Preliminary observations on the sulfide clast bearing pumiceous mass flows in DDH WSP17

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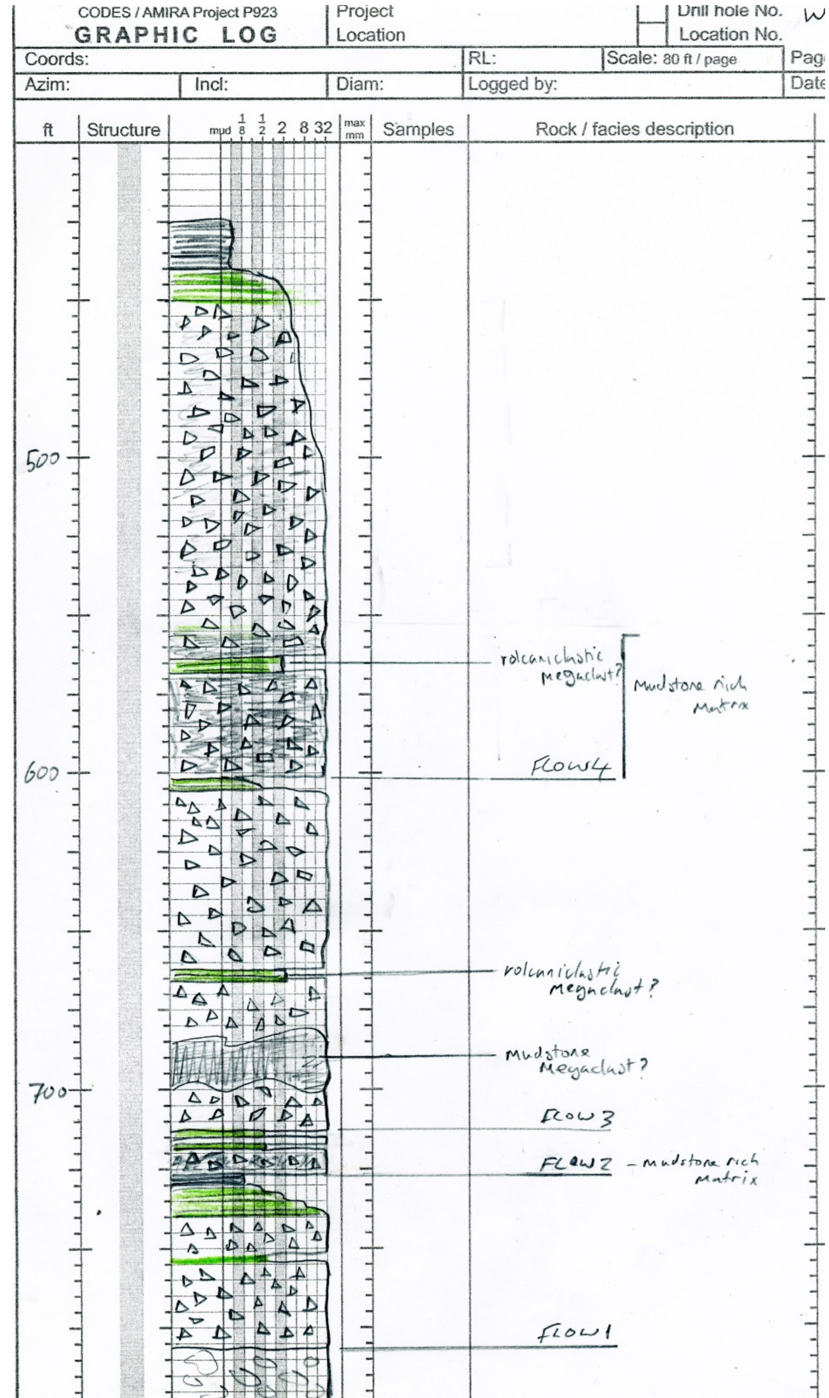

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Executive summary

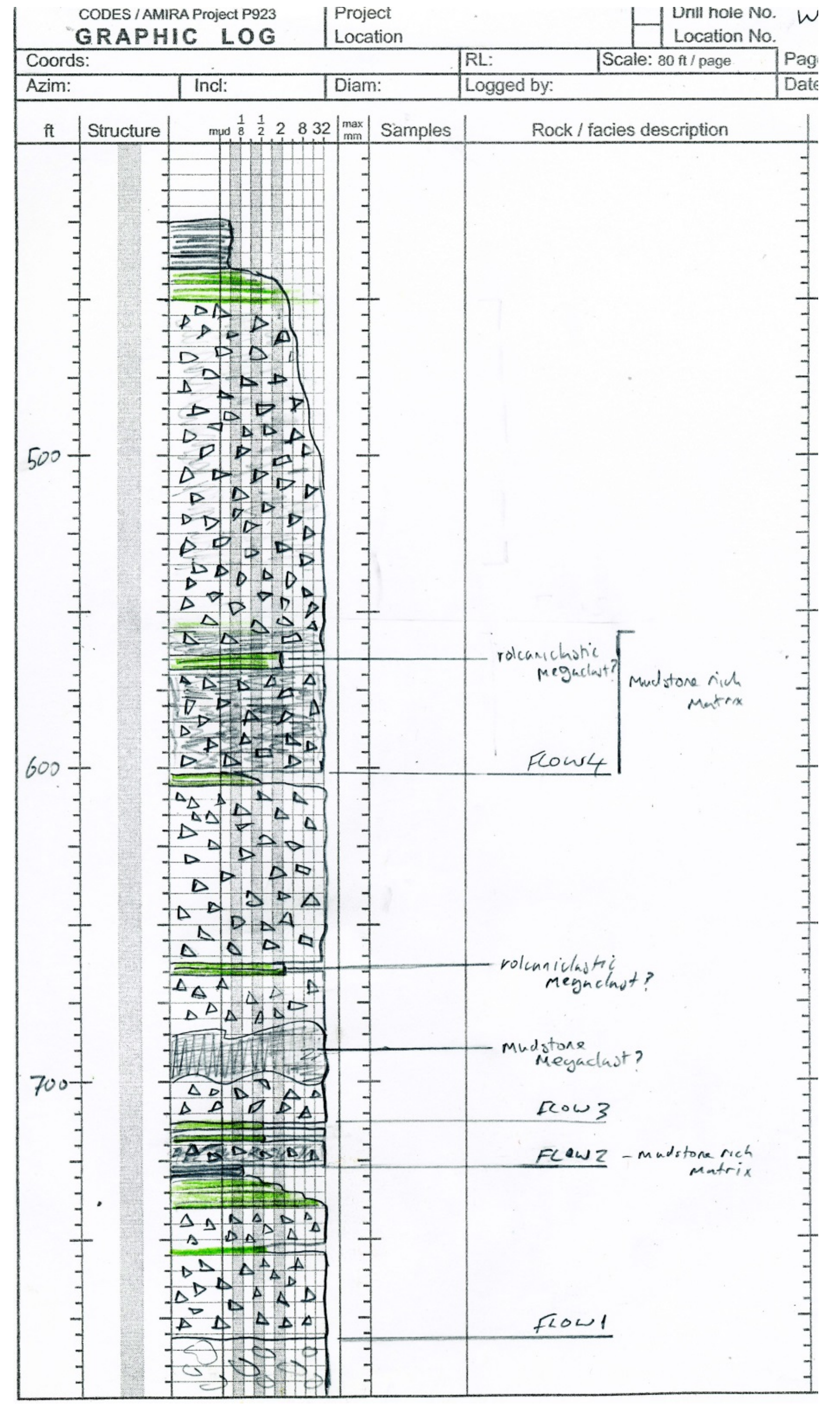
The interval of DDH WSP17 examined can be subdivided into four facies

Massive/laminated organic-rich silt/mudstones represent potentially long intervals of hemi pelagic deposition in the ambient sub wave base environment

The other three facies are all associated with the emplacement of mass flow units

Most (in terms of vertical thickness) are massive to normally graded pumice and lithic flows with a green (presumably originally ash-rich) volcaniclastic matrix

These are common in the MRV and are interpreted to record effectively syn-eruptive redeposition of the products of large volume magmatic eruptions in adjacent shallow marine or subaerial environments

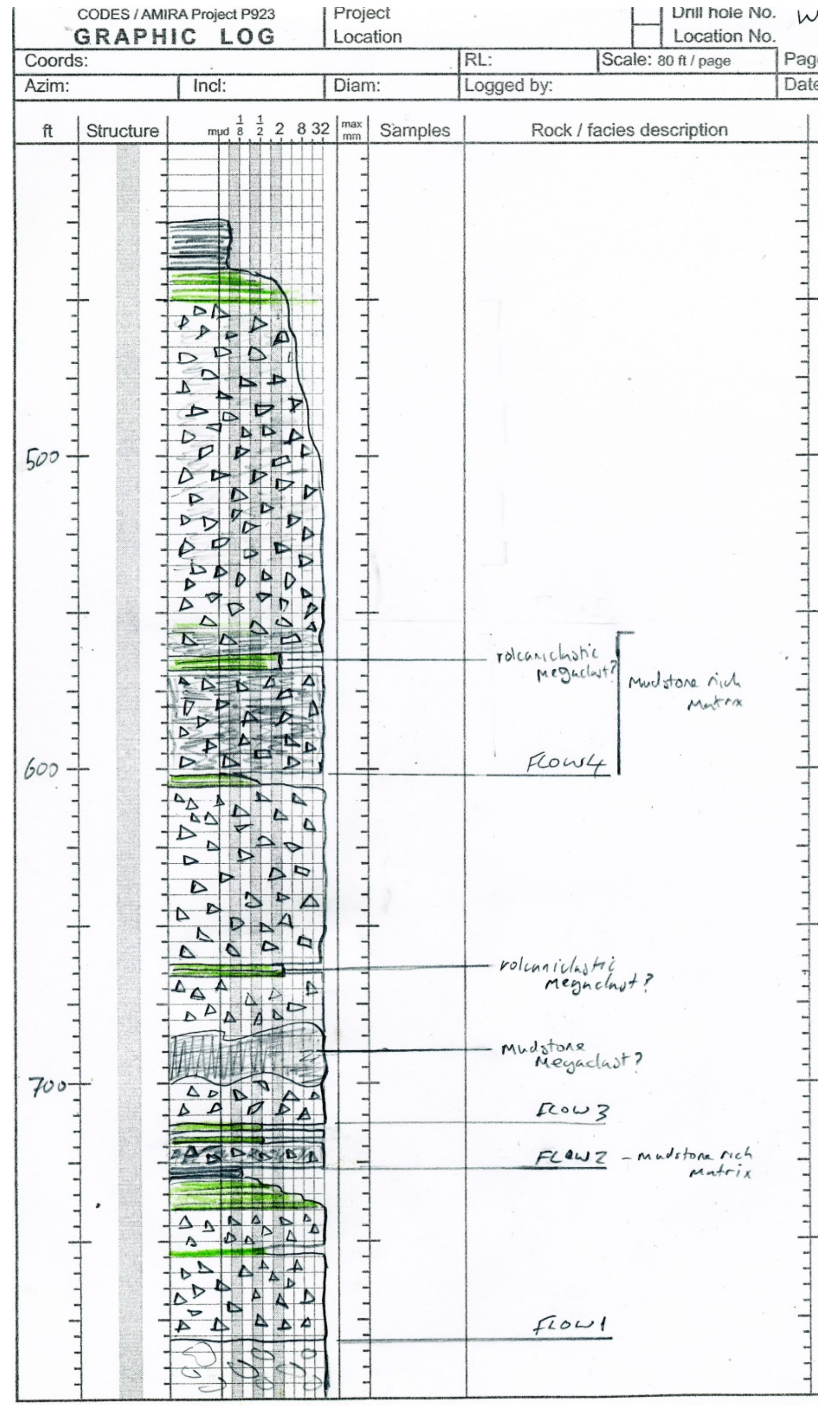


Executive summary

However, the sulfide clasts preferentially occur in mass flow intervals that have a dark, presumed mudstone-rich matrix

It is unclear from the relationships observed in the two intervals in WSP17 whether they represent; the basal parts of syn-eruptive mass flows that were enriched in mudstone due to the incorporation of unconsolidated material eroded from the substrate during emplacement; or alternatively whether they represent a different type of mass flow process

If the latter scenario is correct, then it has implications for exploration in that there is the potential that the mudstone-rich mass flows, along with the sulfide clasts they contain, were locally derived, in which case some components of either the matrix or the clasts are likely to be different from those of the syn-eruptive mass flows



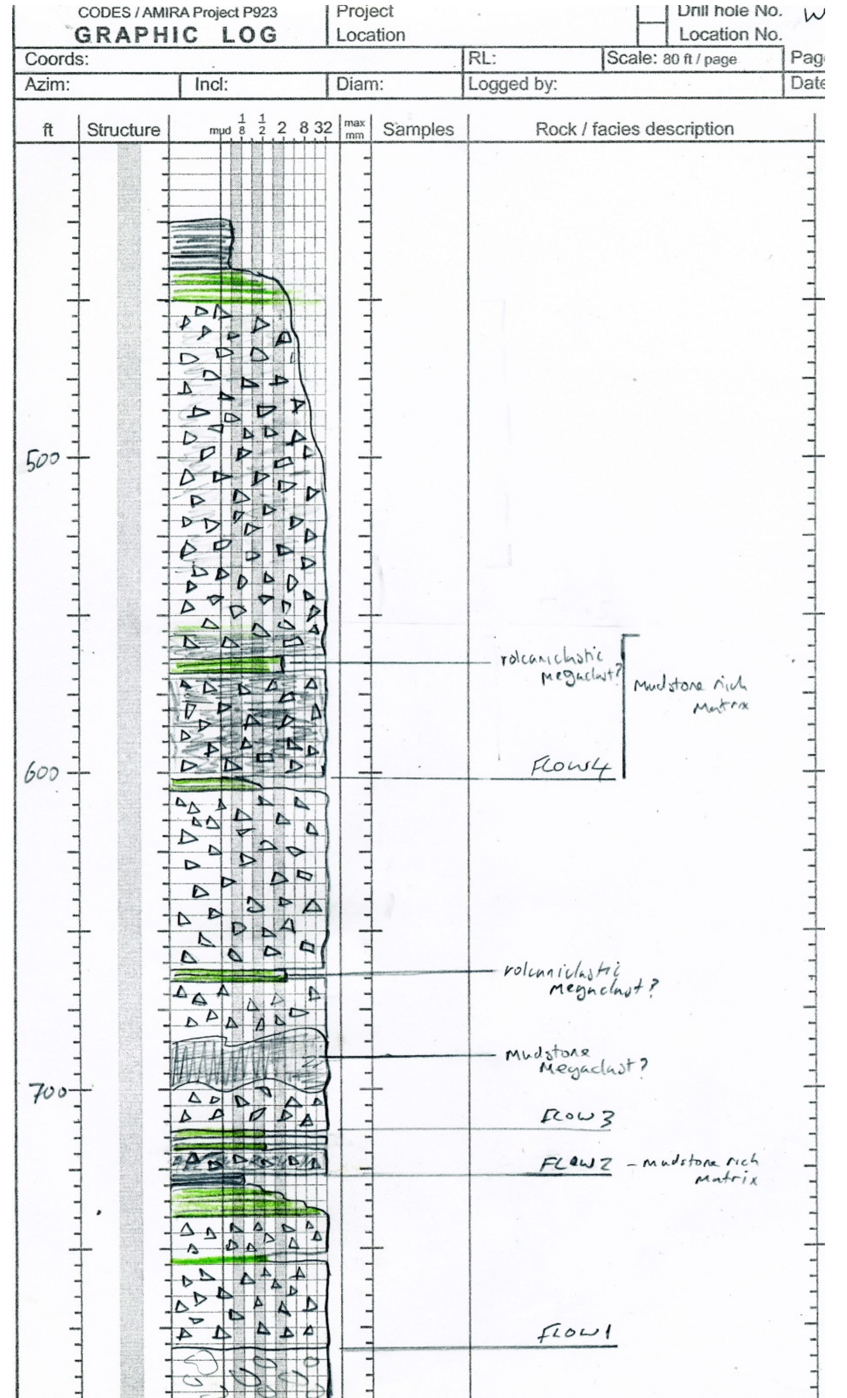
Introduction

This report is based on a 1 day visit to Rosebery in September 2013

The project brief was to comment on the mechanisms by which sulfide mineralised clasts could have been incorporated into the pumiceous mass flows intersected in DDH WSP17

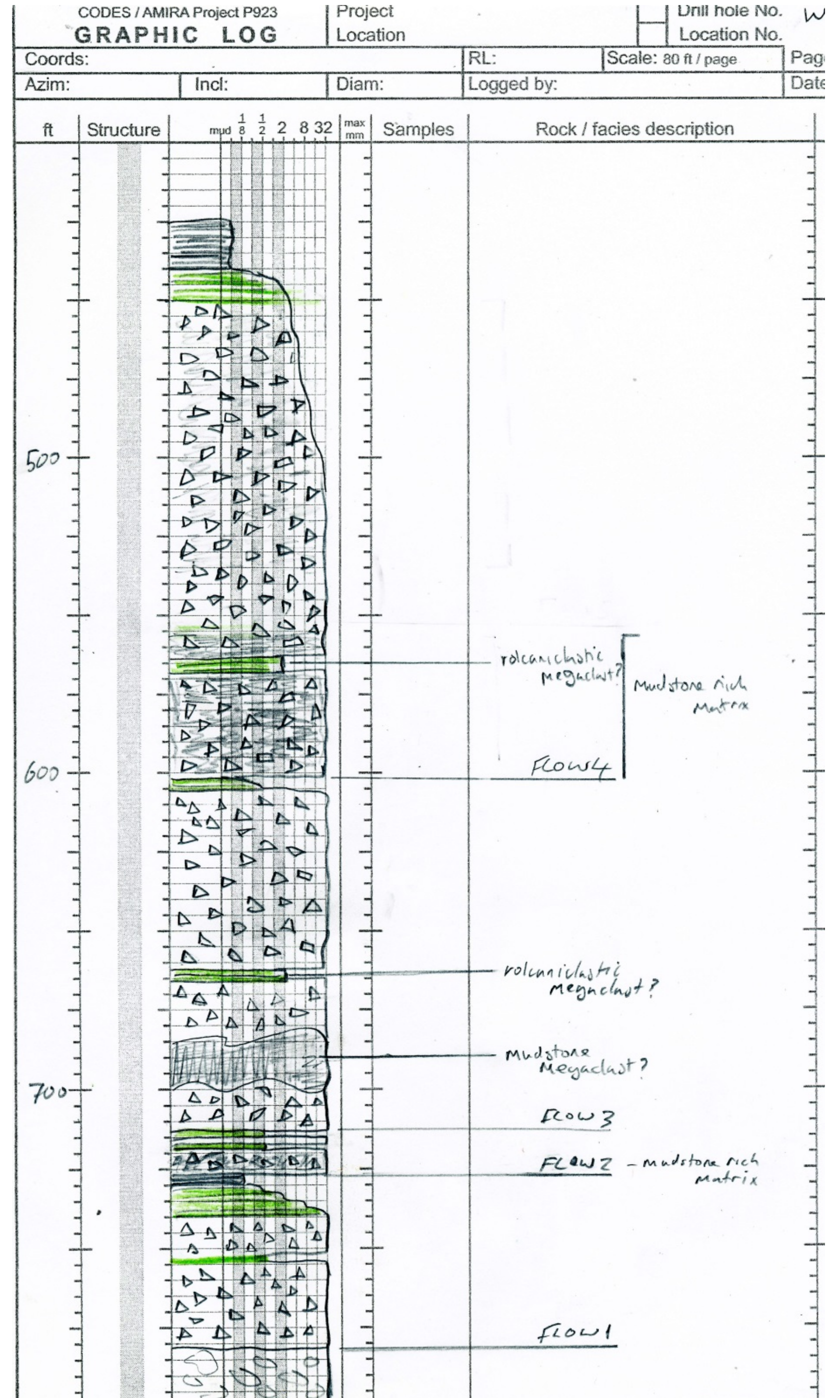
Note that the graphic log and accompanying observations were compiled in two hours on site at the Tullah core shed, and should threrby be considered an initial reconnaissance only

On a separate issue I was also asked to comment on whether the CODES LA-ICPMS geochronological system could help resolve the age of the mineralised succession that has been intersected in the footwall of the Rosebery Fault



The graphic log shown is based on the MMG lithology log of WSP17 and observations made of the core at the Tullah coreshed

It represents the interval between 425 and 800m, which incorporates the mass flows that contain the sulfide clasts, two examples of which are shown below from ~590m (right) and ~595m (left)

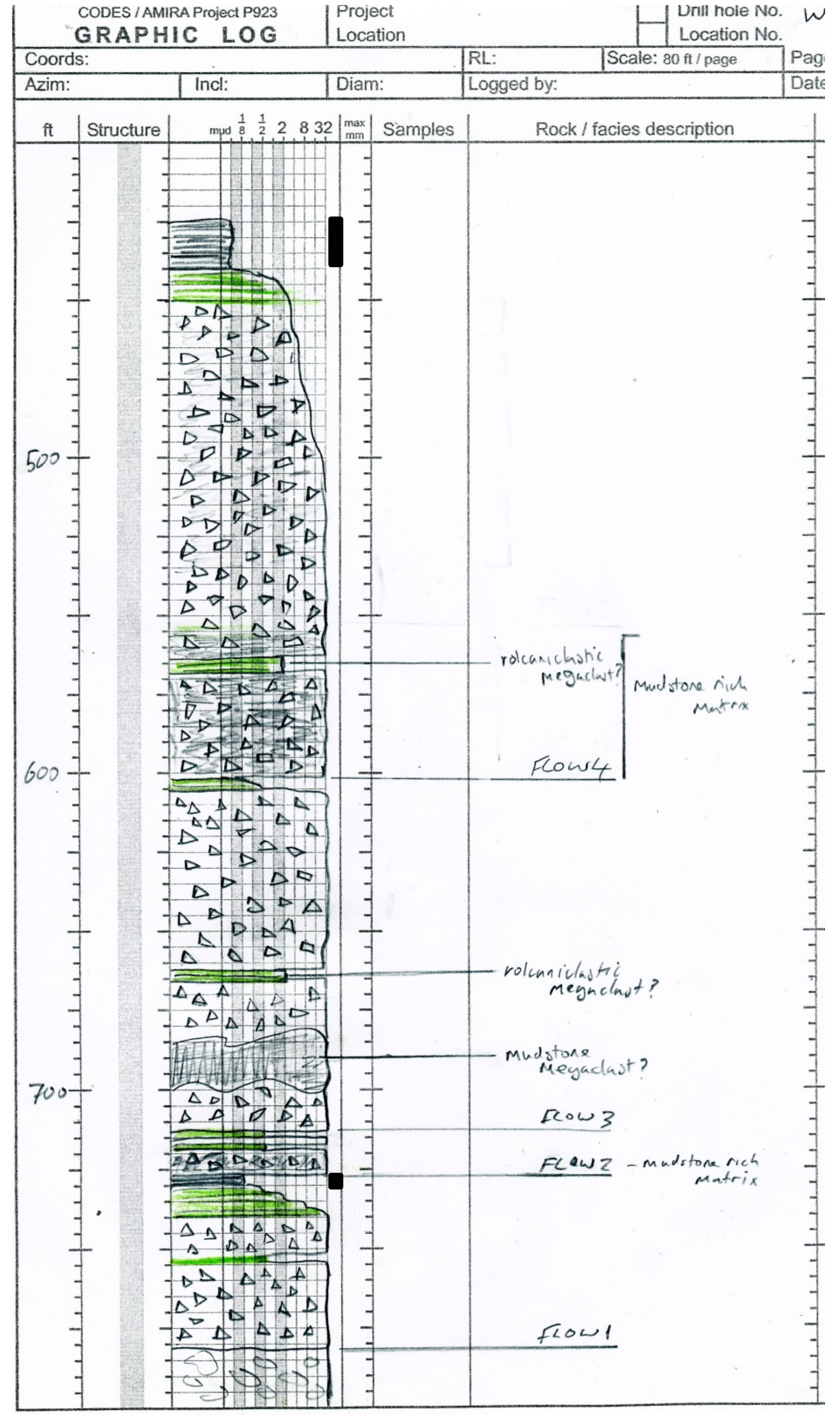


Due to time constraints, a detailed examination of the nature of these clasts was not carried out as part of this study, but the examples shown were dominated by sphalerite and pyrrhotie

Four facies are present in the interval logged;

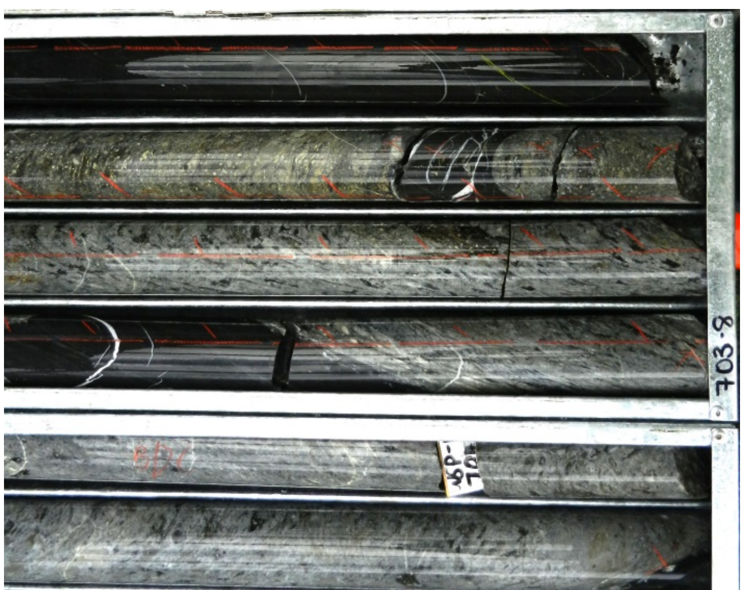
- Massive to normally graded pumice/lithic flows with an ash-dominated matrix
- Massive lithic flows with a mudstone-dominated matrix
- Bedded volcaniclastic sandstones/siltstones
- Massive/laminated organic-rich silt/mudstones

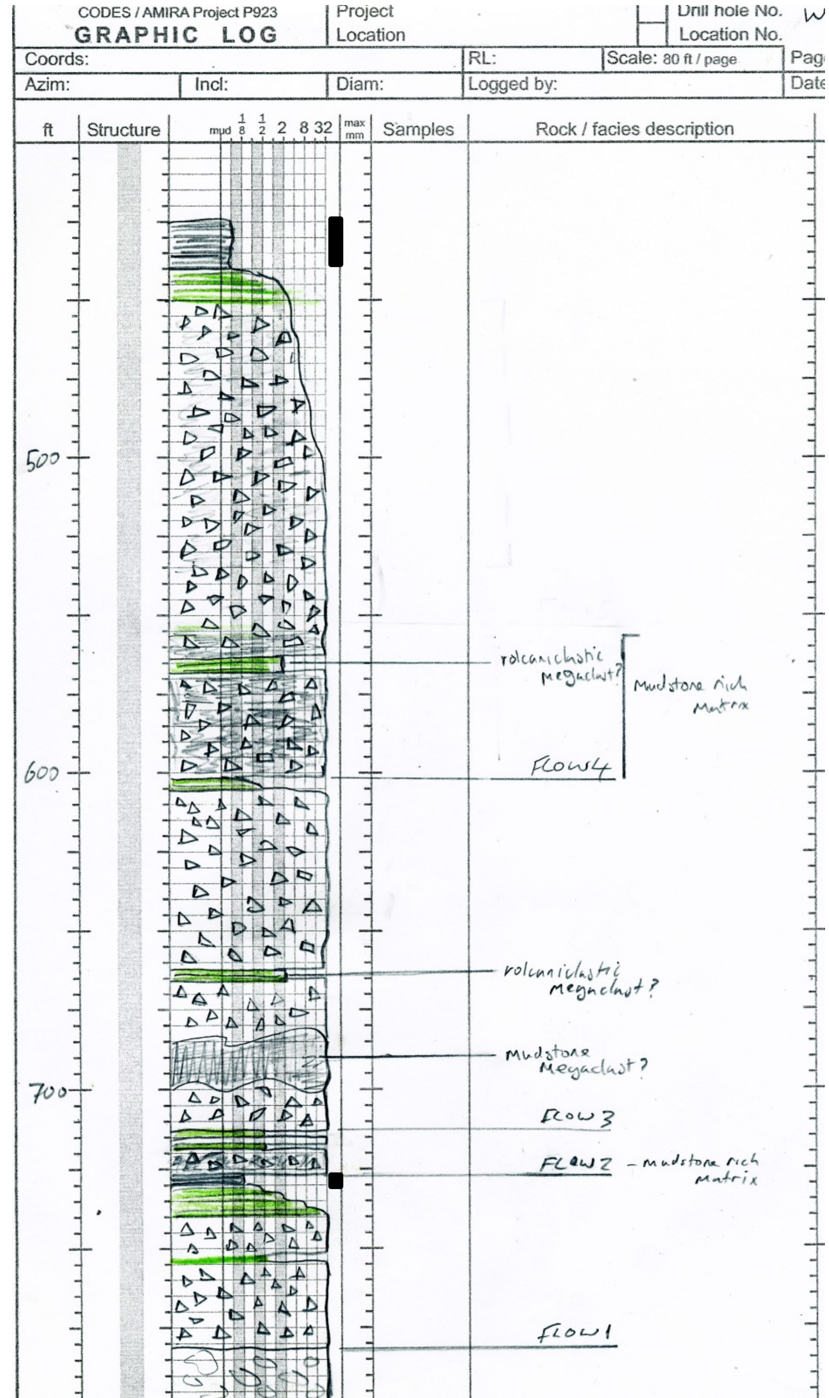
The massive/laminated organic-rich silt/mudstones (black bars) record sub wave base suspension deposition that represents the ambient depositional conditions for much of the preserved belt of the MRVs



The mudstone facies intervals (two in the intersection logged) record significant time breaks between eruptive events

However, as the mudstone substrate is clearly prone to erosion during the emplacement of the pumiceous mass flows (as indicated by the common occurrence of mudstone intra-clasts, the examples shown below are within the lower part of flow 3) it is possible that thinner intervals could have been completely removed so there could have been more breaks between eruptions than is evident

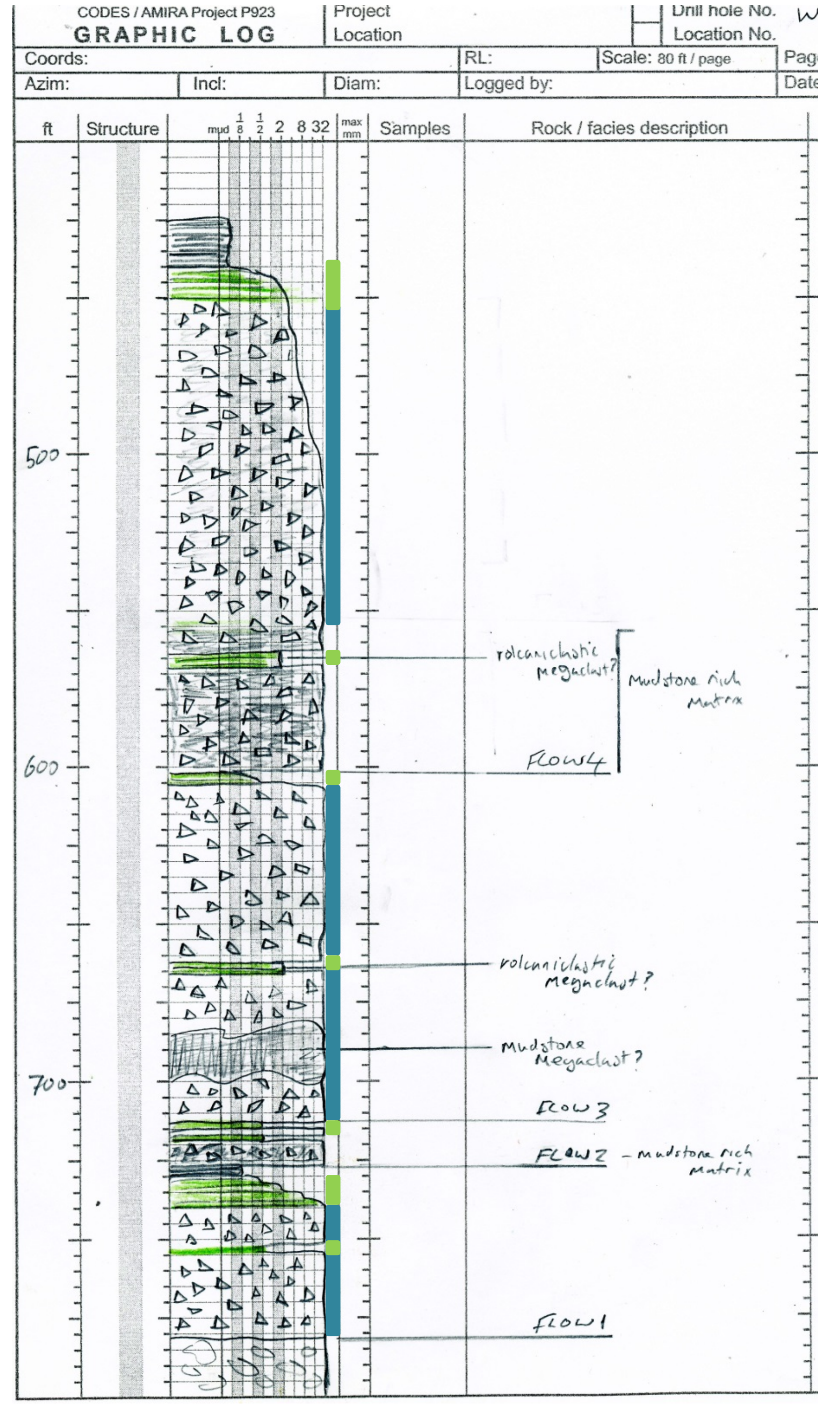




The massive to normally graded pumice/lithic flows with an ash-dominated matrix (blue bars) are a well recognised facies within the MRVs

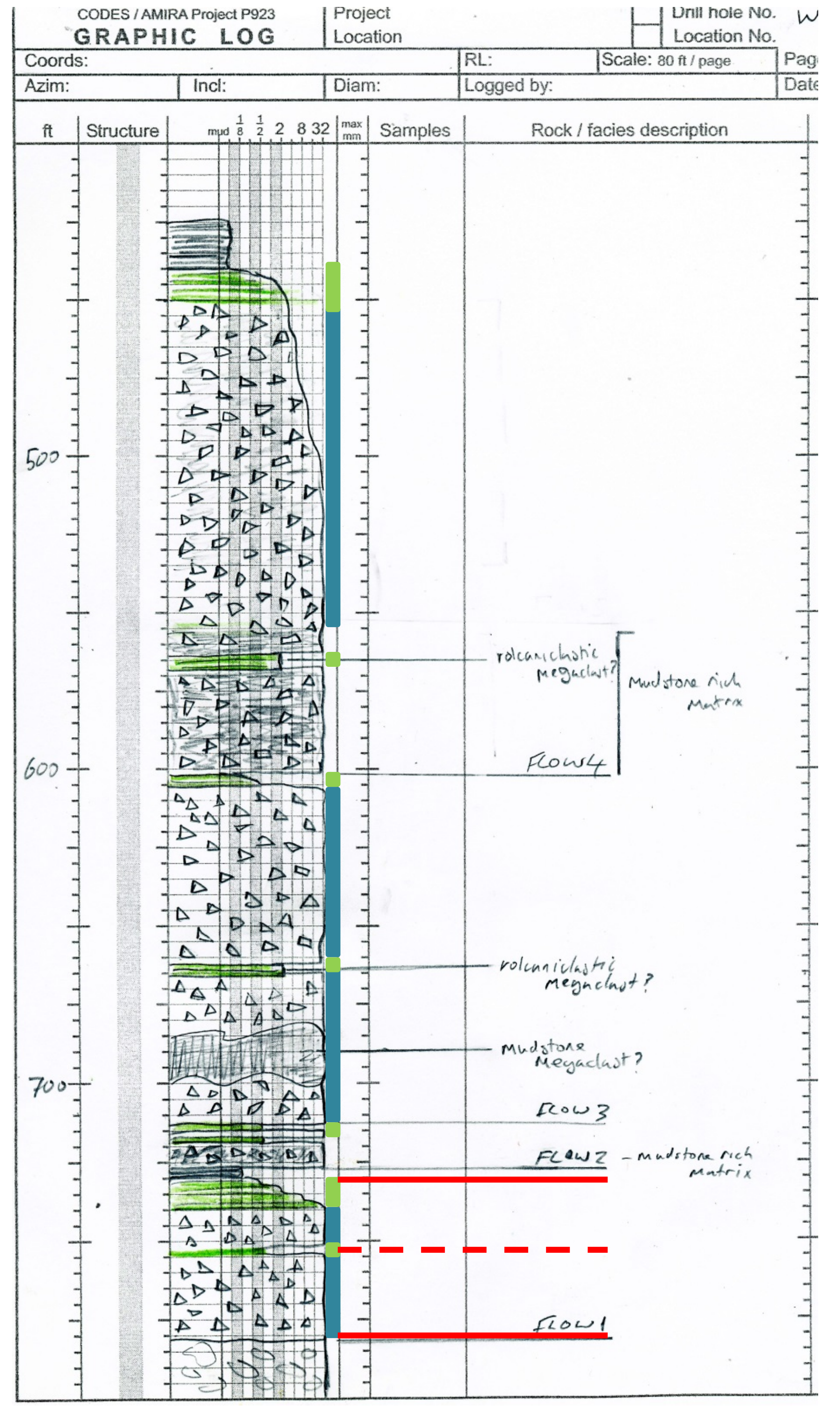
These units are widely interpreted as subaqueous mass flows that were more or less directly fed by ignimbrite forming magmatic eruptions in adjacent shallow water or terrestrial environments

Bedded ash intervals (green bars), where normally graded (e.g. ~450, 610 and 735m), are interpreted to represent fine-grained material elutriated out of the mass flow during emplacement that settled out of suspension after the main body of the flow had been deposited



Where they are not normally graded (e.g. 565, 660 and 715m) due to the constraints imposed by drillcore based analysis it is difficult to determine whether these volcaniclastic sediment intervals formed in the same manner, but for some reason did not preserve normal grading. (e.g. one possibility is they represent relatively short inter-eruptive breaks when only the coarser elutriated ash was deposited and the finer fractions remained in suspension)

Alternatively they may represent mega-clasts of volcaniclastic sediment eroded from the substrate in the same manner as the mudstone intraclasts described above

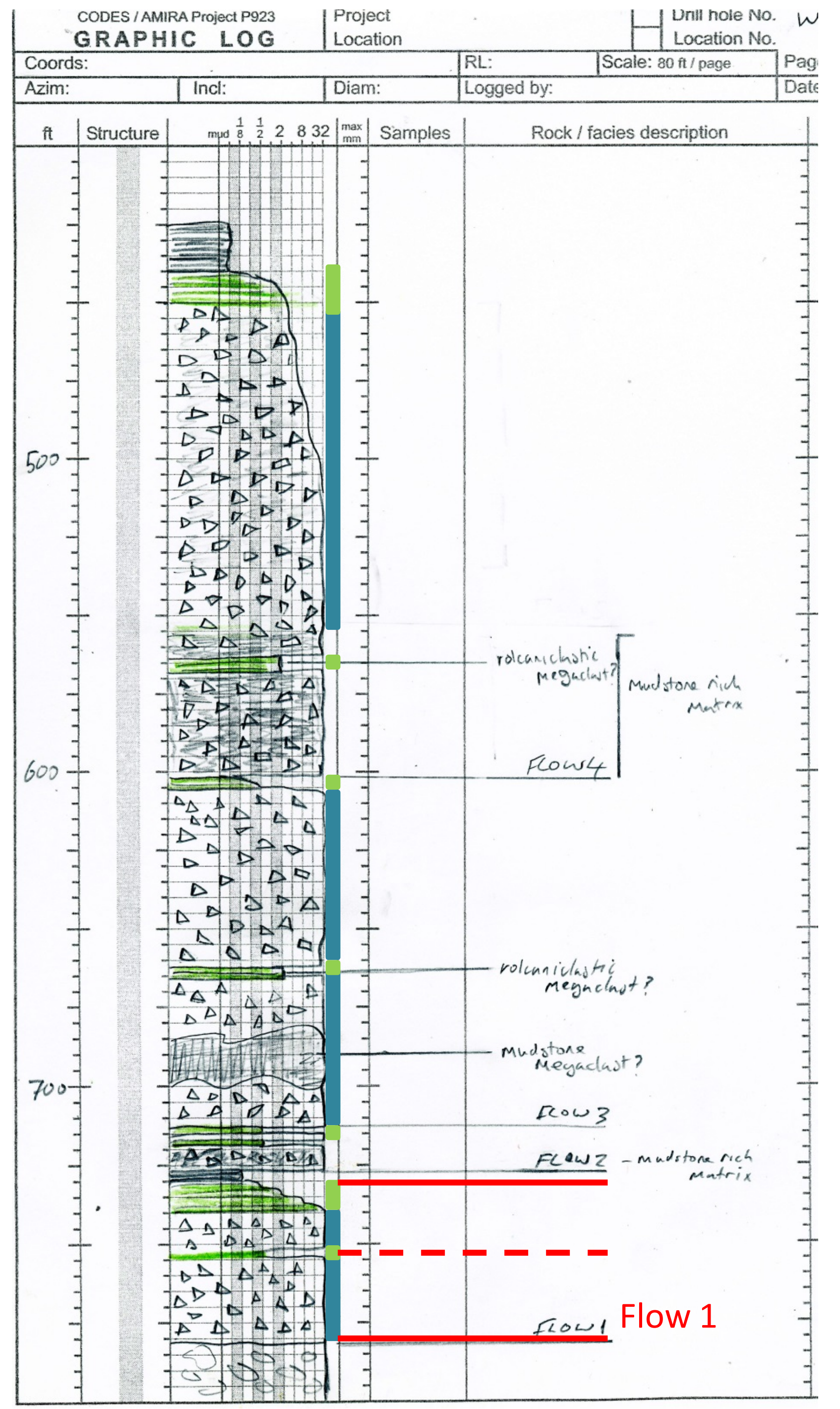


Taking this into account, there are at least four mass flow events preserved in the interval logged that are here numbered from oldest to youngest

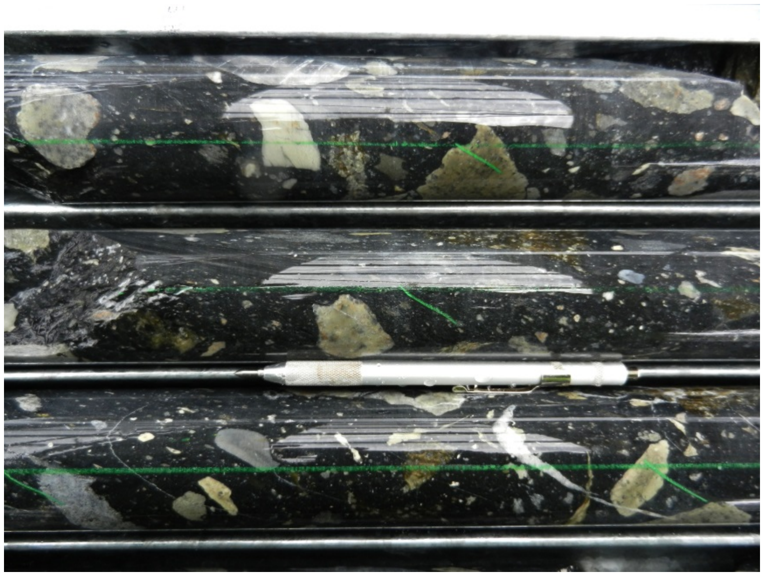
The lowermost unit, flow 1, overlies a distinctive rhyolitic breccia unit

It has an ash rich matrix and an interval of massive volcaniclastic sediment in its upper part that may represent an inter-eruptive break or a mega clast

It is succeeded by a normally graded interval of volcaniclastic sediment that is capped by mudstone, indicating a significant time break before the emplacement of flow 2

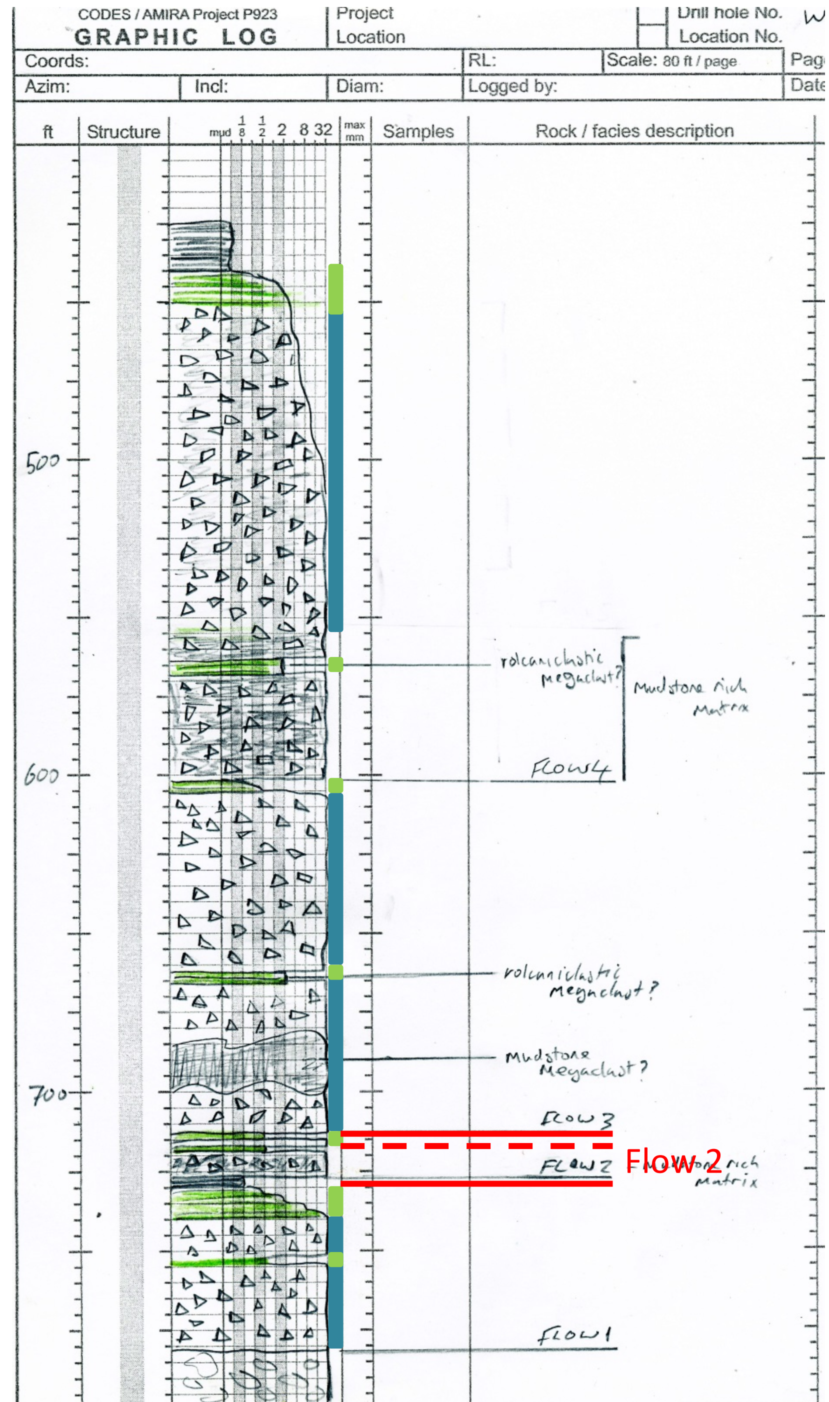


Flow 2 is a distinctive unit in that it has a dark coloured, presumably mudstone-rich matrix (picture shown is from ~723m) compared to the green coloured (presumably ash-rich) matrix of flow 1



It also contains sulfide clasts

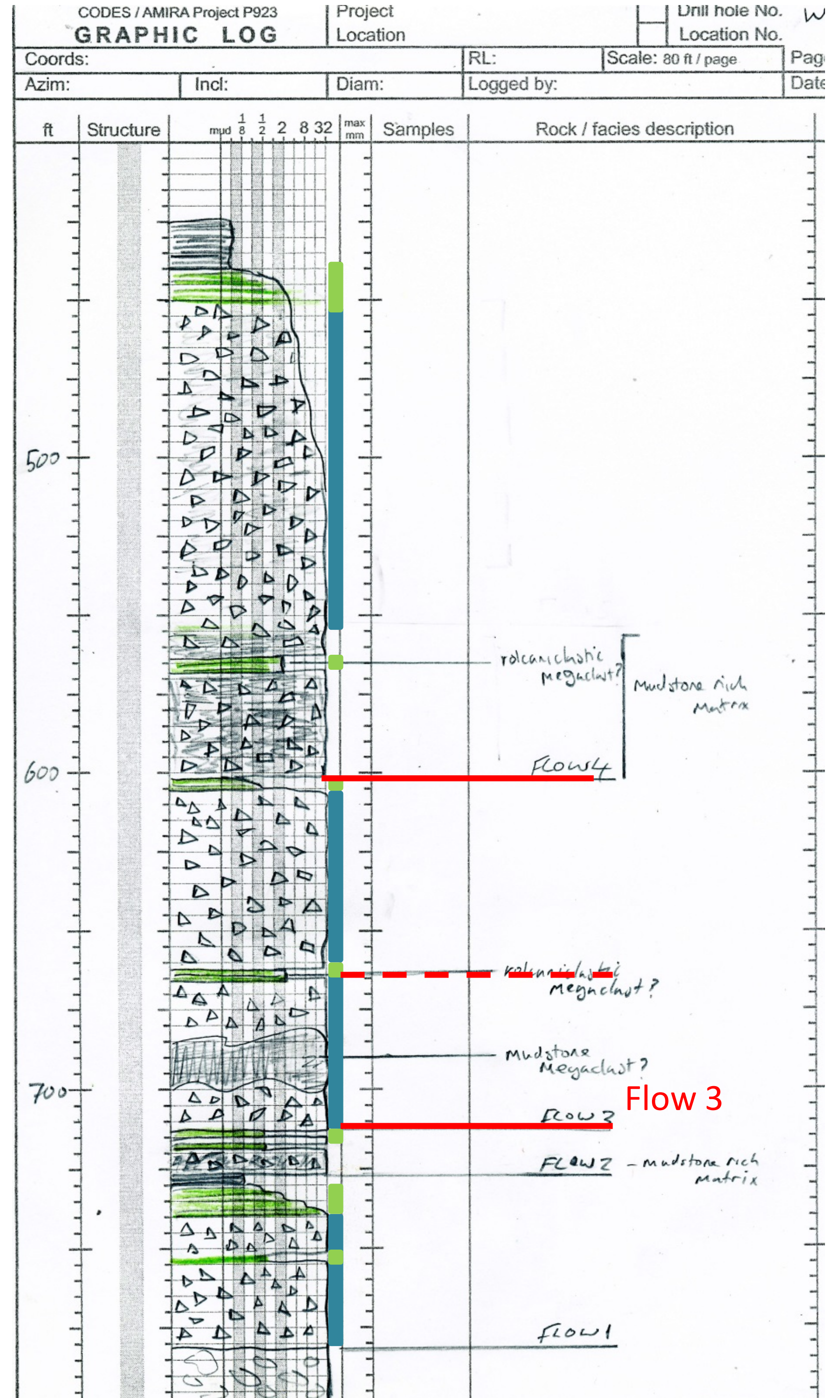
It is separated from the overlying flow 3 by two thin intervals of massive volcaniclastic sediment on either side of a thin volcaniclastic breccia, and there is no mudstone present indicative of a significant time break



Flow 3 is a thick (>100m) unit with a green ash-rich matrix and common mudstone intraclasts

It includes a 15m thick mudstone interval in its lower part that was interpreted by the MMG geologist who logged the core as a mudstone mega-clast and I concur with this interpretation

It is separated from the succeeding flow 4 by a normally graded interval of volcaniclastic sediment but there is no mudstone present

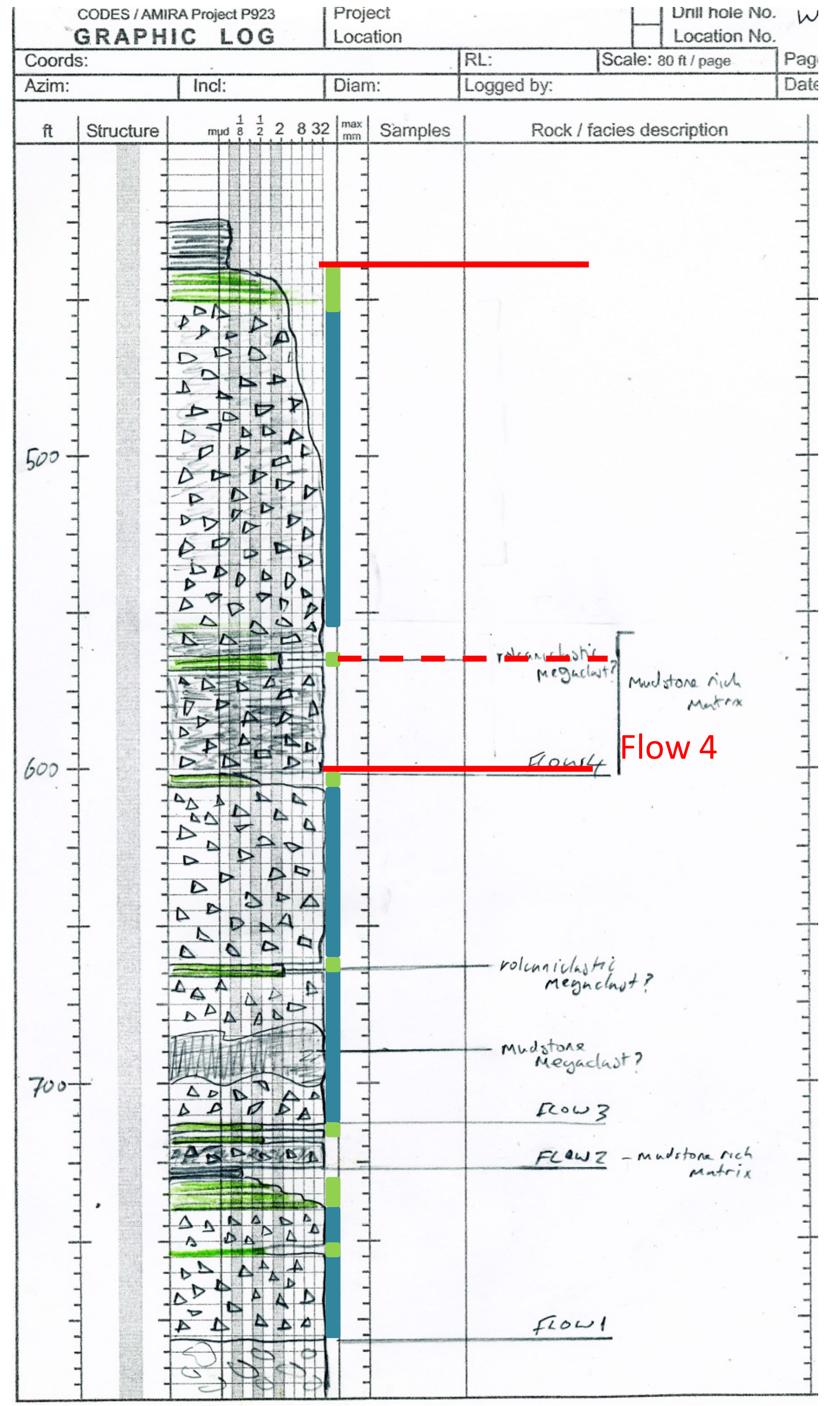


Flow 4 is another thick unit (>150m) that is capped by a normally graded interval of volcaniclastic sediment that is succeeded by mudstone indicating a break in eruptive activity

An interval of massive volcaniclastic sediment in its lower part may represent an inter-eruptive break or a mega-clast

The lowermost 50m of the unit (which includes the massive volcaniclastic sediment interval) has a dark, presumed mudstone rich matrix and contains a significant number of sulfide clasts

Above 50m the matrix becomes less dark and greener presumed to indicate the proportion of mudstone is dropping off relative to the proportion of volcaniclastic material



General interpretation of the succession

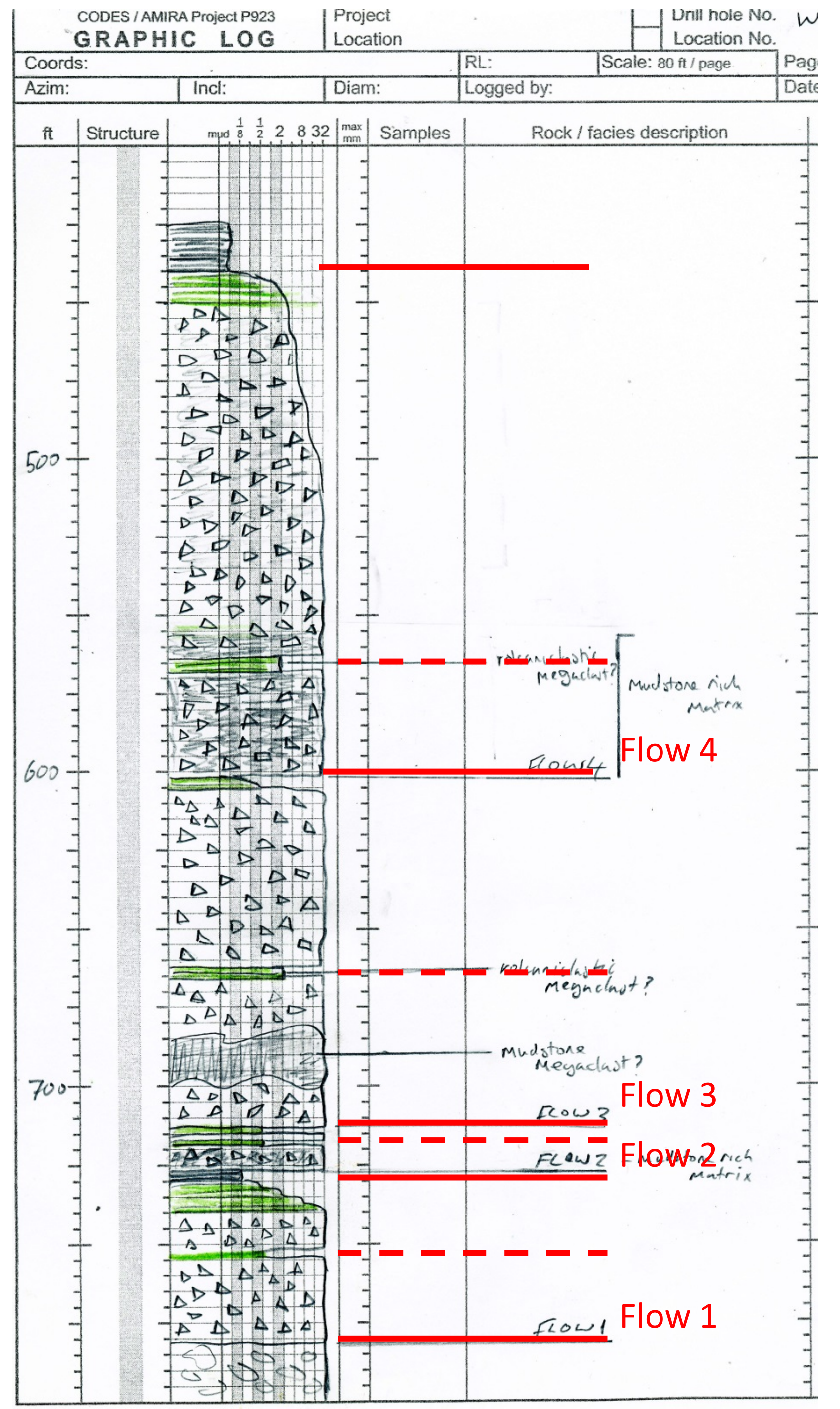
Water depth; absolute water depths are speculative, but the preservation of graded ash beds on top of some of the thick syn-eruptive mass flows indicates that the tops were not re-worked, and sub wave base water depths must have been deeper than the uncompacted thickness of these units (several hundred metres?)

Position wrt basin margin; the fact that the reworked products of the eruptive events recorded by the thick pumiceous and lithic mass flow facies are restricted to relatively thin density graded volcaniclastic intervals, suggests a basinal setting at some distance from the basin margin. In a more proximal basin margin setting, thicker more diverse bedded volcaniclastic intervals overlying the thick effectively syn-eruptive pumiceous mass flows would be expected, reflecting post-eruptive reworking of the unconsolidated volcanic ejecta delivered the marine environment via fluvio-deltaic systems

Provenance of the sulfide clasts

As was recognised by the MMG geologists who originally logged the WSP17, the vast majority of the sulfide clasts occur in the regions that have a dark (mudstone-rich)matrix i.e. flow 2 and the basal third of flow 4

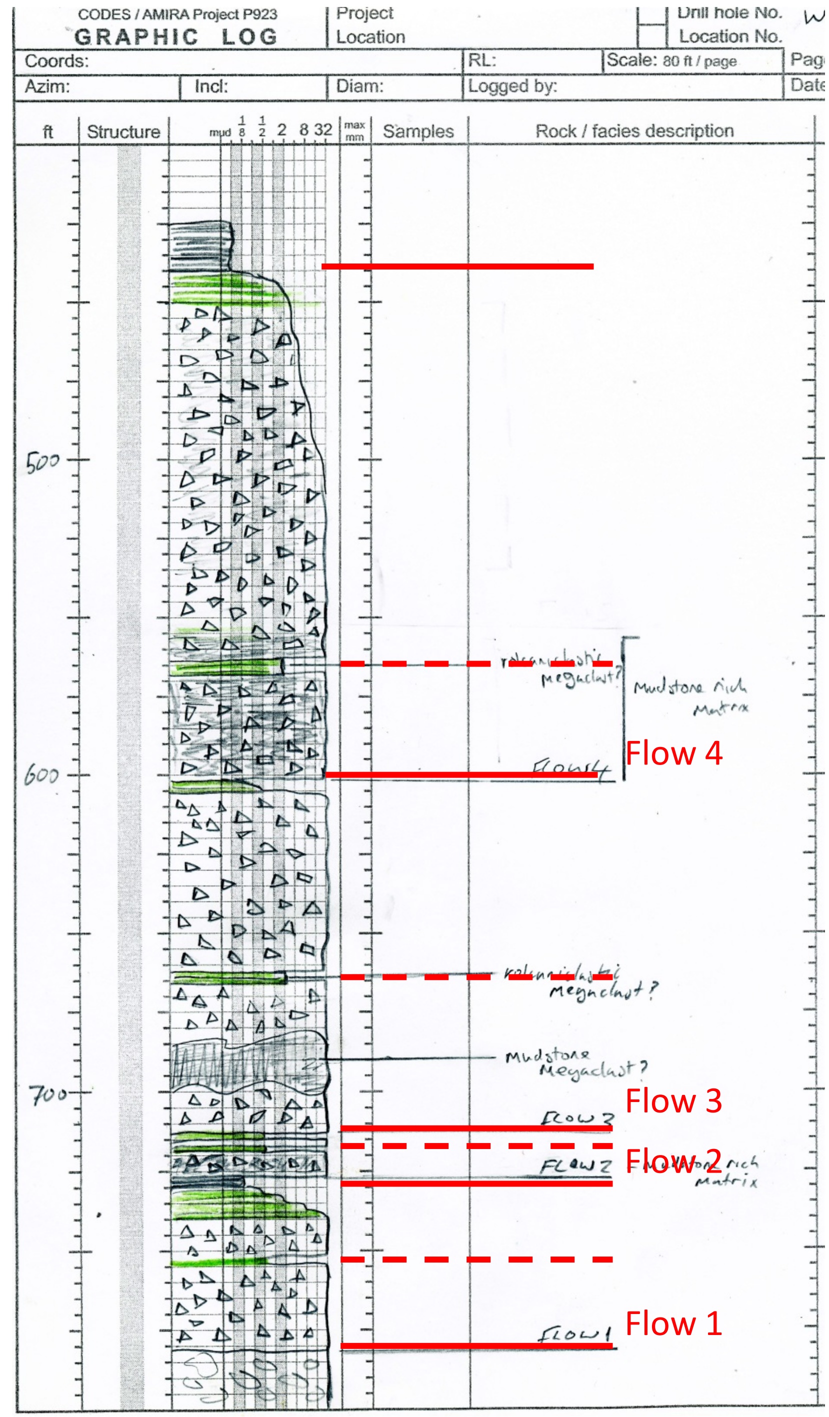
The interpretation of these mudstone-rich zones is therefore critical to the provenance of the sulfide clasts, and given that the relationships of the two intervals to the adjacent pumiceous/lithic mass flows are different, two scenarios are possible based on the interval logged



Scenario 1; based on the fact that, in contrast with flows 1 and 3 that have ash rich matrices and no sulfide clasts, the intervening flow 2 has a mudstone rich matrix throughout as well as relatively abundant sulfide clasts, it is possible that these different characteristics reflect a different origin/provenance

In general, the normal (ash-rich) pumiceous mass flows that occur within the basinal sediments in the MRV are interpreted to have been more or less directly sourced from major magmatic eruptions in adjacent shallow marine or subaerial environments

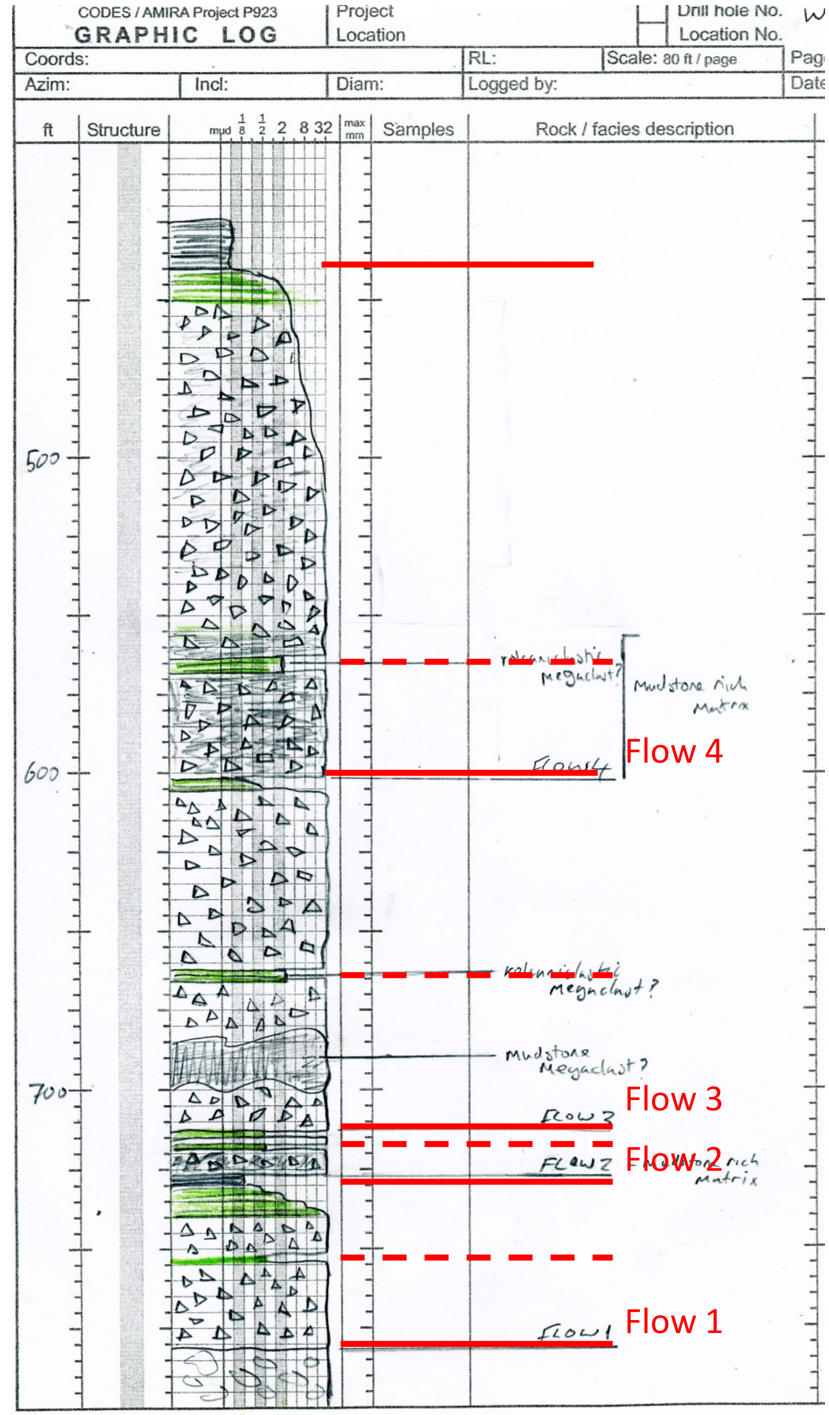
In a best case scenario in terms of mineral exploration, the flows with mudstone-rich matrices could, in contrast, be relatively locally derived which would imply the same for the associated sulfide clasts



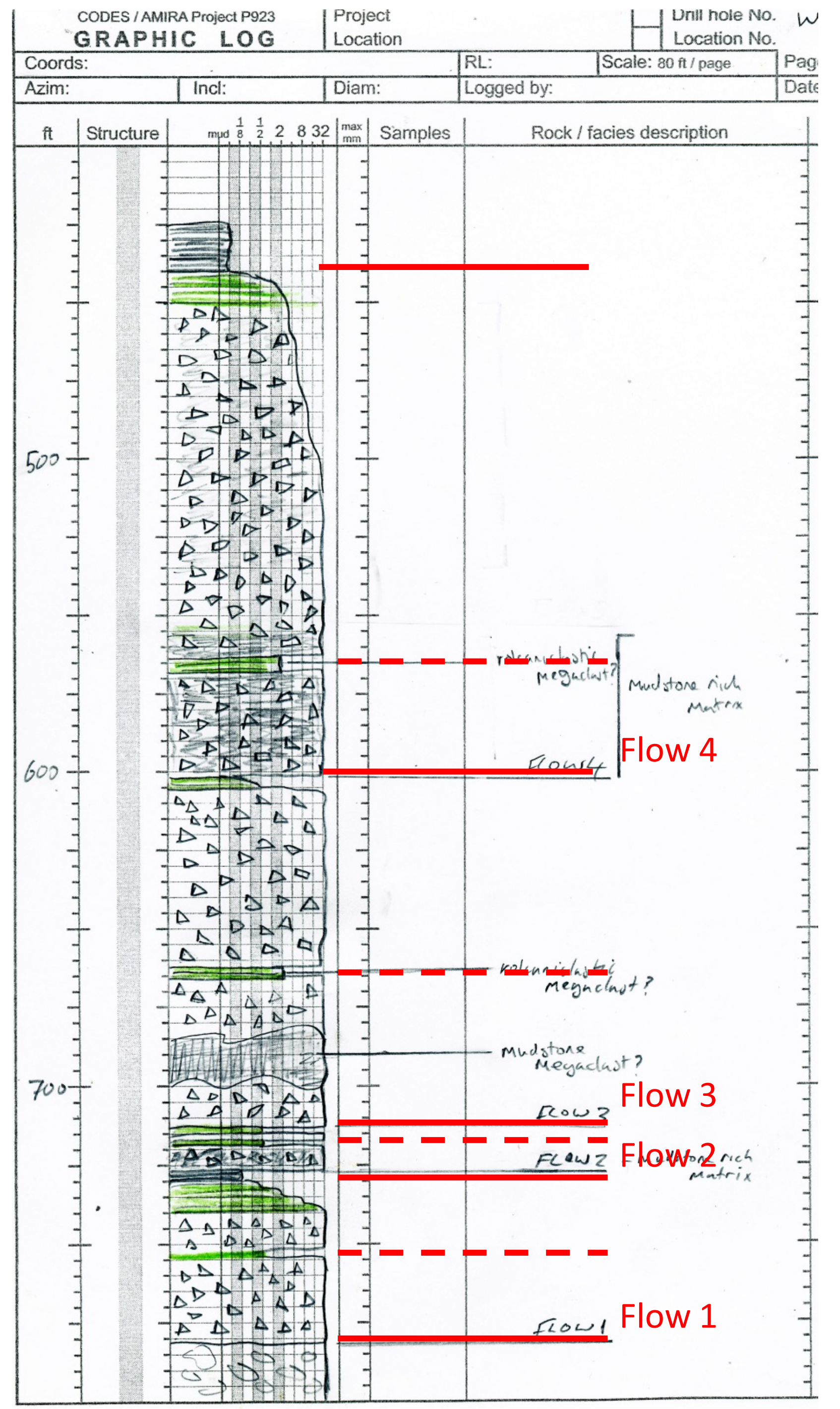
Possible mechanisms for the generation of the mudstone rich breccia units could include:

1. Slumping of the muddy substrate associated with the development of local growth fault scarps (given there is no mudstone separating the mudstone rich flow 2 from the ash-rich flow 3, and hence no evidence of a significant time break, it is possible that seismic activity associated with the eruption that would ultimately generate flow 3 caused the slumping event that produced flow 2)

2. Disruption of the muddy substrate due to the nearby intrusion of high level intrusive (cryptodomes) or extrusive coherent volcanic units (pers. comm. J. McPhie); depending on its extent and geometry the rhyolitic breccia unit that underlies flow 1 could record such an event



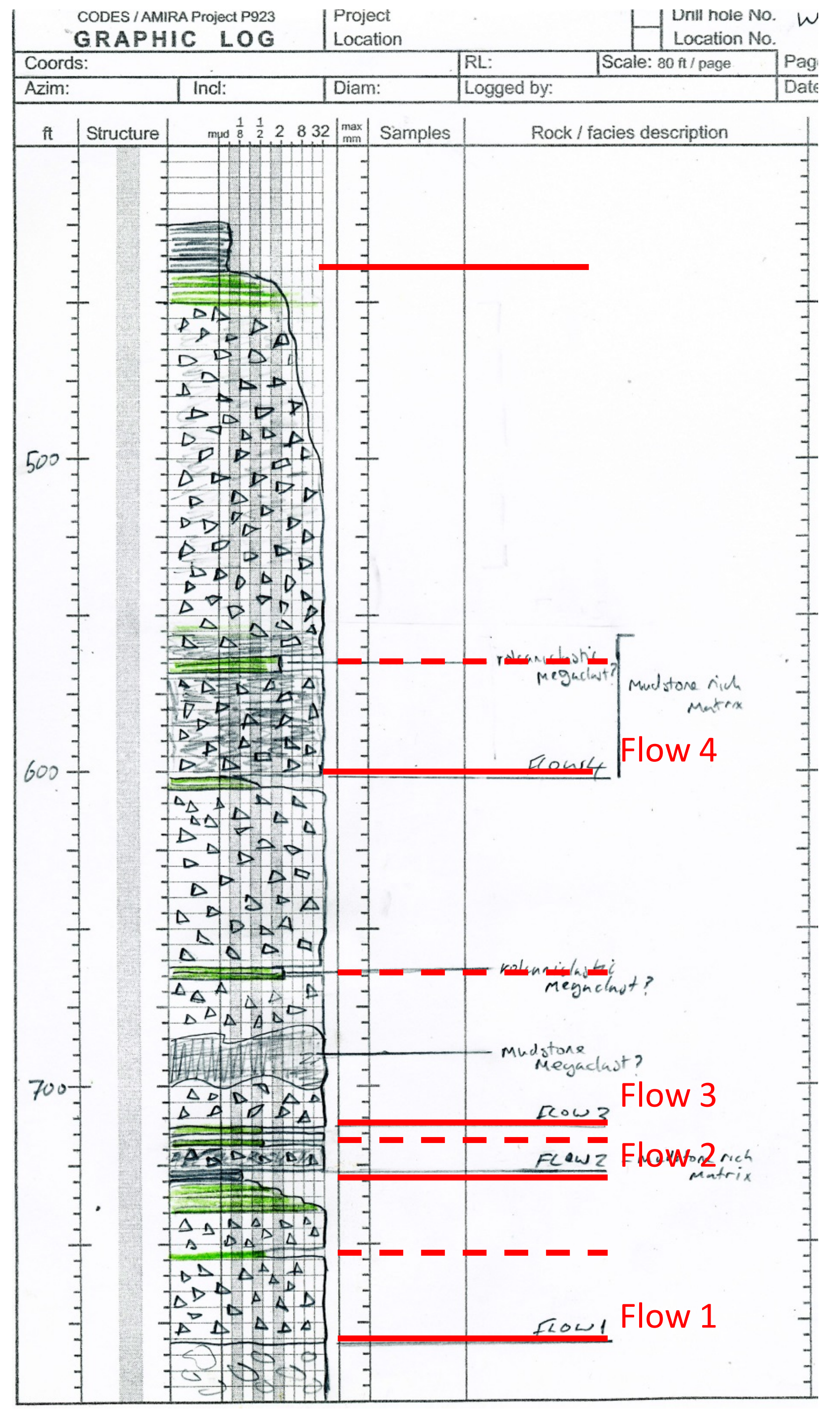
Either of these scenarios would be potential sites for seafloor or sub sea floor mineralisation formed by hydrothermal activity focussed on syn-sedimentary faults (scenario 1) or adjacent to a submarine volcanic centre (scenario 2)



Scenario 2; is based on the fact that the mudstone matrix rich basal part of flow 4 seems to grade upwards into a "normal" ash-rich pumice flow i.e. in contrast to flow 2 it does not appear to record a separate mass flow event

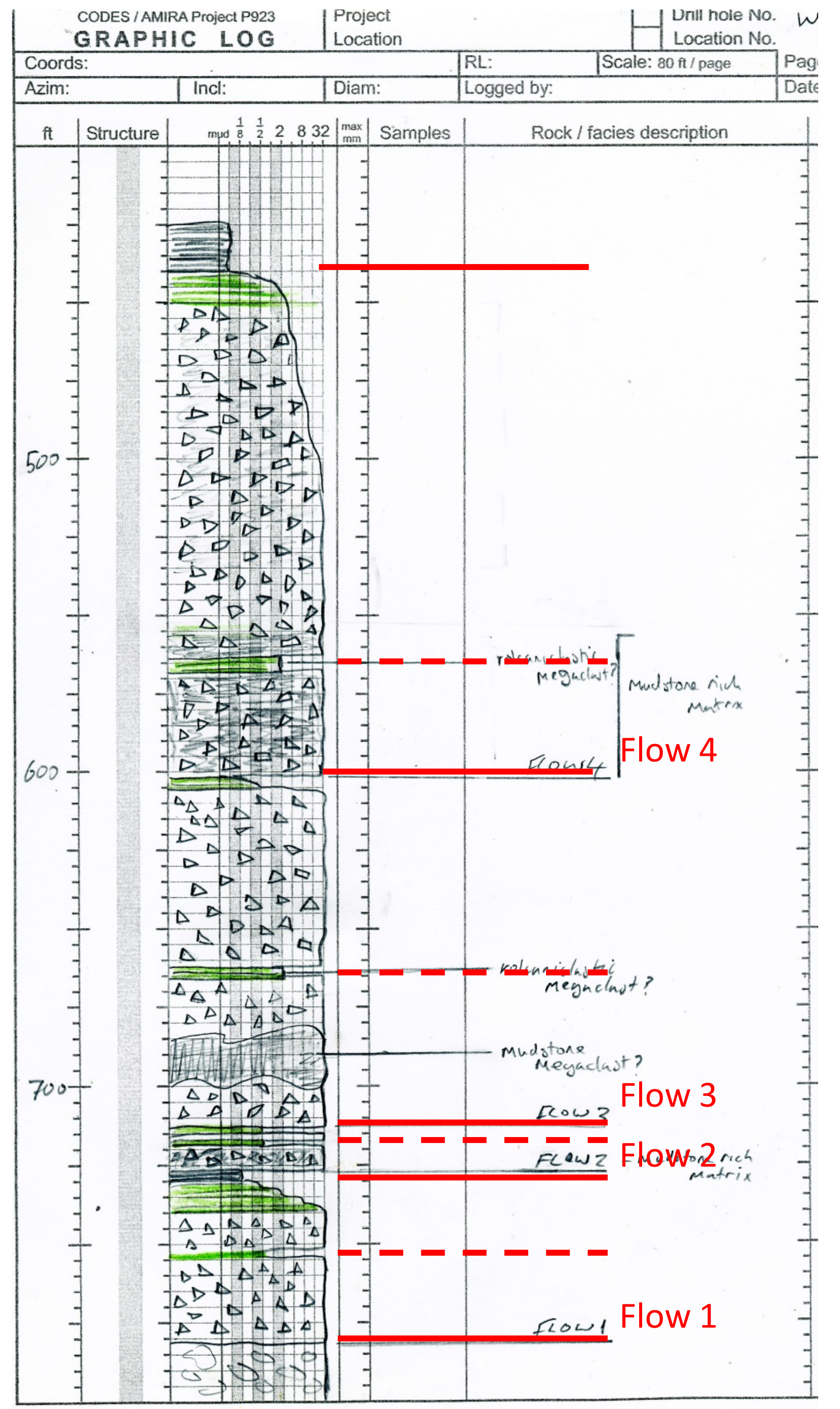
The mudstone (and volcaniclastic sediment?) intraclasts clearly demonstrate that the pumiceous mass flows had the capacity to erode the substrate along their flow path

It is therefore possible that the mudstone matrix rich zones (all of the relatively thin flow 2 and the basal part of the much thicker flow 4) represent areas of the flow where unconsolidated mudstone intraclasts were disaggregated during emplacement



Given the interpreted basinal setting, the mudstone (and the sulfide clasts that preferentially occur in these zones) could have been incorporated anywhere along the flow path from the source eruption, which as they are dominated by magmatic processes are assumed to have occurred in adjacent shallow or subaerial settings

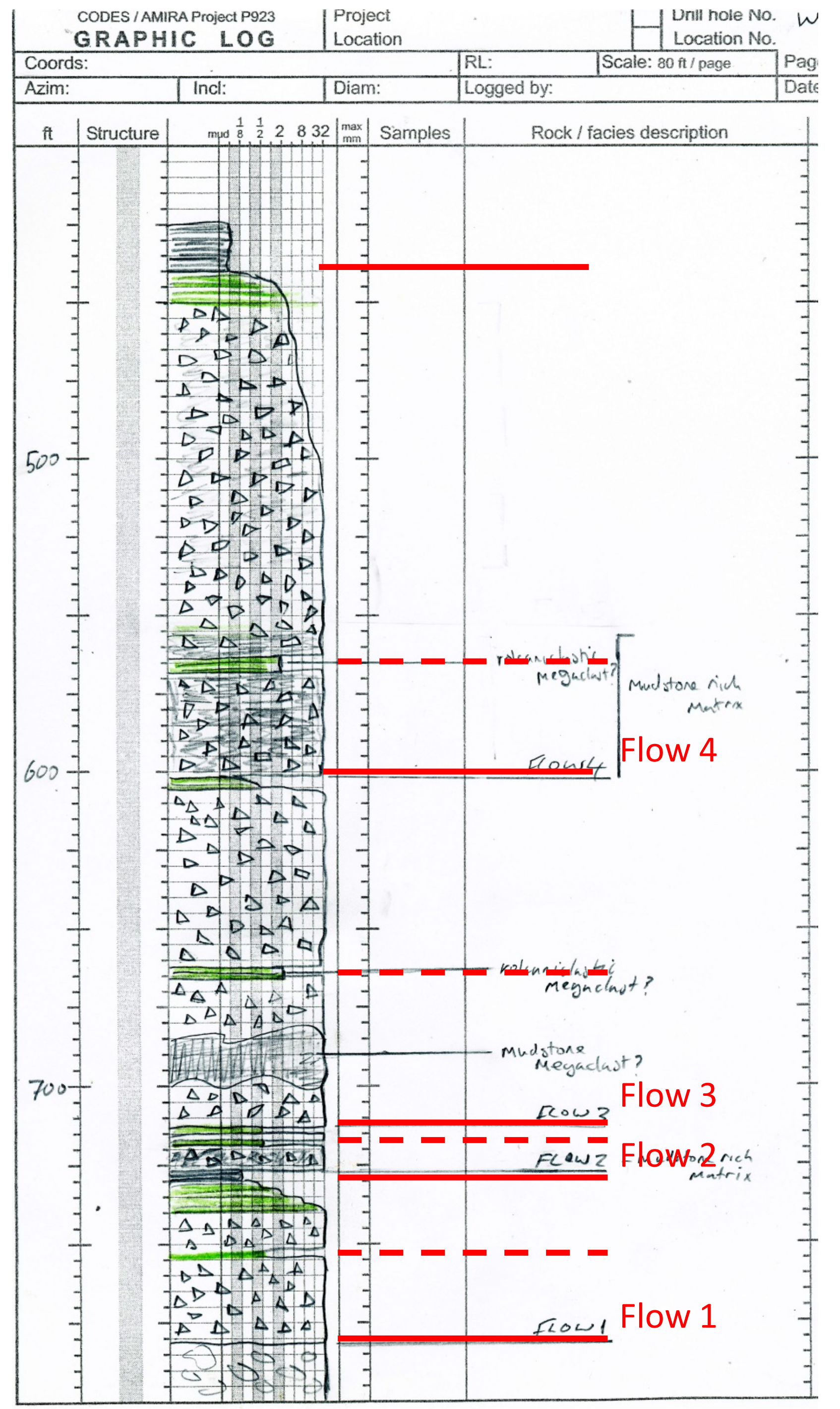
It is clear that if this scenario is the correct one then the significance of the sulfide clasts for mineral exploration is minimal



Determining the origin of the mudstone-rich mass flows

In scenario 1 the mudstone-rich mass flows are discrete and potentially locally sourced mass flow events, whereas in scenario 2 they are locally modified areas within the “normal” syn-eruptive pumice/lithic mass flows fed by shallow marine or subaerial magmatic eruptions

The key to determining the correct interpretation therefore lies in comparing the mudstone-rich zones to the adjacent ash-rich zones in each case



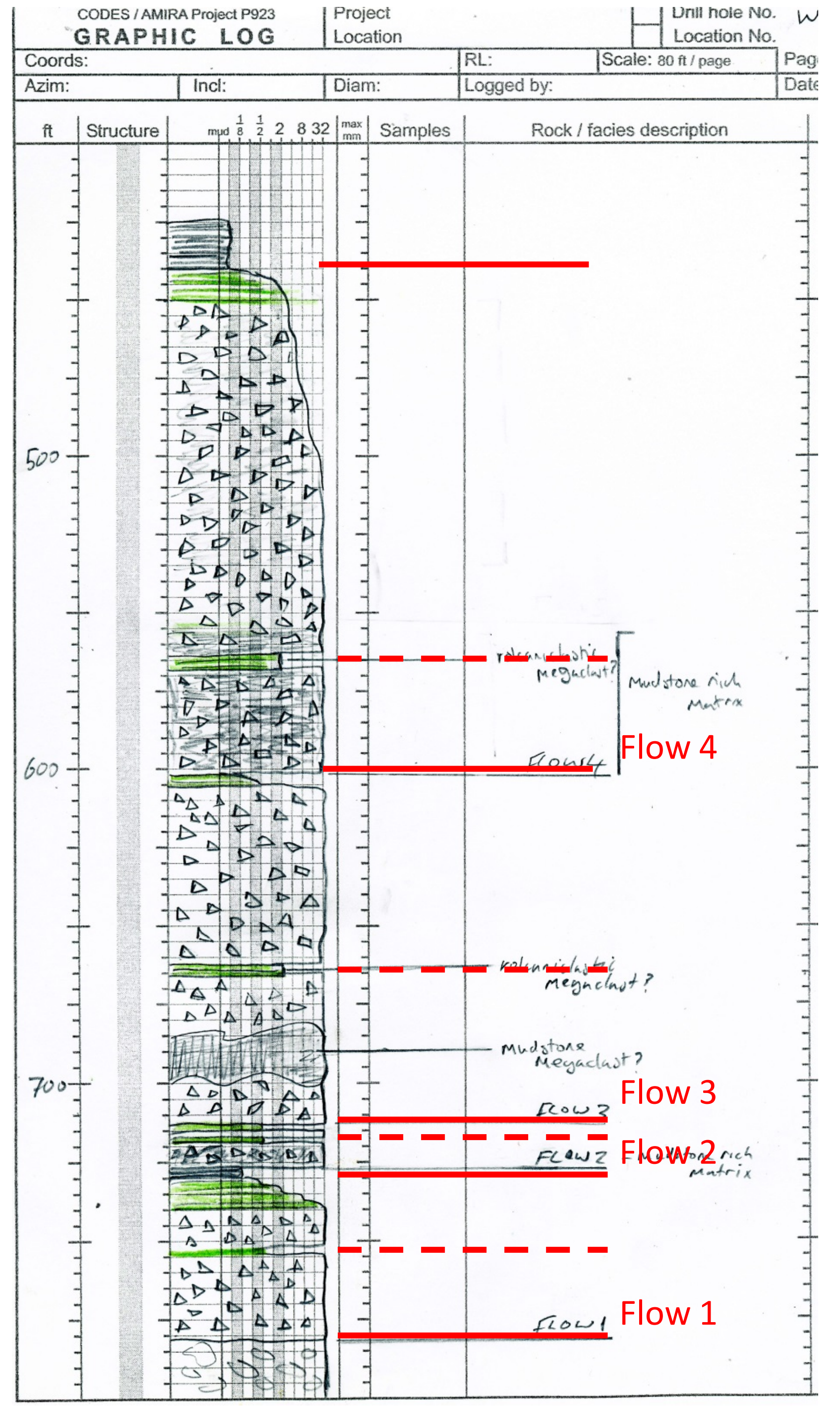
If they have different origins (scenario 1) then components of either the matrix (in addition to the interpreted greater proportion of mudstone) and/or the clasts should be different

If they have the same origin then they should be the same, although the proportions may differ

There are a number of ways that a comparison might be attempted:

Detailed characterisation of both the matrix and clast components could be documented by careful observation supported by petrography

The latter would also confirm that the dark areas are actually due to a mudstone-rich matrix, and determine whether they also have sulfides

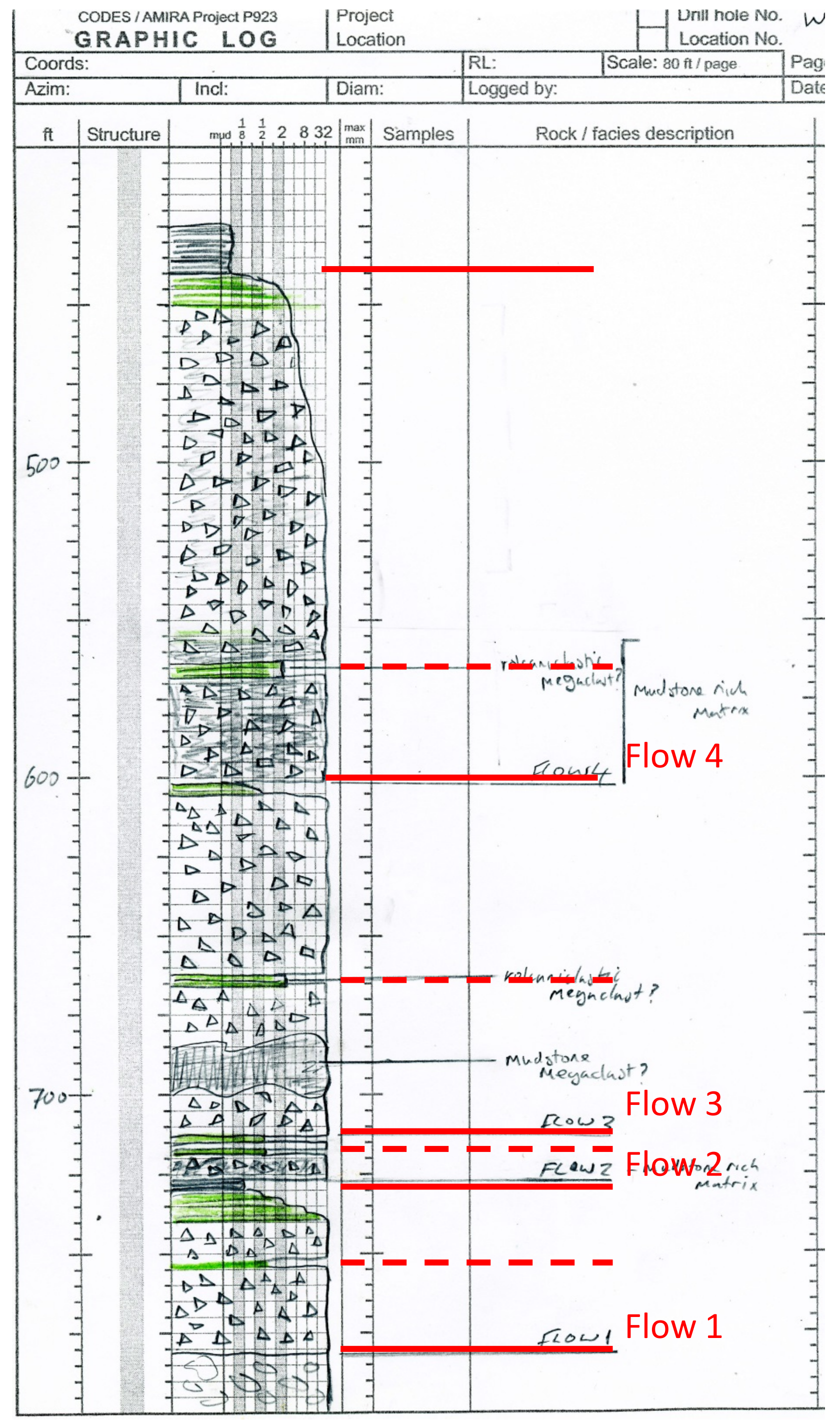


The different areas could also be compared in terms of their trace element geochemistry

There are a range of organophile elements (e.g. As, V, Mo, Ni etc.) which should be present in the dark, mudstone rich matrix zones, and their distribution may give some sense of whether these zones are distinct, or whether they grade into the adjacent ash-rich deposits

The distribution of organic carbon could form a similar function

Note that this characterisation study is already underway. Samples of each clast type from the mudstone matrix rich portion and the ash rich matrix portion (upper) of flow 4 have been collected for comparison including petrography and geochemistry, including REE



A comment on the capacity of the CODES LA-ICPMS U-Pb geochronological system to determine the age of the mineralised succession in the footwall of the Rosebery fault

I have not yet been able to obtain a copy of the imminent paper on refining the geochronology of the MRVs by Jim Mortensen et al

However on the basis of the dates I was sent by KD (Tyndall Group samples range from 496-497.3 Ma and > 499.3 Ma for rhyolite intrusives at the base of the White Spur Formation) and a discussion I had with Sebastien Meffre, it is clear that the CODES system will not help resolve the problem because our best dates involve a 1% error

In an attempt to provide an alternative method to tackling the problem, I have briefly reviewed the provenance and geochemical work done in AMIRA Project 921, which suggests that one avenue of potential, if it has not already been attempted, would be to use trace element ratios

Although standard ratios like Ti/Zr are too variable to be useful over the scale of the whole MRV belt, they have proved successful when applied locally.

In the example shown from AMIRA P921, Ti/Zr and Ti/Y ratios clearly discriminate between the Rosebery footwall and host successions

I was not able to find data on the WSF in the Rosebery hangingwall in the AMIRA reports, but I am sure plenty exists that could be used as a basis for comparison with the mineralised succession to the south of the fault if this has not already been attempted

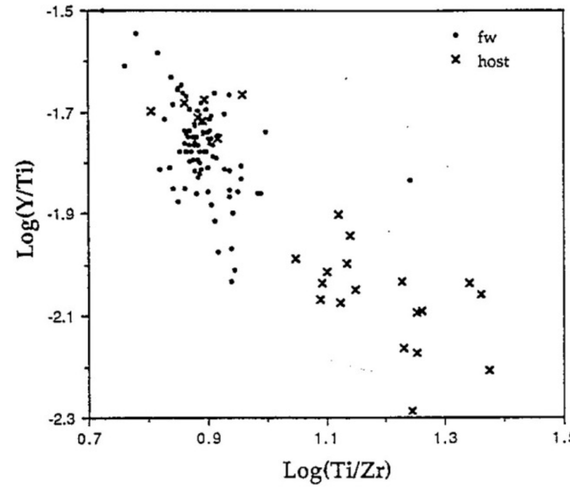


Fig. 12 Immobile trace element diagram. Footwall (dots) and host sequence (crosses) compositions from Rosebery. Data are from Naschwitz (1985).

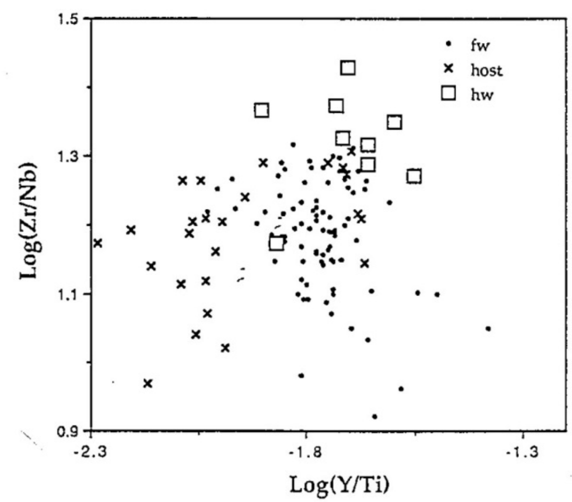


Fig. 13 Immobile trace element diagram. Footwall (dots), hanging wall (squares) and host sequence (crosses) compositions from Rosebery. Data are from Naschwitz (1985).