WATER AT THE PHOENIX LANDING SITE. P. H. Smith[1] and the Phoenix Science Team, [1]Lunar and Planetary Lab, University of Arizona, Tucson, AZ 85705, psmith@lpl.arizona.edu.

Introduction: The Phoenix mission, the first of NASA's Scout class, landed inside the arctic circle on Mars on May 25, 2008 at 23:38:24 UTC. At the first downlink opportunity pictures were returned showing a gently undulating landscape of patterned ground reminiscent of polar terrain on the Earth. Thus began a successful scientific investigation that lasted 152 sols and returned 30,000 images along with reams of weather and mineralogical data. Archiving of this data set is expected to be complete in May 2009.

The mission and its goals have been previously described [1]. Using instruments designed to measure atmospheric properties, mineralogy and chemistry as well as the geologic setting itself, Phoenix attempts to verify the presence of the water ice that was predicted based on thermodynamic principles [2] and was first discovered using Odyssey's GRS instrument [3]. By studying the soil associated with the ice, Phoenix can learn the history of the ice, in particular, if liquid water has modified the soil chemistry.

The Geologic Context: The Phoenix Lander touched down at 68.22° N, 234.25° E (areocentric) on the northern plains of Mars. On a regional scale the Lander is sitting at an elevation of -4.1 km (referenced to Mars Orbiter Laser Altimeter topography) in a valley covered by the Scandia Formation, a deposit that surrounds the northern margin of Alba Patera, a shield volcano [4]. The Scandia Formation is interpreted as volcanic ash associated with eruptions from Alba Patera and/or as fine-grained ancient polar deposits [5]. On a local scale the Lander touched down on partially eroded ejecta deposits located ~20 km from the rim of the 10 km diameter, bowl-shaped crater, Heimdall. Phoenix has the distinction of landing at the highest latitude on Mars and on the youngest terrain (<0.5 Bya) relative to the five other landed missions (two Viking Landers, Pathfinder, Spirit, and Opportunity).

The 2.35 m long robotic arm (RA) and associated Icy Soil Acquisition Device (ISAD) were used to excavate a dozen trenches within the RA work volume [6]. Widespread icy soil was found a few centimeters beneath a surface cover of soil and examined in detail for two trenches on the left (DodoGoldilocks) and right (Snow White) portions of the work volume. Further, icy soil was uncovered beneath the lander during descent as the thruster exhaust eroded the soil cover. Scrapings from the hard, white layer in the Dodo trench were observed to sublimate in <4 sols.

Sampling and digging operations after sol 20 through the completion of the primary mission took place in and near the Snow White trench in the center of the Wonderland polygon. A layer of hard material was uncovered at 5 cm depth. The material was dark but shiny when freshly scraped, became brighter in the blue within one sol, and took on soil color within 4 sols. The layer is thought to be an ice layer with a large soil content, a sublimation lag developed over days.

The soils excavated by the ISAD are cloddy, with mechanical properties similar to those found for cloddy soils sampled by the Viking Lander 2 [7]. The cloddy nature of the soil may be a consequence of cementation associated with calcite or perchlorate identified from TEGA and MECA WCL, respectively, and may be adided by a small amount of surface moisture.

Evidence for aqueous processes: A sample of sublimation lag was delivered to TEGA in the "Wicked Witch" sample. The small endothermic peak and evolution of water indicate a small amount of water ice. Integration of the endothermic peak provides an estimate of the enthalpy of 0.35 J, which corresponds to 1.04 mg of water ice (latent heat of fusion of ice is 333 J/g). There is no direct method to measure the amount of sample delivered to the TEGA oven, however, the ice content of the "Wicked Witch" sample is estimated at 2.5 % assuming a full oven.

Evolved water. The Differential Scanning Calorimeter thermal analysis and water profiles from a surface sample dubbed "Baby Bear" were derived by subtracting a second day TEGA run (baseline with volatiles removed) from the first day run. Water evolves around 290ºC and then again near 760ºC.

Water release beginning 290ºC and continuing to 550ºC may be due to a variety of phases. The important implication of this lower temperature water release is that the group of minerals or phases that are candidates can only form by aqueous processes.

Two endothermic inflection points with onset temperatures at 720 and 785ºC likely represent the decomposition of calcium carbonate and a hydroxyl-bearing phase, respectively. The endothermic reaction near 785ºC may be a result of the evolution of water near 760ºC. Formation processes for the candidates producing the higher temperature water release are complex as some may form by non-aqueous igneous or metamorphic processes. Even so, water must have been associated with the magma body or a precursor material, respectively.

Calcium carbonate detected by TEGA and MECA: Thermal and evolved gas analysis and solution chemistry measurements indicate the presence of Ca-

carbonate in the soil above the ice-rich layer [8,9]. TEGA measures an endothermic peak at 720ºC accompanied by an increase in evolved CO_2. MECA Wet Chemistry Lab has determined the solution pH to be 8.2±0.5 with (Ca^{++}) at 10-3 M; the addition of an acid tablet (2-nitrobenzoic acid) resulted no change in pH indicating a strong buffering capacity. These observations taken together are strong indicators for the presence of calcium carbonate. Carbonate dissolution and precipitation are among the most important chemical reactions in soils on Earth [10] and buffer the pH of terrestrial soils and surface seawater around 8.2-8.3.

A key question is whether the carbonates formed in-situ or were transported by eolian processes. Carbonates are predicted and expected to form on Mars [11,12]; however, they have not been widely observed from orbiter and lander missions. Carbonates have been identified in martian meteorites [13,14] and orbital observations have suggested they occur at less than 5 % in the global dust on Mars [15]. Nearly all occurrences of Ca-carbonates in terrestrial soils have formed by pedogenic aqueous processes.

Liquid Water: Phoenix has not found any evidence for liquid water in the soil in the current epoch, the maximum surface soil temperature measured by the Thermal and Electrical Conductivity Probe was ~260K.. Quasi-periodic cyclical changes in solar insolation occur in the North polar region due to orbital forcing that causes variations in obliquity and orbital eccentricity [16]. In the current epoch, northern summer occurs during aphelion, and obliquity is relatively low (25.2°). As the obliquity exceeds 30°, the polar cap becomes unstable and pumps water vapor into the atmosphere saturating it and forming ice clouds. Over the last 10 MY maximum obliquity approached 45° and increased the summer insolation to 2.5 times the present value. A key unknown is the persistence of high latitude surface ice as obliquity increases and low-latitude ice deposits become thermodynamically favorable [17,18].

Conclusions: Phoenix has validated the Odyssey discovery of near surface ice. The ice table first seen under the lander exposed by the thrusters is measured to be from 3 to 16 cm deep from polygon center to trough. Through visual inspection, sublimation of ice chips, scanning calorimetry, and mass spectrometry the water ice identification is secure.

The overlying soil has no measurable water or ice in the current epoch, although surface deposits are implied by the 3-µm band seen from orbit by the spectrometers: OMEGA and CRISM. The discovery of calcite and minerals that release water at low temperatures argue for a past when the soil was moist. The cloddy nature of the soil may be a consequence of cementation associated with calcite or perchlorate and a small amount of water.

In the late summer water ice is observed to fall from the clouds at 4 km altitude and ground fogs are seen late at night in the lower ~700 m of atmosphere and frost forms early in the morning [19]. These tiny grains of ice could easily melt if temperatures were warmer and frost thicker during a different climate cycle or in warmer microclimates, especially in the presence of salts with low eutectic temperatures. Note that the low water activity of brines makes them unsuitable for life.

Phoenix has provided a polar weather station and the data taken throughout the Summer season can now be used to update global circulation models. Once the models accurately predict the observed interaction between the atmosphere and the surface, then the potential for a habitable zone during recent epochs with higher obliquity can be better ascertained. A large rise in humidity and temperature is required to create a habitable environment; this possibility is being actively investigated.

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