onics on Mars. For instance, the lack of obvious fossil scarps along martian fracture zones permits a lower bound on spreading rate (for a given plate-boundary geometry), as does the observation that the spreading rate must exceed that of the transition from rough to smooth axial topography (Sleep estimates that the dividing line would occur at a full spreading rate of about 30 millimetres a year on Mars). The thickness of crust generated at a spreading centre, for a given mantle potential temperature, scales inversely with gravity[4], as does the change of crustal thickness with mantle temperature. Sleep conjectures that if the crust of the southern uplands was generated by plate tectonics as well, the younger and thinner lowland crust formed after the mantle had cooled by about 100 °C. The minimum age for subduction scales inversely as the square of gravity, so he suggests that reorganizations in plate geometry would be expected as spreading centres approached martian trenches.

In a move guaranteed to send many workers in martian geology scurrying back to their benches, Sleep has offered a specific plate reconstruction for the formation of the northern lowlands. According to that reconstruction, the high-standing linear features Phlegra Montes and Scandia Colles are transform fault tracks or traces of plate triple junction, the Gordii Dorsum escarpment[11] is a plate breakup margin (see photograph), and the volcanoes Olympus Mons and Alba Patera sit astride abandoned ridge-axis segments that remained magmatically active after spreading ceased. Further, his proposed timing for the plate tectonic formation of the lowland crust would rule out earlier proposals[7–9] that rim remnants of large and presumably ancient impact basins are preserved as inliers within the lowland plains.

Sleep sets out several ways by which his ideas could be tested. The duration of genesis of lowlands crust in his reconstruction is 200–300 million years, possibly sufficient to discern an age gradation from variations in impact crater densities. The subsidence of thermally generated topography may give rise to differential vertical motions along older channels and lava flows. By the same process, the present lowlands will have subsided relative to the southern uplands, perhaps reversing the sense of escarpment along the passive margin at a time significantly later than the initial breakup. The patterns of gravity anomalies across passive margins, extinct subduction zones and fossil fracture zones may be distinguishable and detailed mapping of the geology of key features may resolve their origin. Finally, the hydrothermal alteration of the upper crust and the subduction of water might have been responsible for removing surface water, so studies of the role of water in magma generation beneath the Tharsis Montes, and of how the history of water on Mars dovetails with the proposed history of plate subduction, offer promise as further tests.

Sleep's proposal is a shot across the bows of the conventional view of martian geological history, and vigorous debate can be expected. But the notion that we may after all have a record of plate tectonics on another planet and that it may, unlike that of the Earth, include a record of global mantle cooling is sufficiently provocative that such a debate is welcome. ☐

Sean C. Solomon is in the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington DC 20015, USA.

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STAR FORMATION

Hubble looks at a stellar nursery

STAR formation occurs in clouds of gas — composed primarily of molecular hydrogen (H_2) — when portions of the cloud collapse under the influence of gravity. It is generally accepted that the later stages of this collapse are associated with a disk of gas and dust surrounding the young star, and evidence for such disks around about half of the young stars in the Orion Nebula (the middle 'star' in Orion's sword) has now been seen by C. Robert O'Dell and Zheng Wen, using the newly refurbished Hubble Space Telescope — of the five young stars shown above, four have disks. Planets are thought to coalesce in the disks as a natural part of the star-formation process. A nice cartoon of this can be seen in the opening credits of the television show *Star Trek: The Next Generation.*

The work by O'Dell and Wen follows years of study of related disks in the Taurus and Ophiuchus molecular clouds, using infrared and millimetre-wavelength observations, by Beckwith, Strom and Andre and collaborators, who first found evidence for disks surrounding about half of all young stars. The new observations are important because we can see directly the outer boundaries of the disks, where the gas is being heated (by radiation from a nearby massive star) to the extent that it is ionized. As the electrons recombine with the atoms, distinctive light is emitted, allowing astronomers to estimate the mass of hot gas, which is probably much less than the total mass of the disk. O'Dell and Wen find that there are typically a few Earth masses of ionized gas associated with their disks. (The masses traced by the infrared and millimetre-wavelength observations are usually much greater.)

If disks are relatively common around young stars in our Galaxy, planets like those in our Solar System might also be common. As described on pages 610 and 628 of this issue, a near-infrared image of the disk around the main-sequence star β Pictoris shows evidence for the presence of planets. β Pic is being seen at a later stage of evolution than the stars studied by O'Dell and Wen — much of the gas and dust associated with its birth have been dissipated — but the results are complementary and suggestive. We see first the disks around young stars, and later the traces of planets as the disks disappear. The final step — seeing the planets themselves — still lies in the future.

Leslie Sage