RECENT SCIENTIFIC RESULTS FROM SPIRIT'S OBSERVATIONS OF SULFATE SANDS ON THE SIDE OF SCAMANDER CRATER, COLUMBIA HILLS, MARS. R. E. Arvidson[1] and The Athena Science Team, [1]Earth and Planetary Sciences, Washington University in Saint Louis, Saint Louis, MO, 63130

Introduction: Spirit has been exploring the Inner Basin in the Columbia Hills for much of its mission, including documenting the volcaniclastic deposits associated with Home Plate and associated sulfate and opaline silica deposits formed in aqueous environments. During a drive south Spirit drove onto the side of the the 8 m wide Scamander crater and became embedded in sulfate-rich sands. An extensive measurement campaign was implemented while analyses, tests, and simulations were underway to determine the best extrication procedures. The data show that Spirit excavated through sulfate enriched crusts within the crater and exposed deeper sulfate-rich sands. These deposits are interpreted to have formed via aqueous processes when volcanism associated with construction of Home Plate was active. Subsequent downward translocation of the more soluble ferric sulfates are inferred to have occurred during later periods associated with solid-state green house warming under modest snow covers during periods of high spin axis obliquity.

Measurement Campaign: Spirit's right front wheel drive actuator has been inactive for several years. As a consequence the rover is typically driven backwards to minimize pushing this wheel and torquing the suspension. On sol 1871 during a 7 m southward drive Spirit stopped on the side of Scamander crater located in an area called Troy (Figs. 1-2). Subsequent drives to place the rover onto a plateau to the southeast of the crater led to embedding in sands. Drives were halted on sol 1899 when the left middle wheel stalled. Drive attempts started again on sol 2088 after extensive testing, modeling, and analysis led to plans that would minimize further embedding. In between these sols an extensive measurement campaign was conducted to survey the surroundings and make detailed in-situ measurements using the Instrument Deployment Device to deploy contact instruments.

Numerous measurements were conducted using the Microscopic Imager, Alpha Particle X-Ray Spectrometer, and Moessbauer Spectrometer on the soils disturbed by the left front wheel, an area called Ulysses (Fig. 3). Additional measurements were conducted as a function of depth on the undisturbed surfaces to the east of Ulysses, including use of the Rock Abrasion Tool to exacavate into the subsurface for additional measurements. A key result is that the disturbed soils in Ulysses are poorly sorted angular sands dominated by ferric sulfate and basaltic mineral end members. Further, the sulfate end member is present in the RAT hole nearest Ulysses but is not present in the hole to the east, i.e., outside of Scamander crater.

Removing that bimodal trend and combining with imaging data show that there are four stratigraphic layers in the embedding region (Figs. 4-5). The top layer consists of well-sorted, rounded aeolian basaltic sand mixed with nanophase iron oxides. This layer is underlain by a thin, visibly red (i.e., sharp ferric absorption edge) layer dominated by nanophase iron oxides. Within Scamander crater the next layer is a sandstone deposit a few cm thick that has a distinctive enrichment in Ca-sulfate material. This layer is underlain by deposits enriched in SiO2. The bottom layer constitutes the bulk of the material in Ulysses and is characterized by the highest SO3 content, including a relatively high abundance of ferric sulfates.

Water-Related Processes: The sulfate deposits in Scamander crater are interpreted to have formed in hydrothermal or steam environments when volcanism associated with construction of Home Plate was active. These materials, as ejecta and local wind-blown sands, filled in the crater. The distinct layering is interpreted to be associated with downward migration of relatively soluble species during periods of high obliquity, when the site would have been covered by snow. Solid-state greenhouse warming at the contact between the snow and relatively dark soil is the likely cause of formation of liquid water for vertical translocation. Thus while embedded on the side of Scamander crater Spirit has uncovered evidence for two timescales of water-related processes: formation of aqueous deposits associated with early volcanic activity and subsequent continuing redistribution of soluble species associated with orbitally-induced climatic change.

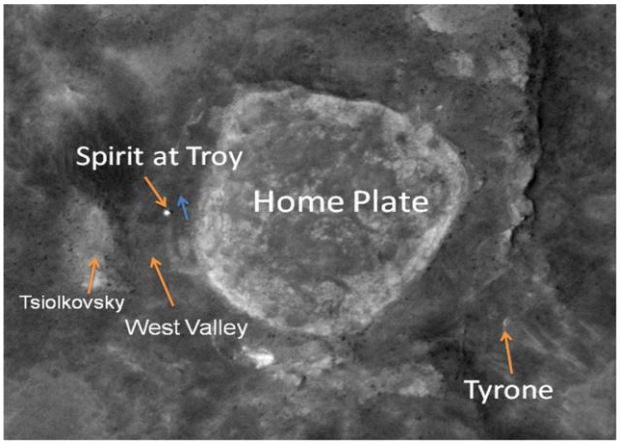

Fig. 1 – View of Home Plate showing location of Spirit in its embedded location in Troy. Scamander crater is not evident in this view. Home Plate is approximately 80 m wide. Blue arrow shows direction that Spirit is facing. Frame ESP_013499_1650_red courtesy Hi-RISE Imaging Team, University of Arizona.

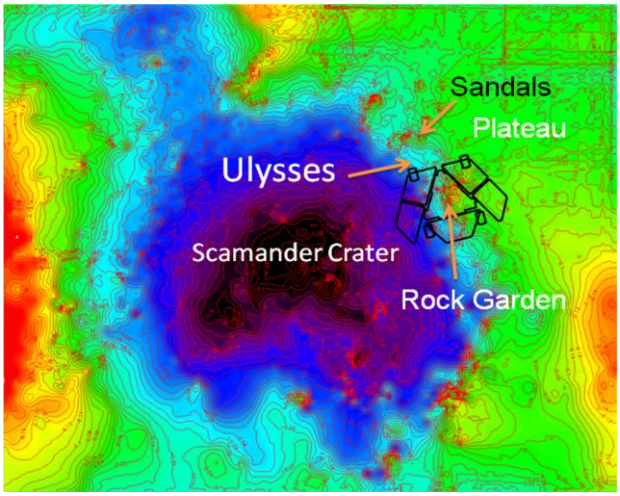

Fig. 2 – Topographic map with regional tilt removed. Scamander crater is approximately 8 m wide and 25 cm deep. Ulysses is the sulfate-rich soil region disturbed by the left front wheels. Rock Garden is the group of rock clasts under Spirit and part of the crater rim. Sandals is a pair of rocks evident in Fig. 3. Relief between red (high) and black (low) is about 50 cm. Generated by Ron Li, Ohio State University, from sol 1870 Navcam stereo images.

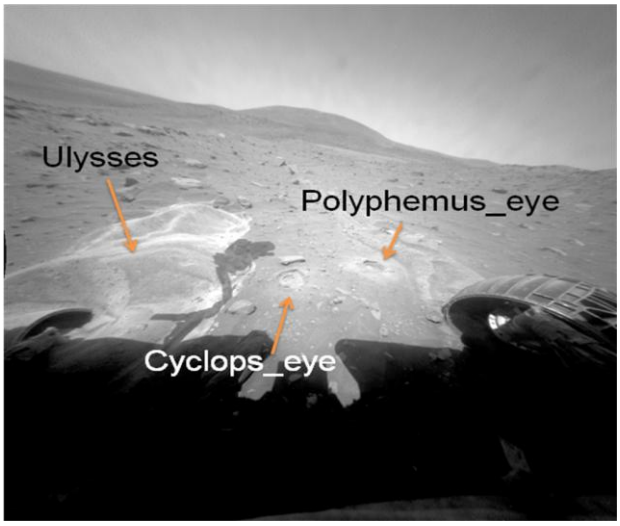

Fig 3 – Front Hazcam view acquired on sol 1998, facing northwest, and showing the key areas for which Microscopic Imager data, APXS, and Moessbauer observations were acquired, including multiple targets in Ulysses. Cyclops_eye and Polyhphemus_eye using the RAT to expose deeper and deeper horizons. Sulfate-rich soils are found in Ulysses and Cyclops_eye but not in Polyphemus_eye. Husband Hill is on the horizon.

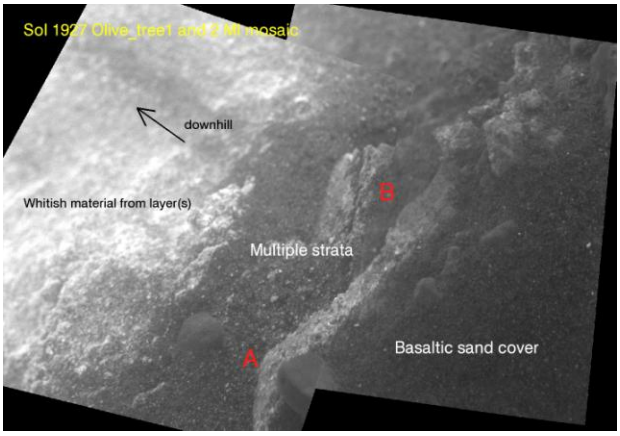

Fig. 4 – Microscopic Imager view of portion of the eastern cliff in Ulysses showing sandstone layers enriched in Ca sulfates. North is to the top and the image covers about 6 cm in width and was acquired in shadow.

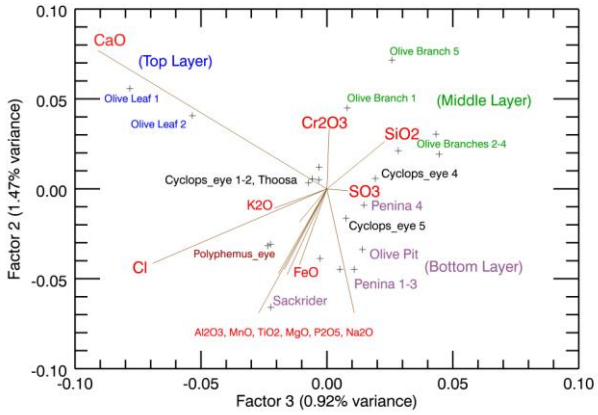

Fig. 5 – Factor loading plot from a correspondence analysis for APXS data acquired in Ulysses and to the east. Factors 2 and 3 are shown because Factor 1, capturing 96% of the data set variance, is simply dominated by the sulfate and basaltic endmembers, i.e., it is a mixing line. Blue labeled targets correspond to the upper sandstone layer enriched in Ca sulfates, green to the underlying layer with SiO2 enrichment, and purple to the bottom layer that dominates soil exposures in Ulysses. Note the movement toward sulfate targets for deeper (high number) Cyclops_eye targets.