

DATA REPOSITORY ITEM

I. Analytical Methods

Magmatic anhydrites have been analyzed in thin sections and amphibole and pyroxene grain mounts in epoxy plugs, polished in absence of water with diamond paste. Chemical composition of magmatic amphibole and anhydrite were determined using Cameca SX100 electron microprobe at Oregon State University, using 30 nA current, 15 kV accelerating potential, and a beam size of 1 to 5 μm .

Laser-ablation ICP-MS analysis of anhydrite were performed in the W.M. Keck Collaboratory for Plasma Mass Spectrometry at Oregon State University using a VG ExCell quadrupole ICP-MS and NewWave DUV 193 nm ArF Excimer laser system, with He used as the sweep gas. General analyses conditions were similar to those in Kent et al. (2004) and analyses used laser spot sizes between 50-80 μm in diameter and pulse rates of ~ 5 Hz. ^{43}Ca was used as the internal standard isotope and analyses were quantified with reference to analysis of NIST 612 and 610 standard glasses under similar ablation conditions. Measurement of standard glasses suggest an accuracy better than 10% for these measurements. Phosphorous and silica have been monitored to trace apatite, host mineral or melt presence within the ablated volume, and where necessary the contribution from these phases was subtracted from the measured composition.

II. Summary of Analytical Data on Anhydrite

Table DR1: Average compositional data for anhydrite

	YANACocha: Inclusions in			Pinatubo	Pinatubo	Julcani	High Temperature Hydrothermal			
	high-Al A	low-Al A	Cpx	inclusion	pheno	pheno	Butte	El Salvador	Ajo	DLppm
Electron microprobe data (oxide wt %)										
SO ₃	58.92	58.27	58.72	58.26	58.48	58.30	58.38	59.24	58.14	320
P ₂ O ₅	0.13	0.12	0.19	0.26	0.11	0.19	0.10	0.08	0.10	113
CaO	39.21	41.61	40.89	41.18	41.04	39.63	41.80	40.28	41.56	231
FeO	0.48	0.47	0.23	0.59	0.04	0.02	0.01	BDL	BDL	361
SiO ₂	0.06	0.19	0.06	0.10	0.00	0.01	0.26	0.03	0.07	129
SrO	0.71	0.45	0.36	0.28	0.22	1.75	0.14	0.22	0.11	380
LA-ICP-MS analyses (ppm)										
Sr	3763(232)			1895*	33634	(4415)	1184*	2593*	826*(36)*	
Y	23 (2)			25	3	(0.3)	115	37	74 (0.9)	
Ba	38 (12)			43	14839	(878)	1	2	5 (1.5)	
La	73 (5)			213	42	(2.4)	78	18	251(6.5)	
Ce	167 (10)			356	61	(3.2)	151	39	487 (10)	
Pr	24 (2)			38	6	(0.4)	18	6	58 (1.1)	
Nd	101 (9)			134	23	(1.1)	69	28	211 (3.6)	
Sm	16 (2.4)			16	3	(0.3)	16	7	31 (0.7)	
Eu	4 (0.7)			4	1	(0.1)	5	3	3 (0.1)	
Gd	8 (2.5)			10	2	(0.3)	17	8	22 (0.6)	
Dy	3 (1.5)			5	0.5	(0.1)	20	7	12 (0.3)	
Er	1 (0.5)			2	0.2	(0.1)	12	3	5 (0.1)	
Yb	1 (0.7)			1	BDL	BDL	12	3	3 (0.1)	

(-): 1 sigma error, * 1sigma error similar for Pinatubo phenocryst, Butte, El Salvador, & Ajo.

Magmatic anhydrites from Yanacocha (Peru), Pinatubo (Philippines), and Bulolo dacite dike at Julcani (Peru) and high temperature hydrothermal anhydrite from Butte (Montana, USA), El Salvador (Chile), Ajo (Arizona, USA). high-Al A = aluminum-rich amphibole (wormy); low-Al A = aluminum-poor amphibole; BDL = below detection limit; DLppm = detection limit (ppm).

Additional rare earth element data are plotted in Figure 3B, normalized to primitive mantle values of Sun and McDonough (1989).

III. Samples and Preparation

Anhydrite-bearing samples were prepared in two manners. Most amphibole, pyroxene, and anhydrite crystals were mounted in epoxy plugs and polished with diamond grit in a water-free environment with alcohol as lubricant to prevent dissolution of water-soluble anhydrite. The Julcani samples contained phenocrystic anhydrite and were provided by Don Noble as mounted in standard polished thin sections.

IV. Additional References

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V. Mass balance estimate for hydrothermal sulfur at Yanacocha

The geologic maps and cross-sections of Longo (2005) were used to estimate the volume of hydrothermally altered rocks at Yanacocha ($\sim 2.5 \text{ km}^3$). These volume estimates are approximate, and likely have errors of $\pm 50\%$. An unknown, but significant amount of altered rock has been removed by erosion (probably $< 20\%$ of the total volume above), so our estimates are minima. The volume percent pyrite within these rocks is based on estimates of representative rock samples from these zones, which lie peripheral to the main ore zones. They are also approximate, and likely have errors of $\pm 50\%$.

The volume of strongly altered, ore bearing zones that can be estimated from the average ore reserve and production grades (0.5 to 1 g/tonne) and the total resource of ~ 50 M ounces ($\sim 1,800$ tonnes) of gold contained in ~ 3 G tonnes oxide ores with abundant alunite and pyrite. In addition, ~ 1 G tonnes of sulfide-bearing Cu-Au are present beneath the Au-bearing oxide ores (L. Teal, personal commun., 2006). Our estimates are minima, because the main orebodies around the main Yanacocha pit have been eroded and glaciated, and the upper sulfur-rich part of the hydrothermal system is missing. The presence of abundant pyrophyllite ($> 250^\circ\text{C}$ stability) in the ores suggests that boiling solutions were at > 10 bar hydrostatic pressure, i.e. at > 100 m depth.

Table DR2: Mass Balance Estimate for Yanacocha Hydrothermal Sulfur

Hydrothermal Zone	Mass	Sulfide	Sulfide	S	Sulfate	Sulfate	S	Sulfur
	G tonnes	Minerals	wt. %	wt. %	Mineral	wt. %	wt. %	M tonnes
conservative & minimum estimate								
Au ore bodies	3	Py, Cv, En (oxidized)	5	2.67	alunite	5	0.77	103
Peripheral propylitic & intermediate argillic alteration	6	Py	2	1.07	tr	0	0	64
Deep Cu-Au sulfide ores	1	Py, Cv, En	2	1.07	alunite	0.5	0.27	13
							sum	181

abbreviations: Py = pyrite; Cv = covellite; En = enargite