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LEAD ISOTOPIC RATIOS, ICP AND XRF ANALYSES, AND FLUID INCLUSION DATA FROM THE KADY Zn-Pb-Cu-Ag VEIN-BRECCIA PROSPECT, NORTHERN BROOKS RANGE, ALASKA

by

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INTRODUCTION

This paper presents ICP, XRF, Pb isotopic ratio and fluid inclusion data from the Kady Zn-Pb-Cu-Ag vein-breccia and disseminated sulfide prospect, located in the southwestern part of the Killik River Quadrangle, in the north-central Brooks Range, Alaska. The Kady prospect is located within Gates of the Arctic National Park near the headwaters of a tributary to Outwash Creek, at a latitude of 68° 12' N and longitude 154° 58' W in T32N, R17E in the Kateel River Meridian.

The north-central and northwestern Brooks Range of Alaska hosts widespread Zn-Pb-Ag sedimentary exhalative massive sulfide (Sedex), vein-breccia, and disseminated sulfide deposits. The vein-breccia and disseminated sulfide occurrences are not spatially associated with igneous rocks, and are hosted by a deformed but only weakly metamorphosed package of Upper Devonian to Lower Mississippian mixed continental and marine clastic rocks (the Endicott Group). The Sedex deposits (e.g. Red Dog) are hosted by black siliceous carbonaceous shale and mudstone of the Mississippian to Pennsylvanian Kuna Formation. Most of the vein-breccia and disseminated sulfide occurrences are Carboniferous in age (Werdon and others, 1998), and along with the Sedex deposits, formed as part of a regional Carboniferous basinal dewatering event (Werdon, in review).

GEOCHEMICAL ANALYSES

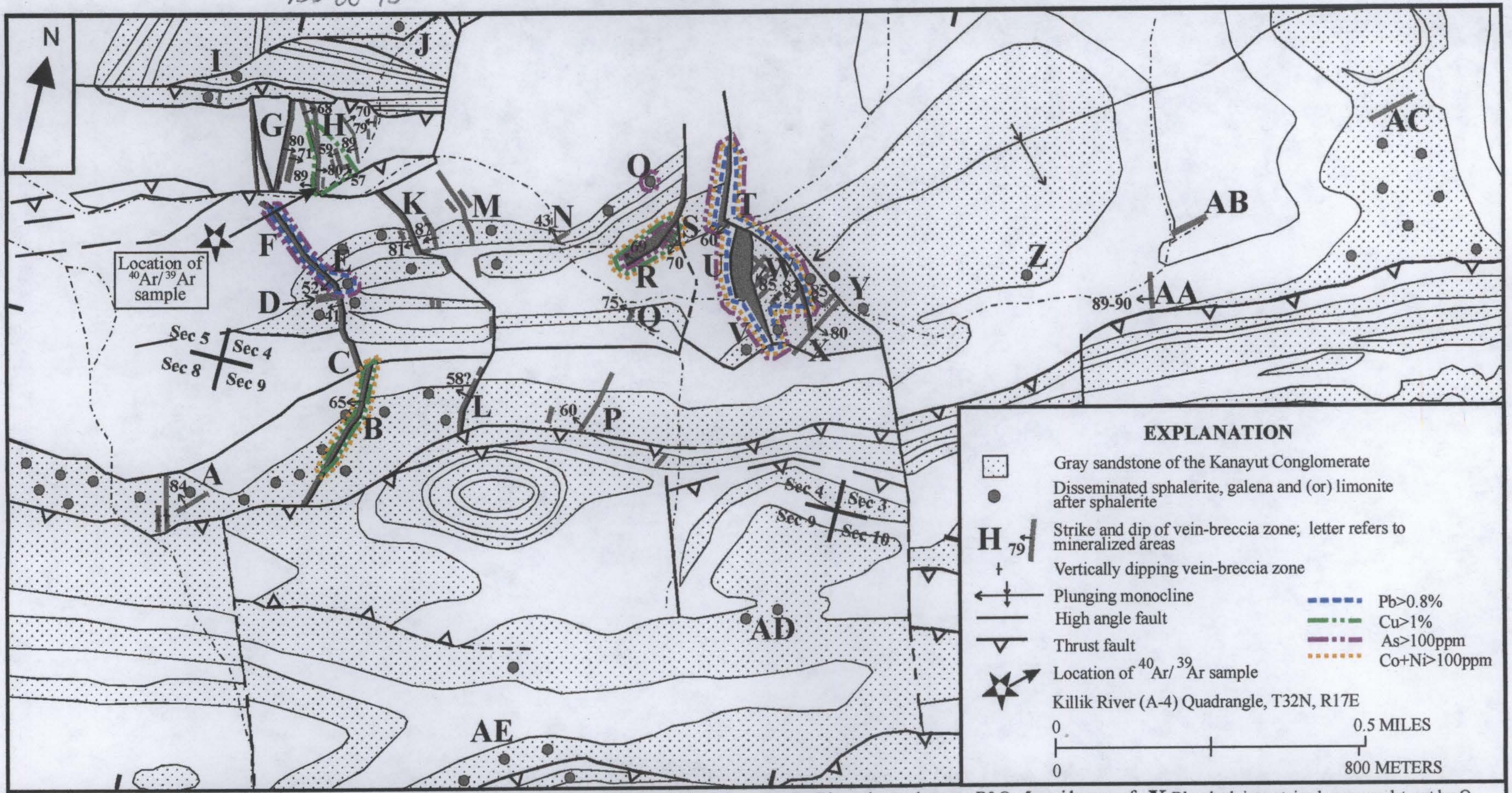
The distribution of sulfide mineralization at the Kady vein-breccia and disseminated sulfide prospect is shown in figure 1. Numerous Zn-Pb-Ag vein-breccia prospects, including Kady, were sampled in 1991 by the U.S. Bureau of Mines as part of their study of the Colville Mining District (Meyer and Kurtak, 1992). Mineralized hand samples were analyzed by Bondar Clegg by the ICP emission spectrometry and fire assay methods. In the U.S. Bureau of Mines data set, rocks from vein-breccia occurrences in the northern Brooks Range show detectable levels of Te, Bi, Mo, and W in ICP analyses (Meyer and Kurtak, 1992), elements that are not generally associated with sediment hosted sulfide deposits (Goodfellow and others, 1993). These element concentrations correlated unusually well with Zn, Cu, and (or) Pb (e.g. Zn-W; $R^2 = 0.999$), particularly in samples in which Zn, Pb, and Cu approached or exceeded Bondar Clegg's ICP saturation limits (2 percent Zn, 2 percent Cu, 1 percent Pb). The Zn interference on tungsten in ICP analyses is a common problem. For example, the W 207.911 spectral line is used for the determination of tungsten, however, if the concentration of Zn becomes too high, then the tungsten 224.875 spectral line is used to overcome interference problems (David Tye, written communication, 1998). This interference was not corrected for in the Meyer and Kurtak (1992) database (David Tye, personal comm., 1993). XRF analyses of several pulps from the Meyer and Kurtak (1992) data set suggest Bi is not present in significant quantities, and that Mo is present at low concentration levels. The very high level of Bi and Mo in Kady sample 5455 is interpreted to reflect an interference problem in the XRF analyses between Pb and Bi and Mo, since the sample contains about 60 percent Pb (table 1). It appears that interference in spectral lines caused false concentrations for Bi, Mo, and W values. It is unlikely that elevated Te concentrations are present within the vein-breccia occurrences, but this hypothesis was not tested with XRF or other methods.

Relatively high levels of Sn, As and Au were also reported in ICP analyses (Meyer and Kurtak, 1992; Kelley et al., 1997), and in emission spectrographic data (Duttweiler, 1987; Kelley et al., 1997); and Sn was reported in XRF analyses (table 1). At Kady, high Sn values occur within veins with high Zn ICP analyses, and there is a weak correlation between the elements. No Sn, Au or As bearing minerals were observed in polished thin sections.

Table 2 contains the U.S. Bureau of Mines geochemical data set (Meyer and Kurtak, 1992) for the Kady deposit. Their data set is keyed to map locations (Werdon, in press) to provide a record of where the samples were taken.

155°00'45"

68°11'39"



A	1m wide Sp-dominant vein with lesser Q, Cp & Gl. Numerous <2 cm Q veins over 150m area. Bleached gray sandst. w/ tr dissem. Sp & Gl.
B	25m wide zone of Q+Cp+Py bx w/ peripheral veinlets (<2cm) of Q+Gl+Cal; Bleached, gray sandst. w/ iron-staining, tr dissem. Sp & Gl.
C	Sandst. bx, cemented & cut by Q+Sp+tr Gl, cut by late Cal veins. 5m wide gossanous area of massive zinc-carbonate.
D	10m by 40m zone of bx oriented parallel to axis of antiform. General paragenesis: sandst. breccia to chalced. Q to blk. Sp to chalced. Q to yell. Sp to Q.
E	30m wide zone of numerous Q veins (<6cm wide) +/-Sp+/-Gl. Some brecciation of sandst. Minor black shale in sheared area.
F	25m wide area of brecciated, quartz veined sandstone with minor Sp & Gl.
G	65m wide zone w/ barren Q veins +/- late Cal. Largest Q vein 1.7m wide, numerous smaller Q veins to 25cm. Large Q vein slightly folded.
H	Numerous Q veins w/ Cp+Sp+tr Gl+/-late Cal (up to 25cm wide). Carbonate cement removal halos, & bleaching near veins. Secondary Azur. & Mal.
IJ	Bleached, iron-stained, gray sandst. Very porous, likely contains disseminated Sp or Gl. Cut by a few minor Q veins (<2cm wide) w/ tr Sp.
KL	Discontinuous vein-breccia zone up to 10m wide. Q w/ lesser Sp & Gl, mostly in sandst., minor amt. in shale. Minor Q-Cal veins at L.
M	Bleached, iron-stained, porous, gray sandst. which likely contains disseminated Sp or Gl. Cut by Q veins (<2cm wide) w/ tr Sp. Zone width varies.
NO	Bleached, iron-stained, gray sandst. w/ dissem. Sp and Gl. Cut by several Q veins (<2cm wide) w/ tr Sp+Gl.
PQ	Discontinuous between P&Q. 5m wide zone of parallel Q veins to 7.5cm at point Q. Q-veining, bleaching & iron-staining of gray sandst. at P.
R	3.8-10m wide, complex vein-breccia zone. Clasts of sandst., shale & sulfides. Barren Q veining to north. Q, Sp & Cp dominant, minor Gl, Py & Cal.
S	30m zone of stockwork Q veins +/- Cal. Fault at base of outcrop contains an inversely-graded breccia w/ clasts of sandst. cemented by Q + tr Py.
T	1.5m wide breccia zone. Sandst. clasts to 75cm & 2 clasts of Sp+Q, cemented by Q+tr Sp+late Cal. 5-15cm wide Sp vein along breccia zone footwall.
UV	30-37m wide major fault zone. Sandst. blocks to 20m. Dominantly Q veining w/ variable Sp & Gl, and trace Cp. Zone narrows towards V.
W	120m by 60m area cut by numerous sub-parallel veins of Q+Sp+/-Gl+/-Cp+/-Py. Width varies between 2mm & 50cm. 1 barren sandst. bx w/ Q.
X	Bleached, iron-stained, gray sandst. cut by Q veins w/ Sp+ minor Cp, Gl & Cal. Trends over towards Y. Zone is approximately 10m wide.
YZ	Bleached, iron-stained, gray sandst. Porous, likely contains disseminated Sp or Gl. Sandst. partially cemented by zinc carbonate.
AA	1m wide zone of thin (<3cm) parallel Q veins. Paragenesis from Q to tr Gl+dark Sp+tr Py+Cp(?) to light Sp.
AB	50m by 10m breccia zone of sandst. clasts w/ Q cement. Intergrown Q & light to medium orange Sp w/ net texture in 5m by 2m area.
AC	Bleached, porous, iron-stained, gray sandst. w/ trace disseminated Sp(?). 10m by 1m zone of thin Q veins w/ minor Sp+Gl.
AD -AE	Bleached, porous, iron-stained, gray sandst. w/ dissem. Gl & tr Sp (up to 2%, average < 0.1%).

Figure 1. Mineralization map of the Kady prospect (Werdon, in press). Letters refer to the location of mineralized vein-breccia or disseminated sulfide zones.

Table 1. ICP, XRF, and fire assay (F.A.) analyses of mineralized hand samples from Zn-Pb-Ag occurrences in the northern Brooks Range, AK.

Element:		Cu	Pb	Zn	**Mo**	Mo	**Bi**	Bi	**Sb**	Sb	Te	**Sn**	Sn	Au
Detection Limit:		1 ppm-2%	2 ppm-1%	1 ppm-2%	ppm	1 ppm	ppm	5-2000 ppm	ppm	5-2000 ppm	25ppm-0.2%	ppm	20ppm-0.2%	1 ppb
Analytical method:		ICP	ICP	ICP	**XRF**	ICP	**XRF**	ICP	**XRF**	ICP	ICP	**XRF**	ICP	F.A.
Prospect name:	Sample #:													
W. Kivliktort Mountain	5601	30	4949	100000	**8**	183	**0**	155	**421**	103	0	**45**	88	13
Kady	5455	2798	597600	7799	**58**	0	**8580**	34	**3111**	2000	55	**143**	0	133
Kady	4183	109100	160	53	**5**	0	**0**	0	**0**	0	0	**95**	88	15
StoryCk.	5432	359	8765	100000	**14**	311	**0**	247	**1759**	621	413	**84**	165	86
Husky	H-55.3'	84	1006	16294	**16**	15	**0**	16	**114**	35	13	**11**	23	
Husky	H-CROCK	268	16700	164700	**8**	2	**0**	7	**545**	118	0	**34**	24	
Husky	H-CSPHL	553	10000	465300	**19**	2	**0**	12	**1628**	224	0	**164**	73	
Husky	H-139B	1400	9979	2503	**18**	17	**0**	28	**1384**	858	33	**21**	33	
Husky	H-56.0'	1103	7122	103000	**19**	14	**0**	6	**466**	178	0	**5**	0	
Husky	H-LJ2	1406	3436	49000	**16**	13	**0**	0	**304**	140	0	**40**	21	
Husky	H-26.8'	292	263000	241100		6		6		2000	0		28	

Notes:

1 - All ICP and fire assay (F.A.) analyses were determined by Bondar Clegg.

2 - The west Kivliktort Mountain, Kady, and Story Creek ICP and F.A. data are from Meyer and Kurtak, 1992.

3 - The Husky ICP data were determined as part of this study.

4 - XRF analyses of standard pressed pellets were determined by Dr. R.J. Newberry using the University of Alaska Fairbanks wavelength-dispersive XRF machine. The procedures of Norrish and Hutton (1969) were followed, including the use of well-characterized natural rock standards.

Table 2. Geochemical data for the Kady vein-breccia prospect. Data are from Meyer and Kurtak, 1992. Analyses are from individual, select, visibly mineralized rock samples. Vein names refer to locations in figure 1.

Vein name	Sample #	Ag LDL[1]0.5	Cu 1	Pb 2	Zn 1	Sn[2] 20	Ni 1	Co 1	Cd 2	As 5	Sb[2] 5	Fe (%) 0.05	Au 1 ppb
AC	**4176**	<0.5	52	1561	297	0	5	0	0	<5	<5	0.47	6
B	**4183**	>100	109100	160	53	88	148	18	0	61	0	9.84	15
B	**5457**	26.1	14560	2372	127	36	64	39	0	43	19	2.73	18
E	**4181**	5.0	5342	923	5457	0	9	6	31	70	0	1.03	12
E	**4182**	>100	240	89900	9337	0	21	5	54	91	105	0.37	29
E	**5563**	7.9	163	17100	14400	21	15	14	114	574	63	0.72	32
E	**5564**	2.2	172	172	97500	48	15	35	675	142	48	2.59	26
F	**4210**	5.8	2266	1840	47300	0	19	15	235	100	41	1.17	43
F	**5604**	16.5	108	18300	7559	0	8	4	31	20	10	0.68	13
H	**4222**	7.1	26900	545	3881	0	35	22	19	64	19	3.25	12
H	**4223**	1.5	14459	132	280	0	28	16	3	76	0	0.67	19
H	**5603**	4.9	17280	525	2310	21	15	9	11	15	0	2.38	17
O	**4140**	0.9	40	1585	125	0	7	2	0	104	0	0.40	5
Q	**4174**	6.2	431	2902	55000	48	11	16	296	96	27	0.89	32
R	**4155**	5.5	5260	6333	56900	44	90	69	517	186	37	2.38	64
R	**4171**	1.7	3589	43	19935	0	45	19	184	94	9	0.93	16
R	**4172**	8.2	12213	3281	108900	83	202	95	1167	110	54	2.60	31
R	**4173**	5.7	36400	303	220100	140	113	115	>2000	176	58	6.08	13
R	**5556**	11.4	16585	965	109500	82	15	37	1107	87	59	2.25	82
R	**5557**	1.1	719	156	11742	0	14	11	78	19	13	0.61	8
R	**5558**	3.0	2454	104	51200	0	20	20	450	131	32	1.20	15
R	**5562**	6.3	5419	997	151400	89	251	230	1784	151	85	1.91	27
S	**5559**	1.1	1559	135	104700	62	70	50	837	161	30	1.33	22
T	**4074**	3.6	3454	731	12461	0	19	5	106	44	9	0.82	9
T	**4075**	5.1	844	207	357900	81	20	87	>2000	242	89	1.14	31
T	**4076**	0.9	688	154	238800	84	32	63	1808	269	57	0.87	11
T	**5560**	16.0	397	18000	357600	0	73	130	>2000	226	105	1.13	63
T	**5561**	2.8	264	154	12630	0	13	6	112	72	16	0.53	10
U	**4071**	>100	387	2900	229800	0	10	55	880	131	199	1.06	58
U	**4072**	>100	354	235600	234600	63	19	32	1140	116	173	0.55	59
U	**4073**	12.6	5428	864	124500	56	38	61	1067	120	67	1.58	30
U	**5443**	>100	332	532000	729	24	211	40	7	334	961	0.23	100
U	**5444**	8.2	1746	1626	22200	96	5	11	207	50	43	1.36	47
U	**5445**	12.9	330	5765	482100	30	0	166	>2000	157	132	1.91	73
U	**5446**	11.5	470	8503	28600	55	2	16	135	70	32	1.65	115
U	**5447**	15.1	259	19600	125200	77	3	44	975	144	75	2.03	29
U	**5456**	4.7	497	9100	12924	0	19	10	154	28	25	0.69	4
V	**5454**	>100	2905	107500	8054	0	23	10	49	69	350	0.79	31
V	**5455**	>100	2798	597600	7799	0	143	22	46	102	>2000	0.33	133
W	**5448**	8.3	563	8600	271700	56	23	88	>2000	125	101	1.13	25
W	**5449**	17.2	558	560	77900	0	3	30	702	89	112	1.59	16
W	**5451**	3.6	3594	148	6952	0	5	10	58	47	9	1.20	4
W	**5452**	0.9	513	243	4708	0	0	4	29	39	0	0.60	2
W	**5453**	4.9	131	4580	5047	0	0	6	35	43	0	0.58	48
X	**5450**	1.7	339	559	4472	0	0	3	26	0	0	0.63	19

1 LDL - lower detection limit; all elements in ppm except as noted. 2 semi-quantitative. All elements analyzed by Bondar Clegg by ICP except gold (fire assay).

LEAD ISOTOPES

Table 3. Lead isotopic ratios for galena from the Kady prospect. Vein names refer to locations in figure 1.

Vein Name	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Sample Description	Reference
-----	18.404	15.605	38.315	galena	1
-----	18.382	15.588	38.228	galena	1
R	18.381	15.628	38.361	galena from a quartz + sphalerite + chalcopyrite + pyrite + minor galena sulfide breccia within a complex vein-breccia zone	2
V	18.369	15.594	38.271	galena from a deformed and brecciated quartz + galena vein	2
B	18.414	15.656	38.465	galena from a quartz + galena + calcite vein peripheral to the main quartz + chalcopyrite + minor pyrite vein-breccia zone	2
U	18.331	15.559	38.143	galena from center of a growth-zoned quartz vein with paragenetically late galena	2
AE	18.369	15.583	38.220	galena disseminated in gray, bleached, iron-stained, porous sandstone	2

1 Gaccetta and Church (1989); 2 Galena for this study was analyzed by Dr. R. W. Hurst, Chempet Research Corporation. Errors in lead isotope ratios are < 0.1% at the 95% standard error of the mean confidence interval. Isotope ratios are corrected for a 0.1% per atomic mass unit fractionation relative to NBS SRM 981.

FLUID INCLUSIONS

Fluid inclusion data for Kady were obtained from the Fluid Inc.® fluid inclusion heating-freezing stage at the U. S. Geological Survey in Anchorage, Alaska. The system was calibrated daily with a pure water standard (0° C freezing temperature) and a pure CO_2 standard (-56.6° C freezing temperature). The iterative calibration process was repeated until 5 consistent measurements were obtained at the one decimal-place level on both standards. Equivalent weight percent NaCl values were calculated from measured freezing temperatures using the least squares equation of Potter and others (1978).

The fluid inclusions range from sub-microscopic to 13 microns in diameter, with the former composing the greater proportion of the fluid inclusion population. The average size of fluid inclusions measured was 3-8 microns. Fluid inclusions less than 3 microns in diameter could not be optically resolved during heating and freezing measurements. Fluid inclusions were classified into three types: primary, pseudo-secondary and secondary using the criteria of Roedder (1976, 1979). Primary fluid inclusions in distinct growth zones within quartz were trapped during quartz deposition. Pseudo-secondary fluid inclusions occur in planes which internally cross-cut, and terminate within the quartz crystal at a growth zone. This indicates the quartz was fractured, the fluid was trapped in the inclusion, and then additional quartz was deposited. Secondary fluid inclusions along fracture planes which completely cross-cut quartz crystals are post-quartz deposition.

All fluid inclusion measurements were obtained from quartz in sulfide-bearing quartz veins (table 4). Fluid inclusions larger than 3 microns were not present in sphalerite or in quartz from breccia textured ore. Therefore the fluid inclusion measurements represent only salinities and temperatures of vein quartz, which may or may not be similar to values for quartz in breccia textured mineralization, or for sphalerite. All primary, pseudo-secondary and secondary fluid inclusions are two-phase, liquid-vapor inclusions with relatively uniform degrees of fill (L~80-90%, V~10-20%). No hydrocarbons, CO_2, or daughter minerals were observed. All fluid inclusions homogenized to a liquid during heating, and there is no evidence to suggest boiling.

The fluid which deposited vein quartz has low salinity (≤6.0 equiv. wt. % NaCl) and low temperature (≤145° C) values. The homogenization temperature of fluid inclusions represents a minimum temperature for quartz deposition since independent pressure correction evidence is not available.

Table 4. Fluid inclusion measurements from vein quartz, which is spatially associated with sphalerite, galena, and chalcopyrite at the Kady prospect. Vein names refer to locations in figure 1.

Vein name and description	Inclusion type[1]	Inclusion size (μ)	Temp. (C°)[2] of melting	Equiv. wt. % NaCl[2]	Homogenization temp. (C°)[2]
H - growth-zoned quartz deposited paragenetically between early chalcopyrite and late galena	P?	3x4	NA	NA	>100[3]
W - vein quartz intergrown with sphalerite	S	3x8	-1.3	2.2	105
	P(GZ)/PS?	5x7	-2.2	3.7	138
	S	3x4	NA	NA	99
	P(GZ)?	3x3	NA	NA	102
U - quartz intergrown with early chalcopyrite, pyrite, bravoite, and galena	P	5x10	-3.5	5.8	NA
	P(GZ)	9x13	-2.3	3.9	125
	P(GZ)	5x9	-3.7	6.0	118
	P(GZ)?	3x5	-3.5	5.7	129
	P(GZ)?	9x12	-3.0	5.0	132
	S	3x5	-2.1	3.5	>99[3]
	S?	4x8	-1.5	2.5	>99[3]
	S	8x13	-1.8	3.1	107
	S	6x8	-1.7	2.9	NA
	P?	3x6	-2.8	4.6	138-143
	P(GZ)	2x5	-3.7	6.0	NA
	P(GZ)	4x12	-3.2	5.2	118
	P(GZ)	3x3	-3.1	5.1	NA
	P(GZ)	2x2	-3.3	5.4	>100[3]

1 Primary (P), primary inclusion within growth zone P(GZ), pseudo-secondary (PS), and secondary (S).

2 Freezing temperature, equivalent weight % NaCl, and homogenization temperatures based on the average of 3-7 measurements on a single inclusion. NA - not available.

3 Minimum temperature; visibility obscured above this temperature (not yet homogenized).

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