

Tectonic Mapping of Mare Frigoris Using Lunar Reconnaissance Orbiter Camera Images

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Conventional wisdom has been that extensional tectonism on the Moon largely ended ~3.6 billion years ago and that contractional deformation ended ~1.2 billion years ago. New NASA Lunar Reconnaissance Orbiter Camera (LROC) high resolution images are forcing a re-assessment of this view. Mapping in Mare Frigoris and the surrounding area has revealed many tectonic landforms enabling new investigations of the region's structural evolution.

Sinuuous wrinkle ridges with hundreds of meters of relief are interpreted as folded basalt layers overlying thrust faults. They have often been associated with lunar mascons identified by positive free-air gravity anomalies where thick basaltic lava causes flexure and subsidence to form ridges. No mascon-like gravity anomaly is associated with Mare Frigoris, yet large ridges deform the mare basalts. Lobate scarps are also found near Frigoris. These asymmetric linear hills inferred to be surface expressions of thrust faults are distributed globally and thought to originate from cooling and radial contraction of the lunar interior. Clusters of meter-scale extensional troughs or graben bounded by normal faults also occur in Frigoris.

Tectonic landforms are being mapped in and around Mare Frigoris using LROC Narrow Angle Camera (NAC) images. Preliminary results show that wrinkle ridges in Frigoris occur both near and distal to the basin perimeter, trend E/W in western and central Frigoris, and form a polygonal pattern in the eastern section. Several complex wrinkle ridges are observed to transition into morphologically simpler lobate scarps at mare/highland boundaries, with the contrast in tectonic morphology likely due to the change from layered (mare) to un-layered (highlands) substrate. Lobate scarps in Frigoris occur primarily in the highlands, tend to strike E/W, and often but not always follow the boundary between mare and highlands. Small graben mapped in Frigoris occur in several clusters adjacent to or atop ridges and scarps, and are often oriented nearly parallel or perpendicular to the nearest ridge or scarp.

Ridges are generally thought to form shortly after lava emplacement (in Frigoris, ~2.6-3.8 Ga). Conversely, lobate scarps are estimated to be < 1.0 Ga. If deformation across ridge-scarp transitions was concurrent, either a) some wrinkle ridges are younger than previous estimates, b) some lobate scarps are older than 1 Ga, or c) late-stage compression reactivated pre-existing mare ridges near the basin margin and thrust faults extended into the highlands to form scarps. The crisp undegraded morphology of many ridges and scarps, coupled with the presence of shallow unfilled graben, suggest some deformation within Mare Frigoris occurred recently, perhaps within 50 Ma. These new populations of lobate scarps, wrinkle ridges, and graben discovered in Mare Frigoris imply a more complex and longer-lasting history of lunar crustal deformation.