ECHUS CHASMA AND KASEI VALLES, MARS: NEW DATA AND GEOLOGIC INTERPRETATIONS.
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Introduction: Echus Chasma is a 175-km-wide, 100-km-long open-ended depression at lat. 1°S, long. 80°W. Kasei Valles extends nearly 3000 km north from Echus Chasma and then east at lat. 20°N, long 75° W. to debouch into Chryse Planitia. Previous mapping indicated the chasma and valles system cut into Hesperian ridged plains material (unit *Hpr*) of the Lunae Planum and Tempe Terra plateaus, and that Tharsis lava units *At4* and *At5* of Amazonia age cover large parts of the channel [1-4]. Across north Kasei, the older unit *At4* flows are sourced east from Tharsis. Younger unit *At5* flowed east from Tharsis and also south from Echus Chasma. Our study of this system utilizes data from HRSC images and derived DTMs, THEMIS, MOC, and MOLA. The ages of units were determined by crater counts (orbits 97, 920, and 2204; crater diameter > 1 km), using the production function coefficients of Ivanov [5] and the cratering model of Hartmann and Neukum [6] to derive absolute ages.

Results: Counts of the unit *Hpr* indicate the average ages of emplacement to be around 3.6 to 3.8 Ga. Ancient east-trending grooves (fluvial or glacial?) and streamlined islands that predate the main Kasei floods were known to have cut Labeatis and Sacra Mensae, remnants of high plateau material at about 25°N. in north Kasei [1-4,7-9]. This erosion was suggested to come from floods sourced to the west by Sacra Fossae and Tharsis, rather than south from Echus, the source of later main Kasei floods [1-4,7]. Our new mapping shows additional east-trending grooved terrain, streamlined islands, and chains of pits much farther north, on the high plateau of Tempe Terra as far as 34°N. within material previously mapped as unit *Hcht* [8] and unit *Hrd* [9]. HRSC topographic measurements indicate the islands reach heights of 50-100 m on Tempe Terra, at least 1 km above the Kasei channel floor. The island heights and locations indicate the ancient western floods from Tharsis were widespread and voluminous. Crater counts indicate that this flood erosion took place around 2.98 Ga. In addition, THEMIS images of north Kasei Valles show the east-trending enigmatic ridge of Uranius Dorsum to extend 2° farther west (120 km; to long. 80°W.) than previously mapped [9]. Some of the lava plains north of Uranius Dorsum are as old as 3.5 Ga (Tempe Terra lavas?) and others are part of younger lava unit *At4*. The *At4* lavas north of the dorsum were emplaced around 2.6-3.4 Ga. The ridge area is too small for accurate crater counts, but it likely dates from 2.6 to 3.4 Ga. Because the ridge is topographically much higher than any geomorphic features of lavas in the area and as its trend is parallel to ancient flood scour, the dorsum may be related to the Tharsis floods (levee or medial ridge?). Images indicate the ridge was flood scoured. [Scouring also appears to have plucked unit *At4* northwest of Labeatis Mensa.] Uranius Dorsum bounds the northeast part of a large lava-covered MOLA topographic low, centered west of Kasei Valles (at lat. 18°N., long. 81° W.) that extends to long 84°W., which is about 420 km away from the previous mapped boundary [8,9] of Kasei. The topographic low's relation to Kasei and Uranius Dorsum likely indicates carving by floods from Tharsis.

We also observed and measured evidence that changes the map boundaries of lava units *At4* and *At5*. As noted, our crater counts indicate unit At4 flows north of Uranius Dorsum are between 2.6-3.4 Ga in age. However, flows south of the ridge, previously mapped as unit *At4* [1-4], date from 1.3 Ga. This age overlaps the age unit *At5* elsewhere. Near Labeatis Mensa, others have determined absolute crater ages of 1 Ga to 1.6 Ga for the mapped area of unit *At4* [10]. Again these ages are much too young. The surface appearance of *At4* and *At5* are very different; *At5* flows are thinner and smoother than those of *At4*. The lava unit south of Uranius Dorsum is much smoother than that of *At4* to the north. Our new mapping extends the north contact of unit *At5* from lat 23°N to about lat 28°N, south of Uranius Dorsum and northeast of Labeatis Mensa.

Emplacement of unit *At*5 took hundreds of Ma and overlapped episodic south Kasei floods. The age dates for unit *At5* range from 1.6 Ga to 90 Ma. These variable ages of *At5* make sense when one takes into account characteristics of terrestrial flood lavas. The majority of terrestrial flood lavas are inflated pahoehoe flows transported 100s of km from vents underneath an insulating crust, with the emplacement of a typical ~1000 km^3 flood lava flow estimated to have taken about a decade [11, 12]. In Kasei the length of the *At5* flood lava deposit is over 1,000 km and 300 km wide. Geologic relations show *At5* covering most of the flood-scoured floor of Kasei, but locally the unit formed concurrently with flooding and pre-flooding. The major grooving and scouring of the Kasei channel occurred about 1.3 Ga to 1.8 Ga, concurrent with older parts of unit *At5*. In addition, unit *At5* abuts grooved floor material (flood/ice scour) near lat. 22.5°N., long. 76.25°W. (south of Uranius Dorsum) and is eroded by floods at lat. 13.82°N., long. 79.69°W.

Lava unit *At5* bears striking similarities to the Cerberus flows in Elysium Planitia. Within Echus Chasma and nearby embayed sapping channels *At5* shows distinctive "platy-ridged" surface morphology [13]. In addition, parts of unit *At5* are relatively youthful, similar to the young Cerberus flows that have been modeled to indicate surface exposure from 1.5 to 200 ma [14,15]. The local platey-ridge surface indicates multiple surges of lava emplacement. Plates form in a 2-stage process: a thick stable crust forms on molten lava; later a surge in the lava flux disrupts this crust and transports large pieces as rafts on molten lava [16].

Although the water flowing north via Kasei Vallis has been suggested to have emanated from Echus Chasma, the large surface area of Kasei Valles in comparison to this much smaller source is a problem. Perhaps the channel had additional sources. For example, chaos is mapped north of Echus Chasma at about lat 13°N [8,9]. Chaos consists of blocks of material usually within depressions that likely subsided when ground water was released [17,18], with magmatic intrusion as the most likely mechanism to have provided the melting energy [19,20]. MOLA topography clearly shows that chaos within Kasei occurs in a very large subcircular depression that has been mostly buried by *At5* lava flows. THEMIS images show that this depression is bound on the west side by a curvilinear ridge, mantled by lavas. In addition, new HRSC and THEMIS images on the plateau directly west of Echus show numerous narrow dendritic channels that also fed water into the chasma. Mapping suggests that the water flowed from beneath what may have been ice-rich layered plateau materials. A resistant material covers the channel floors and locally forms inverted topography. The density of the dendritic channels suggests a lengthy formation age. These channels fed into larger trunk channels (3-6 km wide) that drained into Echus. Younger sapping channels that debouch into Kasei Valles near Echus Chasma follow the path of the trunk channels and also that of plateau graben. The sapping channel floors are embayed and overlain by platy-ridged Echus Chasma lava flows.

On a final note, our high-resolution crater counts are producing very young ages for *At5* lavas in parts of Kasei. These ages are not inappropriate based on Martian meteorites evidence of extensive flood volcanism in the recent past. There are 36 meteorites found on the Earth thought to have come from Mars [21,22]. Although impacts that launch Martian material to Earth may be biased toward young lavas as strong surface enhances spallation [23], the dominance of meteorites < 2 Ga is evidence that parts of Mars (including Kasei Valles) are covered by relatively young igneous rocks [24].

Conclusions: New results indicate that ancient 2.98 Ga western floods from Tharsis were widespread and voluminous, and could account for the east-trending path of north Kasei Valles. Emplacement of unit *At5* appears to have taken millions of years and overlapped episodic south Kasei flood scouring. On the basis of age and appearance, we extend the *At5* contact northward to about lat 28°N. Parts of the *At5* lava unit are rather young and show platey-ridge surface textures. We also suggest other sources for Kasei waters: surface flow on the plateau west of Echus and perhaps a subsurface source north of Echus Chasma.

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