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THE GEOLOGY OF CHARON AS REVEALED BY NEW HORIZONS

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Introduction: Pluto's large moon Charon (radius 606 km; $\rho = 1.70 \text{ g cm}^{-3}$) exhibits a striking variety of landscapes. Charon can be divided into two broad provinces separated by a roughly aligned assemblage of ridges and canyons, which span from east to west. North of this tectonic belt is rugged, cratered terrain (Oz Terra); south of it are smoother but geologically complex plains (Vulcan Planum). (All place names here are informal.) Relief exceeding 20 km is seen in limb profiles and stereo topography.

Oz Terra: Charon's northern terrain is exceptionally rugged, and contains both a network of polygonal troughs 3-to-6 km (and more) deep. A dark, reddish diffuse deposit (Mordor Macula) caps the northern polar region. The overall dark deposit of Mordor Macula does not correlate with any specific terrain boundary or geologic unit and has been interpreted as a radiation-darkened deposit of cold-trapped hydrocarbons that originally escaped Pluto's atmosphere [1]. The crater density at large sizes, where counts are reliable, implies a surface age older than 4 Gyr [2]. The structural belt that bisects Charon consists of subparallel scarps, ridges, and troughs of variable extent, but over 200 km wide in places [3]. These canyons (chasmata) can be up to >50 km wide and ~7 km deep, and often exhibit a pronounced rift-flank uplift. These chasmata resemble extensional rifts on several mid-sized icy satellites [4]. We interpret this assemblage as the structural expression of normal faults and graben that represent substantial, aligned, tectonic extension of Charon's icy crust. Several large craters superposed on the chasmata indicate that this extension is geologically old. They represent global areal extension on the order of ~1%.

Vulcan Planum: The smoother southern half of Charon (Vulcan Planum) forms an apparently continuous surface with generally local low relief (but no overall change in global elevation). Near the bounding scarps to the north, the planum slopes gently downward by ~1 km towards the scarps. Fields of small hills (2-3 km across), areas of relatively low crater density, and at least one pancake-shaped unit are consistent with cryovolcanic resurfacing [5]. Peaks surrounded by "moats" (e.g., Kubrick and Clarke Montes) are up to 3-4 km high above the floors of the moats and the moats 1-2 km deep below the surrounding plains. The moat at

Clarke Montes appears to expose a more rugged terrain, with smooth plains embaying the margins, two of which are lobate. In addition to the moats surrounding these mountains, there are two additional depressions surrounded by rounded or lobate margins. We speculate that both the moats and depressions may be the expressions of the flow of, and incomplete enclosure by, viscous, cryovolcanic materials, such as proposed at Ariel and Miranda [5, 6]. The model ages for the plains point to an age of ~4 Gyr, thus implying an even older age for the northern terrain, and a similar or older age for those chasmata that predate (were resurfaced by) Vulcan Planum. In limited regions on Vulcan Planum, however, craters are sparse, implying that the resurfacing of Vulcan Planum may have occurred over an extended time.

Geological evolution: Charon's surface is dominated by impacts, tectonic deformation, and resurfacing, and as such fits broadly into the accepted picture of geologic evolution on icy satellites [7, 8]. That Charon is so geologically complex, however, would seem to require a heat source for reshaping what would have otherwise been a heavily cratered surface. If the ~4 Gyr age of even the youngest of Charon's surfaces is correct, then this activity dates back to an early warmer epoch. The tectonic record is consistent with global expansion, and the smooth plains consistent with the mobilization of volatile ices from the interior. Charon may have had an ancient subsurface ocean that subsequently froze, which would generate the global set of extensional features, and might permit eruption of cryovolcanic magmas [9].

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