Digital modeling of the rift processes in the Dnieper-Donets Basin, Ukraine

© D. Vengrovich, V. Starostenko, V. Danylenko, 2010

Institute of Geophysics, National Academy of Sciences of Ukraine, Kiev, Ukraine

A model of the lithosphere, incorporating both dynamic and thermal processes, has been developed by solving a coupled system of differential equations governing stress and temperature in a 2D block-structured geophysical medium [Starostenko et al., 1999; 2001]. Using the kinetic energy of block k in functional form:

Fig. 1. Locations of seismic reflection profile Zachepilovka — Belsk (*1*) and Mikhailovka — Prokopenki (*2*) in the central part of the Dnieper-Donets Basin (DDB).

$$T_k = \frac{m_k}{2}\left\{\upsilon_{k-1}^2 + 2\beta\left(r_{ok-1} - r_{k-1}\right)\upsilon_{k-1}\frac{\partial \upsilon_{k-1}}{\partial \vec{r}_{ok-1}} + \right.$$

$$\left. + \beta^2\left(r_{ok} - r_{k-1}\right)^2\left(\frac{\partial \upsilon_{k-1}}{\partial r_{ok-1}}\right)^2\right\} +$$

$$+ \frac{1}{2}\left(1 + b_k\right)^2\left(\omega_{k-1} \times \omega_{k-1}\right)I_{k-1}^{l,j} +$$

$$+ I_{k-1}^{l,j}\left\{\frac{\beta^2}{2}\left(div\,\upsilon_{k-1}\right)^2 + \beta^2\frac{\partial \upsilon_{k-1}}{\partial r_{ok-1}}div\upsilon_{k-1}\right\} +$$

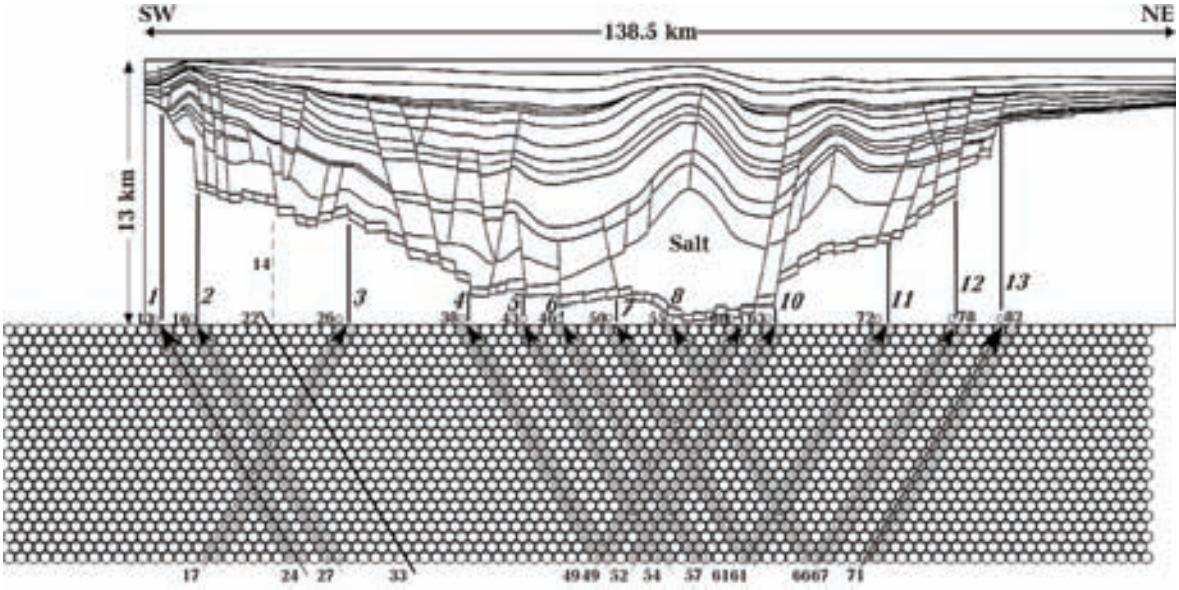

Fig. 2. Initial location of blocked layers of basin basement according to Zachepilovka — Belsk seismic profile: *1* ¯ 0 km (+); *2* ¯ 5.0 km (+); *3* ¯ 24.6 km (–); *4* ¯ 41 km (+); *5* ¯ 48 km (+); *6* ¯ 53 km (+); *7* ¯ 61 km (+); *8* ¯ 68 km (+); *9* ¯ 78 km (–); *10* ¯ 82 km (–); *11*¯ 98 km (–); *12* ¯ 106 km (–); *13* ¯ 113 km (–).

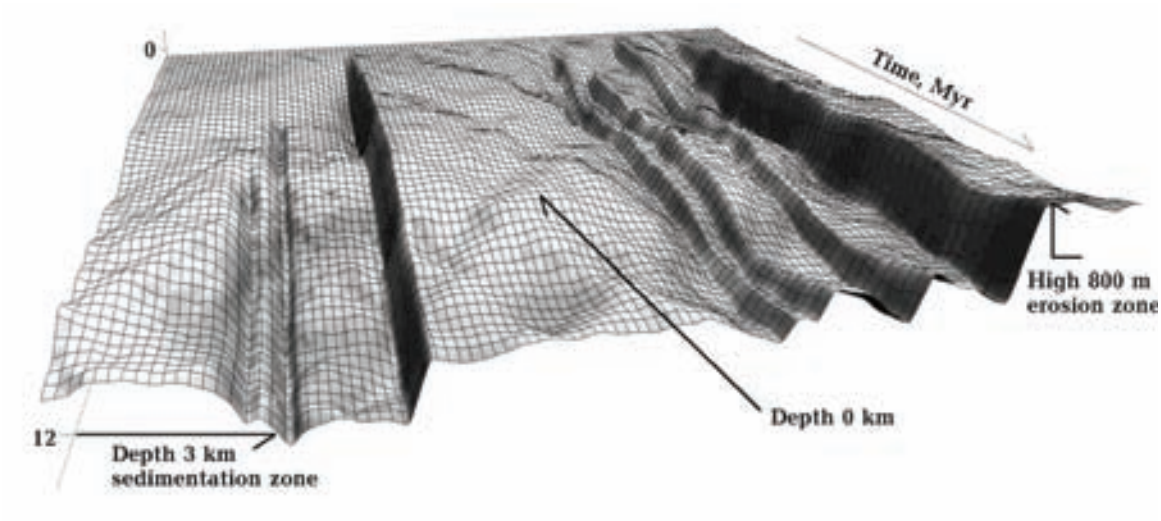

Fig. 3. Model predicted evolution of the sedimentary basin basement horizon along the Zachepilovka — Belsk profile from the beginning of the rift stage (370 Ma) until the late Fammenian.

$$+\left(1+b_k\right)\left[\omega_{k-1}\upsilon_{k-1}\right] m_k\ r_{ok-1}+$$

$$+\frac{1}{2}\beta\upsilon_{k-1}div\upsilon_{k-1}m_k\ r_{ok-1}.$$

We equate the dynamics of block media:

$$\frac{\partial}{\partial t}\left[\frac{\partial T_k}{\partial \mathbf{q}}\right]+\frac{\partial T_k}{\partial \mathbf{q}}+\frac{\partial U_k}{\partial \mathbf{q}}=\mathbf{F}'_k+\mathbf{F}''_k+\mathbf{F}_{kn}+\mathbf{F}_0,$$

$$k=1,2,..,n,$$

where m_k is mass of block k; $I^{l,j}_{k-1}$ is moment-of-inertia tensor of block k–1; $\mathbf{q}$, $\dot{\mathbf{q}}$, ω_l are generalized co-ordinate, linear and angular velocity; $\mathbf{F}'_k$ is summarized frictional force; $\mathbf{F}''_k$, $\mathbf{F}_{kn,}$ $\mathbf{F}_0$ — forces owning to energy dissipation, elastic interaction and gravity.

The main rifting phase forming the Dnieper-Donets Basin (DDB) occurred in the Late Devonian (370—

363 Ma). In this approach the digital simulation of whole DDB region showed that after initial stretching and mantle thermal load the set of blocks became active over a period of 12 Myr.

Fig. 1 shows locations of test in presentation seismic reflection profiles Zachepilovka — Belsk (*1*) and Mikhailovka — Prokopenki (*2*) in the central part of the DDB according to geophysical observations. The mathematical 2D dynamic and thermal model is 140 km in length and 120 km deep and comprises three layers — 'granite', 'basalt', and mantle — with appropriate thermo-physical parameters. Fig. 2. shows the initial 'granite' and 'basalt' layers of blocks that have been built according to Zachepilovka — Belsk profile interpretations. Model results are shown in Fig. 3. as evolution of the sedimentary basin basement horizon along the Zachepilovkav — Belsk profile.

References

Starostenko V. I., Danilenko V. A., Vengrovitch D. B., Kutas R. I., Stovba S. M., Stephenson R. A., Kharitonov O. M. A new geodynamical-thermal model of rift evolution, with application to the Dniepr-Donets Basin, Ukraine // Tectonophysics. — 1999. — **313**. — P. 29—40.

Starostenko V. I., Danylenko V. A., Vengrovich D. B., Kutas R. I., Stephenson R. A., Stovba J. N. Modeling of the Evolution of Sedimentary Basins Including the Structure of the Natural Medium and self-organization processes // Phys. Sol. Earth. — 2001. — **37**, № 12. — P. 1004—1014.