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Paleomagnetism of the Lower Cambrian from the Lower Lena River Valley: Constraints on the Apparent Polar Wander Path from the Siberian Platform and the Anomalous Behavior of the Geomagnetic Field at the Beginning of the Phanerozoic

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Abstract—Detailed paleomagnetic studies of Lower Cambrian reference sections of the Siberian platform were performed; the sections are located within the Chekurovka and Bulkur anticlines in the northeasternmost part of the Siberian platform. The bulk of rocks composing the sections studied (including volcanic flows of basic composition) is shown to have been completely remagnetized by the Mesozoic geomagnetic field. The overprinting time coincides (with certainty in the Chekurovka section and with a high probability in the Bulkur section) with the period of fold–thrust deformations that took place in the study area at the end of the Cretaceous and were associated with the formation of the Kharaulakh segment of the Verkhoyansk fold area. Two possible interpretations of the inferred paleomagnetic directions are discussed. It is shown that, regardless of the interpretation variant, the resulting paleomagnetic poles are well consistent with the apparent polar wander path (APWP) proposed by Besse and Courtillot [1] for "stable Europe." The Late Jurassic pole from the Konder Massif (new data) and the average Permo–Triassic pole from the Siberian platform [37] also lie in the close vicinity of the segments of this curve of the respective ages. This result implies that, at least from the end of the Paleozoic, the North Eurasian plate has behaved like a rigid body (within an accuracy of the paleomagnetic method) and the European APWP can be used as a reference path for the Siberian platform. Based on the results of the paleomagnetic studies, ancient components having the "Khramov" and "Kirschvink" directions were identified in rocks of the Upper Vendian–Lower Cambrian part of the Chekurovka section, stratigraphically located below volcanic flow. The existence of the Kirschvink direction being questioned by some researchers, this result is independent evidence for its reality and is thereby of great importance, because the Kirschvink direction and the related pole form a cornerstone of the inertial interchange true polar wander hypothesis [13], implying a substantial (by about 90°) and rapid (over 20–25 Myr) displacement of the Earth's rotation axis relative to the Earth's surface at the beginning of the Phanerozoic.

INTRODUCTION

Notwithstanding repeated attempts to localize the Early Cambrian paleomagnetic pole of the Siberian platform, this problem is still unsolved. In the mid-1980s, after several paleomagnetic determinations, more or less self-consistent and close to the Middle–Late Cambrian poles of the Siberian platform, had been performed [11], Kirschvink and Rozanov [12] reported a paradoxical result indicating the possibility of a considerable (by more than 65°) shift of the paleomagnetic pole over a relatively short time interval encompassing the Botomian, Toyonian, and (in part) Amginian ages of the Cambrian. Along with certain paleomagnetic data from Australia and North America, the determination by Kirschvink and Rozanov served as a basis for the hypothesis of the inertial interchange true polar wander (IITPW) proposed by Kirschvink *et al.* [13]. According to this hypothesis, a mass redistribution in the lithosphere and mantle in the Early Cambrian changed the Earth's inertia axes: the axis of the maximum moment of inertia became the axis of the intermediate moment, and vice versa. The axis change gave rise to a rapid (over 15–20 Myr) shift of the lithosphere and mantle relative to the Earth's rotation axis, i.e., resulted in a substantial true displacement of the pole over the Earth's surface. This hypothesis and the pertinent paleomagnetic results have been repeatedly criticized, and the very existence of the Kirschvink direction was questioned [21, 35]. Moreover, based on modern instrumentation and methods, Pisarevsky *et al.* [29] published data in favor of the traditional, Khramov position of the Early Cambrian Siberian paleomagnetic pole [11]. However, recent independent results [27] indirectly confirmed the reality of the Kirschvink direction.

Thus, the problem concerning the position of the Early Cambrian pole of the Siberian platform is highly debatable. Its solution is important not only for the ver-

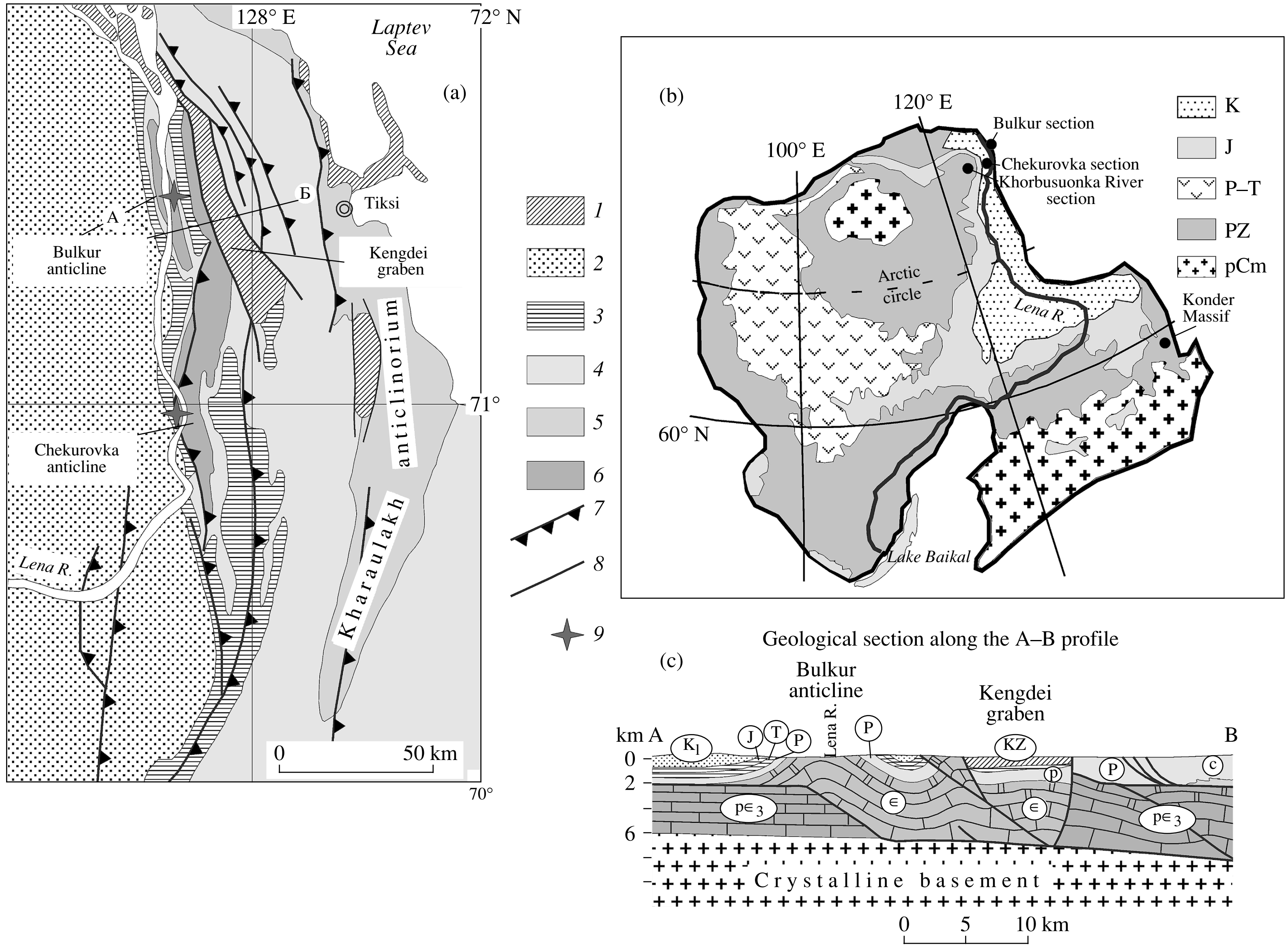

Fig. 1. Geological structure of the study region (a, c) and the geographical position of the study sections (b). Maps (a) and (b) are constructed from data reported in [36]. (a, c) Deposits: (*1*) Cenozoic; (*2*) Cretaceous; (*3*) Triassic and Jurassic; (*4*) Permian; (*5*) Carboniferous; (*6*) Late Precambrian and Cambrian; (*7*) thrusts; (*8*) faults; (*9*) lower Lena River sections studied. (b) K, Cretaceous deposits; J, Jurassic deposits; P–T, Permian–Triassic traps; PZ, Paleozoic cover; pCm, Precambrian rocks (crystalline basement and Riphean cover).

ification of the IITPW hypothesis but also for Late Cambrian–Early Phanerozoic reconstructions, adjustment of the Phanerozoic and Riphean trends of the paleomagnetic poles from the Siberian platform, verification of the hypothesis of the Late Proterozoic Rodinia supercontinent, and so on.

It is important to note that the above paleomagnetic studies displayed another contradiction concerning the polarity pattern of the geomagnetic field in the Early Cambrian. The studies yielding the Khramov paleomagnetic directions indicate that this field was dominated by reversed polarity interrupted by short intervals of normal polarity. On the contrary, the data of Kirschvink and Rozanov imply that geomagnetic reversals in the Early Cambrian were rather frequent and the total lengths of normal and reversed polarity intervals were comparable. Evidently, eliminating this contradiction is of great importance for the construction of the magnetic polarity time scale of the Lower Paleozoic and the elucidation of the Earth's magnetic field evolution in the Phanerozoic.

In 1995–2001, we conducted paleomagnetic studies of Lower Cambrian reference sections exposed in the lower Lena River valley (Fig. 1). The goal of these studies was to gain information on the position of the Siberian craton at the beginning of the Cambrian and to assess the prospects of the sampled rocks for detailed magnetostratigraphic investigations.

Laboratory studies of samples from the Bulkur and Chekurovka anticlines showed that the Cambrian parts of these sections are largely overprinted by the Mesozoic field and this overprinting took place (at least in the case of the Chekurovka anticline) at the time of fold–thrust deformations at the end of the Cretaceous. Along with two known Mesozoic poles of the Siberian platform, the poles derived from the inferred Mesozoic magnetization components were used to clarify the problem of the rigidity of the North Eurasian plate in the Late Paleozoic and the appropriateness of using the European apparent polar wander path (APWP) as a reference curve with respect to the Siberian platform.

In studying the Upper Vendian–Lower Cambrian part of the Chekurovka section, we obtained new data directly related to the position of the Early Cambrian paleomagnetic pole of the Siberian platform. The results of these studies are presented in this paper.

GEOLOGY

During field work of 1995 and 2000, we studied in detail two sections. One section outcrops on the left bank of the Lena River in the area of the settlement of Chekurovka, within the Chekurovka anticline, and the other is exposed a few tens of kilometers to the north on the right bank of the Lena River, upstream from the mouth of the Ulakhan-Aldyarkhai Creek, within the core of the Bulkur anticline (Fig. 1). The sections under study represent the Vendian–Cambrian sequence of sedimentary rocks composing the Kharaulakh Mountains, located in the northeasternmost part of the Siberian platform in the zone of its junction with the Verkhoyansk fold area [3, 30, 32]. The Lower Cambrian rocks unconformably overlie various levels of the Late Vendian Kharayuttekh Formation, whose upper part is represented by limestones and light gray, dark, and occasionally reddish dolomites in the Chekurovka outcrop and by dolomites, black calcareous shales, and limestones within the Bulkur anticline.

The overlying part of the Chekurovka section includes rocks of the Cambrian Tyuserian, Sektenian, and Mayaktakhian formations (Fig. 2). We have not studied rocks of the Middle–Upper Cambrian Ogonyorian Formation, conformably underlain by the Mayaktakhian Formation, and of the overlying part of the section.

In its lower part, the Tyuserian Formation of the Chekurovka anticline is represented by sandstones and gray and greenish brown siltstones giving way upward to red-brown conglomerates with well-rounded pebbles of acidic quartz–feldspar, granite, and orthoclase porphyries of volcanic or hypabyssal origin. Quartz sandstone serves as a cement. The conglomerates are overlain by a diabase lava flow up to 30 m thick underlying limestones and clayey limestones with interbeds of carbonate sandstones. The rocks are colored brown, greenish gray, and occasionally reddish brown. According to Rozanov *et al.* [32], the Tyuserian Formation was deposited during the Tommotian, Atdabanian, and early Botomian ages of the Early Cambrian. The formation is about 200 m thick.

The Sektenian Formation rests conformably on the Tyuserian Formation and consists of massive, detrital (with bituminous nodules), and clayey limestones. Interbeds of marl and argillite are occasionally observed. The rocks are mostly colored grayish green and sometimes light rose. The formation is about 60 m thick and was deposited from the Botomian Age until the second half of the Amginian Age.

The Mayaktakhian Formation is the last of the formations that we studied in the Chekurovka section. This formation, about 60 m thick, is mostly represented by grayish green and red clayey flagstones and was deposited from the end of the Amginian to the end of the Maiskii Age.

Paleomagnetic samples were taken from the lower third of the Tyuserian Formation, exposed in the mouth area of the Ulakhan-Aldyarkhai Creek within the Bulkur anticline (Fig. 2). The lower part of the interval sampled in this section is represented by light-colored greenish gray and yellowish quartz–feldspar sandstones containing two concordant dolerite bodies.

The contacts of dolerites with over- and underlying rocks, the presence of weathering crust remnants on the surface of dolerite bodies [2], the occurrence of erosion pockets, and the presence of conglomerates immediately overlying dolerites and containing their pebble are

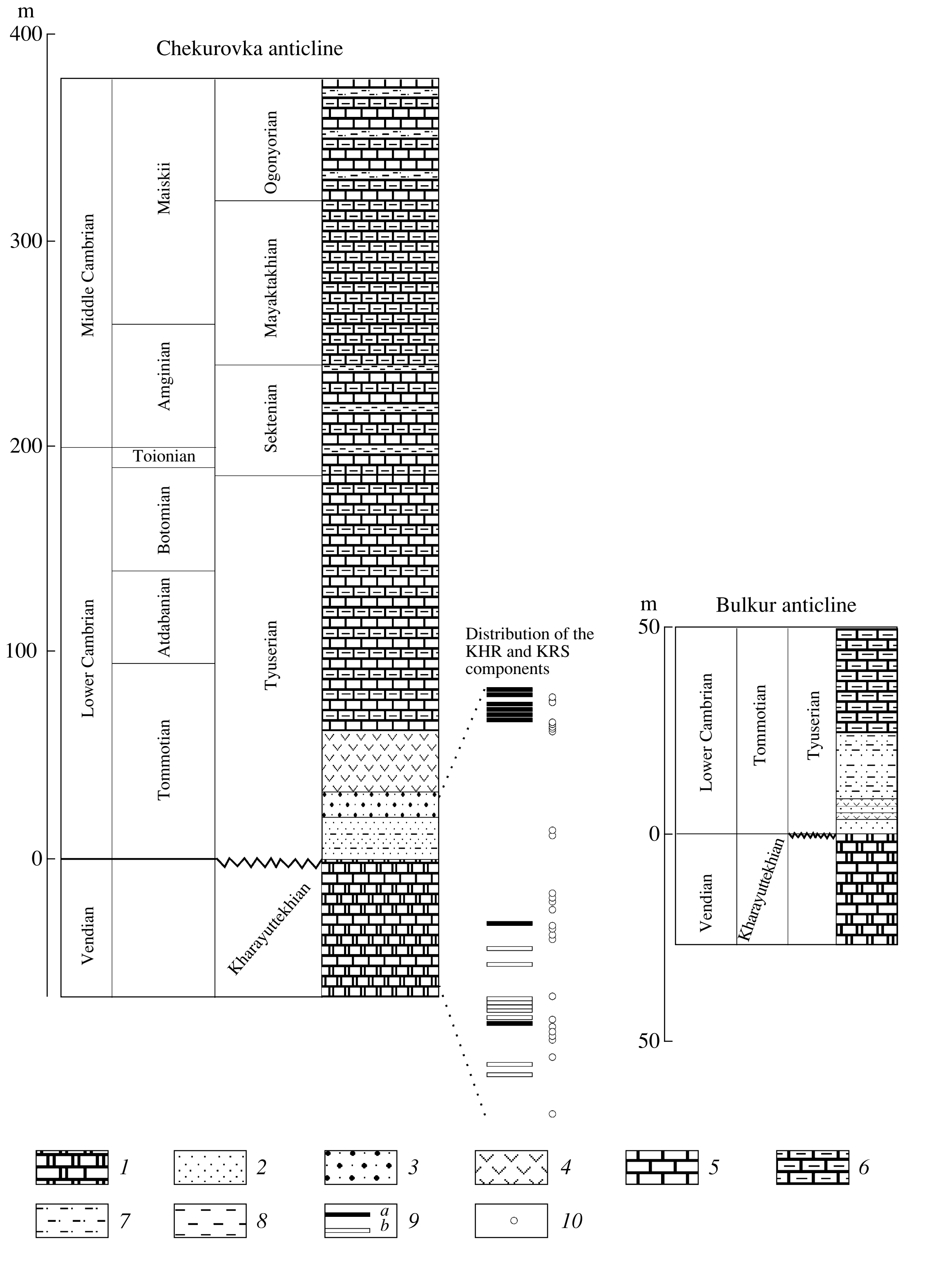

Fig. 2. Stratigraphy and lithology of the sections studied and the distribution of the KHR and KRS components: (*1*) dolomites; (*2*) sandstones; (*3*) pebbles in a sandstone matrix; (*4*) diabases; (*5*) limestones; (*6*) clayey limestones; (*7*) siltstones; (*8*) argillites; (*9*) position of samples with the KRS component of (*a*) normal and (*b*) reversed polarity; (*10*) position of samples with the KHR component.

evidence that the magma bodies in question are volcanic flows rather than sills and are therefore of the lower Tyuserian (Tommotian) age.

Upward along the section, terrigenous rocks give way to clayey massive and lumpy limestone and calcareous siltstones colored greenish gray and brick brown. Rocks of the sampled beds correlate with the lower two-thirds of the Tommotian stage. The overall thickness of the studied interval of the section (including flows) amounts to about 50 m.

The occurrence of rocks in the studied exposures of the Chekurovka and Bulkur anticlines can be characterized, in a first approximation, as monoclinal. The dip azimuths of the sedimentary beds sampled in the Chekurovka section vary within 250°–310°, and their dip angles, within 20°–40°. The respective ranges in the Bulkur section are 50°–90° and 15°–35°.

From the tectonic standpoint, the studied sections belong to the boundary zone between the Siberian platform and the Kharaulakh segment of the Western Verkhoyansk sector of the Verkhoyansk foldbelt (Fig. 1). The Chekurovka and Bulkur anticlines are located virtually at the boundary of the platform, traceable in this region along a N–S trending elongated system of fold–thrust structures.

At least from the Late Precambrian, the territory in question was a marginal part of the Siberian platform and developed under the conditions of a passive continental margin. The collision of the Siberian continent with the Kolyma–Omolon superterrane, starting from the end of the Late Jurassic, led to the formation of the fold structure of the Western Verkhoyansk sector. Starting in the east, the folding advanced westward and was accomplished at the end of the Cretaceous by formation of the system of frontal fold–thrust structures at the boundary with the platform. The Chekurovka and Bulkur folds are constituent elements of this system and are interpreted as ramp anticlines whose formation is related to the westward displacement of sedimentary beds on the basal thrust surface by about 6 km [22]. The basal detachment is supposed to exist between the Upper Precambrian deposits and the crystalline basement according to seismic data and structural relationships [36].

It is noteworthy that the Chekurovka and Bulkur anticlines are actually parts of a coherent large linear fold extending from north to south for more than 100 km. This fold has a gently sloping flexure, and its axis trends NNW in the south of the Chekurovka anticline, farther deviates toward NNE, and regains the NNW strike within the Bulkur anticline.

The time interval of the fold–thrust deformations can be estimated from the following evidence. On the one hand, the youngest of the rocks that experienced folding in the study region are Aptian deposits and, on the other hand, a series of grabenlike basins (Kengdei, Soginsk, and Kungin) lying east of the fault front and filled with Paleocene deposits [36]. This implies that compression conditions existed in the study region at the Early–Late Cretaceous boundary and possibly in the Late Cretaceous and changed for the extension regime by the Paleocene. Thus, the structures under consideration formed at the Early–Late Cretaceous boundary and/or during a considerable part of the Late Cretaceous.

To correctly interpret the paleomagnetic data that can be obtained from rocks composing the Bulkur and Chekurovka anticlines, it is important to have information on possible rotations of these structures relative to the Siberian platform and relative to each other. (We mean rotations of the structures or their elements around vertical axes.) The western flank of the Bulkur anticline is a frontal flattening-out monocline giving way in the west to undeformed deposits of the Siberian platform. No superimposed deformations have been discovered within this monocline, rocks strike here almost parallel to the fold axis, and the axis itself is linear. The Vendian–Cambrian core of the fold outcrops as a continuous, virtually linear band that is not broken by transverse faults, as could be expected if separate parts of the anticline rotated when its rocks were overthrust onto the Siberian platform. Thus, mapping data fairly reliably indicate the absence of any significant lateral (i.e., around vertical axes) rotations of the Bulkur anticline or its parts.

The above considerations are applicable to the southern (paleomagnetically sampled) part of the Chekurovka structure, whose axis is nearly parallel to the axis of the Bulkur anticline. The northern part of the Chekurovka structure, striking differently (Fig. 1), could have rotated through a certain angle relative to the Siberian platform in the overthrust process; however, one cannot exclude that the bending of this part of the Chekurovka structure was due not to rotation but to the presence of some heterogeneities before its front.

Below, we present paleomagnetic arguments that, in our opinion, favor the absence of any appreciable rotations of the Bulkur and Chekurovka structures.

PALEOMAGNETIC ANALYSIS

Methods of Laboratory Studies

Paleomagnetic laboratory studies and preprocessing of their results were performed at the paleomagnetic laboratories of UIPE and IPGP with application of updated modifications of standard methods [5, 7, 11, 14, 19, 20, 34, 39].

All samples were subjected to detailed thermal demagnetization, applied until the complete removal of magnetization in a sample or until the moment when the magnetization value became comparable with the sensitivity level of the measuring instrument; in some cases, heatings stopped when the magnetization vector variation in the demagnetization process became clearly chaotic. Usually, the number of heating steps was no less than 10–12; occasionally, it was even

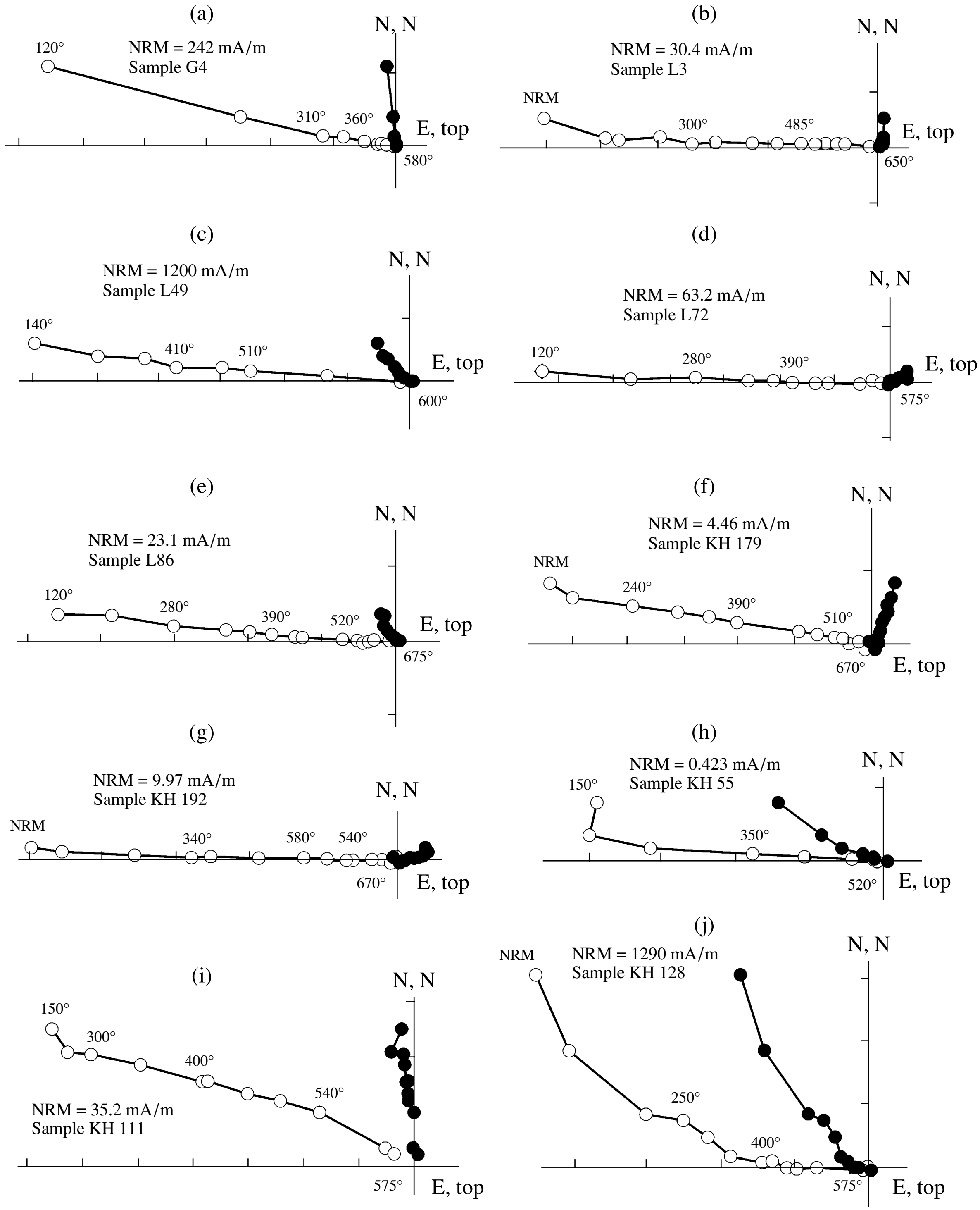

Fig. 3. Zijderveld diagrams: (a–c) samples containing the MZ2 component (Bulkur): (a) pebble, (b) exocontact, (c) flow; (d, e) sedimentary rocks; (f, g, h) samples containing the MZ1 component (Chekurovka); (i, j) Chekurovka samples: (i) flow, (j) exocontact. The solid and open circles are vector projections onto the horizontal and vertical planes, respectively. The diagrams are shown in geographical (a–e) and stratigraphic (f–j) coordinates.

greater. Special nonmagnetic ovens, with an uncompensated field of no more than 5–10 nT, were used for the demagnetization of samples. The remanent magnetization was measured with 2G Enterprises and CTF cryogenic magnetometers. All laboratory procedures were conducted in a room screened from the external magnetic field. The measurement results were treated with the software package of Enkin [7] implementing

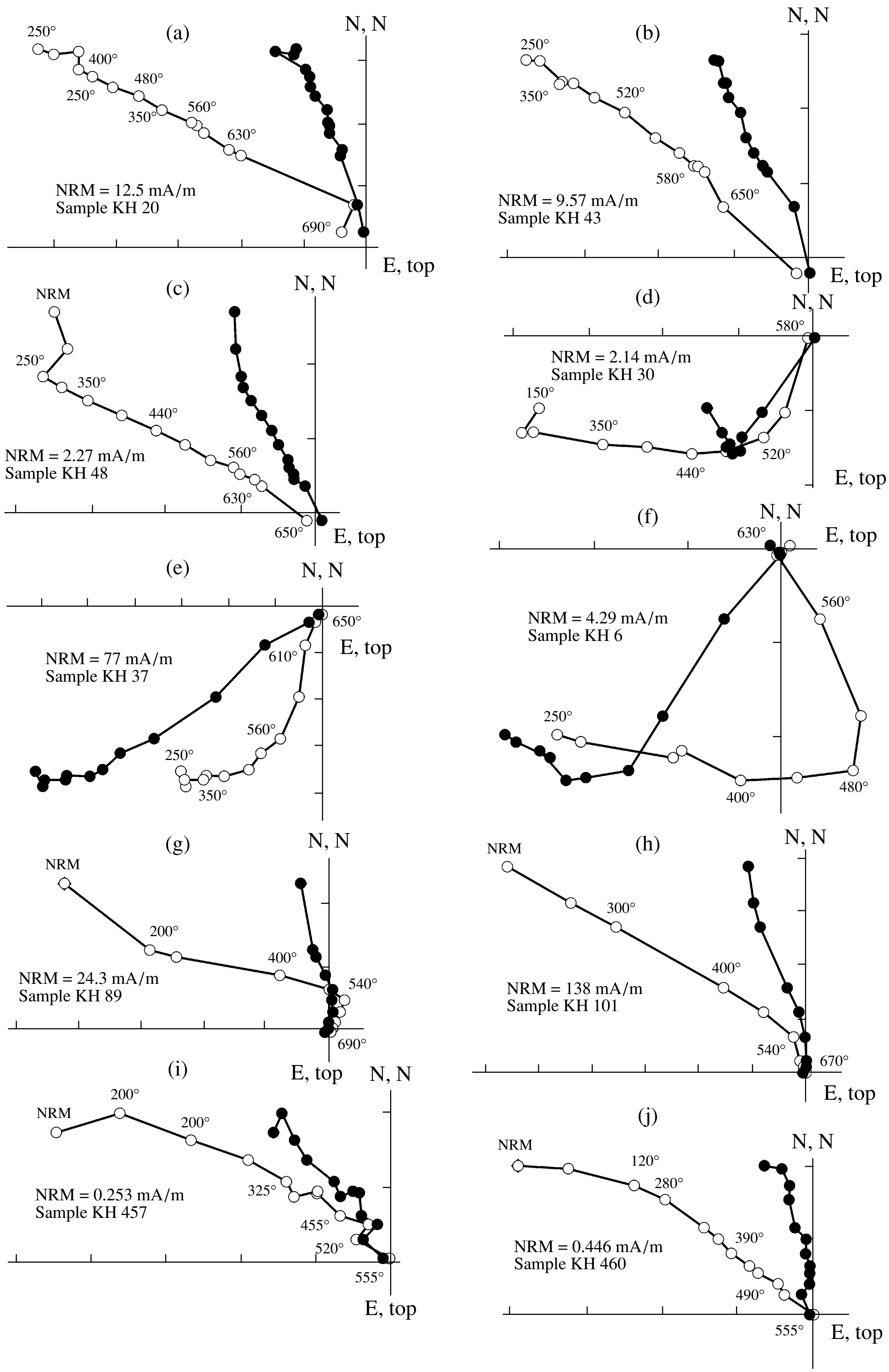

Fig. 4. Zijderveld diagrams in the stratigraphic coordinates: (a–c, i, j) samples containing the KHR component: (a–c) Chekurovka section, (i, j) Upper Vendian of the Khorbusuonka section; (d–h) samples containing the KRS component of the normal (d–f) and reversed (g, h) polarity. The solid and open circles are vector projections onto the horizontal and vertical planes, respectively.

the PCA method [14] for the identification of magnetization components. Intersection points of small circles on stereograms were localized by using the sc100 program of S.V. Shipunov.

Magnetization Components and Distribution of Vectors

Chekurovka Section

Sedimentary rocks. Overall, the rocks of the Chekurovka section are characterized by a complex paleomagnetic record. According to the behavior of the natural remanent magnetization (NRM) vector in the thermal demagnetization process, all samples studied (305 samples) can be subdivided into the following groups.

The first group includes samples with chaotic behavior of the NRM vector, as well as samples whose Zijderveld diagrams, albeit exhibiting some regular features, preclude any reliable identification of magnetization components. Samples of this group have typically small NRM values (~0.2–0.6 mA/m).

The second group includes samples that yield, apart from a low-temperature (recent or laboratory-induced viscous) component, a single component (Figs. 3f–3h) whose vectors in the stratigraphic coordinates have high positive inclinations (~70°) and typically lie in the I and IV quarters of stereograms (Fig. 7a). This component (hereinafter denoted as MZ1) is usually removed in the medium-temperature interval (250–520°C) but in some samples persists until higher temperatures. To simplify the classification, we included into this group the samples in which the MZ1 component is either the most stable or leaves, upon its destruction, an NRM vector that varies chaotically in the process of further demagnetization. Thus, the second group consists of samples in which the MZ1 component is a single identifiable component (apart from the low-stability low-temperature component).

It is interesting to note that the majority of samples of this group were taken from the section interval lying stratigraphically above the dolerite flow and only a minor part of the group belongs to the underlying beds. The magnetization of samples in this group varies from a few to a few tens of mA/m units.

The third group includes samples that yield, apart from the low-stability low-temperature component and/or the MZ1 component, reliably identified more stable components typically destroyed at 500–600°C or higher temperatures (Figs. 4a–4h). The presence of these components is established from linear segments of Zijderveld diagrams directed toward the origin of coordinates in the diagram or from more or less "noisy" remagnetization circles, often starting in stereograms from a region defining the MZ1 component (Fig. 5).

Examination of "final points" (vectors calculated from linear finite segments of Zijderveld diagrams directed toward the origin of coordinates of the diagram) reliably indicates the presence of clusters corresponding to two magnetization components (Figs. 6a and 6b). The vector associated with the center of the first cluster (the corresponding component is denoted below as KHR) has a NNW declination and a moderately steep inclination. The second cluster (the corresponding component is denoted below as KRS) consists of vectors of various polarities that have a NE (SW) declination and a shallow inclination (Figs. 6a and 6b). Although the clusters are well isolated in stereograms, several intermediate points are present between them. Because these points cannot be reliably associated with one of the clusters, they were not included in the calculations of average directions of the clusters (Table 1).

An appreciable number of samples of the third group yielded remagnetization circles (Fig. 5) without "final points," which can be accounted for by either magnetomineralogical alterations associated with heating or weakness of the paleomagnetic signal comparable in value with the sensitivity level of the magnetometer. These circles, as well as the related normals (calculated in accordance with the right-hand rule) and axes, are shown in Figs. 6c and 6d. The majority of the circles (of normal or reversed polarities) are seen to pass through the region of the KRS cluster, but some circles cross the region antipodal to the KHR component.

The intersection region of the circles (in both stratigraphic and geographic coordinates) corresponds to the MZ1 component. Samples of the third group were taken (with rare exceptions) from the lower part of the section, below the dolerite flow, and are most magnetic compared to all of the other samples. Their NRM values range from a few to a few tens of mA/m units.

Dolerite flow and its exocontact. The contact of the dolerite flow with underlying sandstones is hot; the exocontact zone is well defined by a change in the color of rocks, and its visible thickness amounts to 30–50 cm. Fifteen oriented samples were taken from the exocontact zone. The thermal demagnetization results (Fig. 3i) indicate the presence of two magnetization components in the exocontact samples. The less stable component (destroyed in the interval 200–540°C) is close in direction to the MZ1 component of the rocks considered above, whereas the characteristic component (the most stable, directed toward the origin of coordinates in Zijderveld diagrams) has a shallower inclination and is close to the KHR component (see Fig. 3 and Table 1). The structure of the Zijderveld diagrams from exocontact samples suggests that the unblocking temperature spectra of the less stable and characteristic components largely overlap in a considerable portion of samples (Fig. 3i). Therefore, taking into account the closeness of the KHR component, identified in the lower part of the section, to the characteristic component, we believe that the latter is the KHR component contaminated by the MZ1 component.

Thirty samples were taken from various levels of the dolerite flow. Usually, their NRM also includes two

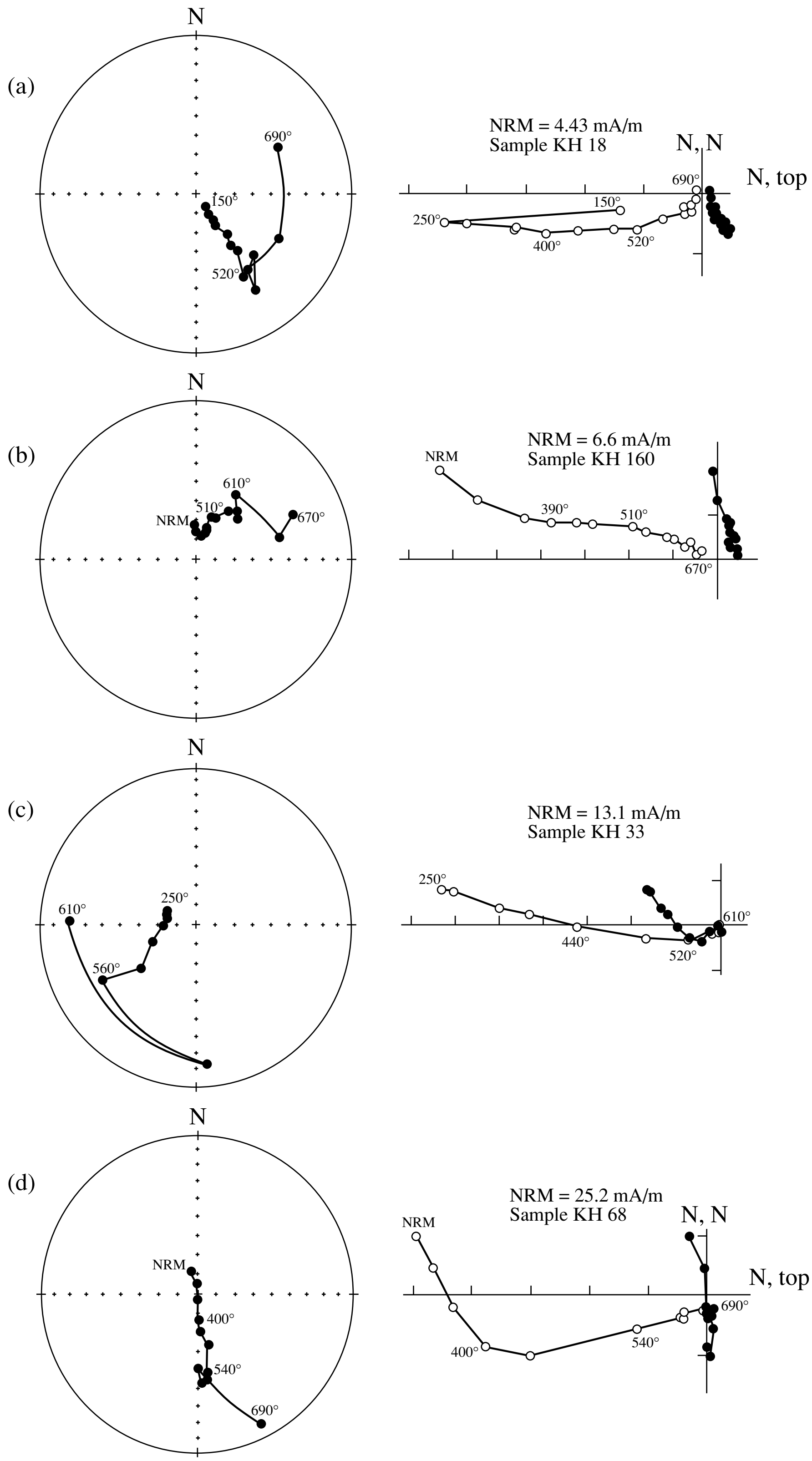

Fig. 5. Khramov (a), Kirschvink (b, c), and intermediate (d) tendencies in the displacements of the NRM vector projections observed during the thermal demagnetization of samples. The solid and open circles are projections onto the lower and upper hemispheres, respectively.

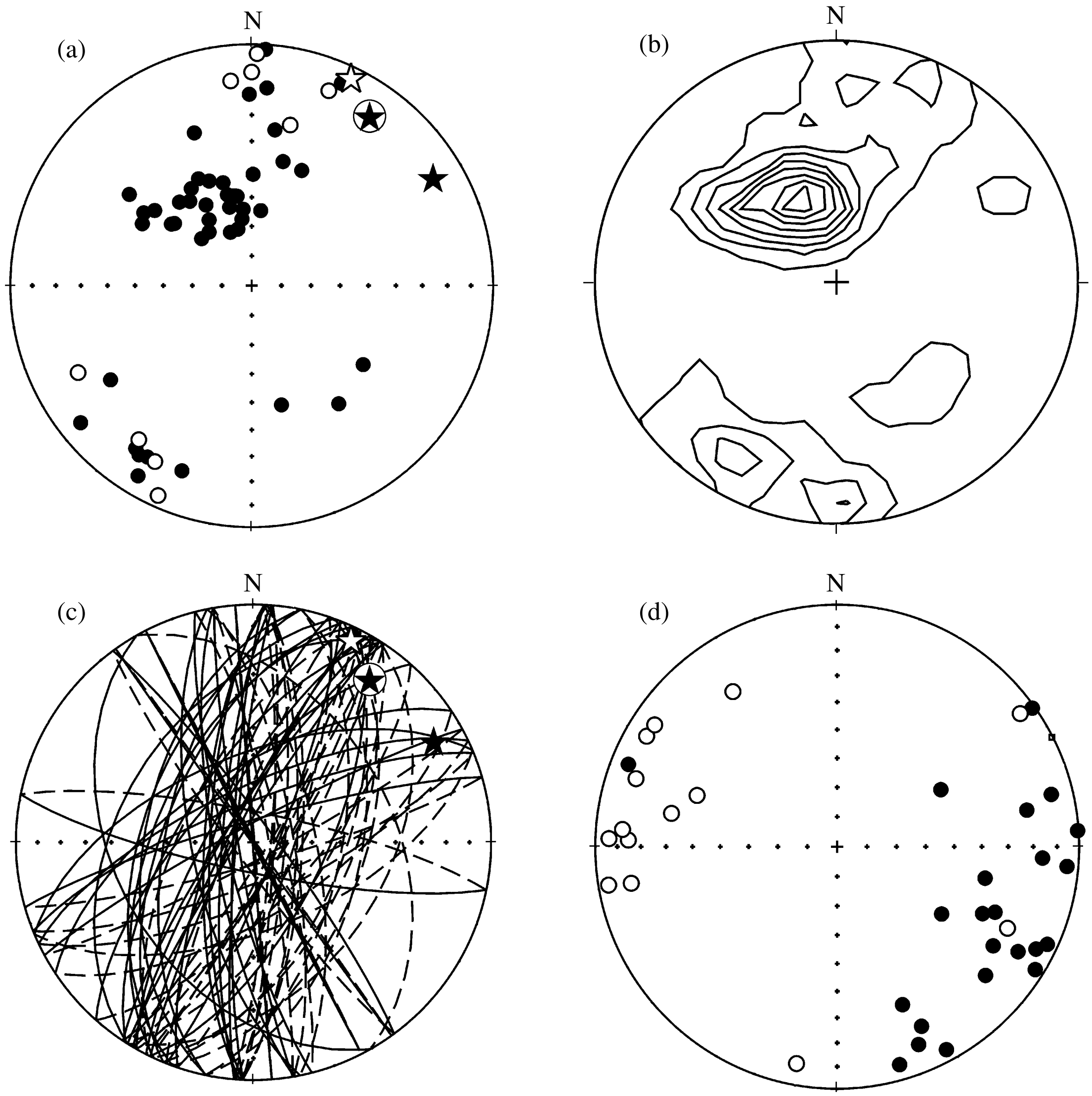

Fig. 6. Ancient components of magnetization in the Chekurovka section: (a) vectors of the characteristic component (MZ1 component is not shown) from the subflow part of the section and (b) diagram showing the density of their distribution; (c) remagnetization circles obtained from the thermal demagnetization and (d) distribution of the normals to these circles (right-hand rule). Stereograms (a) and (c) also show the Kirschvink directions [12] expected for this section with (encircled solid star) and without (solid star) regard for the rotation of the Aldan block in the Middle–Late Paleozoic time [24]. The open star shows the average direction of the group of KRS vectors.

components. The low-temperature component, close in direction to the contemporary geomagnetic field, is destroyed at 300°C and is probably of viscous origin. The high-temperature component has the highest unblocking temperatures, close to the Curie point of magnetite, and is similar in direction to the MZ1 component (Fig. 3j). It is noteworthy that heatings of a few samples revealed stable (medium- and high-temperature) magnetization components close in direction to the KRS and KHR components.

Bulkur Section

We collected 193 samples from this section (65 from sills and their exocontacts, more than 20 from dolerite pebble, and about 100 from the sedimentary sequence).

Sedimentary rocks. The NRM in the majority of samples of the Bulkur sedimentary rocks includes two components. A less stable component, usually poorly resolved, is commonly destroyed in the interval 100–250°C and, judging from the distribution of pertinent vectors, is a superposition of recent and laboratory-induced viscous magnetization components. A more stable component is destroyed in the interval 300–660°C and is represented in a Zijderveld diagram by a linear segment directed toward the origin of coordinates. This component (denoted below as MZ2) has a

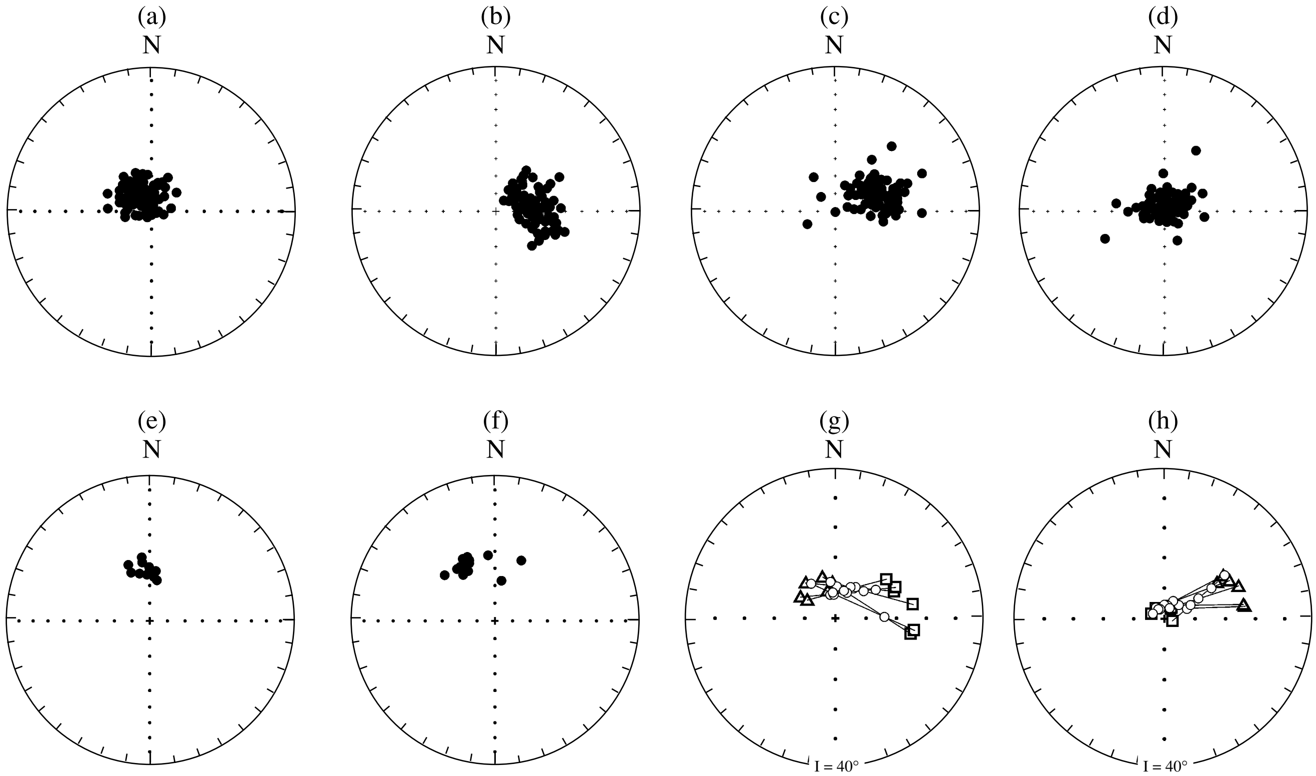

Fig. 7. Distribution of Mesozoic magnetization components in sedimentary rocks of the (a, b, g) Chekurovka and (c, d, h) Bulkur sections in (a, c) stratigraphic and (b, d) geographic coordinates. (g, h) Intersections of small remagnetization circles from the (g) Bulkur and (h) Chekurovka sections. (e, f) Distributions of vectors of the characteristic component (in stratigraphic coordinates) from the (e) Chekurovka flow exocontact and (f) Turkutian Formation rocks exposed in the Khorbusuonka River valley. The solid circles are vector projections onto the lower hemisphere. The gray triangles (squares) are projections of group-averaged (see text) directions in the stratigraphic (geographic) coordinates. The gray circles are intersections of small remagnetization circles.

very steep inclination in the geographic system of coordinates (see Figs. 3d and 3e and Table 2).

A relatively small portion of sedimentary rock samples yield evidence for, apart from the MZ2 component (in this case, intermediate), another stable high-temperature component recognizable as either a linear segment directed toward the origin of coordinates in a Zijderveld diagram or a remagnetization circle in a stereogram. The "final points" corresponding to these components in the stereogram are distributed quasi-chaotically. Among others, two or three "final points" indicate the KRS direction. The remagnetization circles are also distributed without any visible regularity (except that they all start from the region corresponding to the MZ2 component). The NRM value in the studied samples of the Bulkur sedimentary section varies within 0.5–10 mA/m.

Flows and pebbles of dolerite and exocontact rocks. The NRM value in the dolerites of flows and pebbles varies from a few tenths of to a few A/m units, whereas the exocontact rocks are appreciably less magnetic: their magnetization value varies from a few to a few tens of mA/m units. Thermal demagnetization revealed two magnetization components in the samples studied. Similar to the sedimentary rocks described above, the first component is weakly expressed and unstable (being destroyed on heating to 200–300°C) and is also likely to be a superposition of recent and laboratory-induced viscous components. The second, fairly stable component is characteristic, and its maximum unblocking temperatures amount to either 550–580 or 650–670°C in pebbles (Fig. 3a), typically 650–670°C in exocontact samples (Fig. 3b), and 550–580°C in dolerite samples from flows (Fig. 3c).

Vectors corresponding to this component in stereograms form in all cases (flows, pebbles, and the exocontact) compact groups characterized by very steep inclinations in the geographic coordinates (Fig. 7d and Table 2). Comparison of average directions of these groups with the MZ2 direction derived from sedimentary rocks leaves no doubt as to their identity.

Age and Direction of the MZ Component

Laboratory studies showed that the MZ1 component is evidently present in the majority of samples from the section of the Chekurovka anticline; this component has a high inclination in the stratigraphic coordinates and is destroyed within a wide range of temperatures,

Table 1. Characteristic components of magnetization (except the MZ components) from the Chekurovka and Bulkur sections

Component, number of samples	Geographical system of coordinates				Stratigraphic system of coordinates				Synfolding system of coordinates with proportional unfoldings of 73 and 35% for the Chekurovka and Bulkur sections, respectively			
	D	*I*	*K*	α_{95}	*D*	*I*	*K*	α_{95}	*D*	*I*	*K*	α_{95}
Chekurovka section												
KHR component, *N* = 19	79.1	65.7	21.8	6.3	333.4	56.6	25.1	5.9	348.5	66.8	24.8	5.9
KRS component, *N* = 19	23.0	0.2	6.7	14.0	23.6	–4.1	8.7	12.1	23.0	–3.2	8.3	12.4
Exocontact of sill, medium-temperature component, *N* = 14	106.4	63.6	66.3	4.9	338.0	73.7	66.3	4.9	15.0	80.7	66.3	4.9
Exocontact of sill, high-temperature component, *N* = 11	74.8	61.9	163.1	3.6	354.5	60.6	163.1	3.6	12.5	66.3	163.1	3.6
Sill, high-temperature component, *N* = 25	94.9	58.4	42.3	4.5	1.4	70.8	42.3	4.5	33.7	74.2	42.3	4.5
Bulkur section												
Sills, *N* = 44	296.7	86.3	84.9	2.3	57.6	68.1	84.8	2.4	38.2	83.2	84.9	2.3
Exocontact, *N* = 11	343.4	84.8	75.4	5.3	54.5	63.7	91.1	4.8	35.9	79.1	90.2	4.9
Pebbles, *N* = 14	337.0	87.3	93.9	4.1	58.7	65.8	94.1	4.1	47.3	81.1	94.0	4.1
Khorbusuonka River valley												
Reddish limestones of the Turkutian Formation, *N* = 12	337.6	55.4	43.7	6.6	337.6	55.4	43.7	6.6				
Konder Massif												
Dunites of the central stock, *N* = 18	33.7	81.2	10.3	10.3	33.7	81.2	10.3	10.3				
Silty sandstones of the Tottinian Formation from the contact zone, *N* = 10	20.1	78.2	65.3	5.4	20.1	78.2	65.3	5.4				
Black siltstones of the Tottinian Formation from the contact zone, *N* = 6	178.0	–77.0	190.0	4.5	178.0	–77.0	190.0	4.5				

Note: *N* is the number of samples, *D* is declination, *I* is inclination, and α_{95} and *K* (concentration) are statistical characteristics of the Fisher distribution.

from 200 to 500°C and more. In the lower part of the section and in the exocontact, its spectrum of unblocking temperatures often overlaps with the spectrum of unblocking temperatures of other components. The MZ1 effect of other components is least pronounced in the upper part of the section (above the dolerite flow), where the MZ1 component is clearly (with minimum noise) recognizable in the interval 200–450°C. To avoid the effect of other components, we used samples from this upper part of the section for calculating the MZ1 direction. These calculations included at least four points of Zijderveld diagrams, and we chose only those vectors whose determination accuracy, as estimated from the MAD parameter [14], was better than 3°. Comparison of precision parameters of the resulting distribution of 75 vectors in the geographic and stratigraphic systems of coordinates, as well as the proportional unfolding, indicates a possible synfolding nature of the MZ1 component. The maximum concentration *K* = 67.3 is attained with 75% unfolding, the average direction being *D* = 12.7° and *I* = 82.5°. The concentration of the vectors is 43.8 in the geographic coordinates and 63.2 in the stratigraphic coordinates (see Table 2 and Fig. 8).

To elucidate the problem of synfolding of the MZ1 component, the available vectors were divided into six groups in accordance with the attitude of the sampled beds from which these vectors were obtained. In estimating the age of the studied component relative to folding, such a division reduces the influence of irregularity in the distribution of attitudes of the sampled beds. Combined analysis of the average directions of these six groups confirms the synfolding origin of the MZ1 component. The maximum precision parameter (*K* = 330.2) is attained in this case at a proportional unfolding of 72.7%, the precision parameters in the geographic and stratigraphic coordinates being, respectively, 94.1 and 228.9. The Watson–Enkin test [39] applied to the same six directions indicates that the maximum precision parameter is attained at a 72.8%

Table 2. Age and direction of the MZ component

N	Geographical system of coordinates				Stratigraphic system of coordinates				Synfolding (at K_{max}) system of coordinates				Result of the Watson–Enkin test	
	D	*I*	*K*	α_{95}	*D*	*I*	*K*	α_{95}	*D*	*I*	*K*	α_{95}	optimal unfolding	95% interval
Chekurovka anticline														
75 samples	84.3	67.0	43.8	2.5	328.9	79.4	63.2	2.1	Proportional unfolding, 74.7%					
									12.7	82.5	67.3	2.0		
6 groups	78.2	67.5	96.6	6.9	327.2	78.3	243.3	4.3	Proportional unfolding, 72.7%				72.8%	57.4–89.8%
									9.5	81.6	330.2	3.7		
8 groups	82.8	67.4	72.6	6.5	326.3	79.2	184.4	4.1	Proportional unfolding, 81.7%				82.0	66.5–98.1%
									354.1	82.2	201.4	3.9		
14 intersection points: 6 small circles*									22.2	80.3	145.3	3.3		
Bulkur anticline														
72 samples	352.2	86.8	47.8	2.4	65.7	65.5	33.2	2.9	Proportional unfolding, 2.8%					
									3.6	86.6	47.9	2.4		
6 groups	350.5	87.4	530.0	2.9	64.9	66.0	300.8	3.9	Proportional unfolding, 35.3%				36.9%	–14.9–82.3%
									54.9	81.0	855.1	2.3		
14 intersection points: 6 small circles*									23.9	85.4	192.8	2.9		

Note: *N* is the number of samples, *D* is declination, *I* is inclination, and α_{95} and *K* (concentration) are statistical characteristics of the Fisher distribution.

*One intersection, lying outside the region bounded by the points of the circular segments considered, is rejected.

unfolding, the 95% confidence interval being 57.4–89.8% (Table 2 and Fig. 8).

To test the stability of this result, we divided the studied set of vectors into five and eight groups according to the attitude of beds. The first division also indicates a synfolding origin, but the 95% interval is wide (75–111%) and includes the complete unfolding case. With the second division, the evidence for synfolding (the slope of the curve of the precision parameter versus the unfolding amount) is even more convincing (Fig. 8): the concentration maximum is attained at an 82% unfolding with a 95% confidence interval of 66–98%.

Thus, the above analysis clearly indicates a synfolding age of the MZ1 component. The small circles (resulting from unfolding) corresponding to the six groups yield an average intersection point with the coordinates $D = 22.2°$ and $I = 80.3°$ with $N = 14$, $K = 145.3$, and $\alpha_{95} = 3.3°$ (Table 2 and Fig. 7h).

This result is a more accurate estimate of the direction of the synfolding component MZ1, because its calculation did not involve the hypothesis that the magnetization in all of the above groups was acquired at the same deformation stage. It is noteworthy that the direction calculated in this way does not differ on a significant level from the direction estimated from the proportional unfolding, implying that the proportional unfolding hypothesis is applicable to the Chekurovka section.

Analysis of the entire set of samples from the Bulkur anticline indicates a more likely postfolding age of magnetization ($K_{ssc} = 33.2$ and $K_{gsc} = 47.8$; $K_{max} = 47.9$ with an unfolding of 2.8%). However, in dividing the samples into attitude-coordinated groups (six groups, with declinations ranging within 325°–360° and inclinations ranging within 18°–34°), the proportional unfolding procedure yields a concentration maximum at an unfolding of 35% (Table 2 and Fig. 8). The Watson–Enkin test applied to the same six groups gives a maximum at a 37% unfolding, but the 95% confidence interval is from –15 to 82%. Therefore, we cannot state with 95% confidence that the MZ2 component was not acquired after the folding. However, the probability of a synfolding origin of this component is fairly high: the same test shows it to be more than 80%.

The small circles (see above) intersect at a point with the coordinates $D = 23.9°$ and $I = 85.4°$ (Table 2 and Fig. 7g). We regard this direction as the most accurate estimate of the MZ2 component.

In view of the folding age range (see above) and the similarity between the directions of the components considered (Table 2), one may state with a high probability that these components were acquired in the Late Cretaceous.

However, notwithstanding the closeness of these directions, they are statistically different (the angular distance is $\gamma = 5.1°$, with its critical value [19] being $\gamma_c = 4.3°$), and their distinctions are most pronounced in the inclination. The latter circumstance precludes the possible interpretation of this difference in terms of relative rotations of the rocks studied. Even if we suppose that the best estimates of the MZ1 and MZ2 components are the directions obtained as averages over the six groups from the proportional unfolding (see Table 1), the difference in inclination between the Bulkur and Chekurovka sections cannot be related to their rotations, assuming that the components are coeval. In this case, one should expect the differences in strikes of the beds sampled to be consistent with the difference between the estimated inclinations. However, the actual picture is quite contrary: the average dip azimuths of the beds sampled in the Chekurovka and Bulkur sections are about 280° and 250°, whereas the respective declinations are 9.5° and 54.9°; i.e., the compared directions are rotated in the sense opposite to the one that should be expected from the difference between the strikes of the beds sampled.

The distinction between the directions of the MZ1 and MZ2 components can be attributed to the difference between their ages, which can amount to a few hundreds or a few thousands of years, but then we should assume that their formation was sufficiently rapid and the resulting average directions have been subjected to the influence of secular variations.

The possibility of a rapid remagnetization of the sedimentary sections is supported by data that we obtained from Paleozoic northwestern sequences of the Siberian platform [40].

The difference between the directions of the MZ1 and MZ2 components can also reflect a change in the geographic position of the plate that included the Siberian platform. In this case, given the small velocities of the paleomagnetic poles of the adjacent East European and North American platforms, the MZ1 and MZ2 components can differ in age by a few tens of millions of years. This interpretation appears to be less probable, because the study sections are separated by a comparatively short distance (no more than 70 km), are parts of a coherent geological structure, and have the same geological history.

Moreover, this assumption (given that both components are of synfolding origin) requires a very long time interval of folding within a limited region, which also appears to be doubtful. According to [36], the crustal shortening within the study territory during Mesozoic fault–fold movements amounted to about 6 km. The rates of such processes are estimated at 3–6 mm/yr [17]. With regard to the studied sections, this gives a folding time estimate of 1–2 Myr, which is an order of magnitude shorter than the time required (by analogy with the adjacent plates (e.g., see [1]) for the displacement of a paleomagnetic pole by 5°.

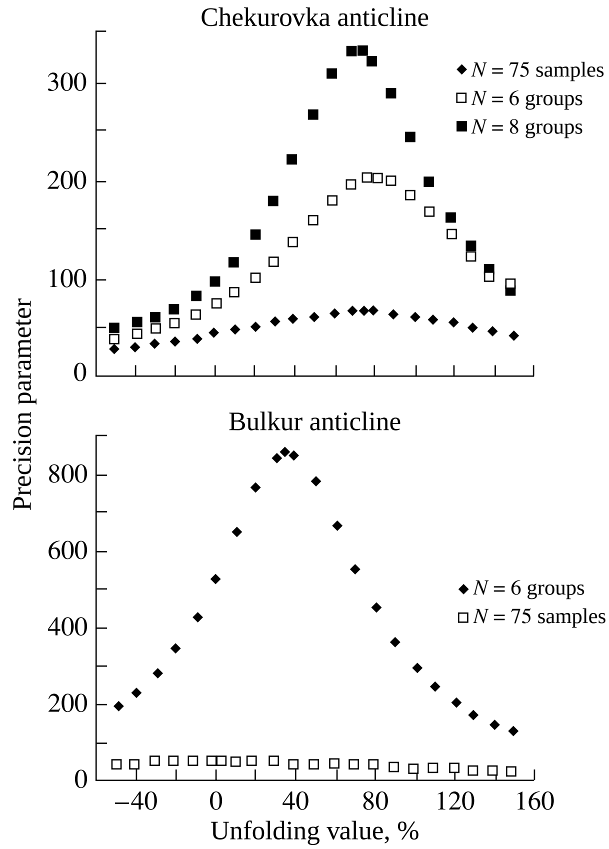

Fig. 8. Diagrams illustrating the synfolding age of the MZ component.

The MZ Components and the Mesozoic Segment of the Siberian APWP

Careful examination of the data underlying the Siberian APWP reveals the paradoxical, at first glance, fact that the Early Paleozoic trend of the curve has been studied and substantiated much better than its Mesozoic trend. Moreover, no determinations that would meet the modern criteria of paleomagnetic reliability have yet been published in relation to the Mesozoic of the Siberian platform (with the exception of data from Early Triassic traps). We know of only two attempts to obtain Mesozoic paleomagnetic determinations with the use of detailed demagnetization and component analysis.

The first attempt was made by one of the authors of this paper (V.E. Pavlov) in studying rocks composing the Konder Massif of the southeastern Siberian platform. The pertinent data were previously introduced only into the unpublished eighth issue of the Russian Catalog of Paleomagnetic Data and were then transferred from this catalog to the World Database (result no. 6843 in [18]). Therefore, we will briefly describe the information characterizing the quality of these data (see also Table 2). The magnetization of the studied sections has two components. The first component, close in direction to the present field, is removed on heating to 150–200°C, and the second, characteristic component is destroyed either near the Curie point of magnetite (dunites and silty sandstones) or at 350–360°C (black siltstones). The dunites were taken from the central core of the massif, and the silty sandstones and black siltstones were sampled near the core in two outcrops of altered contact rocks of the Tottinian Formation. As seen from Table 2, both normal and reversed polarity directions have been discovered in the sections studied. The reversal test [19] applied to these directions is positive.

The chief drawback of this determination is the fact that the age of the Konder structure is mainly estimated on the basis of indirect evidence. However, the available data, including isotopic datings, rather reliably indicate the Late Jurassic age of the Konder Massif [6].

The second attempt was made by Kravchinsky *et al.* [16], who studied Lower–Middle Jurassic deposits of the Irkutsk basin. Unfortunately, demagnetization procedures failed to reliably identify the ancient component of magnetization, and thereby this attempt proved unsuccessful.

It is commonly acknowledged that the consolidation of the North Eurasian plate was mainly accomplished by the end of the Paleozoic. If the Siberian platform and "stable Europe" were actually parts of a rigid plate, the problem of the Mesozoic part of the Siberian APWP would have a simple solution: in this case, the Mesozoic APWPs of Europe and Siberia would coincide and the available European poles could be automatically used for the Siberian platform.

However, some authors indicate the possibility of appreciable movements of Siberian blocks in the Mesozoic [11] and Cenozoic [4]. In particular, Cogne *et al.* [4] divided North Eurasia into three subplates that moved relative to each other in the post-Eocene time along diffusive fracture zones located supposedly along the Uralian fold zone and the Tornquist–Teisseyre line.

The paleomagnetic directions obtained in our study can be used for solving the problem of the rigidity of the North Eurasian plate and the applicability of the Mesozoic segment of the European APWP to the Siberian platform. As mentioned above, the poles calculated from the MZ1 and MZ2 components can be virtual geomagnetic poles of similar time moments of the Late Cretaceous. In this case, by averaging these poles, we obtain an estimate of the true position of the paleomagnetic pole (the MZ pole) that is less influenced by secular variations compared to each of the poles considered separately.

Another possibility is that the poles calculated from the MZ1 and MZ2 components are paleomagnetic poles separated in time by a few tens of millions of years. In this case, the MZ1 component, acquired at early stages of folding, is an older one, of undoubtedly Late Mesozoic age, whereas the MZ2 component, acquired at final stages of or even after folding, is a younger component, possibly of Paleocene age. Although a large difference between the ages of the MZ1 and MZ2 components is, in our opinion, unlikely, we should examine this variant as well.

Figure 9 shows the position of the poles calculated from the MZ1 and MZ2 components, as well as the position of the average MZ pole, relative to the APWP of "stable Europe" [1]. The average pole is seen to be in the close vicinity of the Late Cretaceous segment of the APWP, and the Late Cretaceous European pole nearest to the average pole has an age of 100 Ma (γ/γ_c = 1.6°/7.7°), which agrees well with the available geological evidence on the folding age.

It is interesting to note that the alternative interpretation of the MZ2 age also yields good agreement of the inferred poles with the European APWP. In this case, the MZ1 pole lies near the European 90-Ma pole (γ/γ_c = 0.9°/7.9°), and the MZ2 pole is near the Late Paleocene pole of Europe (γ/γ_c = 3.2 γ/6.0°). It is in the Paleocene that the study region became dominated by extension conditions, leading to formation of grabens, and one could attempt to relate the MZ2 component to these events. However, the hypothesis of two diachronous overprinting sources in closely spaced rocks belonging to the same geological structure appears to us somewhat artificial, although its existence is possible. In any case, the poles derived from our data agree well with the European APWP, which confirms its validity with respect to the Siberian platform.

In order to further substantiate this inference, we consider the position of another two available Siberian Mesozoic poles in relation to the European APWP. The curve of Besse and Courtillot [1] was constructed for the time interval 0–200 Ma. We used the average poles calculated for the Permian and Triassic epochs (Fig. 9) in order to reconstruct the APWP in the interval 200–300 Ma. In doing so, we selected poles from the database presented in [37] in accordance with the laboratory processing quality of collections as the only criterion (the DC parameter is equal to or greater than 3); naturally, poles from Alpine fold zones were discarded.

As was shown by Veselovsky *et al.* [37], the Late Permian–Early Triassic pole of the Siberian platform is indistinguishable, on a significant level, from the coeval pole of Europe (γ/γ_c = 6.8/9.5). It is important that the other Mesozoic pole of the Siberian platform, derived from the Konder Massif, also lies on the European

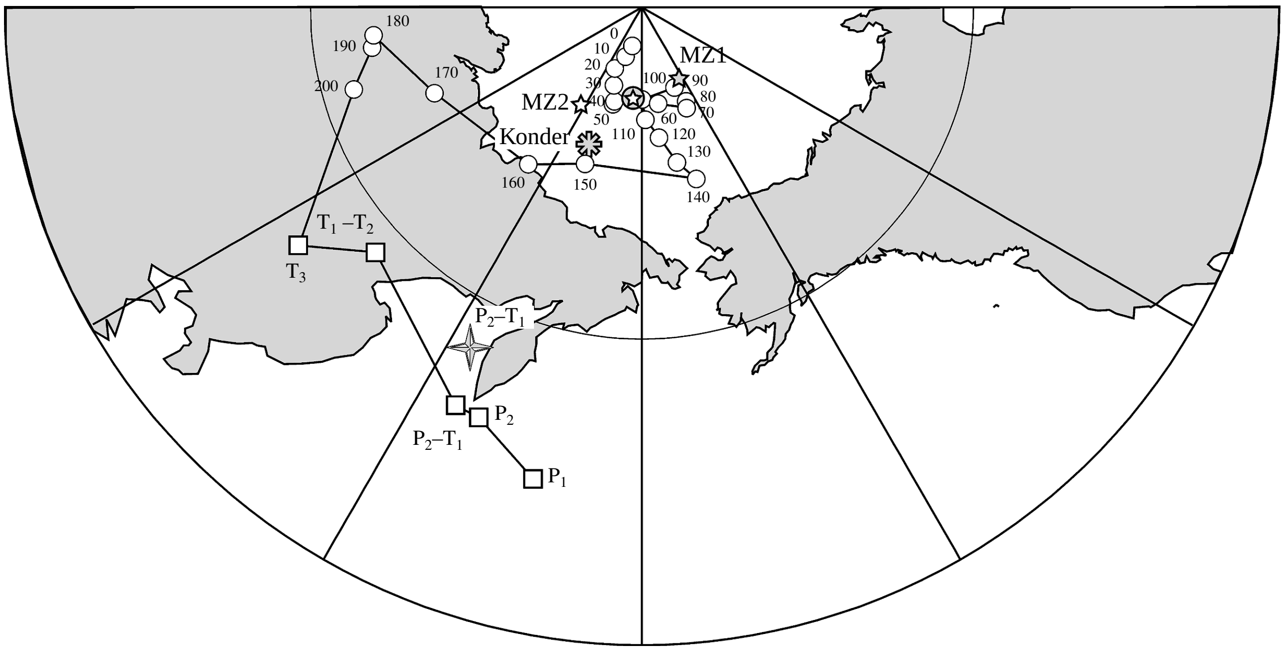

Fig. 9. Comparison of the inferred Mesozoic poles of the Siberian platform with the APWP of "stable Europe." The encircled numbers indicate the position and age of the "stable Europe" poles in the interval 0–200 Ma [1]; the squares show the positions of the Early and Late Permian (P1, P2), Late Permian and Early Triassic (P2–T1), Early–Middle Triassic (T1–T2), and Late Triassic (T3) poles of "stable Europe" [37]. The open star in the gray circle is the pole corresponding to the MZ (average between MZ1 and MZ2) direction. The open and gray stars are the MZ2 and MZ1 poles, respectively. The snowflake is the pole from the Konder Massif. The four-pointed star is the average Permian–Triassic pole of the Siberian platform [37].

APWP (Fig. 9). Thus, the sequence of diachronous Siberian poles is in excellent agreement with the European APWP, and this confirms the rigidity of the North Eurasian plate, at least from the beginning of the Mesozoic. Therefore, the European APWP can be used with confidence as a reference curve for the Siberian platform, and Siberian poles, both those available and those that will be obtained in the future, can be used for further improvement of the European APWP.

The KHR and KRS Components and the Problem of Early Cambrian Paleomagnetic Poles of the Siberian Platform

Now, we examine in detail the KHR and KRS components, which we discovered in the lower part of the Chekurovka section. We used various modifications of the fold test in order to determine the age of these components in relation to the folding time. As a rule, these tests do not give unambiguous results for both components, which might be related to an inadequate variability of the attitude of beds in this part of the section. The Watson–Enkin test indicates a prefolding age of the KHR component, but taking into account indefinite results of application of other tests, we do not regard this inference as reliable enough.

Much better constraints on the age of the components in question can be gained from comparison of their poles with the Siberian platform APWP. The inferred poles lie isolated from all Siberian Phanerozoic poles beginning from the Early Ordovician. However, the KHR component yields a pole located near the Middle Cambrian poles of the Siberian platform [35] and in the close vicinity of the Lower Cambrian pole determined by Pisarevesky *et al.* [29]. Moreover, the KHR pole lies near the pole corresponding to the high-temperature characteristic component, which we obtained from a small outcrop of reddish limestones of the Turkutian Formation in the Khorbusuonka River valley (Figs. 4i and 4j and Tables 1 and 3).

On the other hand, the KRS direction is rather well consistent with the expected direction, calculated from the pole of Kirschvink and Rozanov [12] and corrected for the rotation of the Aldan block relative to the Anabar block [24], as well as without such a correction (Fig. 10).

Thus, both the Khramov and Kirschvink components of magnetization are observed for the first time in the same section. These components were identified, using the detailed thermal demagnetization, by the same method and with the same instruments. Therefore, on the one hand, the Khramov directions cannot be regarded as an artifact resulting from an inadequate demagnetization process and, on the other hand, our data confirm that paleomagnetic directions similar to the Kirschvink direction actually exist in Lower Cambrian rocks of the Siberian platform. It is noteworthy that the polarity of the KHR and KRS components

Table 3. Paleomagnetic poles

Section, component	*N*	Coordinates		Plat	Plong	*A*95 or d*p*/d*m*	*K*
		lat	long				
Chekurovka anticline, MZ1 component*	14	71.1	127.4	83.0	206.0	6.2	41.8
Bulkur anticline, MZ2 component*	14	71.7	127.3	79.5	146.7	5.5	54.0
Average MZ pole	28			82.3	169.8	4.2	42.2
Chekurovka anticline, KHR component**	25	71.1	127.4	–53.4	164.1	6.2/85	
Chekurovka anticline, KRS component**	19	71.1	127.4	–15.2	102.9	6.1/12.1	
Khorbusuonka River valley, reddish limestones of the Turkutian Formation, characteristic component	12	71.4	123.9	–52.5	160.8	6.4/8.9	
Konder Massif*	3	57.3	134.6	76.7	158.8	11.6	113.7
Average pole from Permian–Triassic traps of the Siberian platform [37]	7			56.2	151.7	3.8	255.4

Note*:* *Plat* and *Plong* are the latitude and longitude of the paleomagnetic pole; *lat* and *long* are the latitude and longitude of the sampling site; *A*95 (d*p*/d*m*) is the radius (semiaxis) of the 95% confidence circle (oval); and *K* is the precision parameter. *N* is the number of samples (KHR and KRS components; Chekurovka anticline and Khorbusuonka River valley), groups (MZ components; Chekurovka and Bulkur anticlines), sites (Konder Massif), or independent paleomagnetic determinations (average pole from Permian–Triassic traps of the Siberian platform) used in calculations.

*The pole was calculated as a virtual geomagnetic pole.

**The pole was calculated from the average direction of the magnetization component.

inferred in our study complies with the same pattern that was revealed in previous studies from other sections: directions of the Khramov type commonly have reversed polarity, whereas the Kirschvink directions can have, with equal probability, either normal or reversed polarity.

Which of the inferred components is primary? Unfortunately, our data fail to provide a definite answer to this question. Results of the conglomerate test or data from other types of rocks (e.g., igneous rocks) would be very helpful for the solution of this problem. Unfortunately, Lower Cambrian rocks are of limited occurrence within the Siberian platform, whereas the Lower Cambrian flows and conglomerates of the Bulkur anticline sampled in our study were overprinted in the Mesozoic. Possibly, such tests will be performed in future paleomagnetic studies of the Lower Cambrian of the Siberian platform, but presently, analyzing the inferred directions, we can rely solely on the available data.

The simplest interpretation of the observed paleomagnetic directions consists in that the bipolar KRS component, providing a paleomagnetic pole different from all other Phanerozoic poles of the Siberian platform, is primary, whereas the monopolar KHR component is a secondary metachronous component. In this case, since the pole corresponding to the KHR component is close to the Middle–Late Cambrian poles of the Siberian platform, one can suggest that this component was acquired at the middle or the end of the Cambrian. However, such an interpretation encounters, in our opinion, a very serious objection. Namely, the KHR component is often present in Vendian–Cambrian sections located in various parts of the Siberian platform that differ in geological history and are composed of different rocks. We discovered this component (of both high-temperature and intermediate medium-temperature types) [23] in sections of the Kulyumbe (the northwestern Siberian platform), Kotui and Kuonamka (the western and eastern near-Anabar regions), and Maya (the Uchur–Maya region) rivers. This same component was identified by Shatsillo *et al.* [33] in Late Vendian rocks of the western and eastern near-Sayany regions. Thus, the component consistent with the Khramov direction is present over vast territories and, being a secondary component, should have been due to a large-scale tectonic or magmatic event that occurred on the Siberian platform in the second half of the Cambrian. However, no traces of such an event are known in the geological history of the Siberian platform. Moreover, if this event actually took place, why did it not leave any signatures in older rocks? In fact, no traces of the Khramov component have been detected in Riphean rocks of the Uchur–Maya region [26] and in the northwest [10], north [8, 38], northeast [31], and south [15] of the Siberian platform.

Since the simplest variant encounters serious difficulties, we are impelled to search for an alternative interpretation of the observed facts and, as a possible variant, propose the following hypothesis. Both of the components under consideration are primary in the sense that they were acquired either during the deposition of the sediments studied or shortly afterward. They can be of either synsedimentary or early diagenetic origin, and the difference between their directions is due to the fact that the geomagnetic field of the latest Vendian and the earliest Cambrian had an anomalous character with relatively long intervals dominated by an

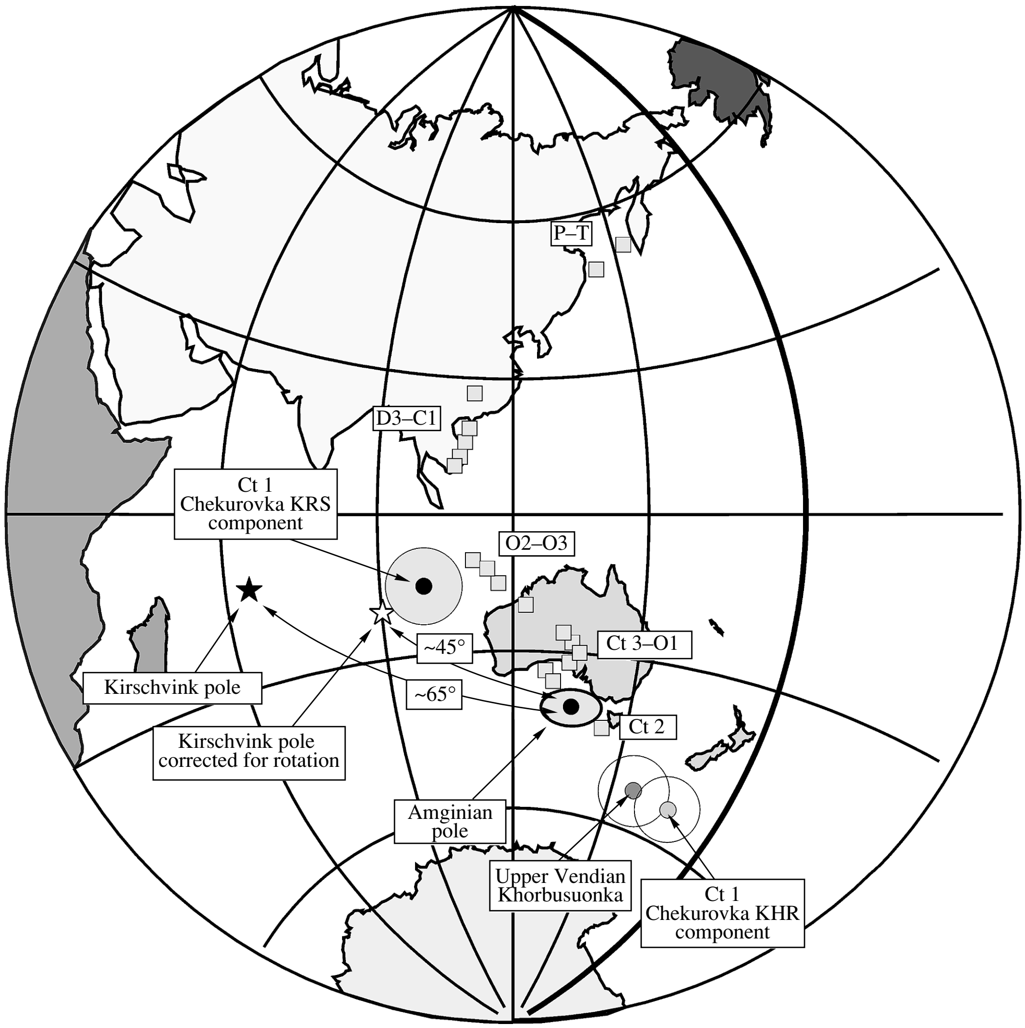

Fig. 10. Comparison of the poles inferred from the KHR and KRS components with Paleozoic poles of the Siberian platform. The rectangles are poles presented in [35]. The Amginian pole is taken from [25]. The solid star is the pole presented in [12], and the open star is the same pole corrected for the possible rotation of the Aldan block relative to the Anabar block in the Middle Paleozoic [24].

axial monopolar dipole field, which was recorded as the KHR component, alternating with relatively short intervals dominated by a reversing near-equatorial dipole, which was recorded as the KRS component. A similar model was proposed by Pesonen and Nevalinna [28] for interpreting the asymmetric reversals recorded in sections of the Kivino Group (1100–1000 Ma).

We believe that such behavior of the magnetic field can account for the majority of paleomagnetic features recorded in sections and reconcile the seemingly antagonistic results obtained by various researchers.

In the case of synsedimentary acquisition of magnetization by sediments, sections should exhibit alternating records of the KHR and KRS components. Such a pattern is observed in the part of the Chekurovka section that was not overprinted by the Mesozoic field.

If the magnetization was acquired rapidly but with a delay comparable in time with the KRS epochs, some levels of the section should yield the KHR component alone, whereas the KHR component of other levels should be superimposed on the relatively weaker KRS component. The presence of the latter can only be recognizable through tendencies in Zijderveld diagrams and through remagnetization circles going into the region of the Kirschvink component. It is clear that, in this case, KHR will be present in samples as an intermediate component. This type of record is observed in the Lower Cambrian section of the Kuonamka River [23].

If the time of the recording process is appreciably longer than the duration of the KRS epochs, one should expect that the thermal demagnetization of such rocks will reveal the presence of only one component of magnetization. This type of record is observed in transitional Vendian–Cambrian rocks of the Kotui River section [23].

However, our hypothesis encounters serious problems related to the interpretation of the paleomagnetic records in sections of the middle Lena River [12] and the Khorbusuonka River [41]. The Lena sections yield no evidence of the KHR component, whereas the presence of this component in the Khorbusuonka section was established, and that somewhat tentatively, only at separate levels.

As regards the middle Lena sections, we think that, judging from the data presented by Kirschvink and Rozanov [12], this component could remain undetected due to the low resolution of their demagnetization procedure. On the other hand, the presence of the KHR component in the Khorbusuonka River sections could be masked by strong contamination by an intermediate Khramov component relatively close in direction to the Mesozoic–Cenozoic component. This interpretation is probably also valid for some of the middle Lena samples.

To test the hypothesis proposed, the range of the Vendian–Lower Cambrian rocks studied should be widened. The Late Vendian of the Sayany and Baikal regions needs more detailed studies. The same is true of the reference sections of the Aldan and Uchur river valleys, which have not been paleomagnetically studied as yet. It is very important to obtain paleomagnetic information from igneous rocks of the Early Cambrian. In our opinion, of great significance could be repeated studies of the classical Lower Cambrian sections of the Lena River. Moreover, careful analysis of available paleomagnetic data from other regions of the Earth is undoubtedly required. We plan to tackle all these problems in our further paleomagnetic investigations of the Lower Cambrian of the Siberian platform.

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