Secondary Mineralogy of the Olkelduhals Hydrothermal system, Iceland: Applications to Past Mars Environments

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Introduction

- Opaline and Amorphous silica, sulfate-rich soils and Fe oxides in association with volcanic materials observed by MER Spirit rover near Home Plate, Gusev crater have been interpreted as evidence of hydrothermal activity on Mars. [1][2][3]
- With an abundance of Fe oxides and Ti-enrichments, the Hengill Volcano hydrothermal system is an exceptional place to study the processes that lead to these secondary minerals. [1][2][3]

Background

- Olkelduhals, Iceland is one of many hydrothermal sites associated with the Hengill Volcano hydrothermal system.
- There has been little to no previous documented research done on this site, thus far making this project a pilot study to see if this site would make a good match for the minerals found at Gusev crater.

Methods

Samples collected by Lindsay McHenry and Jordan Ludyan

Minerology

Every sample was powdered by hand with a mortar and pestle, then analyzed using X-Ray Diffraction.

Geochemical Analysis

Appropriate samples were fused and analyzed using the X-Ray Fluorescence

Objectives

- Analyze the secondary minerals present and compare them to those found at Gusev crater, Mars
- Understand if hydrothermal conditions lead to acid leaching or precipitation

RESULTS:

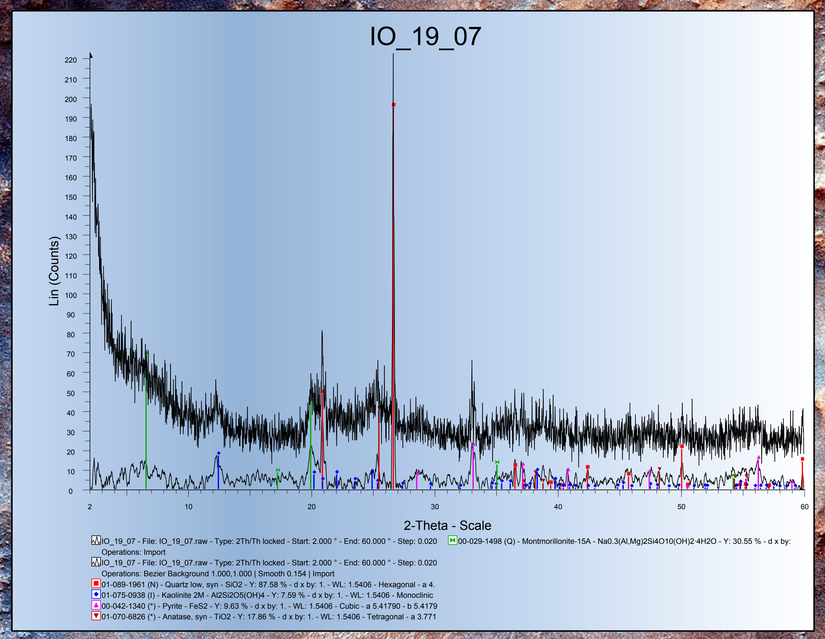
XRD mineralogy results for Olkelduhals rock/sediment samples. Phases listed according to relative abundance.

X: Present
XX: Common
XXX: Abundant

Sample type	Sample ID	Silica phases: Amorphous silica	Silica phases: Opal-A	Silica phases: Tridymite	Silica phases: Quartz (SiO_2)	Carbonates: Calcite - $CaCO_3$	Oxides: Anatase - TiO_2	Oxides: Hematite - Fe_2O_3	Elemental sulfur	Sulfates: Anhydrite - $CaSO_4$	Sulfates: Kalinite - $KAl(SO_4)_2 \cdot 11H2O$	Sulfates: Hexahydrite - $MgSO_4 \cdot 6H_2O$	Sulfates: Alunogen - $Al(SO4)3 \cdot 17H2O$	Sulfates: Pickeringite/halotrichite $(Fe,Mg)Al_2(SO_4)_4 \cdot 22H2O$	Sulfides: Pyrite - FeS_2	Clays: Smectites	Clays: Kaolins	Plagioclase
Substrate (Basalt)	IO-19-15															X		XXX
Mud - acidic spring	IO-19-5				XX										XX			
Precipitate	IO-19-6				X						X							
Mud - acidic spring	IO-19-7				XXX		X								X	X	XX	
Precipitate	IO-19-8				XX										X		XX	
Precipitate	IO-19-9												X	XXX				
Mud - acidic spring	IO-19-10				XX		X									XX		
Mud - neutral spring	IO-19-11				X										XXX	XX		
Sediment	IO-19-12				XXX		X									XX		
Crystals	IO-19-14				XXX													

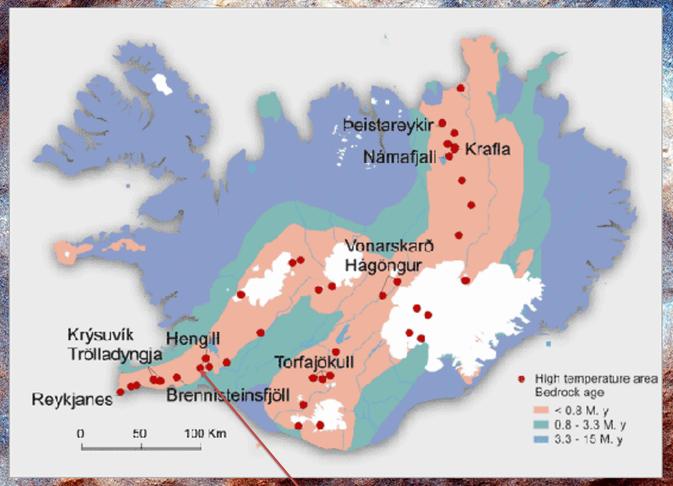
*Major oxide concentrations reported in weight % *Trace metal concentrations reported in ppm

SAMPLE:	Description	SUM (%)	LOI (%)	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Y	Ni	Nb	Zn	Zr	V	Co	Cr	Ce	Sr	Ba
IO-19-5	Mud acidic pool	96.50	16.20	46.10	1.55	6.18	25.03	0.01	0.46	0.16	0.00	0.12	0.56	nd	183	nd	nd	86	207	149	nd	29	53	170
IO-19-6	Crust acidic pool	94.59	9.52	49.00	1.82	5.52	27.55	0.01	0.38	0.09	0.01	0.13	0.48	nd	44	nd	nd	103	361	133	50	31	38	170
IO-19-7	Mud acidic pool	94.09	14.60	48.42	3.59	19.31	6.78	0.01	0.79	0.09	0.00	0.08	0.30	nd	115	nd	nd	220	426	40	152	29	36	184
IO-19-8	Precipitate	104.95	34.70	49.51	1.52	8.08	9.79	0.01	0.74	0.22	0.05	0.07	0.20	11	nd	nd	nd	92	233	47	nd	23	25.64	138
IO-19-9	Precipitate	101.94	14.76	72.86	2.46	6.23	4.72	0.02	0.57	0.15	0.00	0.02	0.06	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
IO-19-10	mud acidic pool	90.45	12.50	50.11	4.88	20.32	1.35	0.02	0.89	0.07	0.00	0.02	0.22	nd	nd	63	nd	299	483	nd	101	29	nd	nd
IO-19-11	Mud acidic pool	90.44	16.00	37.52	3.33	14.10	15.43	0.07	2.54	1.06	0.00	0.03	0.27	nd	86	nd	177	190	357	86	107	28	43	116
IO-19-12	Sediment	93.48	5.59	55.31	3.91	15.00	10.49	0.03	2.20	0.42	0.00	0.03	0.42	nd	nd	52	nd	238	536	43	134	22	nd	147
IO-19-13	Precipitate	103.30	23.59	43.11	1.41	17.14	15.61	0.03	2.10	0.03	0.00	0.00	0.19	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
IO-19-14	Crystals	100.78	0.74	98.29	0.26	0.84	0.32	0.00	0.28	0.04	0.00	0.01	0.03	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
IO-19-15	Substrate	88.29	0.00	43.93	1.00	16.47	10.76	0.23	5.39	9.69	0.60	0.06	0.07	nd	82	nd	44	46	240	55	192	16	115	nd



Conclusions

- Reducing conditions have been confirmed at depth due to the abundance of pyrite in mud samples.
- Oxidizing conditions present at the surface confirmed by the presence of sulfates.
- The abundance of quartz indicates a more diagenetically mature environment, thus indicating that the Olkeduhals hydrothermal site has been active longer than the one found at Gusev crater. This diagenetic maturity and lack of amorphous silica is surprising because it does not correlate with what has been found at other sites included in the Hengill hydrothermal system.



Olkelduhals, Hengill, Iceland [4]

Acknowledgements:

A huge thank you to Jordan Ludyan and Lindsay McHenry for walking me through each step of this process and teaching me everything I know. Also, for providing the samples. Lastly, thank you to SURF for funding the project.

Works Cited:

[1]: Squyres S.W. et al. (2008) *Science*. 320, 1063-1067.
[2]: Ruff S.W. et al. (2011) *JGR*. 116, E00F23.
[3]: Ruff S.W. & Farmer J.D. (2016) *Nat. Commun.* 7, 13554
[4]: https://waterfire.fas.is/GeothermalEnergy/SteamPower.php