P32C MC: Hall D Wednesday 1330h

The Evolution of Volcanism on Mars II *(joint with V)*

Presiding: **M Bullock,** Southwest Research Institute

P32C-0561 1330h POSTER

Mars Plate Tectonics: Surface Geology and Analyses of Topographic and Geophysical Data

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We propose plate tectonism for the embryonic stage (Early Noachian) of development of Mars to help explain distinct features and landforms (also see Maruyama et al. and Baker et al., this volume), including the long-lived Tharsis magmatic complex. The Tharsis magmatic complex has been recently recognized as an Earth-like superplume (GSA Boston meeting, 2001–Maruyama et al., 2001; Baker et al., 2001; and Dohm et al., 2001), similar to the proposed long-lived, fixed mantle/core-sourcing wet Africa and Pacific superplumes of Earth (Maruyama, 1994, J. Geol. Soc. Japan, v. 100, 24-49; Fukao et al., 1994, J. Geol. Soc. Japan, v. 100, 4-23). Other features and landforms of Mars that may be collectively explained by an Early Noachian plate tectonic phase include: (1) the ancient mountain range of Thaumasia highlands (Dohm and Tanaka, 1999, Planetary and Space Science, v 47, 411-431), (2) the highland-lowland boundary (e.g., Scott and Tanaka, 1986, USGS I-Map 1802-A), (3) tectonic macrostructures, many of which are interpreted to be thrust structures (e.g., Schultz and Tanaka, 1994, J. Geophys. Res., v. 99, 8371-8385), (4) circular domes located near the southwestern margin of the Thaumasia plateau (Dohm and Tanaka, 1999, Planetary and Space Science, v 47, 411-431), many of which (a) occur among the tectonic macrostructures of (3), (b) are interpreted to represent explosive volcanism (e.g., andesitic constructs), and (c) are considered to mark former zones of subduction, and (5) gravity and magnetic anomalies identified in parts of the northern plains and Terra Cimmeria and Terra Sirenum regions (Acuna et al., 1999, Science, v. 284, 790-793; Yuan et al., in press, J. Geophys. Res., Planets), which may symbolize former remnant ocean plates with hotspot tracks of island arcs that are transparent through thick sedimentary covers and zones of accreted terrains, respectively.

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Analysis of the Complex Lineament System of Alba Patera, Mars, by Plate Flexure Modelling.

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Alba Patera is one of the most peculiar and outstretched volcanoes known in the Planetary System, measuring up to 2700 km across, with a relative elevation of 7 km. The edifice is constituted by a large shield volcano with flat apex of about 5 km elevation on which formed a younger 2 km high central cone. As reported from the Viking images, Alba Patera is characterised by numerous extensional fractures in predominantly north-south direction. These grabens curve around the summit at about 200 km distance, off-centre toward the east. Some similar structures but over a limited radial extent (i.e. Catenae) are observed at a further distance at the lower slope of the main shield. A few radial compressive features or wrinkle ridges have been also identified on the summit. Using the Finite Element code Tekton, we reconstructed the stress fields induced by deformation under volcanic load and/or subsurface forces with addition of a regional extensional stress from the Tharsis rise, paying heed to the effects of the used parameters and to the failure criterion.

We show that 1) simulating the topographic load as vertical forces or pressures on an elastic plate of constant thickness neglects the internal deformation of the edifice itself and its contribution to the plate thickness, which may be, however, considerable for a thin plate. We added therefore the whole geometry of the edifice, that is the observed topography and the major portion that fills the plate subsidence, and introduced body forces. 2) The bisected shape of the volcano, mentioned above, results in a local zone of higher differential stresses on the flanks.

We obtained three domains of fault-types, a) a region of thrust faults at the summit, b) followed by strike-slip faulting and c) surrounded by concentric normal faults, these with increasing distance from the load centre. The wideness of the fault domains, the positions and the amounts of stress difference maxima depend strongly on the thickness of the plate, the load size, the Young modulus and the particular shape of the load. We also demonstrate how the various fault-domains on the surface and through the edifice are modified by the addition of a regional extensional stress and/or subsurface forces.

P32C-0563 1330h POSTER

Late Mafic Volcanism in Valles Marineris, Mars

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Mars Orbiter Camera (MOC) images show conspicuous dark mantles on top of mesas inside the Valles Marineris and dark sand sheets on their floors. The dark materials overlie all other deposits in the Valles Marineris, including landslides in places, and are therefore relatively young. Generally the dark materials have been interpreted as wind deposits from mafic sources. The question is what were these sources, and where were they located? Were the dark materials winnowed by the wind from adjacent lava plateaus and became trapped in the troughs, or were they derived locally from sites within the troughs? Some of the dark materials no doubt are atmospheric fall out, and some may have been derived from older dark layers in the trough walls and interior deposits. However much of the dark material appears to have been derived from local, late volcanic vents. A thorough search of MOC images covering all Valles Marineris chasmata revealed numerous possible vents associated with low dark mesas, dark cover on high mesas, dark materials lining the base of trough walls (probable fault scarps), and some sand sheets. The structures are rimmed or rimless dark circular depressions, elongate depressions and nested sets of circular rims associated with dike-like linear ridges, mounds topped by holes, short flow lobes, and irregular depressions associated with terrain so dark that most of it is undersaturated in the images. The possible vents occur mostly in some sectors of west Candor, west Tithonium, Melas, Juventae, and Capri/Eos Chasmata. As flow structures are less common than vents, the dark materials appear to come from pyroclastic eruptions inside the Valles Marineris. The materials tend to be transported along low areas and reworked into dunes, suggesting sand-sized grains. Perhaps some of the dark materials are composed of glass beads, as are dark mantles on the Moon. On Mars beads may have formed similarily when mafic materials erupted explosively into its thin, cold atmosphere.

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Mantle Convection and Present-day Volcanism on Mars

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The shergottite meteorites are the most common type of the so-called SNC meteorites, which are believed to be from Mars. The shergottites are igneous rocks, many with radiometric ages of about 180 million years. Observations of very low crater density in some Mars Global Surveyor images indicate that parts of the Tharsis and Elysium volcanic provinces on Mars have been active in the last 30 million years. Together, these observations indicate that volcanism has been an important process in the recent past on Mars. Thus, upwelling mantle convection and adiabatic decompression melting likely remain important at present on Mars.

I am using finite element mantle convection simulations to explore the relationship between convection and magmatism on Mars. The best existing observational constraint on deep density heterogeneities on Mars is the non-hydrostatic geoid, which is to first order axisymmetric about Tharsis. Thus, formulating the models in spherical axisymmetric geometry is a reasonable approximation. The models have a 200 km thick high viscosity near-surface layer and use radioactive heating rates and Rayleigh numbers that are appropriate for the present. Estimates for the radioactive heating rates are taken from geochemical models of Mars that are based on the observed composition of the shergottite meteorites. An important parameter being explored in these models is the fraction of total radioactivity that has fractionated into the crust of Mars.

By combining temperature and velocity fields from the convection simulations with estimated melting relationships for the mantle of Mars, one can calculate a variety of quantities related to adiabatic decompression melting on Mars. (1) What is the current volumetric rate of magma production? (2) What is the spatial distribution of magma production? Is it localized near upwelling mantle plumes, or is it more widely distributed? (3) What is the typical melt fraction? What is the maximum melt fraction? (4) What depth range does melt form at? Results for 1 and 2 can be tested using regional geological mapping. Results for 3 can be tested against geochemical observations such as trace element distribution patterns in the shergottites. These comparisons between models and observations should permit new constraints on parameters such as the total radioactivity budget and the fraction of the radioactivity that is contained in the crust.

URL: http://www.lpi.usra.edu/science/kiefer/home.html

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Mars plate tectonics (1) :An Earth prospective

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We hypothesize the existence of plate tectonism during the embryonic development of Mars, which resulted in the proposed Tharsis superplume (GSA, 2001). Similar to the major influence of superplume on the history of the Earth, we envision the Tharsis superplume to have dominated the geological and climatological history of Mars. Early Noachian plate tectonism is collectively explained by an array of prominent structures and features revealed through Viking-based geological investigations and through the recently acquired high-resolution topographic, imaginary, and geophysical coverage of the Mars Global Surveyor mission. These include: (1) highland-lowland boundary, (2) the Thaumasia highlands mountain range, (3) circular domes among distinct structures of similar trends (e.g., southwest margin of the Thaumasia highland mountain range), interpreted to be andesitic domes associated with subduction zone magma, (e.g., silicic-rich provenances that source andesitic materials to northern plains), and (4) geophysical anomalies such as those identified in the northern plain and regions located to the east-southeast of Hellas basin, interpreted to be the dead spreading centers and probably accreted terrains, respectively. Martian plate tectonism is thought to have continued after the core was frozen, resulting in the death of dynamo, because Mars potential temperature of mantle is expected to be higher than 1500°C, if 34% S-bearing Fe-Ni alloy core was consolidated. In this case, no magnetic stripes would remain in the northern lowland, whereas the proposed southern highland supercontinent that formed during the dynamo would have yielded strong magnetic signatures. For examples EW-trending narrow units with strong remanent magnetism in the southern highland may be accreted oceanic lithosphere. Moreover, the Archean hydrothermal system deposits located along the mid-oceanic ridges on the Earth suggest that the large amounts of carbonate and sulfate are expected to have been subducted into the Martian mantle with accreted fragments remaining in the accretionary complex in the southern highland.

Key words: Mars, plate tectonics, supercontinent, accretion, Archean Earth

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