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AEM for hydrogenic uranium exploration – EQUATOR case study

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Summary

This paper demonstrates the use of airborne geophysics with the EQUATOR electromagnetic system to map paleovalleys and detect buried high resistivity granite massifs beneath low resistivity Neogene–Quaternary cover in the Republic of Buryatia. EQUATOR combines frequency domain and time domain measurements, enabling detailed investigation of the shallow section and detection of conductive targets to ~400 m depth. A 2024 test survey at the Tetrakh deposit (Khiagda field) refined boundaries of lithological units, outlined radioactive granite bodies, and determined depths to the crystalline basement; paleovalleys act as natural traps for hydrogenic uranium mobilized by groundwater from weathered granitoids. An October 2025 survey at the Kupchinsky site produced resistivity maps and 1D inversions in time and frequency domains, reliably delineating the strong geoelectric contrast between low resistivity loose sediments and high resistivity granitoids. Interpreted maps identified paleovalley thalwegs and potentially uranium bearing paleovalleys, with a radioactive granite massif considered a likely uranium source. Comparison of EQUATOR profiles with a drilling line showed consistent mapping of the sediment–granite boundary. Drilling confirmed mineralization evidence (oxidative alteration, radioactivity halo, thin layers with increased uranium concentrations of 0.02%). The study concludes that EQUATOR AEM surveys significantly accelerate and improve hydrogenic uranium exploration.

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Introduction

This paper presents examples of paleovalleys mapping during hydrogenic uranium exploration in the Republic of Buryatia, Russia. The present case study demonstrates that electromagnetic sounding methods can be successfully used to map the palleovaleys (Jiang et al. 2019) as well as the surface of high-resistivity granite massifs buried beneath low-resistivity Neogene-Quaternary sediments (Markandeyulu et al. 2014). In addition, AEM data can also be used to determine the lateral extent of permafrost (Su et al. 2020).
Survey was performed with an airborne geophysical system that includes magnetic, radiometric and electromagnetic (EM) channels. EM measurements were provided by EQUATOR system. It combines the advantages of frequency-domain and time-domain measurements (Karshakov, Moilanen, 2018). This allows for detailed study of the upper part of the section and the search for conductive objects at depths of up to 400 meters

Examples

Tetrakh deposit – test study.
In 2024 test survey was conducted over *the Tetrakh deposit of the Khiagda ore field* in the Republic of Buryatia, Russia (Doinikova et al. 2018). *The Tetrakh uranium deposit* is located in the southeastern sector of *the Khiagda ore field*. Paleovalleys here were formed by paleo-rivers through the weathering crust of the granitoid massifs of the Vitimkan complex of the late Paleozoic. Hydrogenic uranium is uranium that accumulates in ore deposits due to the action of groundwater. Groundwater percolates through rocks (at the granitoids boundary), leaching dispersed uranium, transporting it in solution, and, upon entering certain geochemical "traps," precipitating the uranium to form an ore body. "Paleovalleys" serve as ideal natural "traps" for hydrogenic uranium (Kochkin et al. 2017). The Khiagda ore field is a prime example of a hydrogenous uranium deposit.
Vitimkan granitoids (PZ_1vt) are characterized by high resistivities (1,000 – 9,000 Ω·m) (Bashkeev et al. 2025). The resistivity of the cover basalts (βN) is noticeably lower (500-800 Ω·m). The lowest resistivities occur in loose Neogene-Quaternary sediments (N_2). Thus, the surface of the granite massif buried under sediments is characterized by a pronounced change in resistivity and is reliably indicated on maps and sections (Fig. 1).

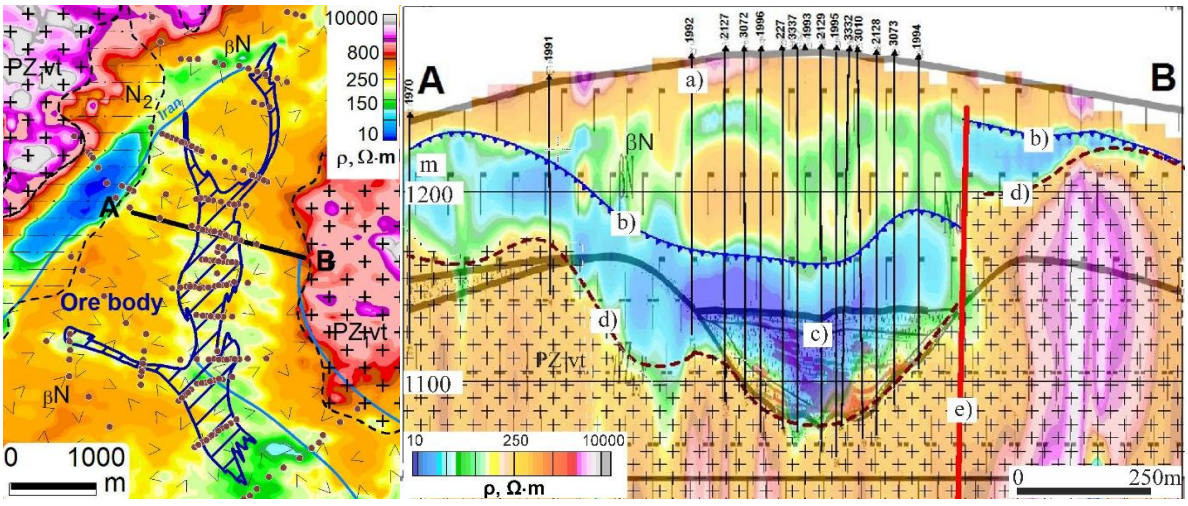


Figure 1 *I) Fragment of the apparent resistivity map for 231 Hz; II) resistivity section along A – B. a) boreholes, b) boundary of permafrost – based on resistivity, c) paleovalley – based on borehole data, d) crystalline basement surface (granitoids) – based on geophysical data, e) tectonic faults – based on geophysical data.*

Test study over *the Khiagda ore field* using the EQUATOR system at *the Tetrakh deposit* refined the boundaries of the area's geological units, including the outlines of highly radioactive granite bodies and ore-bearing paleovalley, and determined depths to the buried granite basement.

Survey in the Kupchinsky site.

In October 2025, an airborne geophysical survey of *the Kupchinsky site* was completed (Fig. 2). The objective was to map the surface of radioactive granite intrusions beneath a cover of loose Neogene-Quaternary sediments. Based on the experience of *the Khiagda* test study, the objects of interest are paleovalleys located near these granite intrusions. They are characterized by a sharp increase in the thickness of loose low-resistivity sediments within an eroded high-resistivity granite massif.



Figure 2 *Overview map.*

Based on the interpretation of geophysical data, the main geological units exposed at the surface were mapped. Neogene-Quaternary basalts are characterized by high-amplitude variable magnetic field and low radioactivity. Loose Neogene-Quaternary sediments are characterized by low resistivity, low magnetization, and low radioactivity. Radioactive granite intrusions (typically leucocratic granites) are noted for significantly elevated concentrations of uranium, thorium, and potassium, as well as relatively high resistivity.

As a result of our research, the contours of *the Kupchinsky site* paleovalleys and their thalwegs were mapped using a resistivity map at a frequency of 231 Hz (Fig. 3-I). To clarify the geological details along all survey lines, a one-dimensional inversion of the EQUATOR data was performed in the time and frequency domains. Examples of interpreted resistivity sections along potentially ore-bearing paleovalleys are shown in Figure 3-II. They demonstrate reliable mapping of the pronounced geoelectric contrast between low-resistivity Neogene-Quaternary sediments and high-resistivity granitoids.

A granite massif with elevated radioactivity along the northeastern edge of the study area (Fig. 3-II) is considered a potential source of uranium for mineralization in paleovalley deposits. In our opinion, the most promising, potentially mineralized paleovalleys recommended for further exploration for hydrogenic uranium are those whose flows could have eroded these intrusions.

Based on the EQUATOR survey results, the customer conducted exploration drilling. A comparison of the borehole data with the resistivity profile along line L11410 is shown in Figure 4. It is clear that the overlying Neogene-Quaternary sediments (N-Q) and the top of the higher-resistivity granitoid massifs (Pz_1) create a contrasting boundary, which has been reliably determined by the EQUATOR EM system. In the central part of the paleovalley, a difference is noticeable between the upper boundary of the granitoids, as determined by drilling data (black line) and geophysical data (red line). This is likely due to the reduced resistivity of the fractured granitoids saturated with mineralized water. A similar phenomenon was observed at the Tetrakh deposit of the Khiagda ore field.

Direct evidence of uranium mineralization was observed in one of the boreholes as epigenetic oxidizing alterations, a halo of elevated radioactivity (>50 μR/h), and thin layers with increased uranium concentrations of 0.02%.

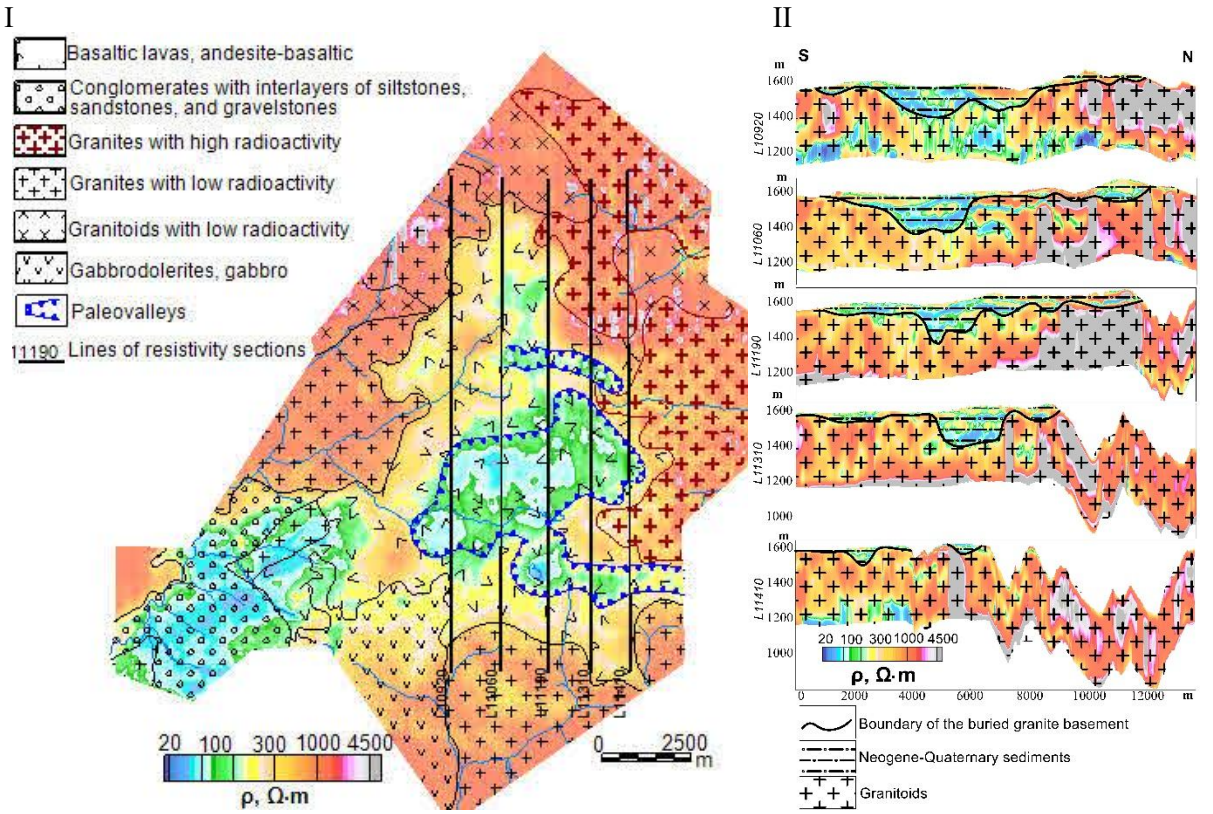


Figure 3 *Resistivity map at a frequency of 231 Hz (I) and interpreted resistivity sections (II).*

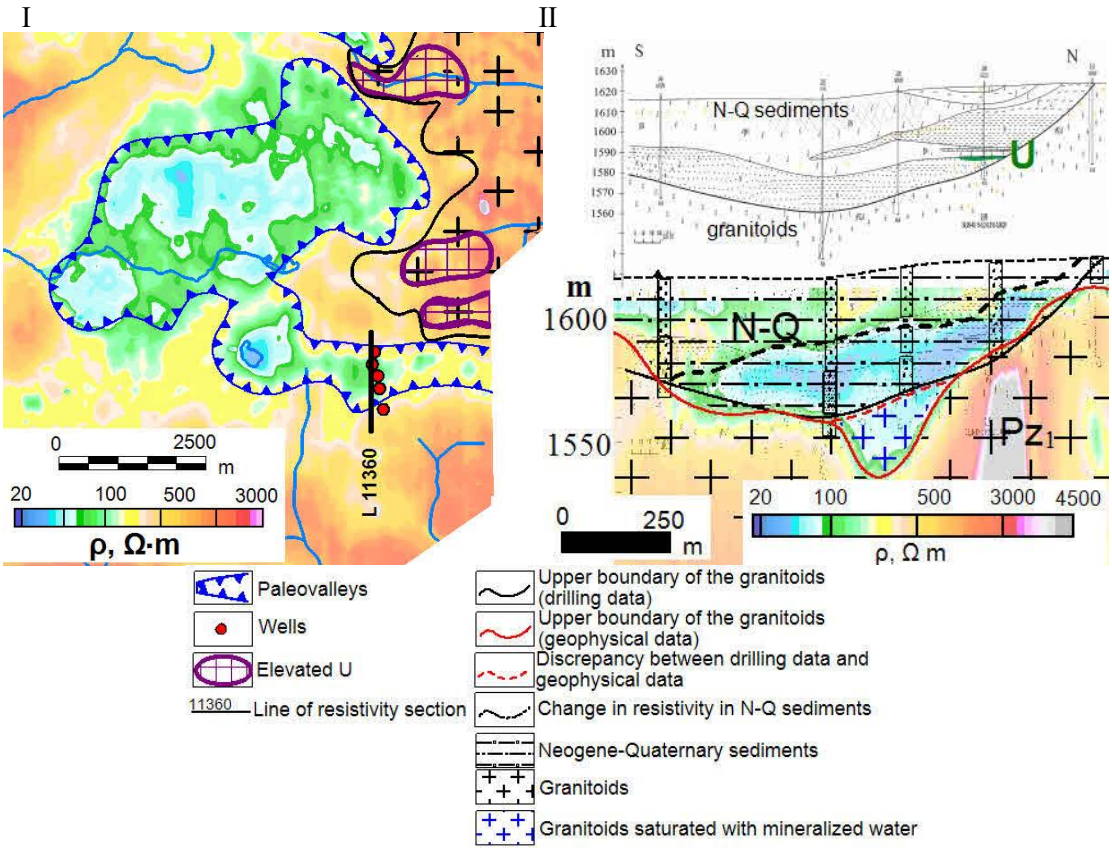


Figure 4 *Comparison of the borehole data with the resistivity profile along line L11410. I) Fragment of the apparent resistivity map for 231 Hz; II) Geological section with boreholes (top) data and Resistivity section (bottom).*

Conclusion

Based on data analysis at *the Tetrakh deposit*, key geophysical indicators for the detection of hydrogenous uranium were identified.
A comprehensive analysis and interpretation of the data obtained at *the Kupchinsky site* allowed us to:
• Clarify the spatial position of geological boundaries on the surface and beneath the Neogene-Quaternary sediment cover.
• Identify potentially radioactive granite intrusions and refine their outcrop contours.
• Delineate and recommend for further study paleovalleys promising for the discovery of uranium ore occurrences.
These conclusions were confirmed by drilling, which discovered a new ore body with an elevated uranium content.
Overall, advanced geophysical surveys using the EQUATOR system significantly increase the pace of exploration for hydrogenic uranium.

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