The Effects of High Altitude on the Sintering Process and Possible Implications for Sintering in Vacuum. K. E.,[1] (Deforeky@hawaii.edu) C. A.,[2] (canderse@hawaii.edu) and Rodrigo Romo.,[3] (rfvromo@gmail.com). The Pacific International Space Center for Exploration Systems (PISCES), 99 Aupuni St. Suite # 212-213 Hilo, Hawai'i, 96720.

Introduction: In Situ Resource Utilization (ISRU) refers to the ability to utilize local resources found in an area of interest. In space exploration and settlement, ISRU aims to utilize resources found on the moon and Mars to build infrastructure, thereby reducing the need for materials from Earth. Consequently, there is a high degree of interest in lunar and Mars regolith as a source for construction materials and volatiles extraction.

Sintering is one proposed method to produce a manufacturing and/or construction material feedstock using lunar and Martian regolith. The Pacific International Space Center for Exploration Systems (PISCES) in collaboration with NASA's SwampWorks successfully developed interlocking tiles made with sintered basalt from a quarry on the island of Hawai'i Fig. 1 below illustrates a geologic map of Hawai'i and sample locations [1].

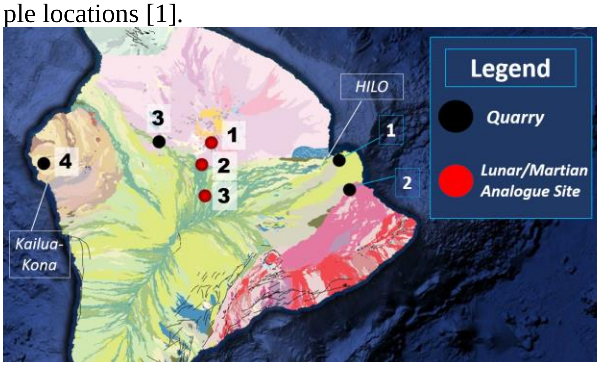

Fig. 1 Geologic map of the Island of Hawai'i and sample locations.

Hawai'i's basalt has chemical properties similar to those of lunar and Martian regolith. PISCES has developed sintered materials under two different thermal profiles (1,149 °C & 1,177 °C) using basalt feedstock. The first generation materials were from a quarry in Hilo and were sintered at 1,149 °C & 1,177 °C, the structural properties of this material exceeded the strength of both residential and specialty concrete [2] Fig. 2 below shows the flexural and compressive strength for the first generation materials.

Sample	Flexural (MPa)	Compressive (MPa)
Residential Concrete	*3.45*	*17.24*
Commercial Concrete	*5.52*	*27.58*
Specialty Concrete	*13.79*	*68.95*
First Gen. Quarry 1 (1,149 °C)	*4.85*	*14.67*
First Gen. Quarry 1 (1,177 °C)	*40.35*	*212.53*

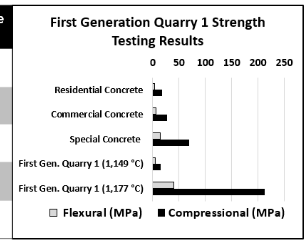

Fig. 2 Flexural and compressive strength testing for first generation material.

Over the last few years the Pacific International Space Center for Exploration Systems (PISCES) has continued this research, investigating the chemical and mineralogical properties of samples. Chemical and mineral analyses have revealed a significant variation in composition among Hawai'ian basalts based on their source, age and flow they originated from. Table 1 illustrates the variance between Hawaiian basalt aggregates of various quarries, then comparing those results to Lunar/Martian regolith chemical data [3] [4].

Sample	SiO2 %	Al2O3 %	MgO %	Na2O %	K20 %	CaO %	TiO2 %	FeO %	MnO %	P2O5 %
Quarry 1	50.4	13	6.78	2.4	0.35	10.1	1.77	10.5	0.17	0.26
Quarry 2A	49.5	12.3	8.89	2.34	0.34	9.61	1.71	10.7	0.16	0.3
Quarry 2B	46.1	8.76	18.6	1.71	0.22	6.73	1.22	12	0.17	0.3
Quarry 3	51	13.4	5.45	2.39	0.4	10.6	1.93	10.4	0.16	0.26
Quarry 4	47.6	11.2	13.3	2.17	0.28	7.87	1.5	11.5	0.17	0.31
Analogue Site 1	54.7	11.6	3.36	2.21	1.9	7.34	3.29	12.3	0.25	1.13
Analogue Site 2	51.1	16.1	3.82	3.9	1.89	6.32	2.53	11.1	0.24	0.26
Analogue Site 3	50.2	13.8	2.92	3.31	1.87	5.97	2.4	9.94	0.23	1.07
Mars Path Finder	52.7	9.218	6.155	2.373	0.464	6.527	1.027	14.86	0	0
Lunar Mare	43.7	12.9	9.56	0.38	0.14	11.02	5.17	16.9	0.226	0.15
Lunar Highlands	45	25.1	7.55	0.41	0.095	14.93	0.525	6.27	0.088	0.115

Table 1 Chemical analysis of Hawaiian basalt aggregates to Lunar/Martian regolith.

Once samples were characterized, they were sintered at 1,149 °C and 1,177 °C identifying the type of basalt and thermal process that is needed to create a durable material at atmosphere. The analyses have shown that Mauna Loa basalts have consistently produced the most durable materials [5] Fig. 3 displays an image of the material created at 1,177 °C.

Fig. 3 Sintered basalt at 1,177 °C

It is unknown if the same thermal processing currently being used by PISCES will work for the moon/ Mars. Although it is not possible to sinter at vacuum at this time, it will instead be investigated by sintering at higher altitude. This will be done at the Hawai'i Space Exploration Analog and Simulation habitat on Mauna Loa, Hawai'i. The habitat is located approximately 2,438 m above sea level. Samples will be collected from various lava flows located within the habitat's vicinity, characterized for mineral abundances via X-Ray Diffraction (XRD). The results from the mineral characterization will be compared to other Mauna Loa samples used previously. Each sample will then be sintered and compared to sintered Mauna Loa and other samples previously sintered by PISCES. Using a RapidFire Pro-LP tabletop miniature kiln, the samples will be sintered at 1,149 °C, the highest temperature recommended by the equipment [6]. The temperature, holding and cooling time will be gradually adjusted as needed to locate the lowest thermal profile possible.

References:

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