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Impact penetrometry of analogue planetary regoliths

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Abstract

Erosion and deposition processes on major and minor planetary bodies generate layers of loose broken up material on the surface. Due to the long period over which these processes have been active, the material in these layers can be, depending on the bodies' size, finely ground into grains similar in size to sand or a finer power such as found on the lunar surface. The subsurface stratigraphy of an asteroid, for example, could help characterise and understand the variety of geological features and granular processes on asteroids, e.g. see [1]. The microstructural properties of the asteroid's surface are also important for understanding the impact history of the asteroid, the interpretation of light scattering observations and thermal modelling.

As the surface of an asteroid or planet will most likely be granular and loose it is then easy to penetrate, for example by using a cylindrical body tipped with a conical or other shaped tip. Such a device, fitted with a force sensor, that measures the resistance to penetration, can then be used to infer the physical properties of the target, in a similar way to penetrometers used on Earth. These instruments can be made small enough to be deployed by spacecraft to investigate extraterrestrial surfaces as with the Huygens penetrometer that investigated the surface of Titan [2].

A prototype impact penetrometer (fig. 1), based on a standard instrument used for making such measurements on Earth, is introduced. For detailed characterisation of the local stratigraphy penetrometry is usually conducted on the Earth using such a standardised penetrometer inserted slowly and at constant speed into the subsurface. Consequently there is an established and extensive library of publications available for the interpretation of this type of instrument. Impact penetrometry, as the name suggests, is conducted during the impact of a projectile. This type of penetrometry has not been so well characterised and interpreting the results, in terms of stratigraphy, is made difficult due to dynamic effects such as variation in friction and drag coefficient with speed.

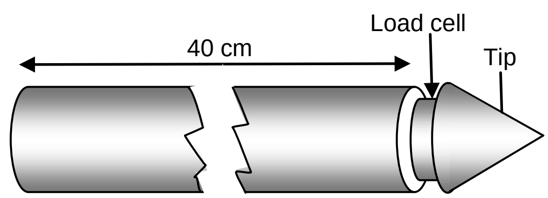

Fig. 1. Penetrometer with load cell.

Here we investigate speed-dependent effects with depth of penetration (see fig. 2) and compare them with the effects of layered material (see fig. 3). We combine a microstructural model [3] with a macroscale model of penetration (see fig. 6) to investigate the importance of momentum effects with impact speed and grain size relative to penetrometer size.

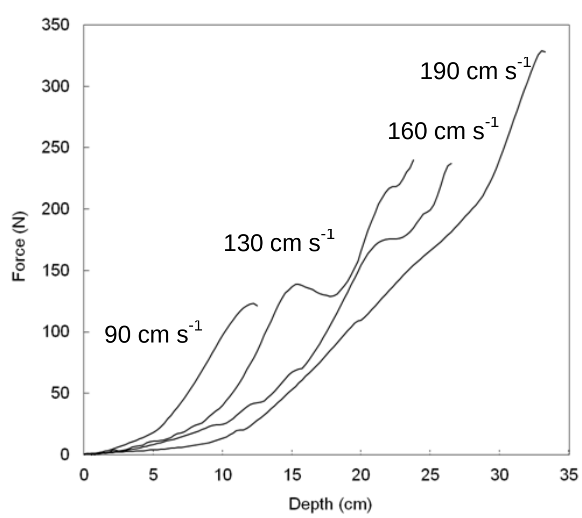

Fig. 2. Force profile with increasing impact speed into sand

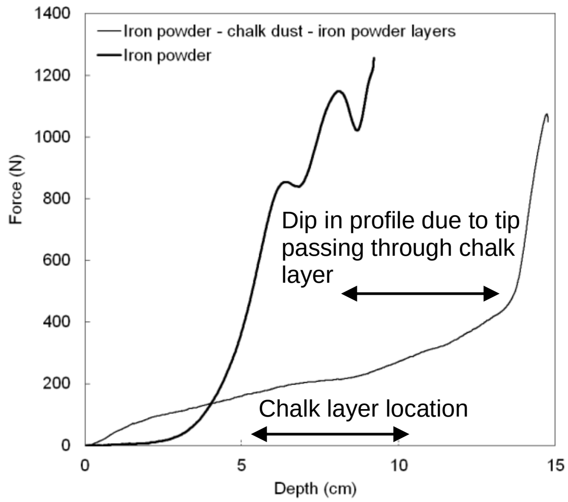

Fig. 3. Force profiles for homogenous and layered material

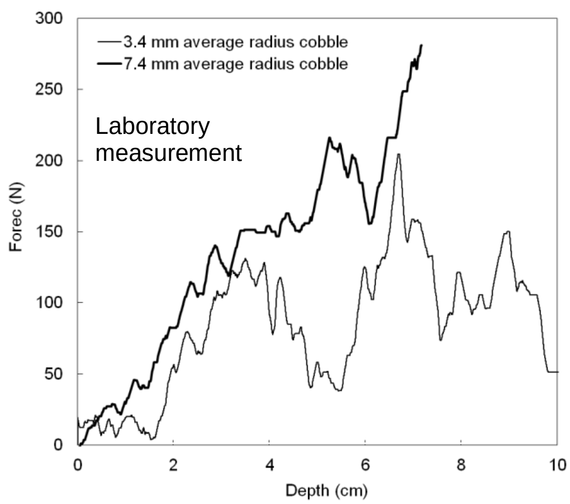

Fig. 4. Force profiles from targets with small and large grains

We assess the penetrometer for detection of microstructural properties of the regolith such as particle size (see fig. 5) and mass and make recommendations, building on our previous work, for further refinement of an asteroid penetrometer.

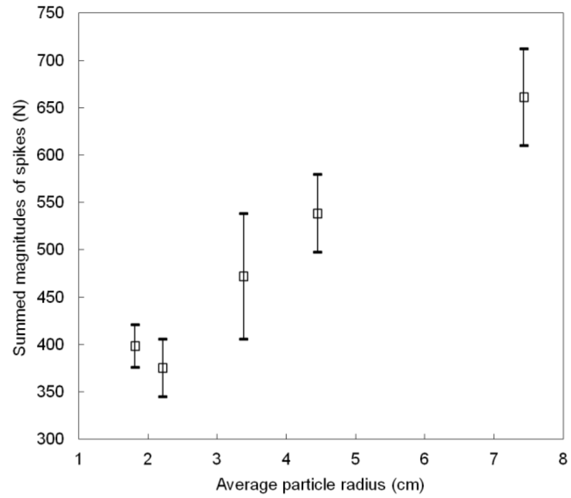

Fig. 5. Increasing peak magnitudes with increasing grain size

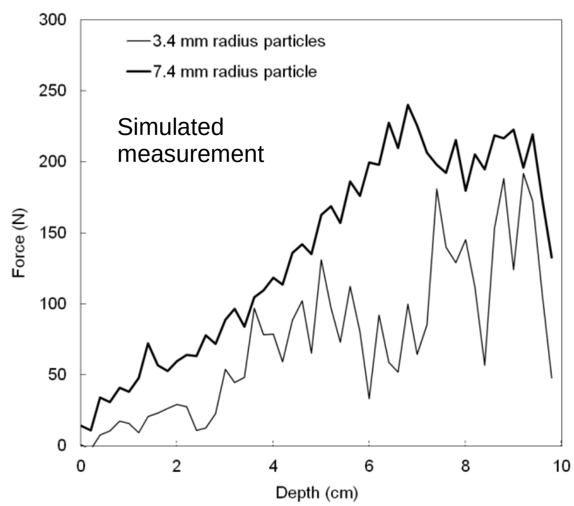

Fig. 6. Combination of microstructural and macrostructural numerical models using modification of model in [3].

References

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