SIMULANT PROVIDER: DELTION INNOVATIONS LTD.

Company Background

The OB-1 highland simulant was originally developed by researchers at EVC/NORCAT (now Deltion Innovations Ltd.) and the University of New Brunswick, both in Canada. Deltion is a mining company that specializes in automation and robotics, mining in space, and tech transfer between these two industries. Recently, the Intellectual Property (IP) rights to the OB-1 simulant were sold to MacDonald, Dettwiler & Associates (MDA) in Brampton, Ontario who are currently determining the utility to renewing simulant production (S. Macmahon, *pers. comm*.). MDA is an international space mission partner that specializes in robotics and space operations, satellite systems, and geointelligence.

Simulants Tested and Available Simulants

Until recently, Deltion held the IP rights to the OB-1 and Chenobi simulants. OB-1 is a standard lunar highland simulant containing 42% Fe-rich olivine slag glass and 58% Shawmere Anorthosite (An_{78}) by weight (Battler and Spray, 2009). These feedstocks were crushed to match the particle size distribution of the Apollo 16 regolith sample 64500 to produce an analogue material with the geotechnical properties to benefit the design and testing of drilling, excavation, and construction equipment for future lunar surface operations. (Battler and Spray, 2009). In addition, agglutinate components are produced directly from Shawmere feedstock using a plasma arc technique (Weinstein, 2008) to better match the physical and chemical properties of highland-derived agglutinates; that version of the simulants was named Chenobi (Battler and Spray, 2009). We studied the OB-1A simulant for this work (Fig. 23).

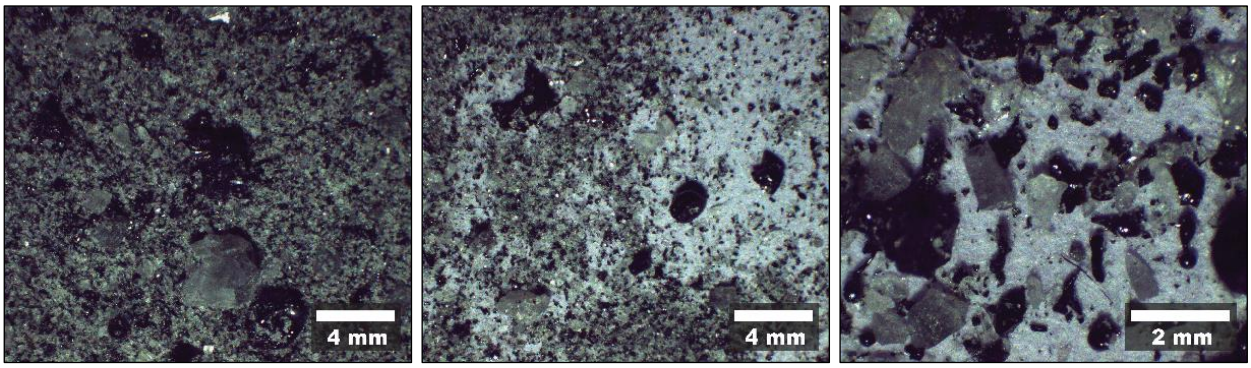

Figure 23: Microscopic images of unsieved OB-1A simulant used for testing. **(Left)** Low magnification (0.75x) overview image of OB-1A bulk simulant. **(Middle)** Low magnification (0.75x) image of a small amount of OB-1A simulant dispersed onto weighing paper for clarity. **(Right)** Higher magnification (2x) image of the small amount of OB-1A simulant.

Particle Size Distribution

The particle size distribution determined by weighing sieved grain size splits for the Deltion highland simulant OB-1A shows a PSD curve that is within 1 standard deviation of an average of Apollo samples (Fig. 24), and a good match to abundances of the larger particles (≥~150 µm). Our results show a steeper PSD curve between 40 and ~150 µm due to a much lower abundance of particles within this size range, but a better match to the smallest particle sizes (Fig. 24).

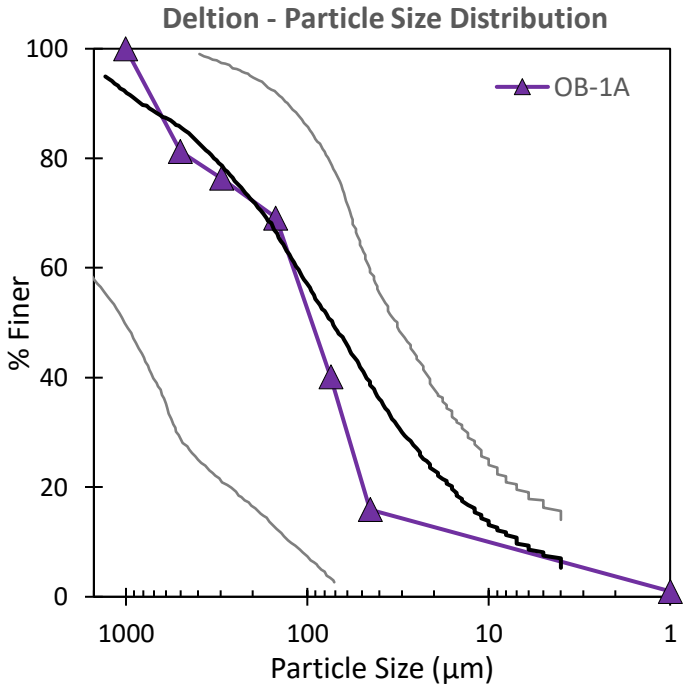

Figure 24: Cumulative particle size distribution of Deltion simulant OB-1A (purple) in comparison to Apollo average PSD (black) and ±1 standard deviation (gray).

Minimum and Maximum Density

The minimum and maximum density values for Deltion lunar highland regolith simulant OB-1A (Table 2) is shown in Figure 25 relative to the range of minimum and maximum density values determined from returned samples. The OB-1A highland simulant has a minimum density value that exceed those observed for lunar samples (Fig. 25); in fact, it plots just within the maximum density range. This would suggest that the OB-1A simulant has a much closer packing, or less void space, when poured into the cylinder than what is observed for lunar regolith samples. The OB-1A highland simulant has a maximum density values that plot within the range of maximum density values observed for lunar regolith (Fig. 25).

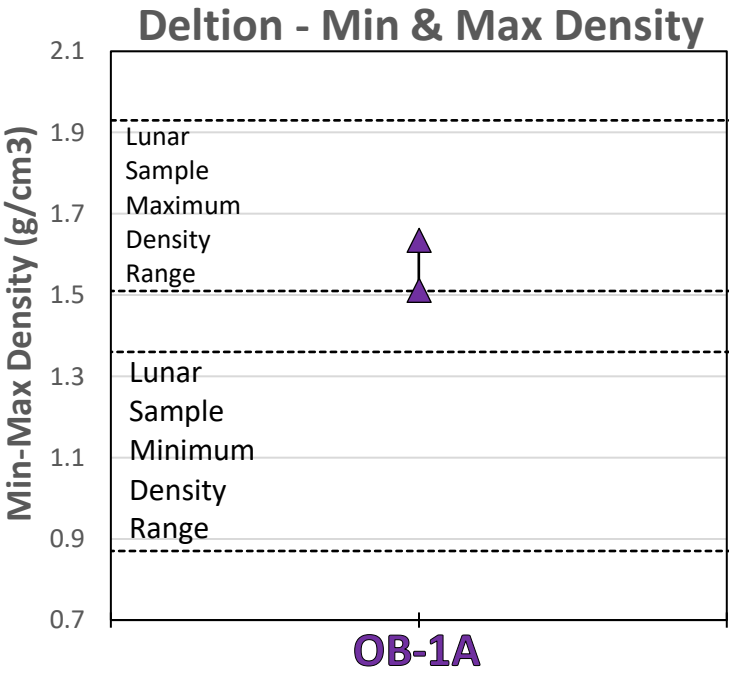

Figure 25: Minimum (bottom triangle) and maximum (top triangle) densities measured for Deltion highland regolith simulant in this study and minimum & maximum density ranges for lunar samples from various studies (Table 2).

Specific Gravity

As shown in Figure 26, the specific gravity value measured for the Deltion lunar highland regolith simulant OB-1A (Table 3) plots within the range measured for various lunar soils (Carrier et al., 1991). The OB-1A simulant plots just below the average specific gravity value of Apollo samples and recommended typical specific gravity value of Carrier et al. (1991). In fact, the OB-1A simulant has the specific gravity value of 3.03 (Table 3), which is the closest to the average specific gravity value of Apollo samples (Fig. 26).

Direct Shear

The cohesion value determined from direct shear measurements for the Deltion highland simulant OB-1A (Table 4) exceeds the values measured for returned lunar samples (Table 4, Fig. 27). In fact, the OB-1A simulant has the highest cohesion value of the simulants examined by this study and is more than double the upper limit measured for returned lunar samples. However, the friction angle determined from direct shear measurements for the Deltion highland simulant OB-1A (Table 4) plots well within the range of values determined for returned lunar samples (Table 4, Fig. 27).

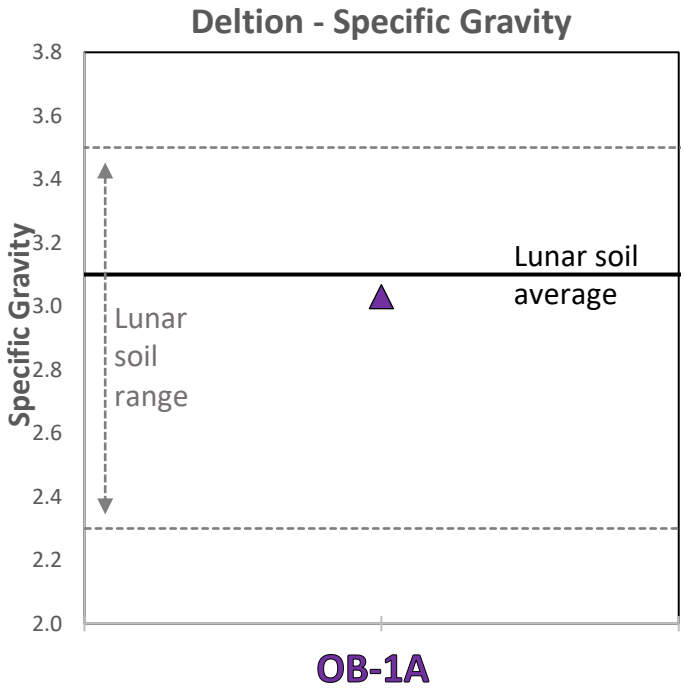

Figure 26: Specific gravity measured for Deltion highland regolith simulant OB-1A and the average and range of specific gravities measured for lunar soils from various studies, as summarized by Carrier et al. (1991).

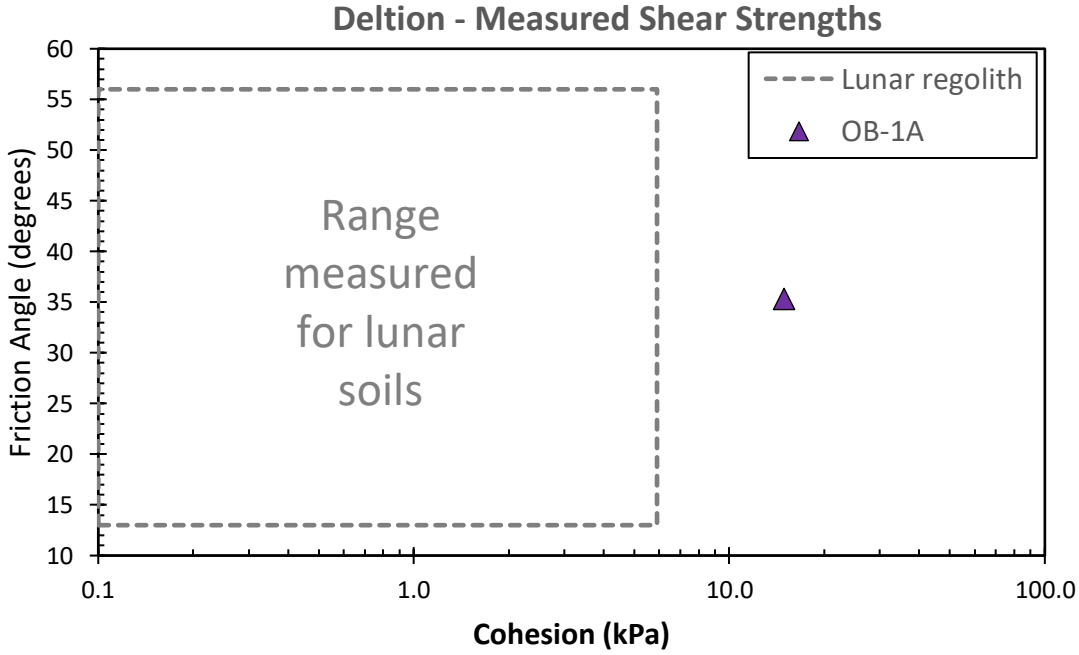

Figure 27: Friction Angles vs. Cohesion determined from direct shear measurements of Deltion highland regolith simulant OB-1A in this study and lunar soil values for lunar samples from various studies summarized by Carrier et al. (1991).

Supply Chain and Quality Control

OB-1A is not currently in production, however the IP rights were recently sold to MDA and their team in determining whether they will restart production of the OB-1A simulant. This will involve determining if there is sufficient demand for the OB-1A simulant and renewing contracts within the simulant supply chain. A company representative did state that they have plans to pull several tons of rock from the mine in Sudbury for an initial production batch and hope to ensure the quality mostly through the production process and final screening of samples. However, their plans are not fully fleshed out at the time the assessment was being written.