THE SHALBATANA VALLIS OUTFLOW SYSTEM IS A PRODUCT OF DRY VOLCANIC MEGAFLOODS. D. W. Leverington, Department of Geosciences, Texas Tech University, Lubbock, TX.

Introduction: The main channel of the Shalbatana Vallis outflow system extends ~1200 km northward across the wrinkle-ridged plains of Xanthe Terra, from the northeastern limits of Orson Welles crater into Chryse Chaos and the southern margins of Chryse Planitia [1,2]. The system heads in a region of disturbance consisting mainly of: 1) chaotic terrain located within Orson Welles crater; and 2) a complex set of fractures and basins located north of Ganges Chasma [2-9]. Development of Shalbatana Vallis may have extended from the Late Noachian into the Amazonian but is believed to have been mainly concentrated between the Middle and Late Hesperian [4-7], roughly 3.5 Ga before present [6].

The channels and disrupted terrain of Shalbatana Vallis are primarily hypothesized to have developed as a result of: 1) rapid generation of meltwater by interactions between magmatic intrusions and ground ice (possibly influenced by the geometry of regional fault systems), and the related release of groundwater held in cryosphere-confined aquifers and the pooling and overflow of water in basins such as that of Orson Welles crater [2,5,9]; 2) disturbance of an aquifer or ice lens by the impact that formed Orson Welles crater [9]; and/or 3) the northward conveyance of water along subsurface conduits connected to a lake in Ganges Chasma [2,3,7,11-17]. Subsidence of terrain in areas such as Xanthe Chaos and the interior of Orson Welles crater are hypothesized by some workers to have involved disturbance of ice-rich materials related to ancient ice-covered lakes that became buried by sediment [18], with this disturbance driven by processes such as magmatism or channel incision [7,9].

Formation of the Martian outflow channels is hypothesized to have required up to thousands of separate aqueous outburst events for each system [19], and a minimum of 1100 floods is estimated to have led to the development of Shalbatana Vallis [17]. Tributary channels and some mass wasting features at Shalbatana Vallis are widely interpreted as having developed as a result of sapping processes [6,20], with possible additional contributions from surface runoff [21]. The various fan-like deposits located within Shalbatana Vallis have been interpreted as alluvial fans or as deltas that accumulated within ancient lakes, and candidate shoreline deposits and wavecut terraces have been proposed at and near some of these features [6]. The transverse ridges present along the floors of the distal reaches of Shalbatana Vallis have been interpreted by some workers as enormous fluvial dunes analogous to those of the Channeled Scabland of Washington [22].

Much of the Shalbatana Vallis system is mantled by anhydrous fines, making it difficult to properly characterize the mineralogy of underlying rocky materials [23-25]. The existence of clays and carbonates at Xanthe Terra, exposed at some plateau surfaces and along parts of the walls of canyons such as Ganges Chasma and channels including those of Shalbatana Vallis, has suggested the possible weathering of bedrock here by meteoric water during the Noachian, prior to development of Shalbatana Vallis [26-28]. Some clays, sulfates, and opaline silica associated with Shalbatana Vallis channels are instead hypothesized to have developed under lacustrine conditions during the Hesperian [27]. Clays exposed within Orson Welles crater have been linked to past lacustrine conditions here or to the local deposition of detrital phyllosilicates during ancient flood events [29].

Weaknesses in Aqueous Interpretations: Past aqueous interpretations of Shalbatana Vallis suffer from major weaknesses including: 1) the improbable nature of hypothesized outburst processes; 2) discrepancies between hypothesized magnitudes of thaw-induced subsidence and plausible volumes of excess ice in the subsurface; and 3) contradictions between the nature of hypothesized aqueous processes and the mineralogy of associated geological materials.

Development of enormous channel systems by explosive discharges from aquifers is unknown in the solar system and is yet to be validated on the basis of realistic hydrological models [30-32]. The largest aqueous flood events on Earth have involved sudden releases of water from lakes dammed by ice or other materials, rather than catastrophic effusions from pressurized aquifers. Formation of large conduits and open chambers in the subsurface is not expected of the low pressures of shallow hydrological processes, and is instead characteristic of the high pressures typically associated with igneous plumbing systems [8,30,33].

Subsidence on the order of many hundreds to thousands of meters in regions of chaotic terrain is not generally expected of thermokarst-related processes [30,33,34]. Thermokarst subsidence results from the thaw of excess ice, which mainly exists where segregated ice has developed or where substantial volumes of surface ice have become buried as relict ice. Segregated ice develops primarily as relatively small lenses within loose sediments located at shallow depths where heave during freezing can be accommodated, and

thus is not expected to develop with great thicknesses. In contrast, the thicknesses of buried ice are only limited by the original volumes of surface bodies of ice, but hypotheses suggesting the past burial of e.g. ancient lakes must also be consistent with the mineralogy of local materials and the nature of preserved landforms.

The phyllosilicates that characterize Noachian-aged uplands on Mars suggest alteration at low water-to-rock ratios [35] and few sites have been identified at Shalbatana Vallis where hydrous minerals are present in notable amounts [27,29]. The relatively well exposed head region of Shalbatana Vallis is dominated in many locales by minerals such as pyroxene and olivine [8,24,25]. The preservation of pristine olivine-rich units of Noachian age in geological units exposed along the walls of Ganges Chasma and at adjacent uplands [36-42] contradicts interpretations of the past existence of large lakes here and the long-term existence in the region of highly porous and permeable aquifers [8,30,34,39,40]. More generally, the extensive exposures of pristine olivine-rich materials of Noachian age on Mars [23-25, 43-49] argue against hypotheses of contemporaneous and younger periods of widespread wet conditions on this planet [8,30,33,34,39,40,50].

A Dry Volcanic Origin for Shalbatana Vallis: As with all other Martian outflow systems [8,30-34,51,52], the attributes of Shalbatana Vallis are most consistent with development as a result of the rapid and voluminous effusion of low-viscosity lavas of mafic or ultramafic composition. This system heads in a region of topographic disturbance associated with volcanic plains and a canyon system with characteristics suggesting development through volcanotectonic processes [8,30,39,52]. Shalbatana Vallis shows evidence for having conveyed low-viscosity lavas along component channels [8] and terminates in an impact basin mantled by wrinkle-ridged flood lavas [34,53-55]. A dry volcanic origin for this system is consistent with the mineralogical characteristics of associated geological units, and does not require the past existence of otherwise unexpectedly wet surface conditions or high atmospheric pressures. Volcanic development of Shalbatana Vallis is consistent with the higher interior temperatures known to have characterized the earlier histories of rocky bodies of the inner solar system, which drove formation of voluminous partial melts of mantle peridotite through decompression processes in environments such as those related to plumes [30,31,33,34]. Formation of the main channel of Shalbatana Vallis is estimated to have involved a minimum erupted lava volume of ~360,000 km^3.

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