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ARE NOACHIAN-AGE RIDGED PLAINS (*Nplr*) ACTUALLY EARLY HESPERIAN IN AGE? H. V. Frey, C. E. Doudnikoff and A. M. Mongeon, Geodynamics Branch, Goddard Space Flight Center, Greenbelt MD 20771

Ridged Plains of Noachian Age?

The prominant ridged plains of Lunae Planum, Coprates, Hesperia Planum and elsewhere are generally considered to have erupted in the Early Hesperian (1,2) and are generally taken to define the base of that stratigraphic system (3). These plains are widespread, covering over 4 x 10^6 km^2 in western Mars alone (1) and are broad, planar surfaces with some flow lobes and parallel, linear to sinuous ridges similar to lunar mare ridges with a spacing of 30 to 70 km. The general interpretation is that the ridged plains (unit *Hr*) are due to relatively rapid eruptions of low viscosity lavas (1,2), and their occurance at the base of the Hesperian represents a major volcanic episode in martian history (3).

In some areas these plains are gradational with another ridged plains unit, mapped as *Nplr*. The ridges of these apparently Noachian-age plains are generally further apart with rougher, more heavily cratered inter-ridge areas (1,2). *Nplr* terrains are widely distributed in both hemispheres of Mars but cover much less area than the more common *Hr* unit. The type area in Memnonia lies southwest of Tharsis in heavily cratered terrain (Npl_1, Npl_2). Other major occurances are further south in Sirenum, between the Argyre and Hellas Basins in Noachis, in the southern portion of Cimmeria Terra and in the northeastern portion of Arabia (1,2). The Noachis and Cimmeria outcrops are distributed roughly concentrically about the Hellas impact basin at approximately 1 and 2 basin diameters, respectively.

The stratigraphic position of these apparently older ridged plains is **Middle Noachian**; in the current geologic maps the unit does not extend into the Upper Noachian and appears temporally unrelated to the more common Hesperian ridged plains (*Hr*) even though these two units are sometimes gradational. The assignment of stratigraphic position is based on superposition relationships and total crater counts; the high density of impact craters on *Nplr* would certainly suggest a Noachian age.

But total crater counts can be misleading: if multiple resurfacing or other crater depopulation events occur and successfully compete with crater production, a given terrain may have an apparently young total crater age even though very old surfaces remain partially exposed in the form of very large craters. Inefficient resurfacing events allow older surfaces to show through and give old crater retention ages based on total crater counts, which may not accurately reflect the age of the major terrain unit. In this paper we examine whether or not the *Nplr* units in Memnonia and Argyre truly represent ridged plains volcanism of Noachian age or are simply areas of younger (Early Hesperian age) volcanism which failed to bury older craters and therefore have a greater total crater age than really applies to the ridged plains portion of those terrains.

Resurfacing in Memnonia and Argyre

We used the Neukum and Hiller (4) technique to determine the number of preserved crater retention surfaces in the Memnonia and Argyre regions where Scott and Tanaka (1) show *Nplr* units to be common. The Memnonia outcrops are the type example of this unit, and we subdivided the study area in MC 16 into two broad units: cratered terrain *Npl* (mostly Npl_1 and Npl_2) and the ridged plains *Nplr*. Our mapping is similar to but not identical with that previously done (1). We counted craters larger than 3 km in diameter and plotted cumulative frequency curves for each terrain unit, then broke these curves into separate branches where they departed from a standard production curve (4, 5). This departure is interpreted to be due to resurfacing, and breaking the curves into separate branches allows determination of the crater retention age of each post-depopulation "surface" independent of previous history (the survivors are subtracted and remaining craters compared independently to the crater production curve). Table 1 summarizes the results for cratered terrain (*Npl*) in Memnonia and for ridged plains (Nplr) in both Memnonia and Argyre, and compares these with similar results obtained by us for Tempe

Terra (6) and Lunae Planum (the type area for the Lunae Planum Age [LPA] ridged plains [*Hr*] resurfacing).

In Lunae Planum no craters larger than 50 km exist within the ridged plains; in Memnonia and Argyre there are craters as large as 117 and 100 km that survive in the *Nplr* unit. The population of old, large craters contributes to the total crater counts which suggest the *Nplr* unit is of Noachian age. We find the cumulative frequency curves for the ridged plains in Argyre/Memnonia can be broken into four branches which have remarkably similar crater retention ages N(1): an oldest branch ~[121,000/115,000], a branch with N(1) = [80,200/76,500], a "Lunae Planum Age" branch at [28,100/22,100], and a still younger branch at N(1) = [6700/6200]. Note that the Argyre ages for *Nplr* are consistently slightly older. These ages compare with resurfacing ages for the cratered terrain *Npl* in Memnonia of N(1) = [226,900], [76,000], [27,900], and [6300]. For all but the oldest (and most poorly determined) branch, the crater retention ages for the different branches are extremely similar from one area to the next.

The craters which determine the ridged plains resurfacing age (those superimposed on the ridges as opposed to showing through the plains) define the N(1) = [25,000 +/- 3000] age branch for both Memnonia and Argyre. This age is nearly identical (with the precision this technique affords) with the oldest branch we find for Lunae Planum: N(1) = [25,700], even though the craters which define this age branch (10-20 km in Argyre, 8-15 km in Memnonia) are significantly smaller than in Lunae Planum (25-50 km). This implies that the thickness of the *Nplr* ridged plains in Argyre and Memnonia is significantly less than we estimate (4,5) for Lunae Planum (350- 600 m). This reduced thickness is what allows the older craters to show through, preserving the older crater retention surfaces at N(1) = [78,000 +/- 2000] and [118,000 +/- 3000]. These older preserved craters contribute to the high total crater counts that suggested the *Nplr* were of Noachian age.

We suggest that for these two areas at least the *Nplr* ridged plains are the same age as those (*Hr*) in Lunae Planum, Tempe and elsewhere: N(1) = [25,000 +/- 3000]. If this conclusion holds in general for the other outcrops of those units mapped as *Nplr*, it may imply that the eruption of ridged plains volcanism was more restricted in time than previously thought. This would have interesting implications for models of the thermal history of Mars, and would make the ridged plains even more important as a stratigraphic marker in martian history.

Table 1. Resurfacing Ages for Memnonia and Argyre

AREA	UNIT	CRATER RETENTION AGE N(1)			
Memnonia	Npl	226,858	75,980	27,866	6,343
Memnonia	Nplr	115,221	76,445	22,062	6,223
Argyre	Nplr	121,300	80,200	28,100	6,700
Lunae Planum	Hr	--	--	25,700	10,100
Tempe	Hr	--	--	22,100	6,500

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DARK MATERIALS IN VALLES MARINERIS: INDICATIONS OF THE STYLE OF VOLCANISM AND MAGMATISM ON MARS

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Rifting on the equatorial canyon system of Valles Marineris provides a unique view of the interior of the martian crust to depths reaching 7 kilometers, exposing several in-situ bedrock units which testify to past volcanic and magmatic processes on Mars. Dark, relatively gray materials, believed to be among the least altered of martian crustal components, are found in a variety of geologic settings in Valles Marineris. These include in-situ wall-rock layers exposed during the formation of the canyon system, canyon floor covering deposits such as eolian dunes, and volcanic materials, possibly indicating relatively recent volcanism in the Valles [1]. Using Viking Orbiter apoapsis color images, we have studied the spectral reflectance and spatial distribution of these materials in an attempt to understand their relation to past episodes of volcanism, tectonism, igneous intrusion, and eolian redistribution in the canyon system.

A series of cliffs in the Ophir Chasma wallrock is interpreted to be exposures of resistant bedrock; the spectral signature of this massive and uniform unit most closely resembles that of terrestrial mafic rocks altered to or coated by crystalline hematite. These Ophir Chasma cliffs may be erosional scars exposing fresh bedrock beneath more weathered wallrock of a similar composition, or they could be a physically and compositionally distinct unit, produced, for example, by igneous intrusion prior to the formation of the Valles.

Application of multispectral mapping techniques to probable young volcanic materials in the Central Troughs yields an inferred distribution of volcanic activity consistent with an interpretation of extrusion along faults near the margins of the canyon floors. Terrestrial examples of similar relationships between tectonism and volcanism include the African Rift Valleys and the Basin and Range Province in the southwest of the U.S., both areas of crustal extension. Since there is no a-priori reason to expect this relationship to occur if the Valles were generated by fluvial erosion or by subsidence of karst or thermokarst, the inferred distribution of volcanism appears to support the hypothesis [2] that the Valles originated through tectonic extension and graben subsidence. While the age of this volcanism is at present poorly constrained, photogeologic indications that it may be relatively recent [1] could suggest that tensional rifting and canyon formation may be ongoing processes.

A thick, regionally extensive deposit observed in outcrops in Juventae Chasma and in a wallrock layer in Coprates is interpreted to be composed of mafic glass on the basis of spectral reflectance, incompetent erosional morphology and marked tendency for eolian redistribution, indicating that the material is easily broken down into sand-sized grains capable of saltation. Multispectral mapping suggests that the eolian floor-covering materials in the lower canyons several hundred kilometers to the east are derived from sources in Juventae and

Coprates Chasmata. The interpretation of this unit as volcanic ash requires that the deposits were produced in pyroclastic eruptions at what was once the surface of the planet, and later buried by almost 3 kilometers of plains materials including the 400 to 600 meters of Hesperian lavas believed to resurface the Lunae-Sinai Planum region. The deposits in Coprates and Juventae Chasmata are thus probably among the oldest of martian volcanic materials.

Voluminous regional deposits of basaltic ash have no terrestrial analogue, although they are common on the Moon [3-8] and may be present on Mercury as well [9]. If we tentatively accept the identification of massive mafic ash deposits on Mars, the Moon and Mercury, then the absence of such deposits from the inventory of present day crustal materials on Earth requires explanation. One possibility is that the processes which produce large pyroclastic eruptions from mafic magmas are confined to smaller terrestrial planets, perhaps because of their reduced gravitational acceleration and atmospheric pressure [10]. Another possibility is that these processes could be confined to the early stages of planetary evolution. By analogy with the lunar mantling deposits, the materials exposed in the layer in Coprates Chasma and in Juventae may represent a relatively volatile-rich phase of volcanism early in the history of Mars, possibly even the late stages of planetary outgassing. The absence of extensive deposits of mafic glass associated with more recent volcanism on Mars and the Moon (and, perhaps, the Earth) might then be due to a diminishing supply of juvenile volatiles. It is interesting to speculate that massive basaltic ash deposits might once have been common on Earth, and later obliterated from the geologic record along with the evidence for an early period of heavy bombardment by impactors.

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