Paleomagnetism of Devonian Rocks in the Ol'doi Terrane, Upper Amur Region

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GEOLOGY

Paleomagnetism of Devonian Rocks in the Ol'doi Terrane, Upper Amur Region

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Deformed thick Paleozoic sequences of the Ol'doi Terrane, sublatitudinally extended along the northern margin of the Amur Superterrane, are considered as fragments of a passive continental margin [2, 4]. To the north, along fault zones incorporated into the South Tukuringra Fault System, they are conjugated with predominantly oceanic formations of the eastern segment of the Mongol–Okhotsk Foldbelt (Fig. 1). In the present work, we first present paleomagnetic poles for Devonian deposits of the Ol'doi Terrane, which are evidence for the significant width of the Mongol–Okhotsk Paleoocean.

A complete section of the Paleozoic deposits of the Ol'doi Terrane is as follows (from the bottom upward): Silurian quartz sandstones, siltstones, and conglomerates (Omutnaya Formation); Lower Devonian (Lochkovian–Emsian) sandstones, siltstones, and limestones (Bol'shoi Never Formation); Lower–Middle Devonian (Emsian–Eifelian) siltstones and limestones (Imachi Formation); Middle–Upper Devonian (Givetian–Frasnian) shales, siltstones, and tuffites (Ol'doi Formation); Upper Devonian (Frasnian–Famennian) sandstones and siltstones (Teplov Formation); and Lower Carboniferous (Tournaisian–Visean) sandstones and siltstones with limestone interlayers (Tipara Formation). In this study, we studied the paleomagnetic characteristics of the Bol'shoi Never, Imachi, Ol'doi, and Teplov formations. Locations of the sample sites are shown in Fig. 1; coordinates of the sites are specified in the table.

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The laboratory investigations were conducted in paleomagnetic laboratories in Irkutsk and Paris. The natural remanent magnetization (NRM) was measured using a JR-4 spin-magnetometer and a CTF SQUID cryogenic magnetometer. Variations in the magnetic susceptibility were controlled using a KLY-2 susceptometer. The thermal demagnetization was conducted using devices with triple protective μ-metal screens. The experimental data were processed using the OPAL-3 automated system [1] and software compiled by R. Enkin [2] and J.-P. Connie (Institut de Physique du Globe, Paris). Statistics in the text and tables represent specimen-averaged values. The averages were calculated based on particular directions observed in three samples (8 cm^3) prepared from each of the collected specimens.

The thermal demagnetization of Paleozoic rock samples is illustrated in Figs. 2 and 3 with the Imachi Formation as an example. The low-temperature component (LTC), present in the overwhelming majority of the samples, is substantially different in the direction from the high-temperature component. In samples from all formations, the LTC is removed at temperatures above 150°–300°C. For 95% of these samples, the LTC is coincident with the direction of the recent remagnetization field in the study region (magnetic declination D = 349°, inclination I = 71°), suggesting the origin of this component in the recent geomagnetic field.

The high-temperature component (HTC) is determined based on rectilinear sectors on Zijderveld diagrams oriented toward the origin of coordinates (Fig. 2). Temperature limits for distinguishing the HTC values (from 150°–300° to 450°–550°C) are comparable for all the formations. According to the experimental data, titanomagnetite is the most probable carrier of natural remanent magnetization. The mean directions of the HTC for each of the formations studied are presented in the table. It is noteworthy that specimens with opposite HTC directions are present in the Imachi (Figs. 2, 3) and Bol'shoi Never formations; we consider this fact as evidence for the primary character of the HTC. The directions for the Ol'doi and Teplov formations at the

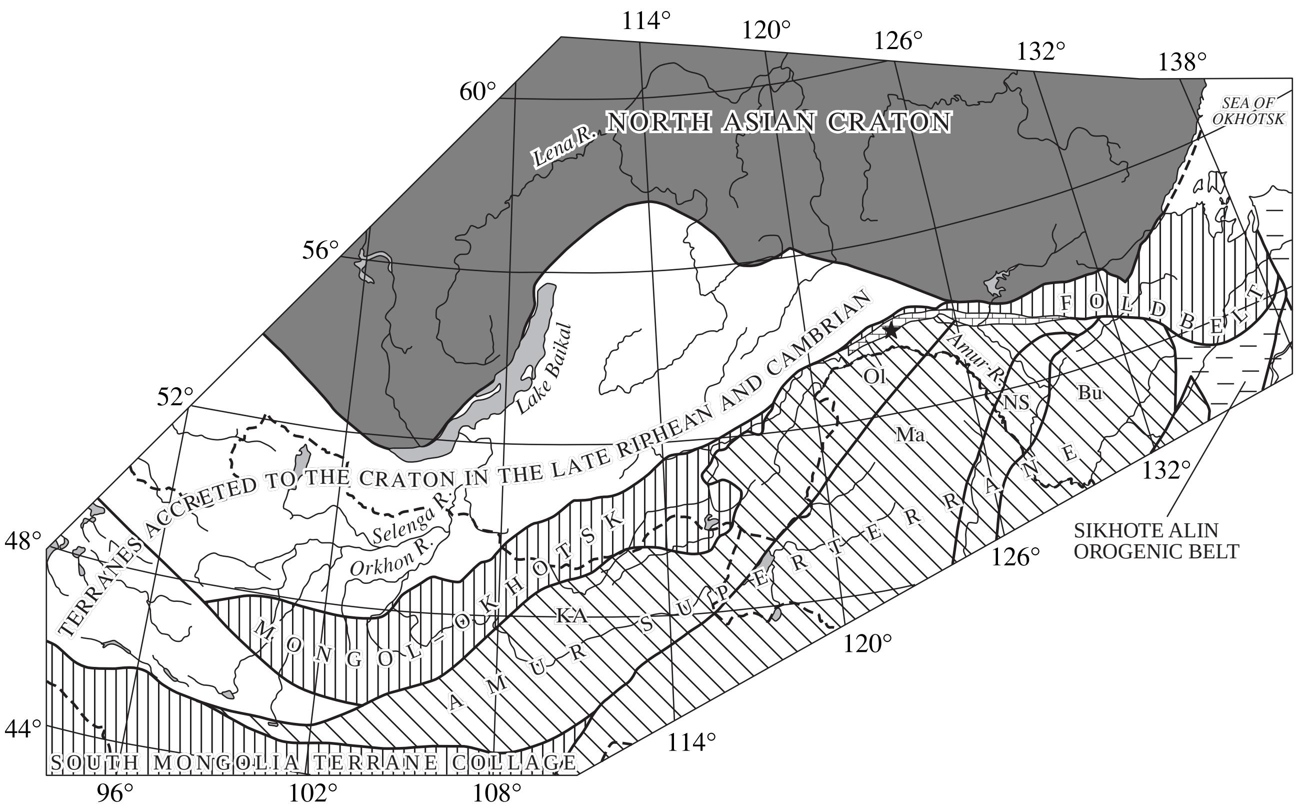

Fig. 1. Schematic map showing locations of the studied objects in the regional tectonic structure (the structural framework adopted from [4]). Terranes of the Amur Superterrane: (Bu) Bureya, (KA) Kerulen–Argun, (Ma) Mamyn, (NS) Nora–Sukhota, and (Ol) Ol'doi. The star shows the sampling site.

sites studied are only characterized by a reverse polarity. The mean directions for all the Devonian rocks studied are consistent with each other (table) and are poorly discriminated within the 95% confidence intervals. At the same time, a small increase in the magnetic inclination (and, hence, in the paleolatitude) is noted for the Teplov Formation as compared to the underlying rocks. This may be evidence in favor of a small successive northward displacement of the Ol'doi Terrane from the Early to Late Devonian.

Mean directions of the natural remanent magnetization vectors of the high-temperature component and their correspondent virtual geomagnetic poles for different sampling sites (coordinates of the sampling area: 54° N and 124° E)

Formation	*n*	*Dg*	*Ig*	*Ds*	*Is*	*c*	α_{95}	*N*/*R*	Coordinates (latitude and longitude) of the paleomagnetic pole	*dp*/*dm*	Paleolatitude
Bol'shoi Never, D_1bn	13	119.5	−37.4	–	–	10.9	13.1	2/11	–		
		–	–	122.6	−7.7	9.5	14.2		21.7/8.8	7.2/14.3	3.9 ± 7.2
Imachi, D_{1-2}im	19	140.5	−6.4	–	–	6.0	14.9	7/12	–		
		–	–	140.5	5.4	7.2	13.4		24.5/348.3	6.7/13.4	−2.7 ± 6.7
Ol'doi, D_{2-3}ol	8	131.1	−6.4	–	–	8.3	20.5	–/8	–	–	
		–	–	132.6	11.2	7.2	22.1		18.4/354.5	11.4/22.4	−5.7 ± 11.4
Teplov, D_3tp	6	140.2	1.4	–	–	11.2	20.9	–/6	–	–	
		–	–	140.8	−18.6	20.8	15.0		35.7/354.1	8.1/15.6	9.6 ± 8.1

Note: (*n*) Number of oriented specimens involved in the statistics (we commonly used the average for each of the specimens based on three samples); (*Dg* and *Ig*), the magnetic declination and inclination, respectively, of the mean direction of the component for a sampling site in the geographic coordinate system; (*Ds* and *Is*) the same, in the stratigraphic coordinate system; (*c*) clustering; (α_{95}) confidence interval with a probability of 95%; (*N*/*R*) numbers of the samples with the normal (*N*) and reverse (*R*) polarities; (*dp*/*dm*) half-axes of the confidence ellipses for a probability of 95%. The values *D*, *I*, α_{95}, *dp*, and *dm* are presented in degrees; the *c* value is nondimensional.

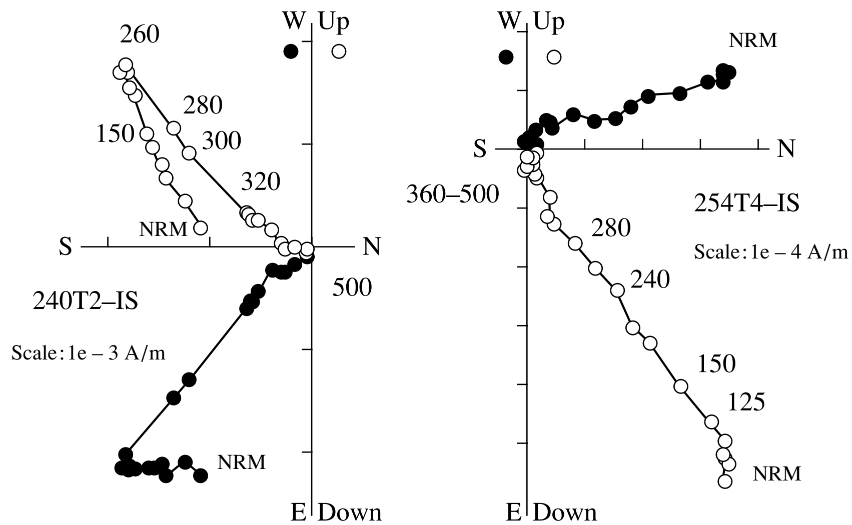

Fig. 2. Diagram of the thermal demagnetization of samples of the Imachi Formation (Sample 240T2 with a normal polarity and sample 254T4 with a reverse polarity). The filled and open circles are projections of the magnetization vector, on the horizontal (N, E, S, and W) and vertical (Up and Down) planes, respectively. NRM is the starting point of the experiment. The temperature is indicated in Celsius.

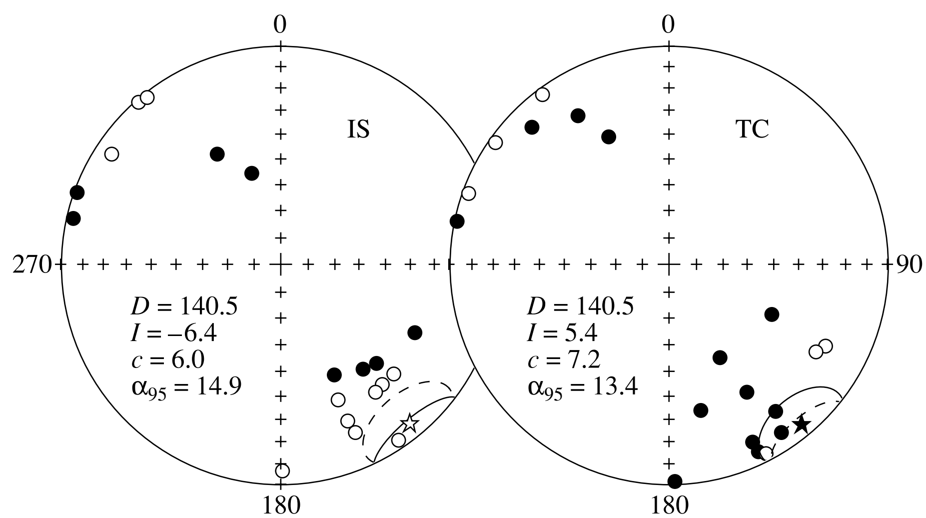

Fig. 3. Distribution of the high-temperature component of the oriented specimens from the Imachi Formation in the recent (IS, in situ) and ancient (TC, tilt-corrected) coordinate systems. The filled and open circles on the stereograms are the normal and reverse polarities, respectively; the asterisk within a 95% confidence interval is the mean direction of the natural remanent magnetization before the laboratory experiments (according to the primary measurement data). *D* and *I*, the declination and inclination, respectively, of the mean direction of the high-temperature component for the site; (*c*) clustering; (α_{95}) confidence interval with a probability of 95%.

The paleomagnetic directions and poles for the rocks studied are presented in the table. Their comparison with trajectories of apparent polar excursion paths (APEP) of the North China Block [8, 11] and North Eurasia [5, 10] are presented in Fig. 4. The paleomagnetic poles are situated near Spain. However, after a displacement along a small circle centered on the sampling point, they coincide with the Middle–Late Silurian and Middle–Late Devonian poles for the North China Block. Since the terrane migrated rather than the pole, such a displacement argues for significant anticlockwise rotations of the Ol'doi Terrane. It should be noted that the Ol'doi Terrane probably rotated when it had already been incorporated into the unified Amur Superterrane. This is suggested by the fact that the direction and amplitude of these rotations are comparable to those revealed for Early Cretaceous andesites (Taldan Formation) in the northern margin of the superterrane [7]. It seems likely that these events were related to the final stage of the Asian continent formation but predated the Indo–Asian collision, because the pole for Late Triassic and Jurassic sediments of the

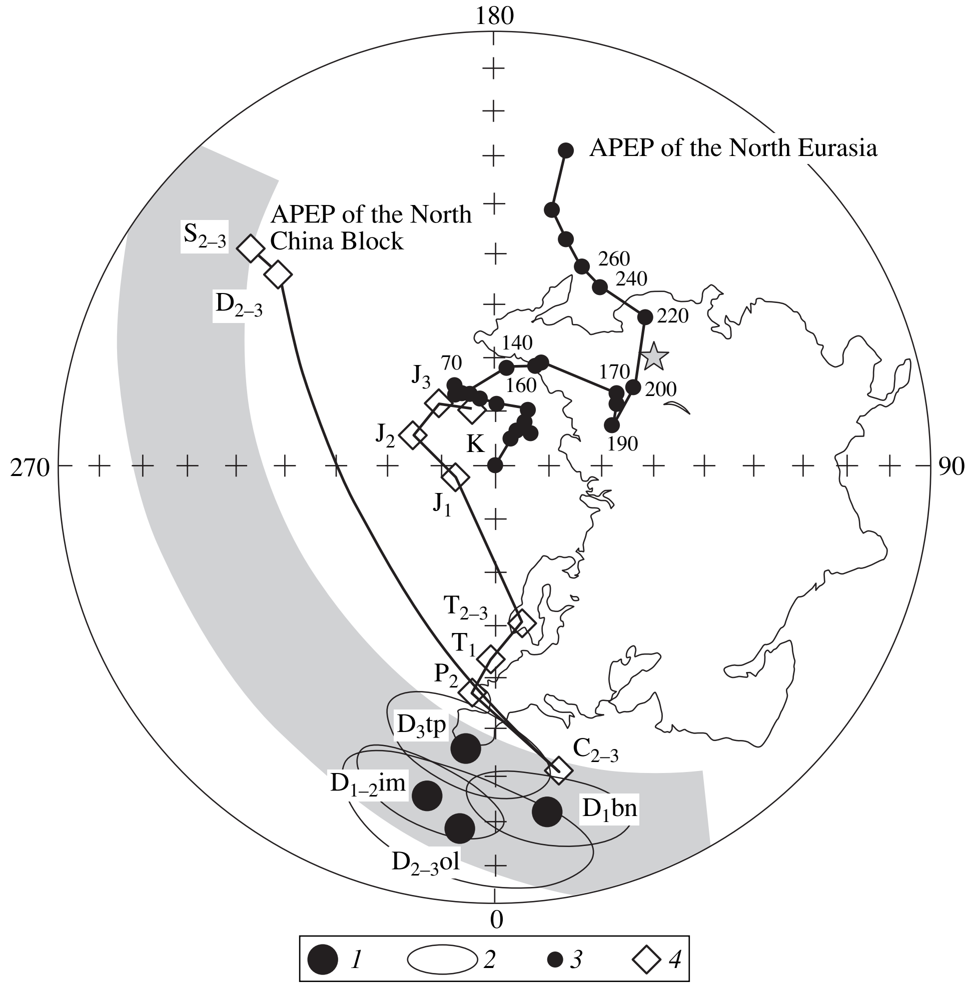

Fig. 4. Positions of the paleomagnetic poles for the Devonian rocks of the Ol'doi Terrane, compared to the reference data for eastern Asia. (*1*) Poles for the Bol'shoi Never (D_1bn), Imachi (D_{1-2}im), Ol'doi (D_{2-3}ol), and Teplov (D_3tp) formations; (*2*) confidence intervals with a probability of 95%; APEP trajectories for: (*3*) North Eurasia [5, 10] and (*4*) the North China Block [8, 11]. Numbers at the points of the trajectory for North Eurasia are the ages (Ma). The APEP trajectory for the North China Block is marked by geological ages (S_{2-3}, D_{2-3}, C_{2-3}, P_2, T_1, T_{2-3}, J_1, J_2, J_3, and K). The shaded band illustrates a possible excursion along the small circle (Euler latitude). The North Hemisphere is presented in an equal-area projection. The asterisk shows the study area.

Upper Amur Depression, obtained earlier based on the metachronic secondary component, has an age of 20–50 Ma and is coincident with the APEP of Eurasia [7].

The subequatorial paleolatitudes obtained for Devonian rocks of the Ol'doi Terrane are not contradictory to the character of fauna therein (corals, bryozoans, crinoids, and trilobites). At the same time, according to the available paleomagnetic data, the North Asian Craton in the Devonian was rotated by 180° relative to its present-day position, and its recent southern margin was situated at latitudes of 50°–60° N [9, 10]. Thus, the margins of the North Asian Craton and Amur Superterrane, which are now separated by the Mongol–Okhotsk foldbelt structures, were at a distance of no less than 3500–4000 km from each other in the Devonian. In the Late Paleozoic and Early Mesozoic, according to the data available, the North China Block and individual blocks of the Amur Superterrane (including the Ol'doi Terrane) progressively moved northward toward the southern margin of the North Asian Craton [3].

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