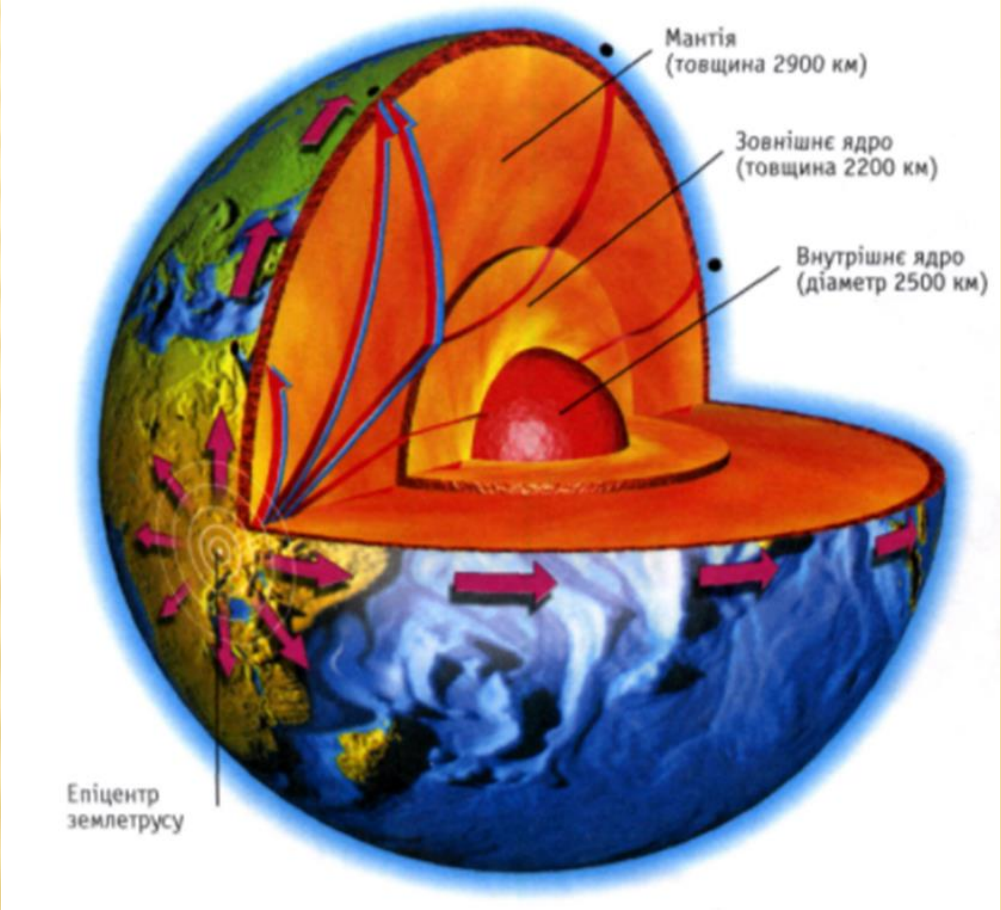
IV AKADEMIA KARTOGRAFII I GEOINFORMATYKI

MODELLING OF THE PALAEORECONSTRUCTION OF THE CONTINENTS AND THE GEOID IN GEOLOGICAL TIME

TSERKLEVYCH A., BADLO T., ZAYATS O., SHYLO E., ŁAPIŃSKI S

22- 24 MAJA 2024 R. WROCŁAW

Astronomers and geodesists began studying the geoid and the movement of the Earth's pole more than a hundred years ago. This is mainly related to the establishment of the coordinate system. Since the Earth has an equatorial bulge, the tidal forces of the Sun, Moon, and other planets cause the Earth's pole to move in space, and this phenomenon is known as precession and nutation. However, there is the so-called true polar wander, which is associated with the action of internal and surface forces on the Earth's surface, and recently scientists have started studying the causes of this movement.

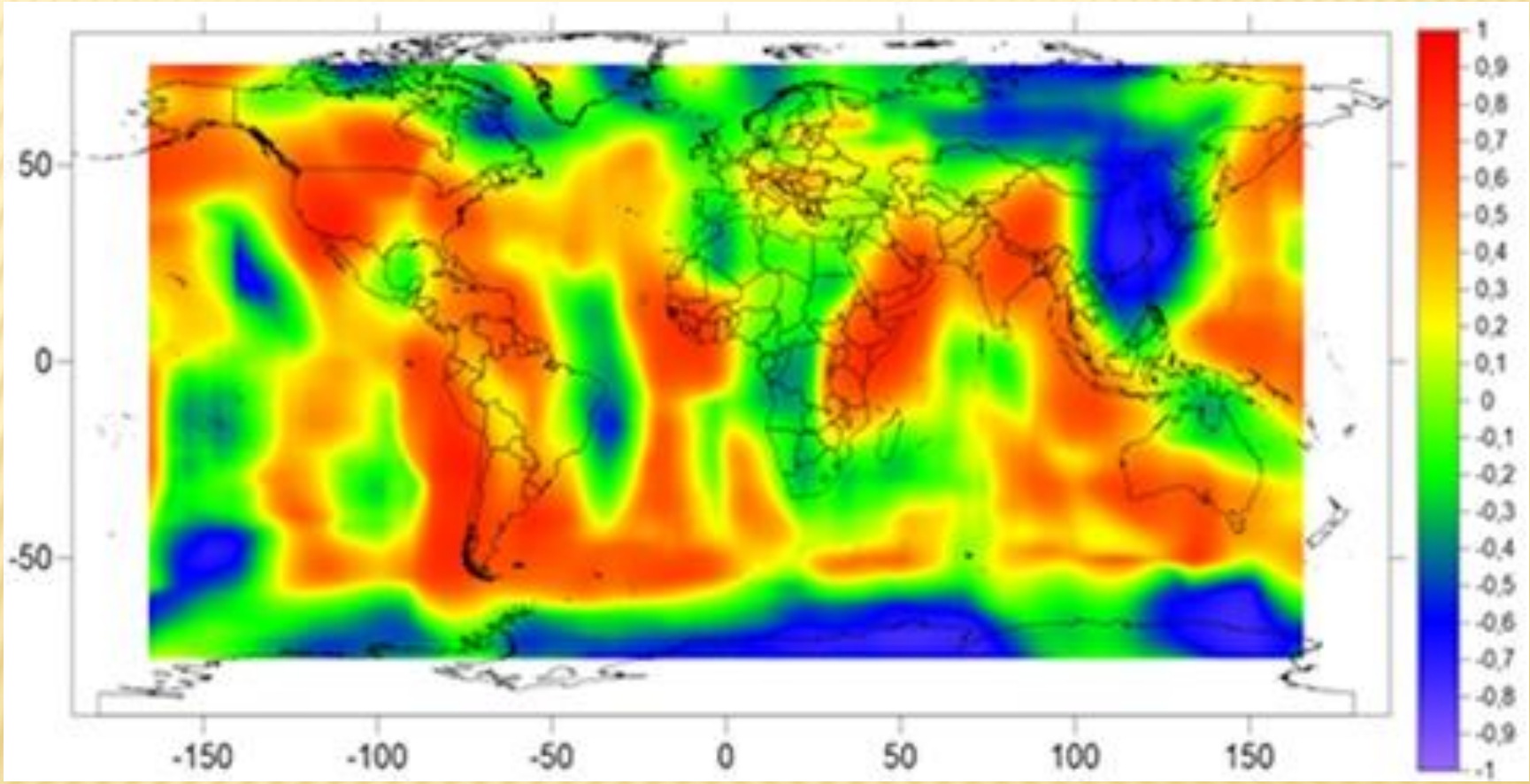


"A global model of the Earth's dynamics should have two aspects: actual and historical. The actualistic aspect involves taking into account all modern parameters related to the shape of the Earth. The historical aspect should include two components: retrospective, i.e. analysis of the history of the Earth since its formation, as well as possible prehistory; and predictive, i.e. the prospect of further development of our planet”

Khain V.E.

The purpose of our research is to conduct a correlation analysis of the relation between the heights of the geoid and topography based on the results of estimated moving correlation coefficients (MCC). By extrapolating the modern correlation model to past geological epochs using known lithospheric surface heights obtained from paleoreconstruction models, the paleogeoid can be determined. The obtained models of paleoreconstruction of tectonic plates in combination with geoid models allow to determine the secular movement of the pole of the axis of maximum inertia, to which the Earth's rotation axis is approaching.

CORRELATION BETWEEN TOPOGRAPHY AND GEOID FOR PRESENT EPOCH

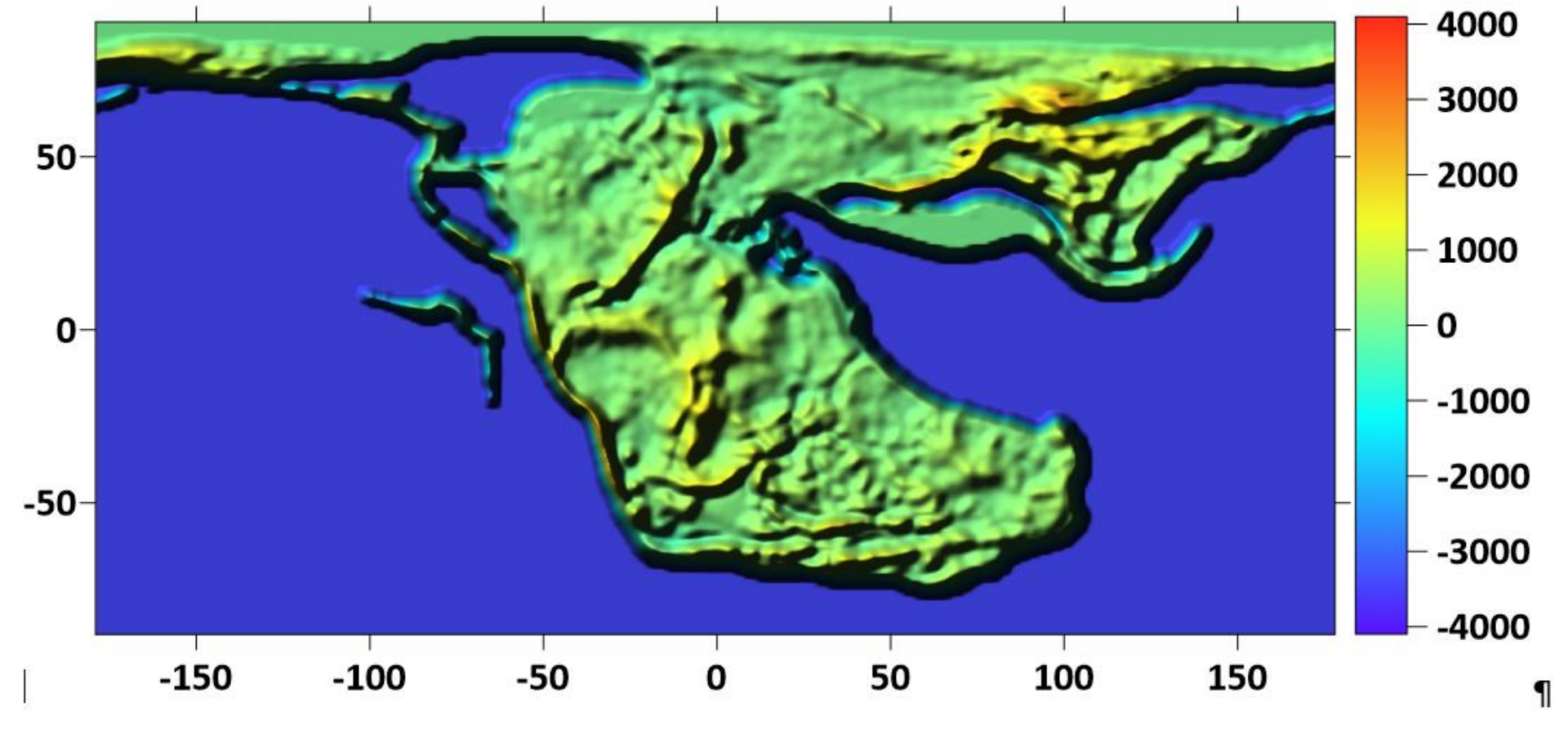


Since there are no correlations between topography and the geoid at a regional level (over 1000 km), we tried to extend this concept to other geological epochs for which we know the topographic heights from paleoreconstructions of continental arrangements. Therefore, we assume that the planetary geoid is formed by density heterogeneities in the mantle.

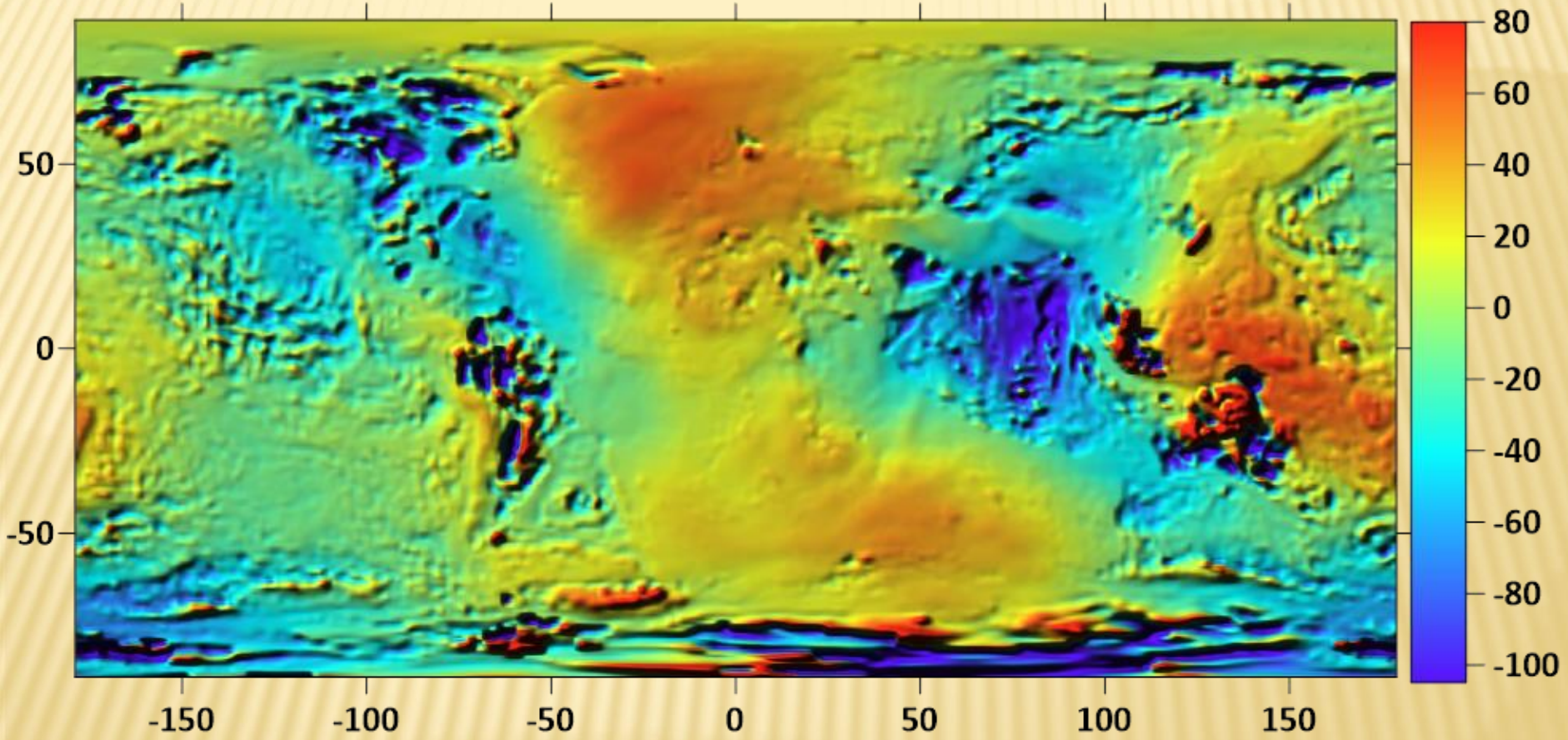
To investigate the correlation between geoid heights and topography, we used data for 1°x1° trapezoids. The input information for our studies were geoid heights from the EGM2008 model [https://www.eye4software.com/hydromagic/documentation/manual/utilities/egm2008-geoid/] and, correspondingly, topography heights [Pavlis et al., 2008] and lithospheric surface heights from models of paleoreconstructions of continents [Scotese and Wright., 2018].

Assuming that the statistical model of the correlation between topographic heights and the geoid remains unchanged for the present epoch, we can construct geoids for specific past geologic epochs. For such calculations, we used known topography heights from paleo-construction model databases [Scotese and Wright, 2018].

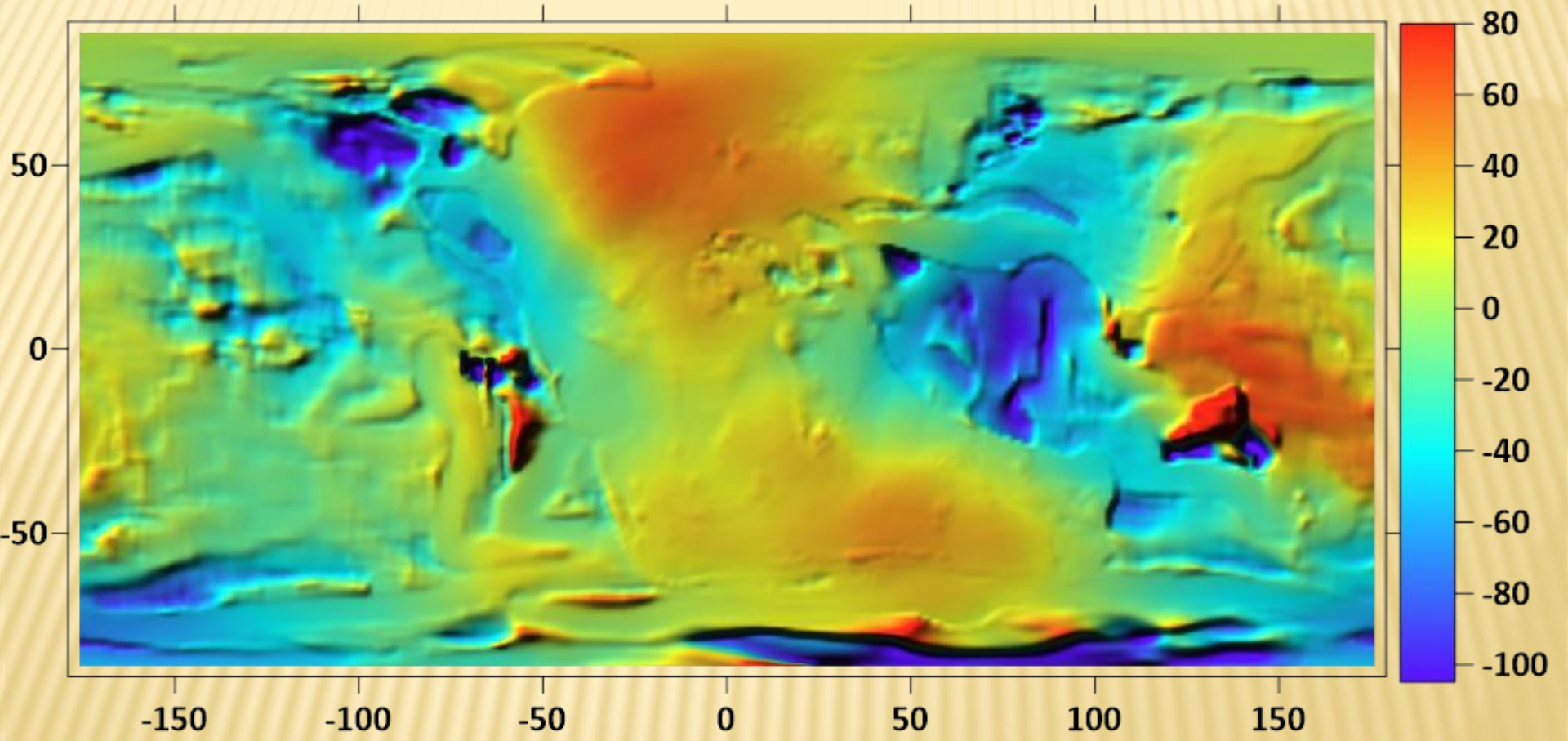
TOPOGRAPHY HEIGHTS (200 MA) (IN METERS)



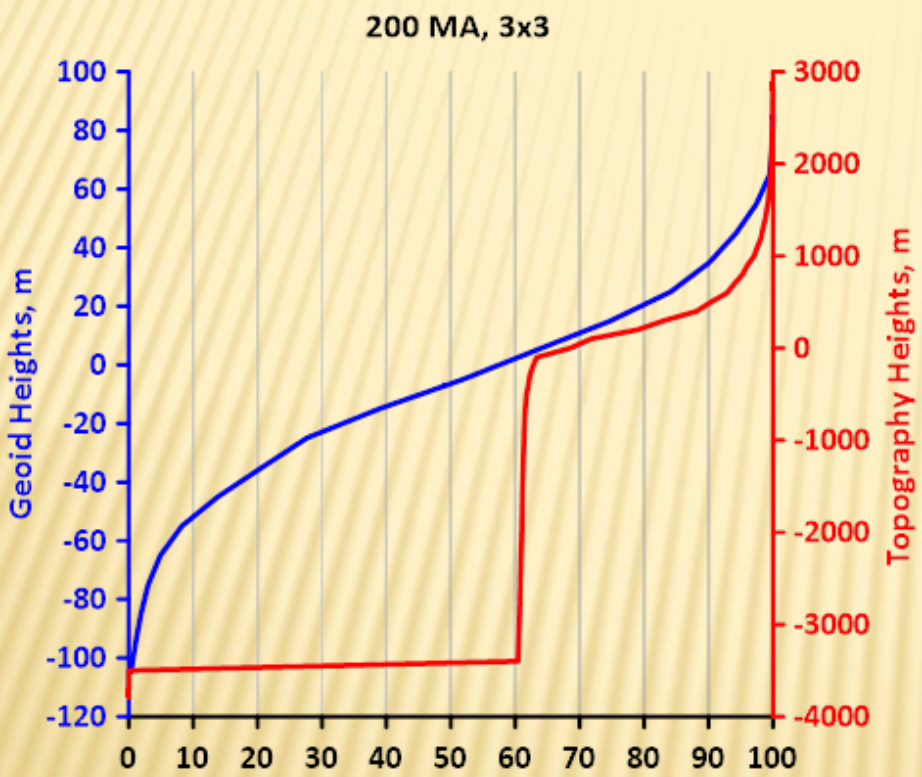
GEOID HEIGHTS 200 MA 3°X3° (IN METERS)

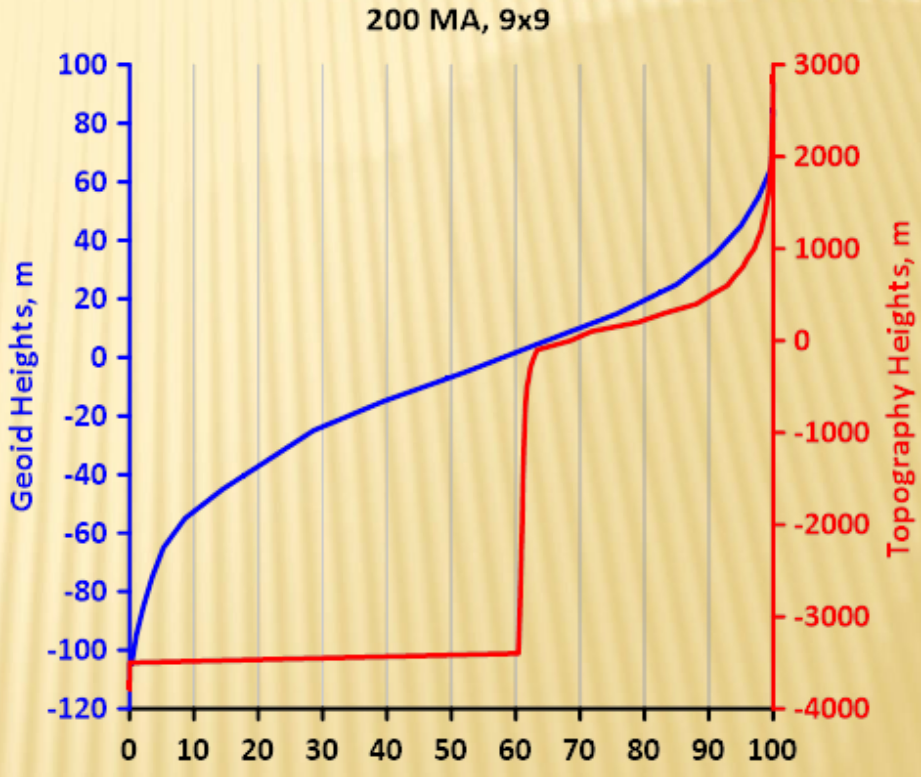


GEOID HEIGHTS 200 MA 9°X9° (IN METERS)

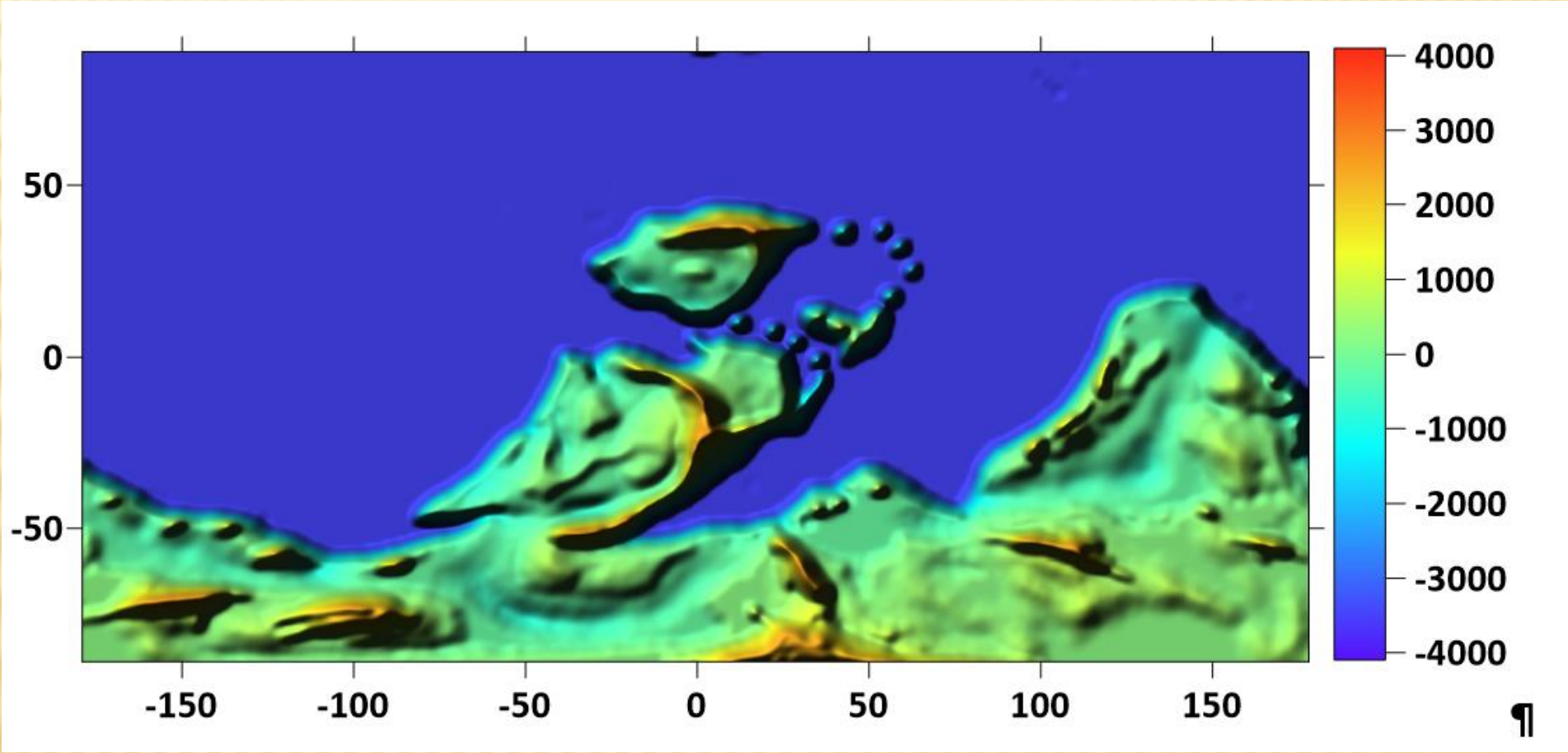


CUMULATIVE ELEVATION PLOTS OF TOPOGRAPHY AND PALEOGEOID (200 MA)

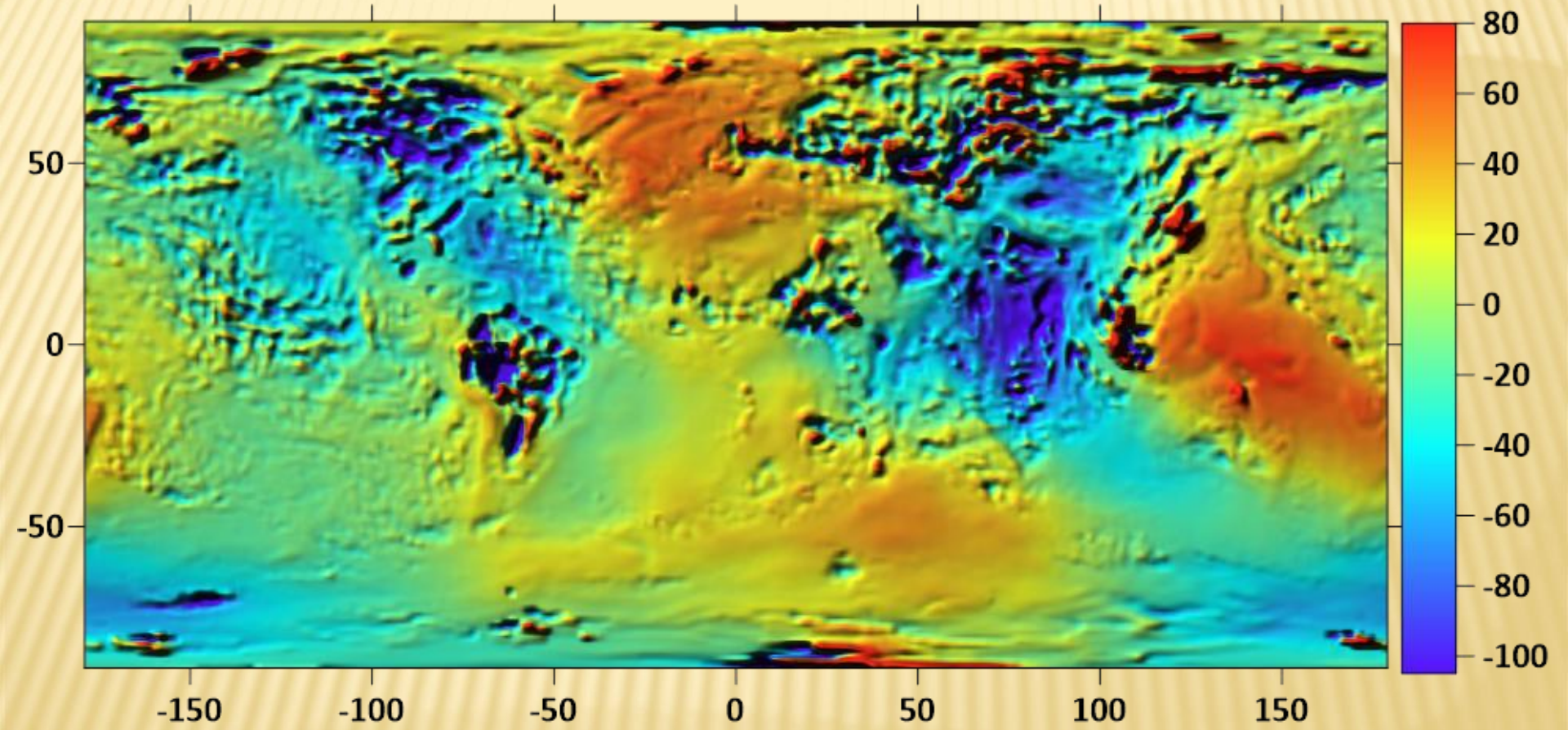




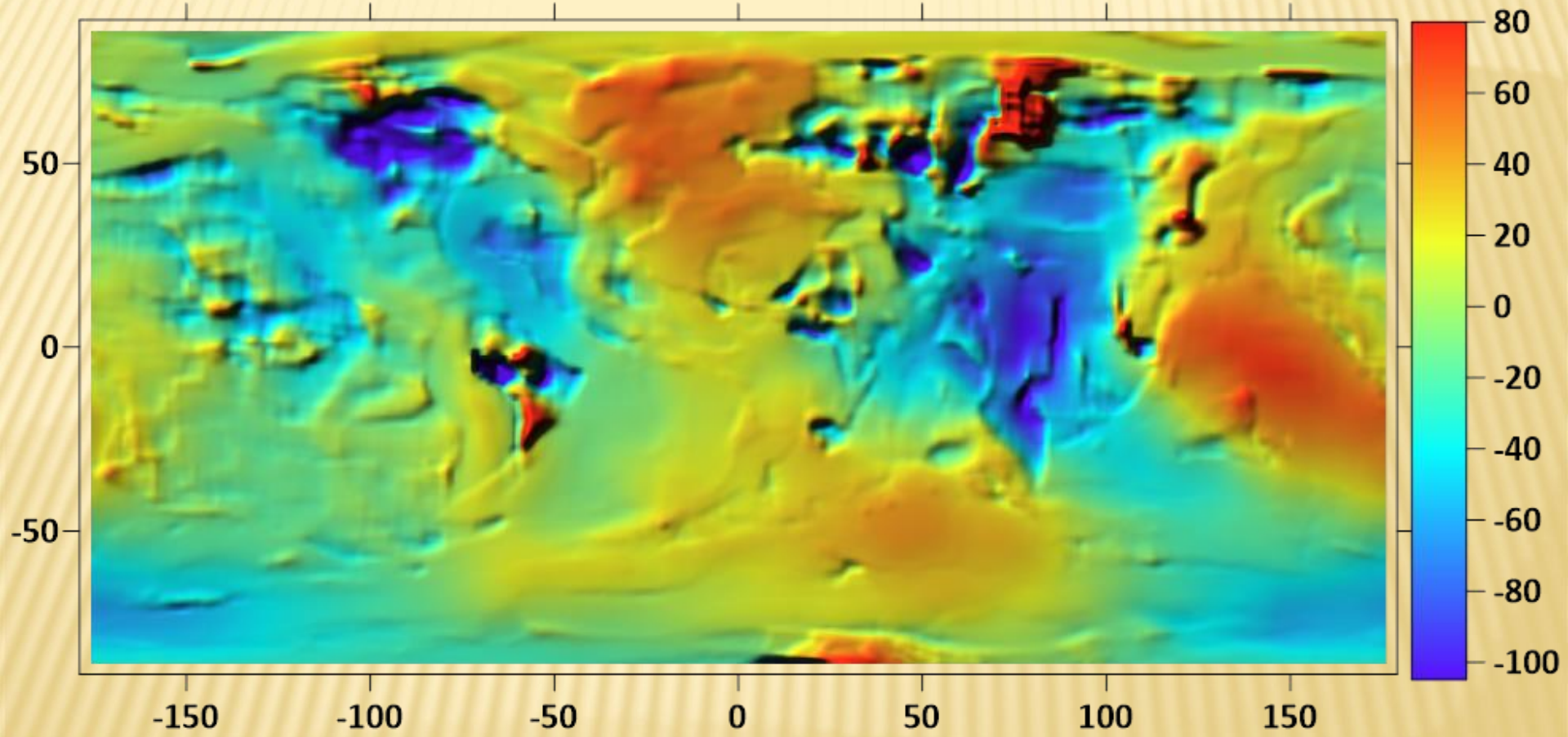
TOPOGRAPHY HEIGHTS (400 MA) (IN METERS)



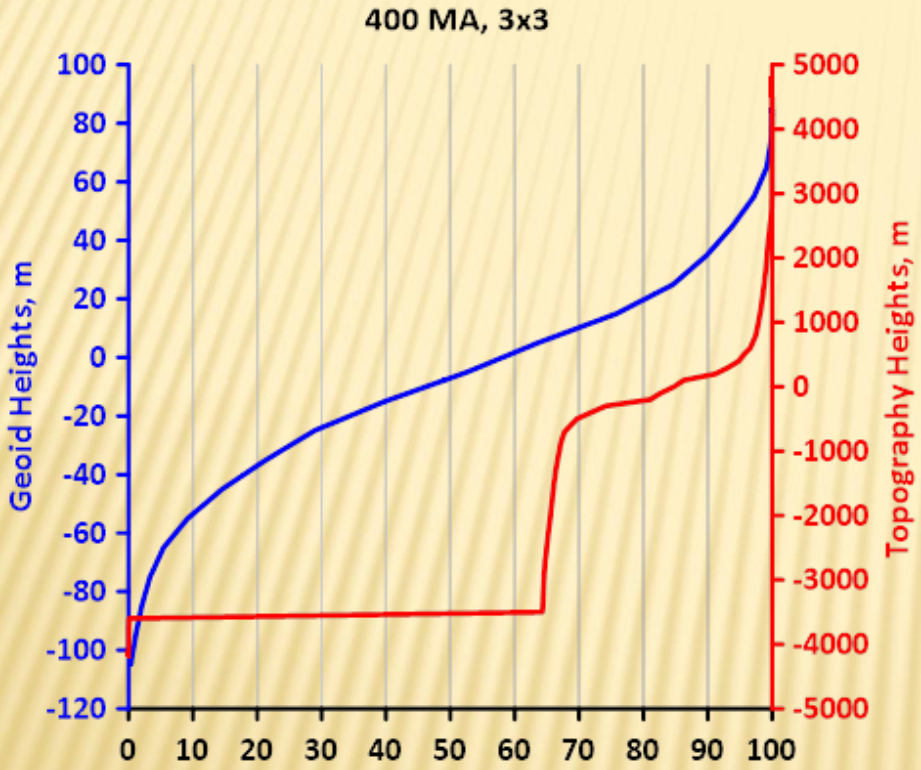
GEOID HEIGHTS 400 MA 3°X3° (IN METERS)

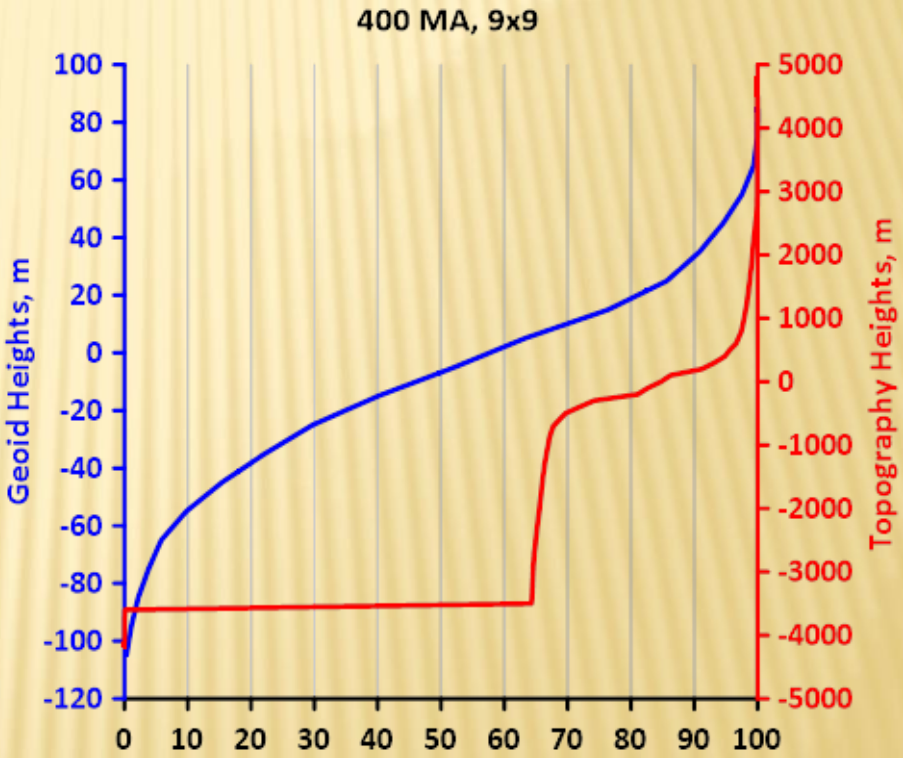


GEOID HEIGHTS 400 MA 9ºX9º (IN METERS)

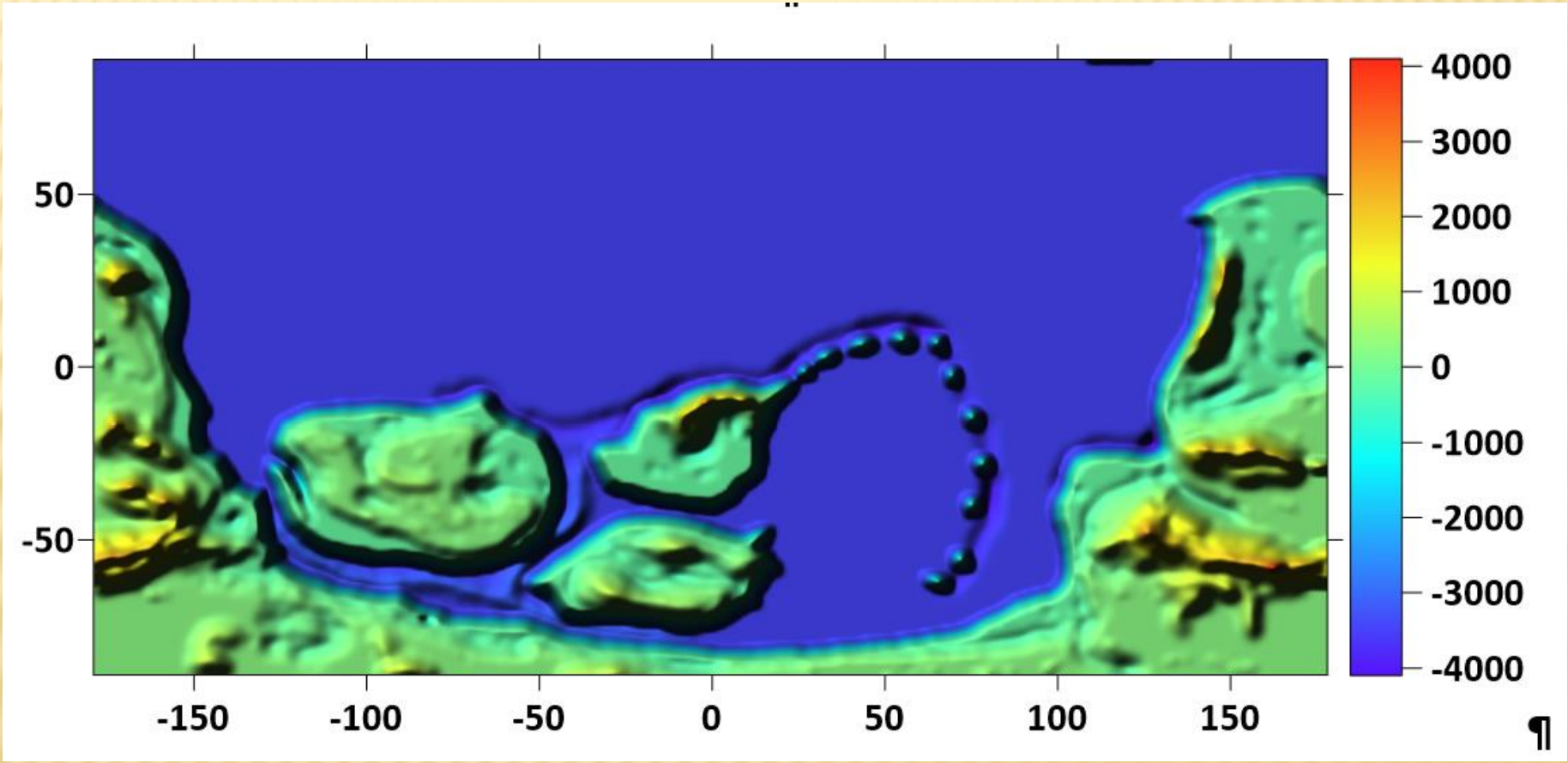


CUMULATIVE ELEVATION PLOTS OF TOPOGRAPHY AND PALEOGEOID (400 MA)

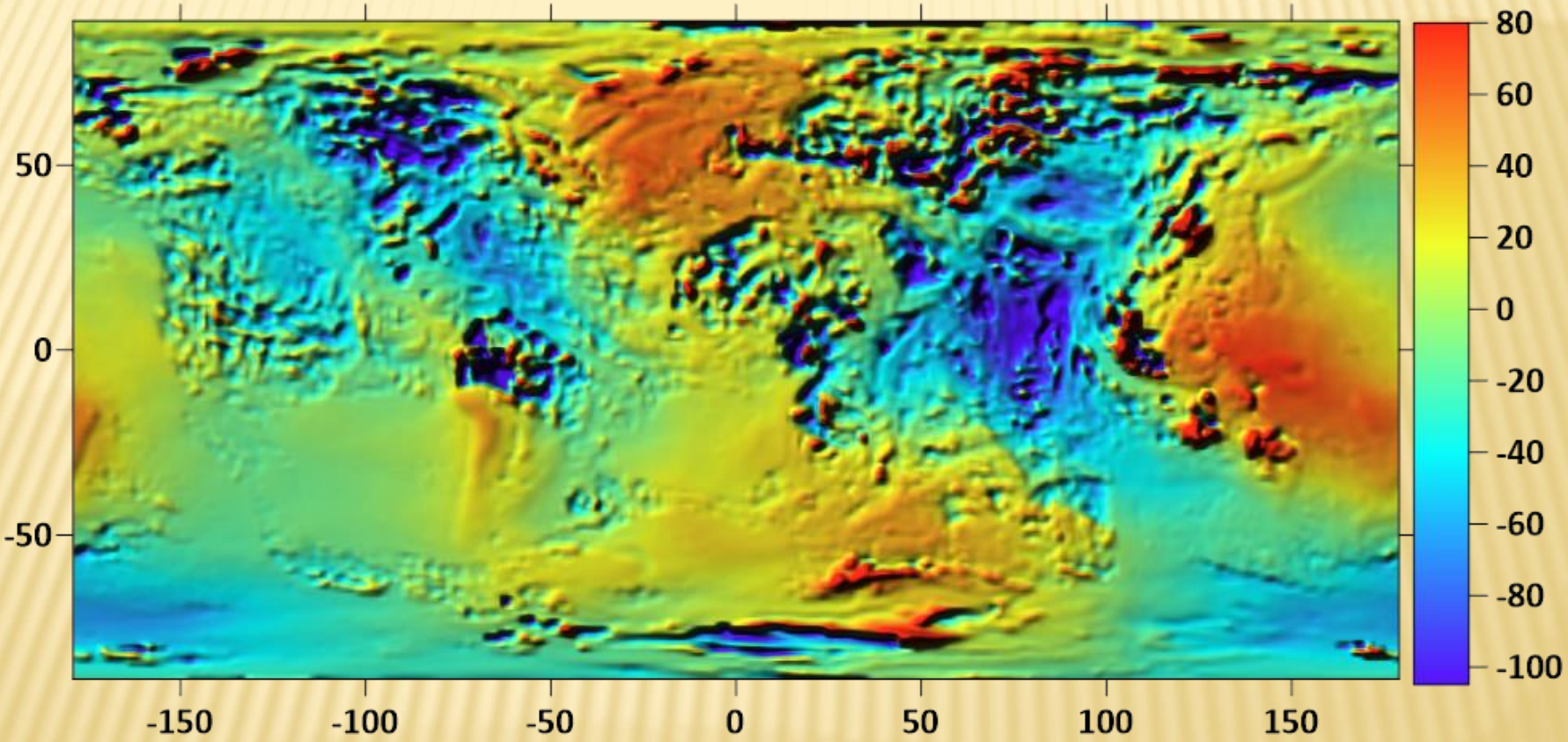




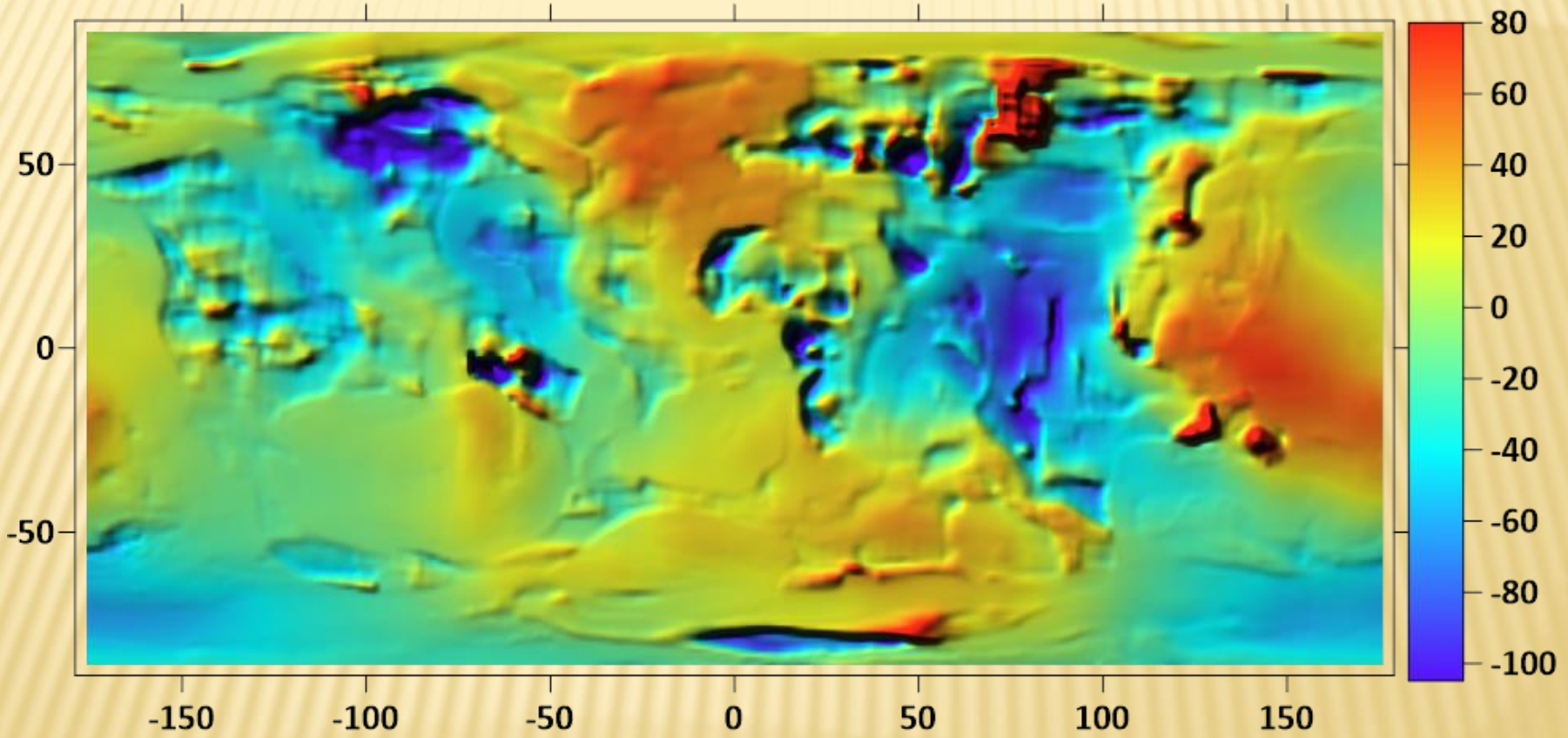
TOPOGRAPHY HEIGHTS (540 MA) (IN METERS)



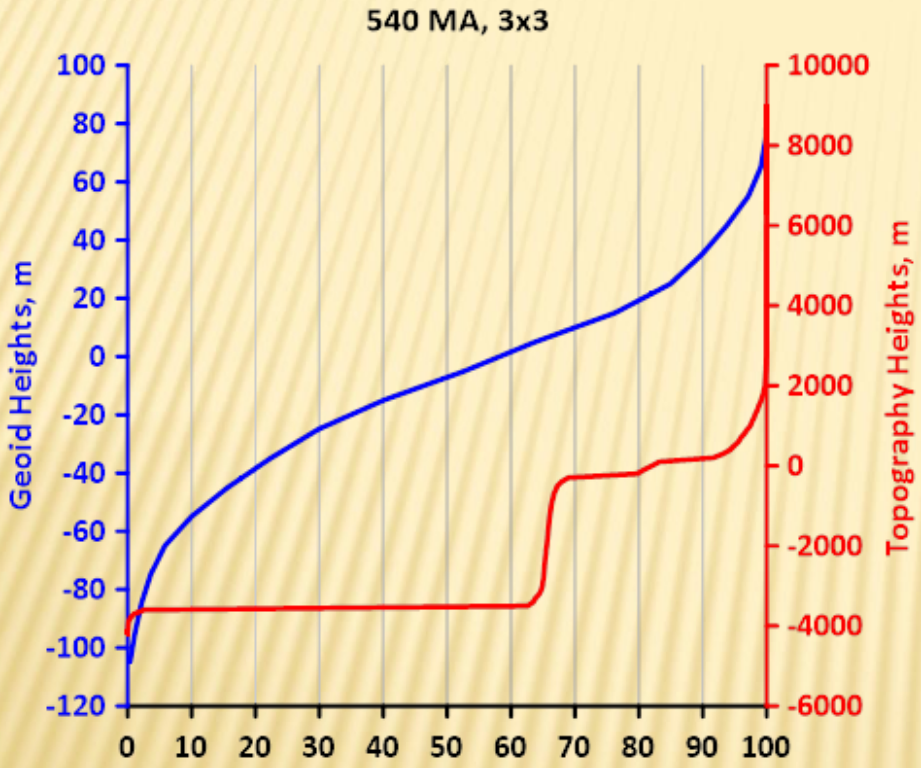
GEOID HEIGHTS 540 MA 3°X3° (IN METERS)

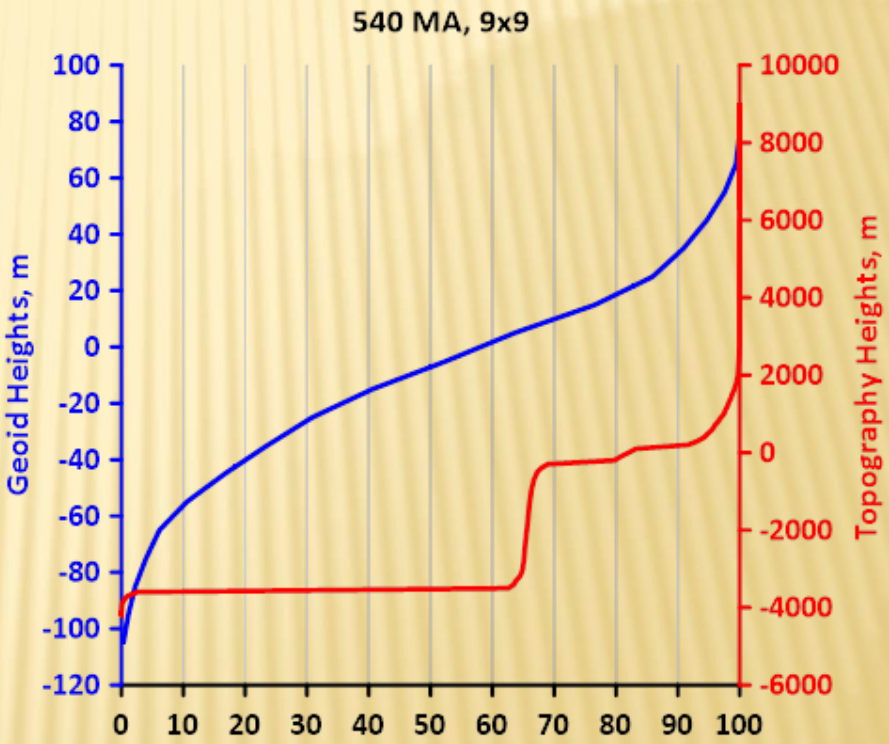


GEOID HEIGHTS 540 MA 9°X9° (IN METERS)

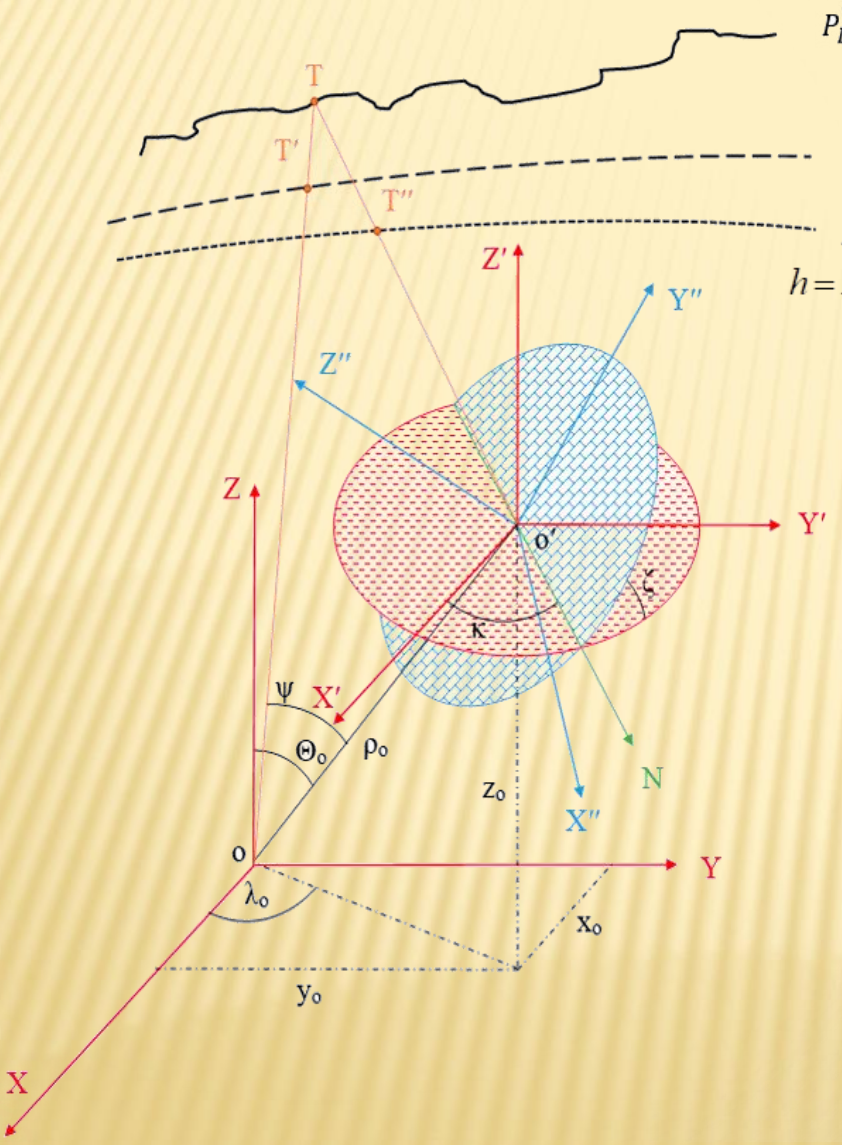


CUMULATIVE ELEVATION PLOTS OF TOPOGRAPHY AND PALEOGEOID (540 MA)





APPROXIMATION OF THE SURFACE OF THE LITHOSPHERE AND THE GEOID BY BIAXIAL ELLIPSOID



$$h = A\cos\theta + B\sin\theta\cos\lambda + C\sin\theta\sin\lambda + D\cos^2\theta + K\sin 2\theta\sin\lambda - \Delta a + H, \quad (1)$$

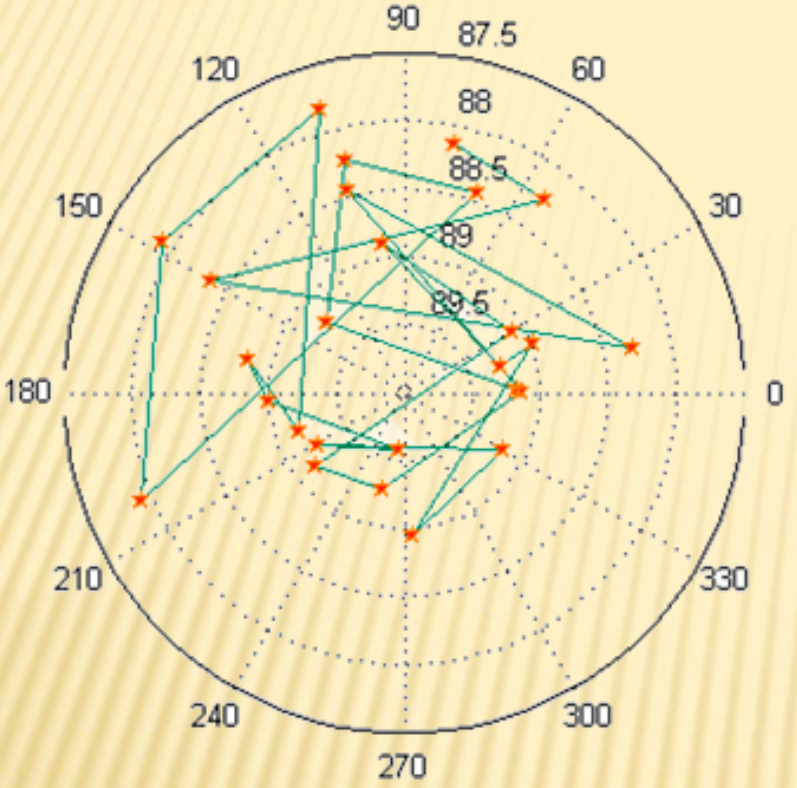
$$\left.\begin{aligned} A &= -\rho_0\cos\theta_0 \\ B &= -\rho_0\sin\theta_0\cos\lambda_0 \\ C &= -\rho_0\sin\theta_0\sin\lambda_0 \\ D &= -\alpha_0 + \alpha(1+\Delta a) \\ K &= \alpha(1+\Delta a)\zeta\sin\kappa \\ \mathrm{M} &= -\alpha(1+\Delta a)\zeta\cos\kappa \\ \Delta a &= a - a_0 \end{aligned}\right\}, \quad (2)$$

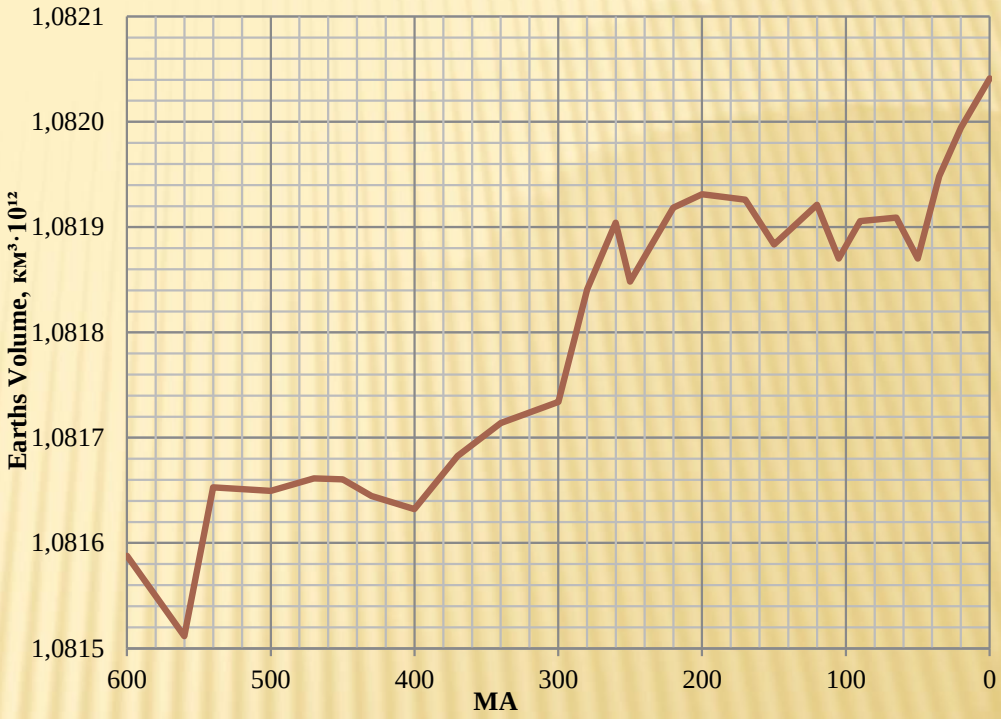
$$\mathbf{C_T} = \mathbf{T}^{-1}\mathbf{Q_x}\mathbf{T}^{\mathrm{T}} \quad (3)$$

THE RESULTS OF APPROXIMATION OF THE SURFACE OF THE LITHOSPHERE BY BIAXIAL ELLIPSOID

DTM ETOPO1	Whole planet		Northern Hemisphere		Southern Hemisphere	
x_0, м	-741,88	±86,04	-1170,64	±1056,31	-38,99	±13,19
y_0, м	-491,57	±57,01	-388,46	±350,52	1,70	±0,57
z_0, м	1421,79	±164,89	1868,02	±1685,58	7287,17	±2462,39
a_{xy}, м	6375117,00	±169,04	6375114,91	±437,96	6376300,87	±533,92
a_z, м	6355640,08	±247,83	6355772,53	±2294,90	6362552,67	±2798,15
1/α	327,31	±6,32	329,59	±33,20	463,79	±80,16
κ	133˚,77	±0˚,02	159˚,30	±0˚,01	110˚,03	±0˚,01
ζ	2˚,61	±0˚,03	2˚,61	±0˚,01	2˚,78	±0˚,01

NORTH POLE MOVEMENT AND EARTHS' VOLUME CHANGING OVER PAST GEOLOGICAL EPOCHS



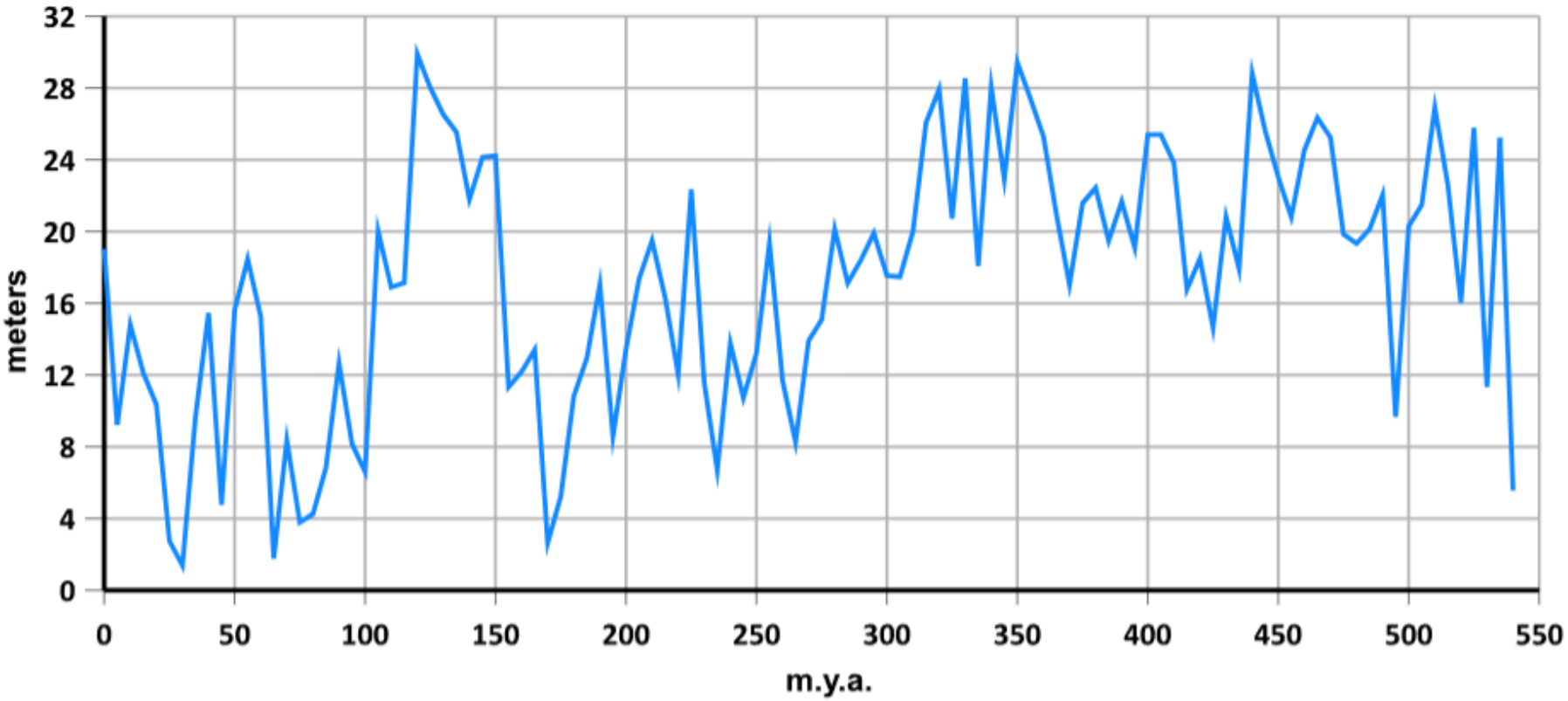


The maximum deviation of the pole of the semiminor axis from the North Pole of the Earth does not exceed 2.6° for the obtained 26 ellipsoids, which approximate the surface of the lithosphere for different geological epochs. That may indicate the critical value of the deviation of the geographical pole from the axis of rotation of the Earth for any configuration of the location of the continents and the water surface.

THE RESULTS OF APPROXIMATION OF THE PALEOGEOIDS BY BIAXIAL ELLIPSOID

Geoid model	x_0, m	y_0, m	z_0, m	ρ_0	a_x, m	b, m	ζ,″	Pole displacement along meridian (in meters)
EGM008 3x3	0.001	0.003	0.045	0.045	6378136.889	6356752.215	0.179	5
EGM008 9x9	-0.000	0.000	0.043	0.043	6378136.730	6356752.088	0.179	5
200 MA 3x3	-0,024	-0,241	0,151	0.285	6378134,241	6356749,874	1,302	39
200 MA	0,.120	0,059	0,055	0.144	6378133,436	6356748,788	0,504	15
400 MA 3x3	-0.074	-0.144	0.037	0.167	6378133.640	6356748.973	1,366	41
400 MA 9x9	0.018	0.038	0.043	0.060	6378132.996	6356748.312	0,716	21
540 MA 3x3	-0.009	0.001	0.006	0.011	6378137.841	6356753.163	0,028	1
540MA 9x9	-0.005	0.178	0.154	0.236	6378134.386	6356749.735	0,179	5

TRUE POLAR WANDER (TPW) IN LATITUDE



INTERPRETATION OF THE OBTAINED RESULTS. CONCLUSIONS

The scenario of the Earth's expansion in the course of its evolution is quite possible and has a good reason, and this hypothesis is supported by a growing number of supporters among scientists studying the Earth's evolution. The reason for this is the compaction of the inner layers of our planet and the expansion of the outer layer.

- The Earth's expansion model helps to explain the movement of lithospheric plates while preserving their deep roots, the presence of continental crust blocks in the oceans, and the ancient age of the oceanic crust.
- The degassing of the Earth is the main source of energy for global tectonic processes and can cause the mantle material to be compressed with a corresponding increase in volume and simultaneous concentration of heavy elements in the core. The possible increase in the volume of mantle substance is confirmed by laboratory studies.

The True Polar Wander (TPW) can be modelled geodynamically, since the spin (rotational) axis closely follows the axis of maximum inertia, which can be determined by the parameters of the second-order geoid in the expansion by spherical functions. We used digital elevation models of paleo-reconstructions of the lithosphere and made sure that the movement of lithospheric plates does not significantly change the height of the planetary geoid. However, on the other hand, we suggest that TPW studies using paleogeoid models, which are associated with lithospheric plate movements due to the influence of mantle convection, provide new insights into pole displacement in geological time.

Thank you for attention