The Hierarchy of Development of Geodynamic Processes of the Earth's Crust During the Development of Kuzbass Deposits

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Abstract. It is established that the acquisition of new knowledge about the development of geodynamic processes of the earth's crust and expansion of their application in the development of subsurface resources is possible on the basis of interpretation of geodetic data obtained during the registration of its kinematics. At the present time in the traditional technologies of geomechanical support of subsoil development kinematic characteristics are the basic information about these processes. Such characteristics are ambiguous. To overcome this ambiguity, the author proposes dynamic parameters of the crustal block, which are used as the basis for the theory of hierarchy of the geodynamic processes of the Earth's crust, which provides the determination of both the time deformations (strains) of the crustal blocks, the potential energy and its density, and the types of geodynamic of the situation.

1. Introduction, relevance and scientific significance of the issue with a brief review of the literature
The study of the geodynamic processes of the earth's crust (GP EC) is one of the main tasks of geodynamics, in which the press pays a lot of attention [1-15]. The analysis of the current state of this problem [1-19] allowed the author to propose the following classification (Table 1).

| Classes | Subclasses |
|---|---|
| For the intended purpose | Geodynamic activity, seismic activity, geodynamic exploration, stability of engineering facilities. |
| On a functional purpose | Natural geodynamic processes of the earth's crust, joint manifestation of natural and technogenic geodynamic processes of the earth's crust, precursors of earthquakes, the impact of manifestation of natural and technogenic geodynamic processes of the earth’s crust on the stability of engineering facilities. |
| According to a time range | Modern, latest, old. |
Continuation of Table

| At the time of action | Slow, fast, old, daily, yearly |
|----------------------|--------------------------------|
| Spatial coverage     | Local, regional, large-scale, global |
| According to the method of study | Geological, geomorphological, geophysical, geodetic, remote sensing, mapping, combined |

2. Formulation of the problem

In addition, this analysis indicates that until now the theory of the development of GP EC in the territory of the Kemerovo region is poorly developed and in the current regulatory documents is not sufficiently covered. At the same time, despite some achievements in this field, there is a problem of studying them. In most cases, GP EC is not available for direct measurements. The models used to study them in traditional technologies are imperfect, which hinders the development process. Their main imperfection lies in their inconsistency with the structures of the earth’s crust and the ambiguity of their parameters. To solve this problem, the author proposes dynamic parameters, the technology of determining which provides the adequacy of models of blocks of the earth's crust (BEC) and accounting for their hierarchy. At the same time, the author proposed the use of geodetic and geophysical methods for the realization of this model [19, 20].

3. Theoretical part

The basis of the theory of the development of GP EC during the development of the Kuzbass subsoil is the dynamic parameters (DP) proposed by the author, which allow to characterize both the changes in time of deformations (stresses) of blocks of the earth's crust, and potential energy and its density, built on spatial models of them, ensuring adequacy to real structures [19, 20]. The proposed algorithm in a single cycle sequentially determine the entire spectrum of DP BECs in a single cycle sequentially according to the algorithm developed by the author. It is implemented in the algorithmic language QBASIC for PC. The initial data in the program "BM" compiled by the author are:

- the coordinates of the vertices of the spatial model, structurally approximating the BEC;
- kinematics of the vertices of the spatial model;
- is the shear modulus and Poisson's ratio;
- average quadratic error of determination of the kinematics of the BEC.

The program "BM" created by the author allows to determine the dynamic parameters of blocks of the earth's crust in four stages:

- at the first stage - changes in the time of deformation of the spatial model of GTP constructions;
- at the second stage - the corresponding changes in the stress time;
- in the third stage - the evaluation of accuracy;
- on the fourth - changes in the time of the potential energy.

The time variation of the energy state of the BEC $dE[t - t_0]$ for the period $[t - t_0]$ of volume $V$ is determined by the change of potential energy of deformation, which is calculated according to the obtained components of the tensor of changes over time of stresses $\Delta \sigma_{ij}[t - t_0]$ and tangent lines $\Delta \tau_{ij}[t - t_0]$.

$$dE[t - t_0] = \frac{1}{V} \left( \frac{1}{2} \sum \Delta \sigma_{ij}[t - t_0] \right)^2 + \frac{1}{G} \sum \Delta \tau_{ij}[t - t_0] V$$  (1)

where G is the shear modulus; v is Poisson's ratio; E is the modulus of elasticity.

The change in the potential energy of deformation of the BEC obtained according to (1) characterizes not only its energy state, but also the formation of a stress center, which can lead to the manifestation of geodynamic phenomena.
In the absence of fundamental instrumental observations on the study of these patterns in the Kuzbass, the author conducted a laboratory computer experiment, the results of which established their dependence on the hierarchy of the structure of the earth's crust. The results of the performed experiment indicate that in the investigated blocks of the Earth's crust of the III-VI grades near the town Belovo in the Kemerovo Region (Figure 1) the changes in the potential deformation energy are estimated up to \(3.28 \times 10^{10}\) Joules at a movement speed of these blocks up to 3 mm/year. With an increase in the rate of motion of earth blocks up to 7 mm/year, the growth of the corresponding changes by the potential deformation energy is estimated to be \(1.77 \times 10^{11}\) Joules, and up to 21 mm/year - \(1.64 \times 10^{12}\) Joules.

![Figure 1. Blocks of the earth's crust of III-VI ranks: 1-III-rd rank; 2 - IV-th rank; 3rd-5th rank; 4- VI-th rank.](image)

The time variations of the components of the deformations of BECs of different ranks are more differentiated. Let us choose as the investigated component the relative change in time in the volume \(\theta(t-t_0)\) (dilatation) of the block of the earth's crust, which is equal to

\[
\theta(t-t_0) = e_{ij}(t-t_0) + e_{ij}(t-t_0) + e_{ij}(t-t_0),
\]

where \(e_{ij}(t-t_0)\) are the components of strain tensor of the 2nd rank.

The dependences of the time variation in the dilatation of BEC III-VI ranks on BECs their kinematics are shown in Figures 2-3.
**Figure 2.** The dependence of the time variation of the dilution of the III-IV BECs on their kinematics.

**Figure 3.** The dependence of the time variation of the dilution of the BECs V-VI grades on their kinematics.

### 4. The results of experimental research and the practical significance

The regression analysis performed by the author made it possible to obtain the following equation of the dependence of the time variation of the dilatation of the investigated BZK \((1 \cdot 10^{-6})\) on their rank

\[
\theta(t - t_0) = -34.08 + 11.94r,
\]

(3)

Where \(r\) is the rank of the block of the earth's crust.

Changes in the dilatation time of BZK allow us to determine both their geodynamic activity and the type of geodynamic situation (TGS). The main types of GS are the compression zone, the stretching zone and the shear zone. The selection of the shear zone is based on the fulfillment of the condition

\[
\Delta \gamma [t - t_o] > \theta(t - t_o),
\]

(4)
where \( \Delta y(t_{i} - t_{0}) = (\Delta y_{x}^{1}[t_{i} - t_{0}] + \Delta y_{y}^{1}[t_{i} - t_{0}] + \Delta y_{z}^{1}[t_{i} - t_{0}])^{1/3} \) - the time variation of the main shift; 
\( \Delta y_{x}^{i}[t_{i} - t_{0}], \Delta y_{y}^{i}[t_{i} - t_{0}], \Delta y_{z}^{i}[t_{i} - t_{0}] \) - changes of deformations in the shift of the crustal block in the time.

If the condition (4) is not fulfilled, the compression or stretching zones are identified. The condition of the extension zone is the following positive values of the changes in the dilatation time

\[ \Delta y(t_{i} - t_{0}) > 3W_{e}[t_{i} - t_{0}]. \]  

(5)

The compression zone is highlighted with the following negative values of the changes in the dilatation time

\[ \Delta y(t_{i} - t_{0}) < -3W_{e}[t_{i} - t_{0}]. \]  

(6)

The development of the shear zone (1·10^{-6} years^{-1}) of the block of the earth's crust of the fourth rank in the region of the town Belovo, depending on its kinematics, which is numerically characterized in the range from 3 mm to 21 mm per year, is illustrated in Figure 4.

**Figure 4.** The development of the shear zone of the BEC depending on its kinematics.

TGS has an applied use of the type for underground geotechnology (choice of the form of production), and with open - a change in the scheme of opening the deposit. The dependence of the impact on the degree of potential strike hazard of the field is different: the compression zone is the largest, and the shift zone is the smallest.

5. **Conclusions**

Based on the results of the research, the following conclusions are drawn:

1. The classification of GP EC is generalized.
2. The dependence of the changes in the dilatation time of the BEC on their rank is established.
3. The theory of the development of GP EC in the territory of the Kemerovo region is developed, which provides both the acquisition of new knowledge about their development and the extension of their application in the development of subsurface resources is possible on the basis of interpretation of geodetic data.

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