Anchoring a geophysical network around the A33 moonquake nest to explore the interior structure and thermal evolution of the Moon. W. D. Poole[1], B. Tian[2], R.A. French[3], J. Garber[4], J. J. Barnes[5], P. H. Smith[5], D. A. Kring[6]. [1]University College London – Mullard Space Science Laboratory, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK (william.poole.10@ucl.ac.uk), [2]University of Toronto, Ca, [3]Northwestern University, USA, [4]University of California Santa Barbara, USA, [5]Open University, UK, [6]Center for Lunar Science and Exploration, Universities Space Research Association–Lunar and Planetary Institute,

Introduction: The International Lunar Network (ILN) Report (2009) [1] suggested using moonquake nests as a method for determining the size and state of the core. Two seismometers would be required [1]: (1) located near the epicentre of a moonquake nest and (2) very near the antipode of the seismic source. Most well-constrained moonquake nests are located on the nearside, with a corresponding antipode on the farside. However, this could be a result of the distribution of the seismic stations set up under the Apollo program [2], which are all on the nearside and therefore would have difficulty detecting farside moonquakes. An exception is the A33 moonquake nest, which is a well-constrained farside moonquake nest located near the eastern limb [3]. This provides a useful opportunity to anchor a geophysical network which has two stations in direct communication with Earth. If a seismometer were deployed within 60° of A33 and at the antipodal point of the moonquake, then it could accurately determine the size and state of the core while also being on the near side of the Moon where line-of-sight communication is possible. Moreover, that limb of the Moon is also the optimal location for a Lunar Laser Ranging (LLR) station needed to constrain the characteristics of the lunar core.

A geophysical station anchored by the A33 moonquake nest could form part of a wider geophysical network that addresses all of the geophysical goals identified by the National Research Council's (NRC) report *The Scientific Context for Exploration of the Moon* [4]. As outlined elsewhere in [5], there is a large range of potential network configurations. Here, we take a closer look at a subset of those networks that is anchored by the A33 moonquake nest and investigate the implications that has for the locations of other stations in the network.

Geophysical Package: To address the goals in the NRC (2007) report, each station in the network would contain (1) a seismometer, (2) a heat flow probe, (3) an electromagnetic (EM) sounding experiment, and (4) LLR at stations visible from Earth. The technical rationale for that series of instruments is discussed in [5].

Landing Site Selection: The optimal network configuration involves four or more stations [1]. If one of them is anchored within 60° of the A33 moonquake nest and another at the A33 antipode, then the best science will be obtained by ensuring that stations are distributed amoung each of the four lunar terranes [6]. Furthermore, the best data will be obtained by seismometers and heat flow probes that are not placed near: terrane boundaries [6]; basin rims; significant concentrations of impact ejecta; unusually thick or thin crust; and on slopes >20° (due to concentrated heat flow). An initegration of all these constraints produces a limited distribution of station locations on the lunar surface, as shown in Figure 1.

EM sounding should be carried out at each of the stations, but has no additional constraints in terms of station location. All nearside stations, in this case the stations within 60° of A33 and at the antipode, should have LLR experiments.

Discussion: In Figure 1, we outline the area within 60° (red line) of the A33 moonquake nest (red star). That region encompasses three different terranes (Feldspathic Highlands Terrane – Outer (FHT-O) in blue, Feldspathic Highland Terrane – An (FHT-A) in pink, and, near the southwestern margin, the South Pole-Aitken basin terrane (SPAT) in orange). However, only the FHT-O region is on the nearside, where the station needs to be located for direct communication with Earth. A station also needs to be placed at the antipode, which is the region outlined with a green line. That region encompasses the Procellarum KREEP terrane (in green). Suitable station locations within the required distance of the A33 moonquake nest and antipode are highlighted with bright blue and green dots in the FHT-O and PKT regions, respectively. Matching locations in the other two terranes that produce an acceptable tetrahedral configuration are highlighted with bright pink and orange dots. Stations in these terranes will not have a direct line of sight with Earth, and would require an orbital communications relay capability. To be effective, all stations need to be operating simultaneously for a significant period of their lifetime. Each colored dot has only one corresponding landing site in each of the other terranes (other colored dots) whilst maintaining this tetrahedral configuration, and ensuring that each site is within suitable terrane given the constaints outlined above. These configurations allow for a basic understanding of the interior of the Moon to be developed on a global scale.

These suggested station locations would take advantage of existing LLR locations set up under the

Apollo and Lunokhod programs. However, the latitudinal extent of the network is not much improved, so we suggest that, in an ideal case, an additional geophysical package be placed at high latitudes in the southern hemisphere.

To fully understand the structure, composition, and thermal evolution of the Moon's interior by augmenting these geophysical measurements with samples returned to Earth, as discussed fully in [8]. Many of the suitable sample sites are in the same areas that are suitable for the geophysical stations described here. Potential sample return sites include those within the PKT (green in Figure 1), which are locations near mare flow intersections and 3.0-3.6 Ga mare within sinuous rilles and crater walls, which can help further our understanding of the mantle and thermal evolution of the interior, respectively. Locations where olivine has been detected, also useful for determing mantle composition and other mare deposits in crater walls, are also found near the stations within the FHT-O (blue in Figure.1). The nature of understanding crust composition and lateral variability means that sample return sites do not coincide with the geophysicical sites set out here, as impact craters large enough to reveal low crust also form anomalously thin crust.

By placing additional geophysical packages where sample return is conducted, specifically over abnormally thick or thin crust, more complex models of crustal thickness can be developed. Additional, seismometers will also help identify and locate shallow moonquakes which may reveal information regarding upper mantle structure, and further our understanding of how differences within crustal thickness can affect heat flow.

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References: [1] International Lunar Network Report (ILN) 2009. [2] Toksöz, M.N. *et al*. Structure of the Moon. *Reviews of Geophysics and Space Physics* **12**, 539-567 [3] Nakamura, Y., 2005, JGR. [4] National Research Council (2007) *The Scientific Context for Exploration of the Moon*, final report. [5] Tian et al. *This LPSC, Abstract #1629.* [6] Jolliff et al, 2000. JGR. [7] Zuber, M., 2008. *37th COSPAR Scientific Assembly*, 3658. [8] French *et al. This LPSC*

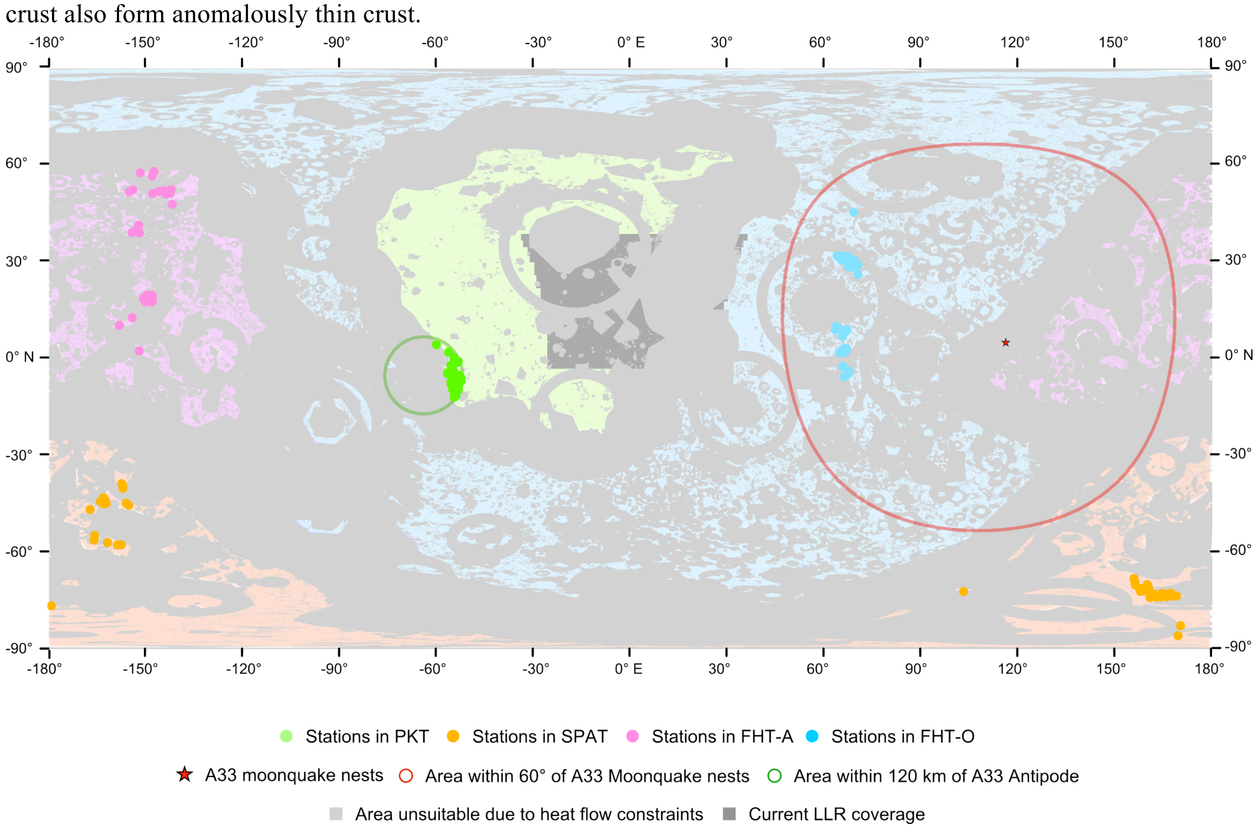

Figure 1. Map showing potential landing sites for a four station geophysical study of the Moon which addresses Concept 2 of [1]. Each colored dot has a corresponding landing site in each of the colored tarranes. The region in light grey are regions which are removed due to constraints on the emplacement of heat flow experiments, whilst those in dark grey are removed as they offer no extension of the current LLR network should a geophysical package be placed there. PKT, SPAT, FHT-A, and FHT-O refer to terranes of [6].