IDENTIFYING LUNAR LANDING SITES FOR SAMPLING LOWER CRUST AND MANTLE MATERIAL. P. Sharma[1], J.F. Blanchette-Guertin[2], C. E. Jilly[3], J. Flahaut[4], A. L. Souchon[5,6] and D. A. Kring[7], [1]Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd, Tucson, AZ 85721 (psharma@lpl.arizona.edu), [2]Earth and Ocean Sciences Department, University of British Columbia, Vancouver BC V6T 1Z4, Canada, [3]Hawaii Institute of Geophysics & Planetology, University of Hawaii at Manoa, Honolulu, HI 96822, [4]Laboratoire des Sciences de la Terre, UMR CNRS 5570, Ecole Normale Supérieure de Lyon, Villeurbanne, France, [5]DTP/IRAP, Observatoire Midi-Pyrénées (OMP), CNRS, Toulouse, France, [6]Observatoire Midi-Pyrénées (OMP), Université Paul Sabatier (UPS), Toulouse, France, [7]Lunar and Planetary Institute, Houston, TX 77058.

Introduction: Although the Earth's Moon is one of the most extensively studied planetary objects in our solar system, our state of understanding of its composition and interior structure is still quite inadequate. In 2007, the National Research Council (NRC) published a report entitled *The Scientific Context for Exploration of the Moon* that summarized the top science concepts for future lunar exploration [1]. One of the concepts (#3) in this report is to use the diversity of crustal rocks to investigate key planetary processes. Specific objectives include determining the composition of the lower crust and/or mantle and to evaluate factors related to planetary differentiation. To help implement that exploration program, we conducted a global survey to determine where the lower crust and/or underlying mantle may be exposed at the surface.

Methodology: Our study is based on an indirect way of quantifying the vertical and lateral heterogeneity of the lunar crust, relevant to the aforementioned science goal, by considering impact craters as natural drills that sample material from layers deep within the Moon's interior. Large complex impact craters and impact basins have the capacity to excavate or uplift material from the lower crust and upper mantle. We examined all the complex craters and impact basins listed in the Lunar Impact Crater Database to determine where on the Moon that material might be found by crew and/or robotic spacecraft.

Excavation depth: Using the Maxwell Z-model for excavation flow [2] and assuming a 45º impact angle for Z=3, the maximum depth of excavation (D_e) is found to be about 1/3 the final transient crater depth (D_{td}) [3].

$D_e = D_{td}/3 = D_{tc}/10$; all parameters in km, D_{td} :transient crater depth, D_{tc} :transient crater diameter (1)

Depth of melting: We calculated depth of melting (D_m) corresponding to each crater to determine if the mantle and/or lower crust are chemically represented in the melt emplaced at the surface by the impact event. We also used that value to determine the depth of material that might be exposed in central peaks, assuming the maximum depth of melting is equal to the minimum depth of origin for central peaks [4]. Eq. 2, derived through curve-fitting of Fig. 22 on page 907 of Cintala and Grieve (1998), was used to calculate the depth of melting (D_m) corresponding to each crater. This equation has also been used in other publications [5,6] for calculating the melt depth.

$D_m = 0.109D^{1.08}$; all parameters in km, D = final rim diameter
(2)

Determination of average pre-impact lunar crustal thickness. To determine if the material excavated by a crater sampled the lower crust and/or mantle, we had to integrate analyses of individual craters with the models of crustal thickness where those impacts occurred. For this study, we used crustal thicknesses derived from models based on Clementine topography and Lunar Prospector gravity [7]. There are three crustal thickness models, two of which are single-layered and one is dual-layered. We considered estimates from all of these models in our study.

We could not use the crustal thickness directly underneath the center of each crater, since it represents the thickness after the impacts in question. We therefore needed an estimate of the pre-impact crustal thickness to accurately evaluate crust-mantle materials affected by the impact events. To calculate the average pre-impact crustal thickness corresponding to each crater in the Lunar Impact Crater Database, we took an average of the crustal thickness corresponding to pixels located at a distance of ±10% of a crater diameter distance from the rim (Fig. 1).

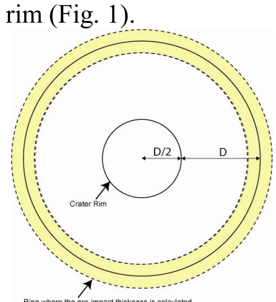

Fig. 1. Calculation of pre-impact crustal thickness

We compared the excavation depth and the maximum depth of melting with the crustal thickness at each of the crater locations to determine if the material in the ejecta blanket/central peak comes from the upper crust, lower crust, or the mantle (similar to the calculations performed in [5]) (Fig. 2).

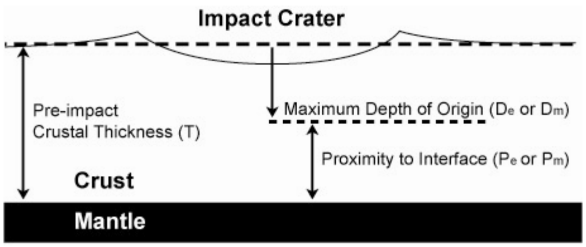

Fig. 2. Comparing maximum depth of origin with pre-impact crustal thickness (figure adapted from [5])

Results: Following computations involving 3480 craters in excess of 20 km in diameter from the Lunar Impact Crater Database, we determined that up to 36 may have excavated material from the lower crust and 2 may have excavated material from the upper mantle. A much larger number may have melted the lower crust (128) and the mantle (39) and distributed that material in ejecta blankets and interior crater melt deposits (Table 1).

	Number of craters	
	Single-layered	Dual-layered
lower crust excavation	x	36
mantle excavation	3	2
lower crust melt	x	128
mantle melt	40	39

Table 1

Interestingly, these sites are geographically distributed across the entire lunar surface (Fig. 3), which has two implications: First, these craters will be able to determine if the composition of the lower crust and upper mantle are everywhere the same or if, instead, they are laterally heterogeneous. Second, one may be able to determine the composition of the lower crust and upper mantle at locations suitable for other science priorities and, thus, enhancing the scientific return for these mission sites.

It is to be mentioned here that we did not include the South Pole-Aitken basin in these calculations since the equations used are not valid for a large impact basin of the size of SPAB. However, we understand that the SPA basin would expose material from the lower crust and probably the mantle also.

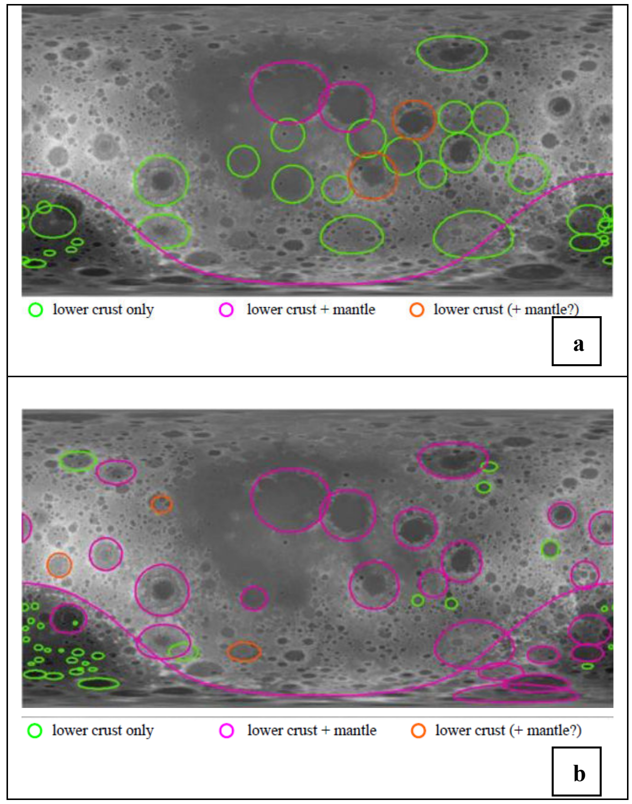

Fig. 3. Global maps of landing site locations where lower crust and/or mantle might be exposed in (a) ejecta blankets and (b) central peaks or peak rings

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