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Abstracts

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Tentative results of the analysis of the main geodynamic processes of formation of the crust and the upper mantle structure of the Greater Caucasus; their spatial variability

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Introduction. The main problems of tectonics and geodynamics are connected with uncertainty of mechanics of continental crust formation and development, including the subsidence of crust blocks, folding formation and mechanisms of mountains uplift. In this study, the methods of structural geology and tectonophysics are used for a collection of reliable data on the development of the active Alpine region.

The model of the sedimentary cover, which is balanced on volumes of sediments. The material of detailed structural profiles was transformed into a quasi 3-D model of the structure of the sedimentary cover of the Greater Caucasus [Yakovlev, 2015] using the method of balanced section compilation "on the geometry of folded domains" [Yakovlev, 2017]. The main data were obtained by measuring the morphology of "folded domains", occupying a space of 0.5-2 km along the profile and consisting from several folds. Pre-folded states of several domains combined into "structural cells" (with a length 5-7 km), which allow obtaining the shortening values for them. The structure of sedimentary cover for three stages of the Caucasus development – pre-folded (J_1 – Pg_2), post-folded (Pg_3 – N_1) and post-uplifted (N_1 – Q) was reconstructed. After additional operations, six parameters for each "structural cell", which are relevant to the geodynamic processes of the Greater Caucasus, were obtained (table 1): the depth of the basement top at all three stages (1, 3, 4,), the value of shortening (2), the amplitude of the uplift and erosion (5), as well as the difference in the depth of the basement top between the first and third stages (6). The material of 24 structural profiles with a total length of more than 500 km was divided into 505 domains, which were combined into 78 structural cells after the reconstruction of the structure. Some strong pair correlations between these several parameters were found; obviously, they have a genetic meaning [Yakovlev, 2015]. It was also found that the depth of the basement top from the pre-folded stage to the present one, consistently passing through the processes of folding and mountains building, tends to come back to the initial level [Yakovlev, 2015].

Factor analysis was used for the complex analysis of those processes that led to the appearance of a certain combination of values of six parameters in 78 cells [Yakovlev, Gorbatov, 2017, 2018]. It was found that the totality of all dispersions of values is determined by two factors, which were interpreted as two processes (not a one or three). There are (table 1; columns 1, 2): F_1, weight 47%, "Isostasy", associated with the stability of the basement top depth and changes of the crust rocks in the density up to mantles meanings, and F_2, weight 40%, “Shortening”, in which the neotectonic uplift is determined by the shortening value.

Clarification of the history of the formation of the crust structure. Based on the idea that isostasy is acting all the time, and based on the facts of the geological development of the region, parameters of the changes of the crust thickness for Chiaur zone for all stages of development were calculated [Yakovlev, Gorbatov, 2018] (Fig. 1). The initial thickness of the crust at the beginning of the sediments accumulation was 40 km, during the accumulation of 15 km of sediments, the crystalline crust degraded and it had a new thickness of 14 km; from the rocks of the former crust, a layer of a new mantle with a thickness of 26 km was formed. The isostatic balance of the modern structure showed that the depth of the sedimentary cover bottom is 20 km; the crystalline crust thickness is 19 km. In case that the uplift of the structure at stage 3 was in its pure form after shortening and full subsidence at stage 2, the modern crust thickness of 19 km includes 15 km belonged to the new mantle (appeared at the stage 2), which, during uplift and erosion (stage 3), acquired the density of the crust rocks again (Fig. 1). Thus, significant amounts of crystalline crust rocks during the formation of folding and growth of mountains eventually experienced compaction (about 15%, 2.83 / 3.30 g/cm^3). The growth of mountains at the last stage is accompanied by decompaction, of course.

Table 1. Results of factor analysis for several massifs of data (Varimax, "with rotation"); “b1, b2, b3” – depths of basement top for stages 1, 2, 3; “Sh” – shortening; “b3-b2” – uplift; “b3-b1” – depths difference. (*) – measured signs; parameters of stages 1 and 2 (“b1”, “Sh”) may be the indicator of diagnosed process.

		(78) F_1	*(78) F_2*	*(42) F_1*	*(42) F_2*	*(36) F_1*	*(36) F_2*	*(91) F_1*	*(91) F_2*	*(49) F_1*	*(49) F_2*
parameters		*1 (Isos.)*	**2***(Shor.)*	*3(Isos.)*	*4(Shor.)*	**5***(Isos.)*	**6***(Shor.)*	*7(Isos.)*	**8***(Shor.)*	**9***(Shor.)*	**10***(Isos.)*
1	b1*	**0.790**	0.022	**0.806**	-0.152	0.470	0.520	**0.811**	0.142	0.634	0.617
2	Sh*	-0.195	**0.938**	0.206	**0.937**	0.543	0.638	0.261	**0.915**	**0.836**	0.416
3	b2	0.665	**-0.736**	**0.767**	0.627	0.674	**0.736**	0.672	**0.732**	**0.777**	0.622
4	b3	**0.982**	-0.158	**0.993**	0.074	**0.970**	0.215	**0.982**	0.179	0.380	**0.923**
5	b3–b2*	0.005	**0.957**	0.061	**-0.943**	0.021	**-0.994**	-0.021	**-0.978**	**-0.979**	-0.098
6	b3–b1	**0.853**	-0.219	**0.865**	0.192	**0.981**	0.023	**0.876**	0.163	0.127	**0.962**
eigenvalues		2.796	2.410	3.019	2.226	2.873	2.254	2.911	2.409	2.822	2.728
weight, %		**46.6**	**40.2**	**50.3**	**37.1**	**47.9**	**37.6**	**48.5**	**40.2**	**47.0**	**45.5**

Regional stability of the result. To clarify the limits of the variety of manifestations of the identified processes, the structures of Dagestan (13 cells) were studied additionally at further investigation; also, the structures of the North-Western Caucasus (NWC, 42 cells) and the Eastern Caucasus (EC, 36 cells) were considered separately and in combinations with Dagestan cells (table 1, columns 3-10). Statistically correct existence of both processes for 78 cells (“b3–b1” in average is -0.5 km) are fixing by loadings larger than 0.7 (bold) for the leading parameters #1 and #2 and by a contrast of these loadings for factors (0.790 vs 0.022, for instance). NWC (42 cells) has very similar result ("b3–b1" is -0.13 km). The separation of two processes/factors for EC (36 cells) is not quite reliable – parameters #1 and #2 are weak and non-contrasting, possible, due to a sharp subsidence of the Chiaur zone ("b3–b1" is -5.2 km here). The addition of 13 cells to the EC distorted the result much more. The reason of result distortion may be in large box-shape folds of Dagestan (instead of small folds in common Caucasus structure), and in the uprising of the region ("b3–b1" is +4.5 km).

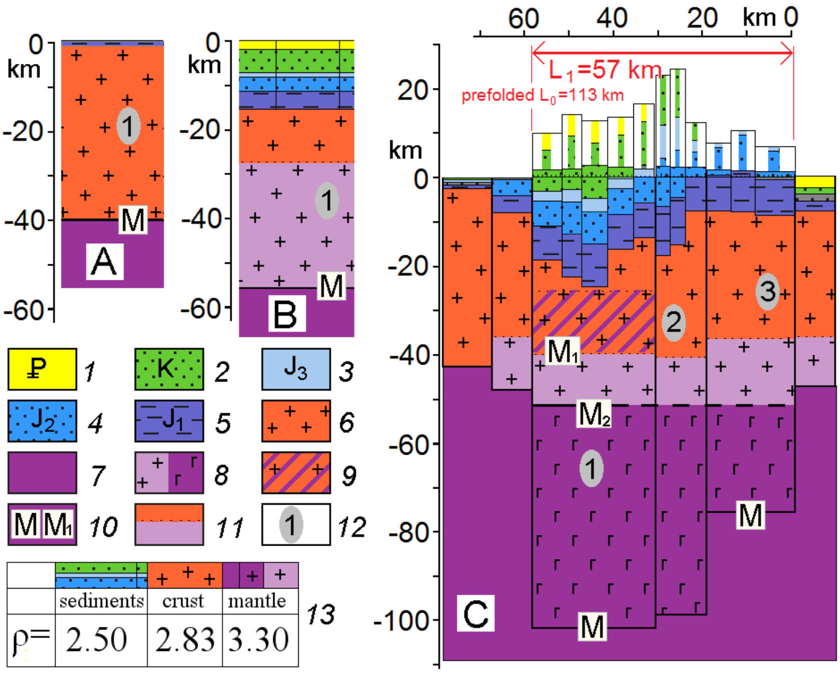

__Fig. 1.__ Model of development of the Greater Caucasus crust structure ([Yakovlev, Gorbatov, 2018], with changes). A – The structure of the crust of the Chiaur zone, the beginning of sedimentation; B – The structure of the crust before a folding; C – The modern structure of the crust and mantle of the Greater Caucasus and of the surrounding blocks. 1-5 – Sedimentary rocks of different age; 6 – Crystalline crust; 7 – Pre-Alpine mantle rocks; 8 – mantle rocks (on density) formed during of the development; 9 – the estimated amount of crust, which was formed at the uplift stage from the mantle; 10 – Moho borders of different ages; 11 – calculated boundaries of the change of rocks density; 12 – tectonic zones (1 – Chiaur, 2 –Tfan, 3 – Shakhdag); 13 – the scale of the densities of the rocks, which were used in the calculations of "isostatic" models.

Conclusions and discussion. Factor analysis revealed a statistically reliable existence of the phenomenon of compaction of the rocks of the earth's crust to the mantle density in the processes of folding in the Greater Caucasus (on about 15% of the initial density) and mantle rocks decompaction during the mountains uplift. The mantle rocks decompaction partly has relation to the previous shortening of the structure. Regional changes in the proportion of such processes can be strong. The four main mechanisms are widely used in widespread publications to explain the subsidence and sedimentation in basins (e.g. [Teixell et al. 2009]); their main postulate is the constant volume of continental crust rocks (or their constant density). There are, briefly: 1) a stretching during the rifting, 2) the temperature cooling, 3) overlay of the structure by sediments or by nappes, 4) the local structure near a strike-slip faults (pull-apart). The materials, presented in this study, make it possible to supply this list with important mechanisms of vertical movements by compacting the crust rocks to "mantle" values of densities and decompaction of mantle rocks to "crust" densities.

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