Paleomagnetic data of the Siberian Mesoproterozoic rocks (Udzha and Olenek Uplifts, Northern Siberia)

Pasenko A.M.[1], Malyshev S.V.[2], Savelev A.D.[2]

[1] Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences, Moscow, Russia
[2] Saint-Petersburg State University, St. Petersburg, Russia

email: pasenkoal@ya.ru

Introduction

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 Mesoproterozoic of Siberia – [Evans et al., 2016]. The problem of the Precambrian segment of the apparent polar wander path (APWP) for Siberia, rests still to be far from its solution.

The latter, obviously, hampers the elaboration of Precambrian paleogeographic reconstructions, solution of numerous other important tasks of the Earth Sciences.

The Late Precambrian key section of the Udzha Uplift seemed to be one of the most promising object to elaborate the Mesoproterozoic segment of APWP of the Siberian platform. Until recently, the rocks composing this section have been considered to be of the Mesoproterozoic and Vendian age.

During last several years we have carried out the paleomagnetic studies of Late Precambrian rocks of the Udzha and Olenek Uplifts including the Mesoproterozoic Udzha and Unguokhtakh formations as well as intrusions representing two Mesoproterozoic magmatic events, and Neoproterozoic Khaypakh Fm of the Olenek Uplift (fig. 1).

For a long time, on the basis of paleontological data [Semikhatov, Serebryakov, 1983], it was believed that the Khaypakh and Udzha Fm formed simultaneously in the Neoproterozoic. However, recent isotopic data cast doubt on this correlation. The paleomagnetic method will help to clarify the correlation schemes of Precambrian sedimentary rocks in northern Siberia.

Methods

Paleomagnetic studies were carried out in the Laboratory of the Main Geomagnetic Field and Petromagnetism at the Institute of the Physics of the Earth (Moscow, Russia) according to the standard method [Butler, 1998]. All samples were thermally demagnetized. The paleomagnetic measurements were conducted using a 2G-Enterprise cryogenic magnetometer and a JR-6 spinner magnetometer (AGICO). Heating was performed in a MMTD-80 (Magnetic Measurements Ltd., Aughton, UK) thermal demagnetizer.

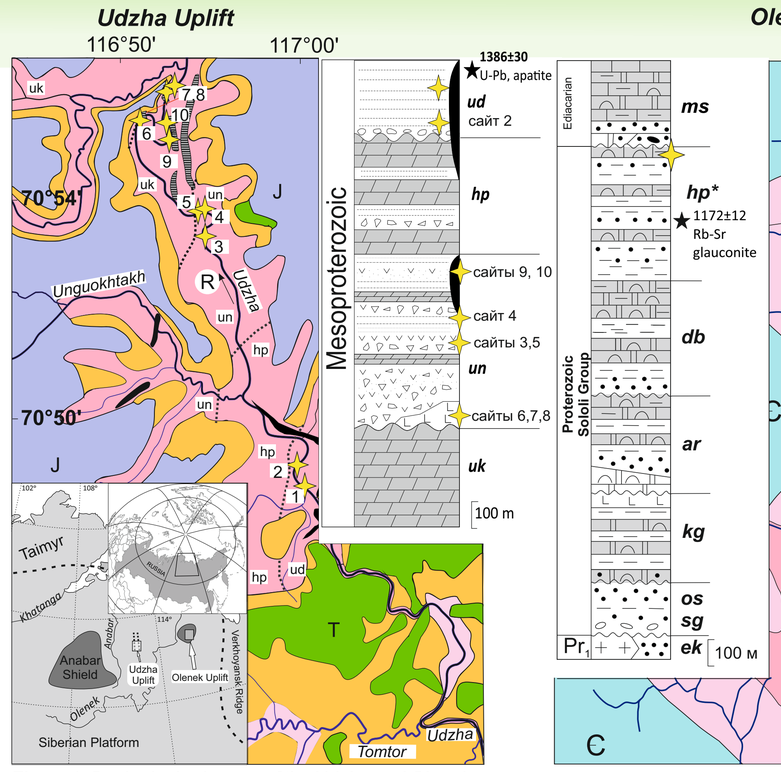

Figure 1. Geological schemes of the Udzha and Olenek Uplifts according to [Gladkochub et al., 2009; Explanatory Note ..., 2016]. The formations of the Udzha Uplift: uk - Ulakhan-kurung; un - Unguokhtakh; hp - Hapchanyr; ud - Udzha. Formations of the Olenek Uplift: ek - Eekit; sg - Sigynahtakh; os - Osorkhay; kg - Kyutyungin; ar - Arymass; db - Debengda; hp * - Khaypakh; ms - Maastakh.

Figure 2. The results of thin-section studies of sedimentary and igneous rocks of the Udzha Uplift.
No. 212 - detrital titanomagnetite of the Unguokhtakh Fm with decay structures. No. 212a - a melted lithoclast in the tuff of the Unguokhtakh Fm. No. 281 - skeletal crystal of titanomagnetite. No. 284 - heterophase oxidation structures in a titanomagnetite crystal. No. 283 - fine lattice of heterophase oxidation in a titanomagnetite crystal. No. 149a - hematite oolite with quartz grains and hematite cement in sandstone Udzhinskaya suite. No. 149b is a general view of the sandstone section of the Udzha Fm in transmitted light. No. 254 - detrital titanomagnetite in siltstones of the Unguokhtakh Fm. No. 254 is a general view of the siltstone of the Unguokhtakh Fm in transmitted light with parallel nicols. Accepted abbreviations: Ilm - ilmenite, TiMt - titanomagnetite, Hem - hematite, Q - quartz.

Results

Based on the results of the studies, the following data were obtained:

Udzha, Unguokhtakh and Khaypakh Fm:

middle- and high-temperature (MT and HT) magnetization components are isolated (table 1). The primary nature of the HT-components is due to their stability and bipolar distribution. For the Unguokhtakh Fm is the positive reversal test (γ / γc=0.8° / 10.3°, McFadden, McElhinny, 1990). In Unguokhtakh Fm rocks, various magnetic minerals carry the same direction of the HT-component (fig. 2). The difference between the obtained poles from younger ones.

Magmatic bodies:

The isolated HT-components (table 1) are associated, as a rule, with magnetite or titanomagnetite. Thin-sections studies have shown the presence of heterophase oxidation structures in titanomagnetite grains, and there are skeletal magnetite / titanomagnetite grains (fig. 2). This indicates the formation of these grains in the process of primary crystallization. It may indicate the primacy of magnetization.

Table 1. Directions of the magnetization components isolated in the rocks of the Udzha and Olenek Uplifts

		Geographic				Stratigraphic				Paleopole		
Site	**n**	**D°**	**I°**	**K**	**α95°**	**D°**	**I°**	**K**	**α95°**	**Φ°**	**Λ°**	**dp/dm, A95°**
Khaypakh Fm. Limestones (Olenek Uplift) (N 71.1°, E 124.1°)												
HT-component												
Average for samples	**50**	**237.4**	**-13.8**	**19.5**	**4.7**	**-**	**-**	**-**	**-**	**-16.8**	**63.4**	**2.5/4.8, 3.4**
Udzha Fm. Sandstones, siltstones (Udzha Uplift) (N 70.8°, E 117°)												
MTW-component												
1, 2	20	344.0	46.4	10.5	10.6	343.9	46.0	10.1	10.8			
MTE-component												
1, 2	16	131.2	47.9	8.5	13.5	130.0	45.4	9.2	12.8	13.8	161.7	10.3/16.3, 13.0
HT-component												
Average for samples	**38**	**228.7**	**3.2**	**10.0**	**7.7**	**228.9**	**5.3**	**10.7**	**7.4**	**-9.9**	**67.2**	**3.7/7.4, 5.3**
Unguokhtakh Fm. Tuffs, siltstones (Udzha Uplift) (N 70.9°, E 116.9°)												
MTW-component												
3, 4, 5	18	330.7	39.6	11.3	10.8	337.9	45.2	11.1	10.9			
HT-component												
Average for samples	**36**	**217.3**	**-27.6**	**26.1**	**4.8**	**220.9**	**-26.1**	**20.7**	**5.4**	**-27.7**	**71.0**	**3.2/5.8, 4.3**
MTW-component (Udzha and Unguokhtakh Fm, N 70.8°, E 117.0°)												
1, 2, 3, 4, 5	38	-	-	-	-	341	45.6	10.8	7.4	-44.9	141.2	6.0/9.4, 7.5
Magmatic bodies of the Udzha Uplift (N 71.0°, E 117.0°)												
HT-component												
6 (basalt flow)	7	197.4	-33.5	42.2	9.4	-	-	-	-	-36.3	96.4	6.1/10.7, 8.1
7 (basalt flow)	7	220.9	-37.4	33.4	10.6	-	-	-	-	-37.9	69.7	6.6/11.9, 8.9
8 (carbonatite dyke)	7	29.1	10.8	79.7	6.8	-	-	-	-	-21.9	85.5	3.5/6.9, 4.9
9, 10 (dolerite sill)	19	207.6	-25.4	19.1	7.9	211.0	-41.9	21.3	7.4	-39.9	79.2	5.9/9.1, 7.1
Mean Pole	**4**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-34.4**	**82.9**	**14.0**

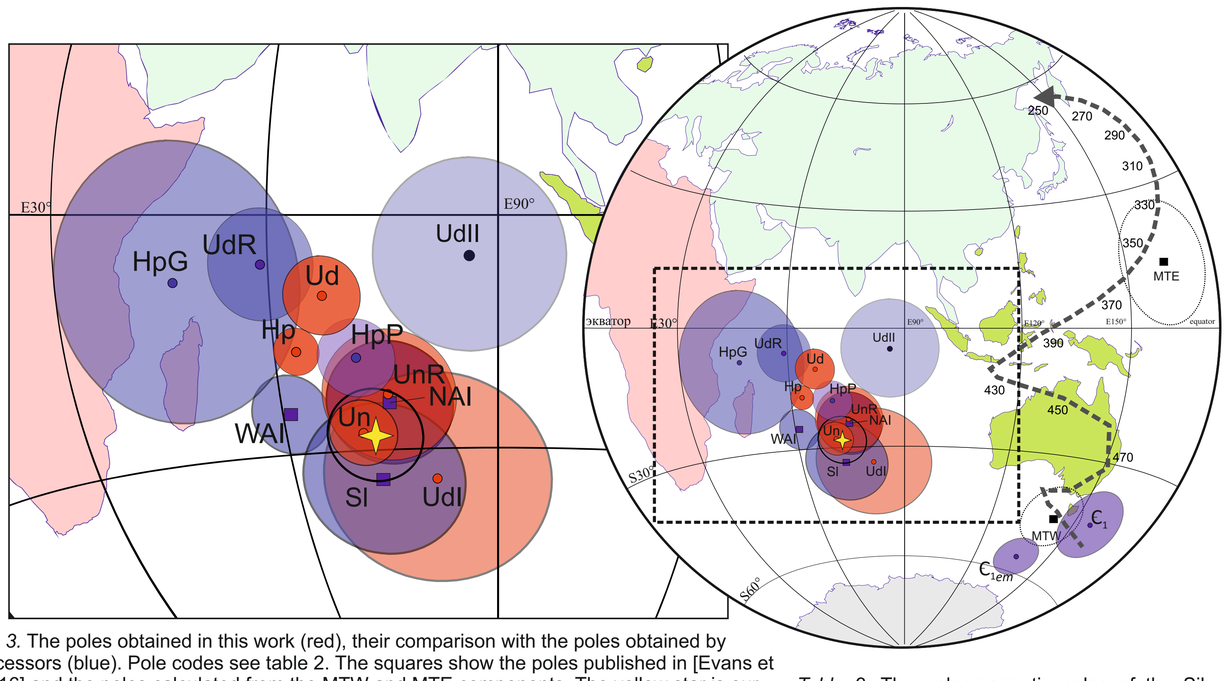

Figure 3. The poles obtained in this work (red), their comparison with the poles obtained by predecessors (blue). Pole codes see table 2. The squares show the poles published in [Evans et al., 2016] and the poles calculated from the MTW and MTE components. The yellow star is our proposed averaged paleomagnetic pole ~ 1500 Ma. The dotted line shows the APWP for the Paleozoic of the Siberian Platform [Torsvik et al., 2012].

Conclusion

- New paleomagnetic poles were obtained for the times of the formation of the Upper Khaypakh Fm, the Udzha and Unguokhtakh Fm of the Siberian Platform (fig. 3).
- On the territory of the Udzha Uplift there are magmatic bodies with an age of ~ 1500 Ma.
- The paleomagnetic poles of the Upper Khaypakh Fm of the Olenek Uplift and the Udzha Fm of the Udzha Uplift do not coincide (fig. 3), which indicates that they formed at different times. This contradicts the accepted correlation scheme for these suites.

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Table 2. The paleomagnetic poles of the Siberian platform obtained in this work and the poles obtained by predecessors.

Object	*Code*	*Age (Ma)*	*Φ*	*Λ*	*A95°*	*References*
West Anabar Intrusions	WAI	1503±2	-25	61	5	[Evans et al. 2016]
North Anabar Intrusions	NAI	1483±17	-24	75	8	[Evans et al., 2016]]
Sololi sill	Sl	1473±24	-34	73	10	[Wingate et al., 2009]
Unguokhtakh Fm	UnR*		-23	75	9	[Rodionov, 1984]
Unguokhtakh Fm	Un		-28	71	4	This study
First Udzha magmatic event	UdI		-34	83	14	This study
Mesoproterozoic intrusions of northern Siberia (WAI+NAI+Sl+Un+UdI)	**NSI**	**≈1500**	**-28**	**73**	**6**	**This study**
Undzha Fm	UdR	R3	-6	59	7	[Rodionov, 1984]
Undzha Fm	**Ud**	**1500-1386**	**-10**	**67**	**5**	**This study**
Khaypakh Fm	**Hp**	**<1030**	**-17**	**63**	**3**	**This study**
Khaypakh Fm	HpP	900-800	-18	71	5	[Pavlov et al., 2015]
Khaypakh Fm	HpG	<1030	-8	47	17	[Gurevich, 1983]
Second Udzha magmatic event	UdII	≈1385	-5	85	11	[Malyshev et al., 2018]
Mean Early Cambrean	$Є_1$	$Є_1$	-44	157	8	[Khramov et al., 1982]
Emyaksa Fm	$Є_{1em}$	$Є_1$	-56	138	5	[Pavlov et al., 2018]