XXXVI International Conference Interaction of Intense Energy Fluxes with Matter

Problem of South Pole-Aitken basin origin

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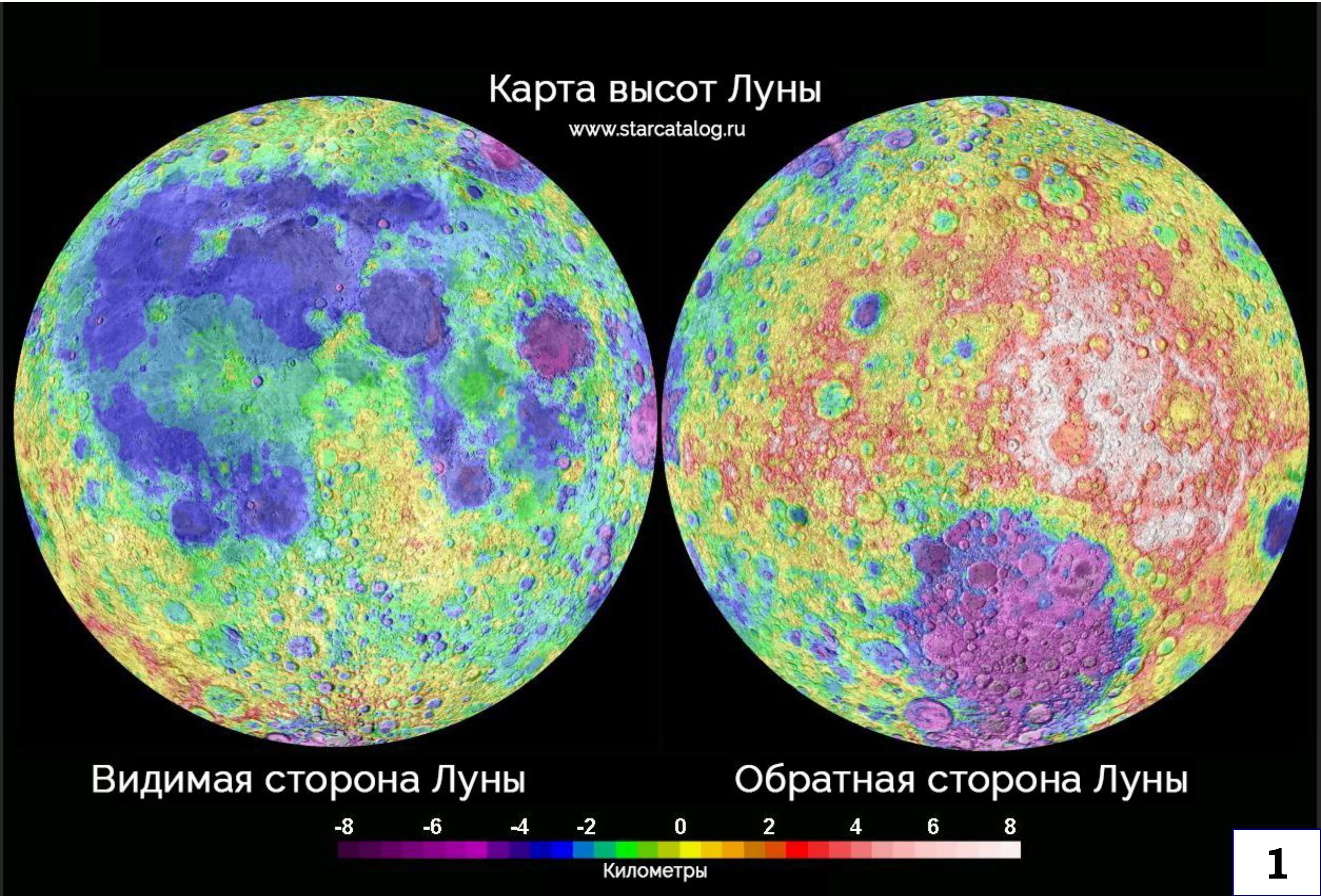
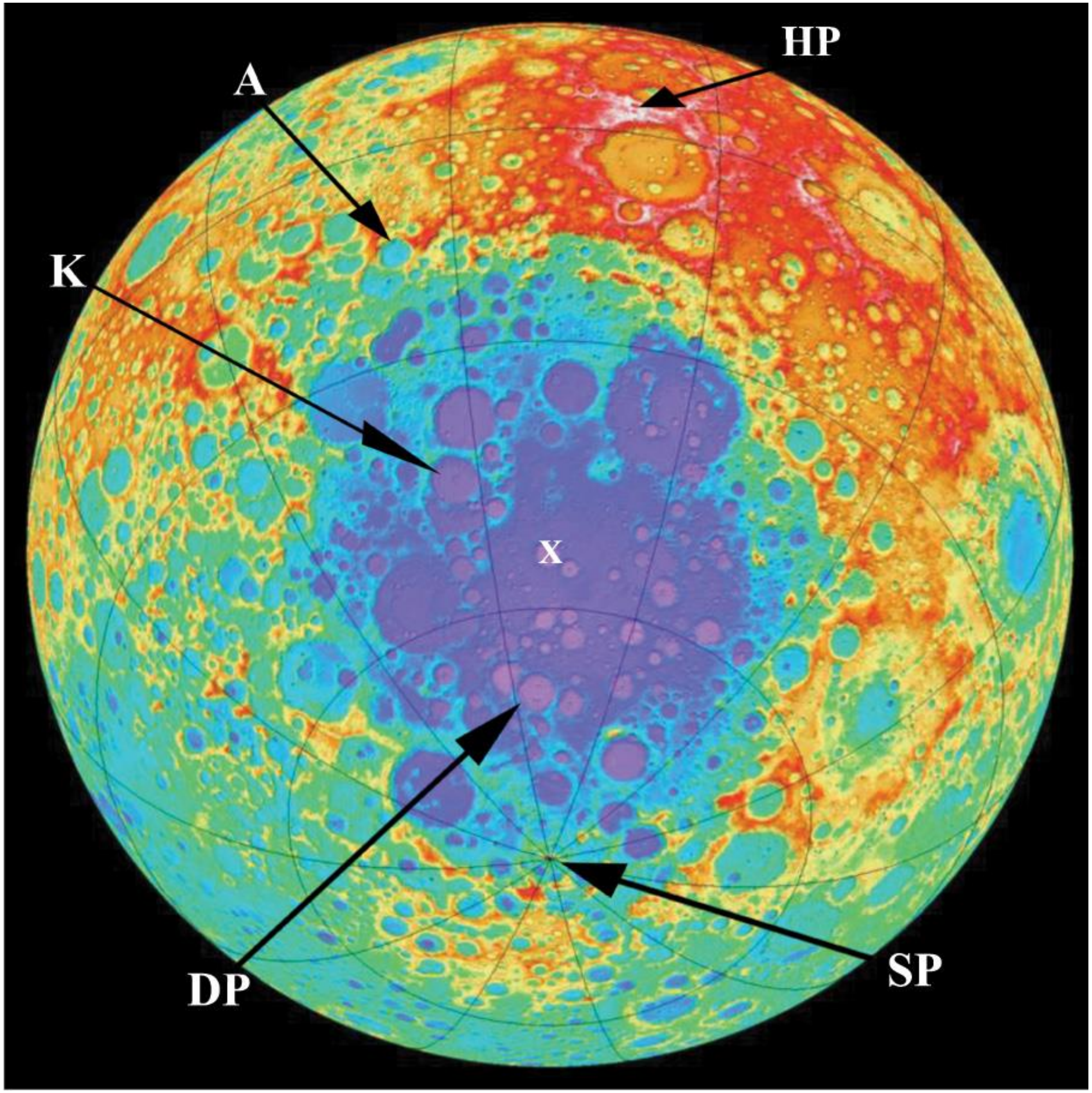
Near and far sides of the Moon



South Pole - Aitken basin on the Moon

www.wms.lroc.asu.edu



HP= +10.786 km

DP = – 9.12 km

SP – South Pole

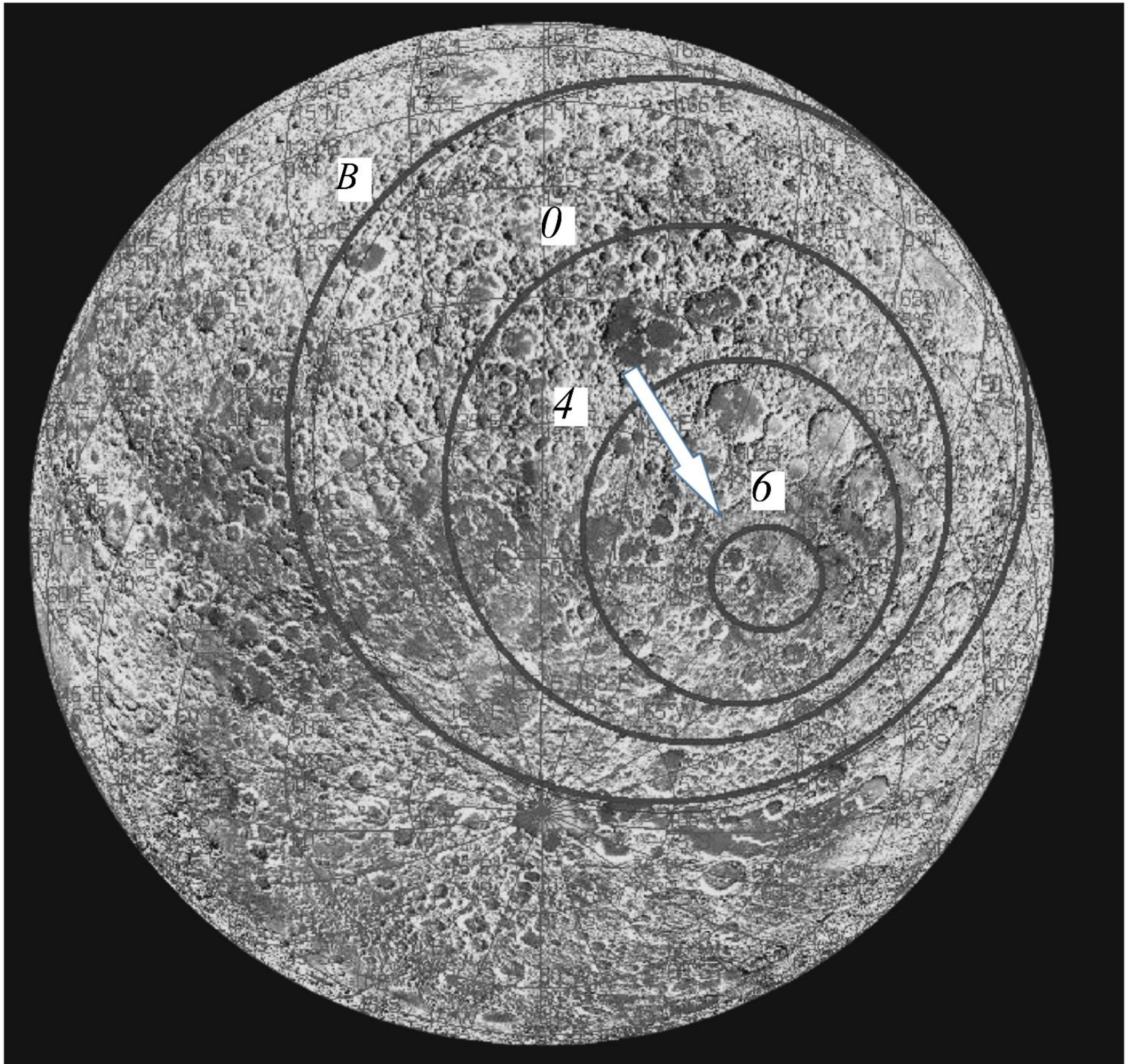
A – Aitken crater

K – Karman crater

x – center of SPA basin

HP – Highest point
DP – Deepest point
(in Antoniadi crater)

South Pole - Aitken basin on the Moon



$D_B \approx 3500$ km

$D_0 = 2400 \times 2050$ km

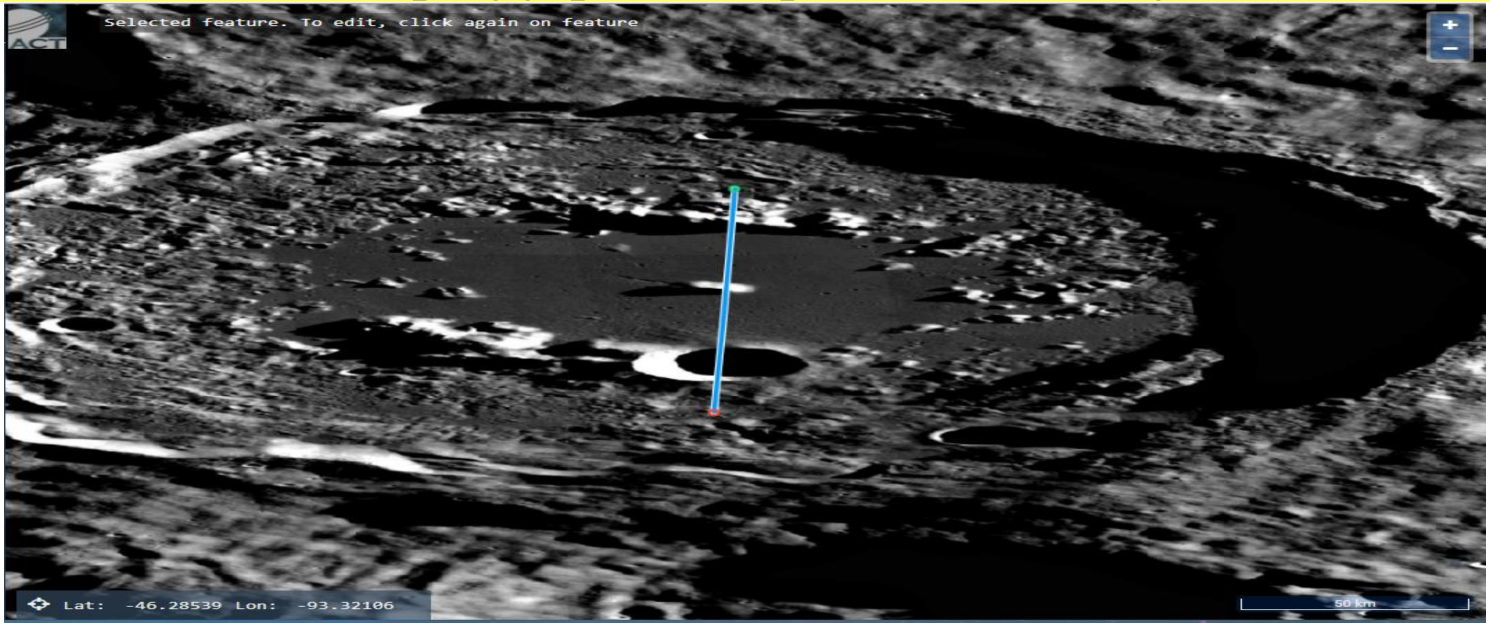
$D_{-4} \approx 1300$ km

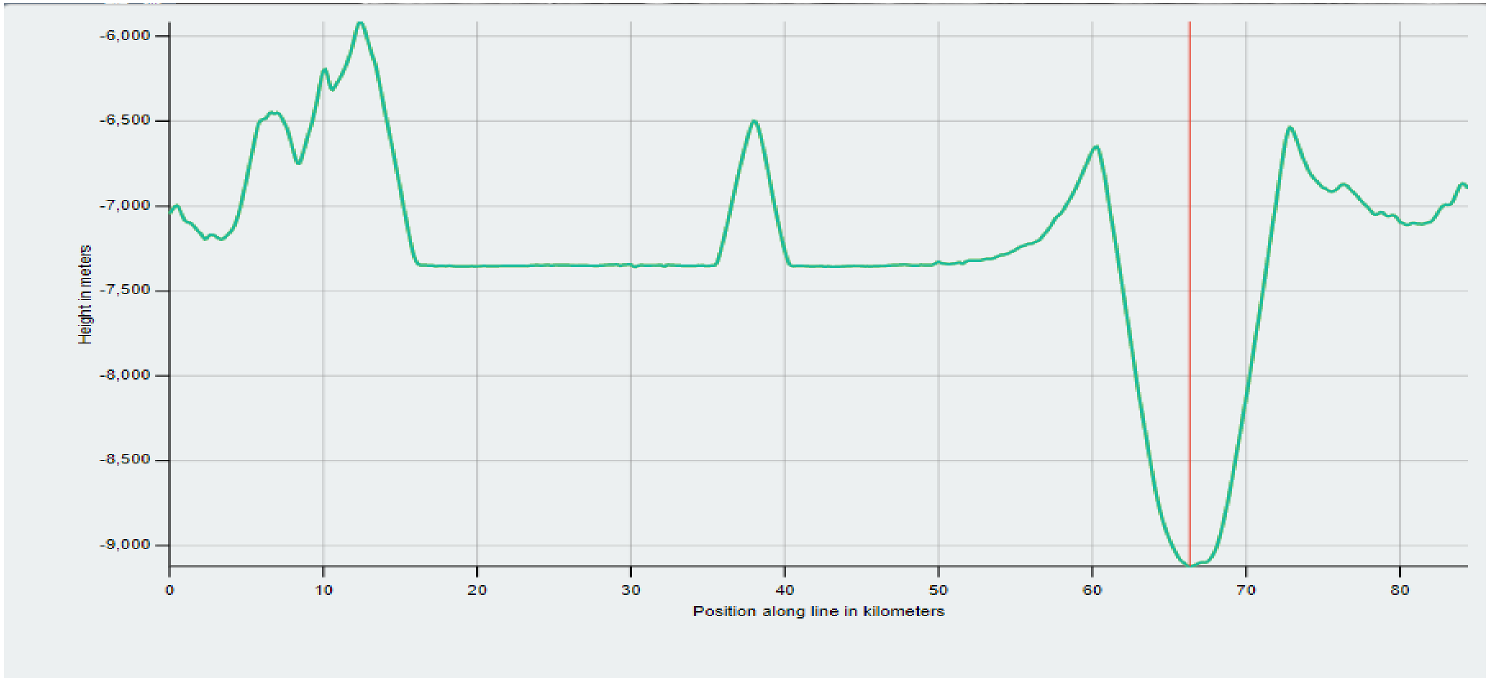
$D_{-6} \approx 400$ km

Shevchenko at al. (2007)

Antoniadi crater (D = 150 km)

https://quickmap.lroc.asu.edu/





Purpose of the message

The hypothesis is proposed that the South South Pole – Aitken basin (SPA) may have arisen as result of cumulative crater formation mechanism during the last four cometary bombardments of Moon by galactic comets.

Parameters of cometary nuclei:

d = 100 – 3500 m;

ρ = 1 g/cm^3;

$m = 10^{12} - 10^{17}$ g

V = 450 km/s

$E = 10^{20} - 10^{25}$ J

Fallings of comets have the character of "comet showers"

Δt = 1 – 5 million years

T = 20 – 37 million years

$N = 10^5 - 10^7$ comets

During 1 shower on Earth enters:

$E = 10^{27} - 10^{28}$ J - energy

$M \sim 10^{21} - 10^{22}$ g - substance

Barenbaum (2002, 2010)

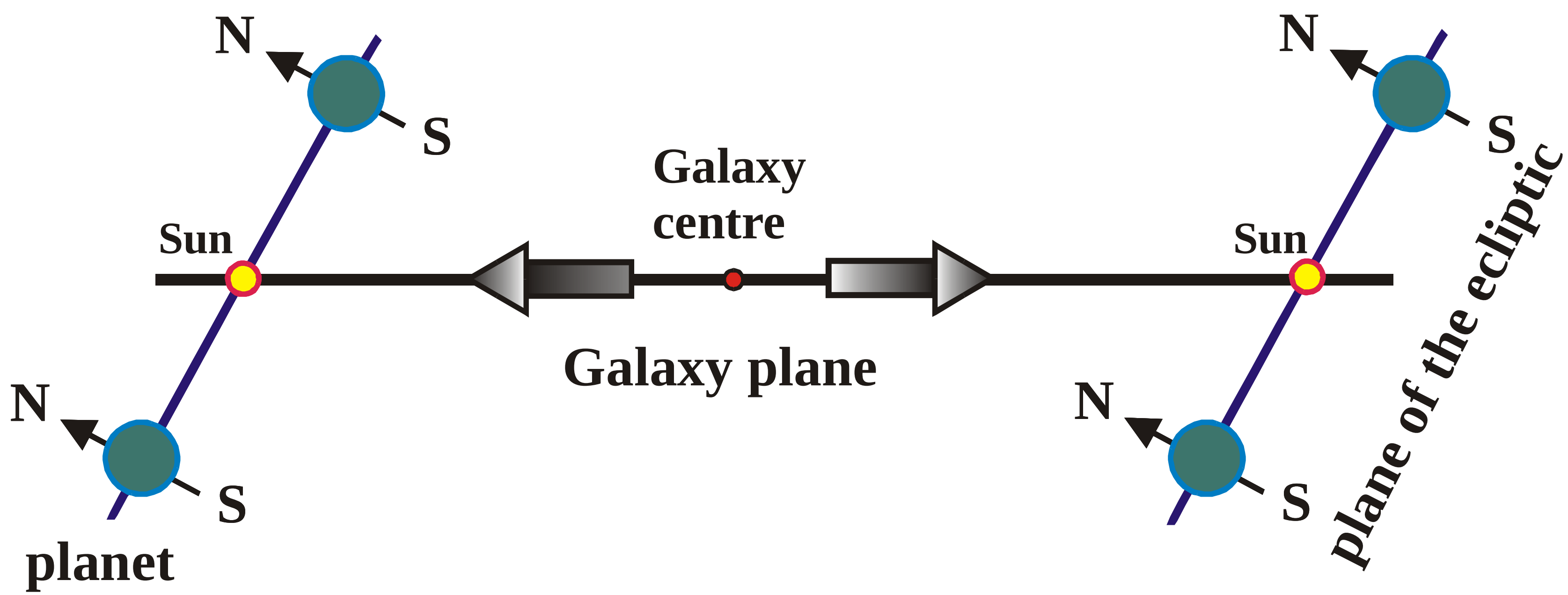
2. Two physical mechanisms of interaction galactic comets with planets surface :

1. **"Elastic" mechanism**, which is realized on planets without atmosphere (Mercury, Moon) or with a very bad atmosphere (Mars). At this mechanism, the main kinetic energy of galactic comet is spent on mechanical formation of a huge crater funnel.

2. **"Inelastic" mechanism**, implemented on planets with a dense gas shell (Earth and Venus). In this case, kinetic comet energy of is transmitted to the shock wave, which penetrates deeply into lithosphere of planet and expends energy on evaporation, melting and heating of rocks.

Barenbaum, Shpekin (2016)

3. Scheme fallings of galactic comets on planets



4. Influence of Sun motion in Galaxy on the latitudinal distribution of density fallings of galactic comets on Earth

Calculation reduces to integration the formula for φ in range from 0 to $\varphi_{max} = -tg\vartheta \cdot tg\delta$, where φ_{max} determined from the condition $I(\varphi_{max}) = 0$.

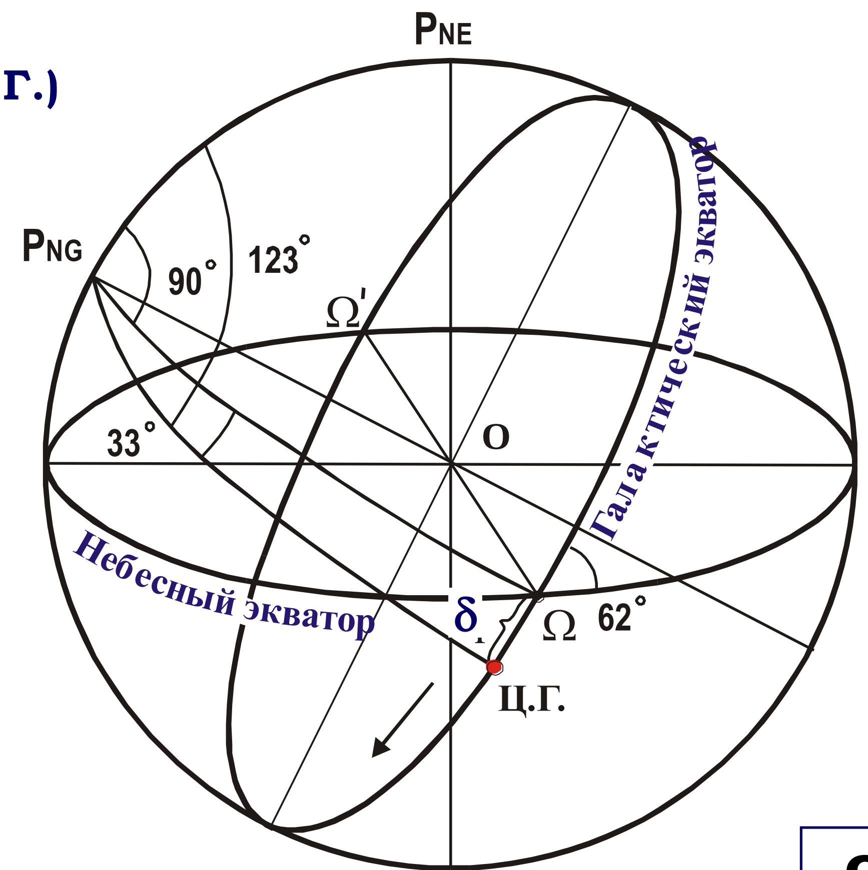
$$I = I_o \cos\varphi \ (\sin\vartheta \cdot \sin\delta + \cos\vartheta \cdot \cos\delta \cdot \cos\varphi)$$

I_o – density flux of galactic comets;

δ(t) – declension point of Galaxy center (Ц.Г.)

φ – hour angle;

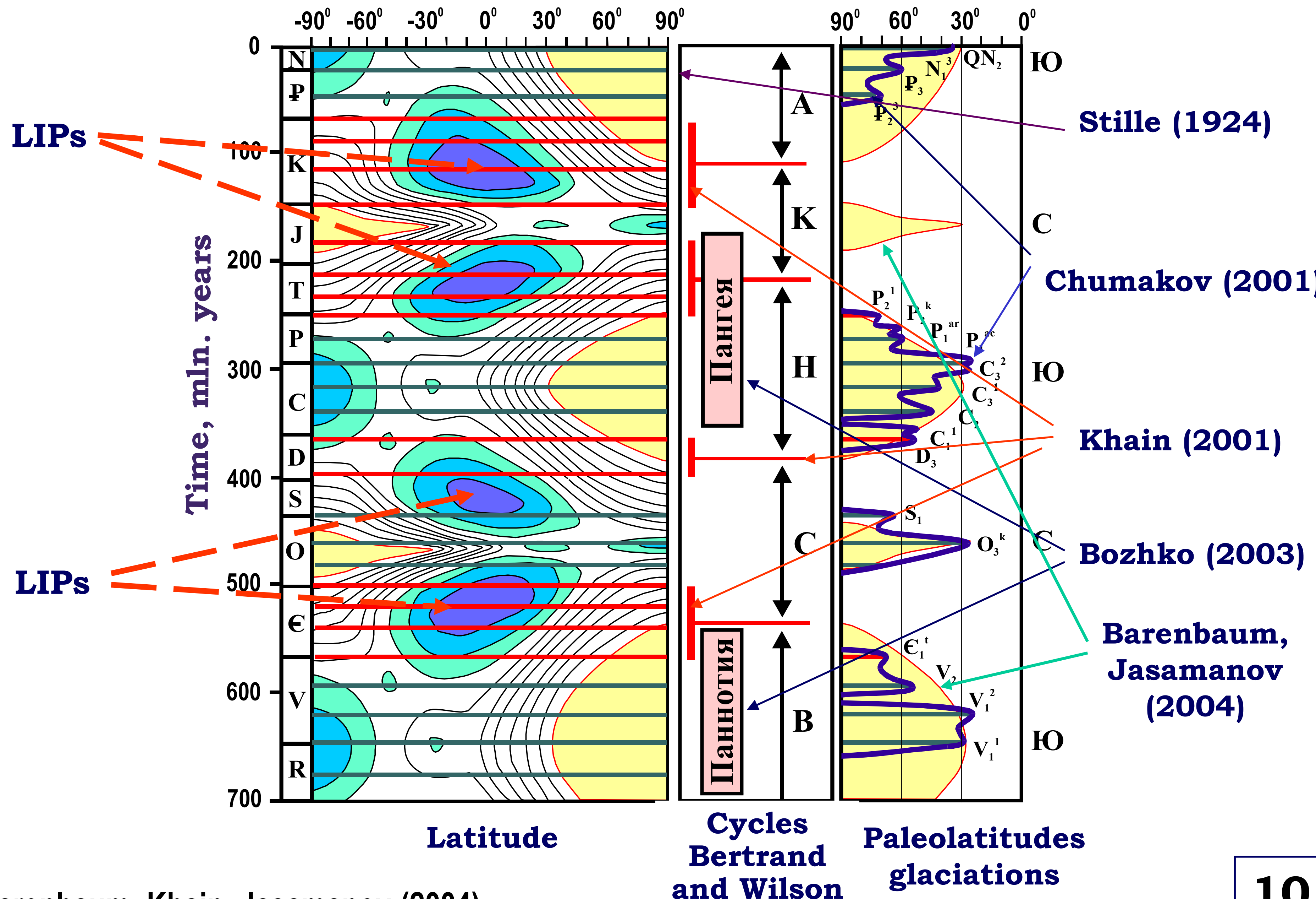
ϑ – latitude.



To harmonize with the facts is assumed precession plane ecliptic with period of 2.7 billion years that accounted for as $\delta'(t) = \delta(t) + \omega t$, where ω - angular velocity of precession

Barenbaum (2002)

5. Planetary effects caused by falls of galactic comets on the Earth



Barenbaum, Khain, Jasamanov (2004)

6. Phenomenon of "Newest uplifts"

In period <u>from 5 to 1 million years</u> the synchronous lifting of land surface took place almost on all continents of the globe. At this time, experienced a significant rise of surface of Antarctica continent, Greenland, Central and North-East Asia, most part of Africa, west parts of North and South America, Guiana and Brazilian shields, Ural, Scandinavian mountains, Siberian platform, mountain of Alpine belt and many other structure.

Territory	Lifting height
Pacific coast	few hundred meters
Siberian Platform	200 – 1000 m
South Africa	300 - 400 m in the west 900-1200 m in the east
Arabian platform	2 km
Alpes	3 km
Himalaya	6 km

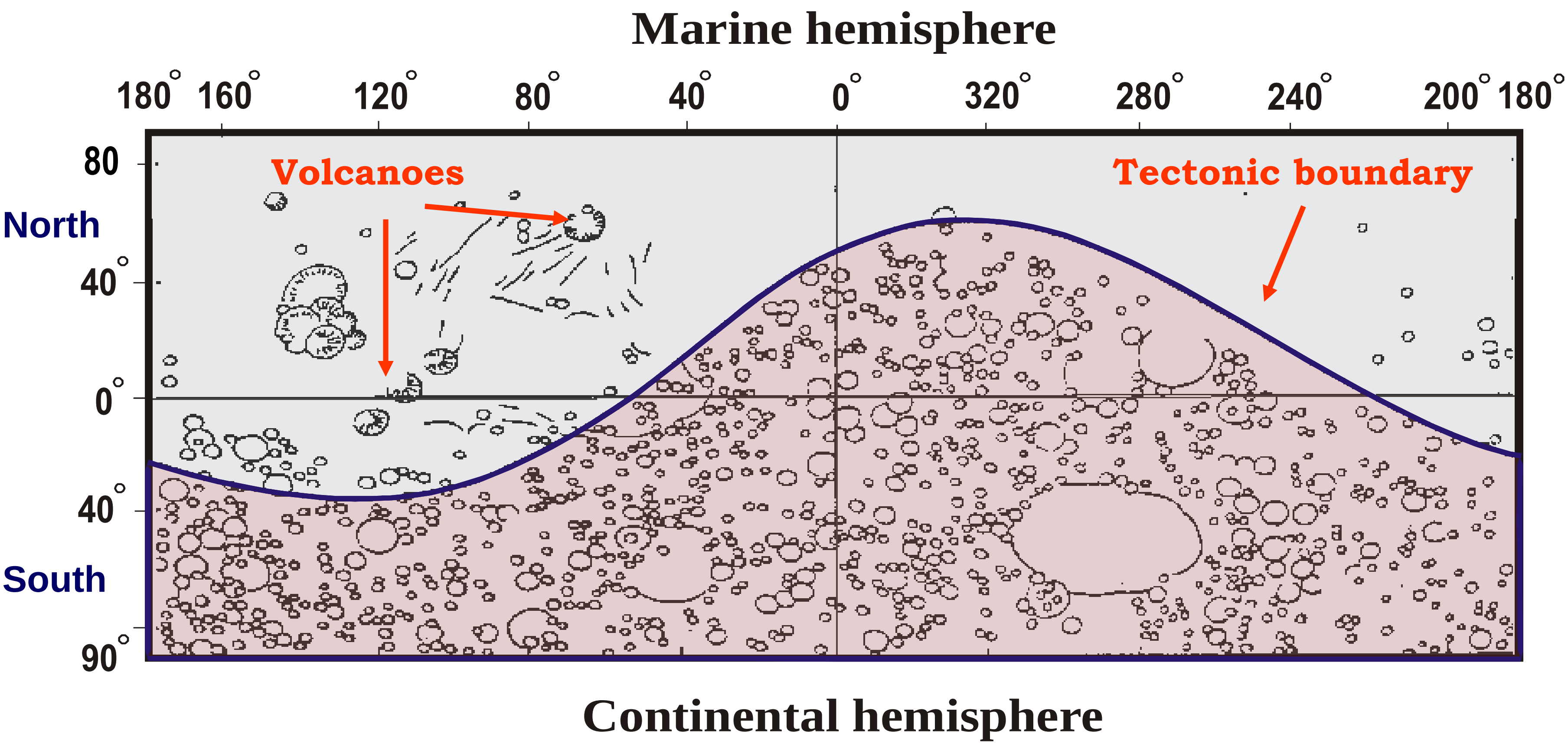
Today the considerable rising of asthenosphere under most of the mountains is observed that is accompanied in some places by outpouring of lava.

Artushkov (1994)

The need energy of ~10^{27} J

Craters on the Mars

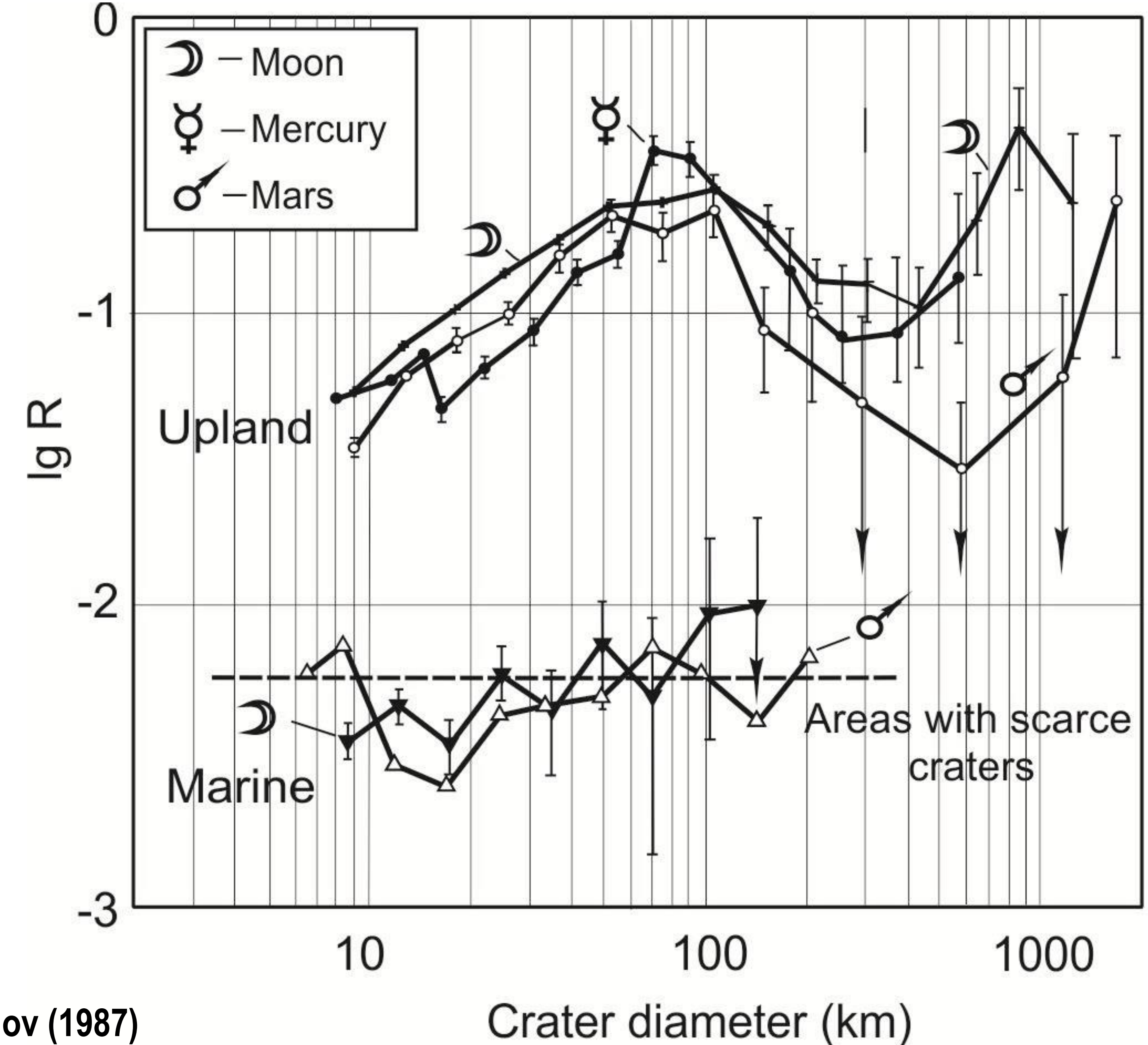
“Elastic” + “Inelastic” interaction mechanism of galactic comets with lithosphere



Southern "continental" hemisphere of Mars is highly covered by craters and higher at 2-6 km than the northern "marine" hemisphere. Tectonic boundary with width ~300 km is obtained as the section of a spherical Martian surface by plane inclined to axis of it rotation by an angle of 45° (Kazimirov, 1977)

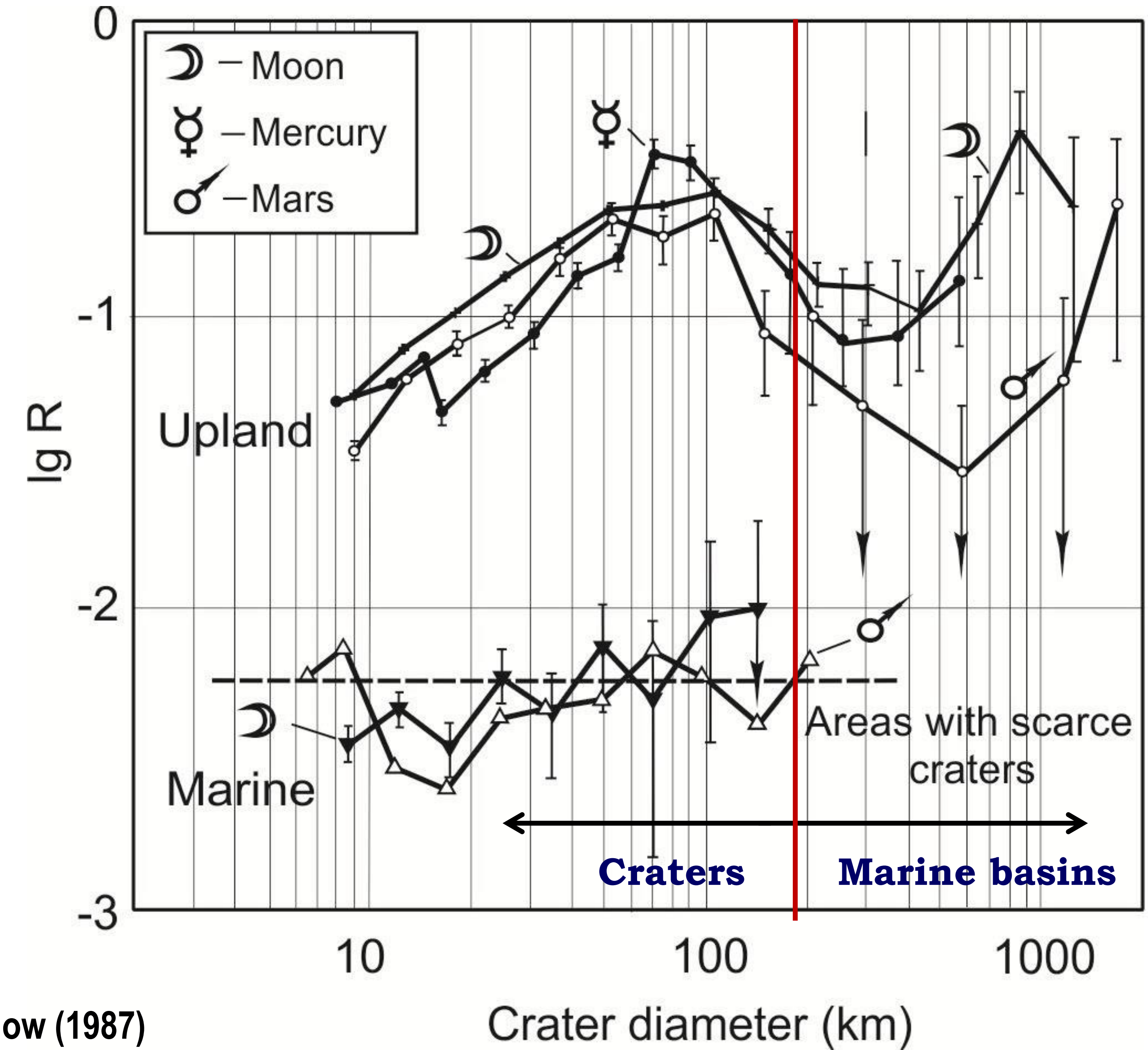
Shaded relief map of Mars (1972)

8. Differential size distribution of craters on Moon, Mars and Mercury



Woronov (1987)

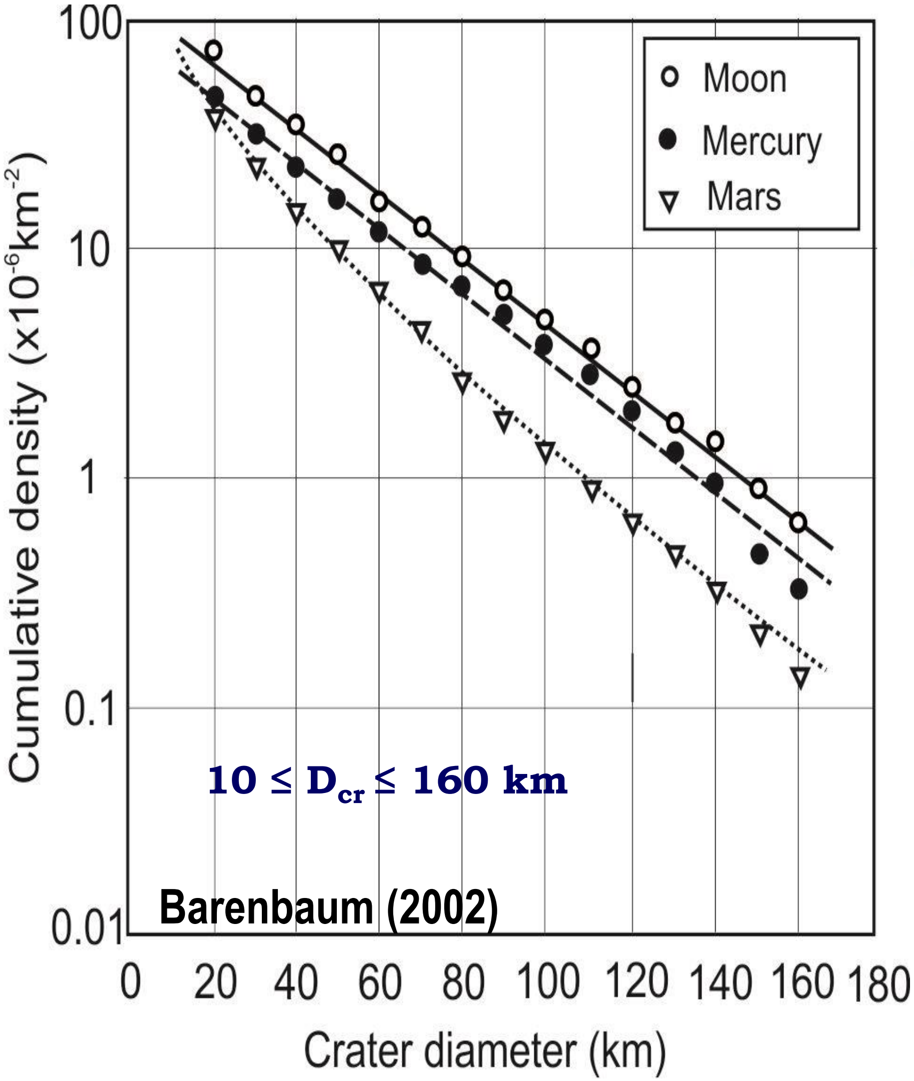
9. Differential size distribution of craters on Moon, Mars and Mercury



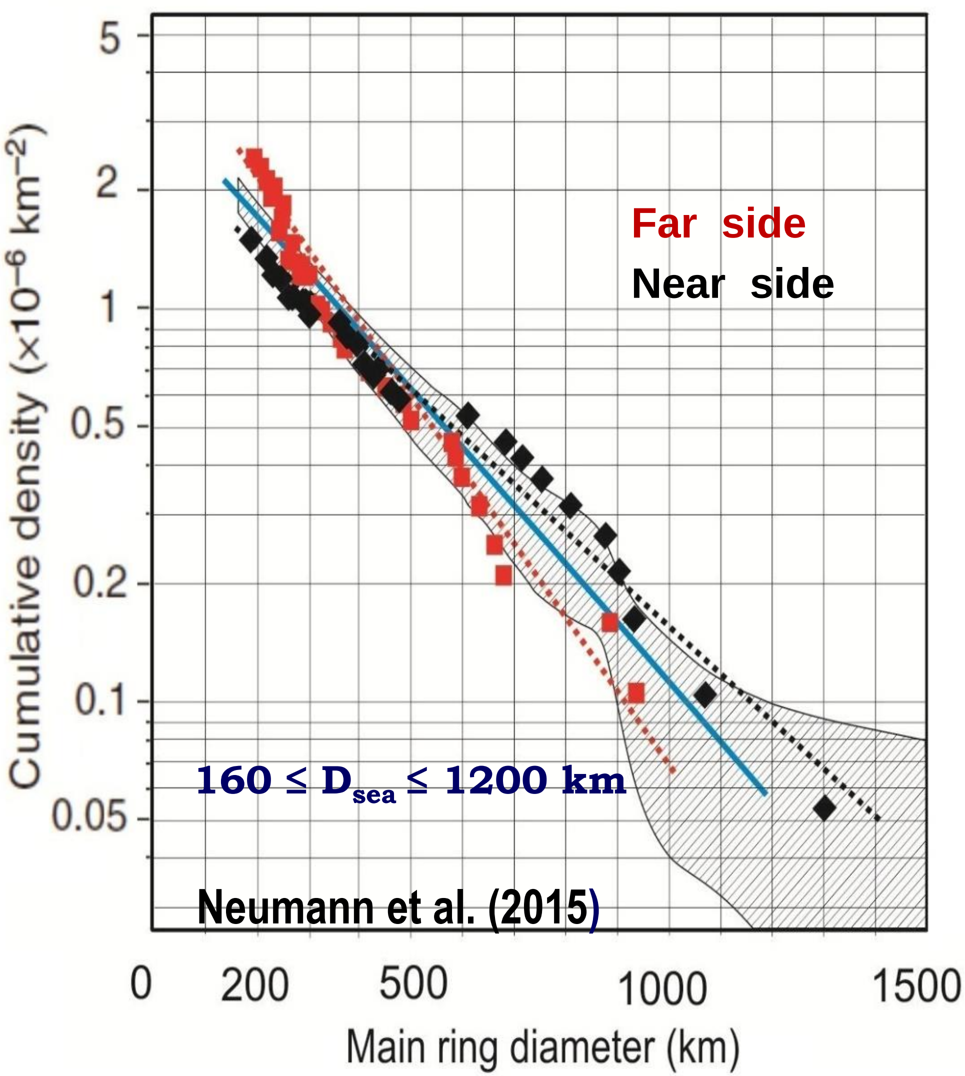
Woronow (1987)

10. Size distribution of craters and marine basins

Craters on Moon, Mars and Mercury



Marine basins on Moon



Barenbaum, Shpekin (2018)

11. Cumulative effect – imposition of crater funnels created by galactic comets

We consider the formation of lunar craters, seas and mascons by galactic comets as a random process, to which probability theory is applicable.

The formation of craters, seas and mascons on the Moon caused by falls of galactic comets, is considered as a random process, to which probability theory is applicable. This theory uses the values of mathematical expectations **M**, characterizing the average values of random variables. At that the summation result of several independent random variables is also random with mathematical expectation:

$$M_{\Sigma} = \sum_{1}^{k} M_i \qquad (1)$$

Let the random variable be diameter of emerging crater D, and distribution of craters themselves obeys an exponential law: $n(D) = n_0 \exp(-\lambda D)$, where n_0 and λ are constants and the craters diameter are within $\alpha \le D \le b$. Then the process of crater formation can be characterized by mathematical expectation $M = \overline{D}$, where average crater diameter:

$$\overline{D} = \frac{n_o \int_{\alpha}^{b} D e^{-\lambda D} dD}{n_o \int_{\alpha}^{b} e^{-\lambda D} dD} = \frac{(\alpha + \lambda^{-1}) e^{-\lambda \alpha} - (b + \lambda^{-1}) e^{-\lambda b}}{e^{-\lambda \alpha} - e^{-\lambda b}} \qquad (2)$$

11.. Cumulative effect – imposition of crater funnels created by galactic comets

In particular, for $a = 0$ and $b = \infty$ the quantity: $\mathbf{M} = \overline{\mathbf{D}} = \dfrac{1}{\lambda}$

When craters in result from falls of several comets are imposed, diameter of resultant crater is increased. The size distribution of such "complex" craters will remain exponential, and their average diameter will be:

$$\overline{D_\Sigma} = \sum_{1}^{k} \overline{D_i} = k\overline{D} = \frac{k}{\lambda} \qquad (3)$$

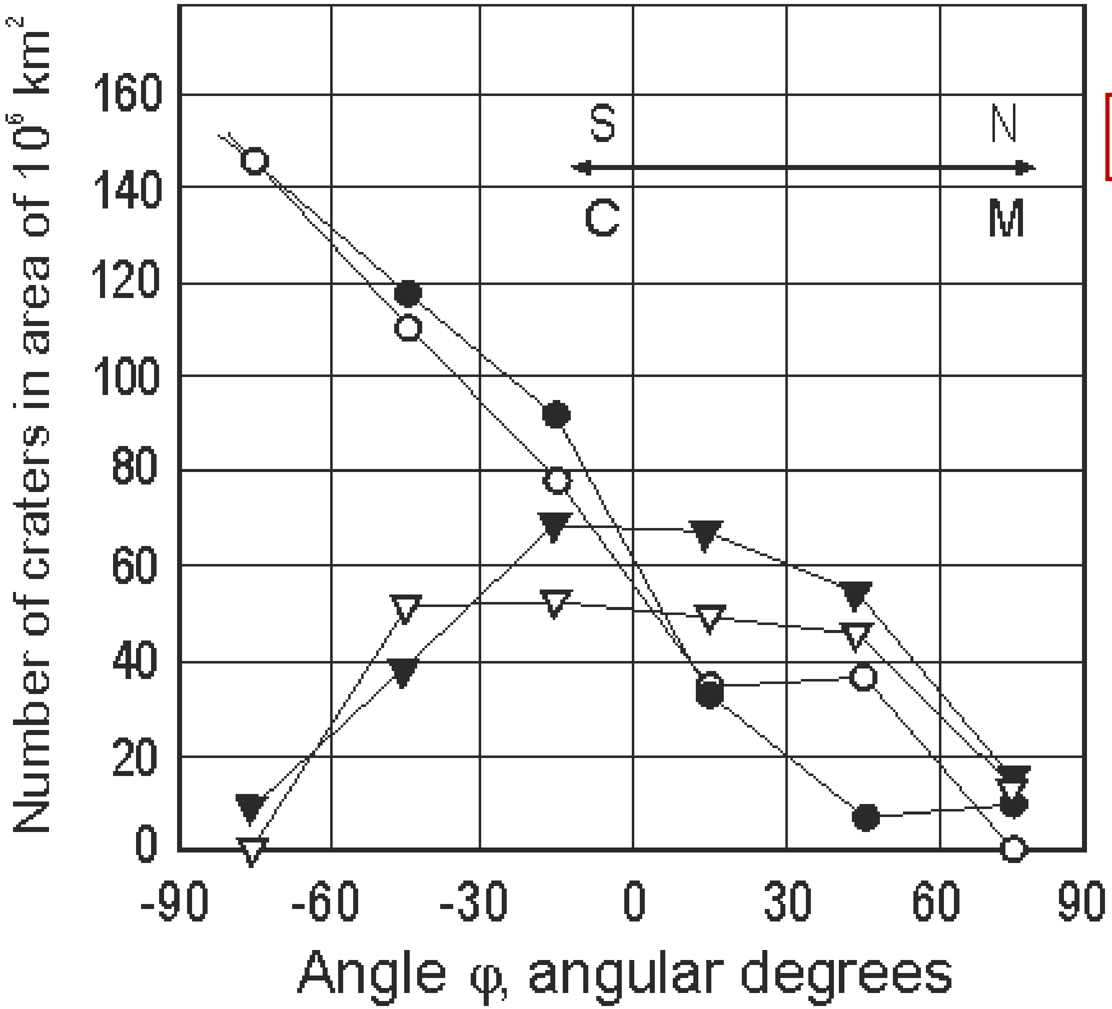
where k – the number of overlaps.

This reasoning is general and therefore applicable to processes that also participate in the formation of sea basins and mascons.

The logic is simple. As k increases, the thermal energy transferred to the rocks increases, as a result of which the volume of magmatic melts that form basaltic seas increases, as well as increases the depth of magma chambers under the craters.

All this leads to a natural increase in the diameter of complex craters and sea basins, as well as to the growth of amplitudes of Bouguer gravitational anomalies under sea basins.

12. Latitudinal distribution of craters created by comets and asteroids on Mars

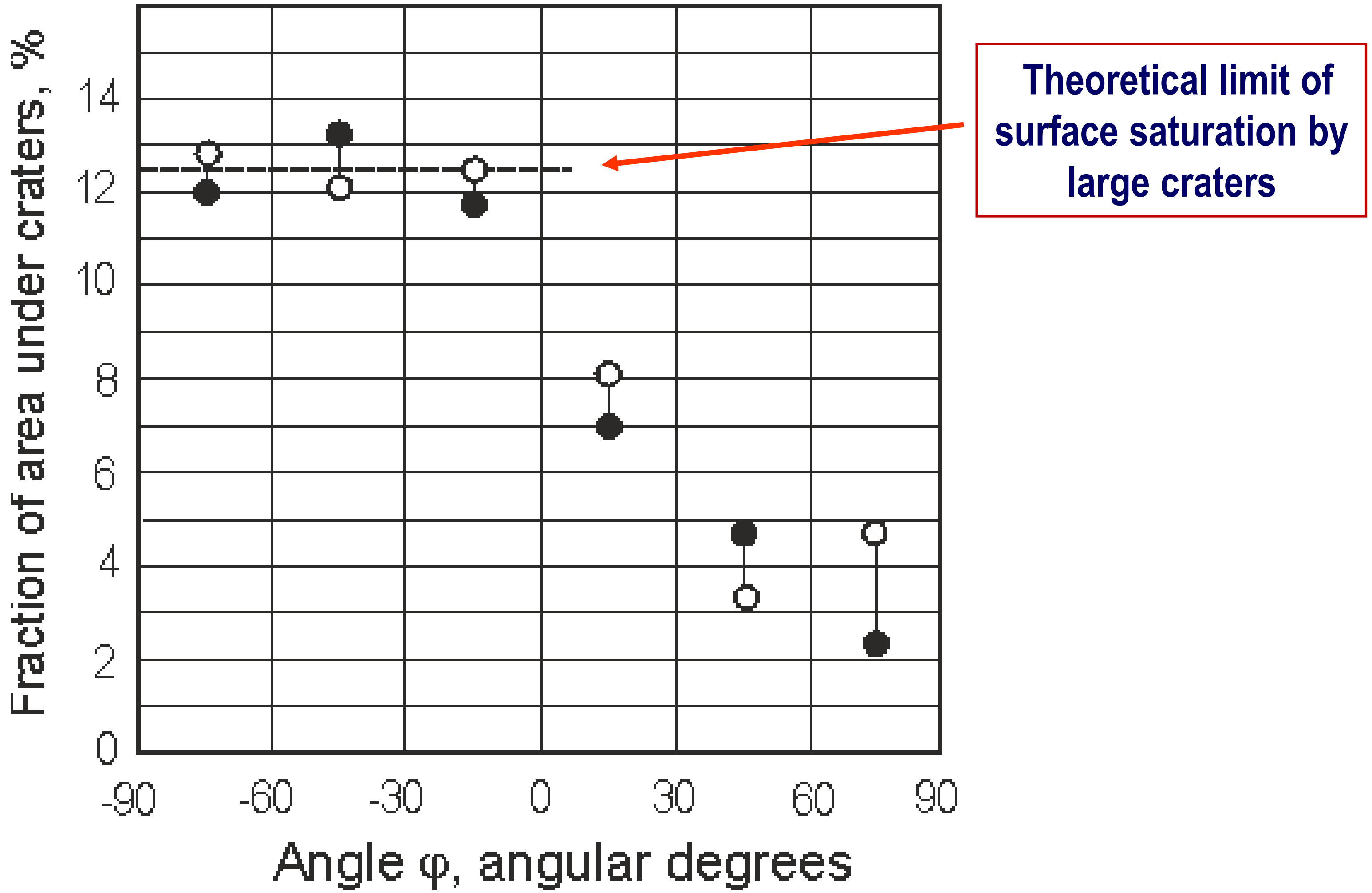


$N_{max} \approx 1.5\times10^{-4}\ km^{-2}$

Number of craters from galactic comets (circles), and asteroids (triangles) in 6 latitudinal zones of Mars along S-N axis (light icons) and C-M axis (dark icons)

Barenbaum (2002)

13. Saturation degree of individual latitudinal zones of Mars with all craters

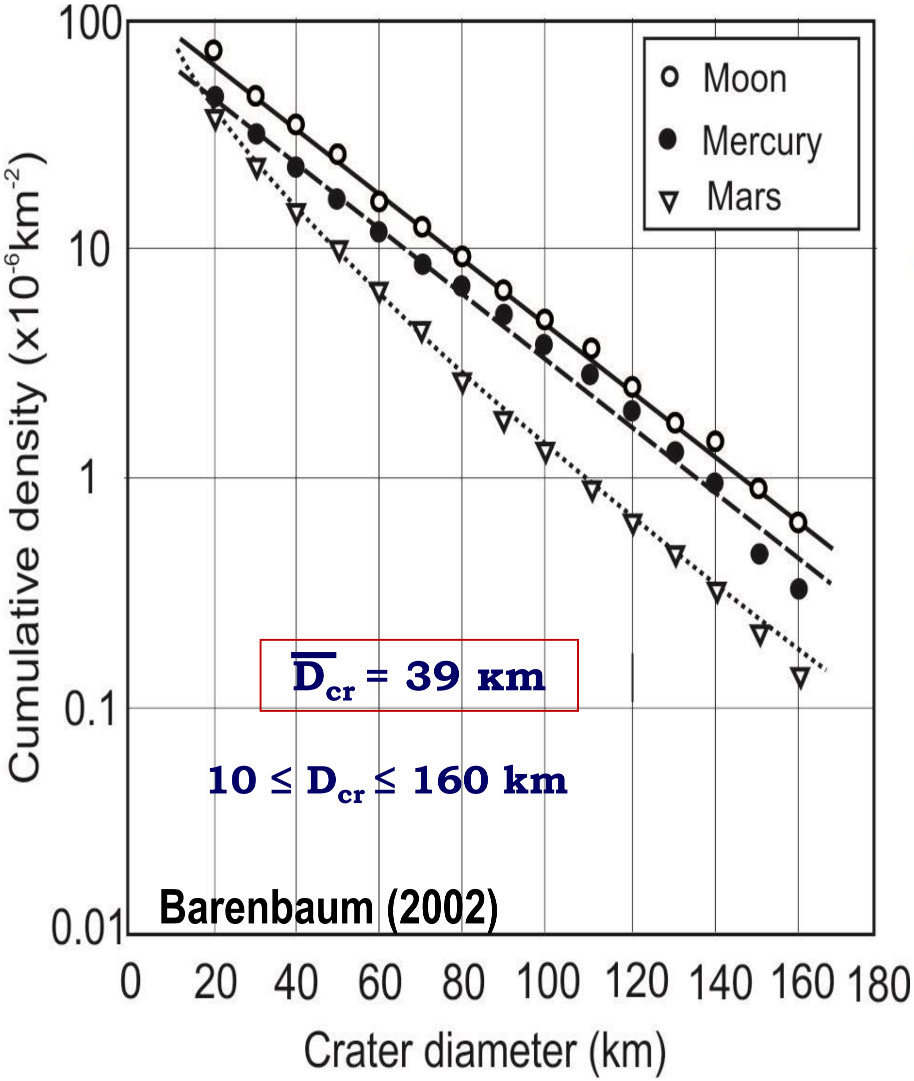


Saturation of individual latitudinal zones of Mars with all craters along S-N axis (light circles) and C-M axis (black circles): dashed line — theoretical limit of 12.5%

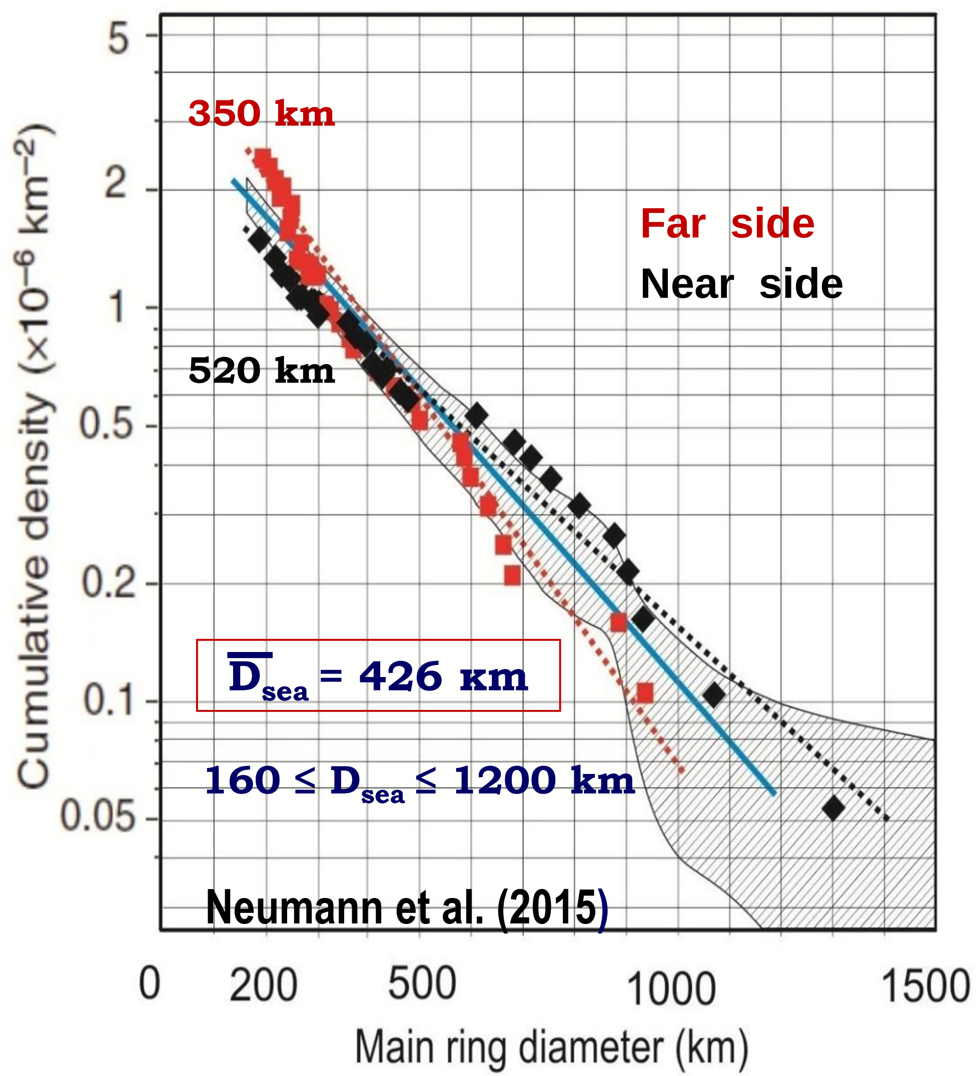
Barenbaum (2002)

14. Density of falls galactic comets

Craters on Moon, Mars and Mercury



Marine basins on Moon



$$k = \overline{D}_{sea}/\overline{D}_{cr} = 11 \pm 2$$

Barenbaum, Shpekin (2018)

14. Estimation of galactic comets flux density in Orion-Cygnus jet stream by number of craters on Mars and marine basins on Moon

The density of fallings of galactic comets of Orion-Cygnus onto planets

$$kN_{max} \approx 2\times10^{-3}\ \text{km}^{-2}$$

The duration of the last comet bombardment Δt = 4 mln years

Flux density of galactic comets in the Orion-Cygnus jet stream

$$\Phi = kN_{max}/\Delta t \approx 5\times10^{-10}\ (\text{year km}^2)^{-1}$$

Calculation results for confirmation

Planets	Earth	Mars	Moon
Number of fallen comets (pieces)	2.6×10^5	7.2×10^4	1.5×10^4
Average time between falls of comets (years)	16	56	270
Kinetic energy of fallen galactic comets (J)	1.3×10^{27}	3×10^{26}	7.4×10^{25}

Barenbaum, Shpekin (2018)

15. Energy of SPA basin formation by galactic comets

Parameters of SPA basin

Square S_{SPA} = 3×10^6 km^2

Depth H_{SPA} = 6 km

Volume V_{SPA} = 1.9×10^7 km^3

Rock density ρ = 3.3 g/cm^3

Mass M_{SPA} = 6.2×10^{22} g

Settlement terms

Highland mass $M \approx M_{SPA}$

Ejection rate rocks $v \approx 1$ km/s

$E_{SPA} = M_{SPA} v^2/2 \approx 1 \times 10^{25}$ J

$N_c = kN_{max} S$ = 6000 comets

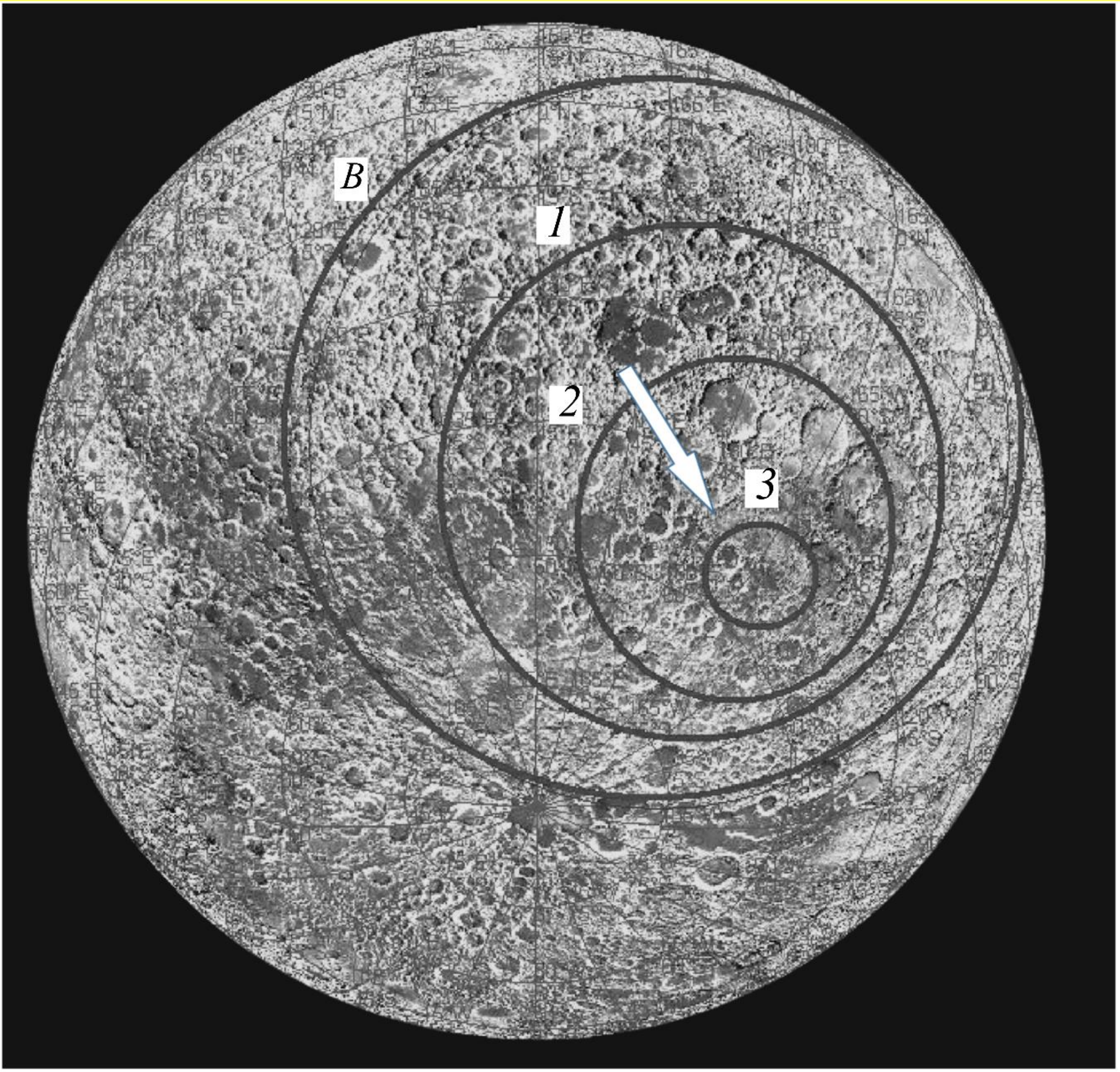
$E_\Sigma = N_c E_c = 3 \times 10^{25}$ J

Corollary :

Galactic comets energy of is enough to SPA basin form

Barenbaum, Shpekin (2020)

Conclusion



$D_B \approx 3500$ km, ~58°, 65 Ma

$D_1 = 2400$ km, ~54°, 65 Ma

$D_2 \approx 1300$ km, ~45°, 23 Ma

$D_3 \approx 400$ km, ~35°, 5-1 Ma

The SPA basin may have formed as a result of the last 4 cometary bombings.

Conclusion

A hypothesis is proposed according to which the South Pole-Aitken basin on the Moon arose under the influence of galactic comets falls.

<u>This hypothesis differs from other known hypotheses in that</u>:

1. **The SPA basin on the Moon was formed not as a result of the fall of one large cosmic body, but as a result of several bombardments of the Moon by high-speed galactic comets.**

2. **The physical mechanism of the formation of the SPA basin under impact of bombardments by galactic comets is similar to the "cumulative mechanism" of the creation by these comets marine basins larger than 180 km on the Moon, as well as on Mars and Mercury. The main difference is that the SPA basin was formed as a result of not one, but last four comet bombardments.**

3. **The elliptical shape and specific ring-shaped structure of the basin is caused not only by the oblique incidence of galactic comets, but also by an increase in the angle of their incidence relative to the modern plane of the Moon equator during of each subsequent bombardment.**

4. **The formation time of the SPA basin should be considered Cenozoic, which is the age of the basin is 65 mln years.**

Thank you for your attention!