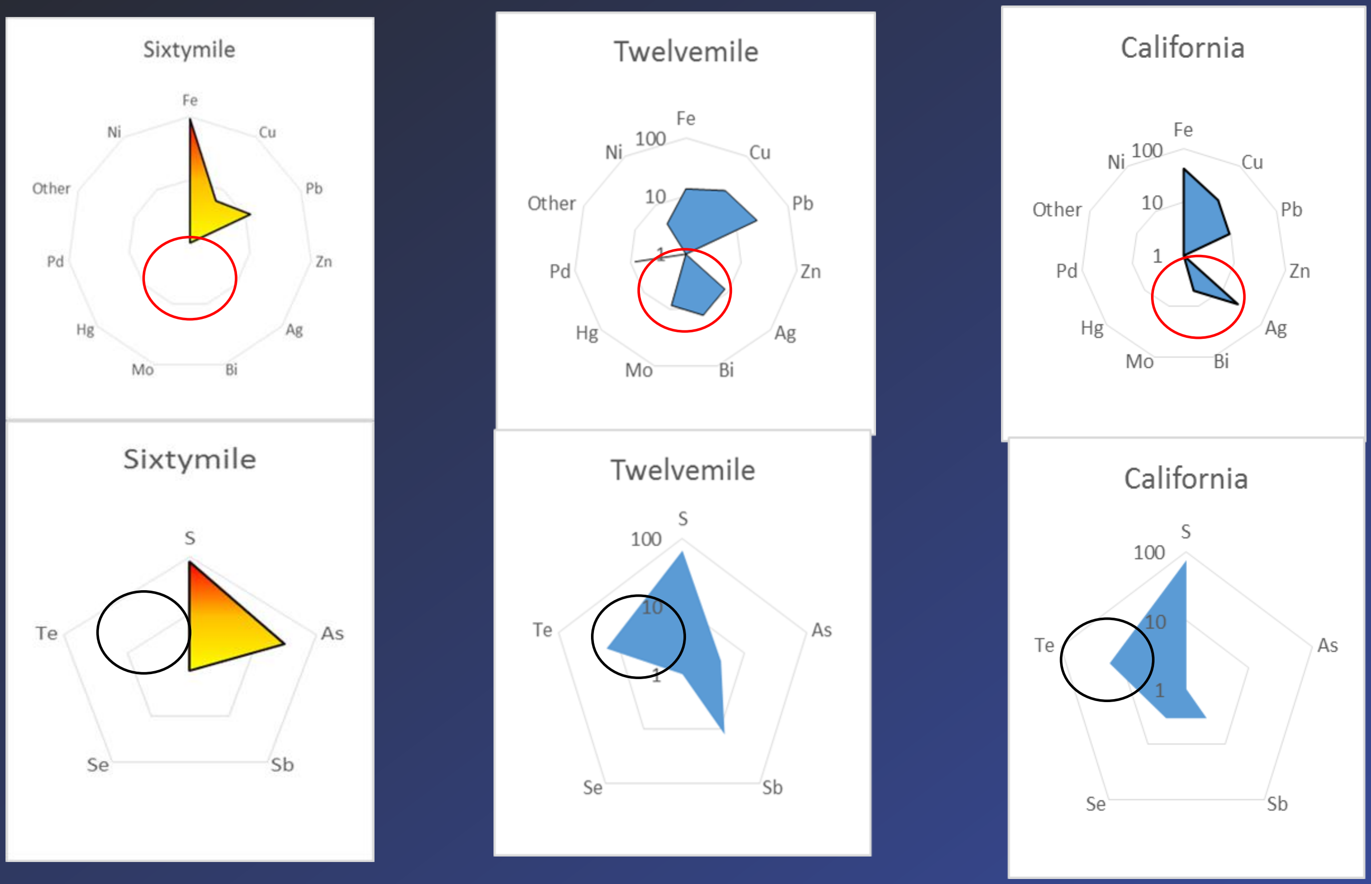




The Fortymile sample comprises inclusion suites of gold from Clinton and Maiden Creeks. We never really sorted out the source style of gold in Clinton Ck- it contains some odd minerals, this may be because its an epithermal occurrence or because of fluid interaction with some local very odd rocks.

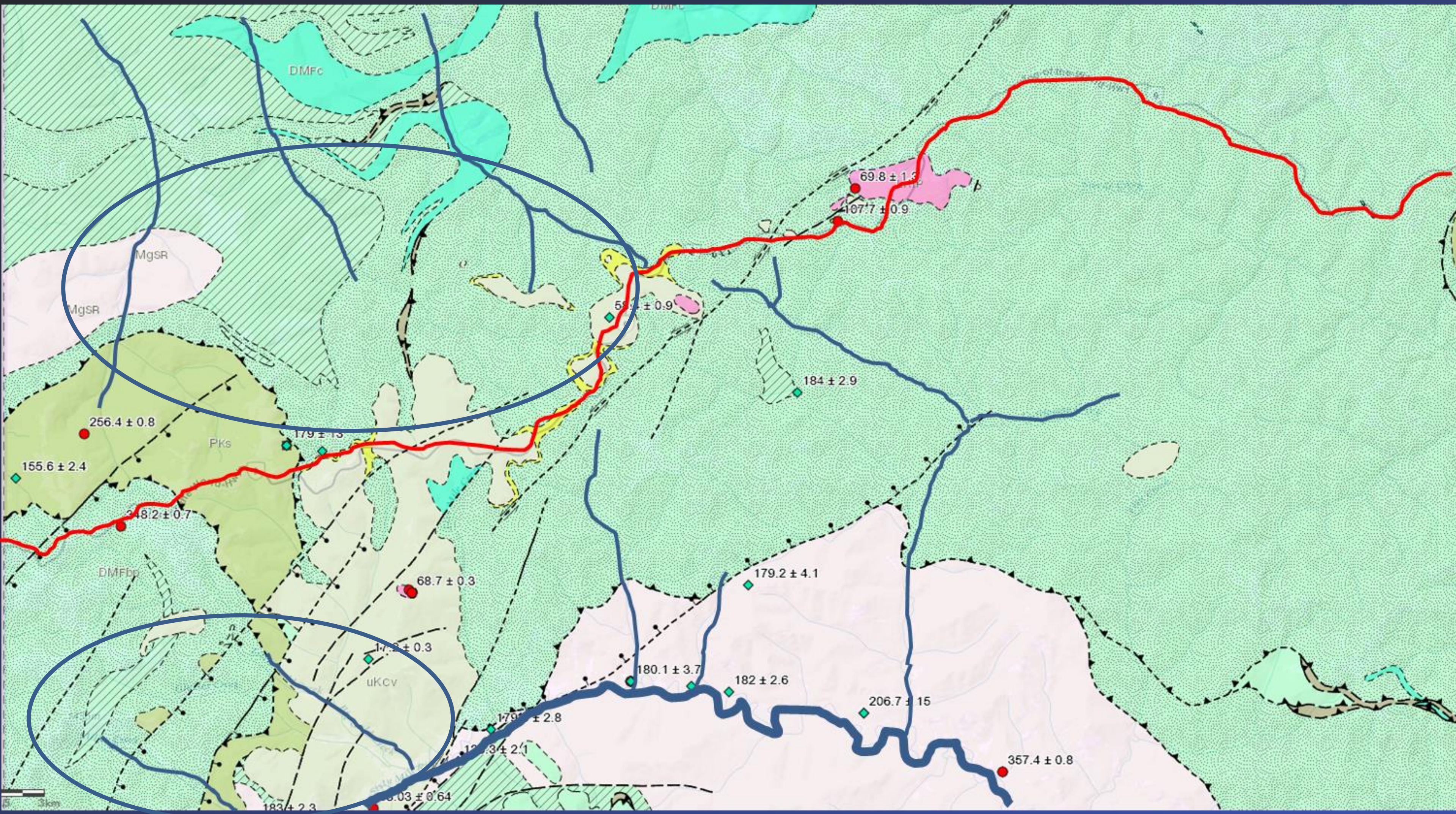
Its tempting to think of the Browns/Bruin signature as an intermediate between Sixtymile and Fortymile types. I'm not convinced this is defensible yet, but it COULD be that we see a different result form the same fluid regionally- modified by local lithology. In support of this is the simple A-As signature- its just metals that vary.

Sixtymile vs California and Twelvemile



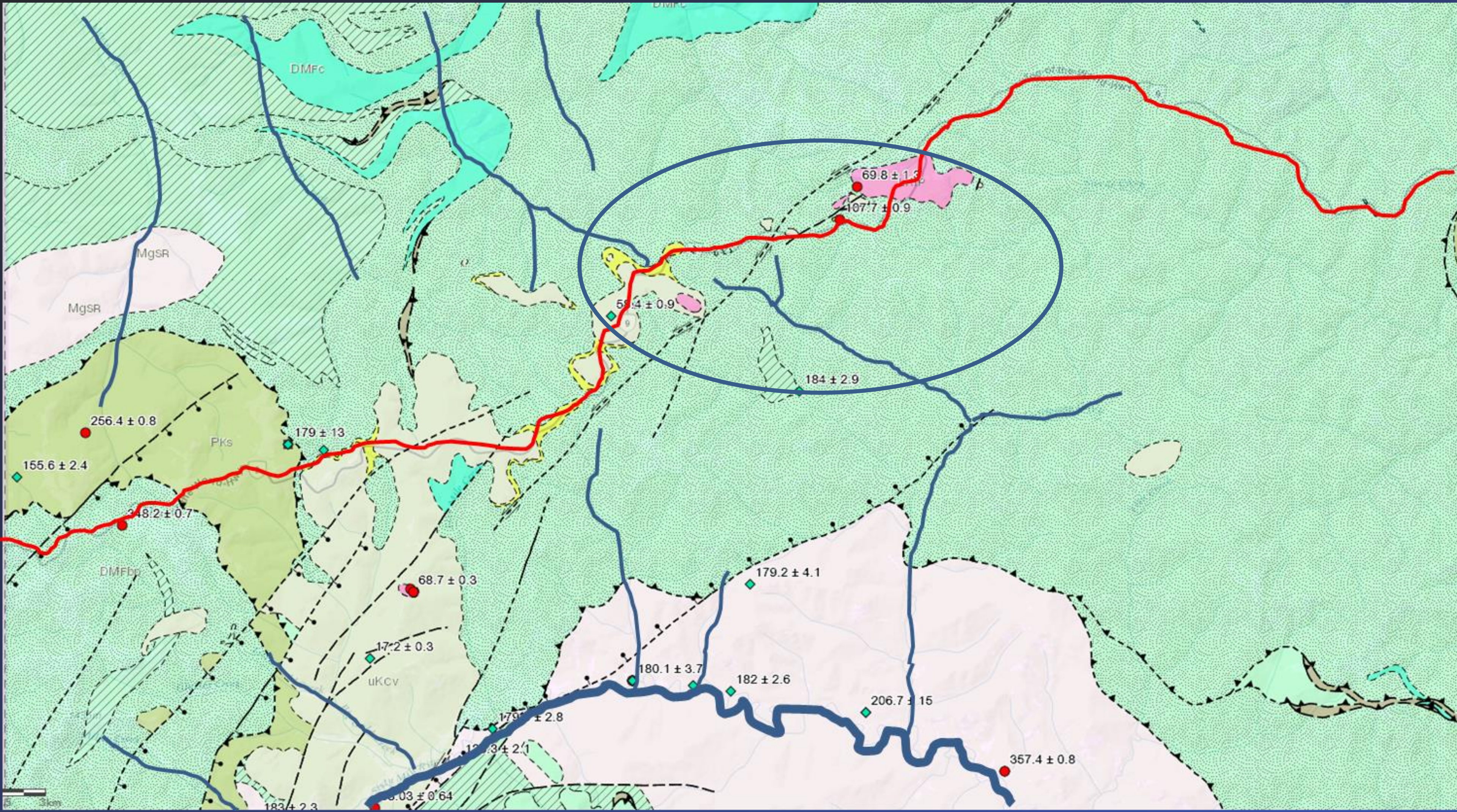
Some major differences- highlighted by colour-coded circles. The differences in mineral inclusion assemblage override the apparent similarity in Ag between Twelvemile and Sixtymile. So conclusion- Twelvemile and California Ck gold is genetically different to that from Sixtymile. Its useful to break the inclusion signature down into mineralogy. From Twelvemile and California we see Cu sulfide, molybdenite, a Bi signature and one Pd-bearing inclusion. This is unlike any signature of orogenic Au

Linking to Geology :Sixtymile District



Lithologically there is no reason why gold in Moose/Browns/Bruin should be different from that in the Sixtmile District – similar rocks mapped

Linking to Geology :Twelvemile and California Creeks



The intrusions mapped are something of a smoking gun for the signature of gold from these creeks.

Twelvemile and California Cks: comments

Gold from these creeks is:

- Not the same as each other
- Not the same as Sixtymile gold
- Potentially related to the Prospector Mountain Cretaceous intrusives

Possibilities for targeting are porphyry style (on the basis of copper sulfide inclusions- and the Bi-Te signature, (I also note that a molybdenite inclusion showed up in a particle from Bruin- so there might be a bit of dispersion…)

Another possibility is that we might have some epithermal Au- this is probably more compatible with the high Hg levels. Of course porphyry and epithermal are not mutually exclusive, and gold from both styles could contribute to a placer – maybe in different proportions according to the spatial relationship with individual drainages. The epithermal environment generates a range of gold signatures, because geochemically it is variable. This also makes it difficult to characterise- because we are looking for multiple sub populations- or trying to characterize a comostional continuum

Concluding comments: 1

What we know:

- Sixtymile type mineralization is most similar to gold from Moose Ck- the lack of inclusions in Au from Moose Ck is also compatible with this hypothesis.

- Sixtymile type gold probably forms a component of gold in Browns and Bruin Creeks. There are other contributions too- maybe minor from porphyry/epithermal sources, but more importantly the high Ag component- we don't know much about this except it is common to both populations.
- The shape analysis vs composition for Browns ck seems to give us an indication for two sources rather than a single source itself exhibiting two signatures.
- Ideally I would have a larger inclusion suite to unpick alloy vs inclusions for these populations- see 'future work' .
- Data suggests a possible connection between Au in Clinton/Maiden Cks and Browns/Bruin. I'll chat to Jim Mortensen and see if he can shed any light on it.

Concluding comments: 2

The majority, if not all Au in Twelvemile and California Ck is of magmatic hydrothermal origin. Its still possible that there is some 'Sixtymile type' there as well- difficult to say.

The most likely explanation for the data we have currently is that we are looking at gold from a porphyry/epithermal transition- much the same as Cyprus/Klaza. That may influence exploration strategies- i.e. set limits on distance from the intrusion. Is the intrusion continuous at depth though? If so, we could be looing at epithermal Au above it. Does geophysics help here?

You need to think about the sampling sites along the Creeks- this may be important, and we may have lost some compositional resolution if the samples I received are composites from several sampling points along the same creek.

Future work

I still have large amounts of material unmounted. I could easily mount lots more and screen for inclusions. I would then selectively analyse alloy from particles which host inclusions. That way I would build up a better picture of the potential multiple influences on the sub populations contributing to each placer population. This data set is unusual because of the low incidence of inclusions- normally I would expect at least double from a study of this size

I'm happy to propose this as a project for a final year student starting September- that way analysis costs will be covered. If no students want to take the challenge- I'll find another way.