Neotectonics on the Lunar Nearside. A. Valantinas[1] and P. H. Schultz[2], [1]Niels Bohr Institute, University of Copenhagen, [2]Department of Earth, Environmental, and Planetary Sciences, Brown University.

Introduction: It is thought that lunar mare-related tectonics are strongly associated with extensional and compressional stresses caused within the mare basalts, which ceased from 3.6 Ga to 3.0 Ga ago [1,2] with some as recent as 1.2 Ga ago [3]. Later studies however, showed signs of younger tectonics like small lobate scarps and graben which were determined to be less than 100 Ma in age [4-6]. Individual examples of possibly even younger and still active tectonic features known as wrinkle ridges were documented from Lunar Orbiter photographs [**7**], but the global extent of such regions still ongoing modification could not be determined due to limited coverage. Here, we identify globally active tectonic regions of wrinkle ridge assemblages using Lunar Reconnaissance Orbiter data. Freshly exposed boulder outcrops, crisp morphologies, significantly low crater densities and small crater cross-cutting relationships suggest that some wrinkle ridges are very young and still ongoing modification. A majority of our analyzed active wrinkle ridges are outside of mascon basins and spatially correlate with ancient deep seated dike intrusions in the nearside of the Moon [8]. These findings reveal an Active Nearside Tectonic System (ANTS) and a state of lunar interior which may not be explained alone by global contraction.

Results: The Lunar Reconnaissance Orbiter (LRO) Diviner radiometer data and high resolution LRO Narrow Angle Camera (NAC) images allow documenting globally over 500 individual wrinkle ridge segments (see **Fig. 1**) with varying degree of rockiness. The widespread abundance of boulders on wrinkle ridges can be clearly observed in LRO Diviner thermal infrared boulder abundance maps [9] (**Fig. 2a**). Individual exposed patches vary from few meters to several hundred of meters in size and form either continuous regions or break into several segments along the wrinkle ridge (**Fig. 2b**). Some patches are covered with thin regolith layer, whereas others are completely fresh, which seems to indicate of an ongoing exhumation. All boulder outcrops contain only a few craters, which suggest that boulder excavation is faster than their degradation via meteorite bombardment.

In this study various morphologies of active wrinkle ridges were identified. Small wrinkle ridges (~50 m in width) have crisp morphologies with abundant boulders and crosscut small craters (e.g. **Fig. 3**). Larger wrinkle ridges sometimes form complex structures and include youthful morphologies like the ones seen in eastern Mare Serenitatis (**Fig. 4a**). Boulder outcrops are observed both on slopes and on very low relief topography (<2 degrees). In some cases, boulder fields occur on top of wrinkle ridges, rather than talus along an abrupt break-in-slope (**Fig. 4c**). In this case, either the rate of formation exceeds the rate of regolith development or the regolith drained into small fractures created by the buckling mare basalt below. Small graben on top of some wrinkle ridges require a component of extensional forces during the recent thrust faulting (**Fig. 4b, 4c**).

Discussion: Wrinkle ridges that comprise the ANTS (as well as those along the edges of mare-filled impact basins) indicate of an active Moon. However, wrinkle ridge systems following the ANTS require a mechanism other than mascon-controlled sagging and could be surface expressions of ongoing reactivated faults, a conclusion supported by the discovery of deep seated ancient intrusions by GRAIL [8]. Origin of these crustal weaknesses could be related to the event responsible for the structural and geochemical lunar asymmetry: off-set antipodal effects of the SPA forming impact [10] or the 'Procellarum basin' impact [11]. The latter possibility, however, seems inconsistent with the observed distribution and the results of GRAIL [8]. Apollo seismometers indicated shallow moonquakes perhaps due to crustal weaknesses [12] but the loss of the seismometers preclude further correlations. Morphologically young wrinkle ridges and associated surface expressions in our study could be a signature of strong moonquakes in the recent past.

Wrinkle ridges not only should be a target for future exploration in terms of lunar seismicity but also an area of interest for sample collection. Exposed boulders on wrinkle ridges contain the original *in-situ* bedrock material of lunar basalts which was not available for Apollo astronauts. In addition, the identification of young tectonic features indicative of ongoing moonquakes speak to the need for a global seismic network in order to understand the interior, intensity, frequency, of (and even possible risks from) current seismic activity.

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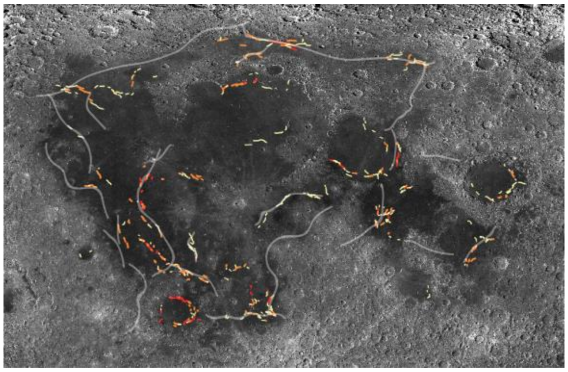

Figure 1. A global map of wrinkle ridge segments that contain abundant boulders patches and make up the Active Nearside Tectonic System (ANTS), shown on the WAC mosaic. The highest boulder abundances marked in red, the lowest in yellow. These regions are visible in the thermal infrared Diviner boulder abundance map [9]. Overlain with deep seated intrusions discovered by GRAIL (white lines) [8].

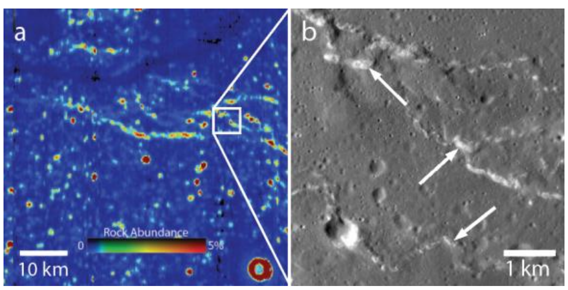

Figure 2. Wrinkle ridge system in northern Mare Humorum as seen in Diviner thermal infrared boulder abundance map (a) and a NAC image close up of one region (b). Low relief ridges are exposing several boulder patches (white arrows).

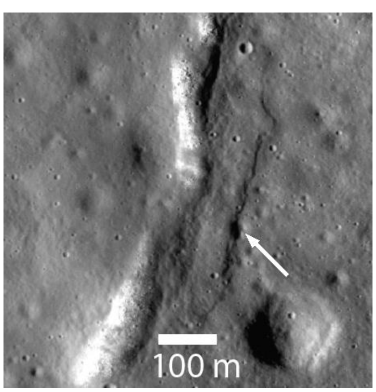

Figure 3. A segment of a rocky wrinkle ridge in Marius Hills (NAC image). A second order wrinkle ridge cross cutting a small 25 m crater (white arrow).

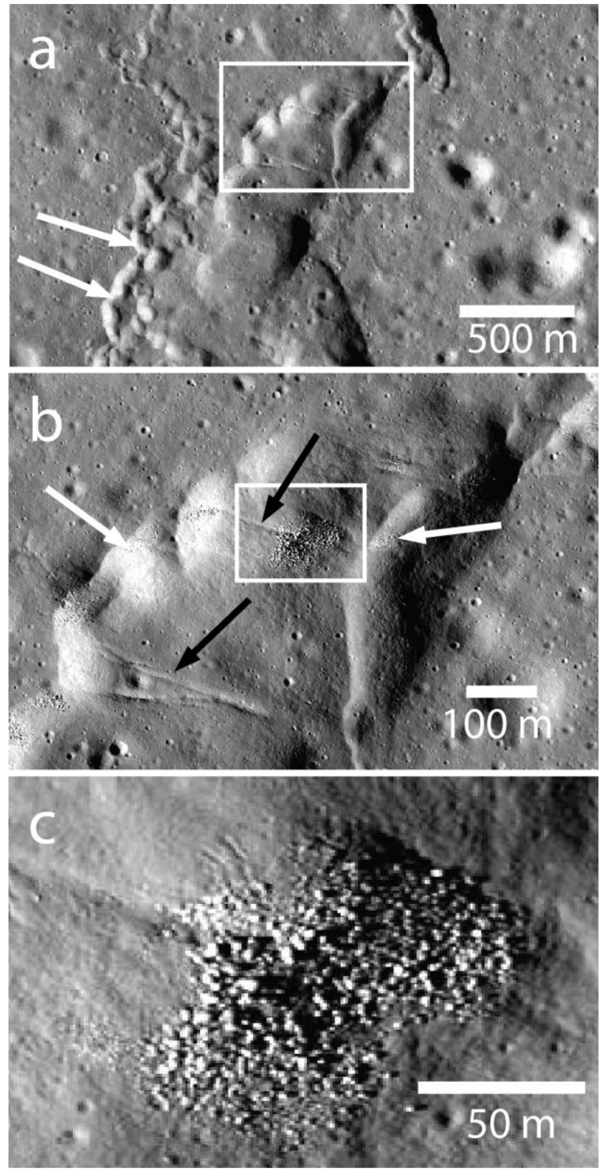

Figure 4. A large wrinkle ridge in eastern Mare Serenitatis (a) and several exposed boulder patches (white arrows). A close up of the area (b) which includes small pristine graben (black arrows) and exposed boulders on slopes (white arrows). A small boulder patch on top of a ridge overlaying a 10 m graben (c). NAC image frame.