STRUCTURAL GEOLOGY OF THE MISTASTIN LAKE IMPACT STRUCTURE, LABRADOR, CANADA.
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Introduction: The Mistastin Lake impact structure (55°53'N; 63°18'W) is a relatively well-preserved 25–30 km diameter complex impact structure in northern Labrador. It formed within the Mesoproterozoic ~1.4 Ga Mistastin batholith, which is part of the Nain plutonic suite of Labrador [1]. The regional map of the Mistastin Lake area published by Currie in 1971 [2] remains the most detailed map (1:50,000) to date; however, it includes inferred geological boundaries for impact melt rocks based on a volcanic origin interpretation (which has been refuted by all other studies). In addition, little to no structural mapping of the Mistastin structure has previously been conducted. This study presents new structural mapping results of this unique structure, based on fieldwork and satellite images.

Methods: Fieldwork was conducted in 2009, 2010 and 2011 from several different basecamps around the structure. A Digital Elevation Model (DEM) mosaic of Mistastin was generated using standard processing and mosaic techniques for DEMs with the Environment for Visualizing Images (ENVI) v4.8 software. The DEM data was sourced from the Geobase website (http://www.geobase.ca/) and was generated by the Government of Canada, Natural Resources Canada, and the Centre for Topographic Information (CTI), Sherbrooke, Quebec. Shaded relief images from different sun angles were generated, and lineations were mapped on the raster images using ArcGIS v.10. A schematic fault map within and around the Mistastin Lake impact structure to a distance of approximately two crater radii was compiled.

Twenty radial profiles across the impact structure were created in ENVI using the mosaic DEM as the reference image. The profile lines were spaced 22.5° apart, starting from the lakeshore across the highest topographical high and further outward to the distance of three crater radii (~42 km) from the centre. Average profiles were compiled for each 45° segment.

Results: *Morphology.* The Mistastin Lake impact structure is defined by a ~28 km diameter circular, ring of hills surrounding Mistastin Lake that contains two islands in its centre [3]. Based on the DEM generated for this study, the maximum height of this ring ranges from 150 to 350 m above lake level, and is highest in the NW quadrant. The rim is lower in the SW quadrant with a rim height range from 150 to 200 m. An elliptical lake that is elongated in the NE-SW direction covers the inner portion of the impact structure.

The DEM and radial profiles reveal a stepped topography surrounding Mistastin Lake (Fig. 1). Three sloped terraces are defined, herein termed the inner, middle, and outer terrace. The inner terrace surrounds the lake, up to 1 to 4 km radial distance from the lakeshore. It is notably lower in elevation (max ~40 m above lake level) than the surrounding topography, has a gradual slope, has less rock exposures, and has a greater amount of vegetation cover. The outer terrace is defined by a variable slope, is characterised by mounds of exposed rock, ranges in radial width from approximately 4 to 6 km, and is most pronounced in the NW quadrant surrounding the lake.

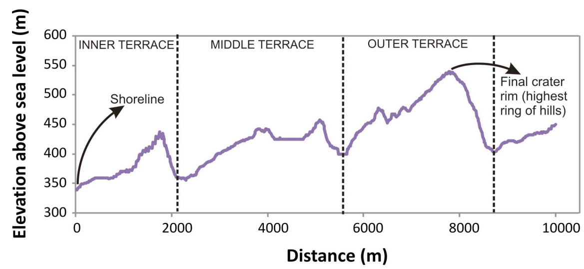

Fig. 1. Example of radial transect showing terraced rim region. Transect starts at the lake shoreline and extends outwards along 260 ° radial line. Three terraces are defined.

Lineations. Regional-scale lineations, outside the ring of hills defining the crater diameter, are tens of km in length and spacing. There are broadly two groups: one set oriented NE-SW parallel to the boundaries of the Grenville province, and a second, later set of parallel, curvilinear regional faults that offset the first set and are concave towards the SW. The density of shorter (<10 km, average ~ 5 km) linear depressions increases within the crater rim, and the outer and middle terraces of the Mistastin structure. Most of these features are parallel to the regional lineations. Some short (<2 km) linear depressions are oriented at different orientations. Within the inner, less rocky terrace, the only lineations observed were alongside the terrace edges.

Glaciation: Scattered glacial crag and tail structures recognized within sun shaded DEM's and by sight from airplane inside and outside the crater rim, are oriented in a SW to NE direction. They are characterized by elongate, streamlined hills consisting of a resistant rock at the high end, and a tapering tail of less resistant rock extending down ice [4]. Within the impact structure Discovery Hill defines a classic crag and tail shape, with a ramp dipping towards the lake in a NE direction. A regional SW-NE glaciation fabric is most prominent in non-rocky areas, such as the lower terrace.

Interpretations and Discussion: *Crater Morphology.* The ring of hills surrounding Mistastin Lake is interpreted as part of the terrace zone and the modified crater rim. The highest and furthest part of the hills, associated with the outermost fault displacement, is interpreted as the apparent crater rim with a diameter of ~28 km, which is consistent with previous work [5, 6]. The two islands, Horseshoe and Bullseye Islands, roughly within the centre of the lake, are interpreted as the remains of the central uplift, characteristic of complex impact structures.

The elongated nature of Mistastin Lake, crag and tail structures, and glacial striations [6] on Horseshoe Island are attributed to the latest glacial event that flowed from SW to NE. Early studies of the Mistastin Lake impact structure, made broad estimates of ~100 m of erosion [7, 8]. These estimates could account for the lower elevation of the crater rim in the SW region, which may have experienced the brunt of glacial advancement within comparatively flat regional terrain. Higher crater rim elevations in other quadrants surrounding the lake could be an effect of differential erosion. Glacier advancement from the SW may have been impeded by the SW portion of the crater rim and been deflected around the crater form. This effect could also explain the much lower erosion estimates (~10 to 20 m) for within the crater rim as reported by [6].

Fault History: There are two main factors to consider when interpreting fault patterns and the tectonic history of impact craters: 1) target lithology (e.g., crystalline or sedimentary target), and 2) the presence of pre-existing structures (e.g., faults). Similar to the 18 km diameter El'gygytgyn impact structure that formed in volcanic rocks, the density of faults within the Mistastin impact structure, gradually decreases outwards from the crater [9] and curvilinear faults concentric to the crater form are rare. In contrast, impact structures within sedimentary target rocks, such as the Ries and Haughton impact structures, exhibit well-developed concentric listric faults that offset earlier linear, radial faults [10].

Long, km-scale, regional lineations outside of the 28 km diameter crater rim are interpreted as pre-impact regional faults, likely related to Grenvillian tectonics, post-emplacement of the Mistastin batholith. Curvilinear regional faults that locally offset the NE-SW at high angles, may also be related to this regional thrusting event. The rectangular and trellised drainage patterns parallel to the regional NE-SW faults beyond the crater rim, are a result of this structural control, typical within massive crystalline rocks [11].

Many of the short lineations within the crater structure parallel to these regional faults, likely represent reactivated faults during the impact event. Other short lineaments at different orientations are interpreted as faults formed during the impact event.

Terraces: The sloped terraces extending up to ~8 km away from the edge of Mistastin lake are interpreted as terraces formed by collapse during the modification stage of crater formation. Boundaries of the terraces are marked by steep changes in elevation, fault patterns, extent of rock exposure, and changes in drainage patterns. The lower terrace is covered in glacial till and is characterized by radial streams controlled by the slope of the terrace, similar to stream patterns observed in other terrestrial impact structures [12]. The chaotic nature of the streams in the inner terrace is likely the result of glaciation [11]. Faults in the inner terrace were only observed on an outcrop (m) scale. The middle and outer terraces are rocky, and are marked by faulting.

The extent of each terrace is apparent on a hill shaded, colourized DEM; however, continuous, clearly defined, curvilinear faults are not evident. Instead, short lineations, typically parallel to regional faults, mark the boundaries of terraces. This observation supports the common interpretation that large fault networks often arise from the linkage of much smaller faults [13]. The result is that the terraces likely comprise many small (10 to 100s of m) blocks, rather than continuous ledges. This is supported by differences observed in radial transects. Displacement of blocks is difficult to determine because of homogenous nature of target rock, no stratigraphy or contact relationships to help mark movement.

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