GEOLOGIC HISTORY OF ISIDIS PLANITIA ON MARS, M.A. Ivanov[1,2], H. Hiesinger[2], G. Erkeling[2], and D. Reiss[2], 1 - Vernadsky Inst., RAS, Moscow, Russia, mikhail_ivanov@brown.edu; 2 – Inst. für Planetologie, Univ. of Muenster, Muenster, Germany

Introduction: Isidis Planitia occupies one of the largest (~1800 km) impact basins on Mars. In this region, landforms of volcanic, fluvial, and glacial origin are abundant [1-5] and the floor of the basin is one of the most important sites of thumbprint terrain (TPT) on Mars [e.g., 2,6]. In order to assess the evolution of the Isidis basin and understand the place and role of different processes in its geologic history, we have mapped in detail an extensive area (between 75- 103°E and 1-27°N) that includes Isidis Planitia (floor of the basin) and its surroundings (rim of the basin) using all available imagery and topographic data sets. Here we describe the morphology of the material units, interpret their nature, give age estimates for the units, and, finally, outline the major steps in the geologic history of the region.

Large-scale topographic configuration of the Isidis basin: The regional break in slopes and distribution of elevations on the floor and the rim of the basin divide the whole region into topographic provinces of lowlands (< -3.5 km, floor of the basin), midlands (from -3,5 to -2,4 km, lower rim), and uplands (> -2.4 km, higher rim). This large-scale topographic configuration of the basin probably governed the spatial distribution of materials emplaced, removed, and redeposited in this region.

Description, interpretation, and age assessment of units: We have defined the units that compose the Isidis Planitia region in a traditional photogeological way: if the surface of a terrain has a specific morphology (within some limits), which is distinctly different from the other terrains, this morphology defines a rock unit [7]. This definition has pure empirical character and does not include an interpretative component. The relative ages of the units were derived from both the stratigraphic relationships and the results of crater counts.

Mountainous materials (Nm) form the uplands and occur preferentially in Libya Montes. The surface of the unit displays high (up to a few km) peaks with lower mounds and ridges. The unit has a specific morphology, occurs in many regions of Mars, and is interpreted as materials formed by large and small impact events [8-10]. The principal constituents of the unit of mountainous materials are thought to be impact breccias. The size-frequency distribution (SFD) of craters on the surface of unit Nm shows at least two isochrones corresponding to the model ages of ~3.97 ($^{+0.04}$/$_{-0.06}$) Ga (formation) and ~3.85 ($^{+0.02}$/$_{-0.03}$) Ga (modification).

Subdued mountains materials (Nms) have lower topography and often surround massifs of unit Nm. The surface of unit Nms is rugged, but lacks the high peaks and its materials overlap/embay structures of the higher mountain peaks of unit Nm. We interpret materials of unit Nms as a mixture of the impact breccias and clastic materials eroded and deposited within intermountain basins. The SFD of craters indicate two model ages of the unit, ~3.86 ($^{+0.05}$/$_{-0.1}$) and ~3.76 ($^{+0.03}$/$_{-0.03}$) Ga.

Unit of upland plains (NHpu) has a flattened surface and embays units Nm and Nms. In places, structures resembling wrinkle ridges complicate the surface of the unit. Graben of Nili and Amenthes Fossae cut upland plains and expose their layered structure. The layers are similar to those that characterize volcanic plateaus elsewhere on Mars (e.g., Lunae Planum) [11,12]. The layered structure of upland plains and possible presence of wrinkle ridges suggest that unit Npu has a volcanic origin. The SFD of craters on the surface of the unit suggests two model ages, ~3.75 ($^{+0.03}$/$_{-0.04}$) and ~3.55 ($^{+0.02}$/$_{-0.02}$) Ga.

Ridged plains (Hpr) have a smooth and flat surface and cover broad areas within the midlands. Several specific features characterize ridged plains: (1) wrinkle ridges, (2) internal layered structure of the plains (3) straight and sharp-crested ridges similar to exhumed volcanic dikes [13]. These features collectively suggest a volcanic origin of ridged plains. The SFD of craters on the surface of ridged plains is fitted by two isochrones, ~3.66 ($^{+0.04}$/$_{-0.05}$) (formation) and ~3.53 ($^{+0.02}$/$_{-0.03}$) Ga (modification).

Plains of *Syrtis Major* (HpSM) demonstrate large calderas, wrinkle ridges, and lava flows/tubes. All these features indicate a volcanic origin of the Syrtis Major plateau [e.g., 14,15]. The high scarps at the eastern edges of Syrtis Major expose its layered structure, which is similar to that seen in units NHpu and Hpr. In the eastern portion of Syrtis Major, the SFD of the craters suggests that the unit was emplaced ~3.49 ($^{+0.08}$/$_{-0.19}$) Ga ago, although the entire plateau was estimated to be of lower Hesperian age [5].

Knobby materials (Hmk) are seen in the transition from the midlands to the lowlands and form a broad zone around the floor of the Isidis basin. Occurrences of the unit represent clusters of small and low mesa- and peak-like mounds. The mesas preferentially occur in association with areas of ridged plains (unit Hpr) and represent their erosional remnants. Disintegrated occurrences of the unit preclude reliable crater counting on the surface of the unit.

Etched upland materials (NHue) occur within the uplands in large areas around Nili Fossae. Heavily degraded craters, low ridges, and scarps with sharp and jagged edges are typical features of the unit. The abundance of the eroded craters implies that the unit was formed due to effective erosion of older materials. The SFD of craters on the surface of unit NHue suggests two

model ages, ~3.78 ($^{+0.04}$/$_{-0.07}$) (emplacement of original materials) and ~3.49 ($^{+0.03}$/$_{-0.04}$) Ga (erosion).

Channeled materials (Hmch) occur in the NW (Arena Colles region, HmchAC) and S (Libya Montes, HmchLM) portions of the Isidis basin. The characteristic features of the unit (fluvial channels/valleys) in both regions suggest its formation during episodes of fluvial activity. The SFD of craters on the surface of unit HmchAC corresponds to a model age of ~3.51 ($^{+0.04}$/$_{-0.07}$) Ga and the surface of unit HmchLM is estimated to be ~3.37 ($^{+0.05}$/$_{-0.09}$) Ga old.

Smooth plains (Hps) have a homogenous surface that usually lacks characteristic morphologic details. The plains form a broad zone that encircles the floor of the Isidis basin. The largest area of Hps is associated with knobby unit; materials of smooth plains embay the knobs. Characteristic features of smooth plains are narrow and very sinuous ridges. The morphology of them is inconsistent with many types of ridge-forming processes (tectonic, volcanic, fluvial, etc.) but closely resembles the morphology of eskers [e.g., 16]. This interpretation suggests that the smooth plains represent materials related to extensive glaciation within the Isidis Planitia region. The SFD of craters suggests a model age of formation of the unit of ~3.33 ($^{+0.1}$/$_{-0.23}$) Ga.

Plains with cones (HAcp) occur within the lowlands and occupy the floor of the Isidis basin. The surface of the plains is smooth, homogenous, and features thousands of small cone-like mounds [17,18]. The mounds or their chains often form long curved lines that in the images of low resolution appear as nested ridges of the thumbprint terrain [1,2]. The mounds occur exclusively within unit HApc and are absent in any other unit. The SFD of impact craters on the surface of unit HApc suggests a model age of its formation of ~3.26 ($^{+0.13}$/$_{-0.4}$) Ga. Impact craters with lobate ejecta that overlap the mounds provide the upper stratigraphic limit of TPT, ~2.8 ($^{+0.46}$/$_{-0.87}$) Ga [19].

Sequence and nature of major events in the Isidis Planitia region: The definition of the units, interpretation of their nature, and assessment of the ages of their formation and modification allow outlining of a model of evolution of the Isidis Planitia region since its formation by the major impact perhaps in the beginning of the Noachian [20]. The presence of the large (Noachian) craters on the rim implies that the actual topographic configuration of the Isidis Planitia region is its long-lasted feature.

Four principal episodes compose the geologic history of the Isidis Planitia region. ***(1) Impact-dominated episode (Noachian):*** Impacts and slope mass-wasting processes dominated formation of the oldest materials (Nm and Nms) and likely were the most important contributors to the initial filling of the Isidis basin. ***(2) Volcanically dominated episode (early Hesperian):*** Volcanism appears as the most important process in the Isidis Planitia region since the end of Noachian (emplacement of unit NHpu). Ridged plains (Hpr) and plains in Syrtis Major (HpSM) continued volcanic activity on the rim of the basin and mostly completed formation of the circum-Isidis volcanic province by the middle of Hesperian. Volcanic materials probably represent the major portion of the fill of the basin. They almost completely buried the previous crater record and were deformed into broad and low topographic ridges, i.e. wrinkle ridges. ***(3) Glacial/fluvial episode (late Hesperian):*** By the end of formation of the circum-Isidis volcanic province, predominantly glacial (NHue, Hmk, Hsp, HAcp) and some fluvial (Hmch) processes dominated the geological evolution and were responsible for the widespread resurfacing in the Isidis Planitia region. Although the ice/water-related units are widespread, the net effect of their formation was apparently negligible. The estimates of the total volume of materials eroded from the rim and deposited on the floor by the glacial and fluvial activity suggest that the maximum thickness of materials on the floor of the basin is less than a few hundred meters. The composite layer of these deposits had buried the broad ridges on the floor of the basin but was not able to erase their topographic characteristics. ***(4) Wind-dominated episode:*** The wind activity dominated during the final episode of the geologic history of the Isidis Planitia region that continues since the beginning of Amazonian. Modification of the surface in this during this time appears to be minor.

References: 1) Greeley, R. and J.E. Guest, USGS Map I-1802-B, 1987; 2) Grizzaffi, P. and P.H. Schultz, Icarus, 77, 358, 1989; 3) Ivanov, M.A. and J.W. Head, JGR, 108, 5063, 10.1029/2002JE001994, 2003; 4) Hiesinger, H. and J.W. Head, LPSC-35, #1167, 2004a; 5) Hiesinger, H. and J.W. Head, JGR, 109, E01004, 10.1029/2003JE002143, 2004b; 6) Lockwood, J.F., et al., LPSC-23, 795, 1992; 7) Wilhelms, D. E. in: Planetary Mapping, CUP, 208, 1990; 8) Tanaka, K.L., and D.H. Scott, USGS Map I-1802-C, 1987; 9) Leonard, G.J. and K.L., USGS Map I-2694, 2001; 10) Mest, S.C., and D.A. Crown, Icarus, 153, 89, 2001; 11) Ivanov, M.A., et al., JGR, 115, E03001, 10.1029/2008JE003256, 2010; 12) Tormanen, T., et al., LPSC-41, #1310, 2010; 13) Head, J.W., et al., Geology, 34, 285, 2006; 14) Greeley, R. and P. Spudis, RGSP, 19, 13, 1981; 15) Schaber, G.G., JGR, 87, 9852, 1982; 16) Kargel, J.S., et al., JGR, 100, 5351, 1995; 17) Hiesinger, H., et al., EGU GA, 11, EGU2009-7812, 2009; 18) Hielscher, F.J., et al., LPSC-41, #2394, 2010; 19) Sturm, S., BchSci Th., - Wilhelms-Universität Münster, p. 51, 2008; 20) Schultz, R.A. and H.V. Frey, JGR. 95, 14175, 1990