

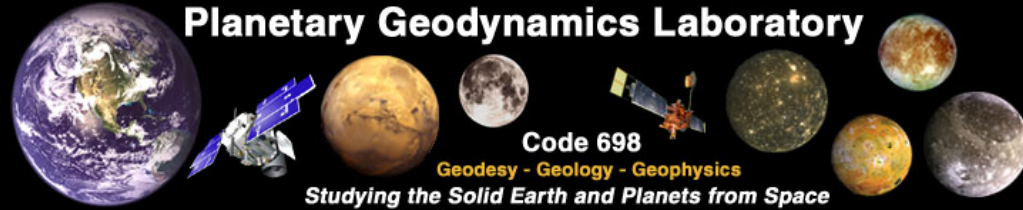
Raytheon

A magnetic perspective on the crust of the Moon and terrestrial planets

Michael Purucker

**Raytheon @ Planetary Geodynamics Lab,
GSFC/NASA**

17 Oct 2008



Outline

Relation of **iron** to **magnetization**, and magnetic fields

Magnetic fields of the **Earth**: Beginnings

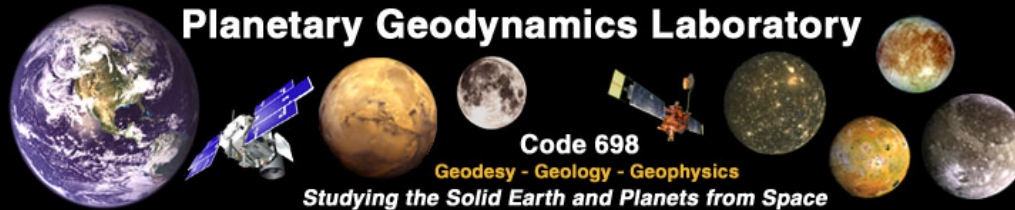
Surprises at **Mars**

Age spots, or youthful markings, on the **Moon**

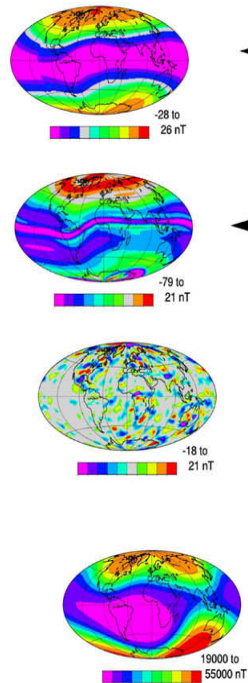
Mercury: In the shadow of the Sun

Return to Earth: Large igneous provinces, rifts, subduction zones, and diffuse plate boundary zones

Conclusions: **New missions and experiments**



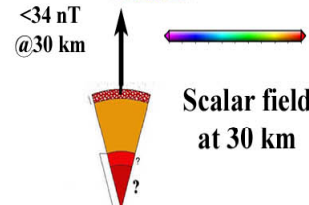
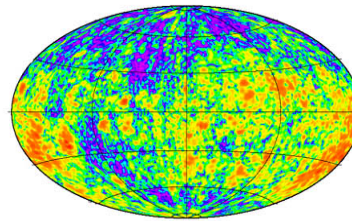
Magnetic fields of the Moon and terrestrial planets



Terrestrial magnetic field complex
at 400 km

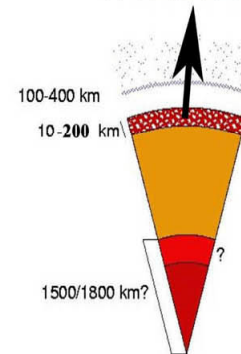
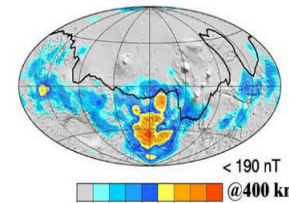
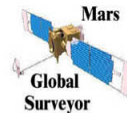
Main field F at 2002.0, Other fields at 1330 LT on 5 Jan 2002 in the direction of the main field

Sabaka, Olsen, and Purucker, Geophys.J.Int, 2004



Lunar crustal field

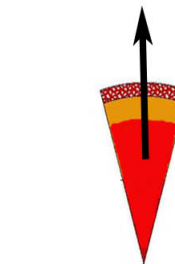
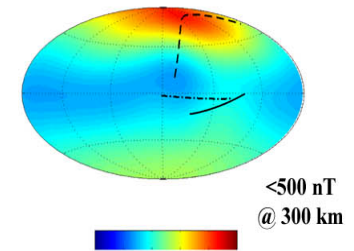
Purucker, 2008



Martian crustal magnetic field

Scalar field at 400 km

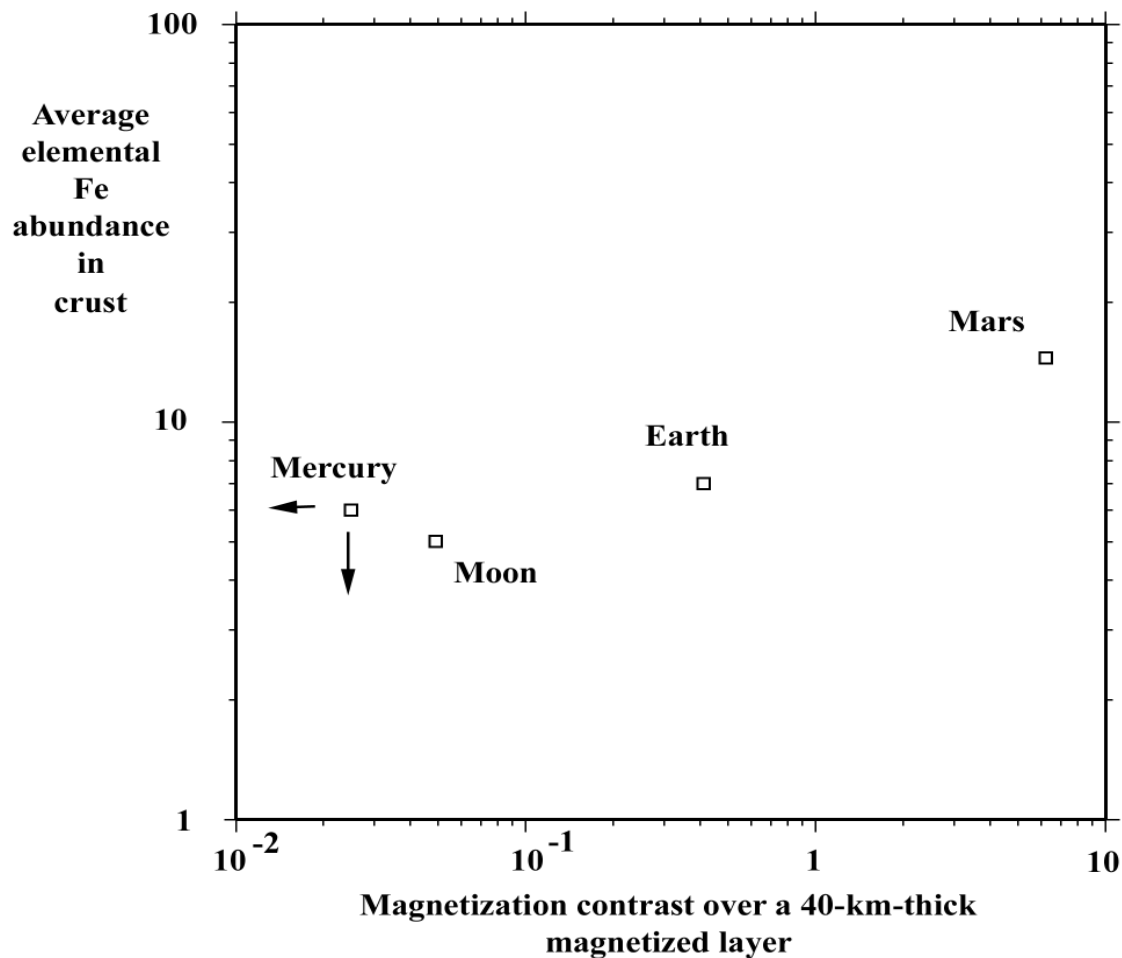
Langlais et al., 2004



Mercury's core magnetic field

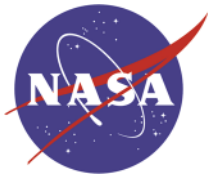
Scalar field at 300 km

Uno et al., in review



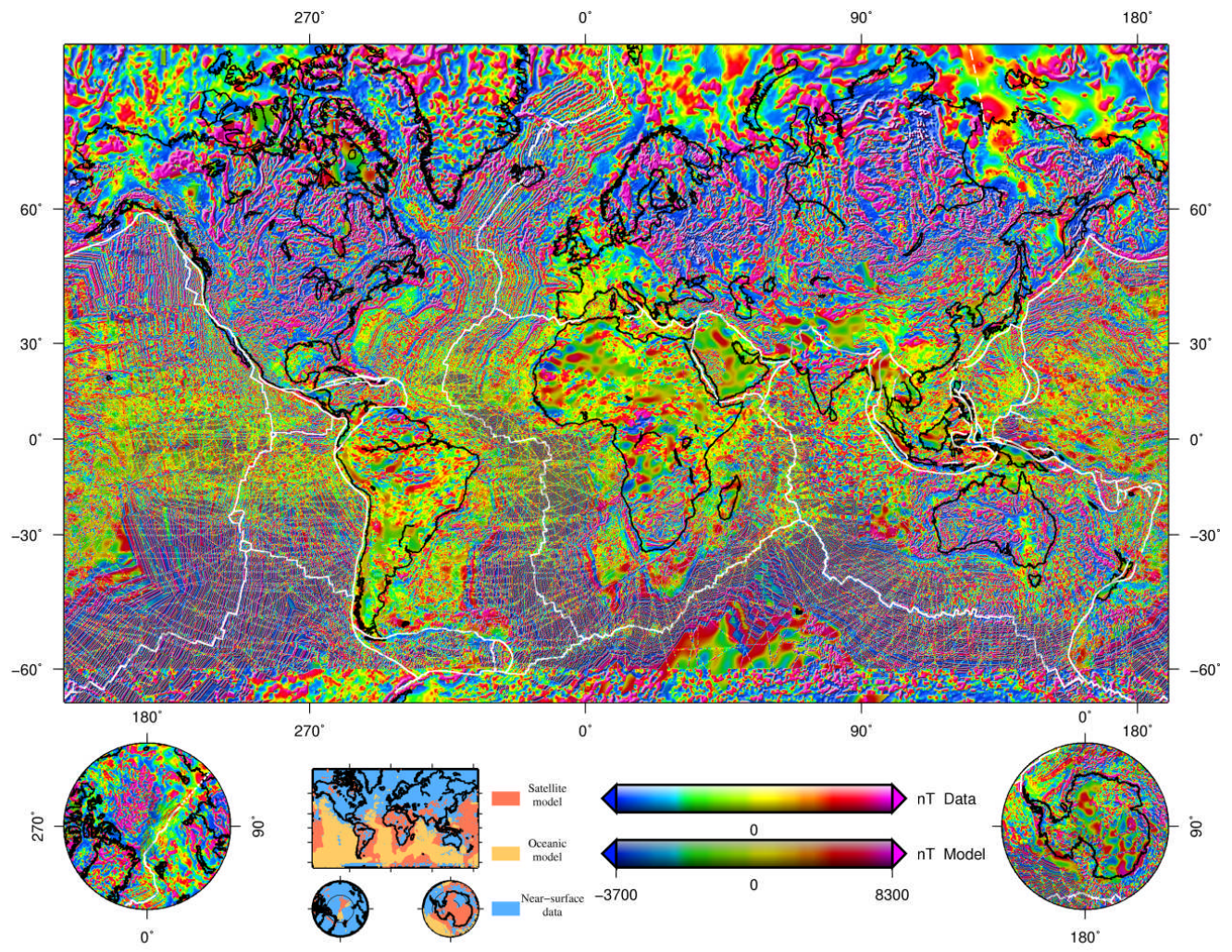
Iron and Magnetization in the crust of the Moon and Terrestrial planets

Purucker et al., 2008

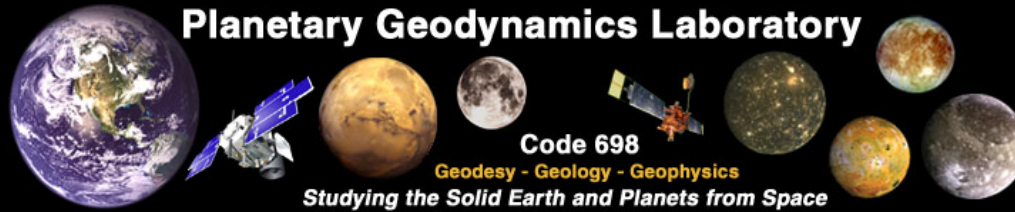
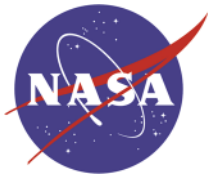


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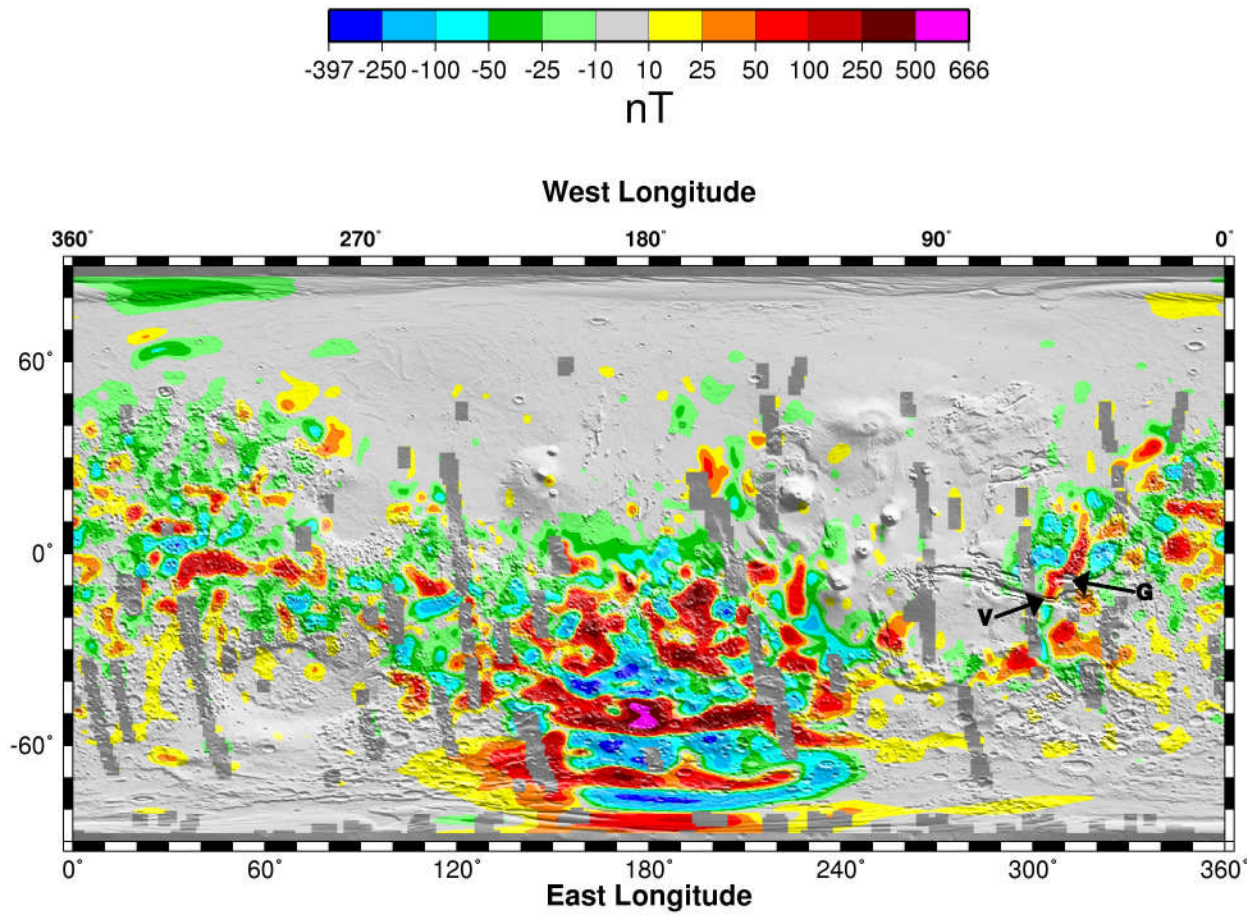
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Geodesy - Geology - Geophysics
Studying the Solid Earth and Planets from Space



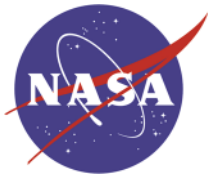
World Magnetic Anomaly Map (2007)



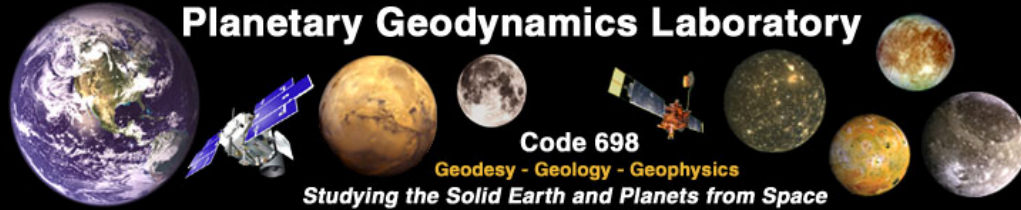
Magnetic fields at the planet Mars as measured by MGS



Purucker et al., 2000



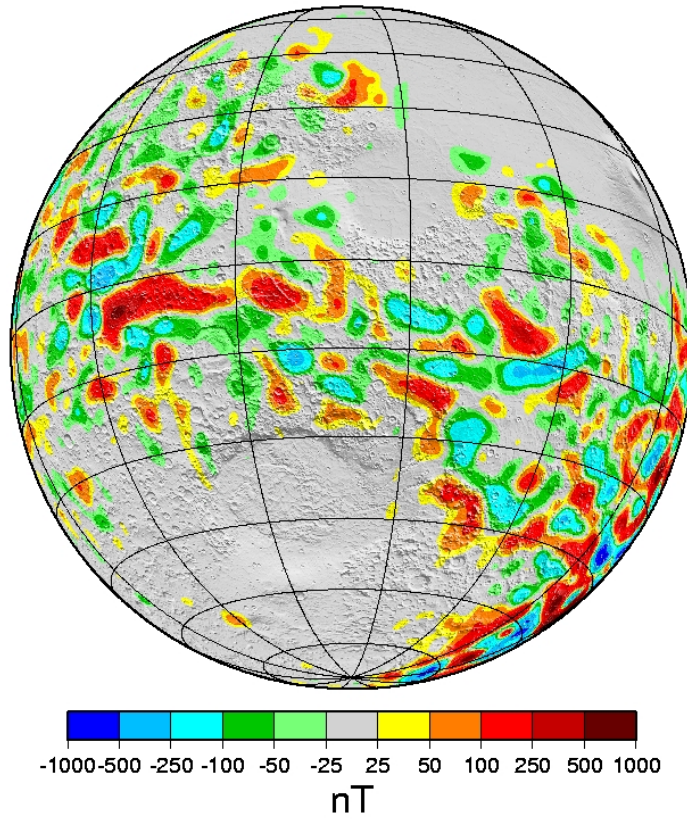
Planetary Geodynamics Laboratory



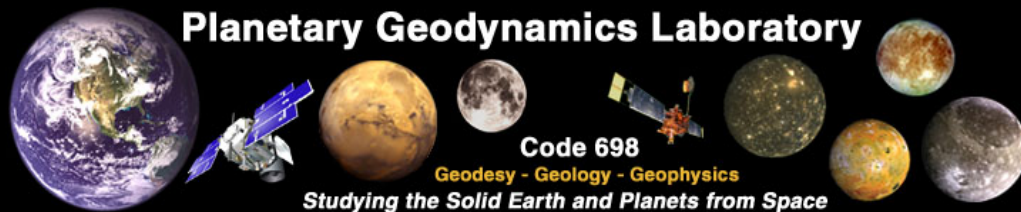
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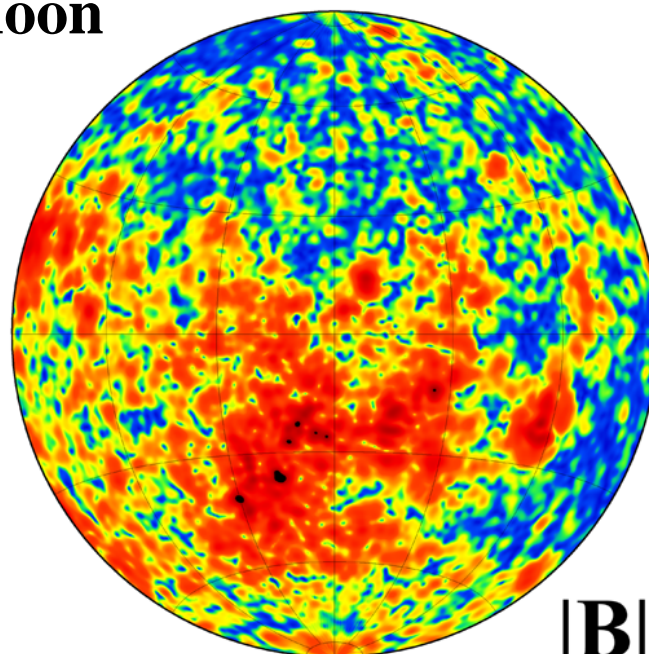
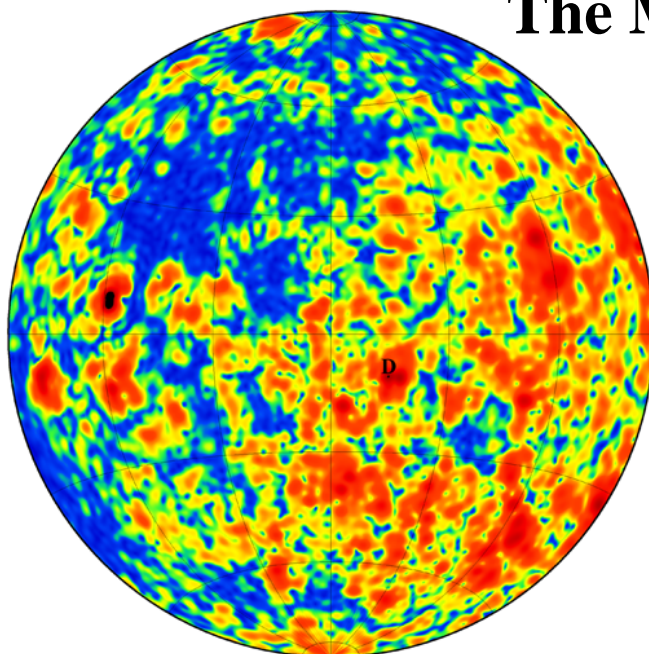
**Magnetic fields over
large Martian impact
basins Hellas, and
Isidis**



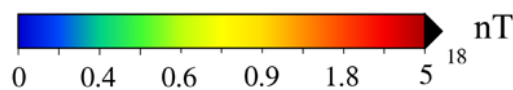
Near side

Far side

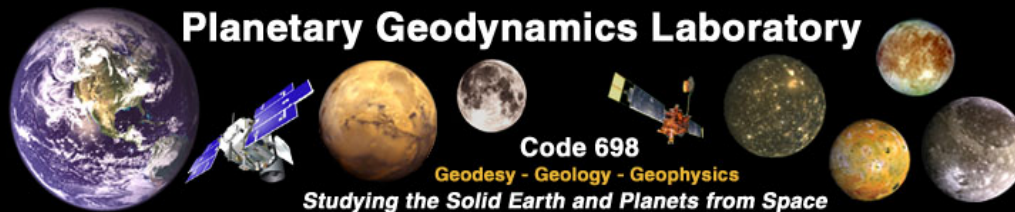
The Moon



|B|



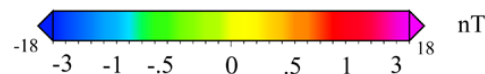
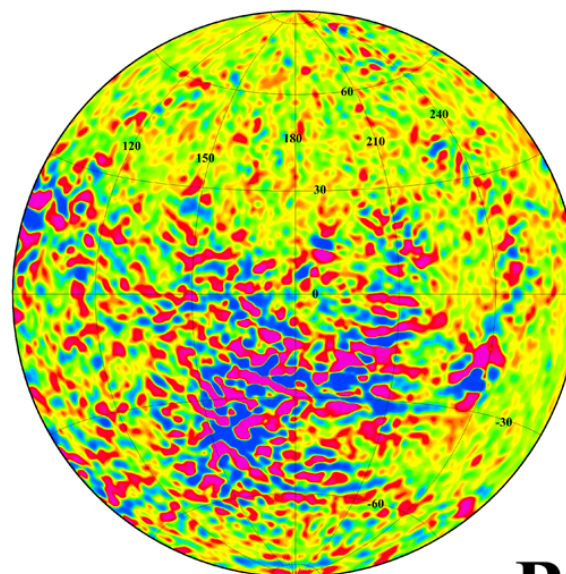
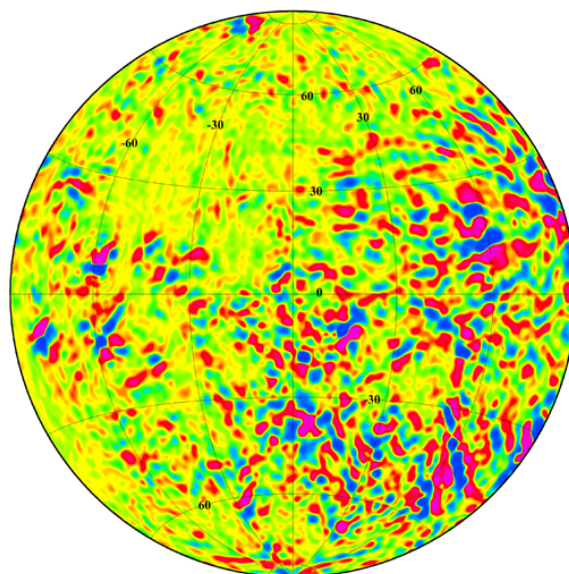
Magnitude scale



Near side

Far side

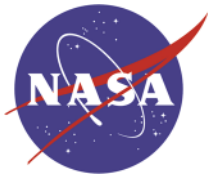
The Moon



Vector scale

B_r

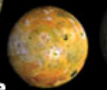
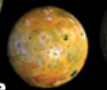
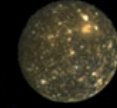
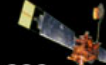
Purucker, 2008



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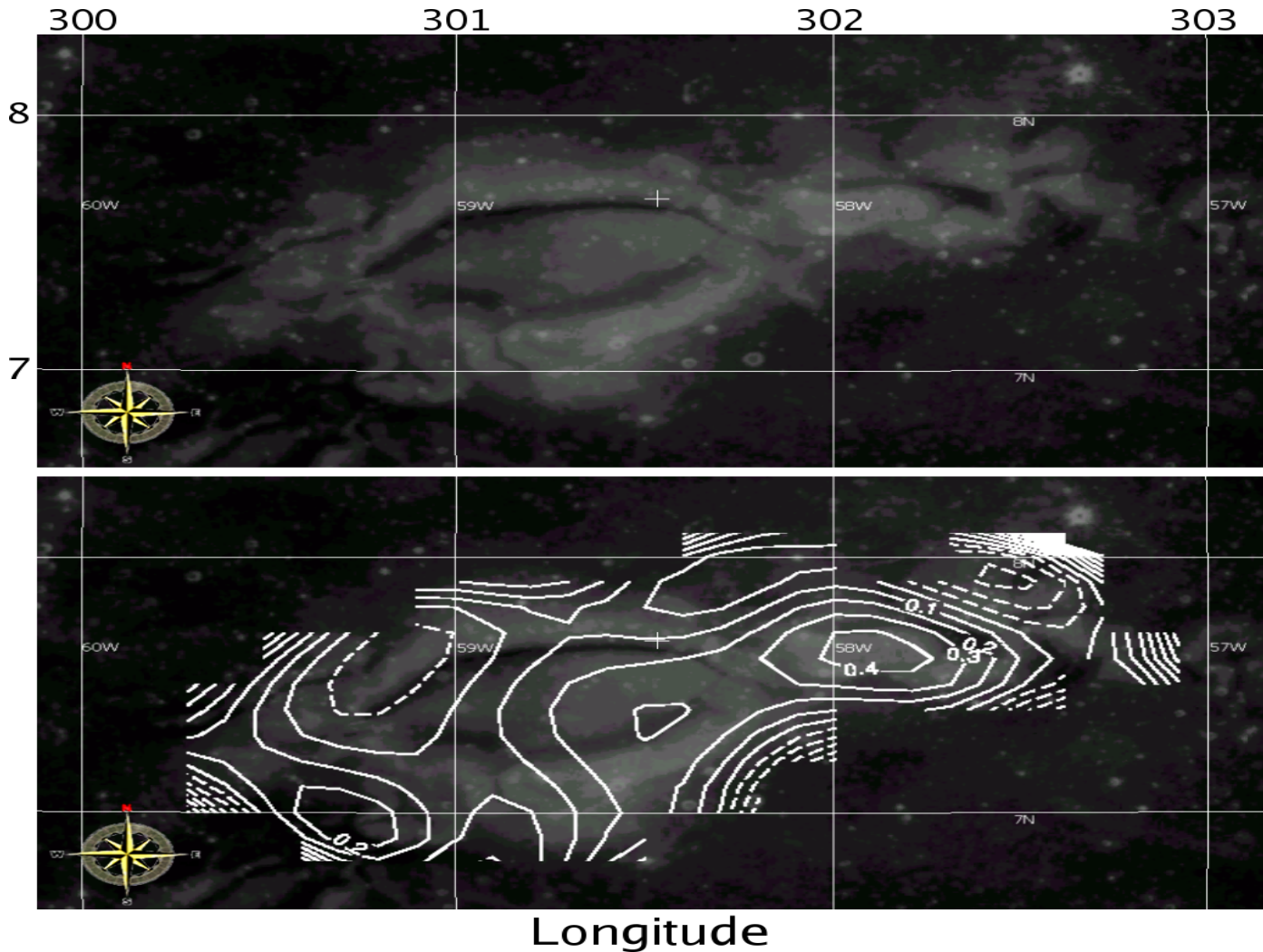


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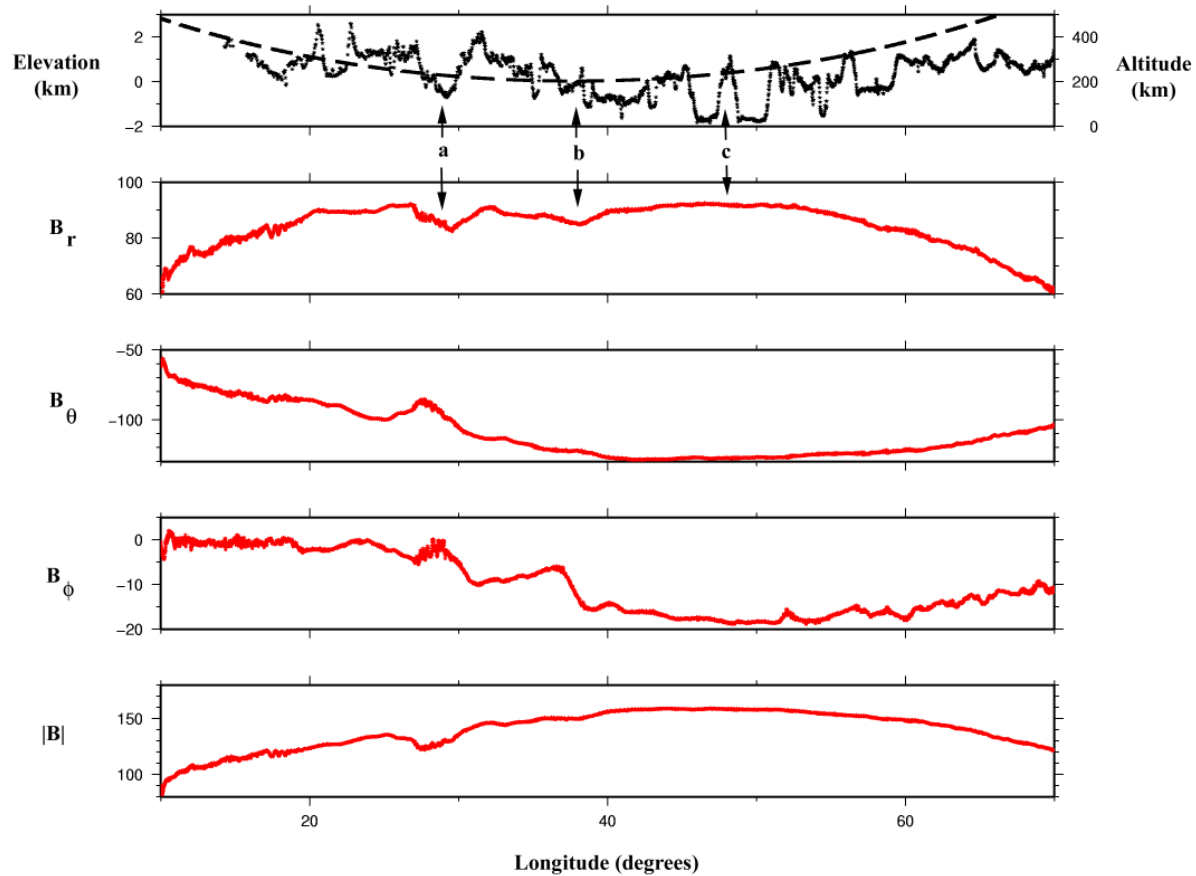
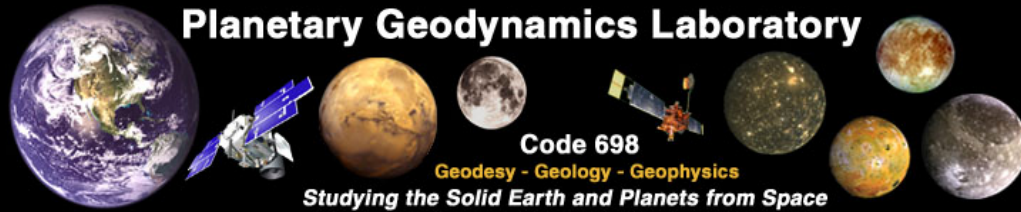


Reiner
Gamma

Latitude

Longitude

Nicholas et al., 2007

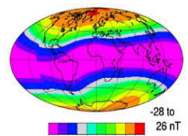


Purucker et al., in review

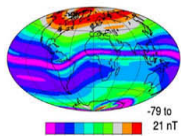
Does Mercury have a crustal magnetic field?



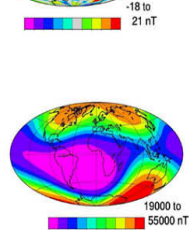
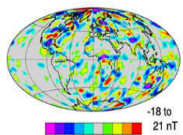
Magnetic fields of the Moon and terrestrial planets



Magnetospheric field



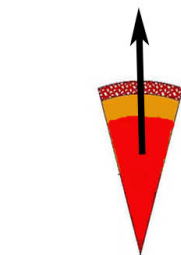
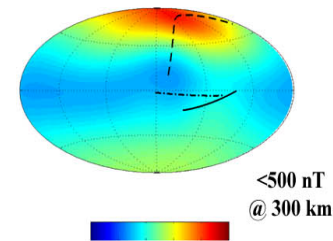
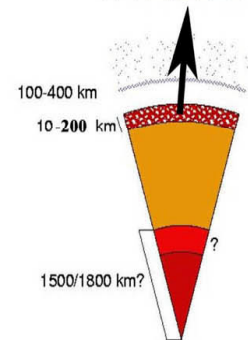
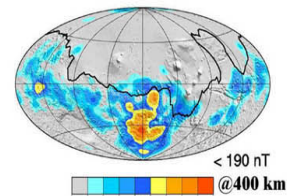
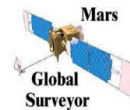
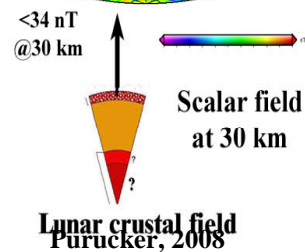
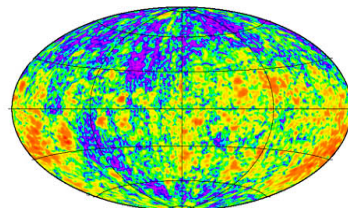
Ionospheric field



Terrestrial magnetic field complex at 400 km

Main field F at 2002.0, Other fields at 1330 LT on 5 Jan 2002 in the direction of the main field

Sabaka, Olsen, and Purucker, Geophys.J.Int, 2004





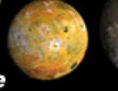
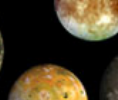
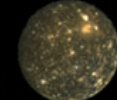
Planetary Geodynamics Laboratory



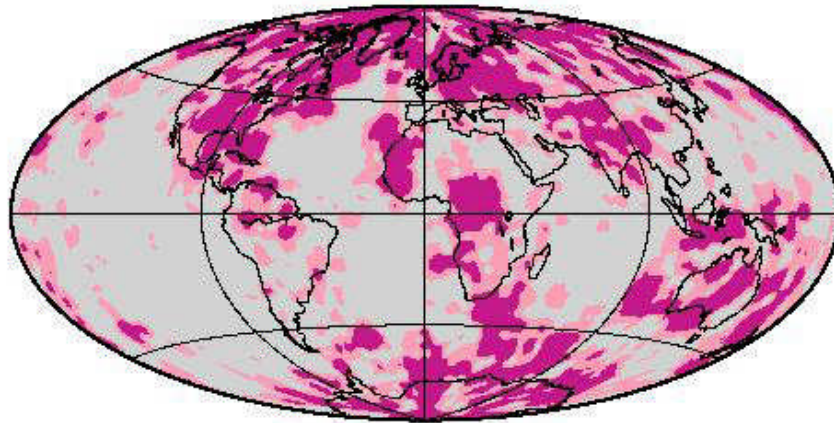
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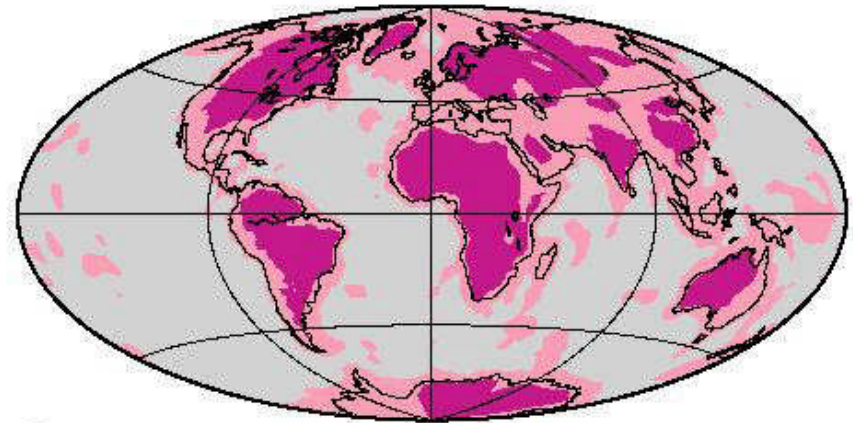
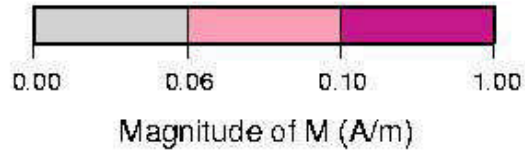
Studying the Solid Earth and Planets from Space



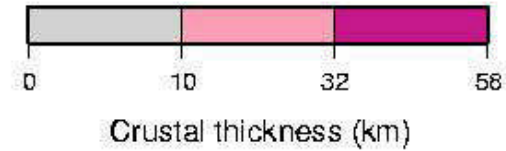
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a



b



On the Earth, crustal thickness and magnetization show a relationship because continental crust is thicker than oceanic crust.

Purucker and Whaler, 2007



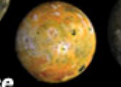
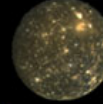
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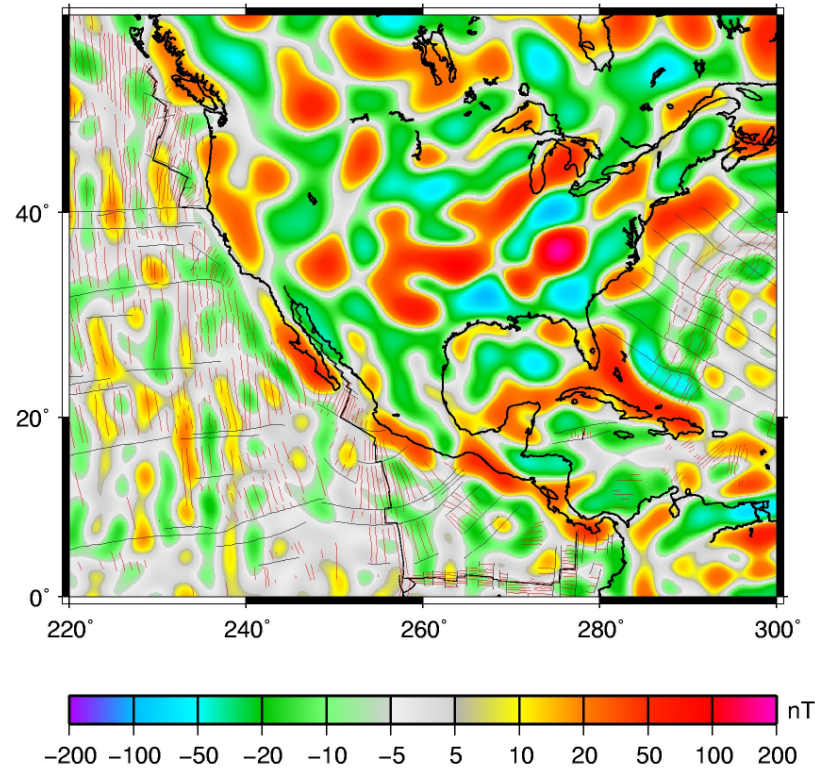
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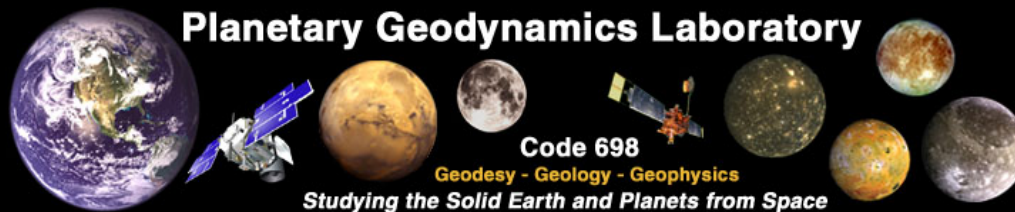


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On the Earth, continental and oceanic crust have different magnetic signatures, and the longest wavelengths are hidden from view.



Maus et al., 2006



DATA **3SMAC, WENA**

or Crust 5.1

$d^{(0)}$

MF-6

high pass
→

$b_{obs, hp}$

Combining magnetic and seismic information allows us to develop a robust magnetic crustal thickness map.

INVERSION

↓

iteration

$d^{(n)}$

forward

$b^{(n)}_{ind, model}$

high pass
→

$b_{obs, ind, hp}$

-
 $b^{(n)}_{ind, model, hp}$

$d^{(n+1)}$

← $\Delta d^{(n)}_{hp}$

+

if yes

← $|\Delta b^{(n)}| < |\Delta b^{(n-1)}|$

test

← $\Delta b^{(n)}_{ind, hp}$

Set $m=+1$ to 0

inversion

if no

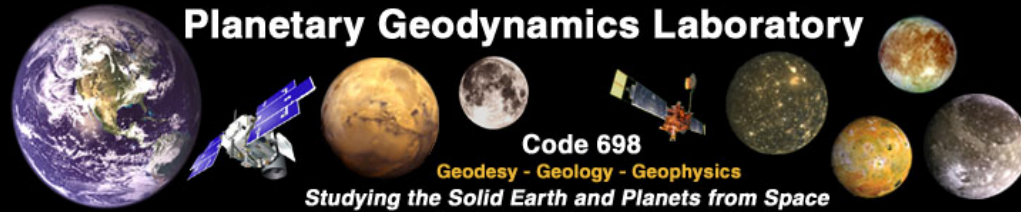
END MODEL

$d^{(n)}$

Magnetic crustal thickness

obs: observed
ind: induced
rem: remanent
hp: high pass filtered

**Fox-
Maule
et al.,
2005**



Assumptions/Scale Issues

- **Magnetic susceptibility is constant**
- **Areas w. significant magnetic remanence are not used in interpretation (Bangui, Kursk)**
- **Global seismic and magnetic data sets have comparable resolutions (SHD 120, Wavelength = 333 km for magnetic).**
- **Seismic data is spatially heterogenous, and of widely different quality**
- **Magnetic data is spatially homogenous away from high latitude auroral zones.**



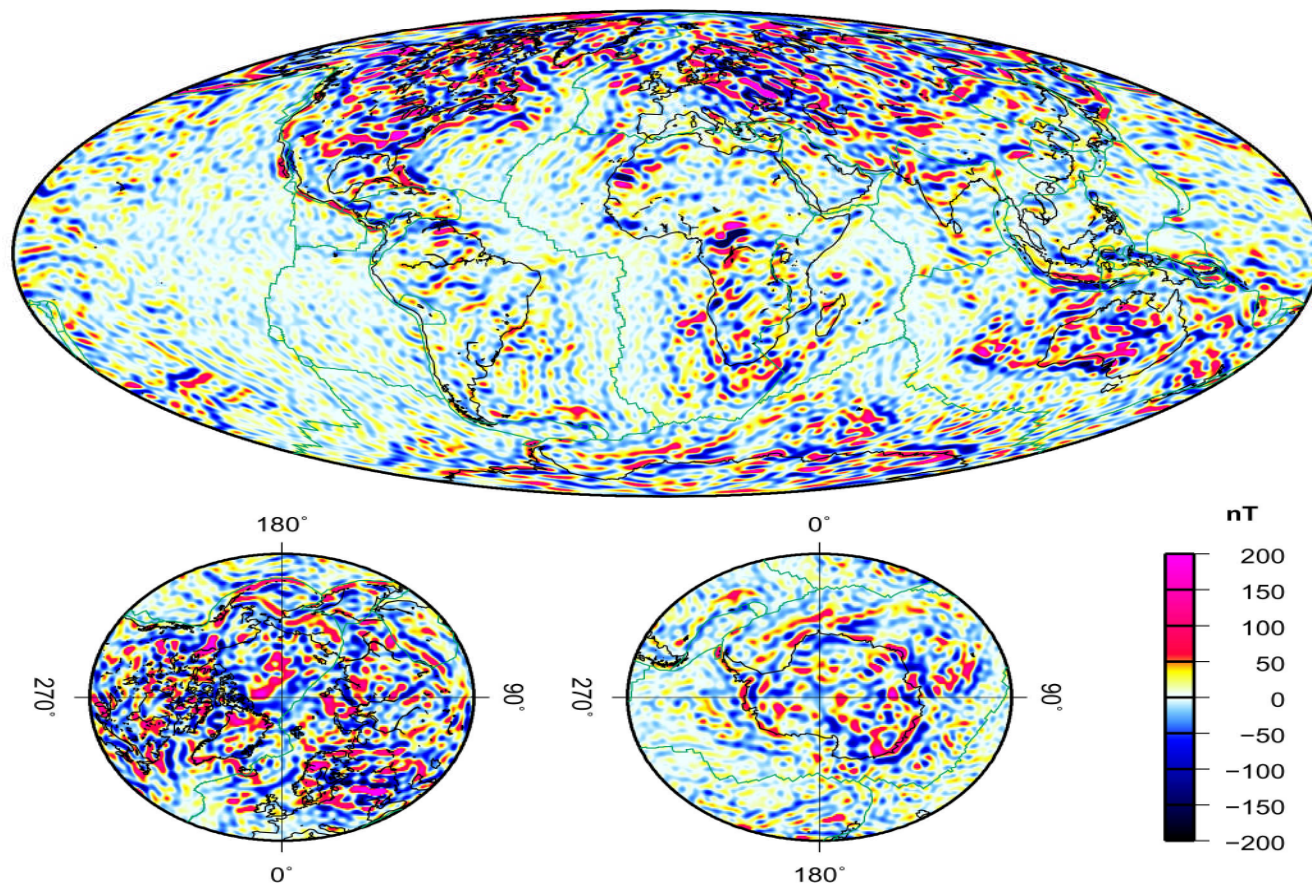
MF-6 (Magnetic Intensity Anomaly at Geoid Altitude)

Planetary Geodynamics Laboratory

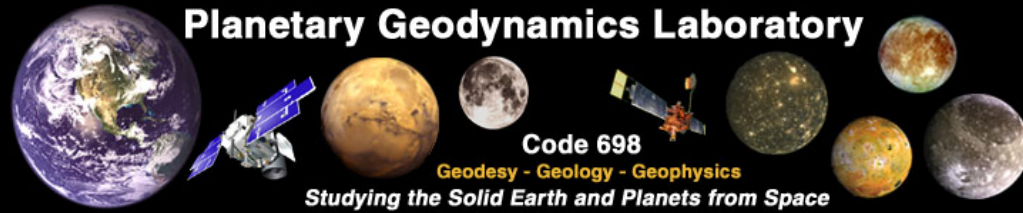
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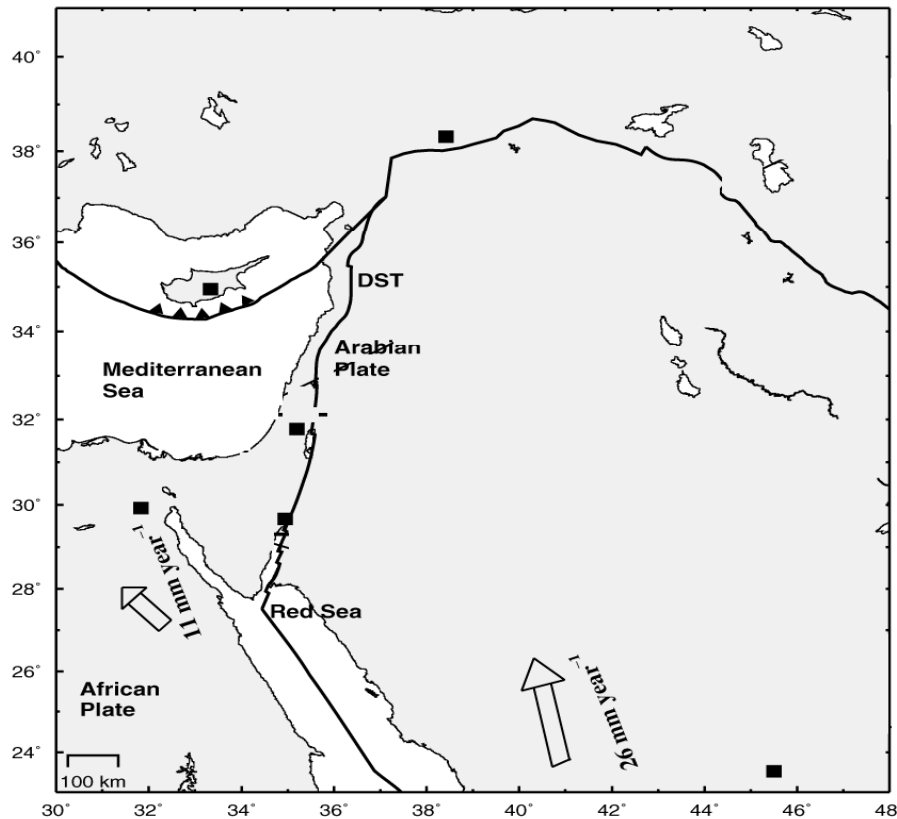
MF6: Magnetic intensity anomaly at geoid altitude



Maus et al., 2007



Regional tectonic setting: Dead Sea region



Moshen et al., GJI, 2006

Thinned lithosphere from seismic analysis

Xenoliths from western Saudi Arabia suggest thinned lithosphere & normal crustal thickness/low heat flow

Magnetic field provides depth to Curie isotherm, not Moho depth

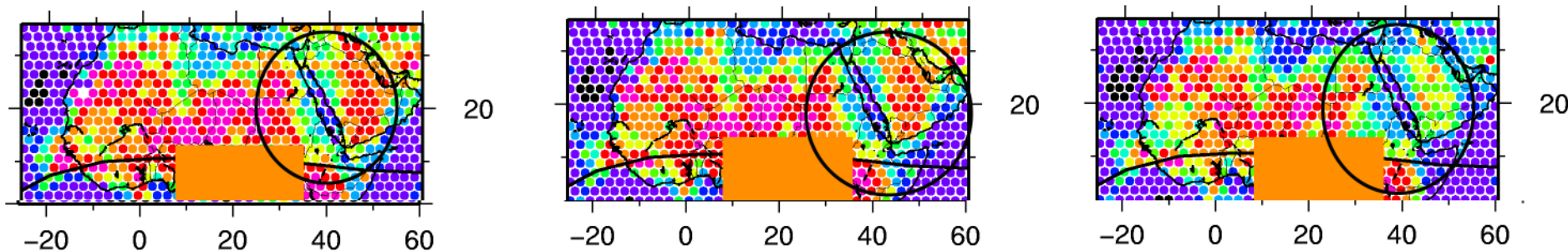


Thermal structure of Red Sea rift basin and surrounding region

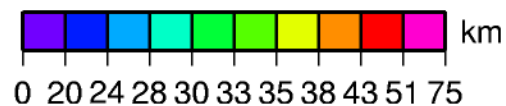
Crust 2.0

WENA

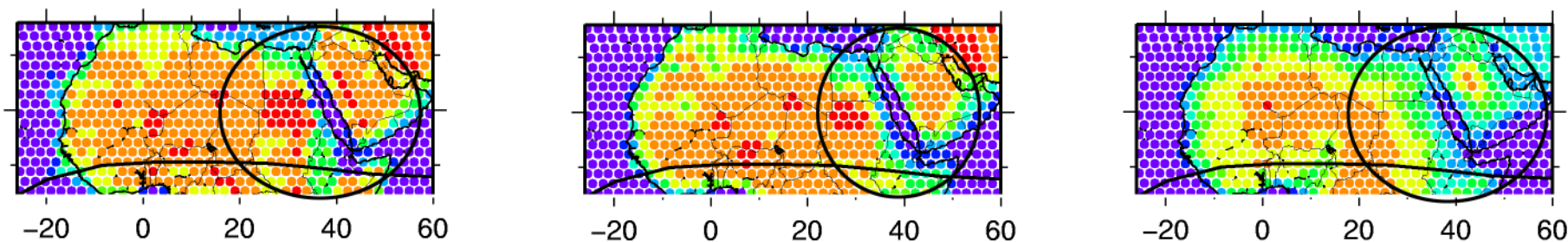
3SMAC



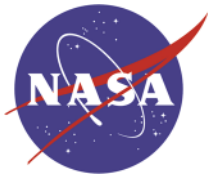
 Bangui region



Starting models



Magnetic crustal thickness using MF-6 and different seismic starting models



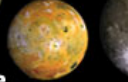
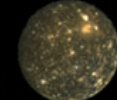
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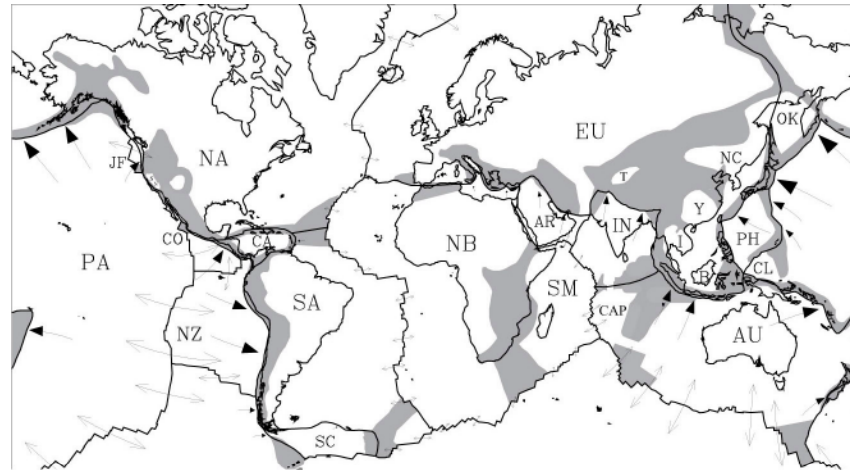
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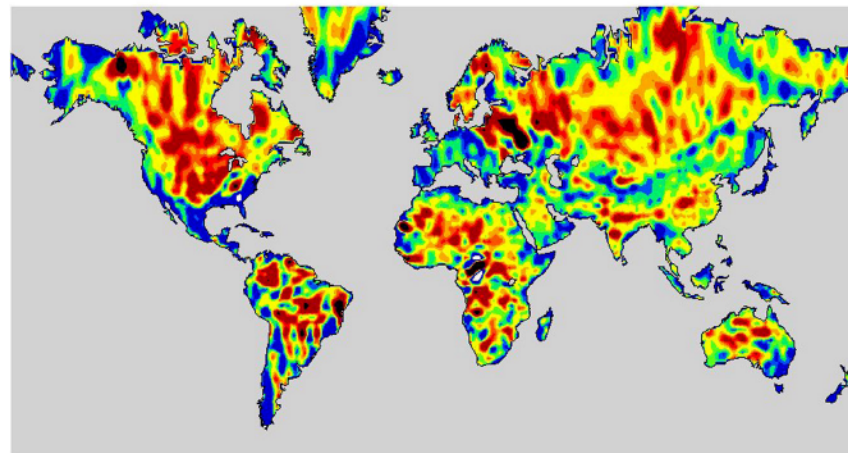


Raytheon

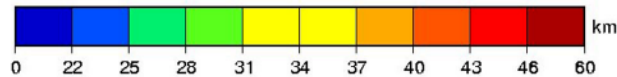


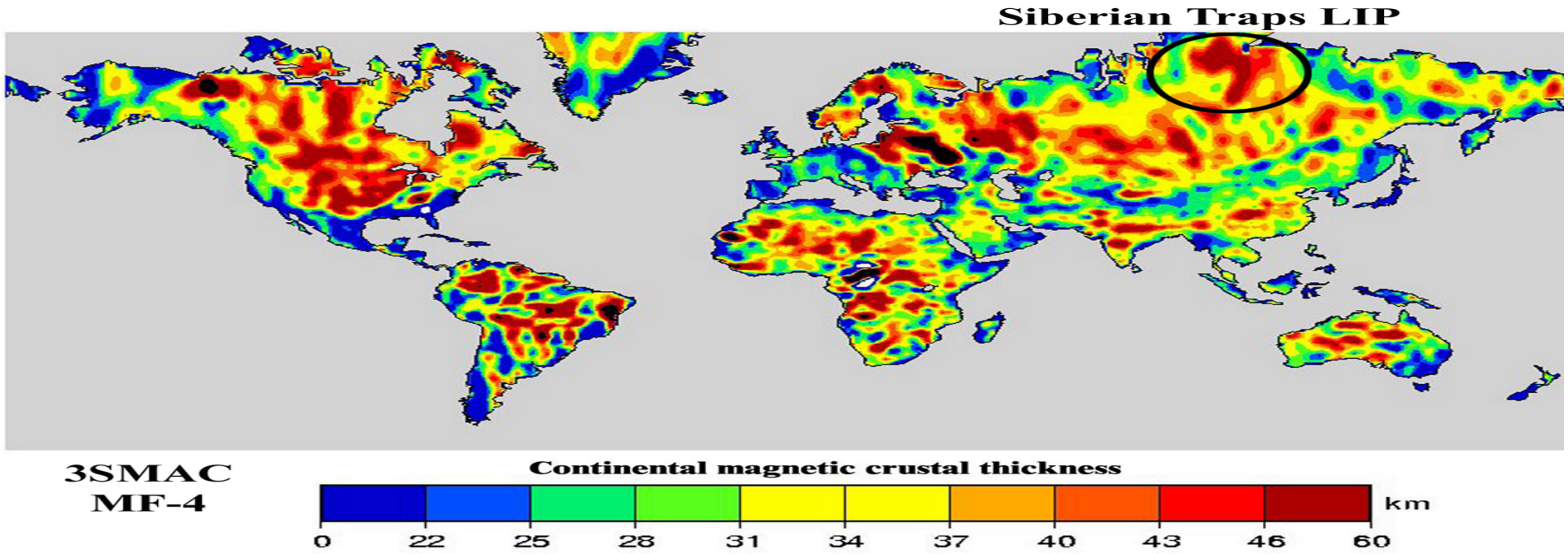
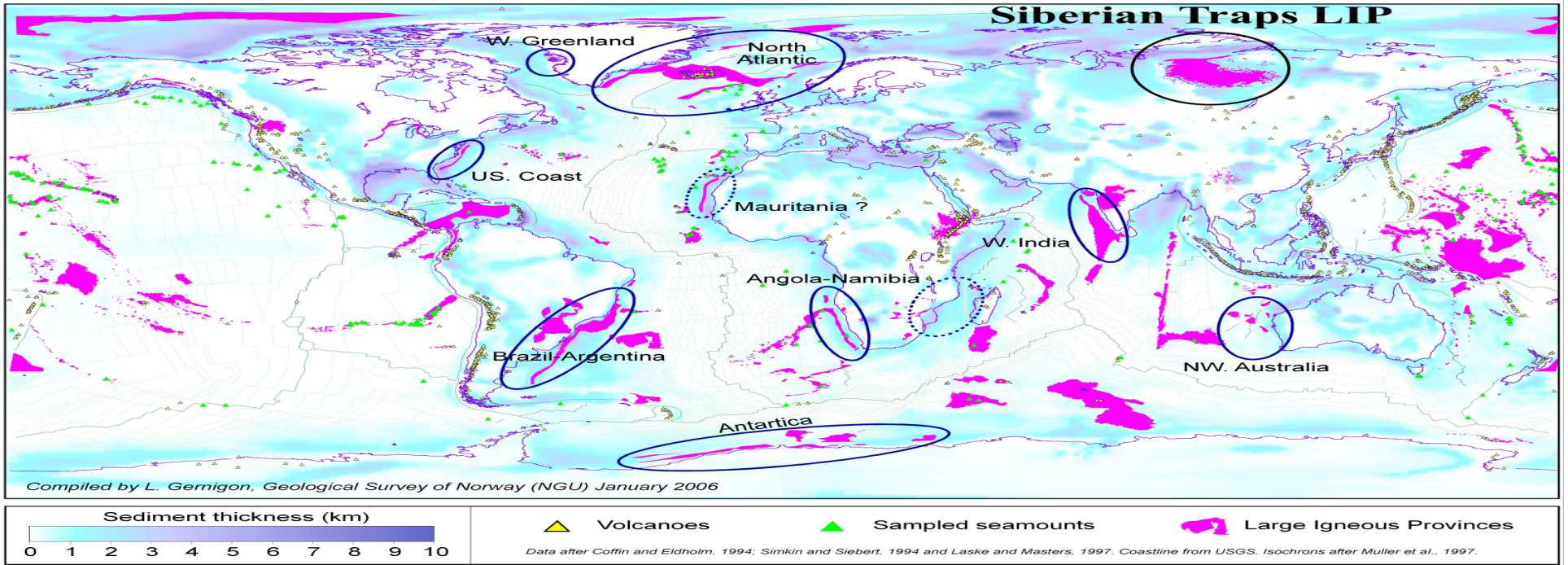
Diffuse plate boundaries (shaded)

Gordon, 1998



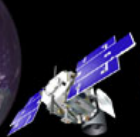
Continental magnetic crustal thickness







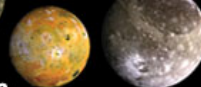
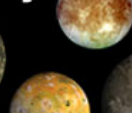
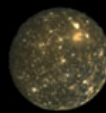
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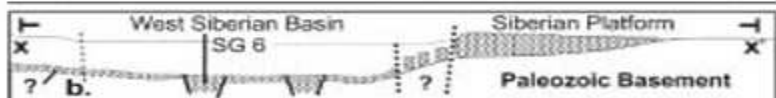
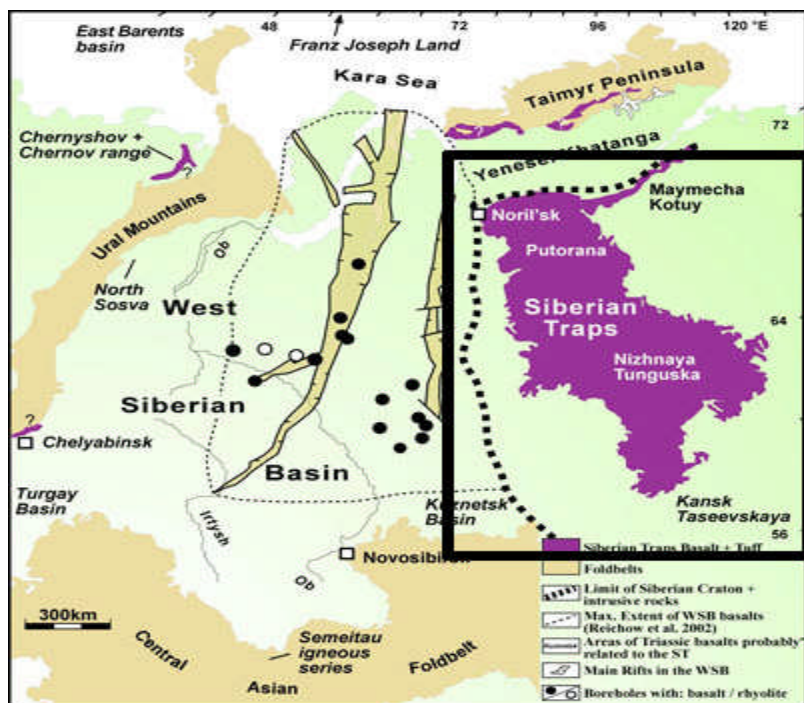
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Geodesy - Geology - Geophysics

Studying the Solid Earth and Planets from Space

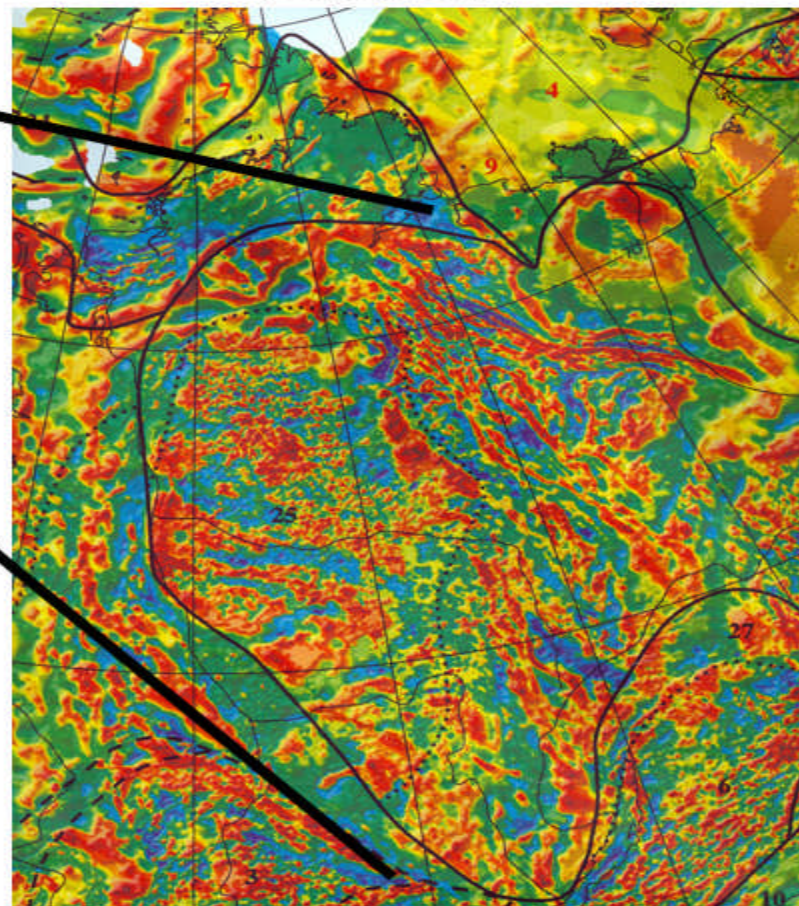


Raytheon

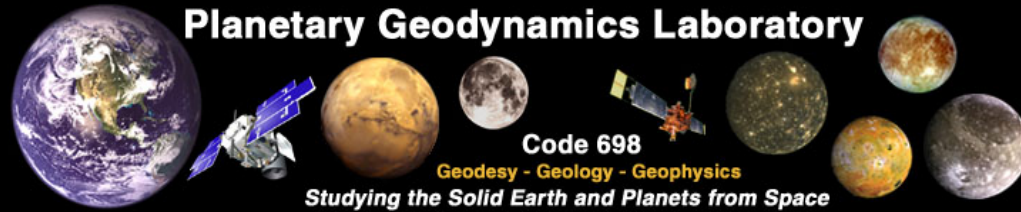


Elkins-Tanton et al., Siberian traps proposal

Aeromagnetics



GSC, 1995



Raytheon

New Missions and Experiments

- **Maryland's Dynamo experiment**
- **Swarm satellite constellation (2010)**
- **Mercury MESSENGER (2011)**
- **Maven (2013)**
- **Venus orbiter w. probe (?)**