Lobate Scarps

Mercury's Global System of Thrust Faults

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PTYS 395
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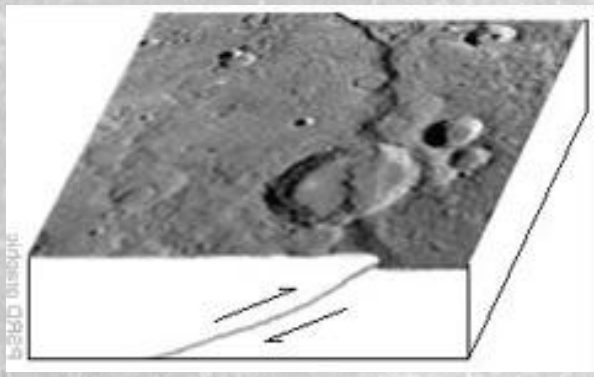
Background is first image of Mercury sent back from MESSENGER
Image Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Overview

- What are lobate scarps?
- Where are they found on Mercury?
- When did they form?
- Why are they there?
- What has/will MESSENGER tell us?

What are Lobate Scarps?

Lobate = having or resembling lobes
Scarp = cliff



Global tectonic feature

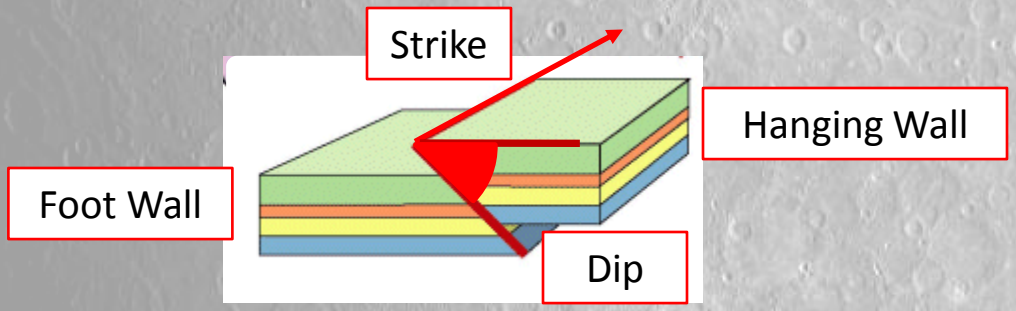
Named "Rupes" from Latin for "cliff"

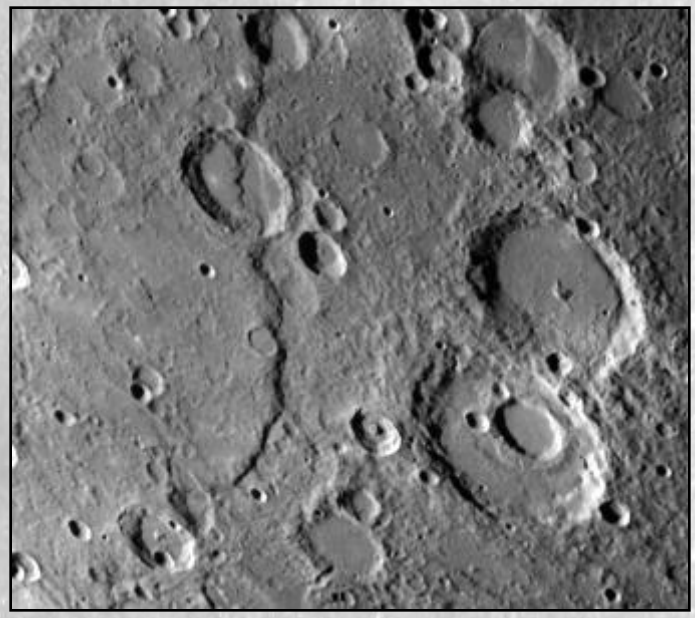
All named after ships

Large, curved cliffs

- Really large!

Interpreted as thrust faults

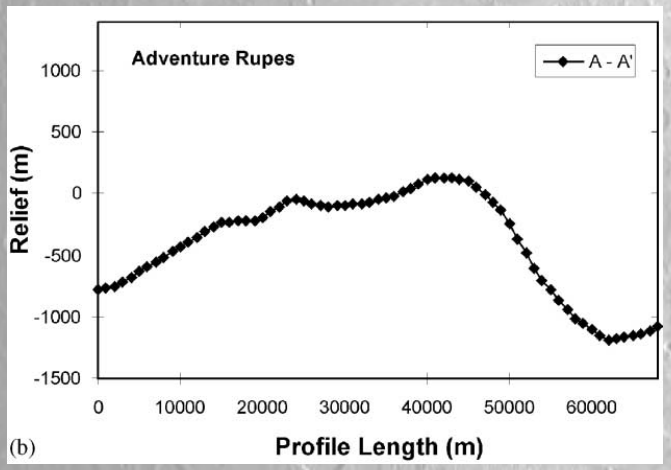




Discovery Rupes, Mariner 10 image

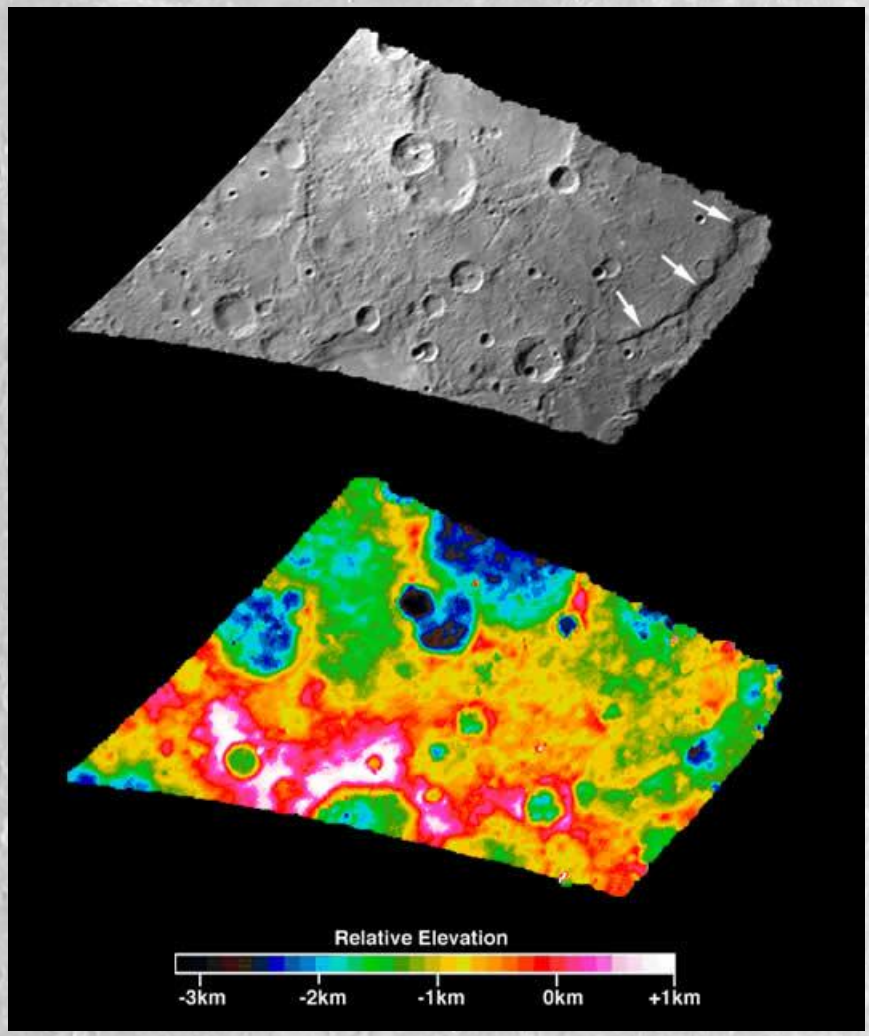
Characteristics of Lobate Scarps

- **No preferred orientation**
- **Sinuous or arcuate**
- **100's of meters in height**
- **100's of kilometers long**
- **Asymmetric cross-section**
- **Steep scarp face**
- **Gently sloping back**



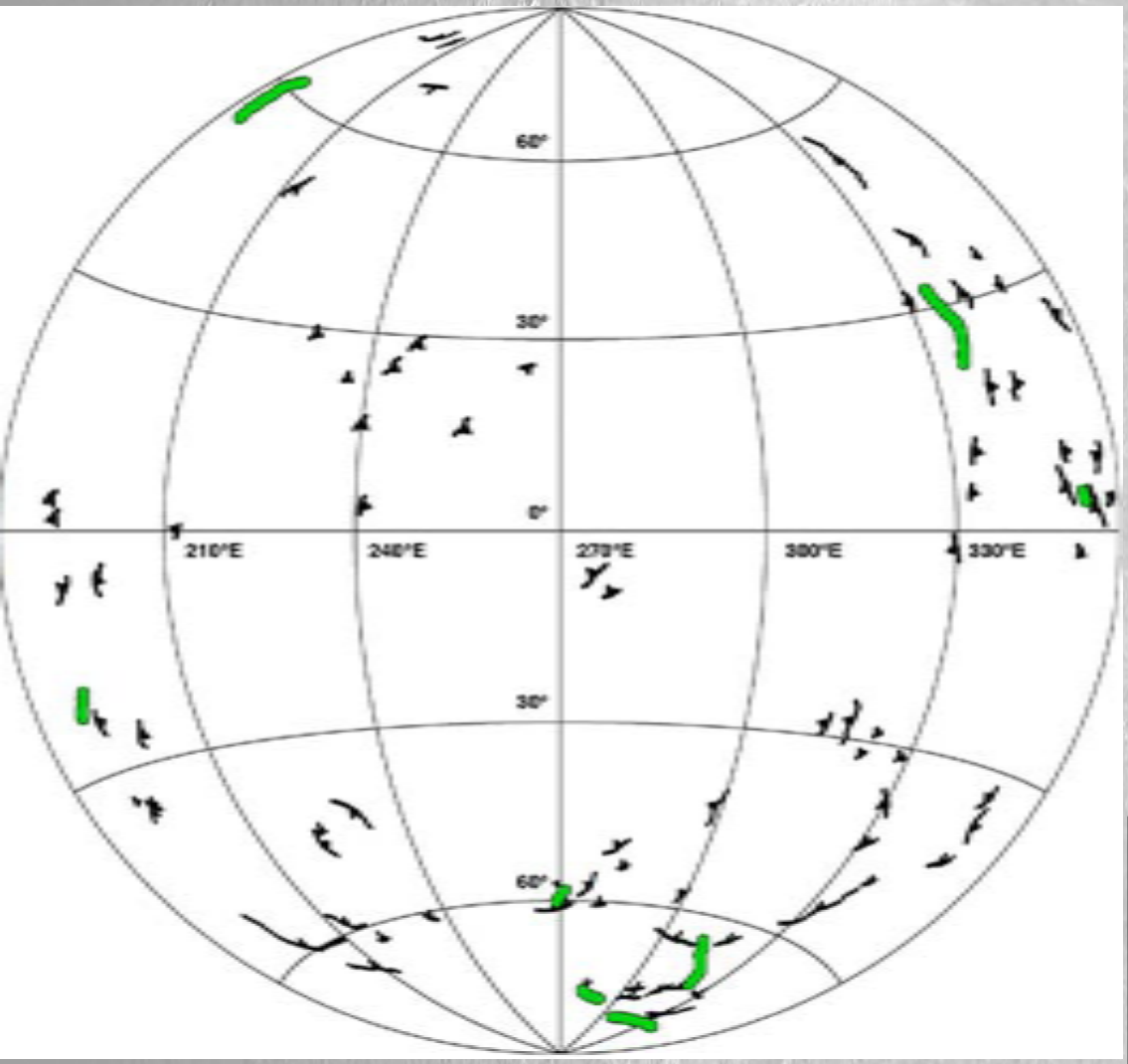
From Watters et al., 2001

Discovery Rupes



airandspace.si.edu/etp/mercury/merc_surface.html

Where are they located?

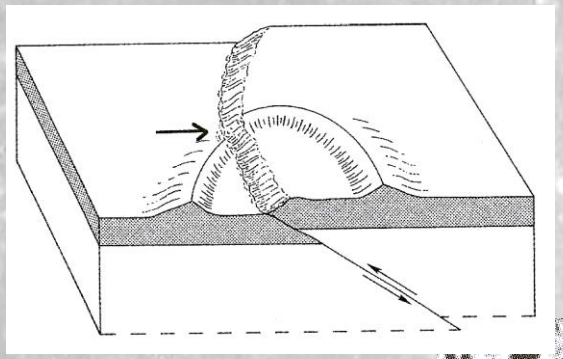


- **Global map of distribution and orientation of scarps** based on Mariner 10 imagery
- Most total length **south of -50^{o} latitude**
- All scarps south of -50^{o} latitude **dip in a northerly direction**
- **No preferred dip direction** north of -50^{o} latitude

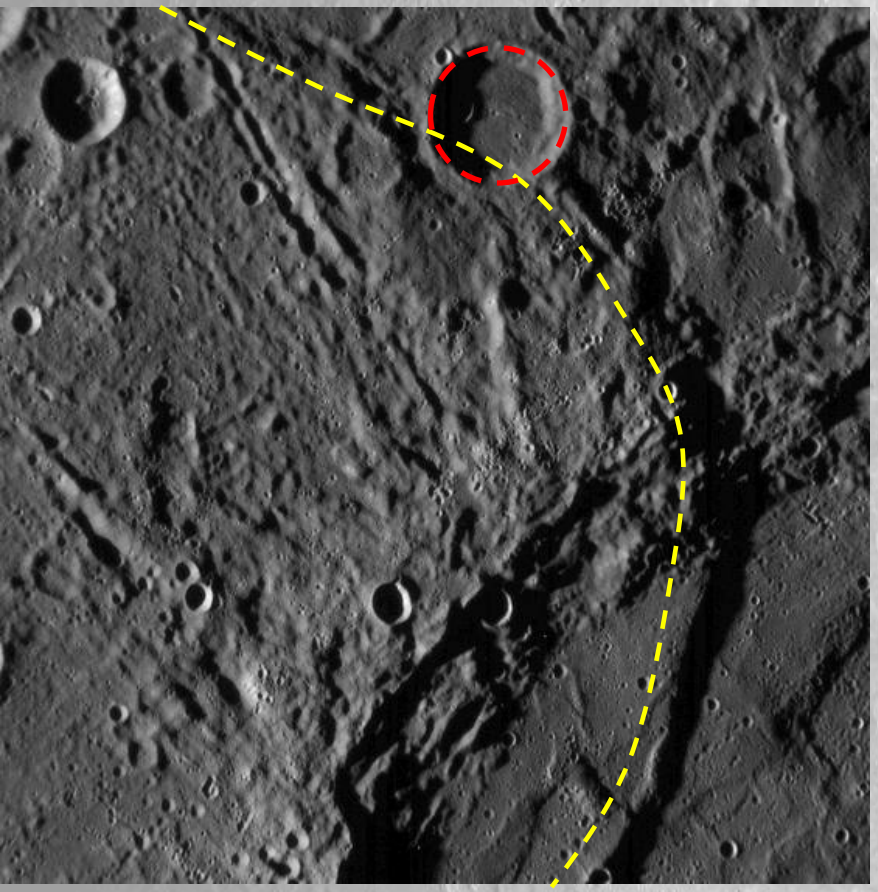
Black lines are thrust faults, with dip direction indicated by triangle
Green lines are high-relief ridges (Head et al., 2007)

When did they form?

- After differentiation, after LHB
- Scarps are dated as **Tolstoj - Calorian** periods

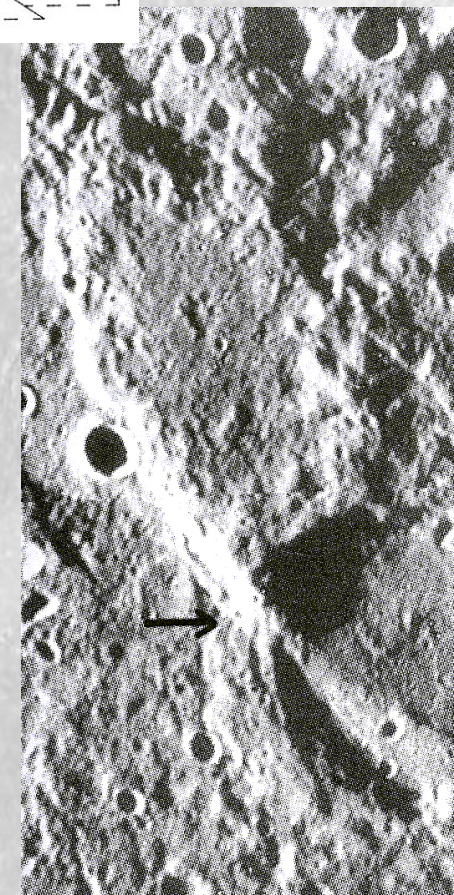


~10 km displacement of Guido d'Arezzo crater by Vostok scarp (Strom & Sprague)



NASA/JHUAPL/Carnegie Institution of Washington

- Probably formed over a few 100 Myr
- Cross-cutting relationships
- **Craters modified by scarps** or scarps modified by craters
- **Infer relative timing of events**



Mercury's Timeline

- Mercury forms
- Lithosphere forms
- Despinning results in shape change and global tectonism
- Heavy bombardment

- **Core shrinks 1-2 km**
  - **Global system of thrust faults forms lobate scarps**

- Caloris impact structure forms

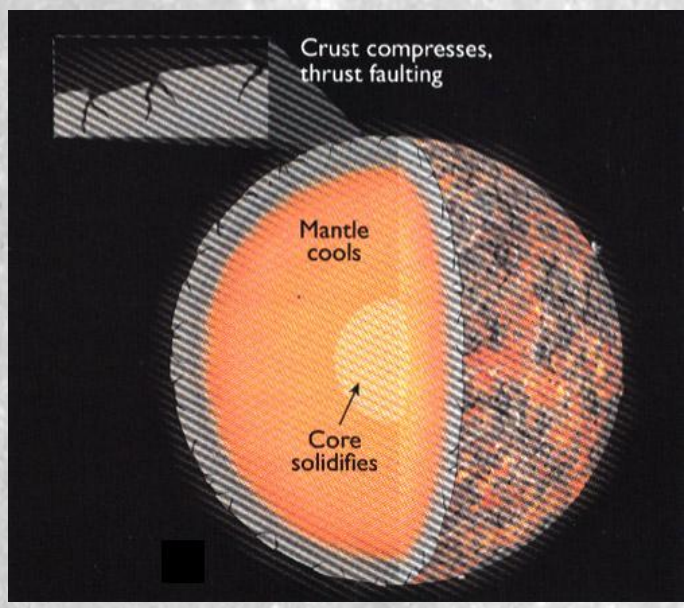
- Lighter cratering continues
- Bright rayed craters
- Polar volatiles accumulate

How did the scarps form?

- Have to understand:
  - Geometry
  - Movements , displacements
  - Stresses

- **Compressional stresses** in brittle regime, upper region of lithosphere

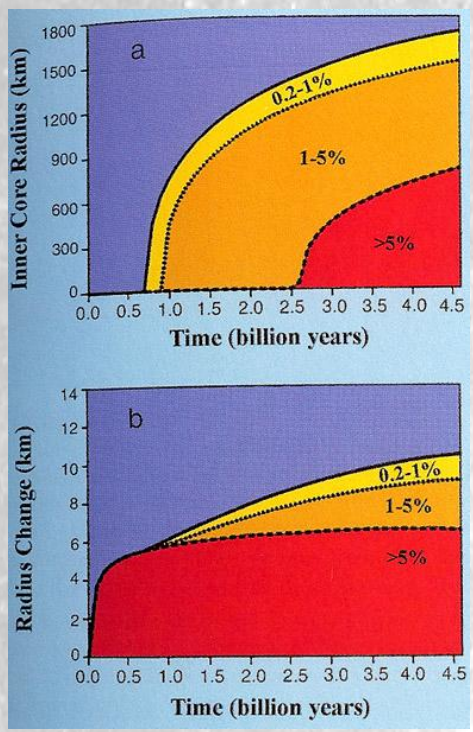
- **Thermal contraction** modeling suggests accommodation of shrinking core
  - Reduction in planetary radius by **1-2 km** (Strom et al., 1975)
  - **Strain measured** indicates radial decrease **<1km** (Watters et al., 1998)
  - Some faults may have been obliterated by **subsequent impacts**



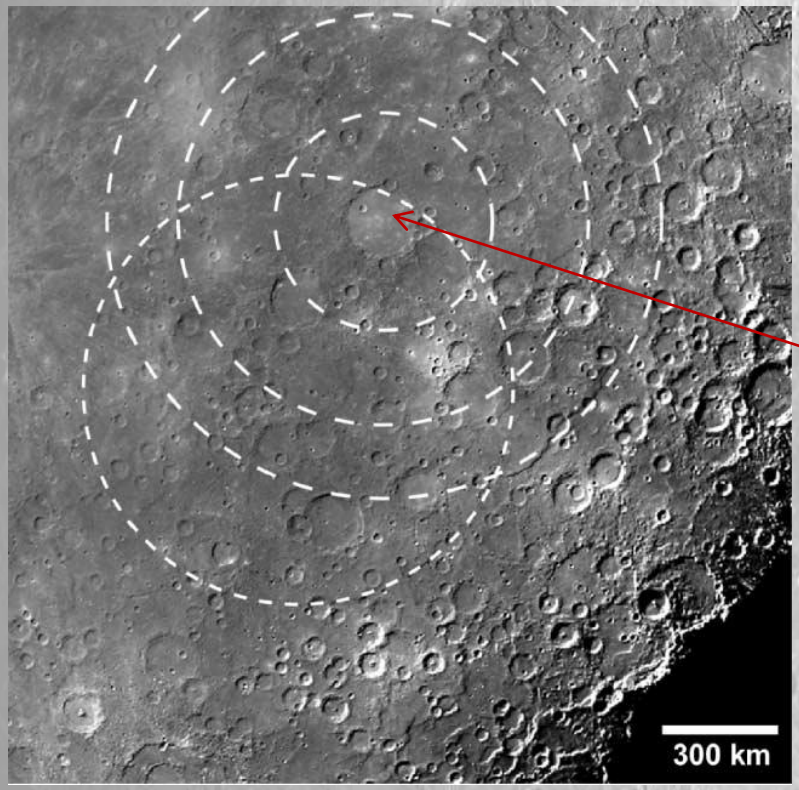
- **Tidal despinning**, reduction in equatorial bulge
  - Models predict normal faulting in polar areas, which has not been observed

Prevailing Theory

- Cooling of large core
- Global contraction
- Compressional Stresses
- Thrust Faulting
- Planetary radius shrinks 1-2 Km

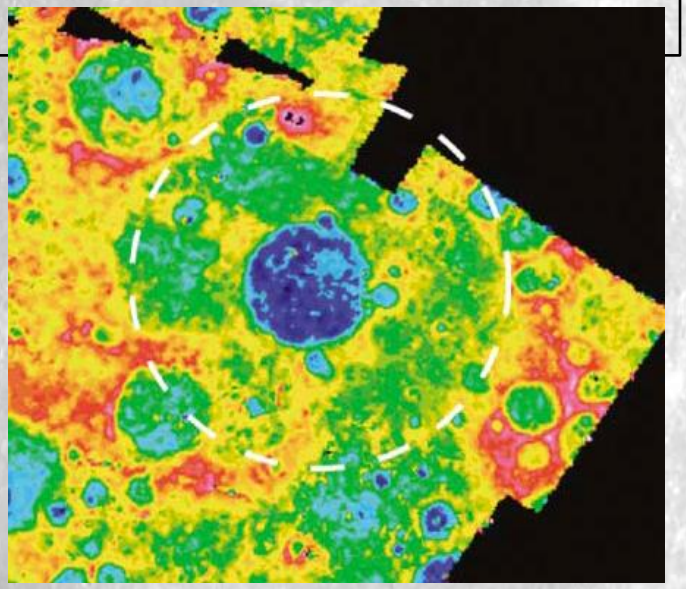


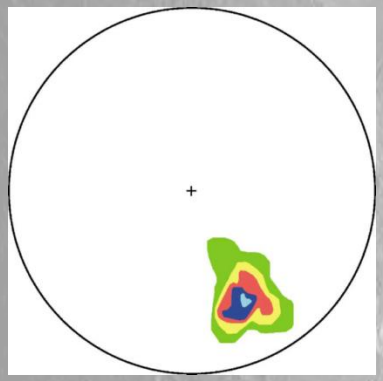
Impact Basins



Spudis and Guest (1988) suggest mechanical weakness resulted from large impact basin, later with tendency to form faults there as crust shrank. (Watters et al., 2001)

43S/54W





Inferred stress directions to form Adventure, Resolution and Discovery Rupes
Western hemisphere, **48S/58W**
(Watters et al., 2001)

Change in Surface Area

Assumptions (**Uncertainties**):

- **Low angle thrust faults (~25°)** more likely than high angle (~45°)
- Average **vertical displacement 500 m – 1 km**
- **Rest of planet similar** to the 25% where faults measured

Assumptions about displacement lead to estimates of **loss of surface area of 31,000 – 63,000 km²** (Strom & Sprague)

Radius of Mercury **= 2439.7 kilometers**

Surface area today = $4*\pi*R^2$ = **74,796,748 km²**

Surface area before contraction = **74,858,076 to 74,919,431 km²**

Difference is 122,683 to 61,328 km²

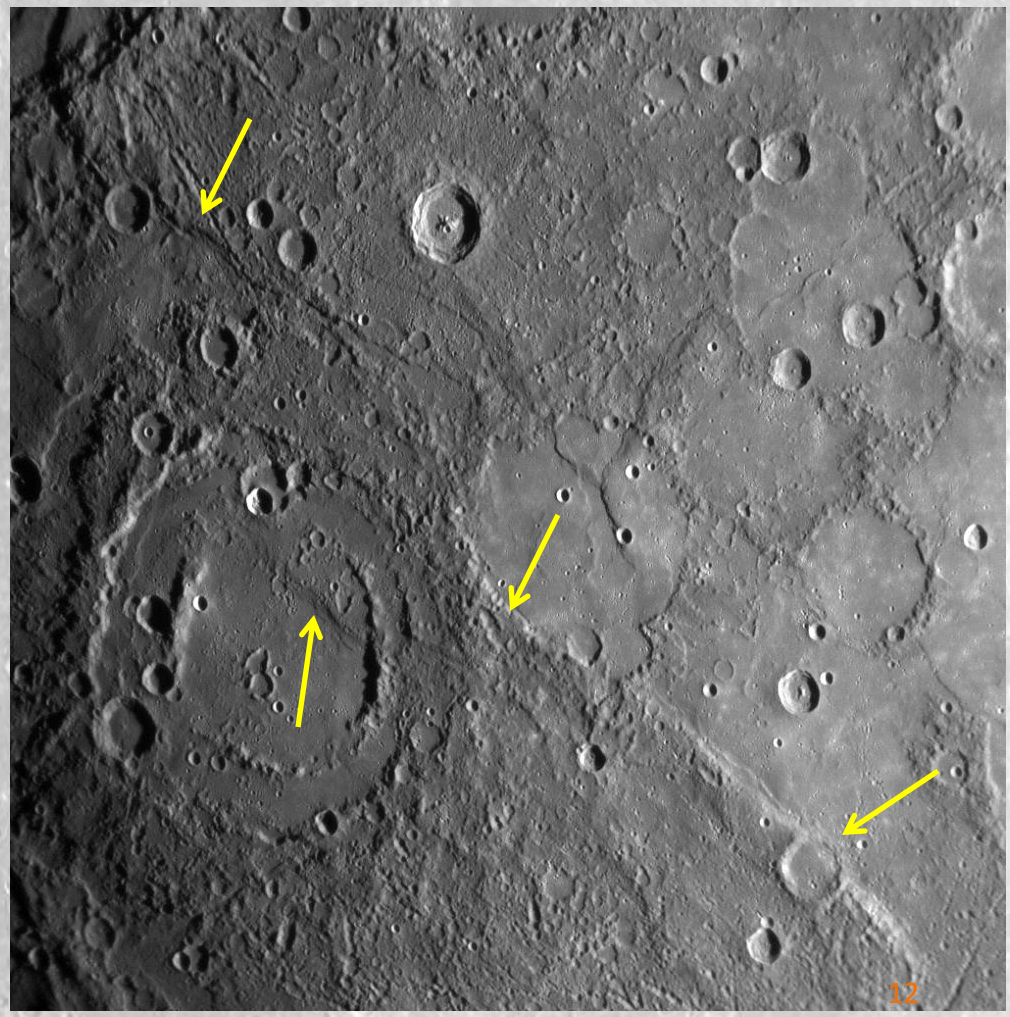
Need better data to reduce uncertainty.

MESSENGER Data Return

- MESSENGER has already imaged a portion of the surface **missed by Mariner 10**
  - **Discovered more lobate scarps**

- Mercury Dual Imaging System (**MDIS**)
  - **New faults** not seen before
  - Detection of **smaller scale faults**
  - Better **global imagery, mapping** of faults

- Mercury Laser Altimeter (**MLA**)
  - **Topographic mapping** of entire planet with
  - Look for **long wavelength folding**
    - Accommodate contraction estimated by models



PIA10177 NASA Photojournal
Image approx. 500 km across
NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Summary

What are lobate scarps?

- Global set of thrust faults spanning hundreds of kilometers
- Up to a 1.5 km high

Where are they found on Mercury?

- Globally

When did they form?

- Tolstojan through Calorian
- After LHB

Why are they there?

- Cooling core shrank
- Crust accommodates shrinking core by compressing, creates thrust faults

MESSENGER

- Has already returned many images of new areas, showing more scarps!
- Future flybys … and orbit to provide complete picture of scarp systems