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New petro-paleomagnetic data of Kandalaksha and Onega Bay Islands in the White Sea

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Region of research

The White Sea is notable for its complex geological evolution and great variety of natural processes. In the tectonic sense, the White Sea depression is located at the junction between the Baltic Shield and the East European Craton. The Kandalaksha Gulf and Onega Bay, which is located in the north-western and south-western White Sea, coincides with the White Sea mobile belt of the Mesoarchean–Paleoproterozoic. The main structural unit that has determined the tectonic evolution and structure of study area from the Mesoprotozic until the present is the graben system. This graben system is called either Onega–Kandalaksha (Baluev et al., 2009a) or Kandalaksha–Dvina (Avenarius, 2004).

Anisotropy of the magnetic susceptibility of Quaternary deposits

In Velikaya Salma Bay (Fig.2) two groups of samples were distinguished by the absolute heights of the selected sections and direction of the magnetic fabric. Based on the fact that this area is experiencing glacioisostatic uplift, it can be assumed that the sections selected at ~ 0 m heights can be almost modern.

These sections are characterized by the fabric that can be expected today in the waters of Velikaya Salma Bay, which arise during the current tidal currents.

In sections at higher elevations, older ones formed in the conditions of another basin that existed at that time.

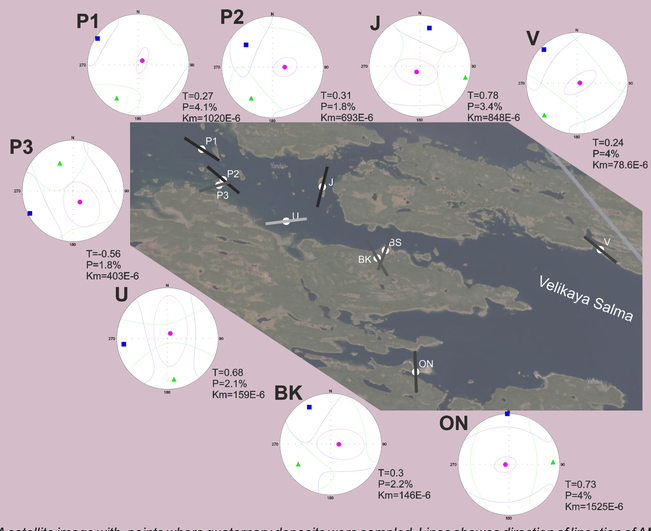


Fig. 2. A satellite image with points where quaternary deposits were sampled. Lines showes direction of lineation of AMS : black - the most reliable, gray - less reliable. Stereoprojections show the mean directions of the principal axes of the anisotropy of magnetic susceptibility with confidence ellipses. K1 - maximum axis, K2 - intermediate axis and K3 - minimum axis, Km is average bulk magnetic susceptibility, P - mean degree of anisotropy, T - value of shape parameter.

Anisotropy of the magnetic susceptibility of Paleoproterozoic complexes

AMS parameters of the magnetic susceptibility in Precambrian complexes showed that most of the samples taken from gneisses have a bulk magnetic susceptibility 5-1000*10-6 SI units. Such a large variation in the parameter is associated with the selection of “banded” gneisses from different parts: the melanocratic with a high content of magnetic minerals and the leucocratic with a smaller one. The degree of anisotropy is quite high, which is most likely due to the manifestation of regional metamorphism. At most points, the rocks are characterized by a planar (oblate) magnetic fabric. In gneisses, we recorded a direct correlation between the direction of gneiss banding and the orientation of magnetic foliation AMS (Fig.3).

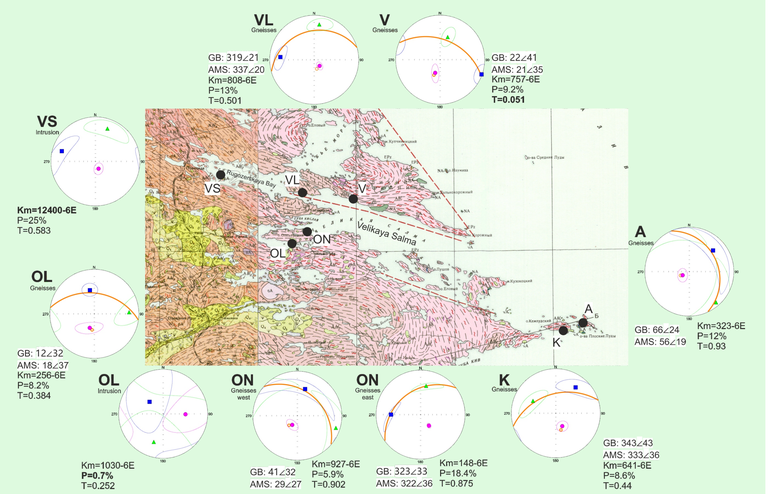
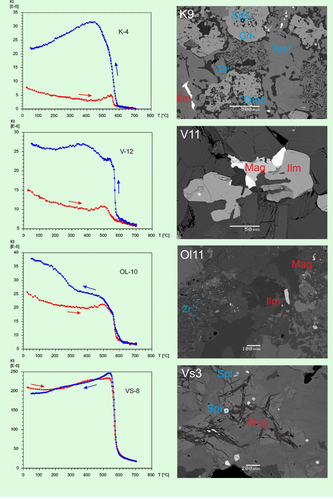


Fig. 3. Geological map 1:200000 with waypoints. Stereoplots shows mean directions of mean axes of AMS with confidence ellipses for each point. K1 – max, K2 – intermediate and K3 – min axes. Orange great circle and pole shows mean directions of gneissic banding. GB – azimuth and dip of gneissic banding, AMS – azimuth and dip of magnetic foliation, Km – average bulk susceptibility, P – mean anisotropy degree, T – value of shape parameter.

In the sampled intrusives of the Kandalaksha Gulf the magnitude of the magnetic susceptibility anisotropy (AMS) has different values. Intrusion on Visokiy island (VS) has the highest values of bulk magnetic susceptibility (8000-20000 * 10^{-6} SI units), degree of anisotropy, and also oblate magnetic fabric as in gneisses (Fig. 3). As a result of microprobe spectrometry, the presence of secondary fine magnetite was established, which most likely has the main contribution to AMS. Intrusion on Olenevskiy Island reveals another type of AMS. Thus, the bulk magnetic susceptibility has the same values as in the country gneisses, however, the degree of anisotropy is much less (up to the few percents) (Fig. 3). As a result of petrographic studies and microprobe spectrometry, we found that the intrusive massif on Olenevsky Island is metamorphosed to a granulite facies (clinopyroxene, orthopyroxene, plagioclase, garnet). However, according to AMS, the minerals of the magnetic fraction can be altered to a lesser extent.



According to the results of thermomagnetic analyzes, it was found that in the selected rocks of the crystalline basement, the main magnetization carriers are minerals of the titanomagnetite group. Paramagnetic fraction also can be difined. In addition, it was found that in the intrusive complexes the mineral content of the titanomagnetite group is higher than in the gneisses, which is also confirmed by petrographic studies (Fig. 4).

Fig.4. Thermomagnetic curves (left). (Kt is the magnetic susceptibility, T is the temperature. Red is the heating curve, Blue is the cooling curve). Magnetic minerals in the rocks (right). (Ilm-ilmenite, Mag-magnetite, SiO2-quartz, Grt-garnet, Omp-omphacite, Amf-amphibole, Pl-plagioclase,

Precambrian complexes located on the islands of the Onega Bay are represented by the Paleoproterozoic dykes of metagabbro and metagabbro-norites and their gneisses.

According to the results of thermomagnetic analysis, it was found that the magnetic fraction is represented by titanomagnetites and, to a lesser extent, by hematite. However, the content of ferromagnetic minerals is quite low in relation to the paramagnetic fraction.

- In all dikes, the bulk magnetic susceptibility ranges from 1 * 10^{-4} - 2.5 * 10^{-3} SI units. The degree of anisotropy is quite low and has values less than 1%, with the exception of two dikes on island Kiy where it reaches 3%. The shape of the magnetic fabric varies from weak linear to strong planar, which is confirmed by the shape parameter, which varies from -0.33 to 0.9.
- Most dikes are characterized by a fairly low accuracy of the mean axes directions for each dike, which is explained by a low degree of anisotropy. For most of dikes with known contact attitude, we established correlation of the main axes of AMS and direction of contact. Some dikes are characterized by the R-type of anisotropy of magnetic susceptibility, but the N-type predominates. The strongest anisotropy of magnetic susceptibility was on the Kiy Island, where the maximum values of the degree of anisotropy and shape parameter were observed. According to different AMS parameters, 3 groups of dikes located on different islands can be distinguished: Kiy, Berezhnoy and Razostrov. The dikes on Kiy Island showed the highest foliation of the magnetic fabric and degree of anisotropy. The dikes on Bereznoy Island are characterized by the largest values of bulk magnetic susceptibility and average values of the degree of anisotopy and ~zero values of the shape parameter. Kondostrov Island with intermediate location has intermediate values of the AMS parameters. On the westernmost island Razostrov the lowest values of the degree of anisotropy (<0.3%) and the lowest accuracy of the average directions of the axes AMS are observed. Thus, there is a trend towards an increase in the degree of anisotropy and the shape parameter in the strike cross of the Belomorsky mobile belt away from the Karelian craton (Fig. 5).

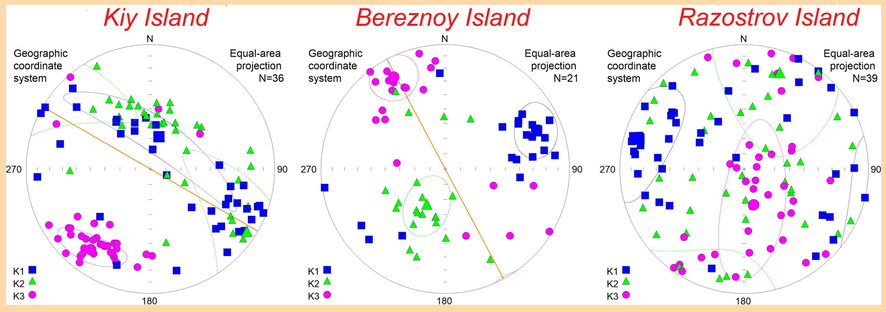


Fig. 5. Examples of stereo projections illustrating the average directions of the main axes of anisotropy of magnetic susceptibility for the three distinguished groups on the islands of the Onega Bay. K1 is the maximum axis, K2 is the intermediate axis and K3 is the minimum axis, the orange great circle is attitude of the contact of dikes.

Conclusion

1. Modern and elder sediments having the reverse stratigraphic order (elder ones are higher than younger ones) can be distinguished on the bases of the direction of lineation of AMS in the Quaternary sediments of the Kandalaksha Gulf. It was determine by the similarity of the AMS parameters in our sections and expected in the neighboring water area of Velikaya Salma Bay. In addition, our study can help to determine the genesis of this sediments. In our data the observed characteristics of sediments more likely are characteristic for the marine formations, not for the basin formations.
2. The nature of anisotropy and the distribution of the principal axes of the AMS ellipsoid in these quaternary deposits are not affected by the precambrian comlexes and structures.
3. There are two generations of intrusives were distinguish in the intrusive complexes of the Kandalaksha Gulf according to AMS and petrographic data. The first one is mostly altered by metasomatic processes, while the second one is mostly altered by the regional metamorphism up to the granulite facies.
4. On the islands of the Onega Bay we observe a decrease in the values of the main AMS parameters with the distance increase from the Karelian craton. It can depend on increasing of the secondary hydrothermal processes during collision in the Proterozoic.

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