POSSIBLE VOLCANIC AVALANCHE DEPOSIT NORTH OF GALE CRATER. J.J.C. Churchill[1], M.E. Schmidt[1], J.A. Berger[2], F. Fueten[1], L.L. Tornabene[2], L.E. Vargas[1] and J. Walmsley[1] [1]Dept. Earth Sci, Brock University, St. Catharines, ON, Canada L2S 3A1, [2]Dept. Earth Sci, Univ. Western On, London, ON, Canada, N6A 5B7, jc09qt@brocku.ca

Introduction: Volcaniclastic sediments have been identified in Gale Crater by the Mars Science Laboratory rover, *Curiosity* [1]. These sediments likely derive from the Gale Crater rim and Peace Vallis catchment [2]. Here we describe an unnamed landform ("North Gale landform"; Fig. 1) located to the north of Gale Crater and outside the present-day catchment that may represent a possible source feature for some of these sediments. We further propose that the landform may be volcanic in origin, .

Methods: High resolution images from Mars Reconnaissance Orbiter's (MRO) Context Camera (CTX) datasets [3] were used to identify morphologic features, structures and units related to the North Gale landform. CTX digtal elevation models (DEM) [3] and High Resolution Stereo Camera (HRSC, Mars Express) DEMs [4] were used to extract elevation profiles of the landform. Mars Orbital Laser Altimeter (MOLA, Mars Global Surveyor) [5] MEGDR elevation data was used for finding regional elevation (Fig. 1) as well as for identifying craters in the region (Fig. 2). Terrestrial volcanoes were measured using Google Earth elevation data (Fig. 3).

Physical Description: It is an arcuate, quasi circular landform with a 40.6 km diameter and a maximum relief of 3.2 km above the surrounding terrain (terrain elevation of approximately -2700 m). It features a large amphitheater (25 km) that opens to the southeast with what appears to be a dissected surface morphology. The landform is surrounded by steep talus slopes (28-34°). A sediment gravity flow (~2 x 5 km, possibly a slump or debris flow) is found on the north side. There are several radial spurs on the outside of the landform that may be dikes. Other landforms in the vicinity may be of volcanic origin, including a pit chain and chaos terrain [6].

This landform is distinct from other dichotomy boundary landforms (mesas, buttes, etc.). For example, Nepenthes Mensae contains a mix of smaller rounded hills and resistant, capped mesas (~3-10 km diameter). Also, Aeolis Mensae east of the landform is a tableland feature with a resistant capping unit. The mesas can be larger (~30-70 km across), but are shorter (up to 2 km high) with near orthogonal margins, whereas the North Gale landform is more rounded. The mesas also lack the radial spurs and collapse features (amphitheater, large scale talus slopes, or leveed flows).

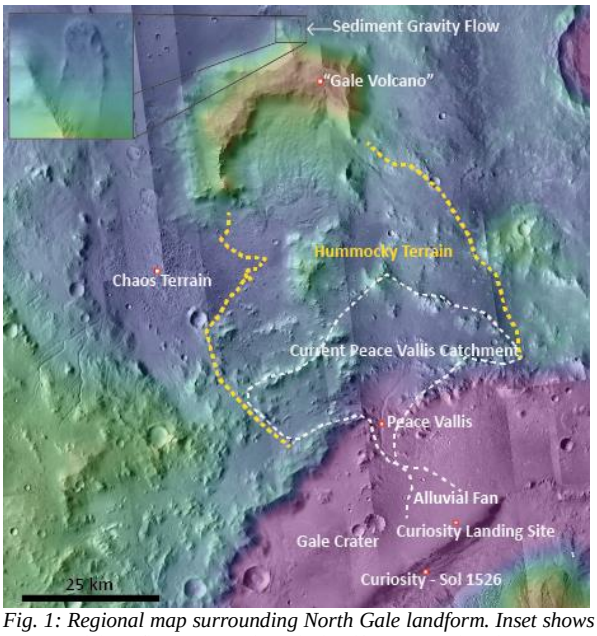

Fig. 1: Regional map surrounding North Gale landform. Inset shows a likely debris flow on North Gale landform's north side. CTX [3] images with MOLA [5] elevation data overlaid.

A Degraded Impact Crater?: The North Gale landform lacks key characteristics of impact craters. The feature sits above the base level of the surrounding topography (Fig. 1, Fig. 2). Impact craters may have elevated rims, but the crater itself sits lower than the surrounding topography except in the case of a pedestal crater. This is not the case for the landform in question; its interior is at the height of the surrounding terrain or higher and the rim is much higher than other craters of comparable size (Fig. 2). There is no evidence of a pre-existing high (e.g., canyon wall, butte, mesa or Southern Highland remnant) and no other landforms north of the dichotomy with a comparable height, such as would be required to create a south-tilting impact crater.

The North Gale landform is surrounded on all sides by talus slopes, slumps and flow deposits (Fig. 1 inset) suggesting that the surface is unconsolidated and not a resistant erosional remnant of a crater. Erosion of the surrounding topography along the dichotomy would be expected to also erode such unconsolidated materials. If it is not an impact, then we suggest the landform is volcanic. Volcanoes are composed of intermixed indurated and friable materials (i.e., lavas and tephras) and are typically mantled by talus and debris aprons.

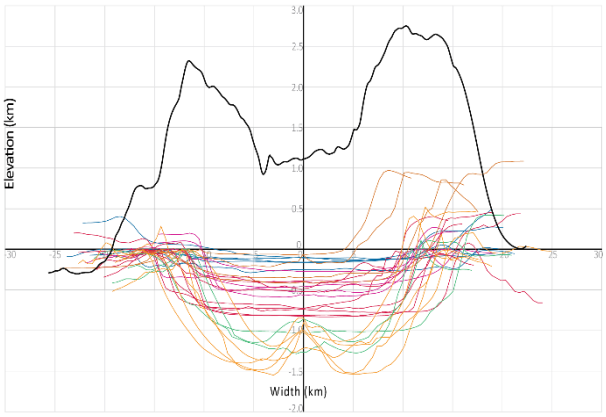

Fig 2: Comparison of the profile of North Gale landform (black, W-E, CTX DEM [3]) with the profiles of nearby craters (N-S, MOLA [5]) of a similar diameter (20 - 30 km). Craters are colored by similar degree of degradation.

Volcanic Debris Avalanche: Terrestrial stratovolcanoes that have experienced sector collapse, including Mt. St. Helens and Bezimianny, have similar profiles along the collapse to the north-south profile of North Gale landform, but a different scale (Fig 3). Features in common include a smooth, steep slope (up to 35°) on one side and a steep amphitheater (also called a collapse caldera, up to 35°), with a rough, tilted floor that flattens with distance on the other side (Fig 3), which are characteristic of large debris avalanches [7].

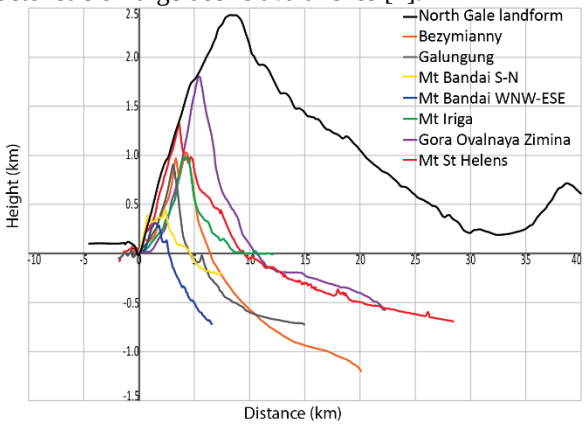

Fig. 3: Profiles of North Gale landform (HRSC [4]) and six terrestrial volcanoes that have experienced major debris avalanches. Profiles were taken along the direction of the debris avalanche.

The terrestrial volcanic examples that have experienced massive debris avalanches are stratovolcanoes, consisting of intermixed lava and tephra, and may suggest that North Gale Landform is also a stratovolcano although no compositional data is available at this time. We note that major submarine flank collapse debris flows occur in Hawaiian shield volcanoes as well [8].

Many local and regional tectonic lineations (e.g., fault scarps, wrinkle ridges, and linear outwash channels) are oriented WSW-ENE, perpendicular to the amphitheater opening. These lineations are consistent with stresses that may cause a preferred orientation to the radial dike swarm and control the direction of collapse [7].

Terrestrial volcanic debris avalanche deposits typically include a hummocky terrain of tilted blocks of volcanic strata and enclosed small basins [7]. An area of hummocky terrain is located between North Gale landform and Gale Crater and the relatively small hills or "hummocks" may be intact blocks of the failed volcanic flank. This hummocky terrain is likely not Gale Crater impact ejecta because it is only found between the landform and Gale Crater and it does not appear in other locations around the crater rim. Some hummocks make up the highs rimming the margin of the present-day Peace Vallis catchment.

We interpret the amphitheater as having been created by a massive debris avalanche because it meets all the requirements for identification of a terrestrial volcanic debris avalanche [7].

Assuming the North Gale landform had a stratovolcano structure that collapsed, we estimate the mobilized volume ranges from 670 to 4700 km^3, depending on the interpreted original height of the landform (4.3 – 13.7 km). A runout efficiency (runout length/descent height) of the debris avalanche of 4 (13.7 km height) to 11 (4.3 km height) would allow the debris flow to reach Gale Crater (58.17 km away); both values are within accepted runout efficiencies for landslides on Mars (2 – 23) [9].

Dating the amphitheater with crater counting is precluded due to the high degree slopes and mass wasting present. Despite these concerns, we estimate a *minimum* age of 1.0 Ga [10].

Implications: 1. North Gale landform is a sector collapse volcano and may represent a newly identified type of landform on Mars. 2. If the landform has undergone a collapse, then sediment from this proposed volcano is a component of the Peace Vallis catchment and may be a source for Gale Crater sedimentary rocks. 3. We advocate for further study of North Gale landform with HiRISE and CRISM to look for surface composition, morphology and identify possible links to the sedimentary rocks observed by *Curiosity*.

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