INTERNATIONAL CONFERENCE ON PALEOMAGNETISM AND ROCK MAGNETISM

Book of abstracts

2-7 October 2017

Kazan

Kazan (Volga Region) Federal University

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NEW ARCHEOINTENSITY DATA FROM LATE (POTTERY) NEOLITHIC PRE-HALAF AND HALAF SETTLEMENTS YARIM TEPE 1 AND 2 (NORTHERN IRAQ)

Stanislava Akimova[1,2], Yves Gallet[1], Shahmardan Amirov[3], Natalia Petrova[3]
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Main objective of this study is to recover the geomagnetic field intensity variations in the Middle East during the 7th and 6th millennia BC, with a particular interest on rapid variations. We will report on new archeointensity data obtained from two ancient settlements, discovered by Soviet archeologists in Northern Iraq between 1969 – 1976 Yarim Tepe 1 and Yarim Tepe 2. Yarim Tepe 2 is dated from the Late Neolithic Halaf period (~5950 – 5300 BC) and is represented as a 7-m thick sequence of cultural deposits, divided into 9 archeological levels (building horizons). Yarim Tepe 1 is dated from the Late Neolithic Pre-Halaf period (~6300 – 5950 BC, including three regional cultural phases: Hassuna I, II and III) and represents a 6,5-m sequence of cultural deposits, divided into 12 archeological levels. A very important collection of artifacts from Yarim Tepe 1 and 2, in particular several thousands of potsherds, is stored at the repository of Archeological Institute in Moscow, where our sampling was undertaken.

We collected 30 groups of fragments from Yarim Tepe 2 and 14 groups from Yarim Tepe 1 from superimposed stratigraphic layers of about 20 cm thickness in average. Each group consists of at least 3 (up to 10) fragments. All data were carried out using the three-axis vibrating sample magnetometer Triaxe, which allows magnetization measurements of a small samples (< 1 cm^3) directly at high temperatures. Archeointensity results were obtained using the experimental protocol developed for the Triaxe magnetometer. This protocol takes into account both the anisotropy and cooling rate effects on thermoremanent magnetization acquisition. Together with other data previously obtained from Syria and Bulgaria the new archeointensity results show the occurrence of rapid geomagnetic field fluctuations during the 7th and 6th millennium BC. Data from Yarim tepe 2 also confirms the occurrence of a short-lasting geomagnetic field intensity peak around ~5500 BC, with intensity variation rates as high as ~ 0.35 – 0.15 μT/year over a few decades. We will also present X-ray data obtained on a set of potsherds from Yarim Tepe 1 and 2, which provide interesting new constraints on the heating temperatures reached during the production of the ceramics.

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MAGNETISATION MODELING OF THE DECAY PRODUCTS OF NANOSIZED TITANOMAGNETITE

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Using the model of two-phase interacting nanoparticles developed by our team [1], we have modeled the chemical and thermo remanent magnetisation of the decay products of nanosized titanomagnetites.

Our investigation showed, that increasing the degree of decay of titanomagnetite results in the growth of a chemical remanent magnetisation up to the values not exceeding thermo remanent magnetisation, which is not dependent on degree of decay.

Ratios of chemical and thermo remanent magnetisations to ideal magnetisation were assessed. Values of the thermo remanent magnetisation to ideal R_t ratio are as follows$0{,}8 \leq R_t \leq 1$. These limits for R_t are with agreement with an experimental data, obtained for the nanosized titanomagnetites [2] and other rocks containing titanomagnetite [3,4]. Similar ratio for the chemical magnetisation R_c show values lower than R_t at any degree of oxidation which is does not contradict measurements of the reference [2] where $R_c \leq 0{,}9$.

Moreover, it appeared, that magnetic interaction between nanoparticles have almost no effect on the thermo remanent magnetisation to ideal magnetisation ratio and at the same time lower R_c.

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MAGNETIC MINERALOGY OF SAMPLES WITH L-SHAPED ARAI-NAGATA DIAGRAMS

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The Thellier experiments on paleointensity B_{anc} determinations on the Middle Jurassic basalts of the Crimean peninsula revealed a weird behavior of the Arai-Nagata (A-N) diagrams which manifests itself in a sharp drop in NRM intensity when a sample is heated to ≈ 400° C accompanying by a very weak pTRM acquisition. On contrary, with a further increase in temperature, this decline suddenly changes for sharp increase in pTRM acquisition with almost no NRM decrease, thus leading to L-shaped A-N diagrams. A breakpoint on the A-N diagrams at $T \approx 400$°C could be attributed to the TM phase with $T_c \approx 400$°C. Experiments with the thermomagnetic curves $ARM(T)$ have shown that these curves show the same sharp drop in intensity as the $NRM(T)$ curves what proves that the nature of sharp drop in NRM intensity cannot be explained simply by its partial destruction due to metamorphic processes. In addition to this observation, the thermomagnetic curves $M_{rs}(T)$ also show the similar behavior being almost demagnetized when heated to 450-500°C, that is, long before reaching T_c. At the same time, the consecutive $M_{si}(T)$ curves recorded in external field = 450 mT indicate that the sample contains only a phase with $T_c \approx 550$°C. As is shown by X-ray and EDS data, the samples contains initially a low-Ti (perhaps partly oxidized) TM grains which undergo further single-phase oxidation (SFO) during thermal treatments. In some cases the oxidation ends up with transformation to hematite what may cause the sharp remanence drop. But often no hematite was found after heating, so in such the case the only candidate triggering the drop seems to be the ongoing SFO, the occurrence of which during heating is confirmed by X-ray data and by changes in $M_{si}(T)$ curves. What concerns the quick $M_{rs}(T)$ decay with temperature, we suggest that it reflects the DS rearrangements while SFO develops. In its turn, the intensive growth of pTRM at the practically stopped NRM decay in the high-temperature sections of A-N diagrams is most likely due to a decrease in the effective size of magnetic grains with a corresponding increase in the efficiency of acquiring high-temperature pTRMs.

GEOCHRONOLOGICAL AND PALEOMAGNETIC STUDIES ON SEDIMENTARY ROCKS OF THE KEMA AND SILASA FORMATIONS OF THE SIKHOTE-ALIN OROGEN.

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The paper presents findings of paleomagnetic and geochronological studies of the Lower Cretaceous sandstones of the Silasa and Kema formations (northern and southern Sikhote-Alin, respectively).

Geochronological studies.

In the course of geochronological studies of detrital zircons from sandstones of the studied formations, it was found that the ages of zircons differ significantly (except for the age of the youngest Albian zircons), which indicates different source areas for the formations. The age of zircons from sandstones of the Kema formation is Proterozoic, while the oldest zircon in sandstones of the Silasa formation is of Devonian age (382 Ma). So it was suggested that the Proterozoic-Paleozoic zircons from rocks of the Kema formation are from the eastern edge of the Eurasian continent. At the same time there are no zircons of the same age (Proterozoic-Paleozoic) in rocks of the Silasa formation. This is explained by the fact that sediments of the Silasa formation were deposited in the geodynamic setting of the outer island arc, separated by the fore-arc basin from the inner island arc, where sediments of the Kema formation accumulated. The fore-arc basin being wide and deep enough, the continental source areas had no effect on the depositional zone of the Silasa formation.

Paleomagnetic studies.

Rock samples from the Silasa and Kema formations have undergone thermomagnetic (Silasa formation rocks) and alternating field (Kema formation rocks) cleaning. The recent and ancient components of magnetization were isolated for both formations. The ancient components have a “pre-fold” age of magnetization as indicated by positive fold tests. In the course of the study, paleomagnetic pole coordinates were calculated for Silasa (Plat = 19.5 °, Plong = 81.6 °, dp = 10.9 °, dm = 7.7 °) and Kema (Plat = 77.1 °, Plong = 354.5 °, dp = 17.9 °, dm = 12.6 °) formations. It is found that rocks of the Kema formation formed at a paleolatitude of 35 °N and those of the Silasa formation at a paleolatitude of 34.5 ° N), which are close in value.

The work was supported by the Russian Science Foundation (project no. 16-17-0016).

NEW PALEOMAGNETIC DATA OF PALEOPROTEROZOIC MAGMATIC COMPLEXES OF INGUL MEGABLOCK (UKRAINIAN SHIELD)

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A small number of Precambrian objects "useful" for paleomagnetic studies and lack of insufficient age determinations by modern isotope-geochronological methods determine the urgency of the problem of constructing the APWP in Precambrian for any Craton.

Favorable in this respect is the earth's crust with a long time of consolidation, in particular the Ukrainian Shield. From the 1970s the paleomagnetic studies from the Institute of Geophysics of the National Academy of Sciences of Ukraine (N.P. Mikhailova, A.M. Glevasskaya, S. N. Kravchenko) obtained the magnetic and paleomagnetic characteristics of igneous rocks and allocated the paleomagnetically informative species of rocks (anorthosites, monzonites, some granites as well as some rocks of the dyke hypabyssal complex) in which the primary NRM component was preserved. In later studies [Elming et al., 1993, 1998, 2001; Lubnina et al., 2009; Bogdanova et al., 2012], paleomagnetic studies of rocks with an age of 2.0 - 1.8 billion years have been concentrated in the Volyn (North-West), Ingul and Dnieper megablocks.

In order to continue these studies a new collection of Paleoproterozoic rocks of the Ingul megablock within the Korsun-Novomigorodsky pluton, Novoukrainsky massif and Korsun-Shevchenkovsky massif with modern geochronological age's determination were studied paleomagnetically. The high-temperature stability ChRM component was isolated in the interval of blocking temperatures of 500-580°C by more than 300 samples from 8 objects.

The paleomagnetic poles were calculated for 1750 Ma (the pole coordinates are Φ = 22.5°, Λ = 167.3°, dp/dm = 4.0°/7.7°) and 1770 Ma (Φ = -3.6°, Λ = 156.3°, dp/dm = 3.3°/5.3°), as well as the paleomagnetic pole for 2037.4±0.6 Ma (Φ = 43.5°, Λ = 141.6°). They are in good agreement with the data obtained earlier for the coeval complexes of the North-West megablock [Elming et al., 2001]. Based on the available paleomagnetic poles, the kinematic parameters (latitudinal drift velocity and rotation speed of the blocks) for the Ukrainian Shield (Ingul and Northwestern megablocks) and Fennoscandia [Elming et al., 2001] were calculated. The paleotectonic reconstructions of the relative position of these megablocks in the time interval of 1770-1750 Ma are presented.

MAGNETOSTRATIGRAPHY AND BIOSTRATIGRAPHY OF THE PERMIAN-TRIASSIC BOUNDARY INTERVAL IN EUROPEAN RUSSIA

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Sections spanning the Permian-Triassic boundary beds are studied in the basin of the Oka River (Vyazniki, Zhukov Ovrag, and Slukino (Vladimir Region) and Okskiy Syezd (Nizhny Novgorod City)). The middle part of the section contains the Vyazniki biotic assemblage (Zhukovian Regional Stage), whereas the upper part contains the Vokhma biotic assemblage (Vokhmian Regional Stage). The transition from the Vyazniki assemblage to the Vokhma corresponds to a period of ecosystem turnover in the East European Platform, the largest in the Permian-Triassic. The stratigraphic level of this change, which is the boundary between the Zhukovian and Vokhmian regional stages, is traditionally accepted as the Permian-Triassic boundary. A complex pattern of paleomagnetic properties observed in multiple change of subzones of normal and reversed polarity is established within the Zhukovian-Vokhmian interval. There are three intervals of reversed polarity and two intervals of normal polarity. Rocks of the lower part of the Zhukovian Regional Stage and the underlying beds of the upper part of the Nefyodovian Regional Stage with a total thickness of 12–18.5 m have reversed polarity. These beds correlate with the r_2R_3P subzone. The upper part of the Zhukovian beds (2.5–6 m) shows normal polarity. These are overlain by beds with reversed polarity (1.5–2.5 m) with remains of Vokhmian vertebrates, suggesting the Vokhmian Regional Stage of the Lower Triassic. These are overlain by beds with normal polarity (2.5–3 m), containing Lower Triassic ostracods and *conchostracans.* The section is terminated with a relatively large interval (over 24 m) of reversed polarity corresponding to R_1T zone. The uppermost part of this interval contains vertebrate fossils of Vokhmian age. Beds between the paleomagnetic zones R_3P and R_1T can be recognized as the NPT zone, the lower part of which (n_1NPT) is Upper Permian (Zhukovian), whereas the middle and the upper parts (r_1NPT and n_2NPT) are Lower Triassic (Vokhmian). The position of the P-T boundary within the zone of normal polarity observed in the sections studied does not contradict its position in the stratotype in the Meishan, South China.

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PALEOMAGNETIC AND PETROMAGNETIC CHARACTERISTICS OF THE REFERANCE SECTIONS CISURALIAN SERIES PERMIAN SYSTEM

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Two reference sections of the Cisuralian Series Permian System Mechetlino and Dal'ny Tulkas were investigated in the Republic of Bashkortostan.

In the Mechetlino section on the right bank of the Yuryuzan River, carbonate-siliciclastic deposits of the Kungurian-Artinskian boundary are exposed. This section contains fusulinids, ammonoids, conodonts and some layers of volcanic tuffs. Also numerous ostracods, calcareous algae, fishes and plants are found here. The Mechetlino section is a candidate for the Global Section Stratotype and Point (GSSP) for the base of the Global Kungurian Stage of the International Stratigraphic Time Scale.

The Dal'ny Tulkas is located on the right bank of the Usolka River at the northeastern margin of the city of Krasnousolsk, in the Republic of Bashkortostan, Russia. The section is represented by thick marine mixed carbonate-siliciclastic deposits of Lower Permian Age. The Dal'ny Tulkas section is proposed as GSSP for the lower boundary of the Artinskian Stage for International Geochronological Scale.

Paleomagnetic data from these sections showed that all sediments recorded magnetizations of reverse polarity and correspond to Kiaman Reverse Superchron.

Petromagnetic characteristics magnetic susceptibility and magnetization chang in interval from $(-0,6) \cdot 10^{-5}$SI to $18,5 \cdot 10^{-5}$ SI and from $0,15 \cdot 10^{-3}$ A/m to $4,72 \cdot 10^{-3}$ A/m accordingly for Dal'ny Tulkas and from $0,1 \cdot 10^{-5}$ SI to $21,8 \cdot 10^{-5}$ SI and from $0,18 \cdot 10^{-3}$ A/m to $6,08 \cdot 10^{-3}$ A/m accordingly for Mechetlino.

CONTRIBUTION OF DIFFUSION TO THE REMANENT MAGNETIZATION OF THE SYSTEM OF ONE-DOMAIN PARTICLES

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The significant influence of the magnetic aftereffect on the remanent magnetization of igneous rocks is associated with the peculiarities of their formation and the duration of the action of a relatively weak geomagnetic field. One of the factors that can change the remanent magnetization can be diffusion, which contributes to an increase in the local concentration of exchange-interacting atoms (ions) and, accordingly, the Curie point.

In this paper, within the framework of the model of random interaction fields [1-3], using the Oguchi method, an estimate is made for the intervals of variation of the Curie point and the change in the remanent magnetic moment of the system of one-domain particles as a function of the concentration of the exchange-interacting atoms of the ferromagnet.

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MAGNETIC CHARACTERIZATION OF PROPOSED TEKTITE-LIKE OBJECTS (URENGOITES, SOUTH-URAL GLASS) FROM SIBERIA, RUSSIA

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Urengoites and South-Ural glass are proposed ‘tektite-like’ objects from Western Siberia (Russia), previously described in [1-3]. Urengoites (U-1, U-2, U-3; ~24 Ma [1]) were discovered near the West-Siberian town of Novy Urengoi [1-2]. Total recovered mass: ~21.65 g. The only recovered South-Ural glass A-1 was found near Magnitogorsk (~90 g) [3]. In spite of previous works [1-3], the magnetic properties of urengoites and South-Ural glass remain unknown. Here we present a comprehensive magnetic characterization for all three currently known urengoite specimens and the only discovered South-Ural glass.

Rock magnetic investigations revealed the presence of ferrimagnetic minerals in all samples. Low-temperature magnetometry (ZFC-FC dataset) points out to magnetite, which was detected in the most magnetic urengoite sample (U-3) via its characteristic Verwey transition at ~120K (<1 ppm). Contrary to previous investigations [2], we could measure NRM for all samples and acquire alternating field demagnetization spectra for the biggest samples (U-1 and A-1). The following SIRM values were recorded: 4.33 $\mu Am^2/kg$ (U-1), 13.20 $\mu Am^2/kg$ (U-2), 62.40 $\mu Am^2/kg$ (U-3) and 9.36 $\mu Am^2/kg$ (A-1).

The obtained χ_0 values for all four samples (U-1 to U-3: from 9.98 to $19.90 \cdot 10^{-9}$ m^3/kg; A-1: $4.66 \cdot 10^{-9}$ m^3/kg) are close to those for Libyan glassed (see Table 1 in [4]). Anisotropy of magnetic susceptibility (AMS) measurements for A-1 sample revealed 28% of anisotropy. SIRM values and non-isotropic susceptibility demonstrate a composite ferrimagnetic and paramagnetic origin of susceptibility. U-1 and A-1 do not demonstrate any field nor frequency dependence of χ_0, which likely indicates the absence of superparamagnetic grains of nanometric size.

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PETROMAGNETIC, GEOCHEMICAL, PALYNOLOGICAL DATA OF HOLOCENE SEDIMENT FROM SHCHUCHYE LAKE, YAKUTIA

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Shchuchye Lake is located in the central part of Oymyakonsky Highland in Yakutiya (63.351465°N, 140.990055°E). The length of the lake is 920 m, width ~ 300 m, depth = 3.5 m. In the central part of the lake, two cores drilled out by a Livingstone piston sampler (thickness 347 and 306 cm). ash layer was recovered at the depth 244 cm which is correlated with Kuril Lake tephra (7.6 ka) of Kamchatka. Radiocarbon data are: 4315±35 (101 cm), 4955±45 (143 cm), 6140±35 (187 cm), 11770±30 (329 cm) (Korzun, 2017). Magnetic susceptibility of sediments varies from 1.75 to 27.2 10^{-9} m^3/kg, Js = 0.001–0.065 Am^2/kg, Jrs = 0.00008–0.038 Am^2/kg, Bc = 7.9–58.06 mT, Bcr = 35.6–80.2 mT. Magnetic particles are mainly pseudo-single domain, rare are single domain. Thermomagnetic data show the formation of magnetite during heating.

The chemical composition of the 346 samples has been studied by X-ray fluorescence analysis. There is clear geochemical zonation through the core section. Low content of TiO_2, Al_2O_3, MgO, K_2O, Rb, Fe_2O_3, LOI are at depth 15–25, 110-130, 215-225 and 320-325 cm. This levels mark low detrital sedimentation. Highest content of Fe_2O_3, P_2O_5, MnO are at depth 250–320 cm which implies autigenic processes. Lepidocrocite are often in the sediment from this depth.

Six palynological zones (TS1–TS6) distinguished in the section indicating to climatic changes and vegetation restructuring. Between 14000–9500 cal yr, vegetation changed from a mix of larch forest-tundra and shrub birch tundra to larch forest. As climate gradually warmed, larch forests became more widespread with denser tree growth and a rich understory of shrub birch and alder. Between 9500–7000 shrub alder became a very important component of the vegetation communities. Dwarf stone pine expanded into the lake area 6000 cal yr ago. Vegetation communities similar to modern were established ca. 2500 cal yr. There is correlation between palynological and rock magnetic data. “Cold” palynozone TS1 with lowest content of Betula pollen is characterized by lowest value of MS. Low MS and Betula pollen concentration are at level 100-130 cm also. Highest MS and highest Betula pollen concentration are in warm palynozone TS2.

Investigation were funded by FEB RAS (15-I-2-067) and RFBR (15-05-06420).

PALEOMAGNETIC RESEARCH OF UPPER VENDIAN REDSTONES OF THE URYUK FORMATION IN THE SOUTH URALS

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Current notions about paleogeography of the East European Platform (Baltica) in the Late Precambrian period are rather vague. This is primarily due to a lack of paleomagnetic data and discrepancies in the available evidence. Unfortunately, there are almost no new Vendian structures on the platform itself appropriate for paleomagnetic research. Therefore, it seems reasonable to study deformed margins of the platform. Of special interest are the South Urals where Upper Vendian sedimentary rocks appropriate for paleomagnetic research are widely spread in the Bashkir Meganticlinorium. The uppermost Vendian section on the west of the meganticlinorium is the Asha Series composed of terrigenous sediments, which combines five formations with gradual transitions among them. The upper two formations (Bakeevo and Uryuk) are of quartzite-arkosic composition, whereas the upper three formations (Basa, Kukkarauk and Zigan) are of polymictic composition. Sandstones and aleurolites prevail over distinctly subordinate argillites and gravelites. Conglomerates form only one marker horizon in the central part of the Kukkarauk Formation. Data obtained recently on two Upper Vendian formations (Basa and Zigan) nearly synchronous in their origin differ dramatically from each other and can be indicative of considerable tectonic motions. More detailed research on the rocks of neighbouring formations should be performed to clarify the events occurred during the Late Precambrian time.

In our report we shall give some preliminary data on the rocks of the Uryuk Formation. Interbedded whitish and tile-red arkosic sandstones in the upper part of this formation reveal the high-temperature hematite-related magnetic component at temperatures exceeding 600°C. In the margin of error, its direction coincides with the direction of high-temperature magnetization in the rocks of the neighbouring overlying Basa Formation. This can suggest the primacy of magnetization, yet only one polarity is recognized. The report will present new results and discuss briefly their consequences.

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USING PETROMAGNETIC DATA FOR THE PALEOCLIMATIC RECONSTRUCTIONS ON THE TERRITORY OF CENTRAL ASIA (WEST TURKMENISTAN)

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The aim of this study is to investigate the perceptivity of petromagnetic characteristics of sedimentary sequences for the paleoclimatic reconstructions on the territory of Central Asia (in particular, Turkmenistan) during the last five millennia. Climate change can lead to the changes of the magnetic properties of the material. During past few decades, petromagnetic methods have been proven as an effective tool for analyzing problems related to the climate and environmental changes.

The most promising methodology for these purposes is to investigate the evolution of the coercivity spectra and thermal demagnetization curves along the sedimentary sequences, which includes the magnetic signal decomposition into different ferromagnetic components and tracing the relative contribution of these components during the sequence accumulation. The proximate complement to this method is to study the evolution of the other petromagnetic parameters (*e.g.* different types of the magnetic susceptibility) through the sequence.

The object of the present study is represented as a 5-m thick sequence of Takyr deposits dated from the late Holocene, situated in Danata region (Karadag piedmont, Western Turkmenistan). The peculiar feature of this sequence is the thin lamination (varvs), where each layer represents one year of sedimentation. The dating of the sequence is based on the superposition of annual varvs. According the varv chronology, the sequence has been deposited for approximately 5000 years.

We will present the preliminary paleomagnetic results, obtained from the pilot batch of samples. The analysis of the demagnetization curves revealed two ferromagnetic components. We estimated the contribution of the paramagnetic, superparamagnetic and ferromagnetic components to the entire signal through the sequence. The analysis of this contribution gives the possibility to investigate material input changes and the autigenic minerals occurrence. Studying the magnetic components susceptibility variations gave us the possibility to reconstruct the depositional conditions. We also made correlation between the petromagnetic properties and varv chronology along the sequence. Preliminary results of the the comparison between the petromagnetic data and the sequence chronology and lithology helped us to make conclusions on paleoclimatic conditions during the sequence deposition.

FIRST RESULTS ON A COMPARISON OF THE QUATERNARY-PLIOCENE SEDIMENTATION RATES IN THE ARCTIC OCEAN: PALEOMAGNETIC STUDY

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Accurate dating of marine sediments from the Arctic Basin continues to remain a subject of great debates over the last decades. Due to the lack of adequate materials for biostratigraphy, and isotope analyses, paleomagnetic reconstructions came on line here but still yielded ambivalent interpretations.

Paleomagnetic study on two sediment cores, retrieved from the Mendeleev Rise, and the Lomonosov Ridge, have provided the opportunity to compare sedimentation regimes on these two profound structures of the Arctic Basin. Cores PS72-396 and PS87-023 were collected during the cruises of *RV Polarstern* from the Mendeleev Rise (Stein et. al, 2010), and the Lomonosov Ridge (Stein, 2015), respectively. Measurements of natural remanent magnetization (NRM) and anhysteretic remanent magnetization (ARM) together the following alternating field (AF) demagnetization were carried out on u-channel samples, obtained from the cores, at the Center for Geo-Environmental Research and Modeling (GEOMODEL) of the Research Park in St. Petersburg State University.

According to preliminary results, core PS72-396 has shown a change from positive to negative inclinations at ca. 120 cmbsf (cm below sea floor) prevailed up to ca. 360 cmbsf, following which inclinations revert to positive ones. In contrast, for core PS87-023, a relevant drop to negative inclinations has been observed only after 330 cmbsf. That could signify a dramatic difference in sedimentation rates between the sites, acting during the Pliocene and Quaternary.

Acknowledgments

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E.A. MOLOSTOVSKIY – MAGNETISM OF SCIENCE AND PERSONALITY

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The teacher had taught us four subjects:
Wisdom, behavior, honor, and devotion.
Four disadvantages were alien for teacher:
Propensity for speculation, excessive flatness,
contumacy and ego.
Confucius, "The analects of Confucius"

My first meeting with E.A. Molostovskiy. The stars were exactly on my side in 1969 when I was a second year student of geological faculty of Saratov State University. Instead the standard practice on the educational ranges I chose the participation in the field works one of the branches of Scientific-research Institute of geology, connected with Saratov State Uinversity. Small squad had completed a boat route by the Mezen river from the regional center "Pyssa" in the Komi ASSR almost till the creek of a river near a town of Mezen, so the whole route was about 700 km.

Some words about wisdom. Never in my life, I had regrets that I missed the educational practice. On the example of a large area of our study, occupied by the field of development of Permian and Triassic platform sediments, Eduard Arkadievich told me about the peculiarities and dangers of field research based on his experience in the savage places, during the long evenings of the polar day, of the Khabarovsk Territory, where he worked from 1954 to 1961.

Edward Arkadievich explained intelligently and enthusiastically about the elements of magnetostratigraphy, types of magnetization of rocks, inversions of magnetic poles, oceanic linear magnetic anomalies, and many other features of paleomagnetism within the limits of our perception of geology and physics. It is important to note, that Edward Arkadievich was awesome popularizer of this scientific branch: his explanatory were figured and in a manner romantic.

Some words about the learning of behavior. For 24 years of working side by side with Edward Arkadievich, I have repeatedly faced and personally experienced the ability of the teacher to encourage employees to do their own things. Here is one of the episodes. It was in the summer of 1971 in Komi ASSR and in Vologda region. As a student of 4-th year of study I was passing my predegree practice, in paleomagnetic group under a guidance of Edward Arkadievich. Our group was displaced in the village of Aikino in Komi ASSR and prepares for realization of important and long route on the Suhona river in the Volgograd region. To make this route it is necessary to have a few boats. Eduard Arkadievich had a plan to rent or buy boats in the village Totma, that in the upper reaches of the Suhona river. For reconnaissance of the situation I was

instructed to leave for Totma village. The way was not so easy: I had to take a train from the Aikino village to the town of Kotlas and go 400km on a railway, than I needed to take a motor ship to Velikiy Ustiug and go about 100km by the Small Nothern Dvina river and the last stage of this trip was 300km of by the plane AN-2. During a day I got to the place and negotiated with the owner of boats in the docks, where I found out that a purchase of boats is possible and I also wondering about its approximate price. After a night in a hotel I prepare to start my way back home. But why had I told this all. I tried to reflect the ability of Edward Arkadevich to trust another "snotty" young beginner a difficult task and to impose responsibility for its implementation.

About the study of honor. Edward Arkadievich himself was unthinkable honor, first, it was honest with himself, and of course he expected this from everybody around him.

Some words about the study of devotion. Here Edward Arkadievich operated under a principle: “Do and live as I do” and persistently tried to instill in students an ascetic attitude to paleomagnetism as a scientific and practical direction in geology and geophysics, this is why he was awarded the respected title "Chef" in a young team of the paleomagnetic laboratory. He was proud of students that finally reached the scientific success. His regrets about the talented students, that left a laboratory and stopped their work in paleomagnetism were sparkage.

Some words about the lack of inclination to speculation. Edward Arkadevich belonged to the category of people and scientists who trust only real facts and convincedly instilled a similar attitude to students.

Some words about the absence of excessive flatness. We can’t say that Eduard Arkadevich had a soft or pliable character, but he was devoid of fanatical indisputability. A definite flatness appeared in relation to the negative features of human characters - laziness, lies, betrayal.

Some words about the lack of stubbornness. Edward Arkadevich was not stubborn, but sometimes he had some form of skepticism.

Some words about the lack of selfish character. Edward Arkadevich was an active lively man. He was deprived of selfishness and self-pride. During the field work, he shared all the hardships of the disorder of life on a par with everyone and always with great humor smoothed out the hard moments of the relationship in a small, constantly closed collective.

PETROMAGNETIC CHARACTERISTICS OF SOILS IN THE ZONE OF INFLUENCE OF "STEPNOVSKOE" UNDERGROUND GAS STORAGE

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Petromagnetic characteristics and spatial features of their distribution in the soil cover of Stepnovsky underground gas storage were studied. The results of investigations of the magnetic susceptibility (MS) and magneto-mineralogical characteristics of the soil cover in the territories of individual UGSs (Schelkovskoye, Severo-Stavropolskoye) in the region of study. The results of study shown that a statistically significant increase in the MB and the content of the magnetic fraction on the average in the artificial gas reservoir in the soil horizons 2-4 times compared to the background territory. The increase of magnetic susceptibility is caused by the synthesis of pedogenic magnetite.

Stepnovsky structure got a status of an industrial gas-oil deposit, which was actively developed for many years. The gas and oil deposits of the Devonian formations are used for gas injection after production. Depth of occurrence of the layers used under UGS is 2000 and more meters. The soil cover is heterogeneous: predominantly chestnut soils, with local areas of dark-chestnut carbonate and alkaline soils. In total, 51 samples of soils were taken on the territory of the UGS mining diversion. The location of the sampling points was chosen in respect with the longest distance from the elements of the technogenic infrastructure of the SUGS. The study revealed that the pH of samples taken from the soils overlying the UGS varies between 6.41 and 8.27. The wide variation in pH indicates the heterogeneity of the soil cover and the intensity of occurring processes. The values of MS of soils in the territory of the mining withdrawal of the SUGS vary in a wide range from 17.2 to 96.9 × 10^{-5} SI units, with an average value of 52.0 × 10^{-5} SI units. In the area of soils distribution moisture values obeys a noticeable differentiation. It was established that the magnetic susceptibility of the soil cover of the SUGS territory of the shows rather wide variations in its values for the area of the mining allotment, both in the samples and in their granulometric fractions. These variations allow to group the soil samples into spatial zones of elevated and lower CF values. Magnetic zoninality reveals a specific features that allow to make a classification of geologic and structural plan of the SUGS for Devonian sediments, otherwise to the spatial boundaries of the current gas content contours. The authors suggest that this behavior of the magnetic susceptibility of soils on the territory of Stepnovsky underground gas storage is due to active geochemical (biogeochemical?) processes that puts mineral matrix of soils in motion. It also pulls the trigger of the processes that forms authigenic complex of ferruginous minerals. a certain role may play the emanation flows of methane from geological strata that is used for pumping the underground gas storage. Indirect criteria for such processes are the facts of groundwater contamination in the territory of the mining site of SUGS methane.

NEW ~1.8 GA PALEOMAGNETIC POLE FROM THE PRECAMBRIAN DIKES OF THE KOLA PENINSULA, NE FENNOSCANDIA

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Paleomagnetism of the Proterozoic magmatic bodies of Scandinavia, Karelia, and southern part of the Kola Peninsula is extensively explored by many researchers, as indicated by the corresponding volume of the records in the paleomagnetic PALEOMAGIA database for Precambrian (Veikkolainen et al., 2014). In particular, the paleomagnetism of intrusive rocks in the southern part of the Kola Peninsula is thoroughly scrutinized in the study of A.N.Khramov and his colleagues (Khramov et al., 1997). However, any information about the systematic paleomagnetic investigations of the Archaean and Proterozoic dikes of the Central Kola block and, especially, Murmansk craton are absent in the literature. For several Precambrian objects of the Kola Peninsula there is a number of paleomagnetic poles, which are presented in the paleomagnetic database (Khramov, 1986); however, this data cannot be presently regarded as sufficiently reliable and has to be verified.

Based on the results of preliminary paleomagnetic studies of 57 Precambrian dikes of the Kola Peninsula, in 31 of them a stable monopolar component of natural remanent magnetization is revealed (D = 353.2°, I = 53.0°, K = 58, α95 = 3.4°). Corresponding paleomagnetic pole of Fennoscandia has the coordinates Plat = 54.5°, Plong = 224.0°, A95 = 3.9° and is located in the immediate vicinity of the Paleoproterozoic (1.9–1.7 Ga) poles of Baltica (Khramov et al., 1997; Veikkolainen et al., 2014). The peculiarities of distribution of this magnetization component within the Kola Peninsula and the rock magnetic characteristics of the corresponding dikes suggest its secondary nature and relate the mechanism and formation time to the regional remagnetization process. According to obtained geochronological data (Rb-Sr, Sm-Nd, U-Pb) we guess, that this remagnetization event could be linked with the Svecofennian orogeny and took place ~1.8 Ga.

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MAGNETIC PROPERTIES OF SOILS ON THE EXAMPLE OF VIRGIN DARK-GREY FOREST SOIL AND VIRGIN LEACHED CHERNOZEM

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This work is devoted to studied the magnetic properties of virgin forest-steppe soils which formed on original vertical uniform unconsolidated parent material. In this work, profile samples of virgin dark-grey forest light loamy soil on aleurite of the Kazanian stage of the Permian system and virgin leached medium-thick fat light-loam chernozem on the Quaternary deluvial loam were used. Both soils is characterized by cumulative type of magnetic susceptibility, its components and F-factor reflecting changes in the ferrimagnetic fraction. In the humus part of the soil profile magnetic materials are present predominantly in fine mineral particles, and their content in the <2.5 µm fraction is reduced toward the soil-forming rock. An estimate of the contribution of the dia- / paramagnetic, superparamagnetic, and ferromagnetic components from the coercive spectra shows that the increase in the magnetic susceptibility in organogenic horizons of forest-steppe soils is due to the contribution of the ferromagnetic component. Strong positive correlations can be seen between magnetic susceptibility and oxalate-extractable Fe and between magnetic susceptibility and Schwertmann's criterion values. The method of thermomagnetic analysis of fraction < 2.5 µm shows that the enhancement of magnetic susceptibility in profiles forest-steppe soils is due to the formation of maghemite-magnetite associations. The mainly ferrimagnetic fraction is represented by small single-domain grains.

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NEW PALEOMAGNETIC DATA FROM LATE PALEOZOIC AND MESOZOIC VOLCANIC ROCKS (SOUTH TRANSBAIKALIA REGION)

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The main objects of the present study are late Permian and Mesozoic volcanic rocks from Selengin-Vitim volcano-plutonic belt. The belt was formed in the back area of Siberian continent active margin. Volcanic rocks are presented by contrastive volcanites more than 5 km thick. The deposits are subdivided into three suits: Ungurkuy (basalts and andesites), Chernoyar (presented mostly by basalts, andesites and tuffs) and Hilok (mostly basalts, pyroclastic flows and tuffs). The age of Ungurkuy suite is deemed to be between Late Carboniferous and Late Permian. The age of Chernoyar suite is Middle-late Triassic. The age og Hilok suite is Late Jurassic. Volcanic deposits of the three suits were studied to create APWP for the Siberian craton. 250 oriented samples from 40 sites were collected from the Chikoy river valley within South Siberia. All samples were characterized by interpretable paleomagnetic signal.

Volcanic rocks of Ungurkuy suite show mostly monopolar (normal polarity) magnetization direction (formed before crustal folding) between Early Permian and Permian-Triassic Siberian poles, which indicates its Late Permian age. The normal polarity of the deposits indicates its formation in the period between Kiama superchron, characterized by reversal polarity, and Illavara hyperchron with mixed polarity - 265 Ma. Direction from Chernoyar suite is well-correlated with Late Triassic APWP of Europe, directions of magnetization are bipolar. From Hilok suite directions of magnetization well-correlated with Late Jurassic APWP of Europe. In conclusion position of calculated poles for the Siberian platform and data for the European platform is pointed to full consolidation of northern Eurasia. The reported study was funded by RFBR according to the research project No. 16-35-00555 mol_a and grant of the Government of the Russian Federation No. 14.Z50.31.0017.

ESTIMATION OF INCLINATION SHALLOWING IN THE PERMIAN/TRIASSIC SEDIMENTARY SECTIONS OF THE EAST EUROPEAN PLATFORM AND ITS SIGNIFICANCE FOR PALEOTECTONIC RECONSTRUCTIONS AND GAD HYPOTHESIS

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It is well known that the effect of shallowing of paleomagnetic inclinations takes place under the compaction of the sediments at the early stages of diagenesis. Traditionally, estimating the coefficient of inclination shallowing implies routine re-deposition and some additional experiments (Kodama, 2012), which is not possible in every paleomagnetic laboratory. The Elongation-Inclination (E/I) method was suggested in (Tauxe and Kent, 2004) for estimating of the inclination shallowing in sediments using statistical approach. E/I method does not require the investigation of the rock's magnetic particles, but toughens the requirements on the primary paleomagnetic data, especially regarding the volume of the individual directions, which significantly restricts the possibilities of the post factum correction paleomagnetic directions for inclination shallowing.

We present the results of paleomagnetic reinvestigation of the some key sections of the Upper Permian and Lower Triassic red beds, located on the East European Platform. The obtained paleomagnetic data allowed us to estimate the coefficient of inclination shallowing by the E/I method and calculate a new P-Tr paleomagnetic pole for Europe. The absence of a statistically significant difference between the mean Siberian, European and North American Permian-Triassic paleomagnetic poles allow us to conclude that ~252 Ma the configuration of the Earth's magnetic field was predominantly dipole. We believe, that the assumption about substantial contribution of non-dipole components in the geomagnetic field at the Permian-Triassic boundary, which has been repeatedly discussed (Van der Voo and Torsvik, 2001; Bazhenov and Shatsillo, 2010; Veselovskiy and Pavlov, 2006), arose due to the failure to take into account the effect of inclination shallowing in the paleomagnetic record of stable Europe (East European Platform and West European Basin).

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ANOMALOUS REMANENT MAGNETIZATION IN THE NEDUBROVO RED BEDS: ITS ORIGIN AND SIGNIFICANCE FOR THE PERMIAN-TRIASSIC MAGNETOSTRATIGRAPHY

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The Nedubrovo member was firstly described by Lozovsky et al. (2001) and is still the subject of continuing disputes due to the uncertainty of the age of its deposits, mainly red beds. Numerous definitions of fauna and flora make it possible, on the one hand, to refer the Nedubrovo rocks to terminal Permian (Arefiev et al., 2016; Lozovsky et al., 2016); on the other hand, to the Early Triassic (Lozovsky et al., 2017). The uniqueness of the Nedubrovo member sediments is also determined by the absence of coeval rocks within the Moscow Basin. Previous magnetostratigraphic studies of the Nedubrovo member rocks revealed that all the sequence is magnetized in reversed polarity, which made it possible to correlate the Nedubrovo layers with the Upper Permian rNPT zone (Arefiev et al., 2015).

In 2015-2017 we made detailed paleomagnetic studies of the Nedubrovo section with the aim to get the new paleomagnetic pole of the East European platform. 151 oriented samples were taken from a series of overlapping trenches on the left bank of Kichmenga River; the total thickness of sampled stratigraphic interval is about 9 m. Detailed temperature magnetic treatment revealed the presence of a monopolar ChRM in most of the studied samples, but its mean direction (N=107, D=244.8, I=-7.7, K=10.7, a95=4.4. VGP: plat=15.7, plong=156.0, dp/dm=2.2/4.4, paleolat=3.9) differs significantly from the expected Late Permian or Early Triassic directions for this site (N60.04521, E45.74047). The presence of the anomalous stable magnetization component cannot be explained by local tectonics, post-Permian remagnetization, or contamination by less stable components of NRM. At the current stage of study, we assume that the magnetic record in the Nedubrovo red beds can reflect the anomalous state of the Earth's magnetic field near the Permian-Triassic boundary, but the additional extended paleomagnetic researches of the over- and underlied sediments are needed to confirm this suggestion.

This study was financially supported by Russian Foundation for Basic Research, project no. 15-05-06843 and Russian Government project no. 14.Z50.31.0017.

THE UPPER CRETACEOUS AND PALEOGENE MAGNETOSTRATIGRAPY OF THE SOUTH OF WESTERN SIBERIA

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Recently we received and analyzed complex (paleomagnetic, paleontological and geological) the data for the Upper Cretaceous and Paleogene on the eight wells in the south of the Western Siberia in three structural-facies zones – Omsk-Laryak (Omsk basin), Tomsk (Bakchar iron ore deposit), Kulunda (the south of the Kulunda basin). Complex researches for these wells (clays, siltstones, mudstones, sandstones and sands) are carry out. The Upper Cretaceous deposits are composed of the Pokur, Kuznetsovo, Ipatovo, Slavgorod and Gan'kino suites overlain by Paleogene sediments of the Talitsa, Lyulinvor and Yurkovsky (?) suites. Biostratigraphic data testify that these deposits were formed in time interval from Albian to Lutetian (?).

As a result of stepwise thermal demagnetization and AF demagnetization on the allocated characteristic remanent magnetization (ChRM) constructed magnetostratigraphic sections for eight wells in three structural-facies zones. Based on complex (paleomagnetic, paleontological and geological) data the summary regional magnetostratigraphic section of the Upper Cretaceous and the Paleogene of the south of the West Siberia is developed. Three magnetozones: single – normal NK_{1-2}(al-st) and two – reversal (R_1K_2km and R_2K_2mt) polarity are recorded in the Upper Cretaceous fragment of the summary magnetostratigraphic section, and two magnetozones of a reversal polarity: R_1E_1zl, R_2E_1t are recorded in the Paleogene fragment of this section. Comparison of these magnetozones with magnetochronological scale [Gradstein et al., 2012] has the following view: the magnetozone NK_{1-2}(al-st) corresponds to Chron C34, the magnetozone R_1K_2km is compared with Chron C33(r), and the magnetozone R_2K_2mt is adequate to Chron C31(n). As a result of this comparison, hiatuses between Campanian (Slavgorod suite) and Maastrichtian (Gan'kino suite) and also between Maastrichtian (Gan'kino suite) and the Lower Paleogene were established.

THE UPPER CRETACEOUS AND PALEOGENE MAGNETOSTRATIGRAPY OF THE SOUTH OF WESTERN SIBERIA

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PALEOMAGNETIC RESEARCH OF THE DEVONIAN AND LOWER CARBONIFEROUS COMPLEXES IN THE MAGNITOGORSK ZONE OF THE SOUTH URALS

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In order to refine our understanding of paleogeography and paleotectonics of the South Urals during the Devonian to Lower Carboniferous time we have continued paleomagnetic research of igneous and volcano-sedimentary rocks of the Magnitogorsk zone along the eastern slope of the South Urals. Altogether we tested about 1300 samples divided into 160 sites from 13 Devonian and 9 Lower Carboniferous sections and performed their successive thermal cleaning (up to 20 steps).

A considerable part of the sampled Lower Carboniferous lava flows reveal, alongside other components, the bipolar high-temperature magnetization component, the direction of which is similar to the reference direction for the Lower Carboniferous of the Baltic Plate. This makes it possible to conclude preliminarily that in the Lower Carboniferous time the segments of the Magnitogorsk arc under investigation were integral to the continent.

The Devonian sections in question show a more complex distribution pattern of the high-temperature magnetization component, that being in agreement with the notions about the unusual geomagnetic field behaviour in the Devonian time. Nevertheless, in some of the sections, mainly volcanogenic rocks and jasperoids, we managed to recognize the high-temperature magnetic component that can be interpreted as synchronous with the rock formation. If that is the case, then the Magnitogorsk arc was located not far from the Baltic Plate already in the Early Devonian time.

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ANALYSIS OF SECONDARY LATE PALEOZOIC MAGNETIZATION COMPONENTS IN THE SOUTH URALS

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Analysis of secondary magnetization components (Late Paleozoic remagnetization) makes it possible to trace the formation of the South Ural folded system. This paper presents new data on Late Paleozoic remagnetization in the rocks of the eastern Bashkir Meganticlinorium. Combined analysis of the newly obtained results and previously published data on Late Paleozoic remagnetization along the western slope of the South Urals shows that in the western segment the intermediate-temperature magnetization component (ITC) is pre-folded or has its origin at the initial stages of deformation. Contrastingly, the ITC revealed in the eastern segment, in the meridional course of the Belaya River, is of post-folding origin. Analysis of secondary magnetic components makes it possible to trace the formation of folded structures at the final stages of the formation of the western segment in the South Urals as a deformed margin of the East European Platform. Collision processes occurred in the South Urals from the Late Devonian until the Late Permian time had undoubtedly their holdovers in the western structures (in present-day coordinates). Within the Baltic Plate passive margin a lateral series of fold-thrust structures was formed due to the collision. Their formation began from the Main Uralian Fault and continued westwards with possible gradual process damping in the direction of the Cis-Uralian Foredeep. Paleomagnetic results obtained by the research study support these concepts.

Along the eastern slope of the South Urals most of the sites under investigation reveal the ITC, which corresponds to Late Paleozoic remagnetization spread widely in the Urals. This component is of post-folding origin within the western part of the Magnitogorsk zone. The latter result enables us to suppose that deformations took place here long before the final stage in the development of the Urals, most probably at the end of the Devonian or at the beginning of the Carboniferous times. As a whole, this supposition coincides with the geologists' ideas of the time of deformation in this part of the Urals. Paleomagnetic data on the Late Carboniferous rocks from the Magnitogorsk-Bogdanovka Graben attest to the fact that this Late Paleozoic magnetization occurred either in the process of deformation or a short time before folding and at the initial stages of deformations. Thus, it can be supposed that in the area under investigation within the central part of the Magnitogorsk zone folding processes took place at the final stage in the development of the Urals during the Kungurian time of the Middle Permian period.

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THE GEOMAGNETIC FIELD CONTINUATION DOWN WITH USING SPHERICAL HARMONIC COEFFICIENTS

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The possibility of an approximation of the main geomagnetic field (MGF) spatial structure using the set of the current loops was considered in our paper "Current model of the main geomagnetic field sources: possibilities and restrictions". Such model, as intended, would assume an extension to the core-mantle boundary. The inverse problem was solved using the gufm-SAT-E3 spherical coefficients But in spite of these coefficients were calculated for the MGF spatial structure at the core-mantle boundary the problem has occurred. As soon as we approach to the core-mantle boundary the magnitude of the many small-scale anomalies increase significantly faster than it would be conditional on decrease in distance to the source. We assumed it can be caused by the overstatement of the higher order spherical coefficients.

To test this hypothesis we carried out the calculation for the simplified model composed of 15 current loops. One of loops encircles the solid core, the other ones are located in the liquid core at different distances from the core-mantle boundary. Such set of sources produces the magnetic field with different-scale anomalies. The values of the magnetic field components were computed on the Earth surface on a regular network. These data were used for the Gauss coefficients calculation in the ideal case of the disturbances absence. The degree of the associated Legendre polynomial varied from 13 to 24. Using obtained coefficients the magnetic field components were calculated on spheres with radii less than the effective radius of the Earth equal to 6371,8 km. The computed spatial structure of the components was compared with the analogous value calculated as the total field of the 15 current loops.

It was found that in the spatial structure of the difference between the field calculated by the direct method and using the Gauss coefficients small-scale anomalies are manifested and shows the rapid growth of their magnitude even at a radius of less than 5500 km. These anomalies are related to the current loops located near to core-mantle boundary. Because of there are only 3 such sources in the current loops set and the size of the anomalies created by them is small, the mean square of difference under consideration starts to increase sharply percentagewise to the mean square of components only at radii of less than 4500 km.

These results are still preliminary. We intend to carry out a more extensive study with the inclusion of volume current systems in the model.

MAGNETIC PROPERTIES OF ARTIFICIAL CRM CREATED ON TITANOMAGNETITE-BEARING OCEANIC BASALTS

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Laboratory modeling of the *CRM* formation on basaltic rocks from the Reykjanes submarine ridge and the Red Sea rift zone containing titanomagnetite (TM) with $T_C \approx 200$ ° C was carried out by 200-hour annealing at different temperatures T_{CRM} in the external field B_{CRM} = 50 μT. Monitoring the *CRM* acquisition with annealing time increasing revealed the strong correlation between *CRM* and M_S (the last one being measured on a sister sample undergoing similar heat treatment). The existence of this correlation implies that the process of *CRM* acquisition actually takes place only in a relatively short initial time interval of annealing, so that the further *CRM* changes basically repeat variations of M_S in time due to the process of oxidation of TM which takes place during the annealing. It is shown that at T_{CRM} = 350 and 400 °C TM grains are subjected to high degree of single-phase (SP) oxidation while annealing at high T_{CRM} = 450 and 500 °C leads to the oxyexsolution. The Arai-Nagata diagrams for samples bearing the induced *CRM* can be approximated by two linear segments with a break point at T = (560-570) °C. For the low temperature interval (T_{CRM},560°C), the calculated field B_{calc} underestimates the true field B_{CRM} by 53-57% at the stage of SP oxidation but by 18-39% for the oxyexsolution stage. For the high-temperature (T>560 °C) *CRM* component, the B_{calc} was 53-71% lower than B_{CRM} for all the samples studied. On the basis of the data presented here and published in the literature we conclude that the error in the determination of B_{CRM} tends to decrease with annealing temperature increase. This circumstance can be related both to the relative narrowness of the blocking temperature interval, centered on necessity near T_C, and to the fact that at T_{CRM} = 500 °C and higher, the samples acquire *CRM* already at the oxyexsolution stage though the actual physical-chemical processes behind these observations are not clear. Nevertheless, this circumstances allows us to suggest that in those cases when *CRM* has been induced not in the course of prolonged secondary heating of rock but during its initial cooling, the error in determination of paleointensity may be relatively small, up to 20% towards its underestimation.

CONSIDERATION OF THE DISTORTION EFFECT OF PALEOMAGNETIC DIRECTIONS DUE TO VISCOUS-PLASTIC DEFORMATIONS USING THE ANISOTROPY OF MAGNETIC SUSCEPTIBILITY DATA (ON THE EXAMPLE OF BERRIASIAN CLAYS OF THE MOUNTAINOUS CRIMEA).

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In the thick lithologically monotonous clay sections it is visually difficult, and sometimes impossible to determine elements of bedding. Generally, it is necessary to extrapolate the clay elements, measured by the closest crosses of hard rocks. Meanwhile, errors in the determination of layers bedding are important, and sometimes decisive, for obtaining paleomagnetic information.

Submicron ferromagnetic particles, generally aggregate on the flakes of clay minerals, forming so a planar anisotropy of magnetic susceptibility (AMS) and vertical disposition of short axis of magnetic ellipsoids while a sedimentation in calm hydrodynamic environment. This circumstance makes possible to make interpretation of the difference between average direction of the projections of short axis of the AMS and the center of the stereogram (in the geographic coordinate system), as a correction for the true elements of the formation.

After application of corrections, calculated using AMS data, in the elements of bedding of Berriasian-Valanginian clay layers of Mountain Crimea, the quality of paleomagnetic data (values of grouping, inversion test results, fold test results) has improved considerably.

The project was supported by RBSF (grants № 17-05-00716-a, 16-35-00112 mol-a).

GEOMAGNETIC POLARITY TIME SCALE AND GENERAL MAGNETOSTRATIGRAPHIC SCALE: ALTERNATIVES OR ANALOGUES?

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Geomagnetic Polarity Time Scale (GPTS) and Generalized Magnetostratigraphic scale (GMS) that has been used in Russia synthesize the paleomagnetic data of the world. In ideal, only the one scale of magnetic polarity should be global. All other paleomagnetic scales may have local or regional nature. But since GPTS chrons are connected to the Geological Time Scale (GTS), and magnetozones of GMS are connected to the General Stratigraphic Scale (GSS) the equitable existence of GPTS and GMS is necessary until all the problems of relationship between two stratigraphic scales will be solved and make possible their merging.

Primary task of GMS actualization should be its verification for conformity to the modern worldwide magnetostratigraphc data. The GMS has not been actualized over 15 years since its publishing, except for Quaternary period. During this time the structure of GTS, the views on location of many stage borders relatively to geomagnetic inversions were largely transformed according to the adoption of new Global Boundary Stratotype Sections (GSSP). Nowadays, the significant differences in paleomagnetic structure of many same-age intervals in CMS and GPS keep on arrising, and sometimes these differences are principal. Thus, the contradictions between GMS and GPTS must be resolved or justified in details.

The advantage of GMS is its hierarchy to the super- and hyperzones, reflecting major stages of geomagnetic field evolution. It is necessary to go on modernizing hierarchic structure of GMS on the quantitative basis, develop and implement quantitative evaluations of magnetostratigraphic data on different areas into the scale.

Today's GMS is not comparable with GPTS because of large differences in detail of communication of paleomagnetic and stratigraphic units, except for Quaternary period. Since the chrons of GPTS are connected to zonal scales of different paleobiochores, magnetozones of GMS are related to the stages only. While integrating GMS with detail biostratigraphic units, it is needed to show the diachronity of the borders of provincial zones relatively to paleomagnetic basis.

PROBABLE ANALOGUES OF THE KLYUYEVSKAYA MAGNETOZONE OF REVERSE POLARITY IN THE TURONIAN-CONIACIAN OF THE LOWER VOLGA REGION

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The paleomagnetic study of Turonian-Coniacian, represented by carbonate formation, detected the presence of the reverse (R) polarity zone in two of the three studied sections. In the surroundings of village Ozerki the samples were collected from 4 sites. The summary thikness of studied deposits ~ 30 m. In the most part of samples there was detected the characteristic components of magnetization, corresponding to reverse polarity. 200 km to the south, in the Kamenniy brod section, the anomalous polarity zone covers the ~15-meter interval within ~45-meter thick carbonate rocks on a background of normal (N) polarity. The Nizhnyaya Bannovka section situated between Ozerki-2 and Kamenniy brod. Here, the ~20 meter thick carbonate formation is completely covered by N-polarity.

The absence of normal magnetized rocks in the section and the lack of information on the long periods of reverse polarity in C34 chron (Ogg et al., 2016) may be arguments in favor of secondary reversal magnetization of the Turonian-Coniacian (and Santonian?) sediments in the area of Ozerki.

However, several conditions preclude its definite acceptance:

R-zone can be traced in different types of rocks (marls, siliceous marls) in 4 sections, distant from each other for a distance of up to 15 km.

The paleomagnetic pole calculated from the most strong magnetic samples statistically coincides with the standard poles for Stable Europe with ages 85-95 million years. However, Late Cretaceous and modern poles are very close to each other.

The reversal test, carried out for the samples from the Ozerki and Nizhnyaya Bannovka sections (with the execution of anomalous directions), is positive. This agrees with the primacy of the magnetization, but it can also be explained by secondary magnetization of the rocks in one or both sections.

In the General Magnetostratigraphic Scale and other sources, there is some data on the inverse polarity epochs in Turon-Santon.

For the final solution of question of the reverse magnetization nature in the Turonian-Coniacian of the Lower Volga region, it is necessary to continue the magnetostratigraphic studies.

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NEW DATA ON THE STRATIGRAPHIC POSITION OF THE MATUYAMA-BRUNHES BOUNDARY IN LOESS-PALAEOSOL SEQUENCE AT ROXOLANY (WESTERN BLACK SEA REGION)

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Roxolany section (46°10'N; 30°27'E) is one of the most representative outcrops within Western Black Sea Lowland. Its 55-meter thick loess-palaesol sequence was stratified by paleomagnetic, paleopedological, thermoluminescence and other methods, but the results are different. Thus in palaeomagnetic studies of Roxolany the Matuyama–Brunhes (M/B) boundary was placed in the diverse stratigraphic horizons.

The authors of (Tretyak et al., 1987) found a number of zones of normal, reversed and anomalous polarity, but attributed the whole 55-m loess-soil sequence to the Brunhes chron of normal polarity. Later, based on the results of the complex investigation of this section and taking into account the paleomagnetic data from other outcrops in this region, the position of the M/B boundary was drawn in the loess located below the PK6 soil at a depth of ~34 m (Tsatskin et al., 1998), which corresponds to the Tyasmyn horizon according the stratification cited in (Bogucki et al., 2013).

Our new paleomagnetic investigations were carried out in a few laboratories with detailed measurements of specimens from duplicated outcrops after full AF and thermal demagnetization. We identified that the M/B boundary in the Roxolany section is located at a depth of 46.6 m at the contact between the buried soils of the Lubny and Martonosha horizons, which generally agrees with the present-day notions about the Quaternary stratigraphy of the south of Ukraine (Bakhmutov and Hlavatskyi, 2016).

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BLOCKING TEMPERATURE OF TWO-PHASE NANOPARTICLES

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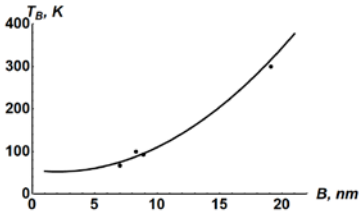

Fig 1. Dependence of blocking temperature T_B on the size of major semiaxis of nanoparticle B of $Fe_3O_4 - \gamma Fe_2O_3$. Dots stands for the experimental T_B [1].

According to Neel, estimating the blocking temperature T_B of single-phase (nanoparticles with single magnetic phase) single-domain nanoparticles, equation for relaxation time τ is used, which is expressed in terms of transition frequencies W_{ik} from one equilibrium state of nanoparticle to another: $\tau(T_B) = W_{12}(T_B) + W_{21}(T_B)$, where $W_{ik}(T_b) = f_0 \exp(-E_{ik}(T_B)/k_B T_b)$ and E_{12} (E_{21}) is a potential barrier between 1 (2) and 2 (1) states, $f_0 \approx 10^9 \div 10^{10}$ is frequency factor. In contrast to single-phase nanoparticles, two-phase nanoparticles can be in one of four states [1]. Thus, spectrum of relaxation times is defined by the transition matrix (4x4) from i- to k- state: $W_{ik} = f_0 \exp(-E_{ik}/k_B T)$, where $E_{ik} = E_{max}(i \to k) - E_{i\,min}$ is a potential barrier separating i- and k- states, $E_{i\,min}$ is total energy of a nanoparticle in i- equilibrium state, $E_{max}(i \to k)$ is maximum energy separating i- and k- states. Assuming that total energy of a nanoparticle is a sum of crystallographic anisotropy energy E_A, magnetostatic interaction energy E_m, interphase exchange interaction energy E_{ex}, and the energy of magnetic moment in external field E_H: $E = E_A + E_m + E_{ex} + E_H$ we can define spectrum of relaxation times [1] and dependence of blocking temperature on the geometric and magnetic properties of a nanoparticles.Results of our calculation of blocking temperature for a system of $Fe_3O_4 - \gamma Fe_2O_3$ nanoparticles are shown on the figure 1. Experimental values of T_b [2] are marked by dots. Increase of blocking temperature is due to the growth in size of nanoparticles.

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CARBONIFEROUS OF THE RUSSIAN PLATFORM: PALEOMAGNETIC DATA

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The new results for the Carboniferous rocks (Moscow, Bashkirian, Visean and Tournaisian stages) from four sections of the Russian Platform are presented. A number of petromagnetic studies were carried out, namely, thermocappametry, measurements of hysteresis loops and analysis of hysteresis characteristics. Electron microscopy was performed to visualize and determine the chemical and mineral composition of the samples. Using an automatic powder X-ray diffractometer, a qualitative and quantitative phase analysis was performed (identification of various crystalline phases and determination of their relative concentrations). The original magnetite and secondary hematite are the main carriers of magnetization in the studied rocks. The analysis of their genesis and degree of variability is carried out.

The isolation of the NRM components was carried out by stepwise thermodemagnetization procedure. All the isolated NRM components have in general the correspondence of their directions to the geomagnetic field of reversed polarity. Only in the rocks of the Turnaian stage is a small zone of direct polarity isolated. Widespread late Paleozoic remagnetization of the Carboniferous rocks of the Russian Platform is detected. This component of NRM (Middle Permian age) is present in all studied rocks. In the red beds of the Moscovian, the natural remanent magnetization components with the inclination shallowing are revealed, which is due to the presence of the large hematite particles or particle aggregates associated with the interaction between the magnetic and clay particles.

Paleomagnetic poles were compared with the coeval poles for the East European plate, which are contained in the World Paleomagnetic Database and scientific articles. The positions of the paleomagnetic poles for the rocks of the Bashkirian and Moscow stages are consistent with the available data. The results on the rocks of the Visean and Tournaisian stages show the presence of partial remagnetization of rocks in Carboniferous time.

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PRELIMINARY ESTIMATION OF PALAEOMAGNETIC POLES FROM MARINE MAGNETIC ANOMALIES AT NW PART OF INDIAN OCEAN

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We study the Indian plate motion during the fast spreading episode between chrons 26 and 24 (60-53 Ma), what is determined by the palaeopole locations. We reconstruct the palaeopoles and the confidence limits using the marine magnetic profiles in Somalian and Arabian basins.

At the first step the skewness parameter $\theta = \mathrm{I}'_r + \mathrm{I}'_0 - \pi$ which defines a shape of the marine magnetic anomalies are found, where I'_r and I'_0 are the effective paleo and ambient inclinations. We use several methods for this and the most precise method is based on the cross-correlation of the observed magnetic anomaly, gradually phase-shifted by increments of 1°, and the corresponding synthetic magnetic anomaly computed at the pole. The knowledge of θ estimates from a single plate gives the effective palaeomagnetic inclination I'_r what allow us to find the locus of paleopoles locations forming the semi-great circle [Schouten and Cande, 1976]. The contemporaneous anomaly located on the opposite side with respect to the ridge gives another semi-great circle and its intersection is an approximate paleopole. Repeating this procedure for other pairs of profiles containing the same anomaly we find the confidence limits of the paleopole location.

We use this approach to anomalies A24 - A26 and the preliminary research findings say that the axis of proto-Carlsberg Ridge was at about latitude 23° S. Note that there are several estimates of this position. One of the first estimates 10° S was found in [McKenzie and Sclater, 1971] also by anomalies in Arabian basin. The estimate 17° S [Besse and Courtillot, 1988] was obtained by continental research. This work was supported by RFBR (project 15-05-0629217)

ASSESSMENT OF POLLUTION FROM VEHICULAR SOURCES USING MINERAL MAGNETIC METHODS IN URBAN ROADS IN JALINGO, NE NIGERIA

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The use of mineral magnetic techniques for assessing pollution from vehicular sources was explored using various statistical approaches. Standard techniques were adopted for measurement of mineral magnetic and geochemical parameters. The magnetic concentration dependent parameters (χlf, χARM, SIRM) revealed that the samples were dominated by ferrimagnetic minerals while the grain size indicators showed that multi domain grains dominated the samples. This implied that the magnetic fractions in the samples might be of anthropogenic origin. The S-ratio, Soft IRM and IRM magnetization and demagnetization curves revealed dominance of low coercive, magnetically soft minerals in the samples while thermomagnetic curves confirmed magnetite as the remanence bearing magnetic mineral having a Curie point temperature of ~ 580 ^{o}C. The significant correlation observed between χlf, χARM and SIRM and Al, Ti, Mn, Fe, Cr and Pb demonstrated that these metals occurred as ferrimagnetic particles of technogenic origin resulting from vehicular sources. Assessment of pollution status of the Jalingo urban roads identified Si and Pb as the priority pollutants of concern. Generally, pollution load index (PLI) was < 1 (mean, 0.66 ± 0.14), indicating that the samples were not polluted in the overall, but the metals were in the build-up stage requiring constant monitoring. The sources of pollutants from principal component and cluster analyses identified the sources of pollution to be mainly from vehicular emissions such as brake linings, exhaust materials, tyre wear, corroded metal parts, abrasion of lubricating oil and road construction materials. This study found that mineral magnetic techniques offer great potential as pollution proxy for soil pollution studies.

Key Words: Environmental magnetism, magnetic susceptibility, ferrimagnetic, geochemical, pollution, anthropogenic sources

MAGNETIC MINERALS AND GAS HYDRATE: INSIGHT FROM THE NANKAI TROUGH, JAPAN

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Interest in gas hydrate occurrences have been increasing in the last decades because of their potential value as an energy resource. Identification of gas hydrate is mostly indirect as gas hydrate commonly dissociates during drill core recovery. Signatures in the rock magnetic record have successfully been used to identify present gas hydrate-bearing horizons in marine sediments, and can potentially indicate former gas hydrate accumulation zones. A specific magnetic mineral assemblage mainly constituted of authigenic ferrimagnetic iron sulfides (greigite and pyrrhotite) has been identified in association with gas hydrate in several geographical areas (e.g. Blake Ridge, Cascadia Margin, Chile-Peru trench).

Our recent studies carried out at Integrated Ocean Drilling Program (IODP) sites in the Nankai Trough, offshore Japan show characteristic rock magnetic properties and magnetic mineral assemblage associated with gas hydrate. Site C0008 (IODP Expedition 316) located in the frontal thrust of the Nankai Trough where no BSR has been recognized, shows occurrence of authigenic ferrimagnetic iron sulfide-rich layers in present day gas hydrate horizons. Our later rock magnetic study of gas hydrate-bearing sediments in the Kumano forearc basin at Site C0002 (drilled during IODP Expedition 338), which is cut by prominent, regional bottom simulating reflector (BSR) observed at ~400 mbsf in seismic data, aims to characterize the present distribution of gas hydrate-bearing horizons in the basin.

Our results support rock magnetism as a useful tool to recognize gas hydrate-bearing horizons.

LATE QUATERNARY VOLCANIC EVENTS IN TUNKA DEPRESSION (PRIBAIKALIE, RUSSIA) RECORDED IN ROCK-MAGNETIC AND GRANULOMETRIC DATA FROM AEOLIAN SEDIMENTS OF BELY YAR SECTION

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We have studied two vertical profiles of Late Quaternary section Bely Yar in Tunka depression (Russia). The distance between Bely Yar-1 and Bely Yar-2 profiles is about 2 km. Laser granulometry has shown that the both sections are represented by alteration of aeolian sands with different mean grain size (124-249 μm) and with fossil soil in basal parts of the sections.

Rock-magnetic study of Bely Yar-1 profile allowed to distinguish individual layers with anomalous behavior of magnetic parameters – sufficient decrease of magnetic grain size (k/SIRM) and Bcr/Bc. Moreover the correlation between magnetic grain size and granulometric mean grain size in those intervals became negative, while in all the other parts of the profile such correlation is positive. We have interpreted such layers as cryptotephra horizons – indicators of volcanic events. This assumption later was proved by direct observation of large number of tephra particles washed out from those horizons, while in all the other parts of the profile tephra particles are practically absent.

Rock-magnetic study of Bely Yar-2 profile have indicated much more coarser magnetic grain size than in sediments of Bely Yar-1 profile except the lowest part. However, we managed to find some intervals with negative correlation of magnetic and granulometrical grain sizes where the magnetic grain size decreases. Those intervals are located approximately at the same stratigraphic levels as cryptotephra horizons in Bely Yar-1 profile, so we consider such intervals as cryptotephra horizons in Bely Yar-2 profile.

Correlation of cryptotephra horizons in doth profiles taking into account available radiocarbon data allows to construct a sequence of volcanic events in Tunka depression during Late Quaternary. The maximal volcanic have taken place in Early Holocene <12000 Kyr, and Late Pleistocene between ~13000 ~22000 Kyr.

MAGNETIC POLARITY STRATIGRAPHY OF THE UPPER CENOSOIC DEPOSOTS OF NER-SEA DAGESTAN (RUSSIA) AND THE AGE OF THE EARLY PALEOLITHIC SITE RUBAS-1

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We studied magnetic polarity in four Upper Neogene (Akchagylian stage) sections of Near-Sea Dagestan. Paleomagnetic studies have shown that Shor-Dere section is the most complete section of Late Neogene – Late Quaternary in this territory. The section Rubas-1, which contains Paleolithic artefacts, corresponds to the upper part of the Shor-Dere section, while sections Ajinoour and Rubas River are likely short fragments, so their correlation with the reference section is ambiguous.

A composite magnetic polarity section of Near-Sea Dagestan was constructed on the base of correlation between Shor-Dere, Rubas-1 and, in part, Rubas River sections. Magnetic polarity pattern of the composite paleomagnetic section is well correlated with the polarity zonation of Akchagylian stage for the neighboring regions of the Caspian basin (Azerbaijan and Turkmenia), the south of the European part of Russia and the Transcaucasus (the Northern Caspian and the Lower Volga region).

Such correlation of the magnetic polarity with those from startotype regions of Akchagylian stage made it possible to identify magnetic polarity zones in the composite section with the magnetic polarity chrons of the Neogene & Quaternary Time Scale (2016). We suggest that the upper part of the composite section can be correlated with Matuyama Chron including Olduvai and Reunion subchrons, while the lower part attributes to Gauss Chron with Kaena subchron. The proposed correlation provides the basis for approximate age estimates for the studied strata and supposes the age of the stone industry from Rubas-1 site not later earlier than 2 million years ago.

STATISTICAL FEATURES OF THE PALEOMAGNETIC DATA IN BRUNHES: REGULARITIES AND OUTLIERS

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The existing paleomagnetic and paleointensity databases consist of records that are sparse in time and space. These records demonstrate a high variability of the characteristics of geomagnetic field in the geological and archeological past. Here we try to analyze the variability of both paleodirections and paleointensites from statistical point of view and compare the results from the archeological and Brunhes epoch data with known models of geomagnetic data secular variations. Our research for the directional data reveals the effects that are in reasonably good agreement with the basic assumptions of the Giant Gaussian Process (GGP) of the secular variations models. However intensity data demonstrate strange additional effects that contrast with both numerical geodynamo solutions and the GGP model. In short, there are too many low intensity data distributed predominantly in high latitudes. We speculate that these effects may be just artefacts of data processing, however the problem is yet unsolved and the actual reason may have a natural origin pointing to some unrecognizable features of the geodynamo generation.

PALEOMAGNETIC AGE DETERMINATION OF THE EDAGARBI GLACIALS OF NORTHERN ETHIOPIA AND ITS SIGNIFICANCE FOR AFRICAN PERMIAN PALEOGEOGRAPHY

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Glaciogenic sediments of Palaeozoic age in Northern Ethiopia have been sampled for paleomagnetic investigations in an attempt to discriminate the age between Upper Carboniferous-Early Permian or Ordovician. Twenty core samples from a tilted bed (strike & dip $130^0/27^0$SW) of the Edaga Arbi Glacials at Negash area and thirteen core samples from sub-horizontally bedded Enticho Sandstone from Enticho area were collected. Alternating Field (AF) demagnetization technique could only demagnetize about 50% of the total intensity of magnetization and thermal demagnetization (TH) is proved to be more effective. Between a temperature range of 120^0C – 350^0C the viscous remagnetizations (VRM) is removed; further heating to a temperature of 650^0C resulted in smooth decay in magnetization intensity to about 50%. The rest of the magnetization is efficiently removed by heating to 690^0C. Magnetization decay curve plots and rock magnetic analyses using Variable Field Translation Balance (VFTB) indicate hematite and magnetite are the carriers of magnetization. The high stability component defines a straight-line segment starting 400^0C and directed towards the origin revealing the Characteristic Remnant Magnetizations (ChRM). The direction of magnetization is determined both by best-fitting line using the least-square technique of Kirschvink and remagnetization circles of Halls for few unresolved overlapping components. The site-mean directions from 11 sites are reversed in polarity with better grouping in the tilt-corrected coordinate and pass the McFadden fold test. This overall site mean direction is Dec = 143.4^0, Inc = 58.8^0 (N = 11, $\alpha_{95} = 9.7^0$) with a corresponding mean pole position of Lat = 26.0^0, Lon = 249.5^0 (N = 11, $A_{95} = 13.1^0$). This geomagnetic pole position is rotated into West Africa coordinates to allow for extensional rifting in the Benue Trough about an Euler pole, at 19.2^0N, 352.6^0E through an angle -6.3^0 (clockwise). The resulting pole is located at $\phi s = 246.6^0$E, $\lambda s = 31.8^0$S (N = 11, $A_{95} = 13.1^0$) and intersects the 270–310 Ma, segment of the Apparent Polar Wander Path (APWP) for West Africa consistent with ages of late Carboniferous to early Permian. This implies the Late Carboniferous Dwyka land ice sheet had extended more than 1000 km further north to Ethiopia than previously known.

GEOLOGY AND PALEOMAGNETISM OF THE CAMBRIAN KOSTINSKAYA FORMATION (TURUKHANSK UPLIFT, SIBERIAN CRATON)

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The studied sections of the Kostinskaya Formation are situated in the eastern part of the Goloyarskaya anticline as well as near the Strelnye mountains in the lower current of the Lower Tunguska River, where they comfortably overlie the Ediacaran Platonovskaya Formation and are intruded by dolerite dikes of the Siberian trap complex.

The purpose of this study is to reconstruct the depositional environments and paleogeographic position of the Turukhansk margin of the Siberian paleocontinent in the early Cambrian using lithological, sedimentological and paleomagnetic investigations of the Kostinskaya Formation.

Using our field geological observations and the available descriptions, a typification of the components of the Kostinskaya Formation was carried out. Four lithogenetic types were established in the studied sections: fine-grained stromatolithic dolomites, fine-grained and micritic dolomites, recrystallized massive, cavernous, thick-slabby dolomites, coarse-grained, massive and cross-bedded dolomites.

Lithological and sedimentological features and the measured rock magnetic parameters indicate that, despite differences in the appearance, structure, texture and magnetization of the rocks, the entire studied section was formed in an arid climate in shallow sea conditions under the influence of tidal currents with the formation of sand bar systems and stromatolite structures, separated by muddy shallows, while the supply terrigenous material containing ferromagnetic grains was minimal or even absent.

A component of characteristic remanent magnetization was defined, which, according to a number of indirect features, may have the age corresponding to the time of sedimentation – the early Cambrian. Another component related to the magnetization reversal in the Ordovician – Early Devonian interval, was also found. The Permian-Triassic flood basalts did not cause an expected regional remagnetization and occurred after deformation and the emplacement of the fold-and-thrust structure of the Turukhansk uplift. The paleomagnetic pole calculated from the characteristic remanence, presumably of the early Cambrian age, corresponds to the Madagascar group of the Ediacaran-Cambrian poles for Siberia. This indicates that the Turukhansk sedimentary basin was in an equatorial position during the accumulation of the Kostinskaya Formation deposits.

The work was supported by the Ministry of Education and Science of the RF (project No. 5.2324.2017/4.6) and the RFBR (project No. 15-05-01428).

STRUCTURE AND FUNCTIONS OF THE PETROMAGNETIC RSEARCH DATABASE OF THE YAKUT KIMBERLITE PROVINCE

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The solution of many problems of prospecting for diamond deposits (interpretation data of magnetic survey, determination of the age of magmatites, identification of satellite-minerals diffusion area, epigenetic changes of diatrem association solids, regularities of placement of fields etc.) is connected with petro- and paleomagnetic researches of the rocks and minerals of the Yakut kimberlite province (YaKP). The complex includes following methods: petrophysical (density, magnetic susceptibility, vector of the natural remanent magnetization NRM), magnetic-mineralogical (anisotropy of the magnetic susceptibility, hysteresis parameters, Curie points) and paleomagnetic (component composition of NRM). Currently received a large specter of magnetic properties for more than 15000 oriented specimens, which representing different age's terrigenous-sedimentary, volcanic and metamorphic formations of YaKP. It is obvious that operational use of this information for solution of the specified problems is impossible without the compilation of a database (DB).

We have developed a Petromagnetic unit, which is integrated into the RSEARCH database of the Institute at the level of "test", one of the geological reference blocks (goelocation). DB allows:

- to import geological-geophysical, geographical and other information about sectors, objects and samples;
- to load data as from separated files LST, MFK-TXT, so from RSEARCH DB and to generate in the interactive mode arbitrary samples from the loaded data set;
- to construct stereograms of the remanent and total magnetization vectors in different projections;
- to calculate descriptive characteristics of parameters on the flatness and in sphere;
- to build graphics of dispensation in volume density and magnetic properties
- to plot 3D model of the total **I** vector for the interpretation of the vector magnetic survey data.

PETROMAGNETISM OF LAKE TURGOYAK SEDIMENTS

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An important component of constructing climate forecasts is paleoecological reconstructions based on the integrated use of geological, biological, geochemical, petrophysical and other indicators. It is shown in this paper that the study of the magnetic properties of lake sediments is informative in the reconstruction of environmental changes.

Unique lake Turgoyak was chosen as object of research. It is the second cleanest lake in Russia after Lake Baikal.

The lake is located on the territory of the southern Urals in Chelyabinsk region.. The area of the lake is 26.4 km^2, the total catchment area is 76.0 km2. The average depth is 19.1 m. The maximum depth is 36.5 m. The water of the lake has a high transparency which is from 10 to 17 m. Altitude above sea-level is 320 m.

Preliminary seismoacoustic studies of the lake water area were held in the framework of the scientific expedition in summer, 2017. It is observed complex picture of the basin morphology and the uneven distribution of sediments on the sections. According to the data of seismoacoustics points for sediments sampling were chosen in the places of lithostratified bedding of layers without the influence of landslide processes and anthropogenic impact. It was selected 6 core columns with a length of over 5 m at points with water depth of about 32 m. Samples for complex laboratory experiments were selected layer by layer in intervals of 2 cm for the five cores columns.

Petromagnetic studies included the measurement of magnetic susceptibility and NRM for samples (1300 pieces) of five columns. Comparison of these parameters made it possible to correlate the sections of sediments collected in different parts of the lake and to reveal the features of sedimentation.

Thermomagnetic studies up to 800 ° C were conducted for the samples of column No. 5 in order to determine the mineralogical features of the magnetic fraction. Coercive spectrometry has let to reveal the features of the magnetic components of the sediment.

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APPLICATION OF THE COERCTITIVE SPECTROMETRY METHOD FOR ESTIMATION OF GEOMECHANICAL PROPERTIES OF CARBONATE DEPOSITS

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Studies of the geomechanical properties of carbonate deposits are in great demand in the development of complex hydrocarbon deposits. Currently, the drilling of new wells, the methods of their completion and the long-term exploitation of oilfields are largely determined by the completeness of knowledge about the geomechanical properties of the section. Core analyses are one of the components of the mechanical properties model. However, such studies are extremely time-consuming. It is known that carbonate rocks under conditions of high pressures and temperatures often show the properties of plastic materials. The content of the clay substance directly influences on such behavior of carbonates. For terrigenous layers, clay content information can be obtained by measuring the value of natural radioactivity along the wellbore (gamma ray logging). However, carbonate deposits have low readings of the GR curve which make it difficult to calculate the content of the clay component. The study on the determination of the magnetic susceptibility (method coercive spectrometry) and physico-mechanical tests of dolomite samples were carried out for testing the hypothesis of bulk clay influence on the geomechanical properties of carbonate deposits. Samples were selected by analyzing the radiometric logging curves for the coring interval. Three groups of samples with a relative content of clay substance were identified at a qualitative level by the form of logging curves. Geomechanical parameters were determined with the help of a laboratory installation of GEOTEK Ltd Company (Penza, Russia). Studies have shown the high sensitivity of the coercive spectrometry method even to an insignificant content of the clay component. The content of the paramagnetic component, depending on the amount of clay minerals in the rock composition, well correlates with the strength and fractal properties. The tests and investigations have made it possible to significantly clarify the lithology differentiation within the groups preliminary highlighted only from the logging curves.

The work was carried out according to the Russian Government’s Program of Competitive Growth of Kazan Federal University.

PALEOMAGNETISM OF THE PHANEROZOIC GEOLOGICAL COMPLEXES OF MONGOLIA AND TYVA

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In the last decade in Mongolia and Tuva were widely paleomagnetic study of Phanerozoic rocks. Geological complexes of these areas are fragments of the Caledonian block of Central Asia.

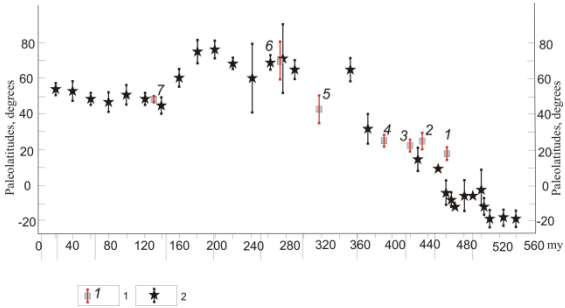

Fig.1. Paleolatitudes calculated of the paleomagnetic poles of Siberia (1) (Pavlov, 2016; Van der Voo, Torsvik, 2004, Besse and Courtillot, 2003) and Caledonian block of Central Asia (2) (Kovalenko, 2017; Kovalenko, in press; Bachtadse et al., 2000; Kovalenko, Chernov, 2008; Van Hinsbergen, 2008).

Analysis of the prefolded close to the primary magnetization showed:

1. Caledonian block moved independently of the Siberian craton from the Ordovician to Devonian, and were located to the North of the Siberian continent (Fig.1).

2. In Devon there was a tectonic superposition of the Caledonian block and Siberia (Fig.1). With this event associated deformation early phanerozoic rocks, granitoid and mantle magmatism.

3. Caledonian strata unit rotated in a horizontal plane relative to Siberia, perhaps because of transpressional type of collision.

Analysis postfolded magnetization showed:

1. In the early phanerozoic rocks of Mongolia and Tuva are allocated to the secondary component of magnetization of direct and reverse polarity.

2. Components of the magnetization of the normal polarity associated with the Mesozoic remagnetization of the rocks. Components of reverse polarity, appears to have been formed during late carboniferous -Permian superchron reverse polarity.

3. The analysis of the distribution of components reverse polarity in the structure of Mongolia allows you to spend some zoning. Allocated region of Mongolia with little postpermian deformations of rocks, with a complex postpermian deformations and areas of rotations of geological block around the horizontal axis (Kovalenko, 2017).

EVIDENCE OF THE EXISTENCE OF THE GOTHENBURG AND MONO LAKE EXCURSIONS BASED ON PALEOMAGNETIC STUDY OF BAUNT LAKE SEDEMINTS (NORTHERN TRANSBAIKALIA)

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We offer to discuss one of the priority items of the palaeomagnetic records: disputes of the Gothenburg and Mono Lake excursions existence. Some researchers adhere to the opinion that there wasn't individual event regarded as Mono Lake but it was just incorrectly dated Lashamp excursion. There is also another opinion that Gothenburg excursion didn't become apparent on the global scale, it was local phenomenon.

Results of the new paleomagnetic studies of the Baunt lake sediments confirm the reality of these excursions.

In 2014 we obtained a sediment core being 13.7 m length. 12 samples from this core were dated in Poznan radiocarbon laboratory (Poland). It helped to calculate average sedimentation rate in this section. The age of core bottom is 29400±250 years.

We sampled 277 cubes (volume 5 cm^3) for paleomagnetic studies.

Two excursions, Gothenburg and Mono Lake were found in studied section. According to the constrained age model, Gothenburg excursion occured at 13300–13100 BP, and Mono Lake took place 26100-25900 BP. Reliability of their identification is confirmed by stability of petromagnetic characteristics values (ARM, SIRM, MS) over the course of the excursions and considerable fall of NRM values.

The study was supported by the Russian Science Foundation (grant no. 16-17-10079).

SURFACE WEATHERING AND UNIAXIAL PRESSURE AS POSSIBLE FACTORS FOR REMAGNETIZATION OF THE DEVONIAN DYKES OF THE KOLA PENINSULA

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For paleomagnetologists studying the natural remanent magnetization (NRM) of rocks, the primary remanent magnetization has great importance. It usually has thermoremanent origin in volcanics and intrusive bodies (TRM). However, a stable secondary magnetization of a different nature (viscous, thermoviscous, chemical, etc.) may appear during the lifetime of a rock due to physical and chemical influences. During the paleomagnetic studies of the Devonian dykes of the Kola Peninsula, we found two components of the NRM of a presumably secondary nature. Therefore, we carried out a series of experiments, where we observed two main factors of remagnetization – weathering, which is responsible for chemical remanent magnetization (CRM), and uniaxial pressure, creating a piezoviscous remanent magnetization (PVRM).

The factor of weathering was selected because most of the studied objects are exposed in wave-cut zone of the Barents and White Seas, which is characterized by aggressive chemical and physical conditions. In addition, during the Valday glaciation (about 20 000 years ago) the Kola Peninsula was covered with an ice sheet up to 3 km thick, creating a quasi-uniaxial pressure on bed rocks of ~ 27 MPa, which could lead to the appearance of a secondary PVRM component.

The results of the "weathering" experiments showed that complete remagnetization by the present-day field occurs in 40% of cases and on the depths not more than 4 cm from the surface. We believe that this remagnetization is caused by low-temperature oxidation of (titano)magnetite. A uniaxial pressure leads to the appearance of a piezoviscous remanent magnetization, whose contribution to NRM is significant, but only for rocks, which TRM was obtained in a weak magnetic field. This could be the cause of remagnetization and the formation of a secondary medium- to high-temperature magnetization component, widely spread in the Devonian dykes of the Kola Peninsula.

MICROMETEORITES IN LAKE SEDIMENTS OF VOLGA-URAL REGION OF RUSSIA

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During summer field trips were collected several cores from Lake Rubskoe. Cores length is about 6 m and maximum age approximately 13 Ka according radiocarbon dating. For investigation chosen core №4 (56.72545° N, 40.60657° E), were sediment sequence not destructed. Core was divided into 2 cm samples. Thermomagnetic curves measured for every fifth sample. The rate of heating was 100°C/min. The measurements made in a constant magnetic field – 200 and 400 mT. We have got thermomagnetic curves of the first and second heating up to 800°C. According obtained data samples were chosen for magnetic separation. The selection criterion was the presence of Curie temperatures above 700°C, which corresponds to the presence of iron-nickel alloys in the sample and Curie temperature 570°C which corresponds to magnetite presence. Magnetic separate was studied using electron microscope Merlin (Carl Zeiss). In samples showed presence of detrital material, magnetite spherules of extraterrestrial origin and iron with impurities and also variability of material concentration in time.

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THE MAGNETIC FABRIC OF THE DOLERITE DIKES WITHIN BERDYAUSH PLUTON, THE SOUTHERN URALS: THE FIRST DATA

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The Berdyaush rapakivi pluton is located in the core of the Bashkirian anticlinorium of the Southern Urals. Its emplacement is related to the Mashak igneous event marking the Middle Riphean rifting in the East European Craton. The U-Pb dating of the Berdyaush granites and syenites yielded the ages of about 1370 Ma [2]. The Northeastern periphery of the pluton and the host rocks are cut by the multiple dolerite dikes. Since these dikes intrude the granite-rapakivi veins and the marbles of Satka Formation, which are deformed with ptygmatic fold structures, we suggest that their formation took place at the later stage of magmatic activity. This magmatic event can be related to the Povalnensky or Inzer mafic complexes of the Upper Riphean [1].

Here we present the preliminary results of the investigation of the anisotropy of magnetic susceptibility (AMS) of the dolerite dikes from the Northeastern periphery of the Berdyaush pluton. About 50% of the studied dikes demonstrate so-called “normal” type of the AMS ellipsoid, when the minimal axis K3 is normal to the contact of intrusion and the other two axis lie in the dike plane. In other sites we found either inverse magnetic fabric, when the maximal axis K1 is normal to the dike plane, or dispersed fabric. In the case of the normal AMS ellipsoid we interpreted the orientation of the maximal axis K1 as the magma flow direction. The studied dikes have the sublatitudinal or ESE strike, and K1 axis is shallow. This fact is consistent with the idea of the lateral magma transport.

The Berdyaush pluton is bounded by the Bakal-Satka regional fault of NE trending in the west. As the studied dikes are generally transverse to this fault, it can represent the long-lived magma feeding zone, which controlled the emplacement of intrusions in Riphean.

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PALEOMAGNETISM, MAGNETIC FABRIC AND GEOCHEMISTRY OF THE SIBERIAN TRAPS INTRUSIONS FROM THE CULUMBE RIVER VALLEY: THE NEW DATA

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The Siberian Traps are well-known as a huge igneous province containing world-class PGE-Cu-Ni Norilsk deposits. Mineralization is related to sill-like intrusions in NW part of the Siberian platform while similar intrusive bodies are widespread around trap province. This selective mineralization of intrusions raises the question on their features in comparing with the other basic-ultrabasic massifs, i.e. their geochemical composition and age.

The Culumbe river area takes the key position in the Siberian Traps due to its localization between the Norilsk-Igarka paleorift zone and the Tunguska syncline. It comprises the intrusive complexes both of the northern and southern parts the province, some of them are ore-bearing as well. It is important to estimate their place in the magmatic and to find criteria for the rich mineralization prospecting.

Here we present the new paleomagnetic data from the intrusions from the Culumbe river. All the studied intrusive bodies have the normal polarity except one sill belonging to the Katangsky complex which has the reverse polarity. Among the other intrusions two statistically different clusters of paleomagnetic directions are distinguished. Besides, the single intrusion of the Kureysky complex demonstrates the paleomagnetic direction which is very different from the rest and is attributed by the lower inclination. The same intrusion is also clearly distinguished from the other by geochemical features. The further investigation will be concerned about the geochemical distinction of intrusions and their comparison with the paleomagnetic data.

We also measured the anisotropy of magnetic susceptibility of the studied intrusions. About 60% of the sites have the normal magnetic fabric, when the maximal axis K1 of the AMS ellipsoid is shallow in sills and corresponds to the magma flow direction. The other sites show either inverse or dispersed fabric. Based on the orientation of the K1 axis in the “normal” sites, we can assume that E and SE directions of the magma transport were predominant during these sills emplacement.

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MAGNETIC FABRIC OF THE PRE-MESOZOIC METAGRANITOIDS OF THE BLYB COMPLEX, THE FORE RANGE ZONE OF THE GREAT CAUCASUS

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Within the Great Caucasus fold-thrust belt, the Fore Range zone has the most complicated structure, and the highest degree of metamorphism was found there. This is the key area for the reconstruction of the Paleozoic history of the Greater Caucasus. At the same time, the interpretation of the evolution of this zone based on the study of its crystalline basement which consists of several salients with the different composition and the structural and metamorphic evolution. The largest Blyb salient consists of different metamorphic complexes and is overlapped by a package of Middle Paleozoic nappes. According to the recent isotopic data the upper levels of the Blyb metamorphic complex are supposed to be Middle-Paleozoic [1]. Metamorphic rocks of the Blyb complex are widely intruded by the granitic bodies of the debatable age and genesis.

We measured the anisotropy of magnetic susceptibility of the metadiorites of the large Balkan massif located in the Small Laba river valley, the metagranites of the Solenaya Ravine intrusion of the Big Laba river and the host gneisses of the Blyb complex. In all the studied objects the minimal axis K3 of the AMS ellipsoid has the NE declination. In the Solenaya Ravine intrusion and its host rocks the minimal axis is normal to the foliation, while in the Balkan massif all axes of the AMS are diagonal to the foliation. The exact orientation of the ellipsoid axis varies from site to site, possibly due to the local tectonics. In general, the magnetic fabric of the granitoids and gneisses corresponds to the NE compressive strains. As the similar strain field was reconstructed from the macrostructures orientation for the thrust sheet formation in the Later Paleozoic [2], we assume that the granitoids' emplacement took place before the main phase of the thrust propagation of the Blyb complex.

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IMPACT OF INNER-CORE SIZE ON THE REVERSING BEHAVIOUR OF NUMERICAL DYNAMO SIMULATIONS

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We investigate 67 chemically-driven dynamo simulations with aspect ratio □ of inner core to outer core ranging from 0.10 to 0.44. As previously reported for the present-day geometry (□=0.35), the reversal frequency linearly increases with the magnetic Reynolds number once a critical value is reached. As a general rule, both this critical number and the slope of this dependency vary with □, the former being minimum for □=0.30, the latter increasing with □. Low efficiency dynamos that do not follow this trend are however observed for $0.20 \leq$ □ ≤ 0.24. Tentatively extrapolating these results to the Earth's dynamo, we note that the inner core's growth could occasion changes in the occurrence of extreme events such as superchrons or hyperactivity reversing periods, and suggest that the singular behaviour observed for $0.20 \leq$ □ ≤ 0.24 could explain the complex field observed during the Devonian period.

VARIABILITY OF THE 0–3 MA PALAEOMAGNETIC FIELD OBSERVED FROM THE BORING VOLCANIC FIELD OF THE PACIFIC NORTHWEST

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The Boring Volcanic Field of the Pacific Northwest (USA), composed of more than 80 eruptive units ranging in age from 3200 to 60 ka, offers a unique possibility to investigate the variability of the Quaternary to late Neogene palaeomagnetic field. To complement previous work on palaeodirections, we conducted 240 absolute palaeointensity (API) experiments with the joint use of the continuous (Wilson) and stepwise (Thellier–Coe) double-heating protocol, along with 620 relative palaeointensity (RPI) experiments based on the pseudo-Thellier approach. We successfully determined absolute estimates for 12 independent eruptive units, as well as relative estimates for 47 out of 132 investigated sites. We compare these results with the existing database for the last 3 Myr and obtain an estimate of the relative variability in palaeointensity on the order of 40–45 per cent as a proxy for palaeosecular variation. API and RPI data suggest a possible asymmetry between normal and reverse polarities.

PALAEOINTENSITY STUDY THE EARLY MIOCENE TARMABER MEGEZEZ FORMATION (ETHIOPIA)

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The early Miocene Tarmaber Megezez Formation (Debra Sina, Ethiopia) consists of approximately 50 independent eruptive units with a heterogeneous petrology (alkaline to transitional basalts). After a close examination of the thermomagnetic and demagnetisation curves of each lava flow, we carried out 150 absolute palaeointensity experiments with the joint use of the continuous (Wilson) and stepwise (Thellier–Coe) double-heating protocol. We successfully determined site-mean absolute estimates for 7 independent eruptive units. X-Ray diffraction measurements and reflected light microscopic observations were additionally done to identify the remanence carriers and their stability. Based on these combined results, we will discuss the reliability of our palaeointensity determinations and compare them with those of the existing database.

REMAGNETIZATION OF THE PALEOPROTEROZOIC ROCKS OF THE KARELIAN CRATON AND BELOMORIAN OROGEN

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The Archean Karelian Craton was formed through the amalgamation of various terranes at ca. 2.70 Ma. The earth crust of the Belomorian belt was produced during the Mesoarchaean to Neoarchaean Belomorian collisional orogeny [Slabunov et al., 2006] and then was re-worked during the Palaeoproterozoic Lapland-Kola collisional orogeny [Balagansky et al., 2014].

We attempted to correlate the time of secondary overprints in magmatic rocks from the ENE part of the Karelian craton and Belomorian orogen. Sumian ~2.45Ga gabbronorites and Jatulian ~2.1Ga mafic dykes have been collected from different parts of the Belomorian orogen for paleomagnetic studies.

Previously isotopic U–Pb dating by titanites suggested regularly trend from 1.92 Ga in NE part of the Belomorian orogen near Lapland-Kola orogen, to 1.8 Ga at SW part near Karelian Craton. However, at the Karelian Craton, the ages of titanites change dramatically from 1888 to 2540–2683 Ma [Bibikova et al., 1999]. In contrast, isotopic ages of rutiles both at the Karelian craton and Belomorian orogen are 1760±20 Ma [Slabunov, 2008].

The paleomagnetic data allowed us to identify an NE–SW-directed rejuvenation trend of remagnetization. The remagnetization trend probably reflects the direction of the collision in the Paleoproterozoic. New paleomagnetic data indicate that rocks of different composition metamorphosed simultaneously in the same conditions remagnetized in different ways.

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MAGNETOSTRATIGRAPHY OF THE JURASSIC–CRETACEOUS BOUNDARY OF WEST SIBIRIAN

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The magnetostratigraphic definitions for three boreholes on the territory of "Imilor" and "Severo-Yeguriahskoe" oilfields were obtained during their study. In each borehole section the Bazhenov formation is represented, as well as the underlying and overlapping formations. 386 samples from 193 partially oriented (top-bottom) cores were studied.

In the studied samples there were identified characteristic components of the magnetization corresponding to both normal (N) and reverse (R) polarities are distinguished, with the inclinations (I) to + 88° and to (-84°), respectively. But the reverse I are recorded only on 13 stratigraphic levels (near 4% of total number of the samples) and paleomagnetic columns are characterized by dominant normal polarity. The domination of N-polarity is contrary to totally accepted information (Ogg et al., 2016) on the complex alternating paleomagnetic structure of Bajossian-Bathonian. Thus, despite the good quality of paleomagnetic data, the most likely version is the secondary magnetization of rocks. Anyway, a few circumstances prevent to take it definitely.

The R-interval in the bottom of the classical Bazhenov formation is traced in remote sections at the Severo-Eguryahskaya well (borehole 61n) and the Imilorskoye (borehole 401) deposits.

The paleomagnetic structure of the sections may fundamentally differ from the real sequence of inversions due to hiatus, inaccurate dating of deposits, uneven sedimentation rate. In addition, information about the regime of the Middle-Late Jurassic geomagnetic field is controversial.

The obtained data accords with the materials of G. A. Pospelova (1976) on the Middle Ob River, registering in the Volgian stage exceptionally normal, and in Bajos-Kimmeridzhe mostly normal polarity.

For the final decision of the question of magnetization nature of Bazhenov and other oil and gas bearing formations of Western Siberia in is necessary to continue their magnetostratigraphic studies.

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ROCK-MAGNETIC AND GRANULOMETRIC STUDYOF ANCIENT MEN HABITATION ENVIRONMENT IN TUNKA DEPRESSION (PRIBAIKALIE, RUSSIA)

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During archaeological rescue works in 2016 in Tunka depression (Pribaikalie, Russia), we have studied geological structure, rock-magnetic properties and granulometric composition of sediments containing archeological horizons on two archaeological sites. "Tuyana" site (51º42'N, 102º41'E) is located at the foot of Hamar-Daban mountain ridge, on the right bank of the Irkut river. A unique multilayer site of the Upper Paleolith was discovered here in 2011. "Zaktui" site (51º42'N, 102º39'E) is located on the tectonically deformed terrace and exposes culturally-containing deposits of Late Pleistocene-Holocene age. The sites are located 3 km from each other, and their sections have a different geomorphological position: Tuyana is located on the valley slope, while Zaktui is on the second terrace above the floodplain. The studied strata are represented by interbedding of subaerial, deluvial, alluvial deposits and fossil soils. The granulometric analysis allows to attribute the sediments to sandy silt with a unimodal fraction distribution (mode 52-88 μm) alternating with silty sands (mode 104-148 μm); only in Zaktui site the silty sand has a bimodal distribution with a secondary mode of 598-704 μm. Rock-magnetic study shows that least magnetic are fossil soils, the most magnetic are the modern soils and subaerial deposits, in deluvial sediments there are interlayers with both high and low values of magnetic parameters. Multidomain magnetite is the main carrier of magnetization in all cases. Despite the geographic proximity of the sections, their structure, granulometric composition and magnetic properties of their sediments are different, that is explained by their location. A joint analysis of the granulometric and rock-magnetic parameters made it possible to specify the genetic types of deposits, the main sources and transporting mechanisms sedimentary material. On the basis of the data obtained, sedimentation environment at archaeological sites in the Tunka depression in the second half of the Late Neopleistocene and Holocene was reconstructed.

MODELING OF CHEMICAL MAGNETIZATION AT LABORATORY ANNEALING OF OCEANIC BASALT

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Oxidation of rocks in natural conditions can lead to the formation of secondary magnetization of chemical nature and, accordingly, to errors in determining the strength of the ancient field.

In order to recognize the components of chemical (CRM) and thermo-remanent (TRM) magnetizations in the natural magnetization (NRM), the influence of annealing on the magnetic properties of the Red Sea basalts in operation of 290–530℃ in air and in argon atmosphere was investigated. The concentration of TiO_2 in titanomagnetite was 15-16 wt%, the Curie temperature in the natural state was T_c = 225±5℃.

During annealing in the magnetic field H = 5G, was observed an increase in the chemical magnetization, which change was satisfactorily described with time by the sum of two functions: exponential and parabolic. It was found that, after annealing for 10 hours in an air atmosphere in the temperature interval 290–460℃, the Curie temperature of formed phase varied from 400 to 505℃ with increasing annealing temperature.

The value of TRM, obtained upon cooling the sample from the Curie temperature of the newly formed phase to the annealing temperature, is 1.2 times higher than the CRM value, formed in the same field. Thermal demagnetization showed that the spectrum of the blocking temperatures of CRM is practically the same as the TRM spectrum.

The absence of explicit criteria for separating these types of magnetization can lead to an underestimation of 20–30%, the definitions of the ancient magnetic field by the method of Thellier.

The observed regularities in the variation of the magnetic characteristics after annealing during operation of 290–460℃ in atmospheric air can probably be explained by the volume mutual diffusion of titanium and iron cations, describing both spinodal decomposition and subsequent heating of samples in an argon atmosphere up to 600℃ of the solid solution homogenized and Restoration of the initial phase.

Annealing at a temperature of 535 ℃ for 10 hours leading to heterophase oxidation of titanomagnetite with the formation of a phase with T_c = 550–580℃. It was found that, in contrast to the first case, subsequent heating to 600℃ in an argon atmosphere did not lead to a restoration of the initial phase.

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BASALTS PALEOMAGNETISM OF THE BOUVET TRIPLE JUNCTION AND THE EVOLUTION OF THE GEOMAGNETIC FIELD.

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Basalts dredged from the ocean floor in the regions of the southern part of the MAR and the Bouvet Ridge to study the geodynamics of the ocean's lithosphere and the evolution of the main geomagnetic field. The samples were taken by the vessel of the Institute of Oceanology of the Russian Academy of Sciences "Academic Strakhov" in regions with Lat = (54°–55°) S, Long = (0°–2°) W and Lat = (53.5°–54.5°) S, Long = (3°–5°) E. The basalts age determined from the analysis of the anomalous geomagnetic field at sampling sites, spreading speed and literature data. Dependence between the decrease in the remanent magnetization of ocean basalts with increase in their age, was compared with the chronos of the geomagnetic field polarity of the Brunhes, Matuyama and Gauss epochs.

Magnetic properties of the samples shows a nonmonotonic change in the remanent magnetization (NRM) of basalts with increasing their age. The most intensive decrease in NRM with increasing age was observed for basalts belonging to the Brunhes epoch. It was found that basalts with age at the boundary of the change in the geomagnetic field polarity of the Brunhes–Matuyama (0.781 Ma), in the vicinity of the Olduvai Chron (1.778–1.940 Ma) in the Matuyama era, and also in the Kaena (3.0–3.3 Ma) in the Gauss era have very low values of natural magnetization. In general, the average value of NRM decreases with age, approximately, in a ratio of 6:3:1. The decrease in NRM is probably due to the effect of low–temperature oxidation of titanomagnetite, main carrier of magnetic properties.

Paleomagnetic fild, determined by the Thelliers' method for basalts' NRM, ranged from 21.7 A/m to 42.5 A/m. The VADM values calculated from these data quite close to the averaged VADM values taken from the world data bank [link].

A positive correlation was established between NRM normalized to the residual saturation magnetization and determined paleomagnetic fild.

The obtained results testify to the fact that during the change of the polarity of the geomagnetic field its value decreases significantly. The structure of the magnetoactive layer in the region of the south of the MAR and the Bouvet Ridge is determined not only by the spreading process and the inversions of the geomagnetic field, but also by the change in its magnitude with time.

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TECHNIQUE AND EQUIPMENT FOR SAMPLING AND ORIENTATION OF THE PALEOMAGNETIC SAMPLES IN THE UNDERGROUND MINES

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Traditionally, in paleomagnetism the orienting of the rock samples is made by using a magnetic compass. In some cases, the magnetic compass measurements can be duplicated using by a solar compass with the aim to exclude the influence of strongly magnetic rocks on the magnetic needle. However, if paleomagnetic studies carry out in underground mine, both of these orientation methods may not be applicable.

We present the methodology and equipment for selection and orientation of the rock samples, developed at the Institute of Physics of the Earth RAS, which can be used, in particular, for paleomagnetic investigations in underground mines, where gasoline powered tools are prohibited. Equipment kit includes a portable sampling device with a pneumatic drive, which allows taking the core samples from the walls and floor of the mine and uses the standard (for paleomagnetologists) drill bits of 1 inch in diameter. Our technique of cores' orienting uses a snap to the mine surveying pickets, as well as a special orienting device used in conjunction with a self-leveling laser level and a laser range finder.

The developed equipment and technique are unique and allow expanding the area of the paleomagnetic researches by including the objects, located in underground mines.

APPLICATION OF MAGNETISM OF MOUNTAIN ROCKS METHODS TO DETERMINE THE PERSPECTIVE ORE FORMATIONS

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The composition, structure and paragenesis of rock minerals are the most important indicators in studying the conditions for the formation of perspective ore formations. Often, the composition of the ferromagnetic fraction of rocks remains without attention. In this paper, the task was set, as a result of the application of magnetic methods of investigation, to reveal the characteristic criteria for the composition of the ferromagnetic fraction of the ore-bearing formations of the Zod gold deposit. It was known that the ferromagnetic fraction of the rocks of this deposit is represented mainly by magnetite.

However, there were no definite data on whether there were other ferromagnetic minerals, what kind of rocks they were associated with and at what stages of the change and at what temperatures they crystallized. Sampling was carried out from three sites subjected to changes in varying degrees. The first section is represented by serpentinites, pyroxenites and gabbroids, second repelled serpentinites and talc-carbonate rocks, and the third quartz-talc-carbonates and carbonate rocks.

The main research methods were: determination of the changes of Is (t) and Irs (t) for continuous heating, and Is (H) and H'cs for successive heating. The Is (t) curves were taken in a magnetic field, and Irs (t) in a zero field. Demagnetization curves were also compiled for the variable magnetic field Iri (h), In (h), Irs (h), Irt (h), H'cs and coercive spectra.

The results of laboratory studies showed that talc-carbonate rocks not affected by ore processes contain mainly magnetite, sometimes together with maghemite and hematite. In rocks altered by ore processes, the content of magnetite decreases (sometimes absent), and iron sulphides-pyrite and pyrrhotite appear. Pyrrhotite, probability, crystallized at one of the first stages of ore formation. In a later stage of ore formation, pyrite crystallized, which occurs both in the host rocks and in ore bodies. Therefore, it can be assumed that the temperature of its reheating should characterize the maximum temperature of the processes following its crystallization.

The application of methods of thermomagnetic studies made it possible to estimate the temperatures of ore processes at the stage following the crystallization of pyrrhotite. Investigation of the changes in pyrite during heating is a promising direction in studying the conditions for the formation of ore deposits.

We can conclude that the methods of rock magnetism can be useful in geological sequence establishing processes, determining the formation temperatures and subsequent changes in the rock complexes being studied.

MAGNETIC PROPERTY OF EXOTIC IRON SILICIDES

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Two exotic iron silicides were studied. First sample was found by a hunter in Transbaikalia on the right bank of the Nercha River near the Ilakta Creek. The sample (15×9×8 cm) has a metallic shape. Chemical composition, hysteresis parameters, thermomagnetic analysis of four pieces of the sample were performed on Camebax microprobe with INCA (Oxford), J-meter automatic coercive spectrometer and magnetic balance (Kazan University), MFK1-FA multifunction kappabridge with CS-3 high-temperature control units (AGICO). The magnetic susceptibility (MS) of the sample varies from 286.61 to 461.8 10^{-6} m^3/kg. Three mineralogical phases were determined: gupeite (Fe_3Si) – Fe (81.60-86.87%), Si – (14.63-15.54 %), Mn – (1.06-1.23%), Ti – (1.13-1.25%), P – (0.30-0.42%); schreibersite (Fe_3P) – Fe (73.53-75.65%), P – (13.79-15.27 %), Mn – (5.00-5.28), Si – (6.62-7.29%), Ti – (0.58-1.79%), Cr – (0.36-0.51%) and titanium carbide (TiC) – Ti – (47.48-68.5%). The gupeite is dominated phase. The cosmic origin of the sample is assumed. Gupeite occur in cosmogenic globular particles from the Yanshan area in China (Yu Zuxiang, 1986). The k–T curves of the first run heating in argon are irreversible. The minor decreases in MS at about 470°C reflect the Curie point of schreibersite. The Curie point of schreibersite from Kolyma fulgurite studied by us is 340°C (Plyashkevich et al., 2016). The sharp drop in MS at about 560°C corresponds to the Curie point of gupeite that is very close to Tc of Fe_3Si which is 566-576°C (Ovchinnikov et al., 2016). Heating in air leads to oxidation. The Curie point shifts to a temperature of 620°C which is also traced on the heating curves of the second run which are reversible. Hysteresis parameters before (after) heating are: Jr = 18.6 {8.23) 10^{-1} Am^2/kg; Js = 7.99 (2.80) 10^{-1} Am^2/kg; Bcr = 9.6 (15.3) mT; Bc = 1.2 (15.3) mT. Magnetization decreased after heating while magnetic hardness increased.

Second sample was found in Magadan region near the Jack London lake. Size of sample is 9×6 ×12 cm, the density is about 12 g/cm^3. MS is (0.46–1.05 10^{-6} $м^3$/кг). The chemical composition of the main mineralogical phase is: Fe – 50.5-54.9%, Si – 43.3-49.4 that correspond to Fe_2Si. Phase 2 (Fe-Ti-Al-silicide) is 0.5%. The industrial origin of the sample is assumed. Heating and cooling curves of the bulk sample are irreversible. Heating curves show a minor drop in the MS and Ji at T = 250°C, then growing at T ~ 500°C, and then decreasing at ~750°C. Phase with Tc=750°C formed in the heating process. The bending of the curves at T= 250°C and T=750°C degrees is clearly visible on the curves of the second run also.

REFERENCE PLEISTOCENE SECTION OF THE CENTRAL-KAMCHATKA DEPRESSION: PETROMAGNETISM, MINERALOGY, GEOCHEMISTRY, STRATIGRAPHY

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The section is located in the right bank of the Kamchatka River (158º55,670'E, 54 º 54,654'N). 5 units whose names are borrowed from (Braitseva et al., 1968) are studied. 1) Pliocene Blue clays unit (4.0 m). The magnetic susceptibility (MS) is 3.32–5.57 × 10^{-6} m^3/ kg. 2) Middle Pleistocene alluvial unit (up to 24 m). The MS values range from 1.47 to 7.74 (5.33) × 10^{-6} m^3/kg. 3) Middle Pleistocene Moraine-like unit (up to 18 m). The MS are 4.21-7.50 × 10^{-6} m^3/kg. 4) Late Pleistocene lacustrine-alluvial unit (up to 3 m) with MS varies from 0.99 to 8.41 × 10^{-6} m^3/kg. 5) Late Pleistocene polygenetic unit (35 m). Numerous cryogenic disturbances are typical for this unit. The MS sediments vary from 0.64 to 31.541 × 10^{-6} m^3 / kg. Thermomagnetic data show that the magnetic minerals are magnetites with Tc = 580–600°C and titanomagnetites with Tc = 400–550°C. Fossilized sediments contain lepidocrocite. About 20 interlayers of ashes of various compositions are in unit. Geochemical data indicate that the ashes are basaltic-andesite (3 interlayers), andesite (3), dacite (8) and rhyolite (7) compositions. Magnetic properties of ashes are not homogeneous: The MS = 0.6–14.7 × 10^{-6} m^3/kg; Js = 0.06-1.42 Am^2/kg, Jrs = 0.004–0.06 Am^2/kg, Bc = 1.2–34.8 mT, Bcr = 14.6–80.7 mT. Magnetic particles are mainly multidomain, rare are pseudo-single domain. According to microprobe and thermomagnetic analyzes three type of titanomagnetites are in the ashes: titanomagnetites or magnetites with insignificant admixture of Ti (first percentages) and Tc = 580–600°C; titanomagnetites with a Ti > 20% and Tc=- 40–105°C; titanomagnetites with a Ti =2–15% Tc= 380–500°C. Titanomagnetites include an admixture of Al (up to 1.5%), Mg (up to 1.5%), Mn (up to 1%), V (up to 0.5%), Cr (up to 0.5%). Titanomagnetites with low Tc (80–105°C) are stable to heat. Each sample of the ash includes 2–3 phases of titanomagnetites. Among the two phases, the phase with a high Tc is not stable to heating in argon, while the phase with a low Tc is not stable to heating in air. The distribution of the magnetic characteristics along the section is complex. Humus sandy loams of the middle and lower parts of the cover polygenetic unit with lowest values of MS are correlated with marine isotope stages 3 and 5. Sandy sediments with high values of MS, probably, were deposit during cold stage 2 and 3.

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AMS STUDIES OF THE LOWER PALEOPROTEROZOIC DIKES OF KARELIAN CRATON

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The study of the anisotropy of the magnetic susceptibility (AMS) of dike swarms within Precambrian blocks of the Earth's crust allows for typification of dikes that are close in age but differ in composition. To conduct research within the northwestern part of Karelian craton, five groups of Paleoproterozoic dikes were tested: NNW gabbronorite dikes 2.45 Ga, NW diorite dikes 2.4 Ga, NW dolerite dikes 2.4 Ga, EW dolerite dikes 2.3 Ga and EEW dolerite dikes 2.1 Ga.

The main objectives of the study were (1) to typify, based on the AMS study, age-related but different in chemical composition and dike orientation, and (2) to identify by the degree of AMS of the presence or absence of secondary changes in magnetic minerals.

As a result of thermomagnetic analysis, it was established that all samples of the Paleoproterozoic dikes studied by the magnetizing carrier magnetite are magnetite with isometric grains. Linear textures prevail in gabbronorite dikes; the maximum degree of anisotropy doesnot exceed 12%. There is an increase in the degree of anisotropy from the central parts of the dikes to the contact parts. The maximum axis of the ellipsoid of magnetic susceptibility has a SW direction and moderate angles of incidence (30-40°). In diorite dikes, the planar type of anisotropy is predominant. The anisotropy is weak, up to seven percent. The maximum axis of the ellipsoid of magnetic susceptibility has a NW direction and moderate angles of incidence (30-40 degrees). In the dolerite dikes of the NW strike, the planar anisotropy type predominates. Anisotropy is weak, up to six percent. The maximum axis of the ellipsoid of magnetic susceptibility has SE direction and gentle angles of incidence. In dikes of the age of 2.3 Ga, a linear type of anisotropy is established at the contacts of the dikes with host rocks, while a planar type is fixed in their central parts. The maximum axis of the ellipsoid of AMS is NE and moderate angles of incidence (30-40°). In the dolerite dikes of the age of 2.1 Ga, the linear type of anisotropy predominates, but it is also isometric. The degree of anisotropy does not exceed 10%. The maximum axis of the ellipsoid of magnetic susceptibility has NW direction and moderate angles of incidence (30-40°).

As a result of the research, the dikes were typified on the basis of the study of the anisotropy of the magnetic susceptibility. Also, the magnitude of the degree of anisotropy of the magnetic susceptibility for some dikes revealed the presence of superimposed processes.

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THE NEW PALEOMAGNETIC DATA FROM UDJA UPLIFT (NORTHERN SIBERIA)

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In spite of the fact, that during the last two decades some number of new paleomagnetic poles, more or less meeting the modern standards of quality [Van der Voo, 1993], have been obtained for Neoproterozoic of Siberia [Metelkin et al., 2016, 2010, Pavlov et al., 2015], the problem of the Neoproterozoic segment of the apparent polar wander path (APWP) for Siberia, rest still to be far from from its solution. The latter, obviously, hampers the elaboration of Neoproterozoic paleogeographic reconstructions, solution of numerous other important tasks of the Earth Sciences.

There is still significant uncertainty regarding the trend of APWP in the time interval 950-520 million years. This uncertainty is largely due to a lack of reliable paleomagnetic data for this time interval. Therefore, there is an urgent need to get new reliable paleomagnetic data for the Neoproterozoic.

In this report we present new paleomagnetic data from magmatic and sedimentary rocks, of the Late Meso - Neoproterozoic age, exposed in the region of the Udja uplift (Northern Jakutia).

Our paleomagnetic data (in consistency with previously published data of geochemical studies [Gladkochub et al.,2008]) indicate the occurrence of two magmatic events. The paleomagnetic pole correspondinding to the first phase of mafic magmatism (“Unguokhtah event”) has coordinates: Φ=-30.3˚; Λ=86.3˚; Dp/Dm=5.3˚/2.9˚ and is located next to the paleomagnetic pole of the Unguokhtah formation (Mesoproterozoic of the Udja uplift): Φ=-30.0˚; Λ=71.7˚; Dp/Dm=6.5˚/3.6˚. The paleomagnetic pole of the second phase of mafic magmatism (“Udja event”) has coordinates: Φ=-4.2˚; Λ=84.9˚; Dp/Dm=5.8˚/3.1˚ and lies relatively close to the paleomagnetic pole from Neoproterozoic Udja formation, which has coordinates: Φ=-9.9˚; Λ=66.4˚; Dp/Dm=6.6˚/3.3˚. Our paleomagnetic data from Udja formation and from second magmatic event are generally consistent with the early published paleomagnetic data from the region [Rodionov, 1984; Konstantinov et al.,2007].

Our paleomagnetic poles, fall into the central and northern part of the Indian Ocean, and globally support the version of the «Indian Ocean» trend [Shatsillo et al.,2006; Pavlov et al., 2015], in contrast to the «Pacific» trend [Smerthurst et al., 1998] of Neoproterozoic segment APWP.

THERMOMAGNETIC EVIDENCE OF TERRESTRIAL NATIVE IRON IN LACUSTRINE SEDIMENTS FROM BASALTS: ZHOMBOLOK VOLCANIC REGION, EAST SAYAN MOUNTAINS (RUSSIA)

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The particles of native iron, previously discovered by thermomagnetic and microprobe analysis in sediments of different ages from various regions of the world are of extraterrestrial origin. The similarity of the composition, shape and size of native iron particles of terrestrial and extraterrestrial origin testifies the uniform conditions for the genesis of iron particles during the process of planet formation. The article is dedicated to the only case of occurrence of iron particle of terrestrial origin in the lake sediments from Zhombolok volcanic region, East Sayan Mountains (Russia). The exclusivity of the results indicates a very limited distribution of native iron particles from its source - a volcanic eruption and / or fall of a large space body such as a meteorite.

PETRO- AND PALEOMAGNETIC STUDIES ON EARLY PRECAMBRIAN MAFITES/ULTRAMAFITES OF THE KUN-MANIE COPPER-NICKEL DEPOSIT

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Investigations of recent decades have identified in the early Precambrian structures of the southeastern Aldan-Stanovoy Shield the North Stanovoy metallogenic province. The discovery of large accumulations of copper-nickel with platinum and apatite-titanomagnetite ores within the province indicates its high potential. The geological and geochronological data obtained so far made it possible to recognize a stage of late Paleoproterozoic mafite-ultramafite magmatism (1.76-1.69 Ga) represented by numerous and extensive areas and swarms of dikes, sills, occasionally small stocks forming the Dzhugdzhur-Stanovoy belt of minor intrusions.

New petro- and paleomagnetic data on Paleoproterozoic mafites/ultramafites from the Kun-Manie ore field located on the eastern flank of the Pristanovoy collision belt are obtained. The aim of obtaining petro- and paleomagnetic characteristics for two different morphogenetic types of intrusions in the Kun-Manie complex was: to assess stages of the mafite-ultramafite magmatism and the timing of its formation, as well as to look for new, more efficient and economically advantageous methods of research (location) of structures of this type.

The completed petro- and paleomagnetic investigations have successfully correlated the orientation of the principal axes of the ellipsoid of the anisotropy of initial magnetic susceptibility with the attitudes of the intrusions studied. Two stages of igneous activity are recognized in the Paleoproterozoic, one of which is associated with the intrusion of sills and the other with the intrusion of dykes. The coordinates of the paleomagnetic pole have been calculated. Its position corrected for the opening of the Vilyui rift is close to the 1700-1720 Ma interval of the APW path of the Siberian Craton, which is in good agreement with available geochronological data.

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“FOLD TEST” IN THE MONOCLINE

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Paleomagnetic research is a process comprising several steps, one of which is to constrain the age of magnetization of rocks since this is necessary for the development of correct geodynamic models for the formation of certain regional- and global-scale tectonic structures.

A paleomagnetic fold test as a field test is one of the major methods of constraining the age of magnetization. However, in the field we can often observe monoclinic dipping of sedimentary rock strata, which does not allow us to carry out a classical paleomagnetic fold test and to constrain the age of magnetization.

This paper presents a brief summary of methodology and preliminary results of the fold test in sedimentary rocks with monoclinal dipping.

Brief description of techniques employed. After folding, the azimuth and the angle of strata dip at different points of one and the same fold limb (or monocline) differ to some extent (by ≈ 5-20 °). This is due both to the lithological characteristics and conditions under which folding proceeds. This is generally ignored during paleomagnetic studies since the average value of the attitudes for several observation points, as a rule, coincides with the average dip of strata in the limb of a fold or a monocline.

If we take into account that the difference in the dip direction of sedimentary rock strata in one and the same fold limb is the result of folding, then for each sample in the monocline we can measure the individual dip azimuth and dip angle of the stratum and, thus, perform a sort of a paleomagnetic fold test in the monocline. The main difficulty is to determine individual azimuths and angles of dipping of the stratum at the sampling point. For this purpose, the data on the anisotropy of the initial magnetic susceptibility of rocks are well suited, which is often associated with the shape of the geological body: coordinates of an axis of the anisotropy ellipsoid of the initial magnetic susceptibility coincide (are in close agreement) with the dip azimuth and dip angle of the stratum.

Studies carried out following the above procedure show an increase in the tightness of grouping of the ancient magnetization component from 17 to 40% in one limb of the fold (monocline) with the known “pre-fold” magnetization. An increase in the tightness of grouping was observed in all studied samples from various geological structures: sandstones and siltstones of the southern Sikhote-Alin and Solonker zone.

The work was supported by the Russian Science Foundation (project no. 16-17-0016).

ARHEOMAGNETIC STUDIES OF FIRED CERAMIC OF DMITROV SLOBODA-I SETTLEMENT (VLADIMIR REGION, RUSSIA)

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This work is devoted to the archeomagnetic study of samples of the fired ceramics of Dmitrov Sloboda-I settlement in order to obtain data of the geomagnetic field intensity. Settlement Dmitrov Sloboda- I is located in the Murom district of the Vladimir region on the northern periphery of Murom town. The archeological monument belongs to the Pozdnyakov culture and dates from the middle of the second millennium BC. During the investigation the 14 fragments of fired ceramic of Pozdnyakov culture were studied. Examination of a composition of a ferromagnetic fraction present in the demonstration collection, consisting of 7 archaeological samples, were carried out by powder X-ray diffraction method. X-ray phase analysis of the magnetic fraction showed the presence of magnetite which was single-phase oxidized up to maghemite and hematite. To obtain the values of ancient geomagnetic field intensity, experiment was carried out using the modified Telier method [Thellier, Thellier, 1959; Coe, 1978]. The pTRM check-points at temperatures of 300, 400 and 500°C were created on all fragments of ceramics [Peterson at al., 2014]. Also, repeat magnetic field-free heaters at temperatures of 150, 250, 350, 450 and 550°C, so called pTRM check-tail, were created on all samples of the collection to test changes in the composition of magnetic carriers at blocking temperatures above the TRM creation temperature [Peterson at al., 2014]. As a result of the studies, the data of the geomagnetic field intensity recorded in eleven fragments of ceramics from the archaeological site Dmitrov Sloboda - I were obtained. The geomagnetic field intensity varied within ~ 40-77мT in the middle of the 2-nd millennium BC. This work was supported by RFBR, project № 16-05-00378.

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ARHEOMAGNETIC STUDIES OF NEOLITHIC CERAMICS OF VEKSA 3 ARCHEOLOGICAL SITE (VOLOGDA REGION, RUSSIA)

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The work is devoted to the study of magnetization of samples of fragments of pottery of the Veksa 3 archaeological site in order to obtain data about the geomagnetic field intensity in the Neolithic in the center of the Russian Plain. The archeological complex of Veksa is located 20 km north-east of Vologda. The investigated collection of samples is represented by fragments of ceramics of various Neolithic cultures: Kargopol, Lialovo, Modlona, Modlona II. Two duplicates of 17 fragments of ceramics were investigated. The age of fragments of pottery was determined from C^{14} according to the deposit on the ceramic vessel, on the ceramics itself, along the soil with coals and along fireplaces. The study of the composition of the ferromagnetic fraction was carried out by the Curie point's determination on the curves of the saturation magnetization on temperature dependence. Thermomagnetic analysis of the magnetic fraction showed the presence of magnetite and singl-phase oxidized magnetite. Laboratory studies were carried out using the modified method of Tellier [Coe, 1978] with the control of possible changes in the ability of the sample to acquire a thermal remanent magnetization by measuring the so-called pTRM check-point and pTRM check-tail [Peterson at al., 2014]. As a result of the studies, data were obtained about the change of the geomagnetic field intensity recorded in the fragments of pottery of the Veksa 3 monument in the VI-III millennium BC. The geomagnetic field intensity in this time interval varies mainly in the range of ~35 - 60 μT.

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PALEOMAGNETISM OF THE DEVONIAN BASALTS AND REDBEDS AT THE BYKOVSKAYA STRAIGHT (MOUTH OF LENA RIVER, EASTERN SIBERIA)

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We have collected paleomagnetic samples from Late Devonian (Famm.) basalts and sedimentary redbeds at the Bykovskaya Straight (Lena River delta). Most samples carried interpretable paleomagnetic signal. Three paleomagnetic components have been isolated: A+A', C, and D. The magnetization of the overwhelmed majority of Late Devonian samples from the Bykovskaya Straight has been reset by modern (or Late Cenozoic) geomagnetic field (component A+A'). The sole site was characterized by the presence of Late Devonian magnetization component it its samples. The virtual pole, calculated from this component, can be used (combined with other virtual poles) to determine the position of the Late Devonian pole for Siberian craton. Studied sedimentary rocks were characterized by the presence of a metachronous syn-folding component. The comparison of the correspondent pole with European reference Apparent Polar Wander Path permits concluding that the folding in the region took place during Middle-Late Jurassic (160-170 Ma).

ROCK-MAGNETIC AND PALEOMAGNETIC CHARACTERISTICS OF THE STOLB ISLAND (DELTA OF LENA RIVER)

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The Stolb island is one of largest island in the Lena Delta represented by monoclinic sedimentary section from kalkarenites, dolarenites and sandstones, which have generally quartz-feldspar composition with a large proportion of carbonate material. The age of these rocks according to biostratigraphic data from Late Frasnian to Early Famennian. The section includes 37 lithological packets, which were characterized through magnetic susceptibility (k), natural remanent magnetization (NRM) and anisotropy of magnetic susceptibility (AMS).

Usually NRM is variated from 1 to 10 A/м. Value of k is 1.5 × 10-4 SI in average. Their variations from packet to packet are synchronous and these characteristics are depend upon concentration of magnetic fractions that typically for detrital magnetization. The rocks has a flat type of AMS always. The arrangement of Kmax and Kmid axes in the plane of deposition indicates to the stress absence and primary orientation of the magnetic detritus to be kept. But for 4 packets, the ellipsoids of AMS are oriented perpendicular to the bedding, which is probably due to slumping and stirring of sediment during its precipitation. Thus, rock-magnetic variations of the Stolb island can be associated with insignificant changes of concentration of magnetic detritus only and so paleomagnetic signal is probably primary.

The paleomagnetic directions were obtained through thermal demagnetization. There are two components in the remanence. Viscous magnetization destroyed upon heating to 280°C. The second regular component is more stable and unblocked between 300-520°C. The inclination of this remanence is always positive. In generally after heating up to 520°C the NRM is too low for precise measuring or could a raise as result of mineral alterations. In generally after heating up to 520°C the NRM is too low for precise measuring or could a raise as result of mineral alterations. The paleomagnetic pole for stable remanence is slightly differ from Devonian poles for Siberia and additional studies needed yet to find causes of it. In any case, reported results are preliminary and cannot lead to ultimate interpretation.

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MAGNETIC PROPERTIES AND CONCENTRATION OF HEAVY METALS IN SOILS OF THE KRASNYIKUTTOWN (SARATOV REGION)

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In the territory of the Krasnyi Kut town located in the Saratov region complex petromagnetic and ecological and geochemical researches of a soil cover have been conducted. Totally in the town boundaries 24 soil tests was taken in which the petromagnetic properties (magnetic susceptibility, a FD factor, thermomagnetic effect) have been selected. Also mobile forms of heavy metals was defined (Cu, Cd, Cr, Ni, Pb, Zn). The main objectives of this work was establishment of interrelations between petromagnetic and geochemical parameters of soils and verification of application of a petromagnetic method when carrying out environmental monitoring in the urbanized territories.

Measurements of magnetic susceptibility and its frequency dependences were carried out to laboratories petrophysicists of SSU (Saratov) on the multifrequency kappabridge – MFK1-FB, definition of concentration of mobile forms of heavy metals was carried out to laboratories of geoecology of SSU (Saratov) on the atomic absorption spectrometry (Quantum-2AT). The received results have been used at creation of graphic applications by means of the complex program Surfer 8.0. As a result of the conducted field, laboratory and desk researches the main results of researches can be reduced to several conclusions:

1. Calculation of a FD factor has shown that its values vary ranging from 1,40 up to 6,70%, from average 4,9%. Decrease in values of a FD factor in soils demonstrates violation of process of synthesis of superparamagnetic particles that can indirectly be considered as violation of biogeochemical processes in soils as a result of anthropogenic pollution.
2. The studied magnetic properties of soils in the quantitative expression correspond to values characteristic of this type of soils in natural state, except for northern and southeast parts of the city. Thus, a soil cover in town boundaries Krasnyi Kut experiences anthropogenic transformation in certain areas of the city, by results of studying of magnetic properties of a soil cover.
3. Significant correlation interrelations between magnetic susceptibility and concentration of mobile forms of lead and copper were established.

ARCHEOMAGNETIC RESULTS FROM CENTRAL RUSSIA

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We present an archeointensity results from European part of Russia which were obtained during the last several years. Groups of the baked brick fragments were collected from the architectural and archeological sites located in Novgorod, Moscow and Yaroslavl regions. These groups are precisely dated between the beginning 12th and first third of 19th century AD thanks to historical evidences (Russian State archives, First Novgorodian chronicle) and stratigraphy context.

Prior to the intensity experiments, we studied for all fragments from collections the temperature variations of the low field magnetic susceptibility using a MFK1F kappa-bridge with a CS4 temperature control unit (Agico, Czech Republic). Also we investigated of isothermal remanent magnetization (IRM) acquisition and hysteresis loops by MM VFTB (Peterson instruments, Germany) and VSM (LakeShore, USA). Additionally, for a more clear identification of ferromagnetic minerals the experiments Lowrie [Lowrie, 1990] were conducted. Archeointensity data have been obtained when using the protocol, which had been developed for three axis magnetometer “Triaxe” [Le Goff, Gallet, 2004] and takes into account both TRM anisotropy and cooling rate effects.

Comparison of results obtained with nearly coeval data from Europe (Genevey et al., 2008) yields some additional constraints on evolution of geomagnetic field during the second millennium AD.

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PALEOMAGNETISM OF THE DOLERITE SILLS OF THE NORTHERN UCHUR-MAYA REGION (SOUTH-EAST OF SIBERIA)

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This research was concentrated on the Neoproterozoic dolerite sills (Rainbird et al., 1998) of the northern part of the Uchur-Maya district of the Verkhoyansk fold-thrust system.

A paleomagnetic study of three major sills exposed in the Allah-Yun River valley was carried out.

Processing paleomagnetic collection, which included 80 samples, was held in IPE RAS laboratory by standard procedures. Stepwise thermal demagnetizations were carried out (≤16 steps, to 640°C) by using thermal demagnetizer MMTD-80 and JR-6 magnetometer.

The obtained preliminary paleomagnetic directions, on the whole, correspond to the paleomagnetic directions of the previously studied sills of the south of the Uchur-Maiyay region (Pavlov et al, 1992). This makes it possible to consider objects as promising for further study and confirmation of the Siberia-Laurentia connection in Meso-Neoproterozoic

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FIRST PALEOMAGNETIC DATA ON KEBEKTA GROUP REDBEDS (WESTERN ALDAN SHIELD, LATE PRECAMBRIAN)

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The Kebekta group is distributed on the western slope of the Aldan Shield, in the interfluve of the rivers Chara and Olekma. It is represented by a thick strata (up to 1.5 km) of variegated sandstones and siltstones, at the base of which lie slightly graded conglomerate-breccias. The age of the deposits of the Kebekta group is subject of discussion - it is either paralleled with the upper part of the Udokan supergroup (Kemen group) or with the Purple formation of the Baikal-Patom region, which represents the base of the platform cover of the region. The work [Samsonov S.A. et al., 2015] presents geochronological data on clastogenic zircons from sandstones of the Kebekta group, indicating that its age is less than 2000 Ma.

From the sections of the Kebekta group within the Uguisky graben, was selected paleomagnetic collection, represented by red-colored terrigenous rocks.

In the rocks the presence of three components of magnetization was revealed: a low-temperature (close to the modern field of the region), an mid-temperature (close to the direction of Devonian remagnetization, widespread in the rocks of the Late Precambrian-Paleozoic in the south of Siberia) and a high-temperature characteristic component.

The high-temperature component interpreted as primary, characterizes by low inclinations and a wide spread of declinations. The virtual geomagnetic poles calculated by the high-temperature component are approximated by a large-circle arc, while a part of the selected directions is coherent to the known poles of the Neoproterozoic (~ 750Ma) of the south of Siberia (Nersa igneous complex of Pre-Sayan [Pisarevsky S.A. et al, 2013][Metelkin D.V. et al., 2005]). The poles of the Nersa complex also lie on this circle, differing, at the same time, among themselves by ~ 90°. Directions that fit into the system under consideration, and close to the pole [Pisarevsky S.A. et al, 2013], were obtained earlier on the Purple formation [Shatsillo A.V., Fedyukin I.V., 2011].

In our opinion, a complex of new and published data may be indicative of the close age of the deposits of the Kebekta group, the Purpolsky formation, and the Nersa intrusions. On the other hand, the features of paleomagnetic record in Neoproterozoic Siberian objects unequivocally point to the essential specificity of the geomagnetic field of this time, which requires special studies.

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PALEOINTENSITY DETERMINATIONS ON NEOARCHAEAN DIKES WITHIN THE VODLOZERSKII TERRAINE OF THE KARELIAN CRATON

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The Precambrian period occupies ≈82% of the lifetime of the Earth in its geological history and accommodates all the main formation stages of the Earth as a planet including the emergence of its magnetic field. The main characteristics of the geomagnetic field observed on the Earth surface (its geometry, intensity, reversals and their frequency) reflect the deep geodynamical processes, and the paleomagnetic studies are one of the information sources about these processes. The main problem in investigation of so ancient rocks is proving the preservation of the primary components of natural remanent magnetization (NRM) which have been acquired by the rock at the time of its formation. So for the Precambrian there are only 200 results (≈ 5%) among more than 4000 determinations in the modern world databases on paleointensity (WDB) (http://wwwbrk.adm.yar.ru/palmag/database.html & http://earth.liv.ac.uk/pint/).

The results of paleomagnetic studies and paleointensity determinations from two Neoarchaean Shala dikes with an age of ≈ 2504 Ma located within the Vodlozerskii terraine of the Karelian craton are presented. The characteristic components of primary magnetization with shallow inclinations $I = -5.7°$ and 1.9° are revealed; the reliability of these determinations is supported by two contact tests. Paleointensity values are obtained by the Thellier–Coe and Wilson techniques. The calculated values of the virtual dipole moment (VDM) (11.5 and 13.8)×10^{22} Am^2 are noticeably higher than the present VDM ≈ 7.8×10^{22} Am^2. Turning to all available VDM values presented in the WDB for the Precambrian, we see that the interval 3.0–2.4 Ga contains a group of data with rather high VDM values (4–8)×10^{22} Am^2. The new determinations reported here for the age 2504 Ma near the Archean-Proterozoic boundary are consistent with these data. Thus, our results support the hypothesized by Tarduno et al., 2006; Biggin et al., 2009 existence of a period of high paleointensity in the Late Archaean–Early Proterozoic period. Taking into account a fall of VDM values for younger rocks in the Proterozoic one can suggest the non-monotonic paleointensity variation in the remote geological past. The principle possibility of this scenario was recently demonstrated theoretically by Driscoll, 2016.

NON-RIGOROUS BUT QUICK CALCULATIONS OF PSD-MD STRUCTURES USING THE MICROMAGNETIC APPROACH

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The domain structure (DS) and its transformations play a decisive role in the formation and stability of all types of remanent magnetization of rocks. A rigorous approach to the calculation of DS is based on the methods of micromagnetism, but so far it has been applied only to small PSD grains while the bulk ferrimagnetic fraction is mostly represented by large PSD-MD particles, for which rigorous calculations of DS by the micromagnetic method are too costly. In the past, semi-quantitative calculations of DS were carried out for such the grains following the modified Amar-Kittel scheme, which assumes plane-parallel domains and does not allow to consider more complex configurations such as vortex etc. We propose a method to calculate DS for PSD-MD grains using micromagnetic approach but, in order to save time, the following simplifications are introduced: DS is constructed from uniformly magnetized cubic blocks of arbitrary size and arbitrary direction of the vector Ms which rotates by arbitrary angle between the blocks. The work was triggered by the observation that in some cases saturation remanence M_{rs} decays on heating to almost zero far below the Curie temperature T_c. We assumed that initially grains are highly stressed and the decrease in M_{rs} happens when the stresses decay on heating. Now, summing up the stress uniaxial anisotropy energy, the exchange energy of (assumingly) Bloch DWs between the elementary cubes and the total magnetostatic energy and minimizing the sum by the conjugating gradient method, the DS was determined. Calculations were carried out for initial SD state starting from K=7.1·10^4 (J/m^3). While the anisotropy was strong, K>4.6·10^4 (size 2 μm) and K>2.6·10^4 (5 μm), the DS had the flower structure with the relative M_r≈0.85. Below, at K>2.1·10^4 (2 μm) and K>1.6·10^4 (5 μm), M_r reduces to about (0.5-0.7) due to appearance of vortex-like patterns mixed with small homogeneous domains near the edges. With further decrease in K, the SD core shrinks and marginal patterns increases in number leading to M_r decrease to (0.38-0.26). Finally, at K<1.1·10^4 (2 μm) and K<0.6·10^4 (5 μm), the value of M_r sharply decreases to 0.06 and the DS transforms to a mixture of MD and vortex configurations.

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ROCK MAGNETIC AND PALEOMAGNETIC DATA PROCESSING AND VISUALIZATION ONLINE

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The magnetic measurements are aimed to identify grain size, domain state and other properties of the magnetic minerals in samples. Such measuring instruments, as Kappabridge or Coercivity Spectrometer, output measurement results to files, and user needs to evaluate and visualize them.

There are many programs for data processing and visualization, but the problem is, if someone wants to modify them. GitHub is a web-based version control repository for source code management. The Hypertext Vector Graphing Calculator (available from https://github.com/yaroslav1982/Graphr) is a program in javascript, which calculates measurement results and plots diagrams. Procedures for data calculation are implemented. The user can upload measurement file and convert it to CSV format. The diagrams are plotted from the selected columns of data. Users can combine diagrams, preview results and save them in SVG files.

Future modifications will include capabilities with different formats of measurement files. Users can write new functions in javascript and share them on GitHub (please use the hashtag #Graphr in description).

USING OBSERVED AND PALEOMAGNETIC VARIATIONS FOR GEODYNAMO AND AXIAL DIPOLE THEOREM ESTIMATIONS

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Directly from the observations of 1900–2010, the vortex field associated with the variations of the geomagnetic dipole, which is hidden from the observations beneath the core–mantle boundary, is estimated. The average scale of this field is about d = 60 km and its intensity even at a depth ~d is several times higher than the known value of the potential field. The corresponding averaged variations are 1 μT/ka, consistent with the archeomagnetic and paleomagnetic reconstructions. The obtained average time of the variations is ~3 × 10^4 years for the axial component of the dipole and a few thousand years for the components that are non-symmetric with respect to the rotation axis. Assuming certain periodicity here, we obtain a coarse observational confirmation of the central hypothesis of paleomagnetism stating the predominance of axial dipole under averaging.

Considering the obtained scale d of the vortex field, the observational estimate of the specific power F = 0.2 pW/kg of the geodynamo-driving convection is achieved basing on the new and known scaling laws. Also the estimates are derived for the average magnetic field B = 1 mT, velocity u = 1 mm/s (coincides with the westward drift velocity of the magnetic heterogeneities) and hydromagnetic scale h = 7 km in the liquid core of the Earth. The obtained values are compatible with the local turbulent and global time intervals characteristic of jerks, secular and paleomagnetic variations including reversals.

Using observed and paleomagnetic variations for geodynamo and axial dipole theorem estimations

CONVECTION AND MAGNETISM IN DEEP INTERIORS OF THE EARTH AND PLANETS

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With the allowance for fast rotation, I cardinally simplify the system of equations for the convection similar to that taking place in the core of the Earth and other terrestrial planets. Here, the turbulent convection is not very much above its critical level. Another important fact is that the turbulent transport coefficients are by several orders of magnitude higher than the corresponding molecular values. These features allow the strongly simplified numerical models to be used for the successful approximation of the geodynamo-like systems.

Such hydromagnetic dynamo is only possible at sufficiently powerful convection. In the Earth's core it should mainly be the non-thermal convection very much in excess of its critical level with the molecular transport coefficients. However, in the case of the medium - or large-scale fields, the critical energy level caused by the turbulent transport coefficients is likely to be only slightly below the actual level. This probably explains both the 22-year success of this type of simplified geodynamo models and the energy scaling laws for hydromagnetic fields, which generalize these models. Energy-dependent analytical and observational estimates of hydromagnetic scale sizes, and velocities in the core are presented. These typical parameters are partly in a new way linked to the observed and ancient geomagnetic variations.

The geodynamo-supporting Braginsky's convection (under the crystallization of heavy fraction from the liquid onto the solid core) should be started less than 1 Ga ago whereas the more ancient geodynamo was supported by the compositional convection of another type. The known mechanisms implementing this convection, which differ by the scenarios of magnetic evolution, are reviewed. Thus may help identification of the sought mechanism through the most ancient paleomagnetic estimates of the field's intensity and through the numerical models. The mechanisms of generation and the absence of generation for the primordial and recent magnetic field of the studied terrestrial planets are discussed. The probable scenarios implementing the compositional energy support of convective geodynamo from the time of planet's accretion to present are observed.

Convection and magnetism in deep interiors of the Earth and planets

HYDROMAGNETIC SOURCES AND EXPONENTIAL SPECTRA OF GAUSS MULTIPOLES SINCE 1590

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From 1590 till 2015 we estimate hydromagnetic sources of Gauss multipoles via their logarithmic time derivatives every 5 years using IGRF and gufm1 geomagnetic models. Just below the core-mantle boundary of the Earth, each derivative is equal to the ratio of the value obtained from the magnetic induction equation to the multipole value. Averagely holding this in the entire core, we determine the ratios named as hydromagnetic sources by driving velocity gradients, angles between the geomagnetic field and the velocity field, and to a lesser degree by magnetic diffusivity. For the sources, we propose a new exponential or generation-dissipation spectral analysis. We obtained major exponential decay-grow periods and secular variations, which allow a precise separation of the observed geomagnetic field evolution into intervals of “quiet” and “disturbed” field. Since 1900 the quiet field is characterized by low-amplitude variations of typical frequencies or values of the sources around 1/(66 yrs). The field disturbance starts with an abrupt increase of these frequencies up to ~1/(5 yrs). Afterwards, a brief stabilization occurs at this level followed by an abrupt or stepwise return to “quiet” frequencies.

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PECULIAR MAGNETIC PROPERTIES OF TEKTITE-LIKE IMPACT GLASSES FROM THE ZHAMANSHIN ASTROBLEME, KAZAKHSTAN

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The object of this study was tektite-like impact glasses collected on the surface of Zhamanshin meteorite crater, Kazakhstan (48°24'N, 60°48'E), with the diameter of ~13 km, formed about 1 Ma [Florensky P. V., Dabizha A.I. The meteorite crater Zhamanshin. M.: Nauka, 1980]. Tektite-like glasses, locally called irghizites, occur as sprays, droplets, dumbbells, strips, twigs, fragments up to 3-5 cm long and weighing up to 2-4 g. They most likely formed at the time of a shock-explosive event from the fine spray of a strongly overheated impact melt with an initial temperature of 2500-3000°C, cooling extremely fast, at rates up to ~ 200°C/s. Irghizites show generally very low magnetic susceptibility (K) and natural remanent magnetization (NRM) ranging from 0.6 to $7.0 \cdot 10^{-7}$ m^3/kg and from 2.3 to $286 \cdot 10^{-7}$ Am^2/kg, respectively. Furthermore, over 90% of samples show K and NRM values concentrating near the lower limits of their respective ranges.

For 30 selected samples, NRM was af demagnetized by the field up to 100 mT, followed by similar demagnetization of the anhysteretic remanent magnetization (ARM) acquired in a 100 mT af, 50 µT DC field. NRM/ARM ratio in most samples proved to be very low, < 1, while TRM/ARM ratio is expected to be about 2.5-3 [*cf.* Sholpo L. Ye. Applications of rock magnetism for the solution of geological problems. L.: Nedra, 1977]. Blocking temperatures have been estimated for 10 samples using thermal demagnetization of the 3-axis IRM [Lowrie W. Geophys. Res. Lett. 17, 159 (1990)]. The low-field IRM(100 mT) is the dominant component in all samples and unblocks at 350-450°C. In some cases an intermediate component IRM(300 mT) unblocks between 500-575°C, while in three samples a measurable hard component IRM(1 T) occurs, unblocking only at 675°C. Therefore, the carrier of the low-coercivity IRM component may be titanomagnetite and/or magnetite, while the high-coercivity component is due to a hematite-like phase.

Presence of strongly oxidized, up to Fe(III), iron forms in irghisites is somewhat unexpected, bearing in mind that the latter should have been formed in a high-temperature, strongly reducing environment. Resolving this inconsistency would require further detailed studies; however, one may speculate that the amount of ferromagnetic minerals in irghisites is very low, and thus, only a tiny fraction of total iron needs to be in the Fe(III) form to explain the observed behavior.

This study has been carried out using the facilities of the St. Petersburg University Scientific Park.

SHORT-TERM GEOMAGNETIC DEVIATIONS OF THE HOLOCENE BY THE EXAMPLE OF THE SECTIONS OF THE CHIRCHIK-AKHANGARAN REGION

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For the last 13000 years of relatively short geomagnetic deviations, there is an opinion from the complete denial of them to the postulation of the objectivity of the existence of three deviations – Etruria (2800 years), Solovki (6000 years) and Gothenburg (12000 years).

The Holocene deposits are widely distributed along the valleys of the rivers Chirchik-Akhangaran region of Uzbekistan. Showing geomagnetic structure in the magnetization patterns from sections of holocene sediments of the Chirchik-Akhangaran region shows that deposits of the second terrace in the Keles section magnetized in the direction of modern earth's magnetic field (the average value of the declination is 356^0, the average value of the inclination is 58^0), only at a depth of 0,6-0,8 m in proluvial deposits installed short-polar excursion of the geomagnetic field (maximum value of the declination is 165^0, maximum value of the inclination is 30^0). The holocene deposits of the second terrace in the upper reaches of the Keles river are magnetized along the direction of the modern geomagnetic field (the average value of the declination is 358^0, the average value of the inclination is 58^0), here the polar excursion is not established. The magnetic properties of the Holocene deposits of the second terrace of the Chirchik river basin also have the direction of the modern magnetic field of the Earth (the average value of the declination is 350, the average value of the inclination is 580). However, in several sections in the upper part of the proluvial and diluvial loess sediments a short polar excursion is established (the maximum value of the declination is 178^0, the maximum value of the inclination is 38^0).

Holocene alluvial deposits of the floodplain and the first terrace have a magnetization in the direction of the modern magnetic field of the Earth (the average value of the declination is 5^0, the average value of the inclination is 58^0).

Identification of paleomagnetic levels in the columns of magnetic polarity of the sections studied made it possible to compile a scale of the geomagnetic polarity of the Holocene. Three microchrones of the Holocene (one polar excursion and two reverse episodes) are established. The age of the polar excursion on the thermoluminescent method (TL-method) is determined in 7800 years, the first episode is 5700 years and the second is 1600 years.

NEW PALEOMAGNETIC DATA FROM 2.45–2.1 GA INTRUSIONS OF CENTRTAL KARELIAN AND KIANTA TERRANES (KARELIAN CRATON)

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We present data from Early Paleoproterozoic mafic dykes and Archean host rocks within two terranes in the Karelian Craton, eastern Fennoscandian Shield. Three groups of dykes have been collected within Pyaozero area of Central Karelian terrane: NE–trending ca. 2450 Ma gabbronorite and diorite dykes, NW-trending ca. 2310 Ma dolerite dykes, and NNW-trending ca. 2130 Ma continental MORB-type tholeiitic dykes (Stepanova et al., 2014). Samples from 2130 Ma dolerite dykes within Tulos area of Kianta terrane were also collected.

All studied mafic dykes from the Pyaozero area carried two stable components NRM – high temperature characteristic component, named G, and mid-temperature/coercivity component H. The component G (D=95.3° , I=44°, α_{95}=8.9), which is thought to represent the primary 2450 Ma magnetization of the dykes, has a paleomagnetic pole at 21.3°S, 285.2°E (A95=8.9°, N=9 sites). The commonest intermediate-steep-NNW directed component (H) fixes an extensive Svecofennian remagnetisation (Mertanen et al., 1999) and is interpreted to be ca 1840 Ma. It yields a paleomagnetic pole at Plat=51.7°N, Plong=219.1°E (A95=6.1°, N=14). Baked contact tests for the 2450 Ma dykes is positive, as shown by the absence of component G in host Archean rocks at a distance from the contact. Baked contact test for component H is negative, it indicates regional remagnetization ca 1840 Ma.

The paleomagnetic results for dolerite dyke within Tulos area show that a strong Svecofennian overprinting is pervasive in the area. Dolerite dyke carry only secondary magnetisation, its unbaked host granulites carry intermediate NNW down direction (close to component H in dyke). Mean direction of this component (D=357° , I=44.4°, α_{95}=4.1°). Negative baked contact test indicates regional remagnetization during 1800–1900 Ma Svecofennian orogeny.

According to these data, at 2450 Ma Central Karelian terrane was located at the latitude of ca 30°S. After that, by the time of 2100 Ma, it moved to the moderate northern latitudes with 26° clockwise rotation and reached the tropical northern latitudes with 113° counterclockwise rotation by 1900 Ma. At this time both terranes were located at the same place within a confidential interval.

PALEOMAGNETIC CHARACTERISTICS OF QUATERNARY SEDIMENTS OF THE NURATA SECTION OF UZBEKISTAN

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The Nurata section which is located on the southern slope of the Nurata ridge can serve as the base section among the eopleistocene deposits of Uzbekistan. Here pleistocene deposits are represented by deluvial-proluvial formations and they form upper layers (1-4) with a thickness of 5.0 m, eopleistocene deposits form the middle and lower parts of the section.

The middle part of the section (layer 5) with the thickness of 32.0 m is represented by dense, calcareous, yellowish-brown siltstones, and the lower part of the section (layers 6-8) with a thickness of 15.0 m is represented by alluvial alluvial formations with interlayers and lenses of dense, Strongly calcareous siltstones. The bottom layer (layer 9) is not sustained both on the area, and on a vertical.

The 1750 of oriented samples were selected for paleomagnetic study.

A study of the magnetic properties of rocks showed that the natural remanent magnetization (NRM) of rocks along the section profile varies within the limits $(0,1\text{-}18,0)\cdot10^{-6}$ SGS with an average value of NRM of $3,8\cdot10^{-6}$ SGS

The magnetic susceptibility (MS) of the rocks in the section varies within the limits $(1,0\text{-}2,8)\cdot10^{-6}$ SGS at an average MS value of $2,0\cdot10^{-6}$ SGS. A slight increase in MS values is noted at the top of layer 6, related to subsequent post-sedimentation changes in the rock.

Detailed paleomagnetic studies have shown that the deposits of the section are magnetized by direct and reverse polarity. A total of six reverse and the same directly magnetized horizons are recorded in the section.

The reverse magnetized zones of the section have the following directions. The average value of the declination is 1870, the average value of the inclination is -58^0, and the directly magnetized zones of the section - the average value of the declination is 7^0, the average value of the inclination is 58^0.

In conclusion, we note that this section can serve as a regional paleomagnetic reference section for the eopleistocene deposits of Uzbekistan.

BACKGROUND MAGNETIC COMPONENT OF THE COSMIC DUST, COLLECTED FROM THE PEAT

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Cosmic dust (CD) and micrometejrites (MM) are very small particles of a solid substance of micron size, present in the world space and falling to the Earth. 60 tons of cosmic dust every day settles on the planet Earth. The author has accumulated a great experience of microprobe diagnosis of CD and MM in sedimentary rocks. It was decided to transfer this experiment to peat in order to study the dynamics of the arrival of dust cosmogenic particles on the Earth's surface.

Of particular interest was the microprobe analysis of regions with low Irs values. It turned out that in these zones there is almost no terrigenous magnetic material. Magnetite (Mt) microspheres with a detrital surface, native Fe and a small amount of other native metals were found. These findings were attributed of the CD and MM. The microparticles were collected by a sample of peat with a volume of 1 liter. As a result of this experiment, a significant amount of material was isolated: about 4 mg of magnetic substance and 200 mg of non-magnetic substance of various origins. The magnetic substance was mainly represented by Mt microspheres, native Fe and intermetallides (FeCr, FeW), presumably of cosmic origin. Similar particles can form in other processes, so it is important to have different arguments in favor of this hypothesis. Consider them.

Particles of Fe in form can be conditionally divided into two groups in size: up to 50 microns and more than 50 microns. It is known, that particles with a size of up to 50 μm do not heat up during flight through the atmosphere. Indeed, all the fine particles have sharp, angular shapes, while particles larger than 50 μm have clear signs of melting. These arguments also work in favor of the hypothesis of their cosmic origin. The particles of native Fe could also have a volcanic origin. However, the following considerations work against this argument:

1. In several analyzed layers there is approximately the same number of particles of Fe. This indicates a relatively uniform supply of such particles from outer space. Particles of Fe of volcanic origin arrive impulsively.

2. There are no active volcanoes in the area of the studied peat bog.

3. Some of the Fe particles have very characteristic paths of a few microns in size, which were previously observed in meteorites. As a result, a technique was developed that allows a significant amount of background CD and MM particles to be collected from peat. The study of KP by other methods will yield new fundamental results, including the properties of interstellar CD and MM

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UAV BASED AEROMAGNETICS, ITS PRESENT AND FUTURE

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The idea of using unmanned flying complexes for geomagnetic field measuring was expressed and substantiated in 1995 by St. Petersburg geophysicists and specialists from Australia independently of one another. The obvious advantages of the method are: no risk of human loss, economic benefits, organization simplification, solution of a wide range of geological problems. However, it was only in 2011 that the first real use of UAV complexes took place in Canada. Tue company Sander geophysics together with Carleton University made use of an UAV aircraft (Geosurv II); the sensor was fixed on the forward placed bar. Since 2012 magnetic surveys using UAV aircraft launched by a catapult have been performed in Canada nearly yearly. As early as 2013 a UAV gradiometric survey with sensors fixed on the wing tips was performed. Since 2015 surveys on UAV aircraft have been effectuated in China and Finland. Only once a UAV copter with the sensors towed on a cable was used in Canada (2014). In Russia the development of unmanned aeromagnetometry is concentrated on the use of copters. Irkutsk National Researched Ttechnical University and LLC “Geotechnology Siberia” have succeeded in obtaining data whose quality is not inferior to that of large scale ground magnetic surveys. The copter complex built at Trofimuk Institute of Oil-Gas Geology and Geophysics SB RAS in the most lightweight and compact one not only in Russia but worldwide. It provides possibilities for large scale surveys (1:1000 and even more). Group of companies “Geoscan” (St. Petersburg) announces some success in a similar research.

The most innovative development (there is nothing analogous elsewere) is the creation of a helicopter borne complex with a rigid wing sensor providing compensation for the carrier noise. At present the company “Radar MMS” (St. Petersburg) is testing the complex on a special test site. Research on UAV helicopter based survey in Russia is still in the experimental stage, the method is not used commercially yet.

On the basis of monitoring the state of UAV based geophysics in Russia and abroad performed by geophysicists of Institute VIMS and JSC “Geologorazvedka” since 2012, we can assume that the main consequence of replacing conventional geophysics by UAV geophysics at the stage of exploration and prospecting is the possibility of obtaining detailed survey data by means of UAV, i.e. a final disuse of conventional land based methods, which allows for a drastic reduction of expensive borehole drilling.

PALEOMAGNETISM OF THE SIBERIAN TRAPS INTRUSIONS IN NORILSK REGION: THE PRELIMINARY DATA

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In spite of the long history of the investigation in the Norilsk region, many questions about the genesis of the Cu-Ni-PGE deposits are not solved yet. Ore deposits are associated with two types of the layered intrusions, namely Norilsk and Lower-Talnakh types. Nowadays, 7 Permian-Triassic intrusive complexes are distinguished in this region, belonging to the Siberian Traps province. For the complete reconstruction of the geological history it is necessary to reveal the sequence of the emplacement of the intrusive complexes and their correlation with the volcanic sequence. However, geochemical and isotopic methods singly do not provide the reliable correlation of the intrusions and lavas.

We used the paleomagnetic methods in order to obtain the additional information about the relative age of different intrusions. Based on the comparison of the paleomagnetic directions, the previous paleomagnetic studies allowed to the correlate the Norilsk-2 intrusion with the Morongovsky-Mokulaevsky level of the volcanic pile.

In this work, we carried out the detailed thermal demagnetization of about 400 samples collected during the field work in the summer 2016. Different intrusions demonstrate the quite contrasting paleomagnetic directions. This fact confirms the perspectives of the proposed technique for the distinction intrusive complexes.

Also, the presence of normal polarity in the intrusive bodies of the Ergalakh complex was revealed, which was suggested in [1] but was not proved with the paleomagnetic study of the modern quality. In addition, we obtained the statistically different paleomagnetic directions in the intrusions referred to the same Norilsk type, including the ore-bearing Chernogorsky intrusion..

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NEW DATA ON PALEOMAGNETISM AND GEOCHRONOLOGY OF PALEOPROTEROZOIC INTRUSIVE ROCKS FROM THE KOLA-MURMANSK TERRANE, NE FENNOSCANDIA

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Mafic dyke swarms within the ancient continental terranes (cratons) are the key objects for the Late Archean and Paleoproterozoic plate tectonic reconstructions. Their attractiveness for the paleotectonics is defined by geodynamic position (continental rifting, roots of the large igneous provinces) and usually they are very perspective objects for geochronology and paleomagnetic studies. One of the most successful example of dyke swarms' using for reconstruction of tectonic evolution of the ancient craton is Canadian Shield and, particularly, Fennoscandian Shield. In spite of many new paleomagnetic and geochronological data, obtained recently from Proterozoic intrusions of Karelian craton (Lubnina et al., 2017), numerous dykes of the neighbour Kola-Murmansk block have not been considered in the tectonic reconstructions of these provinces during the Paleoproterozoic due to absent of reliable isotopic ages and paleomagnetic poles. Nevertheless, it was suggested (Daly et al., 2006), that Karelian and Kola-Murmansk Archean provinces of the Fennoscandian Shield existed together as a single tectonic unit during the Early Paleoproterozoic, before and after of the Lapland-Kola orogeny. In the Mid-Paleoproterozoic (~2.1 Ga) Karelian and Kola-Murmansk blocks were separated by the Lapland-Kola Ocean, which existed until the beginning of the collisional events ca. 1.93-1.91 Ga, however the exact time of the opening and closure of this ocean as well as tectonics of the Kola-Murmansk block at the corresponding time interval remain almost unclear.

We present the first preliminary data on paleomagnetism and geochronology of the numerous Precambrian dykes from the Kola-Murmansk block and discuss their applicability for detailed paleotectonic reconstructions of Fennoscandia in the Paleoproterozoic.

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NEW PALEOMAGNETIC DATA FROM THE EDIACARAN VOROGOVKA SERIES (YENISEI RIDGE, SIBERIAN CRATON)

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The Vorogovka Series is a complex of carbonate-terrigenous sedimentary rocks, preserved in small graben-synclinal structures in the northwest of the Yenisei Ridge. Age of deposits, according to different authors, from Neoproterozoic to Ediacaran. However, recent data indicate that the age of sedimentation within the Vorogovka Basin is less than 585 Ma.

Bottom-up in the stratigraphic sequence, the Vorogovka Series is divided into the Severnaya Rechka, the Mutnina and the Sukhaya Rechka Formations. The paper presents the results of paleomagnetic studies of the deposits of the Sukhaya Rechka Formation. Light-gray limestones of the middle part of the section (2 sites, 20 samples) and fine-grained sandstones from the upper part of the section (3 sites, 29 samples) were characterized through rock-magnetic and paleomagnetic analyses.

Vectors of natural remanent magnetization for both limestones and sandstones, by the results of stepwise alternating field (AF) demagnetizations, behave is similar. The median destructive field vary from 10 to 20 mT. The low-coercivity component of NRM destruct by AF demagnetization up to 20 mT and have not regular directions. Its coercitive spectrum is substantially overlapped by the spectrum of the high-coercivity component. But using the Halls method, the directions of high-coercive component for Sukhaya Rechka Formation were established.

The site-means of high-coercive component have the best clustering in stratigraphic coordinates. The maximum K-statistics (Kmax=699) is achieved at 109.8% of unfolding, thus, the fold test shows that the acquired magnetization is pre-folded. The paleomagnetic pole is located at Plat=29.3°; Plon=41°; with 95% confidence radius B95=2.1°. The resulting mean paleomagnetic pole is close to the corresponding poles of the Madagascar group for Siberia in the Neoproterozoic.

The work was supported by the Ministry of Education and Science of the RF (project No. 5.2324.2017/4.6) and the RFBR (project No. 15-05-01428).

ROCK- AND PALEOMAGNETISM OF THE EARLY PROTEROZOIC GRANITES OF THE AT-BASTAKH BATHOLITH (UDOKAN RIDGE)

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The results of a comprehensive study of the Early Proterozoic granites of the kodar complex of the large At-Bastakh massif, which lies on the northeast of the Udokan Ridge, are presented. Granite batholith has a diameter of about 20 km, has a two-phase structure. The dating of the first phase of U/Pb by the zircons method yielded a dating of 1873 ± 3 million years (Larin et al., 2000).

For paleomagnetic analysis, 270 samples of 27 points were sampled. Two components are distinguished in paleomagnetic recording: low-temperature and high-temperature characteristic. On the stereogram, the distribution of the low-temperature component is chaotic, the high-temperature components form a bipolar distribution in the 1 and 3 sectors, the reversal test is positive. The average direction of the high-temperature component coincides with the directions of the NRM of other granite massifs of the same age. Approximately half of the samples have large values of the NRM and AMS. To explain this phenomenon, complex studies have been carried out, including DTMA, electron microscopy, X-ray diffraction analysis, X-ray tomography and strain analysis. As a result, three generations of magnetite have been isolated, one of which is long thin grains that crystallized in the final stages of cooling along the biotite cleavage and can be responsible for the large anisotropy. The preservation of grains of magnetite is good, there are a small number of hematite lamellas. The results of the strain analysis (V.N. Voitenko, SPbSU) indicate a low strain, anisotropy, probably a reflection of the mineral lineation of flow structures in granites.

At present, thermochronological studies are conducted to determine the age of the NRM directions.

The study was supported by the RFBR, grant No. 17-05-01132.

FORMATION OF ENVIRONMENTAL PALEOGEOGRAPHIC CONDITIONS IN EARLY PERMIAN TIME BASED ON PRELIMINARY MAGNETO-MINERALOGICAL INVESTIGATION OF THE "DAL'NIY TYULKAS" SECTION (THE REPUBLIC OF BASHKORTOSTAN, RUSSIA)

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The analysis of Permian climate and paleogeography can be useful in forecasting of the situation in the future. The exposure characterized the boundary between the Sakmarian and Artinian tiers and represented by intercalation of argillites, siltstones, clays, limestones and sandstones. The paleogeographic studies are conducted with application of magnetic methods. The collection of 24 samples has been selected for carrying out the laboratory magnetic and mineralogical analysis. The complex of methods includes measurements of a magnetic susceptibility, hysteresis methods.

The Sakmara stage is characterized by stability of a magnetic susceptibility and remanence coercivity. Throughout an artinsky century the mode of sedimentation is fluctuate because climatic changes have influenced on different nature processes. A possible cause of such changes is the decrease in sea level due to mountain collision. Climate system tended to be more warming with full degradation of the Gondwana glaciation. In certain areas there was very arid climate because mountains prevented the movement of damp air masses. Around an exposure "Dal'niy Tyulkas"near the Ural Mountains an estuary existed .The analysis of flora and fauna on an exposure confirms conclusions of magnetic researches about sea level changes.

The work was carried out according to the Russian Government's Program of Competitive Growth of Kazan Federal University.

PRELIMINARY MAGNETO-MINERALOGICAL STUDIES OF THE LAKE BOLSHOI KISEGACH SEDIMENTS (CHELYABINSK REGION, RUSSIA)

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Lakes are an indispensable element of many modern and ancient landscaping environments. The main factor of determining sedimentation is the climatic conditions that determine the hydrological and hydrochemical regime of water bodies and the predominant nature of sedimentation.

In the summer of 2016 the staff of the IG&PT KFU carried out an expedition to the Bolshoi Kisegach Lake. Based on seismoacoustic studies the central part of the lake with a depth of about 30 m was chosen for drilling. The 5 columns with a power of 2.7 - 5.6 m were obtained using a specialized coring equipment. Samples were selected with step 2 cm.

Initially, for all samples of the cores, measurements of the magnetic susceptibility were carried out. On the basis of the data obtained, the cores were compared and a correlation scheme was constructed.

The spectra of normal magnetization to field of 0.5 T were obtained for all samples of column No. 3. There was used a coercive spectrometer "J_meter". Hysteresis parameters are determined from the curves of normal magnetization.

In order to determine the nature of the changes in the magnetic susceptibility, we found the contribution of its various components - ferromagnetic, paramagnetic and superparamagnetic.

Variations of magnetic susceptibility components and hysteresis parameters characterize sharp changes in climatic conditions at 130 and 480 cm boundaries.

This work was funded by the subsidy allocated to Kazan Federal University for the state assignment in the sphere of scientific activities № 5.3174.2017/4.6, and partially supported by the Russian Foundation for Basic research (grant no. 16-35-00452).

PALEOMAGNETISM OF TSINA COMPLEX - NEW PALEOMAGNETIC POLE

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This paper presents the results of studying the paleomagnetism of the gabbroids of the Tsina complex, which is located in the Olekminsky block of the Aldan-Stanovoi province of the Siberian craton. Selection of collections of samples for paleomagnetic studies was conducted in 2013 and 2016. The investigations were carried to obtain a new paleomagnetic definition of the Siberian Craton, which has a well-defined geodynamic position and isotopic age.

The Tsina massive is a stratified lopolitic body measuring 9x16 km, which breaks the Early Proterozoic formations of the Udokan complex. The age of the rocks of the main part of the massive is estimated by the U / Pb method as 1867 ± 3 million years.

Of the central gabbro-noritic part of the array, 23 sites were sample, and 6 points from the dikes of the Tsina complex near the massif were also tested.

Samples were subject to temperature cleaning until complete demagnetization. In the low-temperature range (up to 250 °), the components corresponding to the direction of the modern magnetic field are singled out on the Zijderveld diagrams. In the mid-temperature interval (250° - 500°), stereograms are distinguished on the stereograms, the intersection of which coincides with the mean direction of the high-temperature component. In the range from 450° to 580°, sometimes up to 620°, high-temperature characteristic components are distinguished in the samples, they form a cluster in the northeast rumba on the stereogram, there are also several samples with antipodal high-temperature components. 18 sites of the central gabbro-noritic part were used to calculate the average direction of the high-temperature component. Average direction: D = 27.2 ^{o} I = -20.4 ^{o} k = 16.6 a95 = 8.7 ^{o}. The pole calculated for this component (Plat = -19.3^o Plong = 90.2 ^{o} dp / dm = 4.8 / 9.1).

To calculate the average direction for dikes, we used 4 sites. Average direction: D = 24.7 ^{o} I = -27.2 ^{o} k = 69.2 a95 = 11.1 ^{o}. The pole calculated for this component (Plat = -16.1^o Plong = 93.7 ^{o} dp / dm = 6.6 / 12.1). The averaged pole along these two poles (Plat = -17.7^o Plong = 92.0 ^{o} A95 = 10.1) falls into the very beginning of the Early Proterozoic APWP of the Siberian craton and coincides, within the confidence ovals, with the poles we obtained earlier on granitoids of the Kodar complex and gabbro-diabases of the Kuranakh complex of the Olekminsky block of the Aldan-Stanovoi province . Thus, it can be assumed that starting from about 1870 million years, the Olekminsky block was already a single unit and did not undergo a configuration change.

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CONTENT

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