TWO TECTONIC LANDFORMS FROM LUNAR RECONNAISSANCE ORBITER CAMERA DIGITAL TERRAIN MODELS. N. R. Williams[1], M. E. Pritchard[1], J. F. Bell[2,4], T. R. Watters[3], M. E. Banks[3], M. S. Robinson[4], T. Tran[4], and the LROC team, [1]Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853 USA (nrw22@cornell.edu), [2]Department of Astronomy, Cornell University, Ithaca, NY 14853 USA, [3]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA, [4]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85251, USA.

Introduction: Lobate scarps and wrinkle ridges are two forms of contractional tectonic landforms expressed on the Moon's surface [1]. Wrinkle ridges with up to hundreds of meters of relief are associated with contraction and subsidence of basalt filling the mare basins, and are interpreted as folds associated with blind thrust faults. Conversely, young lobate scarps with typically only tens of meters of relief are found globally and interpreted as thrust fault scarps resulting from global thermal contraction [2]. Subsurface fault geometries and mechanical properties of the lithosphere are poorly understood [1-3,5,8]. Radial contraction of the Moon can be inferred from the contraction across lobate scarps globally and is estimated at ~100m [1-3,14]. Topography derived from Lunar Reconnaissance Orbiter Camera (LROC) stereo images provides new insights and constraints on the mechanics and kinematics of the formation of tectonic landforms on the Moon. Relief, morphology, and regional context are described for two landforms and discussed for implications to subsurface geometry.

Data and methods: LROC consists of two Narrow Angle Cameras (NACs) and one Wide Angle Camera (WAC). The NACs acquire images with resolutions as high as 50 cm/px across an approximately 5 km swath, whereas the WAC acquires images with a coarser resolution of ~100 m/px but a wider field of view for regional and global contexts [16]. LROC obtains stereo NAC images when the spacecraft rolls for an oblique viewing geometry. High-resolution (2 m/post) digital terrain models (DTMs) are extracted from these stereo pairs and tied to the Lunar Orbiter Laser Altimeter (LOLA) reference frame [17].

For this study, two DTMs are examined: one for a lobate scarp in Slipher crater, and a second for a wrinkle ridge in Kugler crater that transitions to a lobate scarp outside the crater. Topographic profiles are selected perpendicular to the trace of the landforms in the DTMs. WAC and LOLA [6] global mosaics are also utilized to determine regional context.

Results: The Slipher scarp occurs on a slump bench in the Slipher crater wall (48.3°N, 160.6°E). The scarp is crisp and relatively undegraded by impact craters, and has up to 23 m of relief (Fig. 1). This is similar to the average lunar scarp relief of ~25 m [1,3,7], but it is an order of magnitude smaller than those found on Mercury [9-12] and Mars [13]. The scarp verges up-slope on the slump, indicating thrust motion with an approximately northward dip (Fig. 2). Several segments of the scarp branch off in a splay, while others conjoin to create the primary scarp front. The Slipher scarp may be a continuation of a larger series of parallel and sub-parallel lobate scarps to the east in the crater D'Alembert, but more NAC images are needed for this to be confirmed.

The Kugler-Anuchin wrinkle ridge crosses the floor of Kugler crater (53.8°S, 103.7°E) and transitions into a lobate scarp to the north where it intersects the crater wall. The DTM for this landform only covers the southern-most portion of the wrinkle ridge (Fig. 3). It shows a heavily cratered and highly degraded two-step topographic rise over 300 m high, typical for lunar and other planetary wrinkle ridges [1,8,12]. The ridge front produces a local high followed by a gentler slope rising to the west, raising that side of the Kugler floor (Fig. 4). A listric or décollemont geometry may be responsible for lunar wrinkle ridge development as has been shown for similar wrinkle ridges on Mars [5].

Summary and discussion: The Kugler wrinkle ridge and Slipher lobate scarp, both contractional tectonic landforms, exhibit contrasting characteristics and faulting geometries consistent with analogous lunar and planetary tectonic landforms. The Slipher scarp is an order of magnitude smaller than the Kugler wrinkle ridge and exhibits crisper morphology. The high-resolution DTM profiles provide topography at unprecedented resolutions to observe the morphologies and better constrain fault deformation models. We plan to model faults associated with the Slipher scarp and the Kugler wrinkle ridge using elastic dislocation modeling where slip on rectangular fault planes can predict surface deformation [4]. Fault dips, maximum depths, and the amount of slip can be varied and the predicted deformation compared to these topographic profiles [5].

References: [1] Watters T.R. and Johnson C.L. (2010) in *Planetary Tectonics*, Cambridge Univ. Press, 121-182. [2] Watters T.R. et al. (2010) *Science, 329*, 936-940. [3] Binder A.B. and Gunga, H.C. (1985) *Icarus, 63*, 421-441. [4] Okada Y. (1992) *Bull. Seismol. Soc. Am.*, 82, 1018–1040. [5] Watters T.R. (2004) *Icarus*, 171, 284-294. [6] Neumann G.A. (2009) *NASA PDS*, LRO-L-LOLA-4-GDR-V1.0. [7] Banks M.

E. et al. (2011) *LPS XXXXII* (this conference). [8] Schultz, R.A. (2000) *JGR*, 105, 12,035-12,052. [9] Strom R. G. et al. (1975) *JGR 80*, 2478. [10] Watters T. R. et al. (2009) *Earth Planet. Sci. Lett.*, *285*, 283. [11] Solomon S. C. et al. (2008) *Science*, *321*, 59. [12] Watters T. R. and Nimmo F. (2010) in *Planetary Tectonics*, Cambridge Univ. Press, 15–80. [13] Watters T. R. (2003) *J. Geophys. Res*., *108*, 5054. [14] Pritchard, M. E. and Stevenson, D. J. (2000) in *Origin of the Earth and Moon*, University of Arizona press. [15] Mueller K. and Golombek, M. (2004) *Annu. Rev. Earth Planet. Sci.,* 435-464. [16] Robinson M. S. et al. (2010) *Space Sci. Rev.*, *150*, 81-124. [17] Smith, D. E. et al. (2010) *Space Sci. Rev.*, 150, 209.

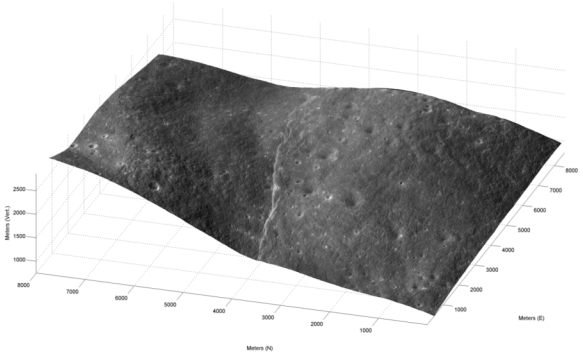

Figure 1: Oblique view along trace of Slipher scarp on a crater wall slump/bench. Topography from LROC NAC DTM M123514622/M123521405, image overlay from LROC NAC M123521405. No vertical exaggeration, lighting from left, image axes 8km x 8.5km x 2km.

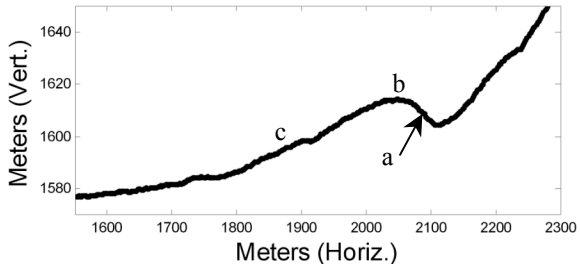

Figure 2: Profile across Slipher scarp verging uphill from shallow bench (left) onto crater wall (right). Scarp consists of a steep scarp face (a), local topographic high (b), and gently sloping back scarp (c). Vertical exaggeration = 4.

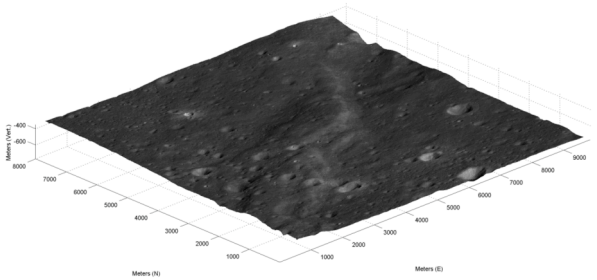

Figure 3: Oblique view along trace of Kugler-Anuchin wrinkle ridge (arrows) on a crater floor. Topography from LROC NAC DTM from M126248295/M126255083, image overlay from LROC NAC M126248295. Vertical exaggeration = 2, lighting from right, image axes 8km x 9.8km x 350m.

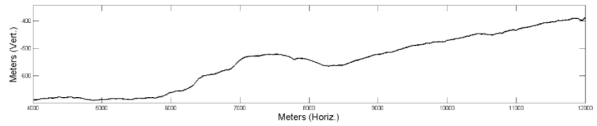

Figure 4: Profile across Kugler wrinkle ridge on the floor of Kugler crater. Horizontal axis 12km, vertical axis range 350m, vertical exaggeration = 4. The ridge front produces a local topographic high (center), followed by a step and shallower rise to the West (right).