Preliminary Fluid Inclusion Micro-Thermometry Study of Quartz Veins from the Virginia Horn Greenstone Terrain
Report 2

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Prepared for: **Mineral Potential Section,**
Division of Lands and Minerals
Minnesota Department of Natural Resources

Attn: Dennis Martin, Manager

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Scope

This report provides the second set of preliminary results for fluid inclusion study being conducted as part of State of Minnesota, Department of Natural Resources' Virginia Horn Fluid Inclusion Project. Included in this report is microthermometric data, histograms showing variation of measured temperatures amongst the inclusions analyzed, bivariate plots. A final report for release in June will provide density/salinity calculations with pressure correction and comparison of this deposit with other Archean Au deposit s of the Superior Province.

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Disclaimer

Results are representative only of material submitted for examination. Data and interpretations provided in this report are only preliminary and have not been fully substantiated.

This report has been reviewed and authorized by Dr. Andrew Conly, LUMINX Director.

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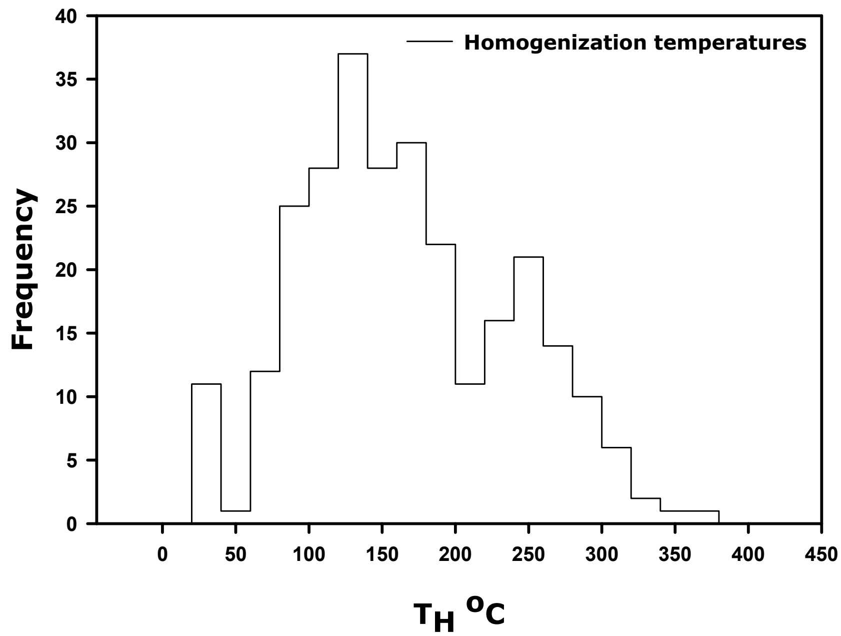


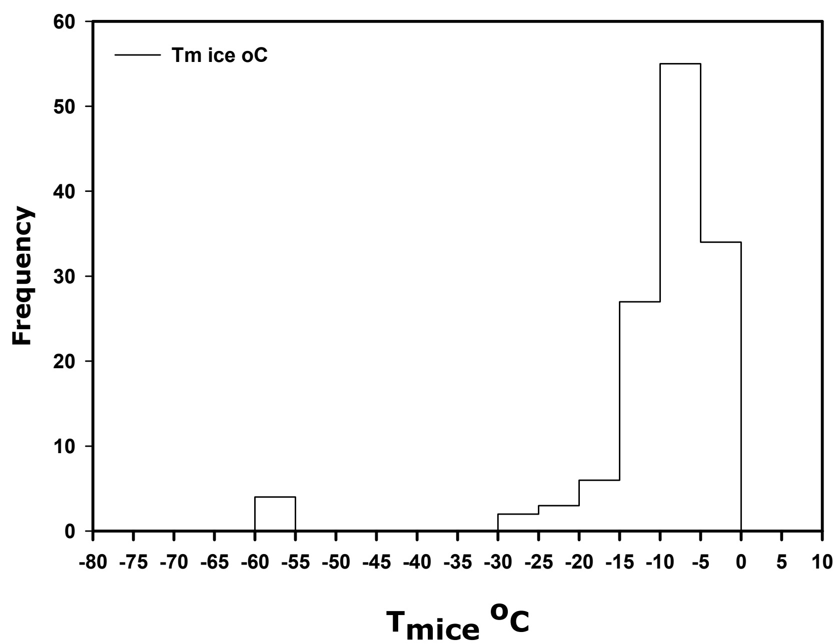
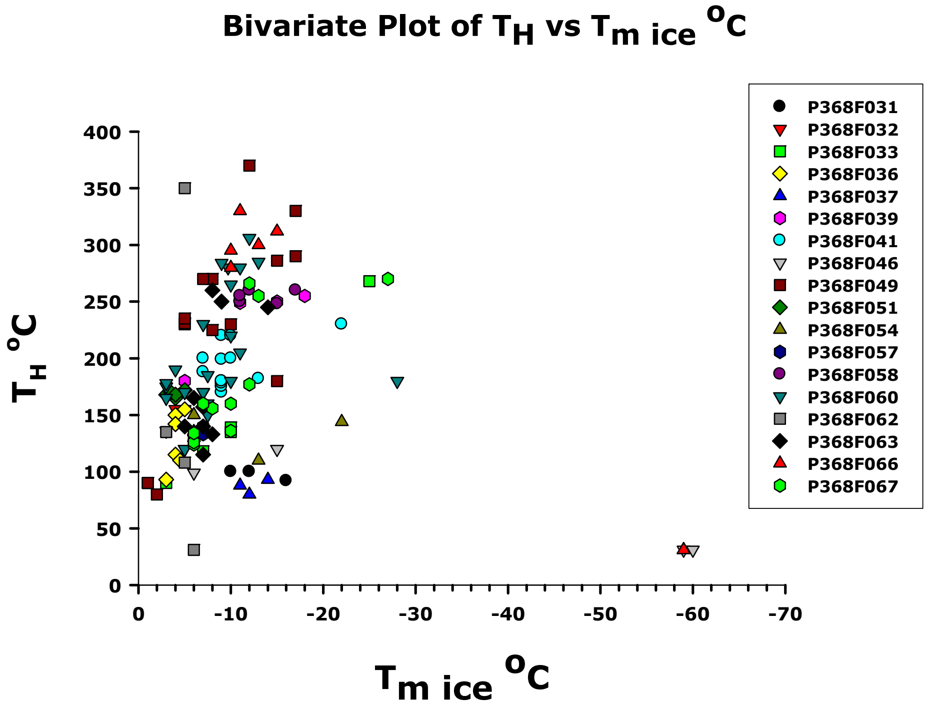


Figure 1. Frequency diagram showing the data for homogenization and melting temperatures of ice for provided samples. T_H °C varies from low to high temperatures with bulk of it around 150. Freezing temperature also show high numbers of low melting temperature corresponding to less CO_2 bearing and high CO_2 bearing FIAs.

A



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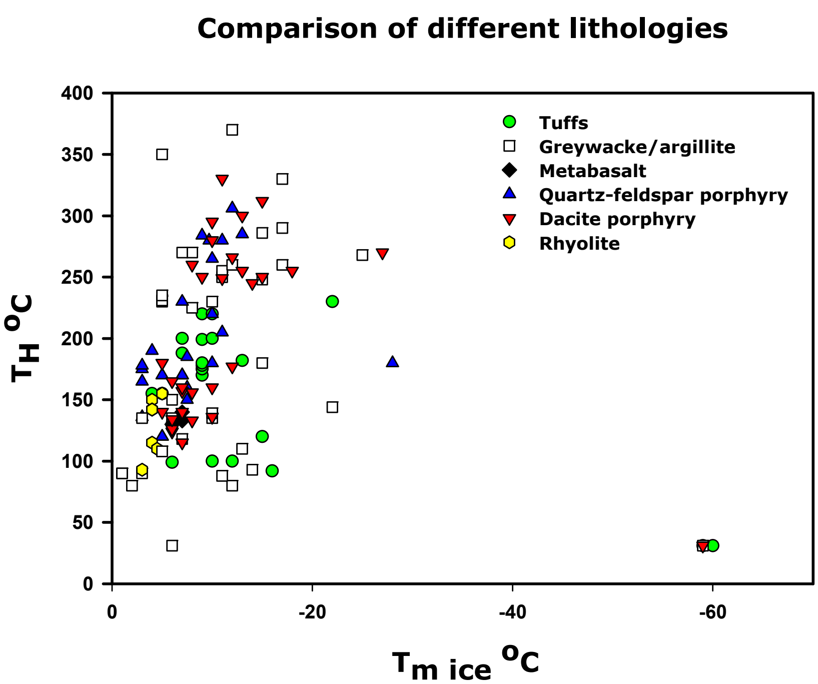

Figure 2. A. Bivariant plot illustrating the distribution of homogenization temperatures (T_H) and final melting temperatures of ice ($T_{m\ ice}$).

Figure 2. B. Bivariant plot displaying the same data as in Figure 2a, but differentiating among different lithological units (tuff, greywacke, metabasalt, quartz feldspar pophyry, dacite porphyry and rhyolite; as provided by Mineral Potential Section geological staff)

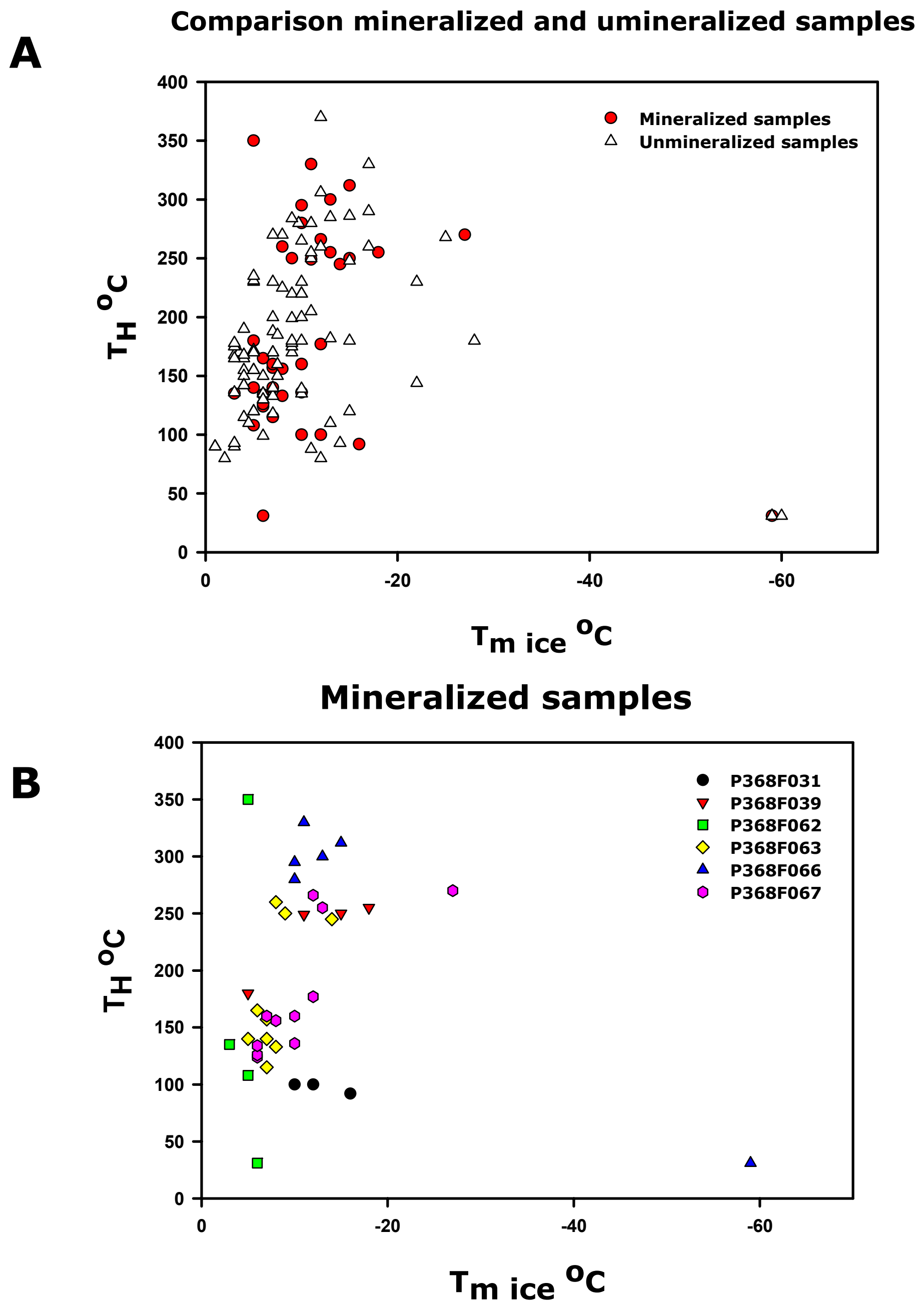

Figure 3. A. Bivariant plot showing the distribution pattern of T_H and $T_{m\ ice}$ among mineralized and unmineralized samples (based on recorded observations by Mineral Potential Section geological staff). Unmineralized samples are evenly distributed along an array of increasing T_H with decreasing $T_{m\ ice}$; whereas mineralized samples display a bimodal distribution, with clustering around 100-150°C and 250-300°C.

Figure 3. B. Bivariant plot showing the distribution pattern of T_H and $T_{m\ ice}$ in mineralized samples. Bimodal clusters are represented by samples of dacite porphyry (P368F039, 063, 066 and 067), whereas mineralized tuff/argillite (P368F031) and grey wacke (P368F062; except for one high T_H analysis) form a tight cluster at low T_H.

Lithology of fluid inclusion samples (provided by Mineral Potential Section geological staff)

P368FI029	Felsic tuff(?) and greywacke
P368FI031	Locally tuffaceous, arenitic graphitic argillite
P368FI032	Siliceous felsic tuff or fine-grained felsic intrusive
P368FI033	Locally graphitic argillite
P368FI036	Rhyodacite? Rhyolite?
P368FI037	Greywacke and tuff
P368FI039	Dacite (intrusion or bomb)
P368FI041	Felsic and intermediate tuffs
P368FI044	Felsic and intermediate lapilli tuff
P368FI046	Mixed schistose tuffs
P368FI048	Talcy, altered tuffs
P368FI049	Greywacke and minor argillite
P368FI051	Orange-reddish altered quartz feldspar porphyry
P368FI054	Greywacke
P368FI057	Metabasalt
P368FI059	Quartz feldspar porphyry
P368FI060	Quartz feldspar porphyry
P368FI061	Schistose to phyllitic slightly graphitic argillite
P368FI062	Siliceous (lithic, arenitic) greywacke
P368FI063	Pale yellow-green dacite porphyry
P368FI064	Pale green dacite porphyry
P368FI065	Pale green dacite porphyry
P368FI066	Pale green dacite porphyry
P368FI067	Pale green dacite porphyry

Current trends observed in FIAS of L-V inclusions:

1. Lithology

T_H varies from 100° to ~200°C in tuff samples

Greywacke displays a wide, continuous range in T_H and $T_{m\ ice}$ from ~50° to 350°C and 0° to -20°C, respectively.

Metabasic rock are very tightly clustered around a T_H of 150°C.

Quartz feldspar porphyry displays a wide, continuous range in T_H and $T_{m\ ice}$ from ~100° to 300°C and 0° to -20°C, respectively.

Dacite porphyry show bimodal pattern:

Cluster 1: High temperature—T_H between 250° and 350°C

Cluster 2: Low temperature—T_H between 100° and 175°C

Rhyolitic samples are tightly clustered between 100° and 150°C.

2. Mineralization

Only mineralized samples show bimodal distribution in terms of T_H, with dacite porphyry samples being the best example. Non-mineralized samples yield an even scattering of T_H that ranges from 80° to 340°C (excluding outliers).

3. CO_2-rich inclusions

These are characterized by low TH (<50°C) and extremely low Tm ice (-60°C). Only a limited number of CO_2-rich inclusions were found. Ignoring the sacristy of data for this inclusion type, CO_2-rich inclusions were measured in mineralized dacite porphyry (P368FI066) and a tuff (P368FI046).

Preliminary Interpretation

The bimodal distribution in TH of mineralized dacite porphyry is similar to the range in TH of inclusions from Williams Mine, Hemlo Au District (LUMINX, unpublished data). The bimodal distribution is suggestive of two fluids: 1) a possible magmatic fluid originating form the dacite porphyry intrusions; 2) a low-temperature meteoritic or metamorphic fluid. In this scenario the gold would originate from the dacite porphyries, be transported away from the intrusions in an exsolved aqueous magmatic fluid, and precipitate as a result of changes in pH and decreasing temperature resulting from mixing with heated meteoric/ metamorphic waters. Salinity data in the forthcoming June report will be useful in substantiating this model. For example, a high temperature and saline fluid is characteristic of magmatically derived aqueous fluids and would have the potential to carry significant quantities of Au; whereas low temperature meteoric/metamorphic fluids are characterized by low salinities.

To better assess if this model is correct, LUMINX proposes the following:

1. Place the existing fluid inclusion data into a geospatial context. It would interesting to see if the wide range in T_H for the grey wacke reflects distance from a dacite porphyry, where T_H would be expected to decrease with increasing distance.
2. Conduct a second round of sampling that is focused on mineralized veins and select a series of veins that occur at different distances from a dacite porphyry.
3. Conduct a preliminary round of oxygen isotope analyses (10-15 samples; approximately $100 per sample). For this it would be important to analyze both high and low temperature veins. Differences in $\delta^{18}O$ values would not only reflect temperatures differences but in conjunction with T_H data, the original $\delta^{18}O$ composition of the various fluids could be determined, which then can be used to constrain the origin of the fluids.

Data Set

The following pages contain the raw T_H, T_{eu} and T_m ice data.

Sample #		T_H	$T_{m\ ice}$	T_{eu}
P368FI029	Felsic tuff (?) and greywacke			
P368FI031	Locally tuffaceous, arenitic graphitic argillite	30		
		35		
		40		
		75		
		76		
		78		
		80		
		80		
		85		
		88		
		90		
		92	-16	-30
		98		
		138		
		100	-10	-30
		100	-12	-32
		100		
		100		
		110		
		150		
P368FI032	Siliceous felsic tuff or fine-grained felsic intrusive	122		
		125		
		130	-6	
		131		
		155	-5	-38
		155	-4	
		157		
		160		
		164		
P368FI033	Locally graphitic argillite	90	-3	
		118	-7	-17
		135	-10	
		139	-10	
		184		
		195		
		268	-25	-38
P368FI036	Rhyodacite or Rhyolite?	115	-4	-57
	small inclusions, isolated Fis,	93	-3	-50
	Many pyrite crystallization in quartz/calcite	110	-4.5	
	veins,	110		
		150	-4	-60
		144		
		142	-4	-59
		148		
		142	-4	
		158		
		155	-5	-58
		160		
P368FI037	Greywacke and tuff	31	-59	
		75		
		80	-12	-55
		85		
		88	-11	
		89		
		93	-14	

		93		
		97		
		100		
		200		
P368FI039	Dacite (intrusion or bomb)	177		
		180	-5	-45
		184		
		189		
		249	-11	
		250	-15	-37
		255	-18	
		257		
		260		
P368FI041	Felsic and intermediate tuffs	170	-9	
		175	-9	
		178	-9	
		178		
		180	-9	
		182	-13	-55
		188	-7	-50
		190		
		199	-9	
		200	-7	
		200	-10	
		205		
		210		
		220	-9	-55
		220	-10	
		220		
		230	-22	-55
P368FI044	Felsic and intermediate lapili tuff			
P368FI046	Mixed schistose tuffs	31	-59	
		31	-60	
		63		
		66		
		67		
		99	-6	
		100		
		120	-15	
P368FI048	Talcy, altered tuffs			
P368FI049	Greywacke and minor argillite	80	-2	120
		90	-1	-18
		90	-1	-18
		110		
		130		
		135		
		180	-15	
		200		
		210		
		216		
		225	-8	-28
		230		
		230		
		230		
		230	-5	
		230	-10	-30
		231	-5	
		235		

		235	-5	
		240		
		240		
		250		
		270	-8	
		270	-7	-40
		286	-15	-35
		290	-17	-52
		317		
		319		
		330	-17	
		370	-12	-50
			-18	
P368FI051	Orange-reddish altered quartz felspar porphyry	168	-3	
		165	-4	-22
		170	-3.5	-26
		172	-5	
		158		
		168	-4	
		170		
		78		
		68		
		70		
		80		
		75		
P368FI054	Greywacke	110	-13	-40
		110		
		130	-6	
		135	-6	
		135	-6	
		140		
		144		
		144	-22	-45
		145		
		150	-6	
		157		
		160		
P368FI057	Metabasalt	130	-6	-17
		125		
		123		
		133	-7	-55
		125		
		140	-7	-60
		143		
		128		
		144		
		90		
		105		
P368FI058	Metabasalt	97		
		98		
		99		
		100		
		105		
		109		
		110		
		128		
		130		
		130		
		133		
		135		

		136		
		248	-15	
		250	-11	
		250		
		252		
		255	-11	
		260	-12	-39
		260	-17	-40
		262		
P368FI059	Quartz feldspar porphyry	31		-59
P368FI060	Quartz feldspar porphyry	120	-5	-27
		120	-5	-29
		136	-3	-25
		150	-7.5	
		160	-7.5	
		165	-3	
		170	-7	
		170		
		170	-5	
		170	-7	
		175	-3	-30
		178	-3	
		180	-28	-64
		180	-10	
		180		-34
		185	-7.5	
		190		
		190	-4	-34
		205	-11	
		220	-10	
		230	-7	
		265	-10	-65
		280	-9.7	-65
		280	-11	-65
		284	-9	-30
		285	-13	
		306	-12	-64
P368FI061	Schistose to phyllitic slightly graphitic argillite			
P368FI062	Siliceous (lithic, arenitic) greywacke	31	-6	-60
		72		
		100		
		105		
		106		
		107		
		108	-5	
		110		
		110		
		135	-3	-59
		137		
		138		
		179		
		180		
		184		
		185		
		350	-5	-55
		31		
P368FI063	Pale yellow-green dacite porphyry	31		
		100		
		115	-7	

		133	-8	
		140	-7	
		140	-5	
		157	-7	
		165	-6	
		167		
		180		
		245	-14	-38
		250		
		250	-9	-55
		255		
		260		-40
		260	-8	-50
P368FI065	Pale green dacite porphyry			
P368FI065	Pale green dacite porphyry	250		
		254		
		260		
P368FI066	Pale green dacite porphyry	30		
		31	-59	
		255		
		279		
		280	-10	-45
		289		
		295	-10	-40
		295		
		300	-13	-49
		307		
		312	-15	-48
		330	-11	-38
P368FI067	Pale green dacite porphyry	124	-6	
		126	-6	
		134	-6	
		134		
		136	-10	
		145		
		156	-8	
		158		
		160	-10	-25
		160	-7	
		160		
		177	-12	
		180		
		200		
		200		
		220		
		240		
		255	-13	-35
		266	-12	-47
		270	-27	

not many inclusions, & very small to observe/measure
Low V-L ratio (Cluster); mostly CO_2
Low V-L ratio (Cluster)
Low V-L ratio (Cluster)
Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
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Low V-L Ratio (Isolated)
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Low V-L Ratio (Isolated)
Low V-L Ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
CO2 Rich, High V-R (Isolated)
CO2 Rich, High V-R (Isolated)
Intermediate V-L Ratio (Cluster)
Intermediate V-L Ratio (Cluster)
Intermediate V-L Ratio (Cluster)
Intermediate V-L Ratio (Cluster)
Intermediate V-L Ratio (Cluster)
Intermediate V-L Ratio (Cluster)
Intermediate V-L Ratio (Cluster)
Low-consistent V-L ratios (Cluster))
Low-consistent V-L ratios (Cluster)
Low-consistent V-L ratios (Cluster)
Low-consistent V-L ratios (Cluster)
Consistent-high V-L ratio (Isolated)
Consistent-high V-L ratio (Isolated)
Consistent-high V-L ratio (Isolated)
Consistent-high V-L ratio (Isolated)
Consistent-high V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
Large high V-L ratios with darker content (other gas speacies) not able to get T_h or T_{fm}
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)

High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
Low V-L raHigh V-L ratio (Isolated)

LowV-L ratio (Isolated)
LowV-L ratio (Isolated)
LowV-L ratio (Isolated)
LowV-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
V-L-S (not very larg, uncertain of daughter mineral)
Many low temperature secondary trail of V-L type FIA

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low V-L ratio (clusters)
low V-L ratio (clusters)
low V-L ratio (clusters)
low V-L ratio (Trail)
low V-L ratio (clusters)
low V-L ratio (Trail)
Low V-L ratio (Isolated)
low V-L ratio (Trail)
low V-L ratio (clusters)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
Low V-L ratio (Isolated)
low V-L ratio (clusters)
High V-L ratio (Isolated)
High V-L ratio (Isolated)

Many small clusters and trails

Low V-L-S ratio (Isolated)
Low V-L ratio (Isolated)
Low V-L-S ratio (Trail)
Low V-L-S ratio (Trail)
Low V-L-S ratio (Trail)
Low V-L-S ratio (Isolated)
Low V-L-S ratio (Isolated)
Low V-L-S ratio (Isolated)

Very small to measure and observe contents of each fluid inclusions

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L V-L (trail)
L V-L (trail)
L V-L (trail)
Low V-L ratio (trail)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Low V-L ratio (trail)
Intermediate V-L ratio (Isolated)
Intermediate V-L Ratio Cluster
Intermediate V-L Ratio Cluster
Intermediate V-L ratio (Isolated)
Intermediate V-L RatioCluster
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L Ratio Cluster
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L RatioCluster

Intermediate V-L Ratio Cluster
Intermediate V-L RatioCluster
Intermediate V-L RatioCluster
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L Ratio Cluster
High 2V-L ratio (Isolted)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (Isolated)
High L-S ratio

High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
Low V-L ratio (Isolated)
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Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
Low V-L ratio (Isolated)

Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
Low V-L ratio (Trail)
Low V-L ratio (Trail)
Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
Low V-L ratio (Isolated)
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Low V-L ratio (Isolated)
Low V-L ratio (Isolated)

High V-L ratios (Isolated)
High V-L ratios (Isolated)
High V-L ratios (Isolated)
High V-L ratios (Isolated)
Stretched
High V-L ratios (Isolated)
High V-L ratios (Isolated)
High V-L ratios (Isolated)
High V-L ratios (Isolated)
Low V-L (Trail)
Low V-L (Trail)

L-V ratio (cluster)
L-V ratio (cluster)
L-V ratio (cluster)
L-V ratio (cluster)
L-V ratio (cluster)
L-V ratio (cluster)
L-V ratio (cluster)
High V-L wt dark gas
High V-L wt dark gas
High V-L wt dark gas
High V-L wt dark gas
High V-L wt dark gas

High V-L wt dark gas
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V_L ratio (isolated)
High V-L ratio (isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)

FIA were very small to observe phase changes

High-IntermediateV-L (Trails)
High-IntermediateV-L (Trails)
High-Intermediate V-L (Clusters)
Intermediate V-L (Isolated)
Intermediate V-L (Isolated)
Low-intermediate V-L (Clusters)
Consistent V-L (Isolated)
Consistent V-L (Isolated) -decpt @ 280
Consistent V-L (Isolated)
Consistent V-L (Isolated)
intermediateV-L (Isolated)
Consistent V-L (Clusters)
AllV gone by 280C, casused stretching
Consistent V-L (Clusters)
Consistent V-L (Clusters)
V-L (Isolated)
V-L (Isolated)- decpt @ 280
V-L (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
Low-Intermediate V-L ratio (Isolated)
stretched

Too small to observe changes, dark bubble (CO_2?)

2 V-L ratio (ie. CO_2 inside water as Temperature changes)
Low V-L (Trail)
Low V-L (Cluster)
Low V-L (cluster)
Low V-L (cluster)
Low V-L (Cluster)
Intermediate V-L ratio (Isolated)
Intermediate V-L ratio (cluster)
High V-L ratio (Isolated)
High V-L (Isolated)
High V-L (Isolated)
high V-L (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
High V-L ratio (Isolated)
All L at room T

All L at room T
Consistent V-L ratio
Low V-L ratio Trail