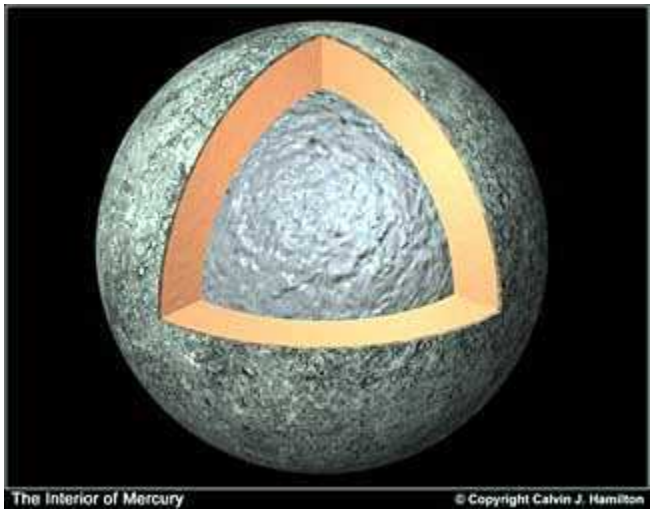
AstroNotes

Newsletter of the Ottawa Centre,

Royal Astronomical Society of Canada

The Geology of Mercury

A Puzzle Wrapped in an Enigma



Abridged Edition

August/September 2003

The New Electronic AstroNotes

by Tim Cole, Editor

- This month marks the launch of an electronic version of *AstroNotes* available on the Centre's web site. Call it "e-*AstroNotes*","*AstroNotes On-Line*", or even "that damn-fool computerized *AstroNotes* thingy"if you like. All you need to read it is a copy of Adobe Reader, which Adobe

provides free of charge.

- Ottawa Centre members still have their choice of editions. If you'd prefer your good old printed copy, you don't have to do a thing. We'd like to convince you to sign up for the electronic edition. Why would you want to do that? Well, we think there are a lot of good reasons.
- •Unlike the archived versions of *AstroNotes* you already find on our web site, the new e-*AstroNotes* is current. In fact, you ought to be able to get an issue before the regular meeting. If you're concerned about plugging up your e-mail account with big attachments, rest easy. We'll send you only an announcement by e-mail. Follow the link in the announcement, and you've got your new issue.
- •You'll get color illustrations. It's too expensive to print *AstroNotes* in color, so we have to convert all the illustrations to greyscale. The on-line version will contain the contributor's original artwork.
- •You'll help the Ottawa Centre save printing and mailing costs. Producing and distributing *AstroNotes* accounts for one of the largest expenses in the Centre's annual budget. Reducing those costs without reducing service will go a long way to keeping the Ottawa Centre surcharge-free.
- •It's easy to change your mind. If you really don't like the electronic version of AstroNotes, just notify us. Before you know it, you'll be seeing *AstroNotes* printed on sheets made from tall and stately trees, hewn before their time, pulped and rolled out... oh, never mind. Guilt trips never worked for me, either!
- We've put a lot of effort into getting e-*AstroNotes* ready to go, but we're not vain enough to think it's all worked out in its final glory. Give it a try. If you see something you think should be done differently, let us know. We can't guarantee we'll be able to make it work, but we'll certainly do what we can.
- Besides, just think how nice Simon's illustrations would be in *color*!

Cover Illustration: Cut-away View of Mercury

- Among the few solid facts known about Mercury's composition is its very high density. This implies the presence of an enormous core, which does not fit well with accepted theories of planetary formation.

AstroNotes
August/September 2003

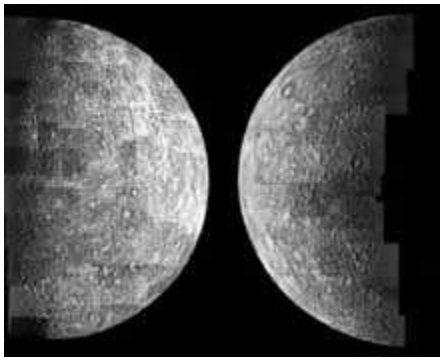
Mercury: Planetary Geology of an Enigmatic Neighbor

by Simon Hanmer, NRCan (Geological Survey of Canada)

- Planetary science has progressed by leaps and bounds in the past few years: (i) we've sent probes to all the outer planets, except for Pluto, (ii) our detailed photographic coverage of Mars from orbiting probes is almost as good as our coverage of Earth, (iii) we've now detected over 100 extra-solar planetary systems, and we're only a few steps away from actually imaging them. So it's ironic that Mercury, a planet we can see with the naked eye for much of the calendar year, is so poorly imaged, so poorly known, and its planetary geology is so poorly understood. All the images we have of Mercury come from the unmanned Mariner Missions of the mid-1970's, principally Mariner 10 in 1974_75. Mariner 10 made three fly-bys, though because of the orbital mechanics of the probe and the planet, Mariner always saw the same hemisphere illuminated by the Sun. This means that we have no images of 50% of one of our nearest planetary neighbors.
- The orbital mechanics of Mercury are unique among the planets, but very similar to those of the moons of the outer Solar System. Because Mercury is so close to our star, the Sun exerts an enormous gravitational pull, raising powerful tidal forces within the rocks that make up the planet. The result is that Mercury's rotation around its own axis has slowed down to

synchronize with its orbit around the Sun, such that it now takes two complete orbits around the Sun to complete thee rotations about its own axis. In other words, there are three Mercurian days for every two Mercurian years! We only discovered the rotational behavior of Mercury in the 1960's thanks to radar beamed from Earth. Before that, visual observations from Earth produced some very crude maps of the planet's surface: crude, and mostly imaginary, like the example from the mid-1930's by the Greek astronomer Antoniadi.

- In case you're wondering why we don't use Hubble to fill in the missing images,



Mosaics courtesy NASA

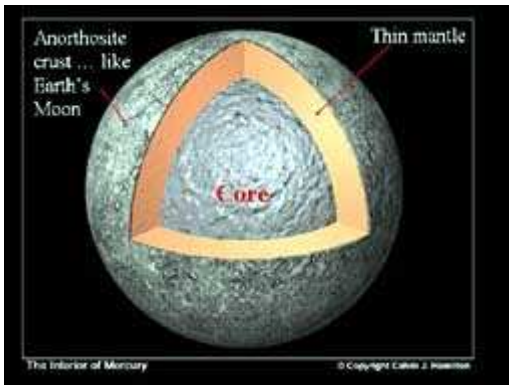
Left: Quadrant imaged by in-bound spacecraft. Right: Out-bound image mosaic.

- NASA won't allow it because of Mercury's proximity to the Sun. Any orientation errors could potentially be fatal for the `scope if it should accidentally look directly at the Sun!

Planetary Formation _ Observation *vs*. Theory

- In terms of its size, Mercury lies somewhere between Mars and our own Moon: in fact it's exactly the same size as Jupiter's moon Callisto. However, from studying the effect of the gravitational pull of Mercury on the Mariner probes, planetary scientists calculate that Mercury is almost as dense as its much larger

neighbors, Earth and Venus. This presents planetary geologists with a difficult conundrum: in order to be small and dense, Mercury must contain a very large, very heavy core of iron and nickel that spans 75% of its diameter. The problem



- is that theory says that planetary bodies form by the clumping together or *accretion* of smaller bodies made of primitive meteoritic material (chondrite) that heats up and *differentiates* into a core, a mantle and a crust. When primitive chondritic material differentiates, it

- yields a much smaller amount of iron and nickel relative to the size of the planet — certainly not 75%. So what's the explanation?
- Two principal theories have been proposed to account for the anomalously large Mercurian core, but neither of them work! Some planetary geologists suggest that the heavy bombardment by meteorites during the accretionary phase of the early Solar System smashed the outer layers of a once much larger Mercury, leaving a core and a thin relic mantle behind. Others suggest that, because Mercury formed so close to the early Sun, its outer layers were volatilized by the energy pumped out by the star at the centre of the evolving early Solar System. The problem is that, by analyzing the light reflected from the planet, we know that the surface of Mercury is made of the same stuff as the surface of our own Moon: a rock called *anorthosite* that has a composition similar to *CoffeeMate,* and a calcium aluminum silicate called *plagioclase*

feldspar. This is exactly the rock that planetary science predicts should form the primitive crust, or

AstroNotes
August/September 2003

- outermost layers, of a normally differentiated planet. In other words, while Mercury may be anomalously heavy on the inside, it is perfectly normal on the outside. So whatever the explanation for the anomalously large core turns out to be, it apparently has nothing to do with stripping off the external layers of a once much larger planet, which is most unfortunate, because current planetary theory doesn't offer us any other explanations!

Comparisons with Earth's Moon

- So what does Mercury's surface look like? Superficially, surface features on Mercury resemble those on Earth's Moon, with heavily cratered terrains versus flatter, smoother plains. Not only does Mercury have one of the largest giant Impact Basins in the Solar System—Caloris Basin, some 1300 km in diameter— but superficially it looks just like the huge Orientale Impact Basin that is mostly hidden from us on the west side of the Moon. But, when you look a bit more closely, the apparent similarities between Mercury and the Moon give way to differences.
- Perhaps the biggest difference is the way the cratered and smooth terrains are distributed. On the Moon, the smooth terrains are the dark Mare that are sharply delimited from the lighter heavily cratered Highlands. This color difference reflects the fact that the dark Mare are made of basalt lava that occurs all over the side of the Moon that always faces the Earth, while the light colored Highlands are made of anorthosite (the *CoffeeMate* rock). However, on Mercury the Smooth Plains (as they are officially called) are all concentrated in one place: they form the floor inside the Caloris Impact Basin, and a collar

around its perimeter. In contrast to the lunar Mare, the Smooth Plains on Mercury are the same color and therefore the same composition as the Heavily Cratered Terrain. Therefore, some planetary geologists have suggested that they are not made of lava, but are formed of fine-grained debris derived from the impact that made the Caloris Basin. However, by measuring the number and size of impact craters, the Smooth Plains are not only relatively young in the history of Mercury, but they are much younger than the impact that made the Caloris Basin. Hence, whatever the Smooth Plains are really made of, they did not form during the major impact event that sculpted the surface of Mercury as we see it today.

- Another major contrast between the Moon and Mercury is that unlike the Moon, Mercury has a second set of flat terrains called the *Inter-Crater Plains*. These plains are impacted by lots of craters and are therefore relatively old, but right next door the same Inter-Crater Plains can flood and drown other impact craters, so the plains are relatively young. The obvious conclusion here is that the Inter-Crater Plains formed during the Heavy Bombardment, about 4 billion years ago — another major difference with the Moon.

AstroNotes
August/September 2003

- What about the impact craters themselves? Superficially, they look just like those of the Moon, with central peaks, flat floors and terraced walls characteristic of the larger examples. However, (i) the transition to these mature crater forms occurs at smaller sizes on Mercury, (ii) the stuff thrown out of the hole by the impact didn't travel as far from the crater as on the Moon, and (iii) the bright rays associated with the larger impact craters are better preserved on Mercury. Some planetary geologists attribute these differences between lunar and Mercurian craters to the greater gravity of the planet due to its large, dense core, however others contest both the measurements

and the conclusion. Hence, we arrive once again at a stalemate in planetary science!

- Other, uniquely Mercurian impact craters formed when meteorites struck the planetary surface while it was hot and, like toffee, too weak to support the topographic contrast between high-standing crater walls and a deep crater floor. Hence, these craters seems to have flattened out almost as soon as they formed, something else that we do not see on the Moon.

Planetary Shrinkage and a Giant Impact

- There are two more major features on the Mercurian surface that we do not see on the Moon, or any other rocky planet for that matter. The first is a series of curved escarpments, hundreds of kilometres long, and more than a kilometre high. These are structures that formed as the planetary surface contracted during a period when the large iron-nickel core of Mercury cooled and shrank. They always cut across the impact craters, so they must be younger than the Heavy Bombardment. Remember that means younger than 3.8 billion years old.
- The other feature unique to the Mercurian surface is called "Hilly and Lineated Terrain," better known as *Weird Terrain*. This is an area of

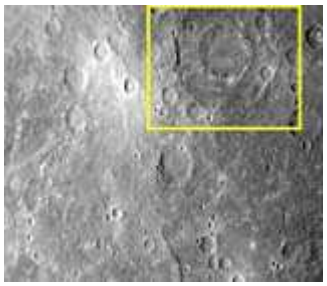


Image courtesy NASA

This double-ringed impact crater seems to have sunk back into the surrounding terrain.

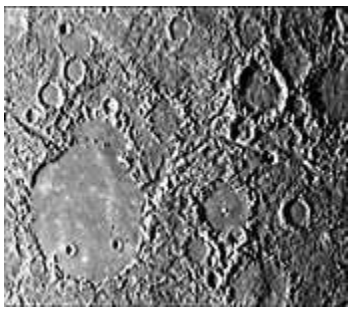


Image courtesy NASA

An example of "weird terrain."

AstroNotes
August/September 2003

- random hills (whose slopes have gradients of up to 50%) that represent a localized upheaval that lifted the surface of the planet and dumped it down again in a random jumble of hills and depressions. This Weird Terrain only occurs in one place, precisely on the other side of the planet from the Caloris Impact Basin. The accepted interpretation is that the giant impact that created the Caloris multi-ringed Impact Basin sent shock waves through the entire planet that converged on the opposing hemisphere, jumbling the surface with no preferred orientation. The terrain includes several rift valleys, like the Ottawa Valley here on Earth.

The Dark Side

- Clearly there are lots of questions regarding the planetary geology of Mercury that we cannot answer with the information we have in hand today. Another unmanned mission is required, but will it happen anytime soon? Meanwhile, radar images from Earth have revealed a bright spot some 500 km across in the unknown hemisphere that could be a giant volcano like those found on Mars, and the same radar images show bright spots at the Mercurian poles that are currently interpreted as ice. That's pretty remarkable for a planet whose maximum surface temperature at perihelion rises to about 500°C!

- As an amateur astronomer, I am very excited by the discoveries currently being made regarding extra-solar planets, and the new-found moons of Jupiter and Saturn, but somehow we seem to have forgotten one of our nearest planetary neighbors; a neighbor that throws up a whole series of questions regarding our most cherished theories of how planets form.
- Perhaps it's time to send another probe.

Update: Planned Mercury Missions

- In fact, there are two Mercury messions in the works. NASA's MESSENGER (MErcury Surface, Space Environment, GEochemistry and Ranging) spacecraft is currently undergoing integration and testing. Scheduled for launch on 10 March 2004, its orbital mission at Mercury should begin in April 2009. Getting to Mercury isn't easy. The mission requires two Venus fly-bys (in June 2004 and March 2006 and two Mercury fly-bys (in July 2007 and April 2008). The MESSENGER web site is at *http://messenger.jhuapl.edu*
- The European Space Agency (ESA) is planning its own Mercury mission, BepiColumbo, with a planned launch in 2011. This ambitious spacecraft uses electric propulsion (*i.e.* an ion engine) and includes two orbiters and the first Mercury lander. The web site seems to move a bit, so start at *http://sci.esa.int*.

— Editor

AstroNotes
August/September 2003

Careful Planning and Quick Improvisation Succeed in Space Biz

by Dr. Tony Phillips, NASA/JPL

- On December 18, 2001, ground controllers at JPL commanded NASA's Deep Space 1 (DS1) spacecraft to go to sleep. "It was a bittersweet moment," recalls Marc Rayman, the DS1 project manager. Everyone was exhausted, including Deep Space 1, which for three years had taken Rayman and his team on the ride of their lives.
- DS1 blasted off atop a Delta rocket in 1998. Most spacecraft are built from tried-and-true technology — otherwise mission controllers won't let them off the ground. But Deep Space 1 was different. Its mission was to test 12 advanced technologies. Among them: an experimental ion engine, a solar array that focused sunlight for extra power, and an autopilot with artificial intelligence. "There was a good chance DS1 wouldn't work at all; there were so many untried systems," recalls Rayman.
- Nevertheless, all 12 technologies worked; the mission was a big success.
- Indeed, DS1 worked so well that in 1999 NASA approved an extended mission, which Rayman and colleagues had dreamed up long before DS1 left Earth — a visit to a comet. "We were thrilled," says Rayman.
- And that's when disaster struck. DS1's orientation system failed. The spacecraft couldn't navigate!
- What do you do when a spacecraft breaks and it is 200 million miles away? "Improvise," says Rayman.
- Ironically, the device that broke, the "Star Tracker," was old technology. The DS1 team decided to use one of the 12 experimental devices — a miniature camera called MICAS — as a substitute. With Comet Borrelly receding fast, they reprogrammed the spacecraft and taught it to use MICAS for navigation, finishing barely in time to catch the comet. "It was a very close shave."
- In September 2001, DS1 swooped past the furiously evaporating nucleus of Comet Borrelly. "We thought the spacecraft might be pulverized," Rayman recalls, but once again DS1 defied the odds. It captured the best-ever view of a comet's heart and emerged intact.

- By that time, DS1 had been operating three times longer than planned, and it had nearly exhausted its supply of thruster-gas used to keep solar arrays pointed toward the Sun. Controllers had no choice but to deactivate the spacecraft, which remains in orbit between Earth and Mars.

AstroNotes
August/September 2003

- Rayman has moved on to a new project — Dawn, an ion-propelled spacecraft that will visit two enormous asteroids, Ceres and Vesta, in 2010 and 2014. "Dawn is based on technologies that DS1 pioneered," he says.
- Even asleep, DS1 continues to amaze.
- Find out more about DS1 at *http://nmp.jpl.nasa.gov/ds1*. For kids, go to *http://spaceplace.nasa.gov/ds1dots.htm* to do an interactive dot-to-dot drawing of Deep Space 1.

Photo courtesy NASA/JPL

This was the final image of the nucleus of Comet Borrelly, taken just 160 seconds before Deep Space 1's closest approach to it. This image shows the 8-km (5 mile) long nucleus from about 3417 km (over 2000 miles) away.
This article was provided by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

AstroNotes
August/September 2003

Two Successful Star Parties

by Debra Tigner, Public Outreach Coordinator and Ottawa Centre VP

- It's always good to plan star parties for the public. It's even better when those star parties are advertised in local papers and on the local television stations and radio. That's when we get the biggest response. On the evening of July 25th and especially August 16th the public response was wonderful! Hundreds of people showed up around dusk at Pinhey's Point to gaze at the stars and look through the telescopes that were set up by dedicated members. The weather gods were very accommodating for us this summer. I had long line ups at my scope even before it got dark! I find it very energizing to see so many interested and enthusiastic people new to astronomy come out and ask questions and really get into it. It confirms my thoughts that there is a huge percent of the population that are highly interested in this subject. I think that we are doing a wonderful service by getting out there and giving people of all ages an opportunity to come and see and satisfy their own curiosity and connect with others with the same interest. Maybe we'll see some new faces at the Centre meetings.
- At the July Star Party, Chris Teron came with his 8" Meade and laptop setup. The ISS made a nice pass across the sky around 10:30pm as well as four iridium flares (about 6 minutes between each one, a very rare event indeed!). These were real crowd pleasers. Bryan Black came with his newly assembled f/8 6" Newtonian along with the mount that he has been discussing at recent Centre meetings. Andre Tremblay, who is just getting back into stargazing after a long layover, brought along his brand new Skywatcher 102mm refractor that he had just bought the night before. Rob Dick brought along a pair of binoculars — as well as Jon Buchannon! Rob handed out about 60 star maps and about 5 old (2001) RASC *Observer's Handbooks*. I'm sure they will be a good reminder for the evening.

About 100 introductory pamphlets from *Astronomy* Magazine were also well received by the visitors. Tim Cole was there with an 8" SCT and also used his green laser pointer, a great teaching tool, to point out constellations and satellites. Gerald Noordhof, a first time volunteer for our star parties, came with his 8" Skywatcher on an equatorial mount. Mike Earl demonstrated his new Celestron NexStar 11. It's an 11-inch GoTo SCT with a built-in GPS receiver, though Mike used a Pentium II laptop to run the scope. He used a #25 (deep red) filter to observe Mars, which brought out the darker features on the planet. After the crowd died down, the rest of us all gathered around Mike's telecope for some awesome observing. That scope gave me I saw my first view of Mars this year and I was blown away! Thanks Mike!

- On August 16th, Mars' perihelion and near-opposition really got the attention of the press and the public. And it was wonderful to show it off to so many interested people. I counted 27 telescope operators reaching out to talk, teach,

AstroNotes
August/September 2003

- and entertain the huge crowd of about 250! So many, in fact that I wasn't able to get everyone's names, but many thanks to all who came out and represented the Ottawa RASC. That must be a record for us and Pinhey's Point. Hundreds of Centre brochures were also handed out, along with lots of old astronomy magazines. It was a great star party. Some of us even stayed all night to view Mars.
- The next star party is planned for September 20th at the Diefenbunker in Carp. Mars will be rising even earlier then, so try not to miss it. Thanks to everyone who gave their time and energy to these events. It means a lot! Hope to see you all at the next amazing gazing session.

Photo courtesy Debra Tigner

Debra views Mars through the "Grovel Scope" — an 8" apochromatic triplet (!) on a Losmandy HGM-200 mount. The telescope's name comes from the contortions needed just to peer through the eyepiece!

AstroNotes
August/September 2003

General Assembly and National Council Report

by Debra Tigner, Ottawa Centre Vice-President

- I was fortunate enough to be able to attend the National Council meeting at the General Assembly in Vancouver on 27 June this year. While the GA was very enjoyable, the Council meeting was less so. There was a great deal of time spent dealing with minor points or issues which have already been brought up at past Council meetings. However, there were some significant events.
- The Canadian Astronomical Society (CASCA) has formed a Solar System and Planetary Science Committee. The Committee has some interest in involving amateurs in the field and asked Peter Jedicke in his own right to be a member. Council endorsed Peter (of the London Centre and national VP) as the official RASC representative

as well.

- Publications are a major cost item within the Society and as such receive a great deal of attention. Every year or two, as at this meeting, there is a lengthy discussion on revising formats, changing distributions, reducing content, electronic distribution, etc. In some cases, the Society bylaws prescribe what is to be distributed to members (such as the annual report) and when. In other cases, electronic distribution of some publications to some members rapidly becomes impractical. Finally, after some discussion, people realized that for every publication we send out, there are some who don't like it and some who do. Changes have been made in the past and will be made again in the future, but they do take time. These are important decisions with significant impacts on the future of the Society.
- The *Beginning Observers Guide* is undergoing a major revision. Council authorized a print run of 5000 copies, once the Publications Committee has reviewed and approved the content. There was discussion again about a spiral binding instead of the current flat binding. This was rejected as it is not popular with book sellers since the spine doesn't show the title. Also, it is generally a more expensive form of binding. The new print run will have a better lay-flat binding that will ease its use in the field.
- The Society is going to add licence plate frames to the list of novelty items we sell. They should be available shortly and will have the RASC name on them. Price will be a few dollars.
- The Light Pollution Abatement (LAP) Committee reported on recent activity. There is a small cadre within the Ottawa Centre involved in LPA, which has had some successes to report. Head of the national committee is Ottawa Centre member Rob Dick.
- The Observing Committee which developed the new Beginning Observer Certificates is soon to be made a standing committee of National Council. They

- are working to expand the certificate programs to include variable stars and lunar observing with other doubtless to follow.
- The MOST (Microvariability and Oscillations of STars) satellite is the smallest telescope ever launched into space. It was launched on 30 June as "carry-on luggage" with other larger satellites aboard a Russian *Rokot*, a revamped ICBM[1]. Not many people may realize that Ottawa Centre member Peter Ceravolo played a major role in the design, construction, and integration testing of the satellite's optics. One of the goals of the MOST program is to use the satellite for outreach activities promoting science interest and education. It will be some time before the satellite is confirmed to be fully operational and is feeding data, but now is the time to start thinking up your research proposals for Canada's "humble" space telescope.
- The Belleville Astronomy Club has applied and been approved as the newest Centre in the Society. Eastern Ontario is really turning into a hot-bed of astronomical activity.
- Next year the GA will be held in St. John's Newfoundland over the Canada Day weekend. The new Okanagan Centre is bidding for the 2005 GA, to be on the Victoria Day weekend. The next National Council meeting will be sometime in October in Toronto.

---

[1] The* Rokot *launch vehicle series is based on decommissioned SS-19 ICBMs. It's great to see them used instead of run through the crusher. — Editor

AstroNotes
August/September 2003