FLUVIAL CHANNELS ON ALBA PATERA: RESULTS OF AMAZONIAN LAVA-ICE INTERACTION?, M.A. Ivanov[1] and J.W. Head[2], 1 - Vernadsky Institute, RAS, Moscow, Russia, mikhail_ivanov@brown.edu; 2 - Brown University, Providence RI, USA.

Introduction: Alba Patera is one of the largest volcanoes on Mars that shows abundant fluvial features, valley networks, on its slopes [1,2]. The presence of these features on the surface of an Amazonian-age volcano indicates that they are younger than the valley networks elsewhere on Mars [2]. The buffered crater density techniques [3] applied to the valley networks on Alba Patera yields an Amazonian age [4]. In the case of the younger features, however, the buffered crater density method gives large error bars. For example, the age estimates of the valley networks on Alba Patera can vary in time interval from ~2.85 to ~1.10 Ga [4]. The more precise age estimates are needed for the understanding of the late hydrologic history of Mars. Because of this, we applied the standard method of the age determination using the crater size-frequency distribution (CSFD, [5]) on units that are defined by their morphology and form distinct stratigraphic sequences.

General topography: The consistent breaks in slopes allow definition of several specific parts of Alba Patera: Western lobe (WL, Fig. 1a), Eastern lobe (EL, Fig. 1a), Main edifice (ME, Fig. 1a), Summit plateau (SP, Fig. 1a), and Summit dome, (SD, Fig. 1a) [6]. The fluvial features on Alba Patera are much more abundant on the northern slopes of both lobes and the main edifice [7-10].The summit dome practically lacks the fluvial features.

Volcanic and fluvial landforms: The northern slope of Alba Patera displays a range of landforms that are related to volcanic, tectonic (graben of Alba Fossae), and fluvial activities. Two types of features represent the absolute majority of the volcanic structures. The first are long (up to a few hundred of kilometers) and broad (10-15 km) ridges with a triangle-shaped cross-section and relatively sharp crests. Elongated, narrow (hundreds of meters wide), and sinuous depressions and their chains mark the crest areas of some ridges. They make up the surface of both Alba's lobes and the main edifice as well [7-6] and extend from the summit plateau down to the lava apron.

Sheet-like lava flows represent the second type of the volcanic landforms. The flows are relatively short (tens of kilometers) and occur in two different topographic localities: a) near the base of the volcano where they form a lava apron and b) in the upper portion of Alba where they overlay flanks of the summit dome and the summit plateau, and the upper parts of the lobes and the main edifice. The sheet flows usually form stacks of narrower (a few kilometers wide) and broader (tens of kilometers wide) tabular flows with steep frontal and side scarps. The elongated triangle-shaped ridges always control the distribution of the sheet flows.

Four sets of channels represent the fluvial features on Alba Patera. The most prominent are long (many tens - a few hundreds of kilometers), narrow (a few hundred meters), and sinuous channels (Fig. 1b) that form a radial pattern on the flanks of the volcano [9]. Some of these channels begin near the summit plateau,and graben of Alba Fossae deform their upper reaches. Some of the long channels cut the surface of the sheet flows. The second type of fluvial features are systems of relatively short (tens of kilometers) sinuous channels that begin near the edges of the sheet flows (Fig. 1c). The channels of these systems usually are merging to form the longer sinuous channels. The edges of the sheet flows and the triangle-shaped ridges control the path of the longer channels. Short (5-10 km), broad (up to 1-2 km), and steep-sided channels/canyons represent the fourth type of fluvial systems on Alba (Fig. 1b). The channels begin in alcove-like steep-sided depressions and are similar to features interpreted to be formed by sapping [11]. The channels usually merge to form the longer sinuous channels. A specific type of fluvial systems forms dense networks of short (a few tens of kilometers) and parallel channels exclusively on the surface of the triangle-shaped ridges (Fig. 1d). These networks mostly characterize the northern slopes of the western lobe and the main edifice of Alba. The vast majority of the channels die out on the slopes of the ridges.

Relative and absolute model ages: The relationships of superposition and crosscutting among the defined landforms indicate the following sequence of volcanic, tectonic, and fluvial events on Alba Patera. The oldest recognizable features in the study area are the triangle-shaped ridges. The sheet flows always embay them and, thus, are younger. All systems of short channels postdate the triangle-shaped ridges and the long sinuous channels postdate some of the sheet flows. The graben of Alba Fossae usually cut the sheet flows and the long channels as well. In some places, however, the sheet flows overlay the graben, which suggests that the formation of the graben, sheet flows, and the channels overlapped in time.

In order to calibrate the stratigraphic sequence of events, we have counted craters (on CTX images) in three areas on the northern slope of the western lobe. These areas correspond to: 1) a triangle-shaped ridge, 2) a sheet-like flow, and 3) a system of channels at the lava flows front. The age estimates for these areas are 1.33 +0.05/-0.05 Ga, 1.34 +0.03/-0.03 Ga, 1.30 +0.03/-0.03 Ga, respectively. Although the error bars of the estimates are small, the absolute model ages of the stratigraphically different units are indistinguishable.

Discussion: Both the triangle-shaped ridges and the sheet flows represent the stratigraphically youngest volcanic features on Alba Patera. The absolute model ages of these features indicate that volcanic activity on Alba ended at ~1.3 Ga ago. This age corresponds to either the Middle- [12] or the Early Amazonian [13] epochs.

The morphology of the volcanic features in the study area indicates that they reflect different styles of volcanic activity. The large length, specific cross-section, and the chains of narrow sinuous depressions at the crests of the triangle-shaped ridges suggest that they represent the cooling-limited [14,15], tube-fed lava flows [7,8,6]. The sheet flows are shorter (likely, they are the volume-controlled flows [14-15]) and represent a drop of lava supply and concentration of the vents at the summit dome. Although the sheet flows are stratigraphically younger, their absolute model age is practically the same as that of the older tube-fed flows. This may imply a rapid decline of eruption rates at the transition from tube-fed to sheet flows.

The long and most prominent fluvial channels usually have no tributaries and do not form a dendrite-like pattern that characterizes terrestrial channels in mountain regions and indicates formation by the surface run-off. The dendrite-like patterns on Alba occur only in areas where the shorter channels are merging. These areas, thus, characterize rather small (tens of kilometers across) watersheds of the long channels. The apparently localized nature of the watersheds and the lack of the topographically closed basins in association with the shorter merging channels suggests that they represent isolated accumulations of snow/ice.

Many of the shorter channels begin near the edges of the sheet flows. This suggest that the advance of the flows triggered melting of the snow/ice packs and caused formation the channels. The steep-sided canyon-like channels that strongly resemble the sapping features probably formed by undermining of lava flows that ran over the snow/ice packs.

The systems of short parallel channels occur in close association with the tube-fed flows. This association suggests that that the channels may have been formed by melting of snow/ice on the roof of the lava tubes if they have been re-utilized by the later lava flows. The channels usually die out on the slopes of the tube-fed ridges, which suggests a limited amount of snow/ice that prevented formation of the longer channels.

Conclusions: Our observations and interpretations of the sequence of the volcanic, tectonic, and fluvial events on Alba Patera leads to the following conclusions. **1)** The volcanic activity on Alba Patera mostly ended at ~1.3 Ga. **2)** The pattern of fluvial features on flanks of Alba is inconsistent with regional surface run-off and suggests the possibility that the formation of the valley networks occurred by lava-induced melting of isolated snow/ice packs. **3)** In all cases, the accumulations of snow/ice, which served as the sources of meltwater, accumulated after formation of the tube-fed flows and before the emplacement of the sheet flows. This implies a narrow range of ages of the formation of the snow/ice packs on Alba Patera, around ~1.3 Ga. **4)** This age indicates the time of a period of enhanced deposition of ice on flanks of Alba, which can be related to the mass re-distribution of volatiles due to obliquity excursions [16.17].

References: [1] Gulick, V.C., Baker, V.R. (1990) JGR, 95, 14325. [2] Carr, M.H., Chuang, F.C. (1997) JGR, 102, 9145. [3] Namiki, N., Solomon, S.C. (1994) Science, 265, 929. [4] Fassett, C.I., Head, J.W. (2008) Icarus, 195, 61. [5] Neukum, G., Hiller, K. (1981) JGR 86, 3097. [6] Ivanov, M.A., Head, J.W. (2006) JGR, 111, E09003. [7] Cattermole, P. (1990) Icarus, 83, 453. [8] Mouginis-Mark, P.J., et al. (1988) Bull. Volc., 50, 361. [9] Hynek, B.M., et al. (2010) JGR, 115, E09008. [10] Ansan, V., Mangold, N. (2013) JGR, 118, 1873. [11] Sharp, R.P., Malin, M.C. (1975) GSAB 86, 593. [12] Ivanov, B.A. (2001) SSR., 96,87. [13] Hartmann, W.K. (2005) Icarus, 174, 294. [14] Head, J.W., et al. (1993) LPSC-24 627. [15] Wilson, L., Head, J.W. (1994) Rev. Geophys., 32, 221. [16] Head, J.W., et al. (2003) Nature, 426, 797. [17] Head, J.W., et al. (2005) Nature, 434, 346.

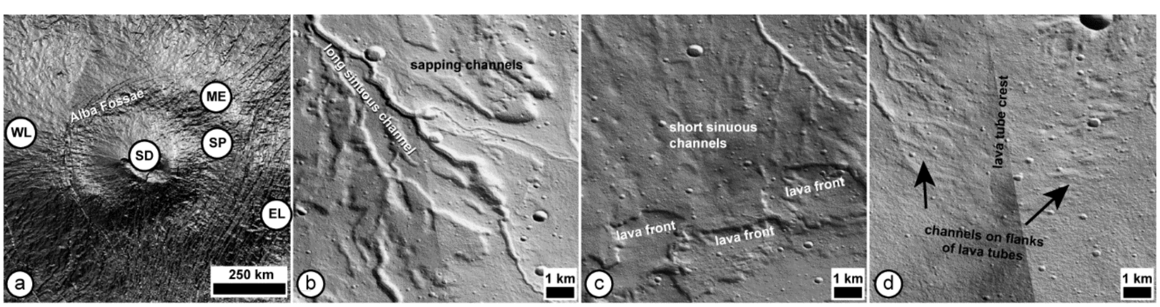

Fig. 1. a) Major topographic subdivisions of Alba Patera (MOLA, 1/128 shaded topography); b) the long sinuous channels and sapping channels, c) the short sinuous channels that begin at the edges of the sheet flows (lower part of the image), d) the systems of short channels on the flanks of the tube-fed flows. All images are parts of a mosaic of CTX images P04_002750_2234 and P13_006152_2234. North is up.