

**ANOTHER LOOK AT THE SUMMIT CALDERA OF APOLLINARIS PATERA.** N.P. Lang<sup>1</sup> <sup>1</sup>Department of Geology, Mercyhurst College, 501 E. 38<sup>th</sup> St., Erie, PA 16546 (nlang@mercyhurst.edu).

**Introduction:** Highland paterae [1-2] represent one of the most distinctive landforms on the Martian surface. The term patera (paterae if plural) was originally applied to any large, flat-floored depression with irregular margins identified in Mariner 9 and Viking imagery and included volcanoes as well as impact craters [3]. However, highland paterae represent an individual class of patera that is volcanic in origin and concentrated mostly around the Hellas basin region [1-3]. This class of patera includes Tyrrhena, Hadriaca, Amphitrites, and Peneus Paterae and is characterized by very low slopes of  $<1^\circ$  to  $\sim 1.5^\circ$  that are deeply incised by channel complexes which are radial to a prominent central caldera [3-5]. The similar morphologies and characteristics of these four paterae suggest a common origin that, based on the presence of abundant channels that cut into an apparently easily erodible surface, may have included explosive activity with effusive eruptions likely occurring later in their eruptive history [4-5]. They are among the oldest central vent volcanoes on Mars [6-7] and may represent a transition from flood lava eruptions, which dominated the early volcanic history of Mars, to more localized eruptions [4].

Here, I describe a recently started project that addresses the processes involved in the volcanic evolution of Martian highland paterae. These processes include the style(s) of volcanic eruptions, processes involved in caldera formation, and the construction and subsequent erosion of the edifice. Specifically here, I focus on Apollinaris Patera. Although Apollinaris Patera, which is located along the northern lowland-southern highland transition, was not originally classified as a highland patera [i.e., 3; see also, 8], it contains many similar morphologic aspects including a large central caldera and extensively channeled and dissected flanks [8]. Thus, it may have an origin similar to Tyrrhena, Hadriaca, Amphitrites, and Peneus Paterae.

**Motivation:** The broad, low-sloped, heavily channeled flanks of highland paterae make them an intriguing class of central vent volcanoes on Mars [i.e., 3]. Based on crater modeled ages of  $\sim 3.5$  Ga [9-10], they also represent some of the oldest recognized central vent volcanoes on the planet. Therefore, studying highland paterae is critical because they further our understanding of Martian volcanic systems by providing a glimpse into volcanic processes on early Mars. In addition, because the constructs have existed for a majority of the planet's history, they undoubtedly must

have recorded surface processes that have operated on them since their formation including aeolian processes and processes involving volatiles. Thus, highland paterae also provide a window into other surface processes that have operated through time and can potentially help further constrain the planet's volatile history [11]. Furthering our understanding of early Martian volcanism and volatile history is essential to helping unlock and document the evolution of the Martian surface.

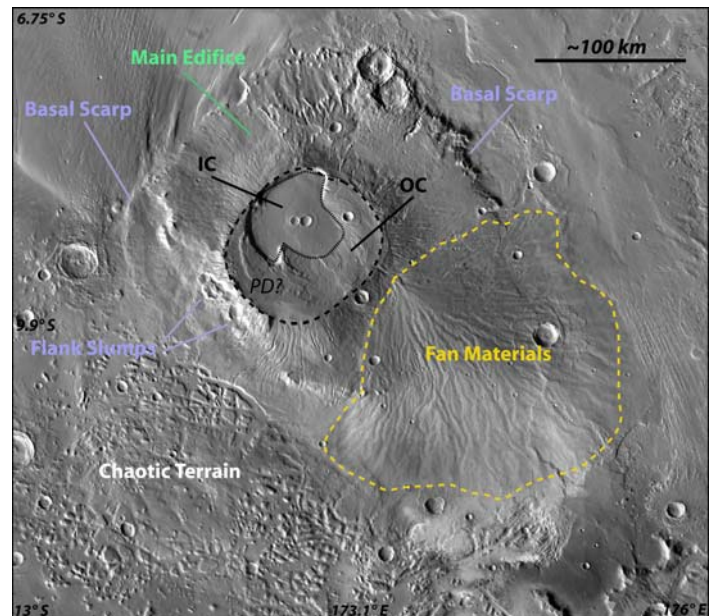
Despite the potential they provide for understanding early volcanic and surficial (i.e., fluvial and/or aeolian) processes, our current perception of highland paterae is based largely on the investigations of only two of these features – Hadriaca and Tyrrhena Paterae (i.e., 4-5, 10, 12). Although [8] and [13] conducted detailed studies on Apollinaris Patera, no significant work has addressed Apollinaris since. This means that highland paterae as a whole represent a relatively little explored class of Martian volcanism, especially in light of recently collected MGS (1997-2006) and MO (2001-present) data. Work by [4] and [5] on Tyrrhena and Hadriaca Paterae, respectively, suggested that highland paterae were built from a series of explosive eruptions that temporally transitioned into more localized, effusive eruptions. [8] came to similar conclusions for Apollinaris Patera [see also, 13]. The occurrence of possibly two distinct styles of eruption (explosive and effusive) raises several critical questions regarding highland paterae. Specifically: 1) *What triggered the explosive eruptions and why the transition to effusive eruptions?* 2) *What were the processes involved in caldera formation?* 3) *What processes have operated on the flanks?* 4) *What was the duration of volcanic activity?* Answering these four questions is necessary to further our understanding of highland paterae.

**Apollinaris Patera summit caldera:** Apollinaris Patera is  $\sim 200$  km in diameter and located along the transition zone between the northern lowlands and southern highlands near  $8^\circ$  S,  $174^\circ$  E, which, in turn, is  $\sim 200$  km north of Gusev crater (Figure 1). [8] divided Apollinaris into four geomorphic units and chaotic terrain. The four units include the main edifice, an outer caldera, an inner caldera, and fan materials. The chaotic terrain is located to the west of the volcano and appears as a series of jigsaw puzzle-like pieces and that are proposed to be related to ice sublimation [14]. The main edifice is roughly circular in planform with slopes of  $\sim 3^\circ$  towards the base and that steepen to  $\sim 5^\circ$  near the summit; much of the base of the main edifice is characterized by a scarp that appears morphologi-

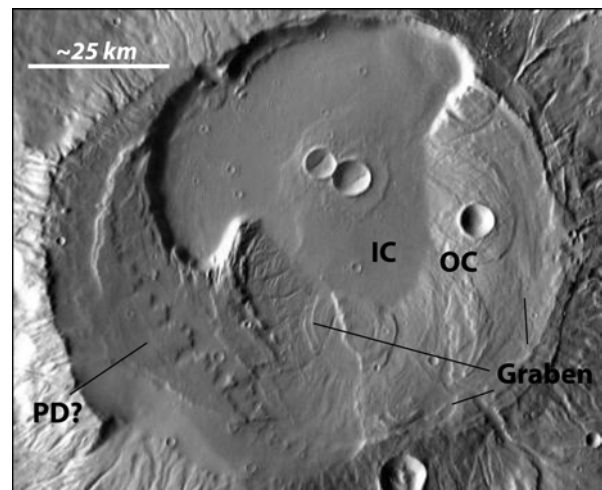
cally similar to the Olympus Mons scarp. Numerous channels that extend from the summit cut the steepest parts of the main edifice. The outer caldera is ~100 km in diameter and is marked by a steep scarp. The floor of this caldera contains deposits that appear to be easily erodible and may represent pyroclastic deposits (Figure 2). These deposits overlie numerous concentric graben that appear to be draped by possible dust deposits. The inner caldera is ~80 km in diameter and is denoted by a scarp along its western margin but is absent along its eastern margin. The inner caldera is much smoother than the outer caldera and, based on relative crater densities, appears to also be younger than the outer caldera; possible pyroclastic deposits present in the outer caldera are absent in the inner caldera. The fan materials extend south from the outer caldera and cover the basal scarp at the southern end of the construct. These materials are interpreted to be effusively erupted deposits [8, 13] and appear to be cut by channels [15], which, in turn, expose numerous layers within the deposits. Crater modeled ages place Apollinaris at ~3.5 Ga [8 and references therein; 16] modeled the fan deposits at ~3.75 Ga.

**Summary:** This project focuses on documenting the structural and volcanic evolution of Apollinaris Patera's caldera. Understanding the evolution of this summit caldera is a critical first step in understanding Apollinaris Patera as a whole because calderas are a surface manifestation of significant internal processes occurring at the volcano including magma chamber formation (i.e., inflation, withdrawal, and resurgence) – processes that may have implications for the physical characteristics of the volcano as a whole. The mechanism(s) that led to caldera collapse and processes that have occurred subsequent to that collapse may leave their mark in the caldera in the form of erupted products (including formation of smaller volcanic edifices), resurgent domes, as well as extensional and contractional structures

**References:** [1] Peterson, 1978, *LPSC*, 3411-3432. [2] Schultz, 1978, *GRL*, 5, 457-460. [3] Greeley and Spudis, 1978, *GRL*, 5, 453-455. [4] Greeley and Crown, 1990, *JGR*, 95, 7133-7149. [5] Crown and Greeley, 1993, *JGR*, 98, 3431-3451. [6] Scott and Carr, 1978, *USGS Map I-1083*. [7] Greeley and Guest, 1987, *USGS Map I-1802B*. [8] Robinson et al., 1993, *Icarus*, 104, 301-323. [9] Greeley et al., 2007, *LPSC*, abs. 1373. [10] Williams et al., 2007, *JGR*, 112, 10.1029/2007JE002924. [11] Mouginiis-Mark et al., 1982, *JGR*, 87, 411-414. [12] Gregg and Farley, 2006, *JVGR*, 155, 81-89. [13] Scott et al., 1993, *USGS Map I-2351*. [14] Carr and Schaber, 1977, *JGR*, 82, 4039-4054. [15] Gulick and Baker, 1990, *JGR*, 95, 14325-14344. [16] Greeley et al., 2005, *JGR*, 110, 1029/2005JE002401.



**Figure 1:** Normalized THEMIS daytime IR image of Apollinaris Patera showing the four morphologic units and chaotic terrain described by Robinson et al. (1993). Dashed white box shows the location of Figure 2. OC = Outer caldera; IC = Inner Caldera; PD? = Possible pyroclastic deposits. Base image from JMars.



**Figure 2:** Normalized THEMIS daytime IR image of the caldera of Apollinaris Patera highlighting the possible pyroclastic deposits (PD?), some concentric graben (Graben), and the inner (IC) and outer (OC) caldera.