MERCURY'S HOLLOWS: CHALCOGENIDE PYRO-THERMOKARST ANALOG OF THERMOKARST ON EARTH, MARS, AND TITAN. J.S. Kargel[1] [1]Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721, USA (kargel@hwr.arizona.edu).

Introduction/Summary: MESSENGER has acquired stunning images of pitted, light-toned or variegated light/dark terrains located primarily on many of Mercury's crater floors (Fig. 1) and on some ejecta blankets. Termed "hollows" by the imaging team, the pits have been described as unique in the Solar System. However, these terrains are geomorphologically similar to some on Mars formed by sublimation of ice-rich permafrost (Fig. 2) and to lowland thermokarst on Earth formed by permafrost thaw; to "swiss cheese" terrain forming by sublimation of frozen CO_2 at the Martian South Pole (Fig. 3); and to terrain at Titan's poles thought to be hydrocarbon thermokarst (Fig. 4). Mercury lacks eolian processes that could erode the pits, and the pits do not possess volcanic characteristics. The most plausible explanation for Mercury's hollows is terrain degradation involving melting or sublimation of heterogeneous chalcogenide and sulfosalt mineral assemblages. Adapting the term thermokarst, I refer to these Mercurian features as pyro-thermokarst; the etymological redundancy distinguishes the conditions and mineral agents from the ice-related features on Earth and Mars, though some of the physical processes may be similar.

Working Hypothesis: Whereas ice has been long suspected and recently was discovered in permanently shadowed craters of Mercury's polar regions, the hollows occur down to the equator, where neither ice nor sulfur is plausible. In principle, the responsible volatiles must be only slightly volatile in the upper crust of Mercury's low to middle latitudes at 400-500 K, but they must be capable of either melting or sublimating on geologically long time scales. Cosmochemically plausible substances that either occur in E-chondrites or are consistent with an hypothesized E-chondrite-like Mercury include many phases and mixtures having low melting temperatures and moderate volatility. Under prevailing upper crustal and surface temperatures, chalcophile-rich "permafrost" can undergo either desulfidation or melting reactions that could cause migration or volume changes of the permafrost, and hence lead to collapse and pitting.

I propose the initial emplacement of crater-hosted chalcogenides[1], sulfosalts[2] and related chalcophile materials such as pnictides[3] in impact-melt pools and ejecta blankets (involving solid-liquid fractionation) and associated dry or humid fumaroles (solid-vapor

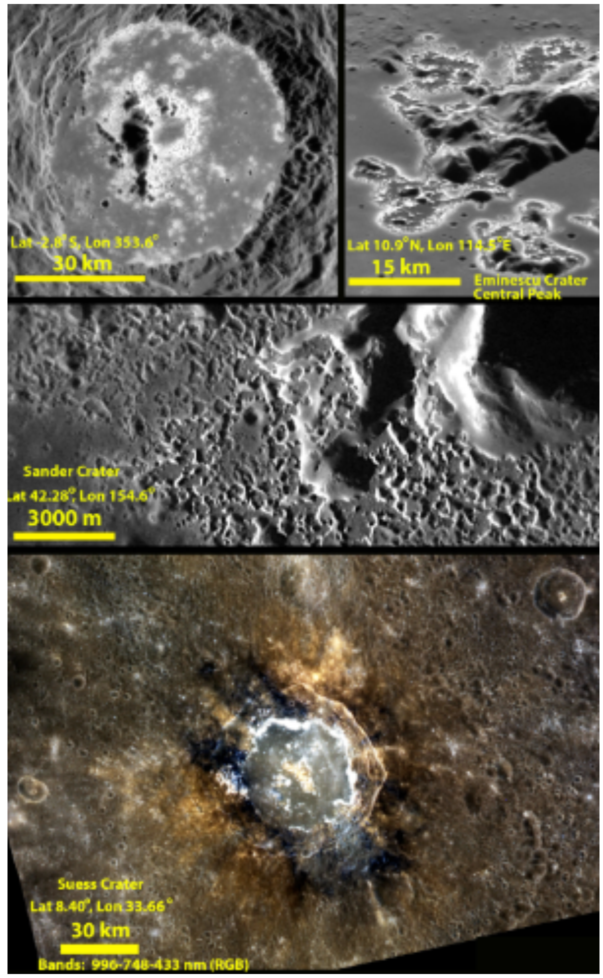

Figure 1: Typical pit-and-hollow terrain on the floors of Mercurian impact craters. The terrains generally form at foot of a central peak or crater walls, usually on probable impact-melt sheets. The pits or deposits adjoining them are typically light toned and commonly occur in craters that have variegated bright and dark ejecta. Pits and hollows occur mainly at low and middle latitudes on Mercury.

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1 Chalcogenides are minerals and compounds made of a chalcogen element—S, Se, or Te—with an electropositive element among the alkalis, alkaline earth metals, transition metals, and/or semi-metals; e.g., pyrite, galena, sphalerite, bornite, athabascaite, and rickardite).

2 Sulfosalts have chalcogen elements bonded with electropositive metals (such as alkalis, alkaline earths, and transition metals) and semi-metals (especially P, As, Sb, Bi, In, and Sn.

3 Pnictides include binary compounds and minerals containing pnictogens (nitrogen-group elements N, P, As, Sb, Bi).

and liquid-vapor fractionation and recondensation). Key phase equilibria largely occur in the temperature range of Mercury's surface and shallow subsurface, as I shall show. Vapor-solid, vapor-liquid, and solid-liquid equilibria of the heated materials resulted in migration and loss of volatiles and anatectic liquids, causing collapse pits to form. Seasonal heating near perihelion may have worked together with geothermal flux or early impact heating to have driven off volatiles and produce the pits.

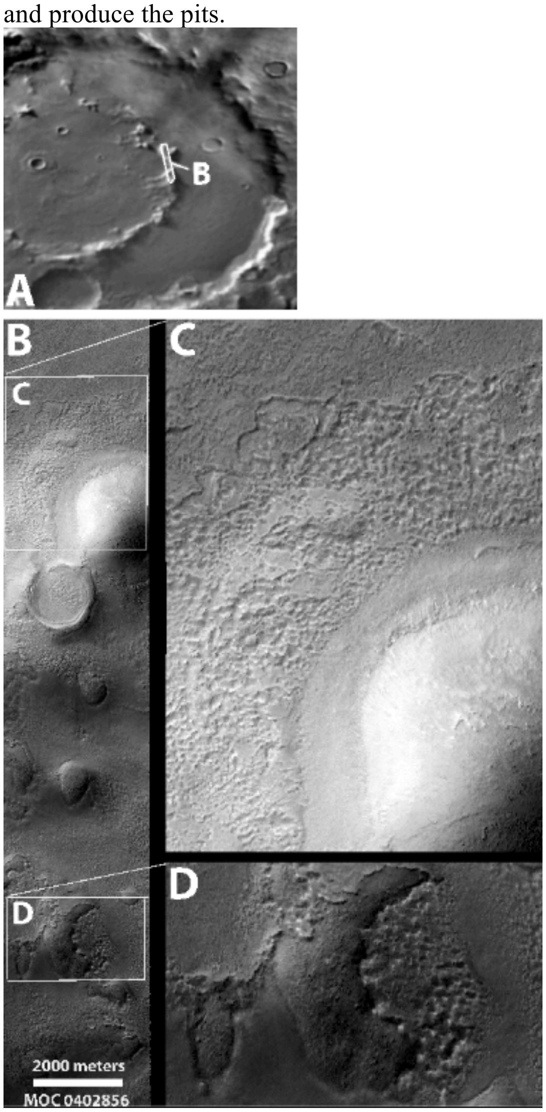

Figure 2 (above). Thermokarst developed near the peak-ring of Kepler Crater, Mars, 46.8 S Lat, 140.9 E Lon. Pitting on the floor of Kepler is confined to the plains adjoining and onlapping the peak ring. The responsible processs is thought to be sublimation of ice from ice-rich dust; climate change is thought to have first caused conditions to allow deposition of ice-rich dust, and then recently its degradation. The middle latitudes are the only places where this and similar terrains occur on Mars.

In some cases, local recondensation of moderately volatile sulfides and other minerals (including the elements Cu, Pb, Au, and others) may have occurred on the rims of the pits; the more volatile components (including the elements As, Se, Te, Bi, and others) may have been transported to the polar regions or lost by exospheric escape. The least volatile components, including most transition metals (e.g., Fe, Co, Ni, Zn, and platinum-group elements), are apt to form relatively refractory lags of sulfides and native metals. Impacts by comets may have caused local oxidation and formation of oxygenated salts and other minerals, whose local recondensation from fumarole gases can explain the light-toned layers and light-toned rims of many pits. Plating of native volatile metals and semi-metals may also account for some light-toned deposits.

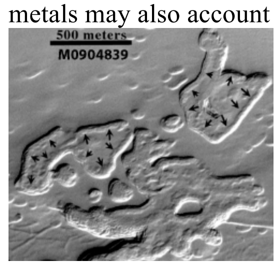

Figure 3. "Swiss cheese" terrain of the Martian South Polar cap. The responsible process is sublimation of CO_2 ice, which is an active process. The perennial dry ice polar cap near the South Pole is the only place where this CO_2-based pit-and-mound "hollow" terrain occurs.

Large contrasts in thermal conductivity as well as local topography-caused shading influences may result in large differences in element mobility and mineral assemblages. There probably exists strong latitude gradients across the surface and vertical gradients in the upper crust in chalcogen-sulfosalt mineral assemblages. Pyrothermokarst on Mercury may be more chemically heterogeneous and complex in its development than any other thermokarst in the Solar System.

Figure 4. Thermokarstic or badlands terrain near Titan's South Pole. The responsible process is believed to be methane dissolution of a volatile, soluble hydrocarbon. Thermokarst is also known from Titan's north polar region, but not low latitudes.