Geoelectrical structure and monitoring in fault zones of Uimon depression in Gorny Altai region using electromagnetic methods

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Abstract. In this paper we present the results of our studies of sections of the Uimon basin in Gorny Altai (Russia) using a complex of electromagnetic prospecting methods. The areas of Baratal Formation at the surface have been investigated. This areas explored in order to understand the stages of formation of the depression. In addition, the possibilities of the electrotomography method for regular observations in seismoactive regions are shown. Comparison of the amplitudes of the resistivity variations based on repeated ERT measurements in different zones of the Terekta fault indicates the activity of its eastern part, which is expressed in significant resistivity variations exceeding 100%. At the same time, the variations in the northwestern part of the fault, reaching 15% on average, are many times smaller.

1. Introduction
To study the structure of the intramontane depressions of Gorny Altai, a complex of electromagnetic methods with a controlled source is used: vertical electrical sounding (VES), electrical resistivity tomography (ERT), sounding by the formation of an electromagnetic field (TEM).

The Uimon Depression is one of the largest depressions in this region, but at the same time it is the least studied. From the north it is bounded by the Terekta ridge, and from the south by the Katunsky ridge. There are deposits of the Proterozoic, Blue, Lower and Middle Paleozoic, Cenozoic in the section of the Uimon depression. The bottom of the depression is represented by Paleozoic rocks of the Terekta Formation overlapped by the Baratal Formation (volcanic metamorphosed deposits). In the western and central parts of the basin, fragments of the Baratal Formation emerge on the day surface, which was a separate subject of study in this work. According to geological data, there are prospects for the presence of mineral deposits in the Uimon depression. Measurements by electromagnetic methods have been carried out by the field team of the IPGG SB RAS since 2011 (Figure 1).
Figure 1. Electromagnetic measurements points scheme in the Uimon depression with elements of a geological map.

Depth sections and models of the Uimon Basin were constructed based on the data from the TEM and VES. The resulting models reflect the highly heterogeneous basement structure and depressive sediments. On the sections, there are areas with outcrops on the day surface of rocks of the Baratal Formation (Sn br) aged Sinyan, represented by volcanogenic metamorphosed deposits. Regional geologists have no idea how the deposits of the formation came to the surface. It is impossible to reliably display the structure of such areas using data from deep-seated methods only. Therefore, in 2020, measurements were started using the electrical resistivity tomography method to build a model of the upper part of the section to depths of several tens of meters.

It is known that the area is classified as seismically hazardous. Therefore, along with the study the fault zone structure at the junction border of the depression with the northern Terekta ridge, repeated measurements by the method of electrical resistivity tomography have been carried out for several years to identify the possible activity of this structure.

2. Interpretation of electromagnetic methods
Based on the results of the TEM and VES data interpretation, a deep geoelectrical model of the depression was built, made by Cenozoic sediments, the thickness of which in individual blocks ranges from 200 to 1000 m and more (Figure 2). The territory has experienced subsidence and uplift many times, which is primarily due to such differences in the thickness of sedimentary deposits [1].

Interpretation was performed using EMS and SONET software packages [2, 3]. Let us consider the geoelectric section according to the TEM data along the profile through the outcrops of the Baratal Formation deposits to the day surface (marked with a dotted line between points 2 and 3). The profile crosses the central part of the depression from northwest to southeast. Taking into account large distance...
between the points, it is impossible to determine the electrical resistivity and dip angles of the sediments, to reliably represent their configuration according to the TEM data.

Figure 2. Geoelectrical section using TEM data.

To clarify and verify the structure of the upper part of the section to depths of several hundred meters, vertical electrical soundings were used. The VES points are located at the same points as the TEM points, marked on the diagram with red triangles. The section according to the VES data is shown in Figure 3. The models obtained from the VES and TEM data are consistent with each other, as well as with the data of the first deep well drilled 200 m from VES 3 and TEM 3 by the open joint stock company «Gorno-Altai Expedition», based on our data [1].

Figure 3. Geoelectrical section using VES data.
Since the structure model at the outcrops of the Baratal Formation was not clear, in 2020 measurements were carried out by the method of electrical resistivity tomography (ERT) through these bedrocks. In Figure 1, the ET profiles: K1, K2, K3, K4 are shown with blue lines. All measurements were carried out with the Skala-48 equipment using the Schlumberger setup and a step along the profile of 5 m. Interpretation of the ET field data was performed using the Dino program (AV Marinenko, INGG SB RAS, [4]). Figures 4 and 5 show geoelectric sections along the K2, K3 profiles as an example. Both profiles begin directly on the deposits of the Baratal Formation and then pass along the depression sediments. In the section along the K3 profile, the formation is distinguished by a block of high electrical resistivity in the range from 1200 to 2000 Ohm·m, as well as by a clear sharply inclined boundary with sedimentary deposits. In fact, the outcrops of the formation are separated by a fault zone from the depression sediments (Figure 4).

![Figure 4](image_url)

**Figure 4.** Geoelectrical section through the outcrops of the Baratal Formation in the K3 ERT profile.

In the section along the K2 profile, the formation boundary with sedimentary deposits is almost vertical, and the specific electrical resistance (RES) is significantly higher than that in the previous section and reaches 3500 Ohm · m (Figure 5). The difference in the resistivity values can be explained by the different degrees of fracturing and watering of the Baratal formation massifs.

![Figure 5](image_url)

**Figure 5.** Geoelectrical section through the outcrops of the Baratal Formation in the K2 ERT profile.

It can be concluded that the Baratal Formation is well distinguished in the geoelectric sections according to ERT data according to the highest resistivity values. The configuration of the blocks, their
geometric dimensions must be further specified using additional measurements. In this case, it is better to use installations that allow achieving greater depth of investigation, for example, three-electrode ones.

3. Monitoring in the Terekta fault zone using ERT method

The depression area belongs to the territory with a high degree of seismic hazard, which determines the presence of seismogenic faults. According to modern seismic zoning, faults have been identified in the southeastern and central parts of Gorny Altai, which can be associated with earthquakes with magnitudes $M = 7.0-7.5$. In addition, in the Uimon Basin, traces of ancient earthquakes are observed in the sediments of the descent stage of the Late Pleistocene glacial dammed lake (100–90 thousand years) with magnitudes of at least 5–5.5 [5]. Therefore, there is a potential threat of destructive earthquakes, and there is also a possibility of blocking rivers with the formation of dammed lakes with unstable dams [6]. At present, geological data have revealed the modern activity of the Terekta fault, which occurs, in particular, as chains of sources. The watered areas are clearly visible on the sections of electrical resistivity tomography and are characterized by varying degrees of variation in electrical resistivity based on the results of regular observations.

For several years (2011, 2017, 2018, 2020) ET measurements have been carried out in the area of prominent tectonic scarps in the northwestern and eastern parts of the Terekta fault in the vicinity of the villages Bashtala and Margala. In the course of the work, a Schlumberger installation with two 24-electrode streamers is used. The step between the electrodes was from 2 to 5 m, which provides sufficient resolution. Interpretation of ET field data was carried out using the Res2DInv and ZondRes2D software packages [7, 8].

On the eastern section of the Terekta ridge in the area of the Margala village measurements along the profile of electrical resistivity tomography with a length of 300 m are repeated for several years. The beginning of the profile is located on the tectonic scarp site and a significant part of it, starting from an elevation of 200 m, passes along a steeply falling slope to the depression sediments. The section is built taking into account the elevation marks (Figure 6).
Figure 6. Results of repeated measurements using ERT method in the eastern part of the Terekta fault (Margala village).

In this part of the Terekta fault, the activity is expressed in significant changes in resistivity over the observation period. In the interval of 100-180 m along the profile for all sections for different years, there is a zone with low values of electrical resistivity, presumably fractured. In 2011, in the lower part
of this zone, starting from an altitude of 1090 m, the resistivity was ~ 40 Ohm \cdot m, and then, in 2017, 2019, the resistivity values increased significantly. On the slope towards the trough, the resistance, on the contrary, became less. The 2020 section is more similar to the 2011 section. Thus, in this part of the Terekta fault, significant variations in resistivity are observed, which may indicate the activity of its northeastern segment.

The second profile, 750 m long, runs along the northwestern slope of the ridge in the area of the Bashkala. The section constructed according to 2020 data reflects small changes in resistivity within 10-15% compared to 2019, except for the profile interval of 500-650 m, where the changes in resistance are greater (up to 20%).

4. Conclusions

The geoelectric characteristics of the Baratal Formation, based on ET data, allow detailing the models of the upper part of the Uimon depression sedimentary cover, which is important for clarifying the formation stages of the depression and prospecting for minerals. Based on the analysis of the results obtained, it was concluded that it is necessary to continue measurements by the ET method on the territory of the Uimon depression, both in order to clarify the geometric dimensions of the Baratal Formation blocks, and the characteristics of the intradepression faults separating the formation and sediments.

The capacities of the electrical resistivity tomography method for regular observations in earthquake-prone regions are shown. Comparison of the resistivity variations amplitudes based on repeated ET measurements in different zones of the Terekta fault indicates the activity of its eastern part, which is expressed in significant resistivity variations exceeding 100%. At the same time, the variations in the northwestern part of the fault, reaching 15% on average, are many times smaller.

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