Six years ago, in November of 1996, an instrument called the Thermal Emission Spectrometer (TES) was launched aboard the Mars Global Surveyor spacecraft; it also carried new-found hope for the scientists who would work with the data. This was the second time this instrument was en route to Mars: the first TES was on board the Mars Observer spacecraft that forever lost contact with the Earth in 1993 just as the spacecraft arrived at Mars. Having another shot at a long-awaited mineralogical survey of Mars using TES was what it took to identify a unique mineral occurrence on the Red Planet. The mineral the TES instrument unequivocally identified is gray hematite (Fe₂O₃), an oxide mineral that occurs on Earth as well as Mars, whose chemistry is similar to that of common rust.

The hematite found on Mars occurs in both fine-grained and coarse-grained varieties. Fine-grained hematite (whose grain diameters are <5-10 microns) gives Mars its red color, which is why Mars is called the “Red Planet”. This fine-grained hematite is dispersed within the copious dust that gets blown around the planet during the seasonal Martian dust storms and is seen as the lighter-colored regions on Mars. In contrast, coarser-grained hematite (>10 micron-diameter grains) is gray, not red like the finer-grained hematite in the Martian dust, since the finer grains scatter the red end of the solar spectrum. A global investigation of Mars by the TES instrument has led to identification of only three main areas of gray hematite exposed at the surface of the entire planet. These gray hematite deposits all occur in darker regions on Mars near the equator including an area called Sinus Meridiani, in a large impact crater called Aram, and within the Valles Marineris canyon system. It is possible that the fine-grained hematite originated through weathering of gray hematite like those three areas near the equator.

Now that scientists have identified these mineral occurrences on Mars, they can begin to interpret the origin of the hematite. To do this, a strategy called “comparative planetology” is used, whereby the geologic processes that form hematite on Earth are thought to be the same processes that...
HEMATITE ON MARS
(continued from front page)

might form the hematite on Mars. Hematite is known to form in oxidizing environments. A common oxidizing environment on Earth is anywhere there are iron-bearing materials that can form hematite through chemical reactions. On Mars there is a lot of basaltic rock (similar in composition to the volcanic rock in Hawaii) where the gray hematite occurs. Basaltic rocks contain iron within the feldspar and pyroxene minerals that make up the rock. In the presence of water, the iron is removed from these minerals and used to form hematite.

There are several geological settings in which hematite is formed on our planet, including the following more common ways: Hematite can form in an ocean or lake whose water contains iron that combines with oxygen and settles out onto the floor as a sedimentary hematite deposit. It can form in a hydrothermal setting, where hot water flows through rocks, and strips those minerals of iron that is later deposited as hematite. Also, another oxide mineral, magnetite (Fe₃O₄), that occurs in volcanic rocks, can react with oxygen in the atmosphere, or in water, and be converted to hematite.

Water is currently not stable on the surface of Mars because the atmosphere is too thin and the surface temperatures are too cold. If a bucket of water were placed on Mars, it would quickly evaporate, or freeze, then sublimate. So, how is it possible that liquid water helped to form the Martian hematite? Although the jury is still out, many scientists believe that early Mars (about 4 billion years ago) was wetter and possibly warmer than today. Those climatic conditions would have enabled liquid water to be stable on the surface. Surprisingly, recent photographs of Mars, acquired by both the Mars Orbiter Camera (MOC) and the Thermal Emission Imaging System (THEMIS), show evidence of possible liquid water seepage along the walls of some canyons and impact craters. It appears that this seepage might have occurred recently on Mars (within the past few million years), or may be occurring on Mars even now. If this seepage is occurring under the present Martian climatic conditions, the water is likely to be rich in dissolved salt minerals that would act to lower the freezing point (as compared to pure water), and allow it to flow freely onto the planet’s surface.

It is likely that water played a role in the formation of the gray hematite on Mars, although the specific geologic process for forming it is still unknown. Scientists are actively debating the gray-hematite issue. Soon the answer may be known because one of the two landers slated to be sent to Mars in the summer of 2003 (and arrive in January 2004) likely will be sent to the Sinus Meridiani hematite region. On board the lander will be a Mars Exploration Rover (MER) that may roam up to 100 meters a day (for about 90 days) and will host a full payload of scientific instruments designed to photograph and measure the chemistry of the rocks and soils of Mars. Scientists will be able to interpret the data received from the instruments on the MERs to learn more about the past and current Martian geologic and climatic environments.

Congratulations to Dr. Steve Howell as he begins his new position with the University of California, Riverside, as a Research Professor in the Physics Department. He departed on November 1st after having been associated with PSI since 1988. While at PSI, Steve headed the Astrophysics group and led research projects on cataclysmic variable stars and extrasolar planets. All of us at PSI wish him well in his new endeavor. Good luck, Steve, you will be greatly missed!

STEVE HOWELL MOVES ON

The Thermal Emission Spectrometer
Has proved a portentous barometer:
For, if what you study
Is grey and not ruddy,
You can map like a manic geometer!

Anne Raugh, 2002
A SHORT HISTORY OF PSI  Part 1
by William K. Hartmann, Donald R. Davis and Stuart J. Weidenschilling
Senior Scientists, PSI

In the Beginning

The roots of PSI were established in the late 1960s, when several young PhD’s graduated from the University of Arizona laboratory of the pioneering planetary astronomer, Gerard Kuijper, and ended up working in a space division of a Chicago organization called IITRI - the Illinois Institute of Technology Research Institute. IITRI provided planning and mission analysis support to NASA HQ for post-Apollo exploration of the solar system—both planets and the Moon—and needed guidance from planetary scientists for this endeavor. Toby Owen and Alan Binder were hired by IITRI in Chicago; however, efforts to attract other young scientists were unsuccessful, in part due to IITRI’s rather unappealing location in Chicago. Binder (who later led the Lunar Prospector mission that discovered ice in the polar soil of the moon) agitated successfully to open a Tucson planetary division of IITRI, and by 1971 this division included Binder, Bill Hartmann (who was working on the Mariner 9 Mars mission, Don Davis (U.A. PhD graduate at that time for participating in saving the Apollo 13 mission), and Clark Chapman (UA student and MIT PhD known for his work on asteroids). We were led by a very capable and clever IITRI manager named Dave Roberts and the first office was in downtown Tucson, at 201 N. Stone Ave.

From the beginning, the philosophy was to develop a group of collaborative scientists in an atmosphere conducive to producing excellent science — a group run by scientists for the benefit of science. The “superstar” model was rejected in favor of a team approach in which individual Principal Investigators would have overlapping but distinct areas of expertise. PSI management sought to attract good young scientists and help them develop proposals that would start their independent careers and fund their work through the group.

Official Founding of PSI

By late 1971, this group had become dissatisfied with the growing overhead and top-heavy management of IITRI, and decided to pull out. We joined a fledgling parent company known as Science Applications Incorporated, which had just been formed by a nuclear engineer, Bob Beyster, who had gone through the same business cycle himself. Hartmann’s employee number at SAI was 224, an irony since SAI grew into the enormous technology firm, Science Applications International Corporation, where employee numbers are now in the high tens of thousands! Beyster allowed us to be a non-profit center within this larger profit-making company, and was pleased with the prestige of involvement in NASA-funded science. We selected the name Planetary Science Institute.

To make the transition, a few of us at a time left IITRI and joined SAI. Hartmann had been participating in the Mariner 9 Mars mission, and in early 1972 returned to Tucson. The newly formed Planetary Science Institute started as a desk in his living room on Sunray Drive in the Tucson mountains. While we looked for a real office, the others made the transition to SAI/PSI. For these reasons, we officially date the birth of PSI as February 1972, and celebrate our anniversary open house each year on Ground Hog Day. PSI found office space in Northwest Tucson and remained there for several years.

Early Work at PSI

Noteworthy research began to flow from PSI immediately. Hartmann and Davis collaborated on a what turned out to be a famous paper, given at a Cornell meeting in 1974 and published in 1975, which first suggested that the Moon formed when a collision with a giant, primordial interplanetary body blew material out of the outer layers of Earth, providing debris to make the Moon. This theory was recognized in 1984 as the leading theory of lunar origin and has kept that place to the present day.

During the 1970s, Chapman carried out observations of asteroids and helped develop the taxonomic system by which asteroids are classified according to different compositions. Hartmann continued work on lunar and Martian cratering. From numbers of craters, he was able to conclude that many lava flows on Mars had ages of “only” a few hundred million years, which is young in planetary terms; this controversial result was confirmed by Martian meteorites in the 1980s and 90s.

Rick Greenberg, an MIT graduate and dynamicist, joined the group in 1976. Stuart Weidenschilling, yet another MIT graduate, who had done postdoctoral work with the famous dynamicist, George Wetherill, joined PSI in 1978. We developed a democratic structure, with decisions made by discussion and consensus. Hartmann served briefly as manager, until his natural inabilities were fully recognized. Davis became manager, a position he has retained, and about which he has complained, ever since.

Now, with Greenberg, Weidenschilling, Davis, Chapman, and Hartmann, we had a group with a powerful depth of un-
derstanding of collisions and aggregation of the primordial bodies, or "planetesimals", that orbited the sun and eventually formed the planets. In the mid 1970s, our PSI group collaborated on creating a complex computer model that allowed us to start with innumerable planetesimals and follow their collisions until they grew into planets — a process called accretion. Some of our ideas were inspired by earlier work, not widely recognized at that time, by a Soviet scientist named Victor Safronov, who was later much honored as the father of collisional accretion theory. We were honored when he was able to visit our office in 1979. The PSI model included complex orbital theory and results from new collision experiments that we conducted at NASA’s Ames Research Center to learn how materials absorb energy or fragment during collisions. In the late 1970s we began publishing these results.

In the mid 1970s, the two Viking missions landed on Mars and placed orbiters in position to send back large amounts of data. Viking scientist, Jim Cutts, joined PSI in 1974 and formed a separate office in Pasadena that same year which did notable Mars research with the Viking results. PSI-Pasadena also absorbed various contracts for work farmed out from Cal Tech’s Jet Propulsion Lab, which ran the Viking mission. Unfortunately, as the Viking mission wound down and JPL policies evolved, the Pasadena office ran out of contracts and closed in 1979. Notable researchers such as Karl Blasius (Mars) and Tommy Thompson (lunar radar) worked with us through the Pasadena office at that time.

The PSI “planet forming model” has continued to evolve under the leadership of Weidenschilling and Davis, and continues to be the basis for much research on planet formation and collisional evolution of asteroids, both in the main asteroid belt and in the more recently verified “Edgeworth-Kuiper belt” on the outskirts of the solar system.

( look for History of PSI Part 2 in the next issue)
HARTMANN AT SWISS INSTITUTE

PSI Mars researcher, Bill Hartmann, spent a week in August, 2002 working with two Russian colleagues at the International Space Science Institute (ISSI), in Bern, Switzerland. This was an outgrowth of several visits over the last few years, when Bill worked on a series of ISSI workshops and co-edited the resulting book, Chronology and Evolution of Mars. PSI’s Stu Weideneschilling also has attended an international workshop at ISSI.

ISSI’s mandate, in part, is to bring together international researchers and, in good Swiss fashion, provide a central meeting facility. As a result, Bill organized two additional small ISSI meetings, in 2001 and 2002 between himself and Ivan Nemtchinov and Olga Popova, both from Moscow’s Institute for Dynamics of Geospheres. ISSI was able to provide per diem assistance for the visiting researchers, and this is especially valuable in the case of Russian scientists, who are currently receiving very little research or salary support due to problems with the Russian economy.

The Russian group has a state-of-the-art code for modeling the passage of meteoroids through planetary atmospheres. The PSI-Moscow team applied this program to study craters on Mars. The workshops produced one paper submitted to the journal Meteoritics and Planetary Science and a second paper currently in preparation. The papers predict the smallest impact craters to form on Mars (less than 1 meter in diameter) and explain the existence of clusters of craters found in Mars Global Surveyor images, due to breakup of impact materials in the Martian atmosphere.

On October 28-29, 2002, PSI hosted a workshop that highlighted current research regarding the geology and surface environment of Mars, and included updates of current NASA missions to the Red Planet and plans for future robotic exploration. The meeting was attended by 32 people, including Tucson-based and other PSI scientists and faculty, graduate students, and undergraduate students from the University of Arizona.

The first day of the meeting, held at the historic Arizona Inn, consisted of scientific presentations and round-table discussions of recent research and mission results, including those pertaining to the abundance and distribution of water and ice in Martian surface deposits.

The second day of the meeting, held at PSI’s Tucson offices, included a review and planning session for PSI’s Mars program. The was an excellent opportunity for PSI’s geographically scattered Mars scientists to update one another and coordinate future activities. The workshop was organized by David Crown and Bill Hartmann, with logistical support from Chris Holmberg, and audio/visual assistance from Kathleen Komarek. A special thanks to all of the out-of-town PSI scientists who traveled to Tucson to contribute to the success of the workshop.
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