THE MARTIAN NORTHERN PLAINS DID NOT RESULT FROM PLATE TECTONICS; **M. J. Pruis** and **K. L. Tanaka**, U.S. Geological Survey, Flagstaff, AZ

The formation of the northern lowlands of Mars has remained a long-standing enigma. Impact and tectonic modes of origin have been proposed [1–3]; the challenge has been to account for (1) the physiographic outline and depth of the northern lowlands and (2) the erosion along the highland/lowland boundary and infilling of the northern lowlands during the Late Noachian/Early Hesperian [4, 5]. Recently, Sleep [6] formulated a plate-tectonic model for the origin of the crustal dichotomy. This model can explain the shape, depth, and relative youth of the northern lowlands by the formation of thin crust and the subduction of thicker, ancient highland crust. However, Sleep did not support his hypothesis with a thorough investigation of geologic evidence. Our examination of Sleep's hypothesis is twofold. First, we determined, both from Sleep's model and the literature on terrestrial plate tectonics, the characteristics and geologic associations of proposed plate-tectonic structures expected to be preserved. Second, we carefully searched for these identifying features at more than thirty key locations using Viking images and topographic data. Because of the many inconsistencies between plate-tectonic predictions and actual observations (as summarized in Table 1), we conclude that large-scale, horizontal lithospheric plate movements did not form the northern plains of Mars during Late Noachian/Early Hesperian time.

Our investigation shows a general lack (or paucity) of evidence for tectonism and volcanism in areas where such activity is predicted by Sleep's model. Where structures at first appearance seem to agree with the model, under closer scrutiny they commonly display incorrect orientation, size, form, and (or) mode of origin. For example, of ten transform-fault systems invoked by Sleep's reconstructions, only two show possible physiographic signatures on Viking images—Phlegra Montes and Scandia Colles. These features form topographic highs rather than broad, deep valleys that typify transform-fault topography [7–9]. At Phlegra Montes, north-trending scarps potentially could be transform faults; however, impact craters and ancient grabens cut by the scarps show no transform offset (rather, some display *horizontal shortening* of craters perpedicular to the scarps [10]). Moreover, wrinkle ridges parallel the Phlegra Montes ridge system, and graben-like structures strike nearly orthogonal across the ridge system. Collectively, these structural orientations indicate that compressional strain was oriented east–west—nearly orthogonal to that predicted by Sleep's plate-tectonic model. (Alternatively and consistent with the observations, Phlegra Montes may be an old fold belt formed by east-west compression [10].) Scandia Colles make up a broad patch of low, rounded, closely spaced mesas and knobs that display no obvious linear structural control. These features were previously interpreted to be remnants of ancient cratered terrain [11]; knobs are common throughout much of the northern lowlands but generally are more widely spaced.

Other major problems for the plate-tectonic model include (1) high crater densities in two regions of the northern plains (Acheron Fossae and Elysium Planitia) that indicate the presence of extant crust significantly *older* than required by the model and (2) lack of evidence for large horizontal strains dominating the planet's tectonic history (instead, minor horizontal strains caused by Tharsis-centered uplift and flexure imposed on a single lithospheric plate is more consistent with much of the observed tectonic record [12]). We do not, however, preclude that local faulting and intense erosion along the highland/lowland boundary during the Late Noachian and Early Hesperian may be due to modest crustal downwarping [5, 13].

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Table 1. Major geologic inconsistencies of Sleep's plate tectonics model.

Plate-tectonic structure	*Mars location(s) examined*	*Features expected with plate-tectonic interpretation*	*Results of search for expected features*
Passive margin	Tyrrhena, Cimmeria, and Memnonia margins	1. Evidence for reversal of surface runoff 2. Extensive normal faulting	1. Absent 2. Minor, local fracturing and thrust faulting [10]
Active margin	Arabia Terra and Tempe Terra margins	1. Deep trench 2. Accretionary complex 3. Forearc basin 4. Extensive faulting of plains along active margin 5. Structurally controlled topography	1. Absent 2. Absent 3. Absent 4. Few structures in northern plains 5. Low mesas and knobs; no apparent structural control
Island (or marginal) arc	Tharsis Montes	1. Narrow, linear gravity and topographic highs 2. Composite volcanoes, ash flows 3. Eugeosynclinal trough (for island arc sequence)	1. Broad, elliptical gravity and topographic highs 2. Shield volcanoes, lava flows, possible ash flows 3. Absent
Transform-fault track	Phlegra Montes and Scandia Colles	1. Deep valley tens of km wide 2. Oblique topographic and structural features 3. Volcanoes, lava flows 4. Lateral offset of pre-existing structure along faults 5. Compression perpendicular to transform	1. Topographic high 100 to 400 km wide 2. Absent 3. Absent 4. Craters and grabens cut by scarps show no lateral offset 5. Wrinkle ridges parallel to Phlegra Montes
Abandoned ridge axis	a. Alba Patera and Olympus Mons b. Gordii Dorsum and parallel trough/swell couplets along Memnnonia margin	1. Normal faults bounding a deep axial valley 2. Axial volcanic chains 3. Abyssal hills <1 km high and <10 km wide controlled by oblique structure at ridge/transform intersections	1a. Mainly narrow grabens incorrectly oriented 1b. Shallow trough bounded by en echelon erosional escarpments and swells 2a. Massive volcanic shields 2b. No volcanoes evident 3a. Absent 3b. Oblique structure along all of Gordii Dorsum; also, trough/swell couplets have 1–3 km relief and average wavelength of 375 km
New crust in northern plains	a. Acheron Fossae b. Elysium knobby terrain	1. Crater densities in northern plains postdate Late Noachian/ Early Hesperian boundary; i.e., N(5) <~200 or N(16) <~25 [4]	1a. Predates predicted age (N(5) = 352±53) 1b. Predates predicted age (N(16) = 156±20)