MODELLING AND ASSESSING ROVER-BASED GROUND PENETRATING RADAR TO IDENTIFY AND MAP LUNAR LAVA TUBES.

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Ground penetrating radar (GPR) has been deployed on lunar missions including Chang'E-3, Chang'E-4, and Chang'E-5 [1]. GPR on a rover aids in the characterization of the lunar subsurface without requiring excavation/sampling. GPR has previously been used to survey lava tubes on Earth, including those in Hawaii Volcanos National Park, USA, the Canary Islands, and the Komoriana Cave at Fuji volcano, Japan [2]. The possible existence of lunar lava tubes has significant relevance for developing lunar outposts. Lava tubes are evidenced on the lunar surface by sinuous rilles and 'skylights 'and have been detected by the Lunar Radar Sounder aboard the KAGUYA (SELENE) spacecraft flown by the Japan Aerospace Exploration Agency (JAXA) and NASA's GRAIL mission, which measured the lunar gravity field [3], [4]. To assess whether GPR could be used to identify and determine the spatial extent of these lava tubes, the conditions were forward-modelled using the software gprMax, which simulates electromagnetic wave propagation using the finite difference time domain (FDTD) method [5]. 3D-models of terrestrial lava tube analogues were used with modified dielectric permittivity and conductivity values for lunar regolith and lunar basalt. These material parameters were obtained from prior lunar missions and are considered realistic. It must be noted that due to low water content in lunar geological settings, GPR penetration depths are far greater than on Earth. This allows to use higher frequencies with smaller antenna sizes and lower payload. GPR frequencies of 50 MHz, 100 MHz, and 200 MHz were used to model wave field propagation and radargrams over 2D and 3D models. In order to simulate noise, Gaussian and exponential random media was generated and added to the dielectric permittivity values to simulate ejecti and natural variability of the lunar geology.

From the resulting GPR radargrams, reflections from the ceiling of the lava tubes were identifiable from visual inspection. Reflections from the floor were, although detectable, relatively obscured by the stronger ceiling reflections, noise, and multiples. Though these forward models are idealized and may not represent reality, the results demonstrate that rover-based GPR is a promising geophysical method for the identification of lunar lava tubes for a wide range of depths and diameters. In addition, GPR profiles across lava tubes could be used as constraints in joint inversions with other lava tube scouting surveys, such as gravimetry.

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