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Thermogeodynamic manifestations in the Caucasus and their genesis

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Abstract

In the work two aspects of thermal character are considered: first of all this is the connection of subduction phenomena with thermal life of the Caucasus on the basis of over interpreted data of magnetotelluric sounding, and secondly, origin of thermostressed condition of the Caucasus and its geological aspects which is manifested in the following:

1. in the zones of anomalous thermodisplacements thermofaults should occur (Le Pishon et al., 1977). These thermofaults are in good correlation with deep faults which are distinguished by geological and seismic methods, these thermofaults may be earthquake sources (Spitak, Racha, etc. earthquakes), also may be channels through which magma derivates (giving mineral deposits) may penetrate on surface (Gugunava and Gijeishvili, 1989);

2. in the body of sedimentary complex thermostressed seals and seal failures occur, which are apparently traps for oil-gas fluids. Good correlation of thermodense anomalies with oil deposits of the Caucasus is shown (Alexidze et al., 1985; Gugunava, 1980).

Everything above mentioned was carried out within frames of stationary thermal model which did not allow us to reveal time characteristics of interconnection of geological medium and thermal field.

Now investigations are being carried out within the frames of stationary thermal model and its interconnection with geological environment.

1 Introduction

In the first place earthquakes are regarded as one of the basic thermodynamic manifestations in the Caucasus. Usually they are called "tectonic", without pointing out the mechanisms of these "tectonic" manifestations. At least three classes of earthquakes, which are conditioned by thermal effects, can be distinguished:

a) earthquakes which are conditioned by subduction of cold-heavy part of lithosphere plate,

b) earthquakes which are connected with vertical thermo-displacements in the crust and the sedimentary complex,

c) earthquakes which are conditioned by thermo dense effects; all of them are connected with thermal processes.

Secondly, thermogeodynamic manifestations are expressed in increased heat flows.

2 Problem discussion

According to Le Pishon et al. (1977), during subduction considerable energy is released which is conditioned see Fig. 1 by advance of plate II under plate I along zone b.

"Elastic energy, accumulated along contact plane b, should be released in earthquakes with accompanying advances. One of the results of considered heating up of sinking plate is that the fraction of surrounding rocks with low melting point will melt down and begin upward migration, thus conditioning magmatism and gradual heating up of the whole zone between c and d. Secondary effect occurs: in d zone anomalously high heat flow appears" (Le Pishon et al., 1977). Let's consider each mechanism separately applied to the Caucasus. Thermal anomalies of the Caucasus correspond just to this very model.

It is necessary to note that this is not the only mechanism of upward migration of fluids. According to the mechanism offered in Gugunava and Gijeishvili (1989), in some regions, when temperature reaches 600°C, a layer of partial melt of water saturation granites and basalts occurs, which can also migrate upwards, increasing heat flow on the surface and conditioning low temperature volcanism (Elbrus, Kazbeg, etc.).

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Formal consideration of subduction in the Greater Caucasus speaks Figs. 2, 3 about perfect correlation with the scheme (Fig. 1) which was considered in Le Pishon et al. (1977).

These are: subduction zone, which was experimentally marked out by method of Deep Magnitotelluric Sounding (DMTS) (Fig. 2) (Alexidze et al., 1985), seismic manifestations, and high heat flow in the Greater Caucasus (zone d) according to scheme in Le Pishon et al. (1977).

In connection with this the mechanism of occurring of deflection of the Greater Caucasus in P_{1-2} period and its uplifting in I_3–P_3 and P_3–Q is very interesting (Gugunava, 1980). It seems that if we consider the whole paleoreconstructional geosyncline scheme (Sikharulidze, 1978) in the aspect of global tectonics, it can be seen as moving in time with the whole plate towards subduction zone and then deflection of the Greater Caucasus area in J_{1-2} period is nothing more than the result of old subduction with formation of deep-water trough before subduction front, and uplifting in J_3–P_2 period occurs along old subduction surface. And only from P_3–Q period old subduction structure wakes up, as illustrated in Fig. 3 (Sholpo, 1978).

Deep-water depression, which is filled with sediments, is more warmed up than surroundings and together with friction warm-up along sinking plate surface (Alexidze et al., 1985) show signs of more warming up during uplifting. It turns out that one and the same phenomena on the surface may be conditioned either by both factors or by each factor separately.

It is very interesting second possible mechanism of earthquakes at the expense of worming up by deep heat of the whole geological structure of the region and occurrence of thermovertical displacements inside it.

On the basis of geological model the stationary model of the Caucasus was constructed, from which appears that beginning from Precambrian till Quaternary period each geological structure, in accordance with their geophysical parameters (ρ – density, λ – heat conduction, etc.), experiences various expansions (seal failure) during warming up. Sometimes expansion of structures is such that structures which are disposed between them, undergo compression (seal).

While shifting from one geological structure to another various vertical displacements occur which in some cases reach high enough values, 16 m/km order and more, which inevitably result faults. Such faults are revealed in the Caucasus, see Fig. 4 (Sholpo, 1978; Hain, 1984).

Figure 4 shows the system of thermo-faults of the Caucasus. Areas of the heightened risk of origin of deep faults, and therefore of earthquakes, are denoted by shaded sections where vertical displacements exceed 16 m/km. Analogous picture of faults sections the whole sedimentary complex granite and basalt.

Often earthquakes are observed along these faults (Spitaki, Racha earthquakes, etc.).

Third mechanism of earthquakes (besides many others) consists in the process of occurring thermodense anomalies (Alexidze et al., 1993; Gugunava et al., 2006), which in some cases are connected with seismomanifestations, as well as oil-gas presence (Gugunava, 1994).

Figure 5 gives the system of thermodense anomalies. Formation of thermodense anomalies may be accompanied by local demolition of "old" structures, thus conditioning seismicity of the given region.

The question about the mechanism of increased heat flow in subduction zone arises. While considering processes at destructive boundaries of plates Hasebe et al. (1970) note that to explain high heat flow it is not enough to evaluate heat effect which is conditioned by adiabatic compression and phase transition, i.e. changes of olivine-shnilel transition.

In Hain (1984) a conclusion is drawn that "it is impossible to explain the existence of magmatism, which is connected with sinking plate, if heat source on plate surface or inside plate is not assumed". In order to settle this contradiction McKensie (1970) supposed that increased heat flow zone is conditioned by secondary convection which occurs while plate is sinking, resulting in warming up during friction at small depths.

We think, that in case of the Caucasus, "speculative" secondary convection is not necessary, and energy lack can be met on the basis of the offered in Alexsidze (1991) and Gugunava (1995) mechanism.

Conducted in Alexsidze (1991) and Gugunava (1995) calculations of the thermal field of the Caucasus for different depths (up to lower boundary of the upper mantle), and especially of the Greater Caucasus, show that in this region 600°C isotherm is lifted clear of the surface of Moho. This means, that in conditions of rehydrated granites and basalts, their partial melting takes place, which existed long before origin of subduction situation (Fig. 4) and lithosphere plate passes through half-melt. From here is the source of heat and melted magma, which penetrates in upper horizons by cracks in the area of thermoelastic vertical and horizontal displacements, as can be seen from Fig. 4 (Le Pishon et al., 1977), which form the system of deep faults.

It may be that this mechanism will be acceptable for some other regions.

3 Conclusions

Basic possible mechanisms of thermogeodynamic manifestations are considered.

1. Thermal nature of subductional occurrences (sinking of cold heavy part of lithosphere plate) and earthquakes which are connected with them.

2. Excessive heat flow, conditioned by emersion of low-temperature fraction within the Caucasus and before subduction front at the expense of friction heat and partial melt of rocks of water-contained granite and basalt in the area of 600°C deep temperatures.

3. Origin of vertical thermodisplacements, conditioned by deep heat, and earthquakes which are connected with them.

4. Origin of thermodense anomalies, as the result of deep temperatures and earthquakes that be connected with them.

5. The mechanisms of increased heat flow in subduction zone of the Caucasus is offered.

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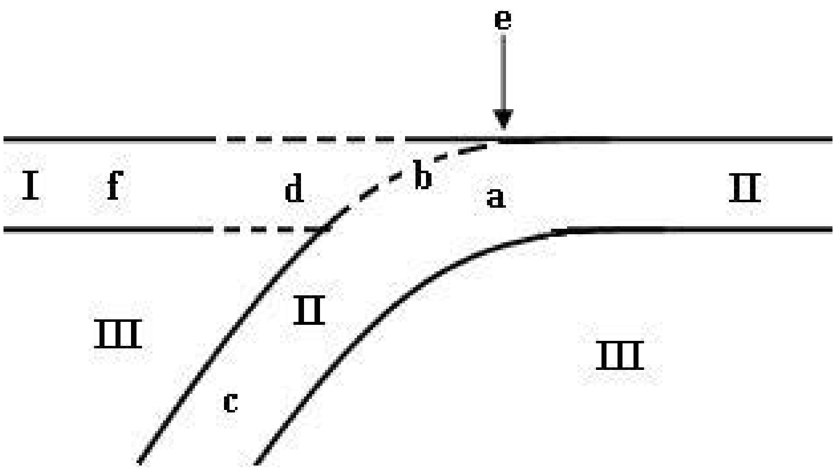

Fig. 1. The model of Sinking Plate (Le Pishon et al., 1977). I, II – lithosphere plates; III – astenosphere; a – bending zone; b – overlap zone; c – sinking part of the plate; d – zone of complex thermal processes; f – not changed part of the plate I; e – near leading edge of the plate I. Details see in the text.

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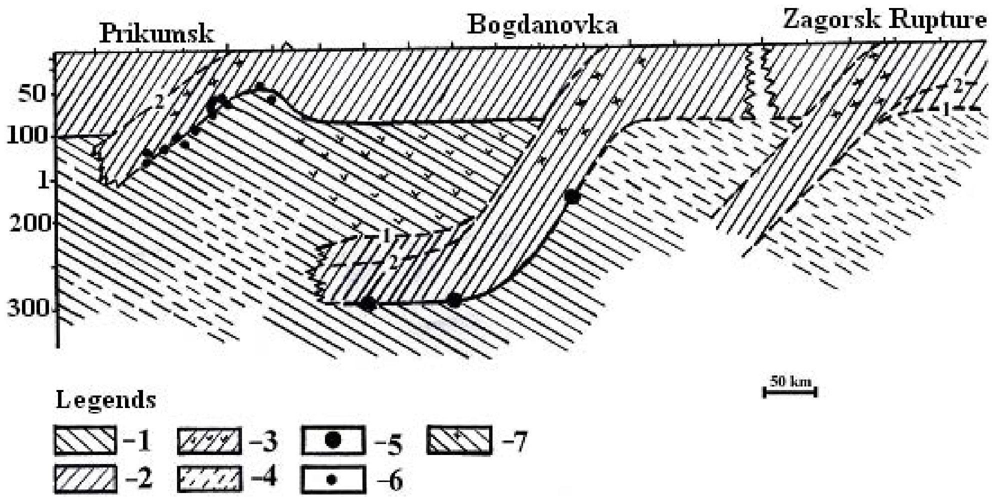

Fig. 2. The scheme of deep geoelectric structure of the Caucasus. 1 – lithosphere plate, 2 – melted anomalous (overheated) astenosphere, 3 – cooled off astenosphere, 4 – astenosphere which was not investigated by DMTS methods, 5 – generalized results of DMTS , 6 – separate results of DMTS , 7 – zones of deep fractures, marked by surface waves (Alexidze et al., 1985; Gugunava, 1980).

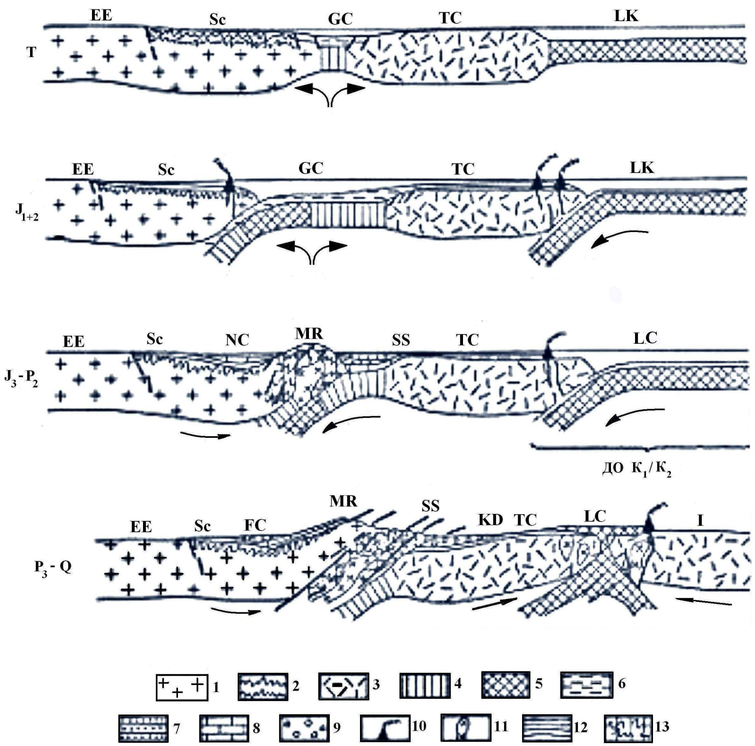

Fig. 3. Possible model of tectonic development of the Greater Caucasus and North Transcaucasus in Mesozoic – Cenozoic period (Sikharulidze, 1978). Legends on the figure are: 1 – Precambrian crust of East – Europian continent; 2 – Paleozoic complex of Scythian plate; 3 – the crust of Transcaucasian and Iran middle masses; 4 – thinned and processed continental crust; 5 – ocean type crust; 6 – schistous formation; 7 – flysch formation; 8 – shelf terrigeno-carbonate formation; 9 – molasses; 10 – volcanic belt; 11 – granitoids; 12 – cover of platforms of middle mass and ocean crust; 13 – deformed deposits of schistous formation; EE – eastern European craton; Sc – Scythian plate; GC – the Greater Caucasus; TC – Transcaucasian middle mass; LC – the Lesser Caucasus (central part); NS – North slope; MR - main mountain ridge; SS – south slope of the Greater Caucasus; FC – front Caucasian defection; KD – Kura deflection; I – Iran middle mass.

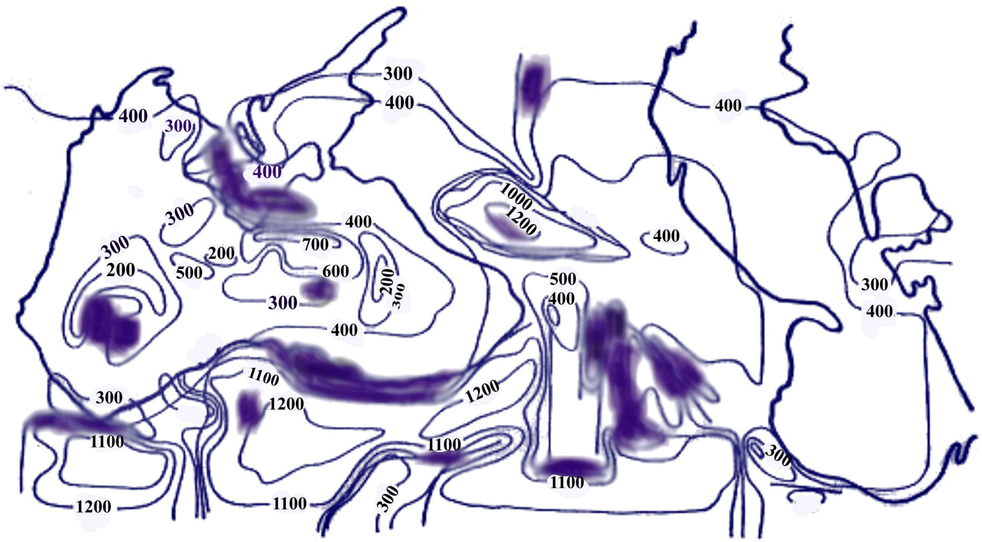

Fig. 4. Vertical thermodisplacements of the Caucasus and the Black and the Caspian Seas water areas.

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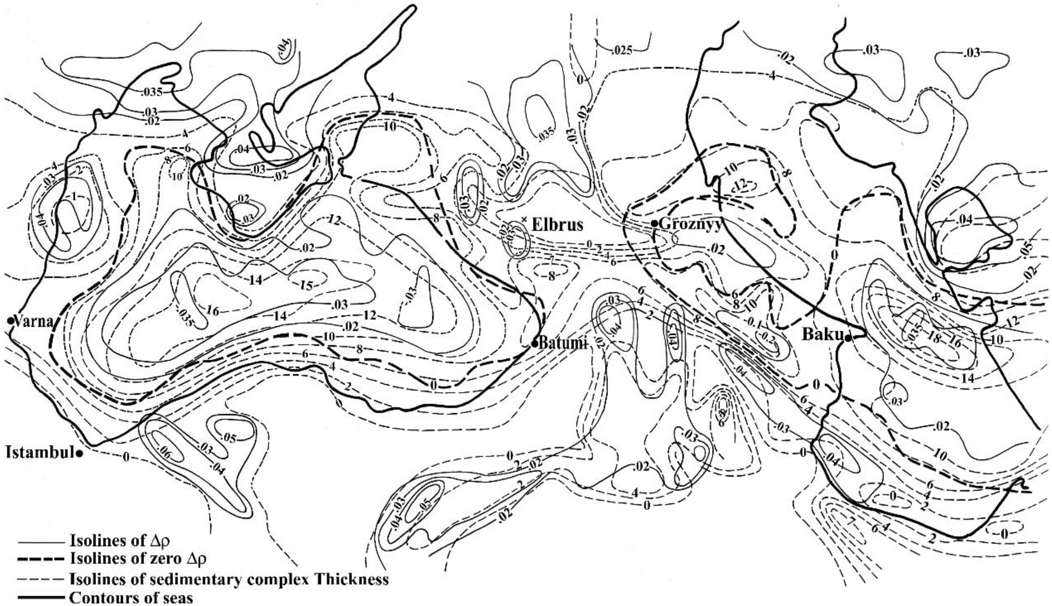

Fig. 5. The map of sedimentary complex thickness (H) and thermodense anomalies ($\Delta\rho$).