The Colorado Plateau of Mars: Layered Sedimentary Rocks of North Sinus Meridiani

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Introduction
On Mars, as on Earth, sedimentary rocks preserve a record of past environments. Layered sedimentary rocks occur in dozens of craters, depressions, troughs, and intercrater plains across the martian surface. However, regional-scale exposures are rare, because most terrain is covered by mantles of dust, silt, and sand.

Northern Sinus Meridiani is the exception.

The region presents Colorado Plateau-scale outcrops of light-toned, cliff-forming, flat-lying sedimentary material that cover at least 300,000 km$^2$, compared to the 260,000 km$^2$ of the Colorado Plateau.

Outcrop Properties and Attributes
Layers in northern Sinus Meridiani are vertically heterogeneous and exhibit lateral continuity over hundreds of kilometers. The materials form cliffs, buttes, and pinnacles during erosion. Bedding is horizontal (or nearly so) and layered units show variations in erosional expression, albedo, and surficial thermophysical properties from one to the next.

The materials are interpreted to be rock.

The layered materials form cliffs, buttes, and pinnacles. Buttes and a small pinnacle can be seen in the 3-d view (right). The materials are inferred to be rock because, under erosional attack, some layers form and maintain near-vertical cliffs of > 20 m height. These examples are from MGS MOC.

Regional view of northern Sinus Meridiani. The location of ~300,000 km$^2$ of light-toned, layered sedimentary outcrops is indicated. Map is a mosaic of Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) red wide angle images acquired in May 1999.

Layered materials exhibit lateral continuity over distances > 100 km. Sub-frames of MGS MOC images are shown, each has the same layer units, labeled 1 - 2 - 3.

Phobos 2 Termoscan 8-12 μm Image 1 March 1989
Dark = 263 K Bright = 263 K

Thermal properties of the outcrops suggest the material is quite indurated. In this view from Phobos 2 Termoscan, the light-toned outcrops appear dark because they are ~20 K cooler in early afternoon than the surroundings. Thermal observations from Viking, Mars Global Surveyor, and Mars Odyssey provide similar results. For example, the rock abundance (estimated from Viking Infrared Thermal Mapper data by P.R. Christensen, Icarus, 68, 217-238, 1986) in some areas exceeds 25%—very high relative to most of Mars.
Stratigraphic Observations

Impact craters at a range of scales are interbedded with the layers of northern Sinus Meridiani. Craters as small as 60 m and as large as 60 km may once have been buried within the stratigraphy.

The photomosaic map, topographic map, and stratigraphic column (below, center) show details of a specific stratigraphic story for northwestern Sinus Meridiani and southwestern Arabia Terra.

The light-toned layered outcrops of northwest Sinus Meridiani can be traced west and northwestward into the cratered terrain of western Arabia Terra, where they are covered by mantles of dust.

The light-toned outcrops have a distinct erosional morphology that forms a pattern of rugged-surfaced ridges (e.g., figures f and g, below). These same ridges are found, mantled with dust, in parts of southwest Arabia Terra (figures b,c,d,e, below; note locations in maps, above). The ridge-forming unit comprises a specific ~180-m-thick layer (Unit R in the stratigraphic column).

The ridge-forming unit (R) is overlain by two scarp-forming units, B and A, and overlain by a unit that is today only preserved by the pedestal beneath the ejecta of the crater labeled "5," above. Units B, A, and the pedestal-forming unit (P) are all about 200 m thick and lie horizontally (or nearly so). Each unit is further subdivided into thinner layers, for example, figure g, below, shows layers in unit R, and figure h shows layers in unit R.

Because the rocks are flat-lying, the topographic map, used in concert with the color-coded stratigraphic column, provide a first-order sense of how a geologic map of the materials would look.

Note that craters 2 and 3 formed at the top of unit A, below unit B. This marks an unconformity in the geologic record.

Also note that crater 4 is still mostly buried within unit B, and the east rim of crater 1 lies below 600 m of the 800 m stratigraphy.

Crater 1 has spectacular layers on its floor (figure a, right). These layers formed in an environment that is not represented in the strata outside the crater. Crater 1 may have once been buried, just as the similar-sized crater 4 remains mostly buried today.

Mars not only has a cratered surface, its upper crust is a layered, cratered volume.