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ANTHILLS AS POSSIBLE BIOINDICATORS OF TALIK ZONES

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The results of studying the regularities of anthills occurrence in the permafrost obtained from geophysical survey data are presented and discussed. It is demonstrated that the anthills of certain species of ants are located in areas with low resistivity and chargeability, typical of talik zones. In the mountain permafrost areas, anthills are located within the tectonic faults zones with discontinuous and island permafrost. It is suggested that the areal distribution of anthills can be used for permafrost mapping.

Anthills, permafrost, talik, resistivity, chargeability

INTRODUCTION

In the summer of 2007, I was the supervisor of geophysical training of the students of the Chita State University in a training area located in the permafrost region. The training objective was to train the students in field geophysics and in studying the electrophysical properties of permafrost using the fast-decaying induced polarization method [*Karasev, 2005*]. Lowering of resistivity and chargeability of the geologic environment was registered on one of the survey lines. At the same time, no significant geomorphological indicators were evident in the location, which would indicate possible changes in the section, nor were any essential changes in the local plant community found. The only specific feature was the presence of large anthills. The anomalous geophysical parameters suggested a change in the permafrost section, and overlapping of the geophysical anomaly and the colony of ants implied their possible interrelation.

To reveal the regularities in the location of anthills, in situ electrical surveys were conducted in the permafrost region, the results of which are shown below.

DESCRIPTION OF THE AREA OF WORKS AND THE STUDY METHOD

The training area is located in the Trans-Baikal region, in the Ivano-Arakhley network of lakes. A natural preserve called Anthills of Arakhley is situated in the riparian forest of Lake Arakhley [*Korsun, 2007*]. It is represented by numerous colonies (reaching several dozens of anthills) of ants living in large anthills up to 1.5 m tall and 3–5 m in diameter. According to [*Radchenko, 1993*], ants of the *Formica aquilonia* species (the northern forest ant), well-spread in the region, build these anthills. The area of works is characterized by discontinuous permafrost with the temperatures of –1...–3 °C [*Kotlyakov and Khromova, 2002*].

The training area was located at the distance of 200–300 m from the southeastern shore of the lake, on the terrace above the flood-plain on the right bank of the River Gryaznukha, flowing into Lake Arakhley. The vegetation is represented by the deciduous birch forest with scarce underwood consisting of rhododendron (*Rhododendron dauricum)* and dogrose (*Rosa canina*). The near-surface pit dug to the depth of 2 m is composed of fine and medium-grained lacustrine-alluvial sands. The top border of permafrost is located at the depth of 2.5–3.5 m. The depth of seasonal freezing is 2.5–3.5 m, suggesting that the permafrost belongs to the continuous type. Within the area of the geophysical survey, there were over a dozen of anthills 0.25–0.50 m in height and 1.0–1.5 m in diameter.

A 100 m long profiles network was deployed in the area (Fig. 1). The distance between the main profiles 1–3 was 25 m. In addition, two detalization profiles 2+10 and 2–10 m were made. Topographic positioning of the survey profiles and of the anthills was conducted by using GPS.

To study the specific features of the permafrost areal distribution, symmetrical resistivity profiling (SRP) and the fast induced polarization (FIP) method were used. The SRP surveys were conducted with A12.5M5N12.5B array using the ERAMAX instrument. The FIP parameters were measured with the C013 instrument [*Karasev, 2005*] using N5M5A50B array. The arrays were installed at such distances as to allow the depth of survey to be equal to 5–7 m, i.e. to exceed the depth of seasonal freezing. The SRP measurements were made across the entire area of survey, while the FIP survey was done at the 2–10, 2, and 2+10 m profiles. The measurement interval for profiles was 2.5 m.

Based on the measurement results, apparent resistivity (ρ_k) and apparent chargeability (η_k) were measured with the time delay of 0.1 ms and areal distribution maps of these parameters were made.

Geological interpretation of the resistivity survey data is based on the difference between the resis-

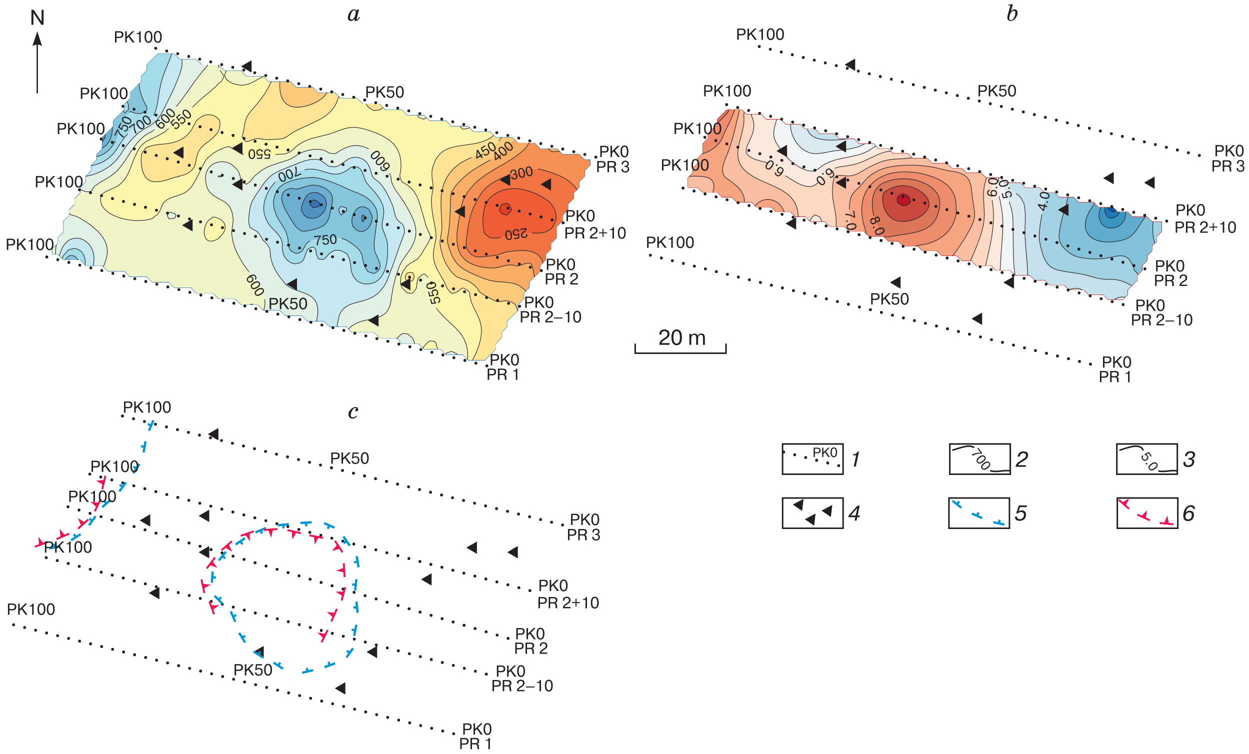

Fig. 1. The results of geophysical area investigations.

a – a contour map of apparent resistivity according to SEP; *b* – a contour map of apparent chargeability according to FDIP method; *c* – contours of geophysical anomalies and a layout of anthills location; *1* – geophysical profiles and survey marks; *2* – apparent resistivity contours, Ohm·m; *3* – chargeability contours (t = 0.1 ms), %; *4* – anthills; *5* – contours of increased resistivity anomaly; *6* – contours of increased chargeability anomaly.

tivity of frozen and of thawed rocks. Although frozen rocks usually have high resistivity as compared to the thawed rocks, the increase in the resistivity of rocks may be caused also by other factors, e.g. the increase in the soil grain size or the decrease of the moisture content. To ensure greater convergence in the interpretation of the SRP, chargeability was employed. Frozen sedimentary rocks are known to have increased chargeability [*Kozhevnikov et al., 1995; Shesternev, 2003*]. Therefore the anomalies of increased resistance and chargeability are interpreted exactly as frozen rocks.

RESULTS

Fig. 1, *a* represents an apparent resistivity contour plot. In the central part of the measured area, isometric anomaly of the increased values of ρ_k can be seen – up to 900 Ohm·m against the background of 300–500 Ohm·m. Increase of ρ_k is also noted in the northeastern part of the area. We assume that the anomalies of apparent resistivity are caused by frozen rocks, which have lower depth than in the other parts of the area.

Analysis of the contour chargeability lines (Fig. 1, *b*) shows that the previously described anomalies of increased resistivity coincide spaciously with the chargeability anomalies. In the central and northeastern parts of the area, chargeability reaches 7–9 % against the background of 3–5 %. Thus, there are reasons to believe that the complex ρ_k and η_k anomalies are associated with frozen rocks.

When comparing the layout of the location of anthills with the contours of geophysical anomalies (Fig. 1, *c*), one can see that the anthills are located in the areas with decreased values of ρ_k and η_k. It seems that in these areas the upper boundary of the frozen rocks is somewhat deeper, which can be related to the existence of closed taliks [*Kudryavtsev, 1981*].

Another example of interrelation between the permafrost morphology and the location of the anthills is the results of the observations I performed in 2012 when studying the mounting permafrost of Altay by geophysical methods. Shown in Fig. 2 is a fragment of a geoelectrical section, made on the basis of electrical resistivity tomography (ERT) data along the profile located on the slope of the Kuray ridge. In the place, the profile crosses one of the currently active tectonic faults of the Kuray fault zone [*Delvo et al., 1995*]. Although the presence of permafrost here is accounted for by altitude zonality, the local factors

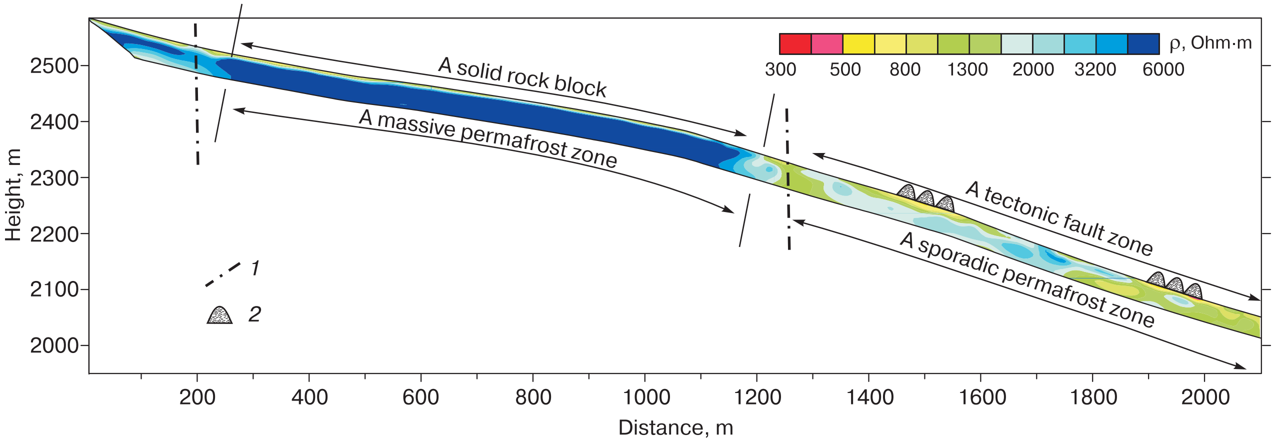

Fig. 2. A fragment of a geoelectrical section on the slope of the Kuray ridge, according to electrotomographic data.

1 – borderlines of geological blocks by tectonic faults; *2* – anthills of a domical type.

(slope exposition, steepness and tectonics) affect formation of the permafrost as well. Indirect of the impact of tectonic events on the formation of permafrost in Mountainous Altay are discussed in [*Olenchenko et al., 2011*]. According to ERT, the depth of permafrost on the ridge slope is 15–25 m. In the profile interval of 200–1,000 m, the section is characterized by high resistivity (more than 3,000 Ohm·m), and only in the near-surface there is a thin seasonally thawing layer with resistivity of 300–500 Ohm·m. Later down the profile and down the hypsometric level, the character of the geoelectrical section changes. On the profile point of 1,260 m the section reveals a subvertical anomaly of low resistivity, interpreted as a tectonic fault, with no frozen rocks within it. In the profile interval of 1,200–2,200 m, background resistivity decreases to 800–2,000 Ohm·m. Local anomalies of increased resistivity and areas of low resistivity are interpreted as discontinuous or sporadic permafrost.

In the profile interval of the 1,505–1,560 m at the altitude of 2,250 m, a colony of ants was found, which built large nests (with the diameter of 0.3–1.0 m) of a domical type out of sand grains and fragments of plant stalks. In accordance with the definitions given in the Institute of Taxonomy and Ecology of Animals, Siberian branch of the Russian Academy of Sciences, by T.A. Novgorodova, these ants belong to the *Formica exsecta* genus. A specific feature of the profile interval containing the anthills is the increased thickness of the near-surface low resistivity layer. Under the colony of ants, there is an anomaly of low resistivity in the section, suggesting a thawing condition of the soil at the foundation of the ants' colony. Another colony of ants was found in the interval of the profile of 1,900–1,990 m, where increased thickness of the near-surface layer with low resistivity was registered.

Thus, it has been established that, under conditions of mountain permafrost, anthills are located within zones of tectonic faults, accompanied by presumably discontinuous or island permafrost. The specific feature of the geoelectrical section in the area of a colony of ants is an increase in the thickness of a low-resistivity layer in the near-surface. This is related to the increase in the eluvium thickness in the crushing zone. It is likely that well-draining alluvial soils are a favorable habitat for ants making their nests there. In the continuous permafrost area at the altitude of 2,355–2,575 m, the thin near-surface layer of low resistivity is presented by waterlogged soils of a thin seasonally thawing layer, which is an unfavorable environment for the ants of the given species.

DISCUSSION OF RESULTS

The results of the geophysical survey and visual inspection suggest possible connection between the areal location of anthills and permafrost. We saw that with the help of geophysical methods in the example of the nests of *Formica aquilonia* in the Trans-Baikal region and of the nests of ants of the *Formica exsecta* species in Mountainous Altay. Let us compare the map of permafrost [*Kudryavtsev, 1981*] and the map of the habitats of the *Formica aquilonia* species [*Dlussky, 1967; Kupyanskaya, 1990; Radchenko, 1993; Berman, 2007; Seima, 2008*] on the territory of Russia (Fig. 3). It is easy to note that the locations of the presence of *F. aquilonia* tend to concentrate near the southern border of permafrost occurrence and are more frequent in the areas of sporadic permafrost. In the European part of Russia, the species *F. aquilonia* is found in the Leningrad region, south of Moscow and in the Kursk preserve, where in the Pleistocene sporadic permafrost was common, which fully thawed

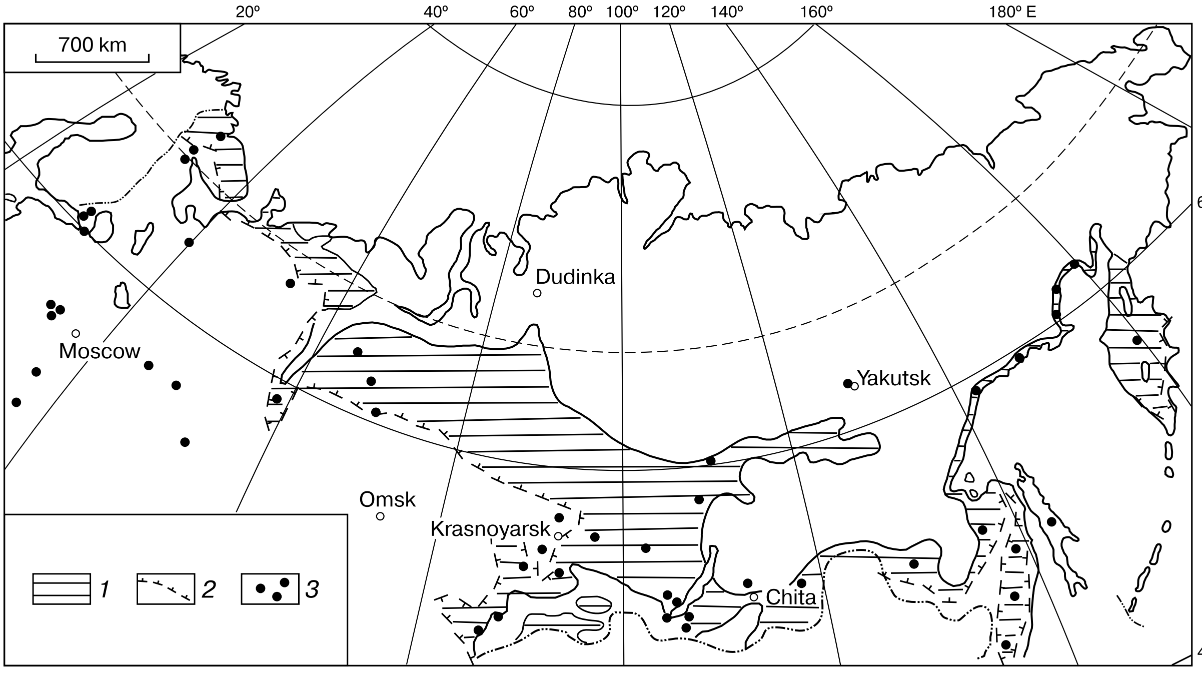

Fig. 3. Geographical distribution of ants *Formica aquilonia* **[*Dlussky, 1967; Kupyanskaya, 1990; Radchenko, 1993; Berman, 2007; Seima, 2008*] a permafrost map [*Kudryavtsev, 1981*].**

1 – the zone of discontinuous, sporadic and massif-sporadic permafrost types; *2* – the southern borderline of the permafrost zone; *3* – habitats of *Formica aquilonia*.

in the Holocene [*Kudryavtsev, 1981*]. There was only one case when a *F. aquilonia* was found in the area of continuous permafrost near the city of Yakutsk; however, this area is known for its numerous talik zones. It is noted that *F. aquilonia* is a more psychrophilic species than its relatives *Formica polyctena* (the small forest ant) and *Formica rufa* (the red forest ant) [*Dlussky, 1967*].

It follows from the above that location of the nests of certain ant species (specifically, *F. aquilonia*) tends to the areas of island permafrost occurrence with taliks of different origin.

Dr. Berman and co-workers have established that "in the north the representatives of the *Formica* genus (except the polar ant) hibernate in various deeply thawing biotopes, which occupy but a small part of the territory and in which the ants can hide themselves in the soil to avoid the low winter temperatures" [*Berman, 2007*]. Together with deep-thawing biotopes (southern slopes, warmed positive ter-

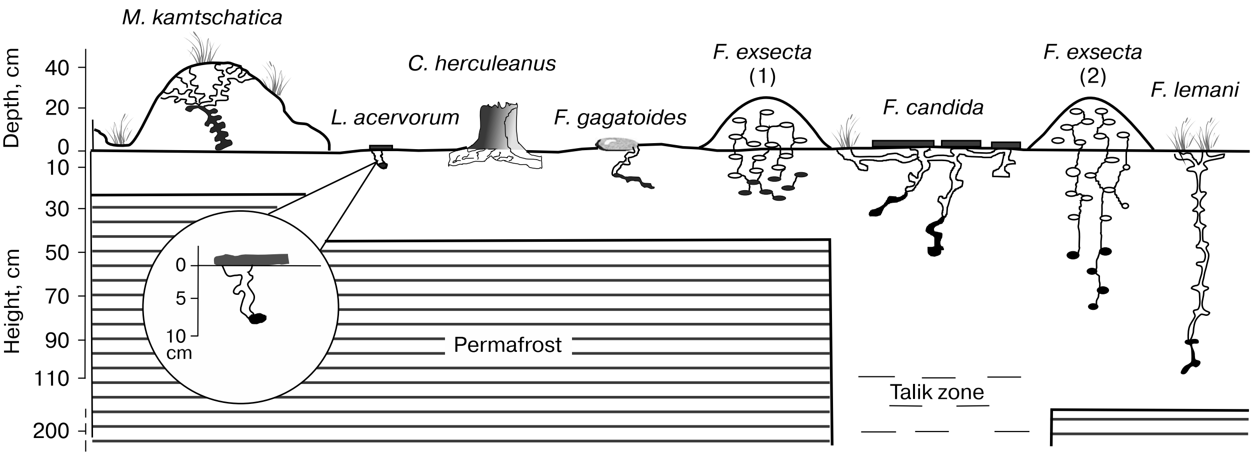

Fig. 4. A layout of an anthill of some ant species in the permafrost zone [*Berman, 2007*].

rain parts), ants quickly penetrate into newly emerging radiation-thermal taliks in the areas with impaired heat exchange of the anthropogenic origin. The nests of *Formica lemani* were reported to have been found in the head of the River Kolyma, in the areas crossed by caterpillar tractors, on forest clearances and in mountain reservations, as well as along the ditches accompanying small abandoned roads [*Zhigulskaya, 2013*].

Fig. 4 shows nests of some ant species found in the permafrost zone. Certain ant species build their nests only in the areas of deep thawing or above continuous thaw zones. It is evident that the anthills of such ants may be used as biomarkers for mapping talik zones in permafrost. It is noted in [*Berman, 2007*] that *F. lemani* never occur in the territories with near-surface "water-impermeable permafrost", which serves as the main factor restricting the occurrence of this species of ants. At the same time, on the shore of the Okhotsk Sea, in the area of discontinuous permafrost, this species is very common. The presence of permafrost does not affect the biotope distribution of only those species which place their nests near the surface. The polar ant and *Camponotus herculeanus* and *Leptothorax acervorum* are referred to such species. Hence, the specific features of location of the nests of these types of ants do not bear any information regarding formation of permafrost, whereas the nests of certain species of ants of the *Formica* genus (for example, of *F. aquilonia*, *F. exsecta*) may serve as biomarkers of taliks.

CONCLUSIONS

It was established as a result of field geophysical surveys and in-situ visual inspection that some ant species (in particular, *F. aquilonia* and *F. exsecta*) build their nests in the areas with low resistivity and chargeability, characteristic of the talik zones.

Under conditions of mountain permafrost, taliks usually accompany tectonic fault zones, marked by low resistivity's and discontinuous or sporadic occurrence of the resistive frozen rocks. Within such zones, numerous large (0.3–1.0 m in diameter) anthills of a domical type are quite common.

Occurrence of large nests of ants in the areas with low resistivity seems to be a regularity revealed under conditions of continental (Trans-Baikal region) and mountainous (Mountainous Altay) permafrost types.

Analysis of the literary sources has confirmed that some ants of the *Formica* genus prefer to build their nests in the areas with deeply thawing permafrost or above continuous taliks. Although this fact is known, it has not yet been practically applied. The regularities of anthill location in the areas of permafrost rocks can be used together with other indicators of talik zones in permafrost studies. For this purpose, it is necessary to identify the most characteristic and easily definable typical indicators of certain ant species, living in different of permafrost biotopes.

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