DEVELOPING AN ANORTHOSITIC LUNAR REGOLITH SIMULANT. M. M. Battler[1], J. Richard[2], D. Boucher[3], and J. G. Spray[1] [1]Planetary and Space Science Centre, Department of Geology, University of New Brunswick, Fredericton, NB, E3B 5A3, Canada, melissa.battler@unb.ca, jgs@unb.ca, [2]Electric Vehicle Controllers Ltd., 2200 Valleyview Road, Val Caron, ON P3N 1L1, Canada, jrichard@norcat.org, [3]Northern Centre for Advanced Technology Inc., 1400 Barrydowne Road, Sudbury, ON P3A 3V8, Canada, dboucher@norcat.org.

Introduction: We must increase our understanding of planetary regoliths, as future human missions to both the Moon and Mars will rely on these surface materials for in situ resource utilization (ISRU) to produce fuel, water, and other life support and construction materials. There are no natural lunar regolith analogues on Earth, and supplies of existing lunar simulants are currently limited or running out, and may not be compositionally representative of typical lunar regolith. To date, all major lunar simulants produced have been based on basalt; however, the bulk of the lunar bedrock - including some potential ISRU landing sites, and likely much of the south pole region - is dominated by anorthosite-norite-troctolite (ANT) suite rocks. Therefore, it is particularly important to gain an understanding of the physical/mechanical behavior of anorthositic regolith. To prepare for upcoming robotic ISRU missions, equipment must be tested on the Earth using a good physical/mechanical simulant. The goal of this study is to develop an anorthosite-based physical/mechanical lunar regolith simulant, in order to assist Electric Vehicle Controllers (EVC) Ltd. and the Northern Centre for Advanced Technology (NORCAT) Inc. with lunar drilling and excavation equipment design.

Background: Lunar regolith is an unconsolidated material covering the entire surface of the Moon. It is about 4 to 8 m thick over the Mare regions, and roughly 10 to 30 m thick over the older Highland regions [1]. More than 80% of the lunar bedrock is composed of the ANT suite rocks of the Highlands, with Mare basalts accounting for only ~17% of the bedrock. Lunar regolith is a complicated substance unlike any material found on the Earth, due, in part, to the lack of an atmosphere and atmospheric weathering processes on the Moon. Regolith is composed of particles that were derived either from lunar bedrock, or from older regolith, which was formed when repeated meteoroid impacts pulverized the lunar bedrock, over-turning and mixing it, until it became a fine powder. Regolith is still undergoing modification and evolution today, and thus it is a dynamic material. It consists of mineral fragments, rock fragments, breccia fragments, glasses, and agglutinates (smaller particles, bonded by vesicular glass). Particles are heterogeneously mixed, and can range in size from microscopic to several meters or more in diameter, averaging between 60 and 80 μm. Particles are angular in shape, which has implications for regolith physical properties (e.g., abrasive to machinery and damaging to human respiratory systems).

Anorthosite: Anorthosite, by definition, is an intrusive igneous rock composed of at least 90% plagioclase feldspar, with no more than 10% mafic minerals.

Lunar Anorthosite. Anorthosite samples returned from the Apollo missions contain >90% [2] extremely calcium-rich plagioclase, as well as minor pyroxene and olivine, which are relatively iron-rich [1]. Typical lunar plagioclase ranges from An_{40} to An_{98}, although most possess An >70 [3].

Anorthosite Chemistry and Mineralogy. Chemical composition and mineralogy are important in determining the physical/mechanical properties of a rock and its comminuted derivative. Therefore, although our primary goal is to develop a physical/mechanical simulant, we are also concerned with rock chemistry and mineralogy in order to produce a simulant with accurate physical properties, grain shapes, and thus appropriate abrasion, compaction, and other inter-grain interaction properties.

Terrestrial Anorthosite. We have investigated and sampled several terrestrial anorthosites, and have successfully located a viable Archean anorthositic body in Canada (Fig. 1). It is mineralogically similar to typical lunar anorthosites, featuring 90% An_{75-95}, with 10% pyroxene, olivine, garnet and minor amphibole. Although amphibole (and garnet) is not present in lunar anorthosites, all terrestrial anorthosites were found to contain at least small amounts of hydrated minerals, due to alteration of the pyroxene and/or olivine.

Figure 1. Anorthosite used in simulant

Simulant Development Methodology: The following methodology has been followed: (1) select suitable source materials for simulant (rocks, glasses, etc...), and determine target grain size distribution based on Apollo data; (2) create simulant components via crushing and other procedures; (3) perform chemical and mechanical testing and analysis of simulant; analyse mineralogy, and grain size and shape distribution, in addition to various other engineering properties; (4) compare simulant to Apollo samples; (5) determine how to run analogue drilling and excavating tests with maximum fidelity; and (6) use simulant to test robotic equipment.

Progress: A suitable anorthosite source has been located, sampled, and crushed to the desired grain shape and size distribution. A physically representative glassy material has also been crushed to the appropriate size and shape. These two components have been mixed to create our first, 180 kg batch of simulant (Fig. 2), and EVC and NORCAT have commenced drill testing using the simulant. Anorthosite mineralogy has been determined by analytical electron microscopy and preliminary particle size analysis has been completed by sieving. More detailed grain shape and size analysis is currently underway, using scanning electron microscopy, and processes for simulating the glass and agglutinate components are being developed.

Figure 2. Anorthositic simulant; 60% crushed anorthosite, 40% crushed glassy material.

Future Work: The anorthositic regolith simulant will be compared to Apollo 16 anorthositic lunar regolith samples to ensure that physical properties have been replicated as closely as possible.

References: [1] Heiken, G. *et al.* (1991) *Lunar Source Book*, 736p. [2] Peterson, C. A. *et al.* (1997) *LPSC* XXVIII, Abstract # 1608. [3] Frondel, J. (1975) *Lunar Mineralogy*, 323p.