Table 1. Summary of quartz phenocryst $\delta^{18}O$ data, productivity data, metamorphic grade and tectonic setting of volcanic-hosted massive sulfide districts.

District	Total resource (Mt) Massive sulphide	Cu	Zn	Base metal	Median $\delta^{18}O$ (‰)[1]	Metamorphic grade	Tectonic setting	Unit	Age	Quartz phenocryst data Range in $\delta^{18}O$ (‰)	n	Data sources
Kidd Creek, Ontario	132	3.62	8.65	12.72	11.2	Upper greenschist	Not established	Quartz-porphyry	Archean	11.2-11.7	4	1
								Mine rhyolite		10.8	1	
								Mine rhyolite (silicified)		12.3	1	
								Cherty breccia (quartz-chlorite altered)		9.0-11.0	2	
Noranda, Quebec	270	2.60	3.25	5.85	9.6	Lower Greenschist	Back-arc basin associated with island arc	Waite Rhyolite	Archean	8.7-10.8	7	2, 3, 4, 5, 6, 7
								Waite Rhyolite (silicified)		9.6-11.7	6	
								Waite Rhyolite (quartz-epidote altered)		9.8-10.0	2	
								Waite Rhyolite (carbonate altered)		9.7-11.0	3	
								Horne mine rhyolite		9.5	1	
Matagami, Quebec	38.6	0.33	3.11	3.43	10.9	Upper greenschist to lower amphibolite	Not established	Key Tuff	Archean	10.9	1	1, 8
Jerome, Arizona	80.5	1.80	0.66	2.46	8.6	Greenschist	Intra-oceanic island arc	Upper Cleopatra Rhyolite (silicified)	Proterozoic	9.9	1	9,10, 11, 12
								Lower Cleopatra Rhyolite		8.4-8.7	2	
								Lower Cleopatra Rhyolite (silicified)		9.5	1	
Mt Windsor, Queensland	13.6	0.34	1.25	1.94	9.5	Sub-greenschist to upper greenschist	Back-arc basin related to island-arc or continental margin-arc	Trooper Creek Formation	Cambro-Ordovician	7.6	1	1, 13
								Trooper Creek Formation (silicified)		13.7	1	
								Mt Windsor Formation		8.3-11.7	5	
								Mt Windsor Formation (silicified)		11.3-11.9	2	
Bathurst, New Brunswick	264	1.11	18.03	26.35	12.1	Upper greenschist	Ensialic rift	Nepisigut Falls Formation	Ordovician	11.9-12.2	4	14, 15, 16
West Shasta, California	27.5	0.32	0.24	0.56	8.2	Lower greenschist	Back-arc basin associated with island arc	Upper Balaklala Rhyolite	Devonian	7.6	1	17, 18, 19, 20, 21
								Upper Balaklala Rhyolite (silicified)	Devonian	10.0-10.3	2	
								Middle Balaklala Rhyolte	Devonian	7.2-10.0	14	
								Lower Balaklala Rhyolite	Devonian	7.0-9.7	8	
								Mule Mountain Trondhjemite	Devonian	7.5-8.5	2	
Iberian Pyrite Belt, Spain	825	8.13	24.52	41.42	10.5	Lower greenschist	Ensialic rift	Volcanic-Sedimentary Complex	Carboniferous	10.0-11.8	7	22, 23, 24, 25, 26
								Volcanic-Sedimentary Complex (silicified)		11.4	1	
Buttle Lake, British Columbia	29.0	0.57	1.85	2.58	9.3	Lower greenschist	Not established	Massive quartz-feldspar porphyry	Devonian	7.9-9.6	4	1, 27
								Massive quartz-feldspar porphyry (silicified)		7.8	1	
								Massive quartz-feldspar porphyry (sericitized)		7.2-7.5	2	
Hokuroko, Japan	95.1	1.96	4.33	7.41	7.6	Sub-greenschist	Rifted volcanic arc	D_2 dacite intrusions	Tertiary	7.6-8.6	2	28, 29, 30
								Ohtaki quartz diorite		6.8	1	

[1]Median value of quartz phenocrysts from unaltered/least altered samples.

Sources of data: 1—this study; 2—Paradis (1990); 3—Paradis et al. (1993); 4—MacLean and Hoy (1991); 5—Kerr and Gibson (1993); 6—Larocque et al. (1993); 7—Ujike and Goodwin (1987); 8—Lacroix et al. (1990); 9—Gustin (1988); 10—Armstrong and Handverger (1986); 11—P. Handverger (pers. comm., 1995); 12—Anderson (1986); 13—Berry et al. (1992); 14—Lentz and Goodfellow (1993); 15—McCutcheon (1992); 16—van Staal (1987); 17—Casey and Taylor (1982); 18—Taylor and South (1985); 19—Kinkel et al. (1956); 20—Albers (1985); 21—Lapierre et al. (1985); 22—Munha et al. (1980); 23—Barriga and Kerrich (1984); 24—Barriga and Carvalho (1983); 25—Richards and Sides (1991); 26—Munha (1979); 27—Pearson (1993); 28—Green et al. (1983); 29—Tanimura et al. (1983); and 30—Ohmoto (1983).

Table 2. Quartz phenocryst and whole rock $\delta^{18}O$ data for felsic volcanic and shallow intrusive rocks from VHMS districts. Data is taken from this study and the literature.

District	Unit	Sample	Description	Whole rock $\delta^{18}O$(‰)	Phenocryst $\delta^{18}O$ (‰)	Volatile-free SiO_2 (%)	Comment	Data sources
Kidd Creek, Ontario, Canada	Diorite	KC464B	Quartz-phyric diorite.	8.9	11.5	53.2	Intrusive	1
	Quartz porphyry	KC179C	Quartz-feldspar phyric rhyolitic tuff.	11.3	11.7	74.4		1
	Quartz porphyry	KC489A	Quartz-phyric lapilli tuff.	12.0	11.2	72.7		1
	Quartz porphyry	KC515B	Quartz-phyric rhyolite.	10.9	11.2			1
	Quartz porphyry	BC92-135	Weakly sericitized, quartz-phyric rhyolite.	11.9	11.2			1
	Mine Rhyolite	KC375	Black, tuffaceous rhyolite.	11.2	10.8	78.4		1
	Mine Rhyolite	KC406D	Black, massive shyolite.	13.8	12.3	81.9	Silicified	1
	Cherty breccia	2500-1	Cherty breccia with quartz eyes.	11.2	11.0		Silicified	1
	Cherty breccia	2500-4	Cherty breccia with quartz eyes.	10.0	9.0		Silicified	1
Noranda, Quebec, Canada	Waite Rhyolite, Unit 6	384-86	Slightly altered lobe quartz-feldspar porphyry.	11.5	9.1	78.1	Silicified	2
	Waite Rhyolite,Unit 6	385-86	Carbonated quartz porphyry.		9.7	71.7	Carbonated	2
	Waite Rhyolite, Unit 6	593-86	Epidotized, flow-breacciated quartz-feldspar porphyry.	11.6	9.8	76.3	Epidotized	2
	Waite Rhyolite, Unit 6	620-86	Moderately epidotized, flow-breacciated quartz-feldspar porphyry.		10.0	77.7	Epidotized	2
	Waite Rhyolite, Unit 6	618-86	Silicified, flow-breacciated quartz-feldspar porphyry.		11.2	72.0	Silicified	2
	Waite Rhyolite, Unit 6	626-86	Moderately silicified and sericitized, flow-brecciated quartz-feldspar porphyry.	9.9	9.6	74.4	Silicified	2
	Waite Rhyolite, Unit 6	18-87	Slightly altered, flow-brecciated quartz-feldspar porphyry.	11.6	9.1	75.5		2
	Waite Rhyolite,Unit 6	19-87	Highly silicified, lobe quartz-feldspar porphyry.		11.2	80.7	Silicified	2
	Waite Rhyolite,Unit 5	382-86	Slightly altered, massive quartz-feldspar porphyry.	10.9	9.9	76.0		2
	Waite Rhyolite, Unit 3	645-86	Flow-brecciated feldspar porphyry.	10.2	9.8	77.1		2
	Waite Rhyolite, Unit 3	647-86	Carbonated, flow-brecciated quartz-feldspar porphyry.	10.5	10.2	68.9	Carbonated	2
	Waite Rhyolite, Unit 1	536-86	Slighly altered, flow-brecciated quartz-feldspar porphyry.	8.6	8.7	74.8		2
	Waite Rhyolite, Unit 1	534-86	Slighly altered, massive quartz-feldspar porphyry.	8.8	8.8	76.3		2
	Waite Rhyolite, Unit 1	531-86	Slightly altered, flow brecciated quartz-feldspar porphyry.		9.7	76.1		2
	Waite Rhyolite, Unit 1	317-86	Moderately altered, flow-brecciated quartz-feldspar porphyry.	9.2	9.6	73.4		2
	Waite Rhyolite, Unit 1	442-86	Moderately carbonated, lobe quartz-feldspar porphyry.	11.4	11.0	78.3	Carbonated	2
	Waite Rhyolite, Unit 1	443-86	Silicified lobe quartz-feldspar porphyry.	11.1	11.4	81.2	Silicified	2
	Waite Rhyolite, Unit 1	448-86	Spherulitic, lobe quartz-feldspar porphyry.		10.8	74.8		2
	Waite Rhyolite, Unit 1	440-86	Moderately sericitized, flow-brecciated quartz-feldspar porphyry with disseminated sulfide.	11.9	11.7	78.4	Silicified	2
	Dike in Waite Andesite	4-87	Quartz-feldspar porphyry dike cutting Waite Andesite Formation	7.0	11.0	79.3	Dike	2
	Horne massive rhyolite		Quartz-phyric rhyolite.		9.5			3
Mattagami Lake, Quebec	Key Tuff (Norita)	L9 #4	Rhyolitic lithic-crystal ash tuff with 1% 1-2 mm quartz phenoclasts.	10.4	10.9			1
Jerome, Arizona	Upper Cleopatra Rhyolite	127	Hematitic quartz-feldspar-phyric rhyodacite.	14.3	9.9	82.6	Silicified	4
	Lower Cleopatra Rhyolite	UV3	Sericitized and silicified quartz-phyric rhyodacite.	9.4	9.5	84.3	Silicified	4
	Lower Cleopatra Rhyolite	157	Weakly sericitized and carbonated, quartz-feldspar-phyric rhyodacite.	15.0	8.4	73.9		4
	Lower Cleopatra Rhyolite	200	Chloritic, fragmental quartz-feldspar-phyric rhyodacite.	9.3	8.7	70.1		4

Table 2. Quartz phenocryst and whole rock $\delta^{18}O$ data for felsic volcanic and shallow intrusive rocks from VHMS districts (continued).

District	Unit	Sample	Description	Whole rock $\delta^{18}O$(‰)	Phenocryst $\delta^{18}O$ (‰)	Volatile-free SiO_2 (%)	Comment	Data sources
Mt Windsor, Queensland	Mt Windsor Formation	HW14B	Feldspar-quartz-phyric rhyolite, wtih 3-5% 2-4 mm feldspar and 1% 1-2 mm quartz phenocrysts.	11.8	10.5	77.6		1, 5
	Mt Windsor Formation	HW26	Feldspar-quartz-phyric rhyolite, with 10% 2-5 mm feldspar and 5-7% 1-5 mm quartz phenocrysts.	8.8	9.4	73.1		1, 5
	Mt Windsor Formation	HW36	Feldspar-quartz-phyric rhyolite, with 1-2% 1-3 mm feldspar and 0.5% 1-2 mm quartz phenocrysts.	11.8	11.3	80.6	Silicified	1, 5
	Mt Windsor Formation	TH2	Rhyolite	8.3	9.6	78.3		1, 5
	Mt Windsor Formation	WT1A	Rhyolite.	11.9	11.9	80.9	Silicified	1, 5
	Mt Windsor Formation	WT44	Rhyolite	10.6	11.7	78.0		1, 5
	Mt Windsor Formation	WT52	Feldspar-quartz-phyric rhyolite, with 15-20% 2-5 mm feldspar and 3-5% 2-10 mm phenocrysts.	7.5	8.3	75.8		1, 5
	Trooper Creek Formation	SS28	Rhyolite	8.4	7.6	77.5		1, 5
	Trooper Creek Formation	TH11	Rhyolite	12.4	13.6	79.7	Silicified	1, 5
Bathurst, New Brunswick	Nepisiguit Falls Formation	12	Schistose quartz-feldspar-phyric crystal-rich rhyolitic tuff.	8.2	12.1	71.3		6
	Nepisiguit Falls Formation	150	Schistose quartz-feldspar-phyric crystal-rich rhyolitic tuff.	10.8	12.0	72.9		6
	Nepisiguit Falls Formation	153	Schistose, sulfidic altered quartz-phyric crystal-rich rhyolitic tuff.	10.3	11.9	65.3	Altered	6
	Nepisiguit Falls Formation	155	Schistose, altered quartz-phyric crystal-rich tuff.	9.8	11.9	72.4		6
West Shasta, California	Upper Balaklala Rhyolite	1125	Quartz-phyric crystal lapilli dacitic tuff.		7.6			7
	Upper Balaklala Rhyolite	1222	Silicified, chloritic, quartz-phyric dacite.		10.3		Silicified	7
	Upper Balaklala Rhyolite	10149	Silicified, chloritic, quartz-phyric dacite.		10.0		Silicified	7
	Middle Balaklala Rhyolite	IM-4	Quartz-phyric dacite.		9.8			8
	Middle Balaklala Rhyolite	IM-9A	Quartz-phyric dacite.		7.9			8
	Middle Balaklala Rhyolite	IM-17b	Quartz-phyric dacite.		7.4			8
	Middle Balaklala Rhyolite	IM-29	Quartz-phyric dacite.		8.4			8
	Middle Balaklala Rhyolite	IM-35	Quartz-phyric dacite.		7.7			8
	Middle Balaklala Rhyolite	IM-36	Quartz-phyric dacite.		9.3			8
	Middle Balaklala Rhyolite	IM-46	Quartz-phyric dacite.	8.9	8.9			8
	Middle Balaklala Rhyolite	IM-48	Quartz-phyric dacite.		8.0			8
	Middle Balaklala Rhyolite	S-41	Quartz-phyric dacite.		10.0			8
	Middle Balaklala Rhyolite	S-65	Quartz-phyric dacite.		7.2			8
	Middle Balaklala Rhyolite	S-77b	Quartz-phyric dacite.		9.2			8
	Middle Balaklala Rhyolite	S-130	Quartz-phyric dacite.		8.2			8
	Middle Balaklala Rhyolite	S-131	Quartz-phyric dacite.		8.2			8
	Middle Balaklala Rhyolite	S-132	Quartz-phyric dacite.		9.3			8
	Lower Balaklala Rhyolite	IM-42	Quartz-phyric dacite.		7.0			8
	Lower Balaklala Rhyolite	IM-57b	Quartz-phyric dacite.		7.6			8
	Lower Balaklala Rhyolite	S-56A	Quartz-phyric dacite.		7.5			8
	Lower Balaklala Rhyolite	S-133	Quartz-phyric dacite.		7.9			8
	Lower Balaklala Rhyolite	S-135	Quartz-phyric dacite.		8.4			8
	Lower Balaklala Rhyolite	S-136	Quartz-phyric dacite.		8.0			8
	Lower Balaklala Rhyolite	S-139	Quartz-phyric dacite.		9.7			8
	Lower Balaklala Rhyolite	S-140	Quartz-phyric dacite.		8.0			8
	Mule Mountain Trondhjemite	IM-45	Trondhjemite.	7.5	7.5		Intrusive	8
	Mule Mountain Trondhjemite	S-120	Trondhjemite.		8.5		Intrusive	8

Table 2. Quartz phenocryst and whole rock $\delta^{18}O$ data for felsic volcanic and shallow intrusive rocks from VHMS districts (continued).

District	Unit	Sample	Description	Whole rock $\delta^{18}O$(‰)	Phenocryst $\delta^{18}O$ (‰)	Volatile-free SiO_2 (%)	Comment	Data sources
Iberian Pyrite Belt, Spain	Volcanic-Siliceous Complex	544-P25	Quartz-feldspar phyric rhyolite.	12.1	11.0	76.4		9
	Volcanic-Siliceous Complex	544-P10	Quartz-feldspar phyric rhyolite.	13.2	11.4	83.4	Silicified	9
	Volcanic-Siliceous Complex	544-P11	Quartz-feldspar phyric rhyolite.	14.3	11.6	78.2		9
	Volcanic-Siliceous Complex	544-P16	Quartz-feldspar phyric rhyolite.	13.4	9.9	75.9		9
	Volcanic-Siliceous Complex	544-P18	Quartz-feldspar phyric rhyolite.	14.0	10.3	78.1		9
	Volcanic-Siliceous Complex	544-P21	Quartz-feldspar phyric rhyolite.	14.3	10.5	75.8		9
	Volcanic-Siliceous Complex	GF-23	Quartz-phyriuc rhyolitic tuff.	16.8	11.8			10
	Volcanic-Siliceous Complex	1-GF	Quartz-phyriuc rhyolitic tuff.	16.5	11.2			10
Buttle Lake, British Columbia	Myra quartz-feldspar porphyry	14-904@608'	Greenish gray, chlorite-silica altered quartz-feldspar-phyric rhyolite with 2-3% 1-4 mm quartz and 2-3% 2-4 mm ghosty feldspar phenocrysts.	9.3	7.9	72.0		1, 11
	Myra quartz-feldspar porphyry	14-904@650'	Gray, sericite-silica altered quartz-phyric rhyolite with 2% 1-4 mm quartz phenocrysts and 1% disseminated pyrite.	9.6	7.8	82.3	Silicified	1, 11
	Myra quartz-feldspar porphyry	14-919@718'	Gray, sericite altered ash-lapilli tuff with 1% 1-2 mm quartz phenoclasts.	7.4	7.5	59.7	Sericitized	1, 11
	Myra quartz-feldspar porphyry	14-920@684'	Gray, sericitic ash-lapilli tuff with 1% 1-2 mm quartz phenoclasts.	7.4	7.2	62.8	Sericitized	1, 11
	Myra quartz-feldspar porphyry	W103@1160'	Greenish gray, patchily chloritized feldspar-quartz-phyric rhyolite with 5-7% 1-3 mm feldspar and 1-2% 1-4 mm quartz phenocrysts with minor disseminated pyrite.	10.7	9.0	74.3		1, 11
	Myra quartz-feldspar porphyry	W103@1259'	Gray, sericitic feldspar-quartz-phyric rhyolite with 5-7% ghosty 0.5-2 mm feldspar and 1-2% 1-4 mm quartz phenocrysts.	11.1	9.6	72.4		1, 11
	Myra quartz-feldspar porphyry	W127@1213'	Sericitic quartz-phyric rhyolite, with 1% 1-2 mm quartz phenocrysts.	11.4	9.5	75.3		1, 11
Hokuroku, Japan	D_2 dacite	MR1345	Intrusive quartz-phyrite dacite.		8.6		Intrusive	12
	D_2 dacite	H048	Intrusive quartz-phyrite dacite.	15.6	7.6		Intrusive	12
	Ohtaki quartz diorite	JU78SF101	Intrusive quartz diorite.	7.1	6.8		Intrusive	12

Sources of data: 1—this study; 2—Paradis (1990); 3—MacLean and Hoy (1991); 4—Gustin (1988); 5—A.J. Stolz (pers. comm., 1994); 6—Lentz and Goodfellow (1993); 7—Casey and Taylor (1982); 8—Taylor and South (1985); 9—Munha et al. (1980); 10—Barriga and Kerrich (1984); 11—R. Sherlock (pers. comm. 1995); 12—Green et al. (1983).

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