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New Paleomagnetic Data on the Anabar Uplift and the Uchur-Maya Region and Their Implications for the Paleogeography and Geological Correlation of the Riphean of the Siberian Platform

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Abstract—The results of paleomagnetic studies of the reference sections of the Riphean and Late Proterozoic intrusive bodies of two remote areas of the Siberian Platform are presented. Within the limits of the Uchur-Maya region the sedimentary rocks of the Gonam, Omakhta, Ennin and Konder formations were studied; and the Riphean sedimentary rocks of the Burdur and Kotuykan formations on the northern and western slopes of the Anabar Uplift and, also, the Late Proterozoic intrusive complexes, located in the basins of the Fomich, Magan, Dzhogdzho and Kotuykan Rivers were studied. The paleomagnetic poles obtained in the course of this work and the present-day geochronological data give grounds to assume that: (1) the accumulation of the Riphean of the Anabar Uplift occurred after the formation of the Uchurskaya series of the Uchur-Maya region and was completed in approximately 1.5 Ga; (2) the Konder layers, compared according to the correlation pattern accepted at the present time [Semikhatov and Serebryakov, 1983] with the bottoms of the Totta formation, can be related to the appreciably more ancient stratigraphic level; (3) the intrusion of the studied intrusive bodies of the northern and western slopes of the Anabar Uplift occurred nonsimultaneously, although within close time intervals of approximately 1.5 Ga. The estimates of the kinematic parameters of the drift of the Siberian Platform within an interval of 1.7–1.0 Ga is carried out.

Key words: Paleomagnetism, Siberian Platform, Riphean, Late Proterozoic, Mesoproterozoic, geochronology, stratigraphy, and paleomagnetic pole.

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INTRODUCTION

The new isotopic-geochronological data increasingly frequently contradicts to the traditional concepts concerning the Precambrian geological history of various key regions and reference sections [Khomentovskii, 2005; Khudoley, 2003], and with renewed vigor raise the question about the framework of the applicability in the Precambrian of the traditional historical-geological and biostratigraphic methods. In this situation, the vital need of applying the paleomagnetic method is obvious, which gives independent information. This information can be of great significance for the comparison and correlation of sections, for dating species, and for the solution of different paleogeographic and paleotectonic problems.

An important, if not the basic instrument of paleomagnetic studies of the Precambrian, are the apparent polar wander path (APWPs) and the development of Paleo- and Mesoproterozoic segments, which are becoming increasingly urgent. The APWPs are the time series of either the individual or somehow averaged paleomagnetic poles (including, also, averaging through their analytical approximation). The APWPs are based on the results of the individual paleomagnetic determinations: the larger their number and the higher their quality, the more reliable the corresponding APWP.

The new paleomagnetic determinations presented in this work, obtained by us for the Riphean rocks of the Anabar Uplift and the Uchur-Maya region, on the one hand, are intended to make a contribution to the development of the Mesoproterozoic segment of the APWP of the Siberian Platform and, on the other hand, even now they can be used for solving a number of problems of the stratigraphy and the paleogeography of Siberia.

GEOLOGICAL CHARACTERISTICS AND THE AGE OF THE OBJECTS STUDIED

The position of the areas under study is schematically shown on the diagram of the Siberian Platform (Fig. 1). More detailed geological diagrams with the

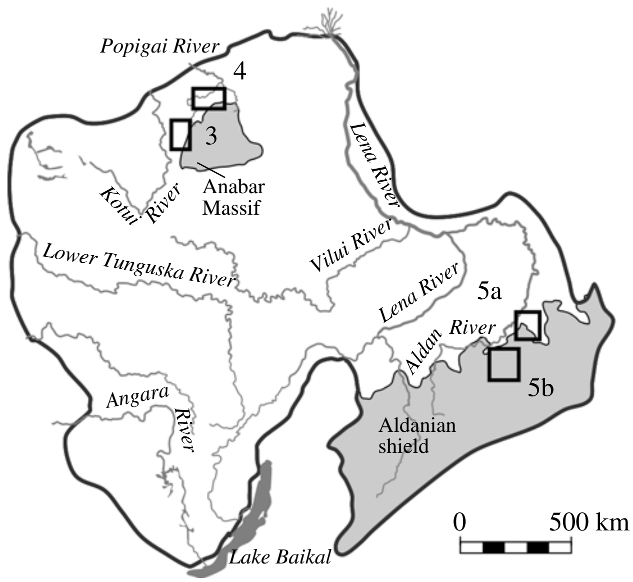

Fig. 1. Map-diagram of the Siberian Platform with the noted position of the study areas: (3) the western slope of the Anabar Uplift (Fig. 3); (4) the northern slope of the Anabar Uplift (Fig. 4); the Uchur-Maya region: (5a) the Bol'shoi Aim River, (5b) the Idyum, Gonam, Uchur, and Algama Rivers (Fig. 5).

investigated outcrops superimposed on them, are presented in Figs. 3–5.

The Northern and Western slopes of the Anabar Uplift

The central part of the Anabar Uplift is composed of the high metamorphized Archean and Early Proterozoic rocks, which on its periphery are overlapped by the Riphean–Paleozoic sedimentary cover. Here, the terrigenous Mukun and terrigenocarbonate Billyakh series, which bed monoclinally with dip angles of several degrees and at some places contain dikes and sills of the Late Proterozoic age, are distinguished in the composition of the Riphean [Okrugin, 1999; Shpunt et al., 1982] (Fig. 2b).

The datings of the fragmental zircons from the bottoms of the Mukun series indicate that its accumulation began not earlier than 1690 ± 9 Ma [Khudoley et al., 2007], but judging by the rubidium–strontium and potassium–argon datings of glauconites from the base of the Billyakh series [Gorokhov et al., 1991], was completed up to 1400 Ma ago. Rb/Sr isotopic data on the argillites of the Yusmastakhsk formation indicate that the Billyakh series was formed up to 1250 Ma ago [Gorokhov et al., 2001]. The U/Pb determination executed by Ernst together with co-authors [Ernst et al., 2000] of the isotopic age based on the baddeleyite dikes on the eastern slope of the Anabar Uplift, intruding on the lower part of the Yusmastakh Formation [Khudoley, 2003], is 1384 ± 2 Ma. The determination of the isotopic age of the intrusive body of the Fomich River valley (the Sm/Nd method) intruding on the Ust-Il'ya Formation is 1513 ± 51 Ma [Veselovsky et al., 2006]. Thus, the available isotopic datings make it possible to state that the larger part of the Anabar Riphean was accumulated within the interval between 1690–1380 Ma. This conclusion does not contradict the paleontological [Sergeev, 2003; 2005] and chemostratigraphical data [Knoll et al., 1995].

In the limits of *the western wing of the Anabar Uplift* (Fig. 3), in the valleys of the Magan, Dzhogdzho, and Kotuykan Rivers, the intrusive magmatic complex was studied, which is represented by dikes and sills of dolerites, intruding on the dolomites of the Kotuykan and Yusmastakh Formations. Over approximately 150 km, 15 intrusions were sampled. From each body 10–20 oriented samples were selected; in a number of cases, the contact zones of intrusions with the host rock were also tested. K/Ar datings, obtained earlier only for two sills and dikes intersecting them of the Dzhogdzho River (Fig. 3, points 4–7, 70), fall in the range from 1397 ± 4 to 1007 ± 12 Ma [Shpunt et al., 1982]. According to [Okrugin, 1999], all intrusive bodies studied by us are related to the region of development of the Western-Anabar dike cluster, which was formed in an interval of 1400–900 Ma. For paleomagnetic studies the sandstones of the Burdur, Labaztakh, and Ust-Il'ya Formations in the Magan River valley were also tested.

On *the northern slope of the Anabar Uplift* (Fig. 4) in the Fomich River valley, sills with a thickness of several tens of meters and rare thin (up to 25 m) dikes, composed of dolerites, were sampled. Over more than 150 km, at 15 points, eight intrusive bodies were sampled. In each of them, not less than ten oriented samples were selected. The intrusive bodies of this region relate to the North-Anabar dike cluster, whose age is evaluated in the work [Okrugin, 1999] as 1300-900 Ma. To obtain a more specific dating, from the intrusive body, investigated by us at points 12 and 13, geochemical samples were selected, whose Sm/Nd isotopic age was 1513±51Ma [Veselovskiy et al., 2006]. For the paleomagnetic analysis the red-colored sandstones of the Burdur Formation (points 11 and 26) and the multicolored dolomites of the Kotuykan Formation (points 24 and 25) were sampled. For conducting the baked-contact test dikes, which intruded on the rocks of both the Burdur (point 11) and the Kotuykan (points 24 and 25) Formations, were sampled.

The Uchur-Maya region (Fig. 5)

For the Riphean rock masses of the Uchur-Maya region and magmatic bodies embedded in them the present-day isotopic determinations are few in number (Fig. 2b). In the lower horizons of the Uchur series the fragmental zircons with a U/Pb age of 1717 ± 32 Ma are found [Khudoley et al., 1999; 2001], and the dike, intruding on these horizons, has a Sm/Nd age of 1339 ± 54 Ma [Khudoley et al., 2007]. The youngest granitoid rocks of the Ulkanskii graben, overlapped by the Uchur series, have an isochronous U/Pb age obtained for zircon of 1703 ± 18 Ma [Neimark et al., 1992]. The sand-

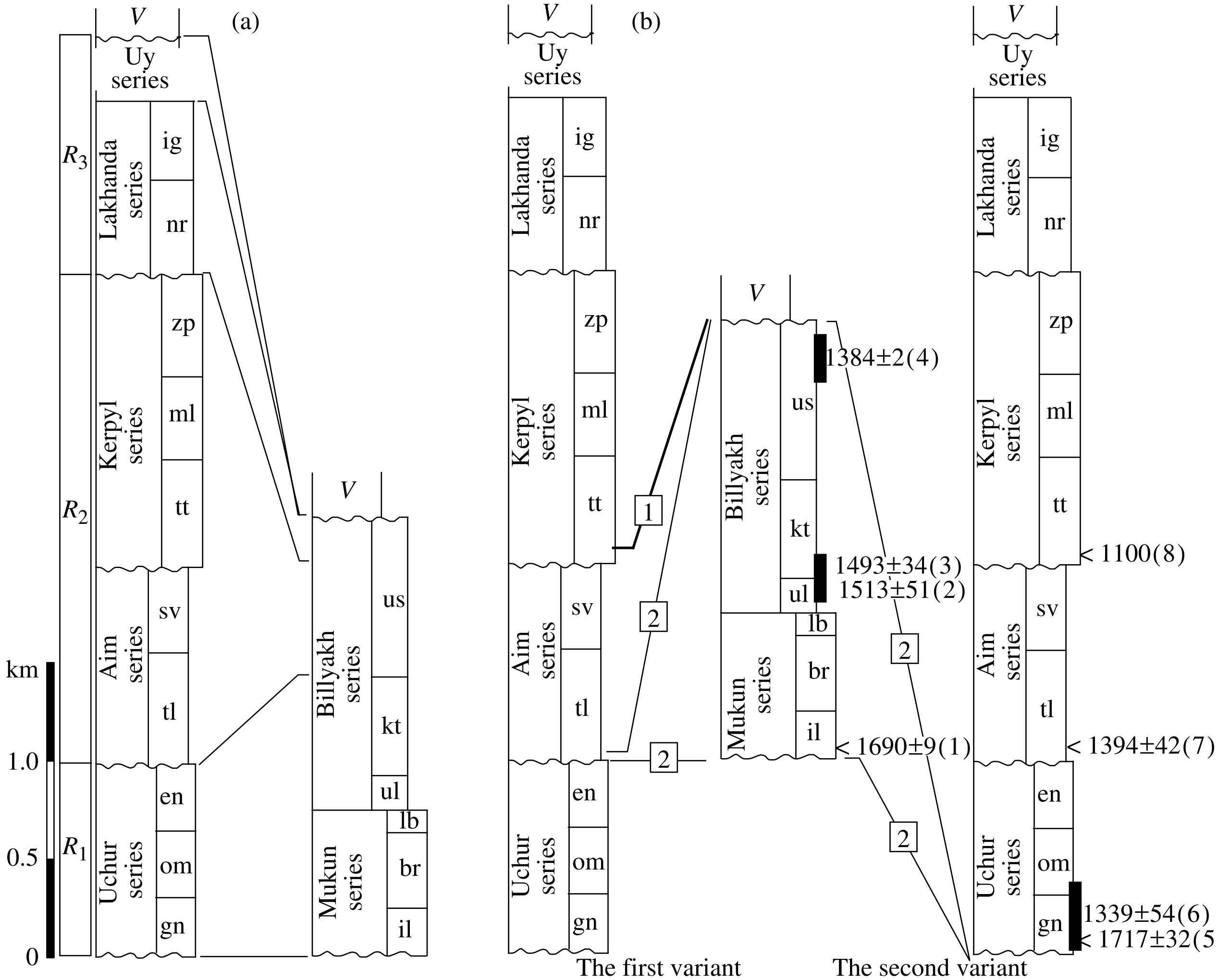

Fig. 2. Correlation diagrams of the Riphean of the Uchur-Maya region and the Anabar Uplift: (a) classical correlation according to [Semikhatov and Serebryakov, 1983], (b) correlation with the account of the present-day isotopic-chronological "1" [Khudoley et al., 2007] and paleomagnetic "2" (this work) data. Riphean Formations. Uchur-Maya region: Gonam (gn), Omakhta (om), Ennin (en), Talynskaya (tl), Svetlinskaya (sv), Totta (tt), Malginskaya (ml), Tsipandinskaya (zp), Neryuenskaya (nr), and Ignikanskaya (ig). Anabar Uplift: Il'inskaya (il), Burdur (br), Labaztakh (lb), Ustil'nskaya (ul), Kotuykan (kt), and Yusmastakh (us). Vendian (*V*) (Yudomskaya series). Intrusive bodies are conventionally depicted by black vertical strips.

(1) 1690 ± 9 fragmental zircons, [Khudoley et al., 2007]

(2) 1513 ± 51 the Sm/Nd data, [Veselovskiy et al., 2006]

(3) 1493 ± 34 baddeleyite, (K.R. Chamberlain, privat communication)

(4) 1384 ± 2 the U/Pb data, [Ernst et al., 2000]

(5) 1717 ± 32 fragmental zircons, [Khudoley et al., 2001]

(6) 1339 ± 54 the Sm/Nd data, the reference in [Khudoley et al., 2007]

(7) 1394 ± 42 fragmental zircons (A.K. Khudoley, privat communication)

(8) 1100 fragmental zircons, [Khudoley et al., 2007]

stones of the lower horizons of the Totta Formation contain the fragmental zircons with a U/Pb age of 1300 ± 5 Ma [Khudoley et al., 1999; 2001], and according to recent data about 1100 Ma [Khudoley et al., 2007]. Rather numerous Rb/Sr and K/Ar determinations of isotopic age, obtained in the sixties–eighties based on the Riphean Formations of the Uchur-Maya region, are often contradictory and they are, obviously, revived [Semikhatov et al., 1987; 1991; Shenfil, 1991].

We have investigated the sedimentary rocks of the Gonam, Omakhta and Ennin Formations of the Uchur series of the Lower Riphean, and also of the Konder Formation [Nevolin et al., 1978], considered at the present time as the lower sub-series of the Totta Formation of the Middle Riphean Kerpyl series [Semikhatov and Serebryakov, 1983]. It should be noted that the Konder layers for a long time were identified with the Ennin Formation [Nuzhnov, 1967; Potapov et al.,

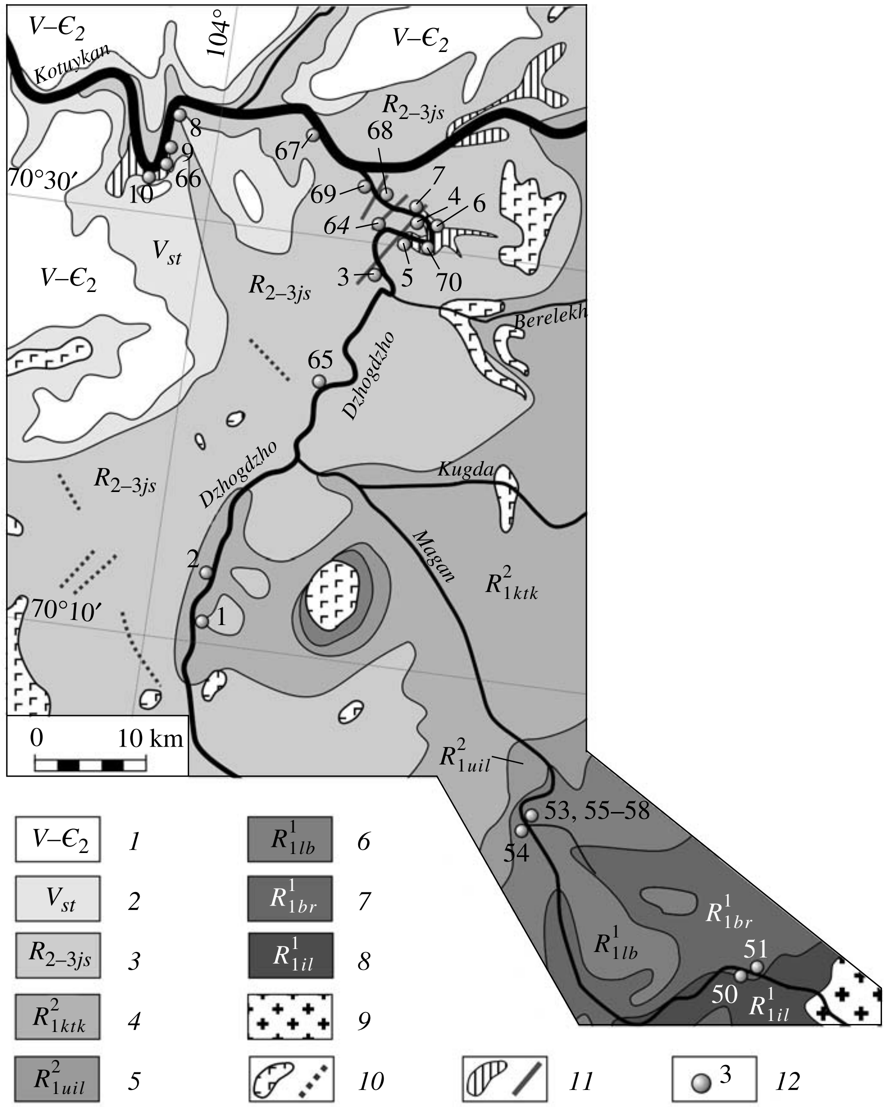

Fig. 3. Diagram of the objects investigated on the western slope of the Anabar Uplift: (*1*) rock of the Vendian–Middle Cambrian, (*2*) Vendian Staraya Rechka Formation, (*3*) Yusmastakh Formation, (*4*) Kotuykan Formation, (*5*) Ust'-Il'ya Formation, (*6*) Labaztakh Formation, (*7*) Burdur Formation, (*8*) Il'ya Formation, (*9*) the outcrops of the rocks of the Precambrian basement, (*10*) the intrusive bodies P_2-T_1, (*11*) the intrusive bodies of Precambrian age, (*12*) points of sampling.

1974] and the results of the studies conducted by us (see below), possibly, partly support this point of view. The sections of the formations mentioned above were studied in the valleys of the Mulam, Idyum, Algama, Gonam, Uchur, Bolshoi Aim, and Aim Rivers (Fig. 5), where the rock inclination in the majority of cases does not exceed 10°. The Gonam Formation in ten outcrops studied is presented by the speckled sandstones, aleurites and rare interlayers of dolomites. The rocks of the Omakhta Formation tested at seven points are composed of red dolomites, and also by the layers of multicolored aleurolites and sandstones. The Ennin Formation is tested in the two outcrops, in which it is presented by the reddish sandstones with the rare interlayers of dolomites. The Konder Formation selected in the four outcrops is presented by the interbedding of multicolored argillites and aleurolites with rare thin bundles of brick-red sandstones.

PALEOMAGNETIC ANALYSIS

Methodology

The laboratory paleomagnetic studies were carried out in the Institute of Physics of the Earth, Russian Academy of Sciences (Moscow), in the Parisian Institute of Geophysics and the Munich University in accordance with the standard methodology [Zijderveld, 1967; Khramov, 1982; Shipunov, 1999; Collinson, 1980; Kirschvink, 1980; McFadden and McElhinny, 1988; 1990; Enkin, 1994; Tors-

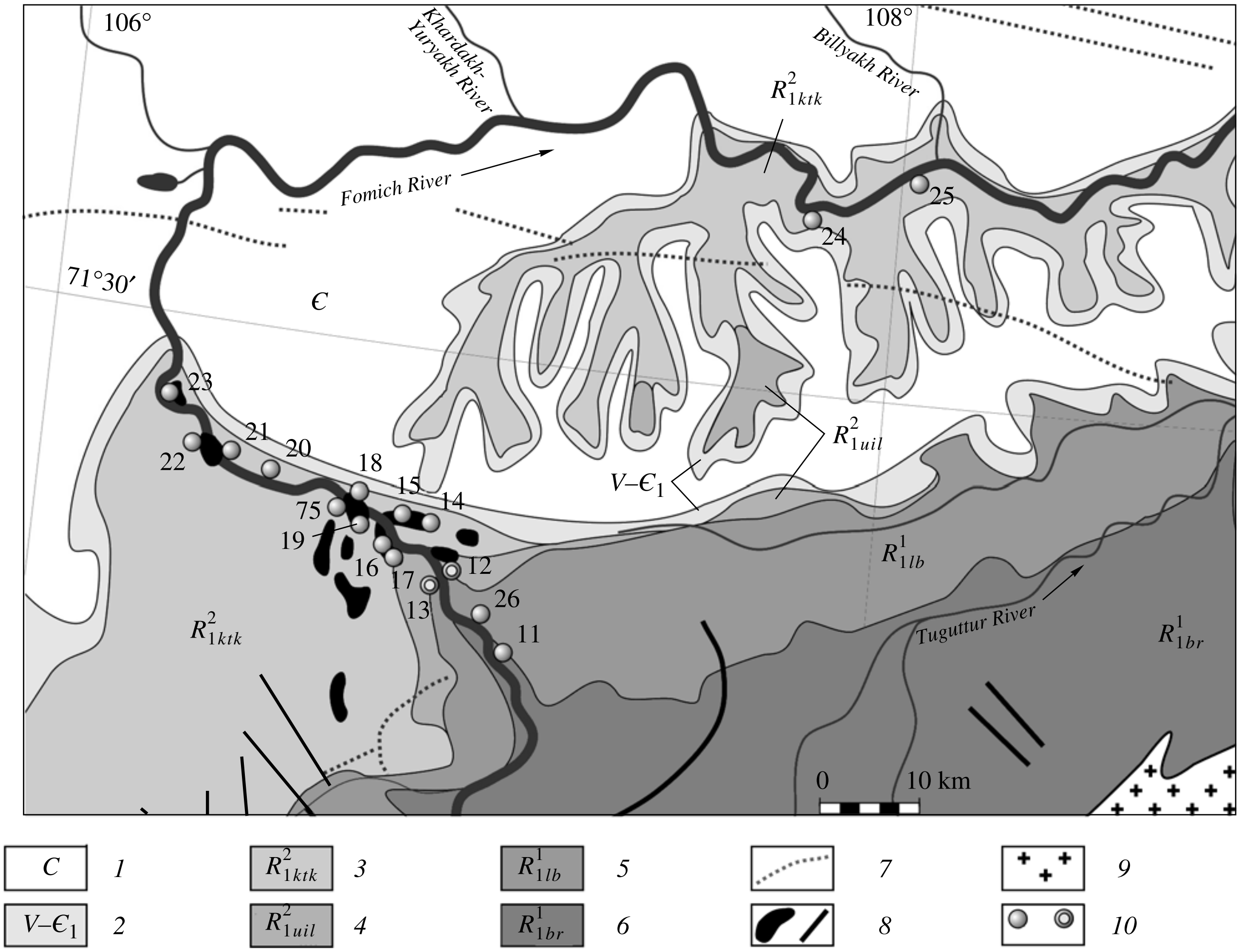

Fig. 4. Diagram of the objects investigated of the northern slope of the Anabar Uplift: (*1*) Cambrian rocks, (*2*) Vendian–Lower Cambrian deposits, (*3*) Kotuykan Formation, (*4*) Ust'-Il'ya Formation, (*5*) Labaztakh Formation, (*6*) Burdur Formation, (*7*) the intrusive bodies P_2-T_1, (*8*) the intrusive bodies of Precambrian age, (*9*) the protrusions of Precambrian basement, (*10*) points of sampling.

vik et al., 1990]. All samples were subjected to detailed temperature cleaning, which was carried out up to temperatures between 580–700°C.

The number of cleaning steps was usually not less than 15, in a number of cases the thoroughness of the cleaning was increased by up to 25 steps. For thermal demagnetization of the samples, nonmagnetic furnaces (including "Schonstedt" TSD-2 and TD-48 ASC) with a value of the uncompensated field of not more than 5–10 nT were used. The measurements of remanent magnetization were conducted on a 2-G Enterprises cryogenic magnetometer and a JR-4 spin-magnetometer. The measurements of magnetization were carried out in space, screened from the external magnetic field. The processing of measurements was carried out with the help of the program packages developed by R. Enkin [Enkin, 1994] and J.P. Cogne [Cogne, 2003], in which the PCA method was used for isolation of the magnetization components [Kirschvink, 1980].

The results of magnetic cleanings

The Western slope of the Anabar Uplift

Temperature cleaning revealed the presence of the clearly interpretive paleomagnetic record at ten sites, which represent nine of fifteen intrusive bodies investigated. The natural remanent magnetization of the samples studied contains one, two, or three magnetization components. In the simplest case the only magnetization component is separated, which is destroyed with heating up to a temperature of approximately 580–595°C (Fig. 6a) and which is connected, apparently, with magnetite. In the case of two-component magnetization the low- and high-temperature components are separated. The low-temperature component is destroyed under heating up to 190–250°C and, judging by the direction, has the present-day age. The high-temperature component is separated in the temperature range of 190–595°C (Fig. 6b).

In the case of three-component magnetization, besides the components mentioned above, the mean temperature component of magnetization is separated

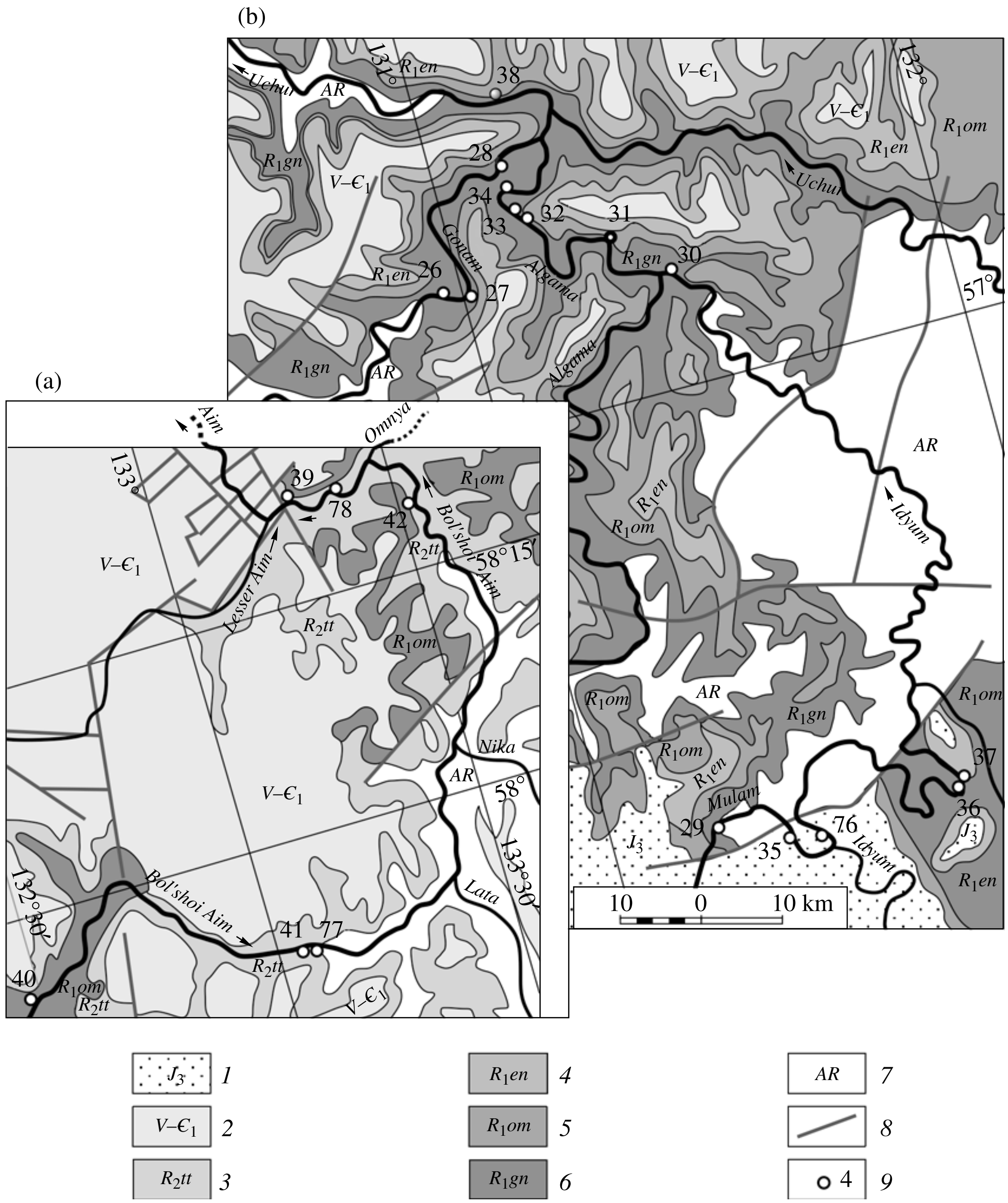

Fig. 5. Position of the outcrops investigated in the (a) Bol'shoi Aim and (b) Uchur (Uchur-Maya region) River valleys: (*1*) the Upper Jurassic rocks, (*2*) the Vendian–Lower Cambrian deposits, (*3*) the Middle Riphean, the Totta Formation/suite; the Lower Riphean, the Uchur series, (*4*) the Ennin Formation, (*5*) the Omakhta Formation, (*6*) the Gonam Formation, (7) the outcrops of the metamorphic rock of basement, (*8*) faults, (*9*) the point of sampling.

within the temperature range of 300–540°C (Fig. 6c). The mean temperature and high-temperature components are oppositely directed; however, they are not strictly antipodal: the angle between them differs from 180° by the value of the order of 20°.

The mean temperature component could be the result of the remagnetization of rocks as a result of their secondary heating, the source of which could be either the younger Proterozoic intrusions or trappean formations of the Permo-Triassic age. However, the tracks of such a reverse magnetization event should be expected in the paleomagnetic record of all samples in the limits of one body, but not in the single cases, as is observed here. The direction of the mean temperature component sharply differs from the expected direction of the trappean remagnetization that rejects this hypothesis. A possible explanation of the observed behavior of direction of the magnetization vector can serve the phenomenon of its partial self-reversal, similar to that discovered by us in the basic rocks close in composition to the Permo-Triassic trappean intrusion of the Stolbovaya River [Gapeev et al., 2003]. However, it is logical to explain the difference in the high-temperature and mean-temperature components from antipodality as being due to the incomplete removal of the present-day magnetization component during the isolation of the mean-temperature component. This is confirmed by the fact that the projection of the vector of the mean-temperature component on the stereogram lies on the great circle, which connects the projections of the vectors of the present-day field and the high-temperature component.

Temperature cleanings of the samples of the sedimentary rocks of the Burdur, Labaztakh, and Ust'-Il'ya Formations revealed in them either the present-day magnetization component or the extremely noisy paleomagnetic signal, whose interpretation is not possible.

The samples of the sedimentary rocks of the Yusmastakh Formation, selected from the near-contact zones of intrusions for conducting the contact baked-contact test, demonstrate an extremely noisy paleomagnetic signal, which cannot be interpreted.

The calculated directions of the high-temperature magnetization component of the intrusion bodies of the Western Anabar region (the mean-temperature component was not used in calculations) are given in Table 1 and are depicted in Fig. 6d.

The following facts give evidence of the primacy of the magnetization of rocks of the intrusive bodies of the valleys of the Dzhogdzho and Kotuykan Rivers: (a) indication of the possibility of the partial self-reversal of magnetization in several samples, (b) the persistence of the chosen components of magnetization over a large territory, and, also, (c) a difference in the calculated paleomagnetic poles from the younger poles of the Siberian Platform. The paleomagnetic pole, which corresponds to the high-temperature component (Table 3, No. 1), lies in close vicinity to the Early Middle Riphean paleomagnetic poles of the Angaro-Anabar block of the Siberian Platform, obtained earlier by K.M. Konstantinov and E.L. Gurevich (the sills of the Sololi River) and by R. Ernst (the Kuonamskii and Chieres dike clusters) (Table 4, Fig. 10, Nos. 19, 20, 27, 28), which also serves as one of the reasons for the substantiation of the primacy of magnetization of the intrusive bodies investigated.

The Northern slope of the Anabar Uplift

In all outcrops studied, except one (Fig. 4, point 75), the detailed temperature cleanings (after removal at 160–250°C of the present-day magnetization) make it possible to isolate confidently the ancient high-temperature characteristic component (Fig. 7a–7c).

The characteristic component has both direct and reversed polarity, moreover, frequently this can be observed in the same outcrop (Fig. 4, points 16, 17, 18, 20, 22, 23, 24). This magnetization component is destroyed within the temperature range of 250– 580°C; its carriers are, obviously, magnetite and low-titaniferous titanium-magnetite.

On the study by V.A. Tselmovich (GO "Borok") of the samples from the intrusive bodies of the valley of the Fomich River with the help of the "Camebax" microprobe, structures are found of the two-stage high-temperature multiphase oxidation of titanium-magnetite with the lamellas of ilmenite (hemoilmenite), with a size from 0.2 to 10 μm. According to [Gapeev et al., 1986], large lamellas with a size of 1–10 μm were formed at a high temperature (tentatively at 1100°C), and the fine particles, with sizes from 0.3 μm to 0.7 μm, at a temperature of 500–700°C. These data, together with the limited development of the secondary low-temperature changes in the grains, indicate in favor of the thermoremanent nature of the chosen characteristic component of magnetization.

It is important to note that in a number of samples the two practically oppositely directed magnetization components are separated (Fig. 7c), that, by the analogy with the example of magnetization of the rocks of the Dzhogdzho River valley given above, can indicate the partial self-reversal of magnetization.

The reversal test [McFadden and McElhinny, 1990], performed at the sample level shows that the obtained directions are statistically (with a 95% confidence level) distinguished (γ/γ_c = 12.4°/11.5°). Nevertheless, the mean directions of the direct and reversed polarity are close to antipodality, and the negative result of the reversal test is most naturally explained by the incomplete removal of the present-day magnetization component during thermal cleaning. Since a difference in the mean directions after reduction to one polarity is small, one should expect that the mean direction, obtained with the averaging of data over the objects with direct and reverse magnetization, practically would not differ from the actual direction.

Coincidence of paleomagnetic directions of the dike and the rocks of the Burdur Formation in outcrop 11 and, at the same time, a difference in these directions (γ/γ_{cr} = 27.4/5.8) from the corresponding direction of the rocks of the Burdur Formation in outcrop 26, located at a noticeable distance (4 km) from the dike, makes it possible to speak about the positive result of the contact test (Fig. 8a).

The averaging of the calculated paleomagnetic directions was carried out at the site level. When the sites originally represented a unique magmatic body (Fig. 4, points 12–13; 14–15; 16–17; 21–22), on calculation of the mean direction they were joined. The mean directions of the characteristic magnetization, calculated for each of 11 sites, are shown in Fig. 8d and are presented in Table 1. The corresponding paleomagnetic pole (No. 2) is given in Table 3 and in Fig. 10. The

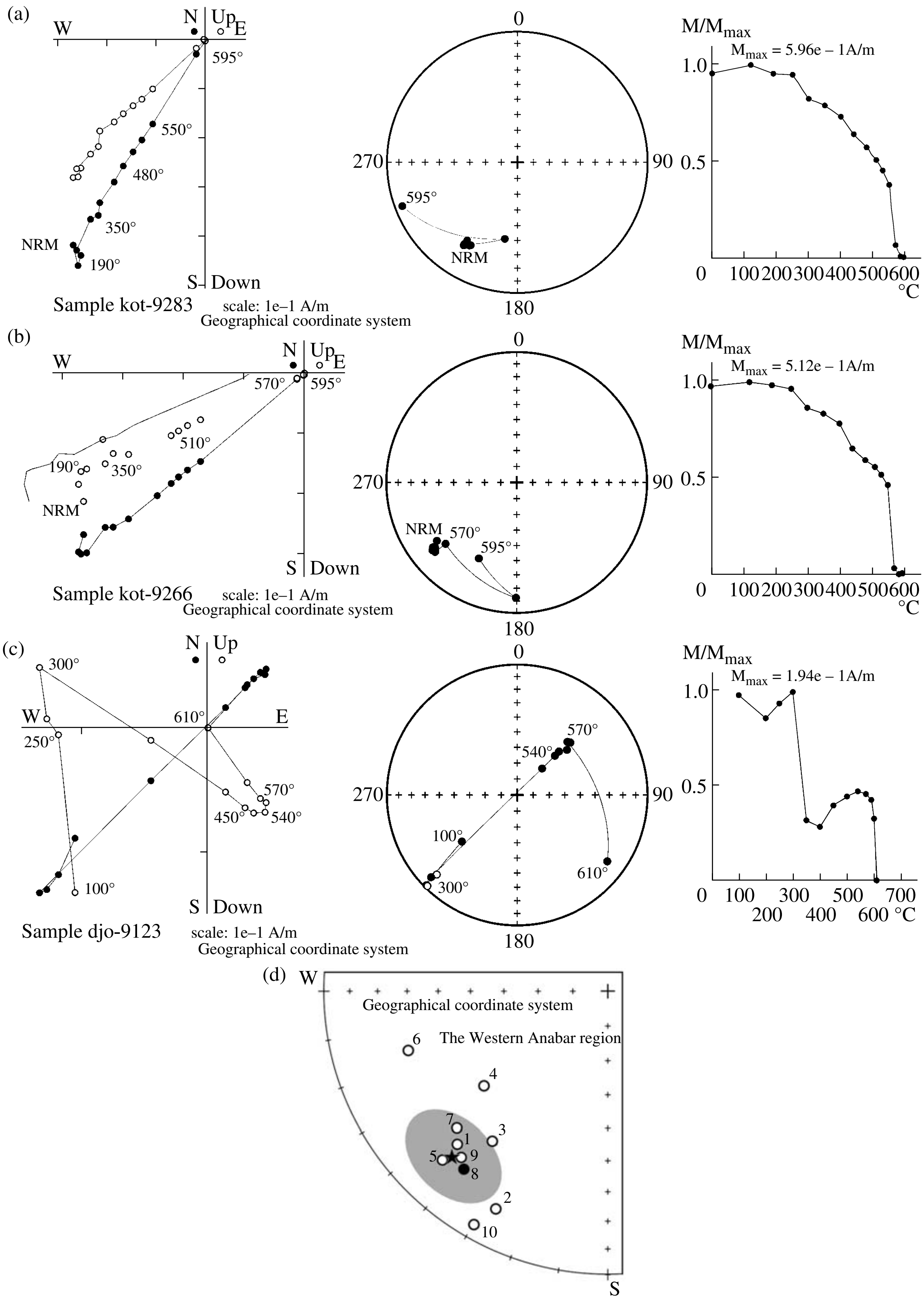

Fig. 6. Results of (a)–(c) temperature cleaning of the samples of the intrusive bodies of the Western Anabar region, (d) the mean directions of the characteristic magnetization component for each site and (asterisk) the mean direction of the intrusive bodies investigated of the Western Anabar region.

Table 1. Paleomagnetic directions: the western and northern slopes of the Anabar Uplift

Number of sample points on the scheme (field numbers)	Sample point		*N*/*n* (*S*)	Geographical system				Stratigraphic system				Notes
	φ	λ		*D*	*I*	*K*	α95	*D*	*I*	*K*	α95	
Western slope of the Anabar Uplift (the Dzhogdzho and Kotuykan Rivers)												
1 (1)	70°11′	104°07′	13/15	44.7	31.2	19.6	9.6	44.7	31.2	19.6	9.6	
2 (2)	70°13′	104°10′	9/12	207.2	–14.6	29.0	9.7	207.2	–14.6	29.0	9.7	
3 (3)	70°28′	104°17′	13/15	216.1	–36.4	35.1	7.1	216.1	–36.4	35.1	7.1	
4 (6)	70°20′	104°20′	5/14	234.7	–44.1	52.9	10.6	234.7	–44.1	52.9	10.6	
5 (7)	70°20′	104°20′	15/15	226.5	–17.9	31.5	6.9	226.5	–17.9	31.5	6.9	
6 (9)	70°20′	104°20′	12/12	255.7	–27.5	41.3	6.8	255.7	–27.5	41.3	6.8	
7 (10)	70°20′	104°20′	14/14	229.9	–28.9	44.1	5.3	229.9	–28.9	44.1	5.3	
8 (14)	70°32′	103°52′	15/15	218.8	20.4	33.3	6.7	218.8	20.4	33.3	6.7	
9 (15)	70°31′	103°54′	9/15	221.4	–16.9	47.7	7.5	221.4	–16.9	47.7	7.5	
10 (17)	70°30′	103°54′	13/14	207.2	–4.5	18.7	9.9	207.2	–4.5	18.7	9.9	
Average (over the sites):	**70°25′**	**104°08′**	**122 (10)**	**223.6**	**–20.9**	**13.2**	**13.8**	**223.6**	**–20.9**	**13.2**	**13.8**	
Northern slope of the Anabar Uplift (the Fomich River). Intrusive bodies												
11 (3)	71°17′	107°09′	8/13	32.5	–3.0	36.8	9.2	32.5	–3.0	36.8	9.2	
12 + 13 (5 + 6)	71°20′	106°55′	11/13	21.1	22.5	29.1	8.6	21.1	22.5	29.1	8.6	
14 + 15 (7 + 8)	71°23′	106°51′	9/10	20.1	18.9	15.6	13.4	20.1	18.9	15.6	13.4	
16 + 17 (9 + 10)	71°22′	106°48′	9/11	21.8	–6.7	10.3	16.8	21.8	–6.7	10.3	16.8	
18 (11)	71°22′	106°44′	5/7	26.2	4.0	11.3	23.7	26.2	4.0	11.3	23.7	
19 (12)	71°22′	106°44′	5/5	17.8	–5.0	23.4	16.2	17.8	–5.0	23.4	16.2	
20 (14)	71°24′	106°32′	6/7	19.8	7.7	47.1	9.9	19.8	7.7	47.1	9.9	
21 + 22 (15 + 16)	71°25′	106°23′	7/17	45.0	2.4	5.5	28.3	45.0	2.4	5.5	28.3	
23 (17)	71°26′	106°15′	5/7	40.6	33.3	39.0	12.4	39.1	37.7	31.9	13.8	
24	71°38′	107°46′	8/12	23.9	0.1	17.1	13.8	23.9	0.1	17.1	13.8	
25	71°40′	108°02′	4/5	39.9	–15.9	28.6	17.5	39.6	–13.7	22.3	19.5	
Direct polarity (*N*)	71°30′	106°30′	55	24.3	11.5	15.1	5.0	24.3	11.5	15.1	5.0	γ/γ_{cr} = 12.4/11.5
Reverse polarity (*R*)	71°30′	106°30′	22	215.5	5.8	6.4	13.3	215.1	5.0	5.9	13.9	
Average (over the sites):	**71°30′**	**106°30′**	**77 (11)**	**27.9**	**5.3**	**22.2**	**9.9**	**27.7**	**5.9**	**21.3**	**10.1**	
Sedimentary rocks												
24 (Kotuykan Formation)	71°38′	107°46′	5/20	190.1	36.3	113	7.2	190.1	36.3	113	7.2	γ/γ_{cr} = 8.7/7.6
25 (Kotuykan Formation)	71°40′	108°02′	11/20	194.2	36.6	16.3	11.6	194.2	36.6	16.3	11.6	
Kotuykan Formation:	**71°40′**	**108°02′**	**16 (2)**	**192.9**	**36.5**	**23.0**	**7.9**	**192.9**	**36.5**	**23.0**	**7.9**	Average
11 (3) (Burdur Formation)	71°17′	107°09′	6/9	34.4	–0.8	108.2	6.5	34.7	–2.4	120.5	6.1	
26 (4) (**Burdur Formation**)	**71°19′**	**107°02′**	**20/20(1)**	**17.0**	**–28.8**	**108.1**	**3.2**	**18.2**	**–27.5**	**76.5**	**3.8**	Average

Notes: φ, λ are the mean latitude and longitude of the object, *N* is the number of samples, from which the particular direction was calculated, *n* is the total number of samples subjected to magnetic cleaning, *S* is the number of sites, *D*, *I*, *K*, α95 are the declination, inclination, precision parameter, and confidence oval radius, respectively, γ is the angular distance between the vectors compared, and γ_c is the critical angle.

Table 2. Paleomagnetic directions of the rocks investigated of the Uchur-Maya region

Number of sample points on the scheme (field numbers)	Sample point		*N*/*n* [C] (*S*)	Geographical system				Stratigraphic system				Notes
	φ	λ		*D*	*I*	*K*	α95	*D*	*I*	*K*	α95	
Gonam Formation												
26 (1)	57°11′	130°57′	6/30 [1]	212.4	4.0	11.9	20.5	212.5	3.3	12.6	19.9	
27 (2)	57°10′	131°01′	12/50 [2]	38.6	11.8	10.8	13.9	38.3	12.0	10.7	13.9	
28 (3)	57°17′	131°06′	13/15	44.4	11.5	17.5	10.2	43.4	13.5	16.3	10.6	
29 (4)	56°31′	131°14′	3/15 [1]	32.8	1.6	7.5	57.1	34.2	4.3	7.5	56.8	
30 (14)	57°08′	131°26′	5/20 [1]	44.4	11.9	92.3	8.2	43.6	14.2	529.7	3.4	
31 (16)	57°11′	131°20′	4/20	16.0	8.6	12.8	26.7	16.4	6.3	11.4	28.5	
32 (17)	57°14′	131°10′	6/19 [2]	24.5	10.2	8.2	25.7	24.6	13.1	6.8	28.4	
33 (18)	57°14′	131°09′	4/19	35.4	20.7	18.8	21.7	37.4	25.3	18.0	22.3	
34 (19)	57°16′	131°09′	6/20 [1]	13.4	8.3	4.6	35.1	13.9	3.0	4.9	33.9	
Average (over sites):	**57°00′**	**131°15′**	**9**	**31.3**	**9.1**	**38.4**	**8.4**	**31.5**	**10.0**	**35.6**	**8.7**	Except 36
Average (over samples): *N*	57°00′	131°15′	53	38.5	9.8	17.8	5.4	38.2	11.8	17.8	5.4	γ/γ_{cr} = 8.4/15.4
Average (over samples): *R*	57°00′	131°15′	6	212.4	4.0	11.9	20.5	212.5	3.3	12.6	19.9	
Average (over samples):	**57°00′**	**131°15′**	**59 (9)**	**36.8**	**6.8**	**15.6**	**5.3**	**36.5**	**8.8**	**15.6**	**5.3**	Except 36
Omakhta Formation												
35 (5)	56°29′	131°23′	8/22 [1]	167.6	17.5	18.9	13.2	166.8	9.9	19.9	12.8	
36 (12) ("Om-A" component)	56°29′	131°45′	16/19 [1]	122.7	–65.0	80.8	4.1	50.2	–60.3	91.0	3.9	
37 (13) ("Om-A" component)	56°29′	131°45′	17/22	41.5	–51.9	90.9	3.8	43.3	–52.2	67.3	4.4	
37 (13) ("Om-B" component)	56°29′	131°45′	5/22	42.2	0.3	51.9	10.7	42.0	4.1	68.9	9.3	
38 (20) ("Om-C" component)	57°23′	131°14′	7/26 [3]	33.2	–33.6	69.1	5.9	33.2	–33.6	69.1	5.9	
38 (20o) ("Om-B" component)	57°23′	131°14′	7/26	41.1	–2.0	34.3	10.5	40.2	2.3	51.5	8.5	
39 (30) ("Om-30" component)	58°22′	133°18′	16/29	254.0	30.0	128.3	3.3	251.3	33.9	107.0	3.6	
34 + 40 + 39 (19o + 23 + 30) ("Om-B" component)	57°37′	132°00′	4/74 [3]	36.3	–9.4	18.6	21.9	36.1	–10.6	27.6	17.8	
"Om-A" (average):	56°29′	131°45′	31 (2)	67.9	–63.5	13.9	7.2	45.9	–55.4	69.6	3.1	Over samples
"Om-B" (average):	**57°00′**	**132°00′**	**16 (5)**	**41.7**	**–0.6**	**48.4**	**5.8**	**41.2**	**2.1**	**66.8**	**4.9**	Over samples
Gonam and Omakhta Formations												
"WEST" component	57°00′	132°00′	17/69 (3)	263.9	0.0	40.3	5.7	263.7	1.8	46.2	5.3	**38 + 39 + 32** (20o + 30 + 17)
"J-60" component	57°00′	132°00′	19/93 (4)	261.7	58.0	55.6	4.5	261.5	58.1	46.3	5.0	**35 + 34 + 38 + 40** (5 + 19g + 20g + 23)
Konder Formation												
41 (25)	57°52′	133°07′	13/20	46.4	–32.4	10.7	13.3	48.1	–28.9	11.1	13.0	
42 (28)	58°18′	133°33′	9/16	53.4	–48.4	36.3	8.7	54.7	–42.5	43.9	7.9	
Average (over samples): *N*	58°05′	133°19′	15	47.2	–39.6	14.4	10.5	47.8	–34.5	15.4	10.1	γ/γ_{cr} = 7.4/18.3
Average (over samples): *R*	58°05′	133°19′	7	232.8	38.4	10.6	19.5	236.8	35.0	12.4	17.9	
Average (over samples):	**58°05′**	**133°19′**	**22 (2)**	**49.0**	**–39.2**	**13.5**	**8.8**	**50.6**	**–34.8**	**14.7**	**8.4**	

Notes: φ, λ are the mean latitude and longitude of the object, *N* is the number of samples, from which the particular direction was calculated, *n* is the total number of samples subjected to magnetic cleaning, *C* is the number of remagnetization circles, *S* is the number of sites, *D*, *I*, *K*, α95 are the declination, inclination, precision parameter, and confidence oval radius, respectively, γ is the angular distance between the vectors compared, and γ_c is the critical angle.

Table 3. Paleomagnetic poles of the Mesoproterozoic objects investigated of the Siberian Platform

Object		Consecutive number	Sample point		N (S)	Paleomagnetic pole (*corrected)						
			φ	λ		Φ	Λ	dp/dm	φ_m	Q_v	Φ*	Λ*
Anabar Uplift:												
	Western slope:	1	70°25′	104°08′	122 (10)	24.5	236.0	7.6/14.5	10.8	5	–13.4	32.7
	Northern slope:											
	– Intrusive bodies	2	71°30′	106°30′	77 (11)	18.9	256.9	5.0/9.9	2.7	5	–9.5	51.6
	– Kotuykan Formation	3	71°40′	108°02′	16 (2)	–2.3	275.9	5.4/9.2	–20.3	3	8.5	74.7
	– Burdur Formation	4	71°19′	107°02′	20 (1)	2.5	270.6	1.9/3.5	–15.4	3	4.6	68.6
Uchur-Maya region:												
Gonam Formation		5	57°00′	131°15′	59 (9)	32.1	273.6	4.3/8.5	4.6	6	–32.1	93.6
Omakhta Formation	“Om-A”	6	56°29′	131°45′	31 (2)	–10.3	275.5	3.2/4.4	–35.9		10.3	95.5
	“Om-B”	7	57°00′	132°00′	16 (5)	23.7	265.4	2.9/5.8	–0.3	3	–23.7	85.4
	“Om-C”	8	57°23′	131°14′	10 (1)	9.4	279.5	3.8/6.7	–18.4		–9.4	99.5
	“Om-30”	9	58°22′	133°18′	16 (1)	–5.6	245.2	2.0/3.7	–16.1		5.6	65.2
Omakhta and Gonam Formations	“West”	10	57°00′	132°00′	17 (3)	2.7	227.8	2.7/5.3	–0.9		–2.7	47.8
	“J-60”	11	57°00′	132°00′	19 (4)	–27.6	251.4	4.9/6.6	–38.7		27.6	71.4
Konder Formation		12	58°05′	133°19′	22 (2)	2.2	266.3	5.6/9.7	–19.2	5	–2.2	86.3

Notes: φ, λ are the mean latitude and longitude of the object, *N* is the number of samples, *S* is the number of sites, Φ, Λ are the latitude and longitude of the paleomagnetic pole, dp/dm are the values of the half-axis of the confidence oval, φ_m is the paleo-latitude, Q_v is the reliability according to [Van der Voo, 1993],

* designate the poles corrected for the opening of the Vilyui rift system and inverted in accordance with the alternative choice of the polarity of paleomagnetic directions (see text).

obtained paleomagnetic poles of the intrusions of the Northern and Western Anabar region lie in relative proximity to the poles, obtained by Ernst from the Anabar dikes with a U/Pb age of 1503 ± 5 and 1384 ± 2 Ma [Ernst et al., 2000].

The primary character of magnetization in the intrusive bodies examined is confirmed by the following facts: (a) indications of the partial self-reversal of magnetization; (b) the consistency of the chosen magnetization components in the outcrops, spread out over an appreciable distance; (c) the presence of grains of titanium-magnetite with the structures of high-temperature oxidation, which indicates the probable thermo-residual magnetization of these grains; (d) the positive result of the contact test; (e) a difference in the obtained pole of the intrusive bodies from the younger poles of the Siberian Platform.

The sedimentary rocks of the Burdur (Fig. 4, points 11 and 26) and Kotuykan Formations (points 24 and 25) also bear a clear paleomagnetic signal (Fig. 7d and 7e). The magnetization of the samples is two-component: the low-temperature present-day component (up to 200°C) and the high-temperature characteristic component, with the maximum blocking temperatures near the Curie points of magnetite and hematite, are separated. The latter fact indicates that in the samples studied both of these magnetic minerals are carriers of magnetization (as a rule, separately). In this case, the direction of the characteristic component does not depend on the mineral-carrier of magnetization.

The vectors of characteristic magnetization form on the stereograms sharp clusters of one polarity for the Kotuykan Formation and of another polarity for the Burdur Formation (Figs. 8a, 8b, 8c). The mean directions, calculated for these clusters are almost antipolar (γ/γ_{cr} = 8.4°/7.6°) and give paleomagnetic poles (Tables 3), different from all younger poles of the Siberian Platform, including the poles, calculated from the sills and dikes intruding on the rocks considered.

The pole of the Burdur Formation is obtained from outcrop 26. The rocks of outcrop 11, as already mentioned, are completely remagnetized by the dikes intruding through them (Fig. 8a).

It is interesting to note that the pole, calculated by us for the Burdur Formation of the Fomich River valley, is located not far from pole No. 29 (Table 4), obtained by

Table 4. Paleomagnetic poles of the Siberian Platform utilized (including cited) in the present work

Region, object	Consecutive number	Age (Ma) **	Coordinates of the object		*N* (*S*)	Φ	Λ	A95 (dp/dm)	Φ*	Λ*
			φ	λ						
Aldanian shield (Uchur, Aim) [Pavlov, 2006]	14	PR_1^2	57°00′	131°00′	35 (8)	11.0	277.0	7.0	–11.0	97.0
Anabar Massif (Bol'shaya Kuonamka River) [Savrasov, 1990]	15	PR_1^2	69°45′	110°20′	215 (18)	15.0	304.0	5.0	–13.9	98.9
Anabar Massif (Bol'shaya Kuonamka River) (determinations of Kamyshova), [Paleomagnetic…,1971]	16	PR_1^2	69°30′	109°30′	85 (10)	–16.0	125.0	7/13	–15.0	99.6
Chaiskaya Suite [Didenko et al., 2004]	17	1863 ± 9, zr	57°36′	110°48′	108 (10)	22.5	277.4	1.5/2.8	–22.5	97.4
Shumikhinskie granitoids [Didenko et al., 2005]	18	1850 ± 5, zr	52°07′	103°48′	92 (2)	23.9	290.0	3.4/6.4	–19.8	83.4
Chieres dike [Ernst et al., 2000]	19	1384 ± 2, bd	70°36′	112°18′	7 (1)	4.0	258.0	5.0/9.0	5.0	55.9
Kuonamskii dikes [Ernst et al., 2000]	20	1503 ± 5, bd	70°00′	110°00′	24 (5)	6.0	234.0	14.0/18.0	5.2	31.8
Debengdin Suite (determinations of A.G. Iosifidi), [Paleomagnatic…, 1986]	21	1241 ± 30, R, K	70°30′	123°00′	20 (7)	6.0	254.0	5.2/10.2	3.5	51.7
Totta Suite [Pavlov, 1992]	22	<1100, zr	60°00′	139°00′		–21.3	245.3	9.1	21.3	65.3
Magla Formation [Pavlov et al., 2002]	23	1045 ± 20, S	59°00′	135°00′	89 (4)	–22.5	230.4	2.5	22.5	50.4
Lakhandinskaya Series [Pavlov et al., 2000]	24	1025 ± 40, S	59°00′	135°00′	(4)	–13.3	203.2	10.7	13.3	23.2
Kandykskie objects [Pavlov et al., 2002]	25	942 ± 19, S 1005 ± 4, bd	59°24′	136°24′	116 (8)	–3.1	176.5	4.3	3.1	356.5
Ust'kirbinsk Suite [Pavlov et al., 2002]	26	950(?)	58°42′	136°42′	21 (3)	–8.1	182.6	10.4	8.1	2.6
Sill of the Sololi River [Konstantinov et al., 2004]	27	1095 ± 5, K	71°00′	124°00′	34 (5)	23.0	239.0	9.5/17.5	–12.1	35.6
Sill of the Sololi River [Gurevich, 1983]	28	1860(?), zr	71°00′	124°00′	26 (1)	23.0	231.0	2.5/4.4	–11.6	28.1
Burdur Suite [Gurevich, 1983]	29	R_1	70°30′	106°00′	28 (1)	7.0	289.0	7.0/12.0	–2.9	84.9
Ilinskaya Suite, effusive rocks of the Vyurbyur River [Gurevich, 1983]	30	R_1	70°30′	106°00′	13 (1)	8.0	295.0	1.6/3.0	–5.2	91.5
Unguokhtakh Suite (determinations of V.P. Rodionov), [Paleomagnetic…, 1986]	31	1260, ä	71°30′	116°00′	18 (1)	23.0	255.0	6.5/12.5	13.5	50.6
Sill Sololi [Wingate et al., 2009, in press]	32	1473 ± 24, bd	70°36′	123°48′	159 (13)	33.6	253.1	10.4	–23.8	47.4

Notes: φ, λ are the mean latitude and longitude of the object, *N* is the number of samples, *S* is the number of sites, Φ, Λ are the latitude and longitude of paleomagnetic pole, A95, dp/dm is the circular probable error or the value of the half-axis of the confidence oval,

* designate the poles corrected for the opening of the Vilyui rift system and inverted in accordance with the alternative choice of the polarity of paleomagnetic directions (see the text),

** designate that in the case of the available isotopic age the data are presented concerning the method of its determination (zr designates the U/Pb data obtained from zircon, bd designates the U/Pb data obtained from baddeleyite, S designates the Sm/Nd data, K designates the K/Ar data, and R designates the Rb/Sr data).

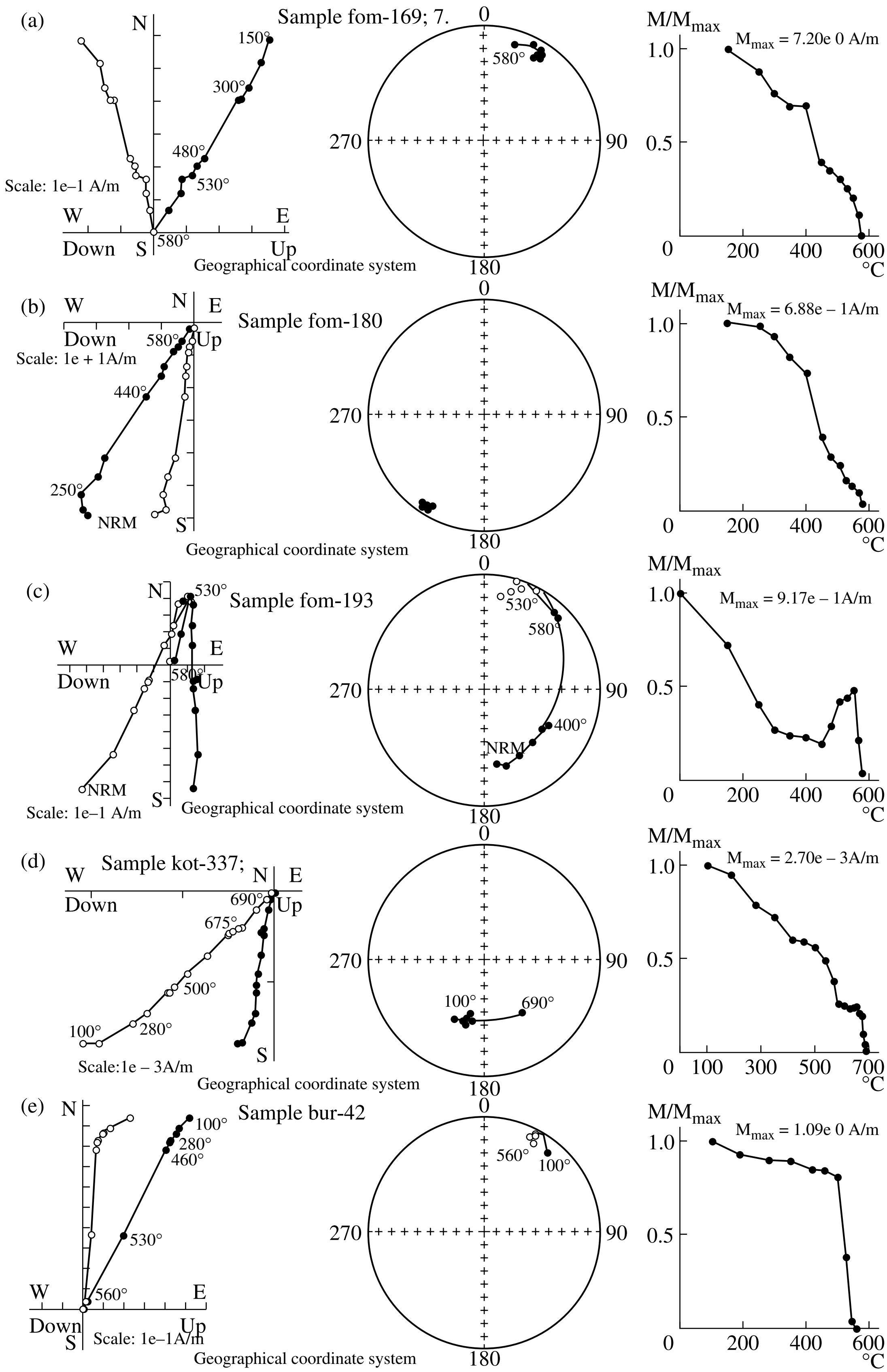

Fig. 7. Results of temperature cleaning of the samples of the intrusive bodies of the Northern Anabar region.

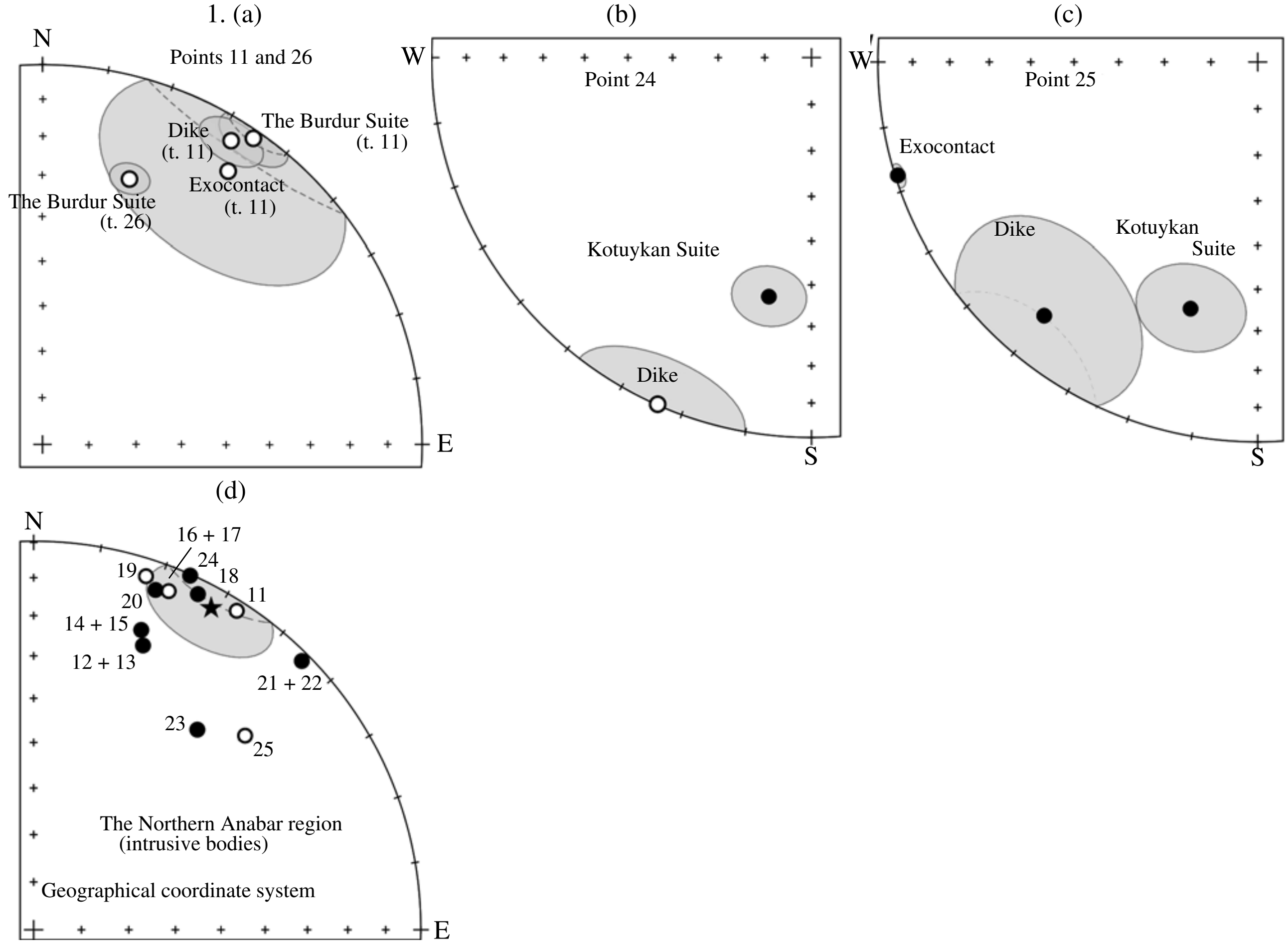

Fig. 8. Stereograms, which illustrate the directions of the identified magnetization components in four outcrops of the Fomich River valley: (a) completely remagnetized by the intruded dike of the rock of the Burdur Formation of outcrop (3) and the mean magnetization direction of the samples of outcrop (4) of the Burdur Formation; (b) the magnetization direction of the rocks of the Kotuykan Formation and the adjacent intrusive body (outcrop 24); (c) the same for outcrop 25; (d) the mean directions of the characteristic magnetization component for each site and the mean direction of the intrusive bodies investigated in the Northern Anabar region (designated by an asterisk).

E.L. Gurevich [Gurevich, 1983] from the rocks of the same formation, that are outcropped several hundred kilometers southward, in the Kotuykan River valley. The directions, obtained in the Kotuykan Formation, are also maintained over the territory: close directions were obtained by us for two outcrops (24 and 25) of the Kotuykan Formation, spread over a distance of approximately 10 km.

The following facts confirm that the characteristic magnetization component, isolated in the rocks of the Burdur and Kotuykan Formations, was formed during or soon after the formation of these rocks: (a) the constancy of directions at large distances; (b) the presence of the almost antipolar vectors of direct and reversed polarity; (c) a difference in the calculated poles from the younger poles of the Siberian Platform and relative proximity to the poles of close age; (d) the independence of the defined direction (in the Kotuykan Formation) from the magnetic mineralogy.

The Uchur-Maya region

The Gonam Formation

In the samples from the tested outcrops of the Gonam Formation, with the exception of section 38 (Fig. 5b), in spite of the predominantly low quality of the paleomagnetic signal, it was possible to isolate the components of natural remanent magnetization. In the majority of cases the low-temperature (present-day) and high-temperature (characteristic) magnetization components are separated (Fig. 9a). The latter is separated within the temperature range of 250– 670°C, and it has both the direct and reversed polarity, passes the reversal test (γ/γ_{cr} = 8.4/15.4) and is connected with hematite. In several samples, in which we failed to carry out the complete separation of the magnetization components, the remagnetization circles were calculated. The directions of the identified characteristic components of nine sites of the Gonam Formation densely group around their average (Fig. 9h; Table 2).

The following facts indicate in favor of the ancient magnetization of rocks of the Gonam Formation: (a) the direction of the identified high-temperature magnetization component is preserved from one section to another and the distance between them is 150 km; (b) the presence of the high-temperature magnetization components of two polarities; and (c) a difference in the obtained paleomagnetic pole from the younger poles of the Siberian Platform.

The Omakhta Formation

A considerable part of the samples studied of the Omakhta Formation demonstrate an extremely noisy signal, which makes these samples unsuitable for paleomagnetic study. In those cases, when the quality of the paleomagnetic record nevertheless makes it possible to carry out an interpretation, the component analysis is complicated because of the presence of several magnetization components (Table 2).

In the samples from outcrop 37 (Fig. 5b), besides the present-day low-temperature magnetization component, two more components are separated: the mean temperature component "Om-A" (up to ~615°C) and the high-temperature component "Om-B" (up to 675°C) (Fig. 9b).

From the stratotype of the Omakhta Formation, near the Berdyakit stream (Fig. 5b, outcrop 38), altogether, 140 samples were selected and it was possible to carry out component analysis only for 14 of them (excluding the samples, completely remagnetized by the present-day field). Here it is possible to isolate two magnetization components: the mean-temperature component "Om-C" (520–630°C) (Fig. 9c) and the high-temperature component "Om-B" (630–680°C), which has a direction similar with the direction of the magnetization component with the same name of the samples from outcrop 37.

The samples, selected from outcrop 39 (Fig. 5a), demonstrate the presence of the high-temperature magnetization component (540–690°C), designated by us as "Om-30" (Fig. 9d). In one sample component "Om-B" is present.

In unique samples from outcrops 34 and 40 it is also possible to detect the presence of the high-temperature magnetization component "Om-B" (500–670°C). The mean direction of the high-temperature component "Om-B" for all five outcrops of the rocks of the Omakhta Formation, where it is separated, is given in Table 2.

Magnetization components "Om-A", "Om-C" and "Om-30" are separated in some of the outcrops or in the closely adjacent sites. Possibly, their origin is caused by certain local reverse magnetization events, which appeared in the concrete outcrops. Relying on the position of poles "Om-A", "Om-C" and "Om-30" between the poles of the Uchur series (see below) and the poles of the Burdur and Kotuykan Formations of the Anabar Uplift (Fig. 10, Nos. 3 and 4), such events could occur in the course of time after the accumulation of the Omakhta Formation up to the beginning of the formation of the Burdur deposits.

By reason of the geological conditions of the study area it is possible to present only several arguments in favor of the Omakhta age of component "Om-B": (a) it, in contrast to all remaining components, is identified in five of the outcrops studied, which are located at a distance of about 100 km from each other; (b) the paleomagnetic pole (Table 3) calculated from the mean direction of component "Om-B" lies close to the pole of the Gonam Formation, which appears logical, taking into consideration the absence of interruption in the sedimentation between the Gonam and Omakhta Formations; (c) the pole of component "Om-B" differs from the younger poles of Siberia.

It should be noted that in six outcrops studied of both the Gonam and Omakhta Formations, the two additional magnetization components "J-60" (Fig. 9f) and "West" (Fig. 9e) are confidently identified. In the majority of samples these components are unique (with the rare exception of the low-temperature present-day magnetization component) and they have exclusively one polarity. The pole of component "West" lies in the region of the location of the poles of the intrusive bodies of the Anabar Uplift, and the pole, which corresponds to component "J-60", is located in immediate proximity to the pole of the Totta Formation [Pavlov, 1992] (Fig. 10, No. 22). The components indicated are, in all likelihood, the result of the regional remagnetization, whose age can be evaluated as Mesoproterozoic.

The Ennin Formation

The natural remanent magnetization of all samples is present as either the present-day magnetization component or by an extremely noisy signal and it cannot be subjected to interpretation.

The Konder Formation

Of the four outcrops tested, it was possible to identify the magnetization components in only two of them (outcrops 41 and 42, Fig. 5a), spaced-apart over 40 km. The natural remanent magnetization of samples from these outcrops is connected, predominantly, with hematite and represented by two components (Fig. 9g): by the low-temperature present-day (up to 240°C) and by the high-temperature (300–700°C) bipolar characteristic components. The identified high-temperature component successfully passes the reversal test ($\gamma/\gamma_{cr} = 7.4/18.3$; Fig. 9i). In the other two outcrops the rocks are either remagnetized by the recent magnetic field or the directions of the stable magnetization component, identified in separate samples, are distributed chaotically.

The calculated pole of the Konder Formation (Table 3, Fig. 10, No. 12) lies in the equatorial region in the localization area of the poles of the magnetization compo-

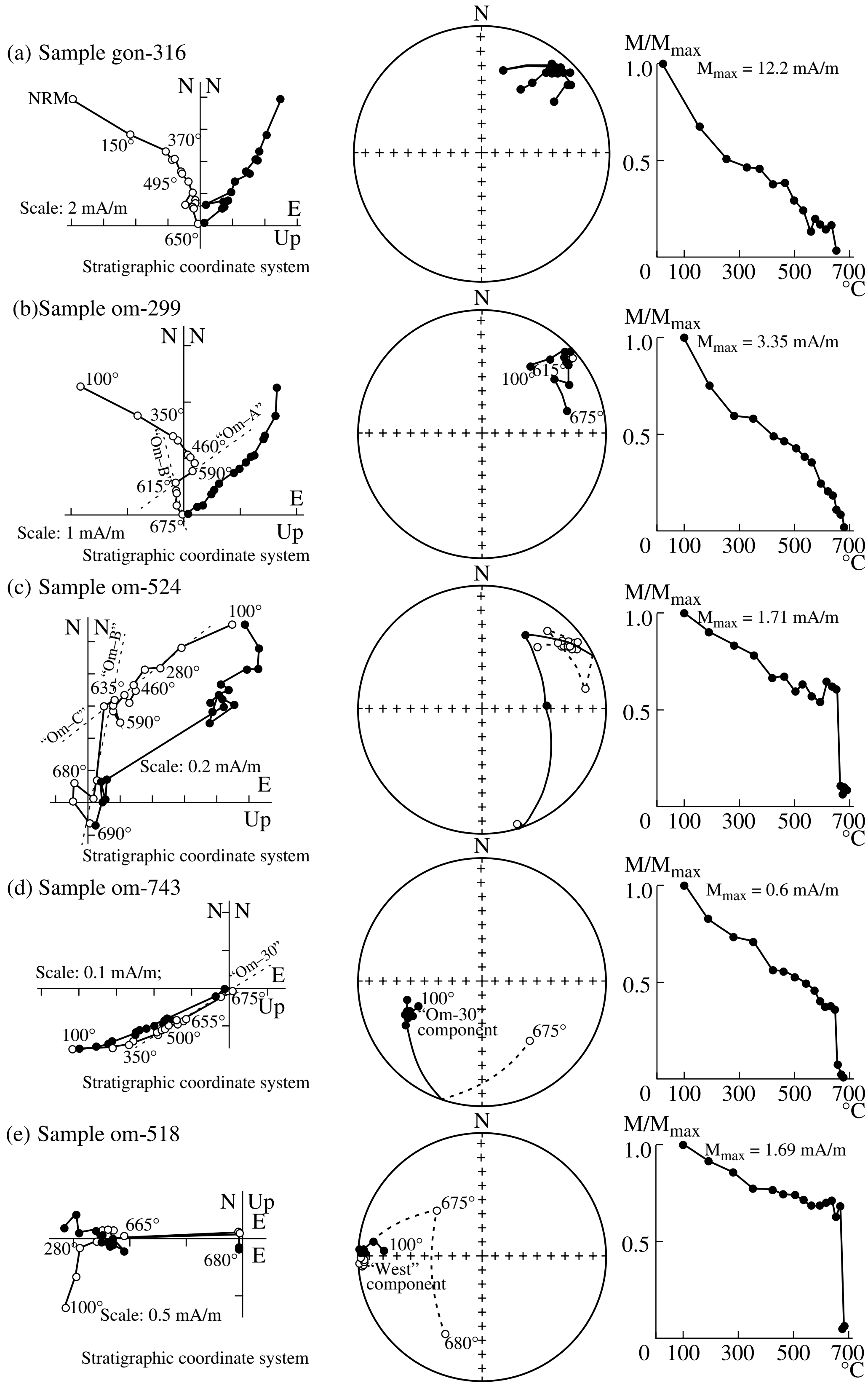

Fig. 9. Results of temperature cleaning of the samples of sedimentary rocks of the Uchur-Maya region. Zijderveld diagrams, stereograms and demagnetization curves of samples of the (a) Gonam , (b)–(f) Omakhta, and (g) Konder Formations. Stereograms, which illustrate the directions of the identified magnetization components in the rocks of the Uchur-Maya region: (h) the Gonam Formation, (i) the Konder Formation, (j) the Omakhta Formation.

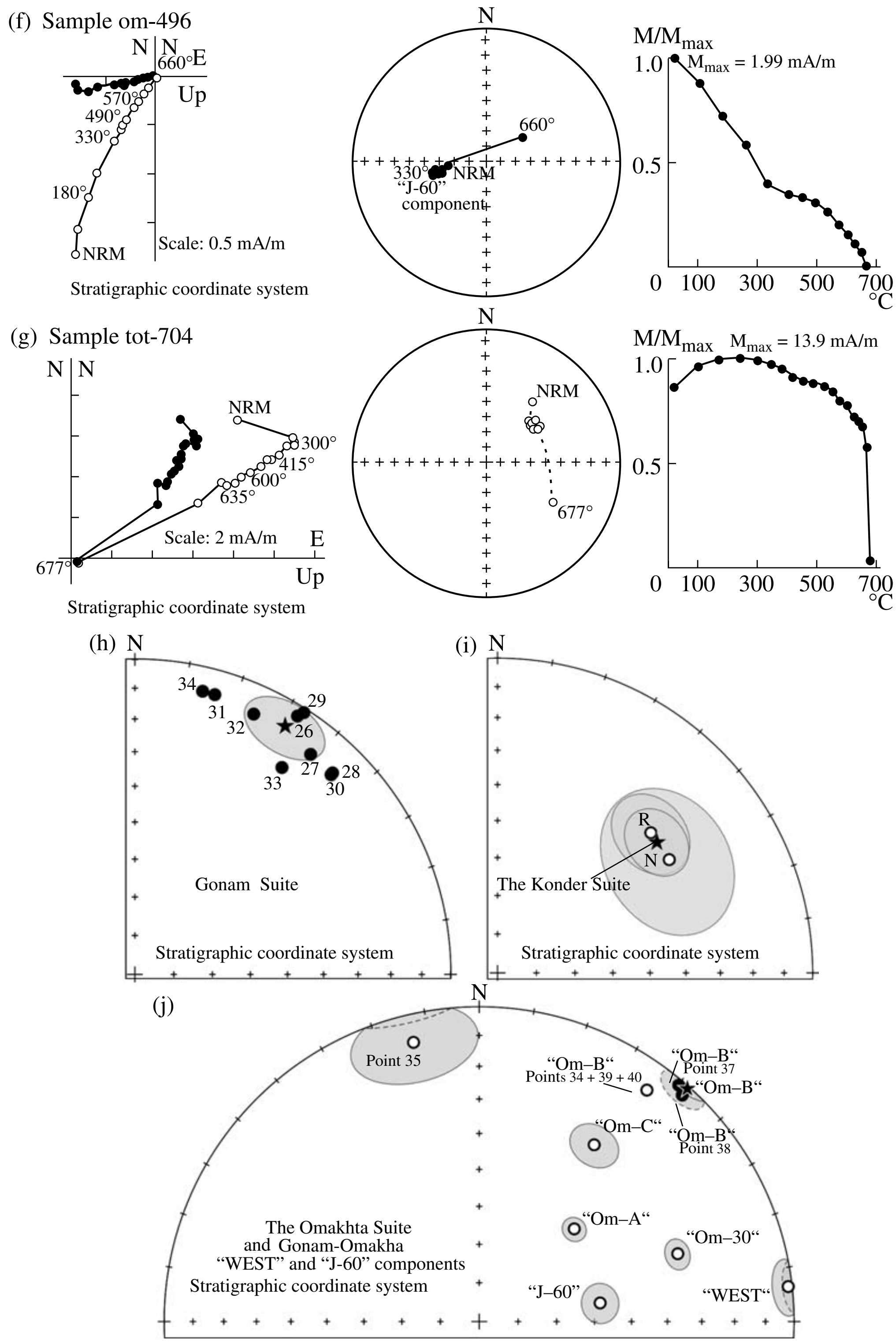

Fig. 9. Cont.

nents of the Omakhta rocks. The following facts count in favor of the primacy of magnetization of the Konder deposits: (a) the consistency of the direction of the magnetization component in the remote outcrops; (b) the presence of magnetization vectors with direct and reversed polarity; and also (c) a difference in the pole, which corresponds to the mean magnetization direction, from the younger poles of Siberia.

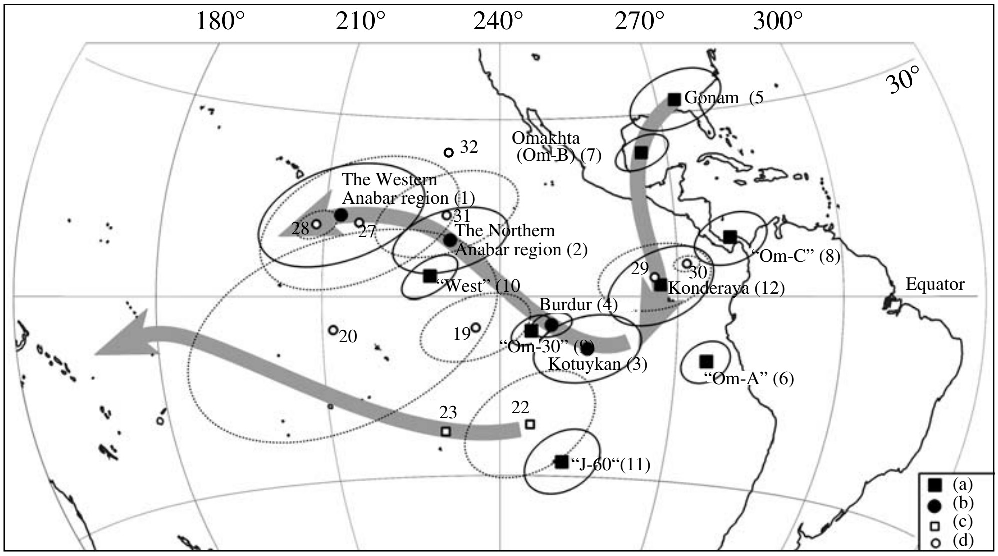

Fig. 10. Paleomagnetic poles of the Siberian Platform, obtained in this work (Table 3), and the poles, obtained earlier and utilized in the text (Table 4): (19) the Chieress dike [Ernst et al., 2000], (20) the Kuonamka dikes [Ernst et al., 2000], (22) the Totta Formation [Pavlov, 1992], (23) the Malginskaya Formation [Pavlov et al., 2002], (27) the Sololi River sill [Konstantinov et al., 2004], (28) the Sololi River sill [Gurevich, 1983], (29) the bottoms of the Burdur Formation [Gurevich, 1983], (30) the Il'inskaya Formation [Gurevich, 1983], (31) the Unguokhtakhskaya Formation (determination of V.P. Rodionov) [Paleomagnetic…, 1986], (32) the sill of the Sololi River, (a) and (b) paleomagnetic poles, obtained in this work for (a) the Aldan and (b) the Angaro-Anabar blocks, (c) and (d) paleomagnetic poles, obtained earlier for (c) the Aldan and (d) the Angaro-Anabar blocks.

RESULTS AND DISCUSSION

The calculated paleomagnetic poles substantially supplement the Siberian paleomagnetic database; all of them are obtained with the use of up-to-date procedures and to one degree or another (depending on the specific geological situation) correspond to the currently accepted criteria of paleomagnetic reliability (Table 3; [Van der Voo, 1993]). This makes it possible to use them together with already available data for solving a number of paleogeographic and stratigraphic problems.

Due to the obvious deficiency in the isotopic datings of the magmatic rocks of the areas investigated, the paleomagnetic data enable one to impose essential restraints on the age of the formation of these rocks. The comparison of the paleomagnetic poles of the intrusive bodies of the Western and Northern Anabar region shows that they statistically significantly differ from each other ($\gamma/\gamma_{cr} = 21.8/16.1$). Consequently, the emplacement of the intrusions indicated did not occur simultaneously, although within the relatively close intervals of a geological time scale of approximately 1.5 Ga [Veselovskiy et al., 2006].

The immediate vicinity of the paleomagnetic poles of the sills of the Sololi River in the Olenek elevation [Gurevich, 1983; Konstantinov et al., 2004] and the Unguokhtakhsk Formation of the Udzhinsk uplift (definition of V.P. Rodionov) [Paleomagnetic…, 1986] on the one hand, and the poles of the Northern and Western Anabar region on the other hand (Tables 3 and 4, Fig. 10), should be considered as an indication of the closeness of the ages of these objects to the age of the intrusive complex of the Northern Anabar region, i.e., to 1.5 Ga. This estimate, in general, does not contradict the available isotopic datings. Thus, the age of the sill of the Sololi River varies from 1090–1100 Ma (K/Ar, [Gurevich, 1983]) up to 1860 Ma (U/Pb, D.P. Gladkochub and T. Donskaya, privat communication). Furthermore, the K/Ar determination based on the bulk sample (such determinations frequently turn out to be underestimates) gives for the Unguokhtakhsk Formation an age estimate of 1260 Ma [Paleomagnetic…, 1986]. The proximity of the paleomagnetic poles of the magmatic bodies, spaced-apart over many hundreds of kilometers indicates that 1.5 Ga ago a large-scale magmatic event occurred in the Siberian Platform territory, whose influence runs far beyond the limits of the Anabar Uplift.

The grouping of the poles of the Ilinskaya [Gurevich, 1983], Burdur, and Kotuykan Formations in a narrow region indicates sufficiently rapid sedimentation, at least, for the larger part of the section of the Anabar Riphean.

The sills of the Fomich River valley, which lie in the Kotuykan and Ustilinskaya Formations, are, probably, very close in age, which is confirmed by the proximity of the direction of the identified ancient magnetization components. Thus, the accumulation of the larger part of the (if not the entire) Riphean sedimentation mass of the Anabar Uplift occurred within the interval between 1710–1630 Ma (the age of the youngest formations of the basement) and 1513 ± 51 Ma (the age of the sill of the Fomich River valley occurring in the Ustilinskaya Formation).

The position of the poles of the Il'inskaya and Burdur Formations of the Anabar region [Gurevich, 1983] not far from the pole of the Konder Formation of the Uchur-Maya region, obtained in the work considered, can be treated as an indication of the closeness of the ages of these formations. Thus, in spite of the classical comparison of the Konder horizon with the bottoms of the Totta Formation of the Kerpyl series of the Uchur-Maya region [Semikhatov and Serebryakov, 1983], the Konder deposits, apparently, are close in age to the bottoms of the Mukun series, and, consequently, they are appreciably more ancient than the Kerpyl series (Fig. 2b). The paleomagnetic pole of the Konder Formation calculated in the present work differs significantly from the pole, obtained from the stratotypic section of the Totta Formation in the Northern Ui River valley [Pavlov, 1992]. In this case, the Konder paleomagnetic pole lies noticeably nearer to the poles of the Uchur series (the Gonam and Omakhta poles), than to the reliably identified pole of the Malginskaya Formation of the Kerpyl series [Pavlov et al., 2002]. This fact should be considered as indication of the appreciable difference in the age of the Konder and Totta (Kerpyl) rocks.

And, finally, the paleomagnetic determinations and the present-day isotopic-geochronological data presented in the paper make it possible to propose some new arguments relative to the correlation of the Riphean sections of the Anabar Uplift and the Uchur-Maya region. It should be recalled that until recently for the correlation of the Riphean sections of these regions the classical scheme was used [Semikhatov and Serebryakov, 1983] (Fig. 2a), according to which the sedimentary rocks of the Riphean of the Anabar Uplift were correlated with the entire Riphean rock mass of the Uchur-Maya region.

The correlation proposed by us (Fig. 2b) is based on the following facts and considerations:

1) in the lower part of the Aimchan series the fragmental zircons with an age of 1394 ± 42 Ma are discovered (A.K. Khudoley, private communication), i.e., the Aimchan series is younger than this age;

2) the Anabar Riphean is more ancient than 1384 Ma (the dike of this age [Ernst et al., 2000] intruded on the Yusmastakh Formation) and could be more ancient (at least, its larger part), than 1513 ± 51 Ma [Veselovsky et al., 2006];

3) there is a large disagreement between the Aimchan and Uchur series, which, possibly, corresponds to a prolonged interruption in sedimentation [Semikhatov and Serebryakov, 1983; Khudoley, 2003];

4) the poles of the Anabar Riphean differ from the poles of the Uchur series and it means that the age of these formations is different.

These data leave only two possible alternatives for correlation of the reference sections in question. The first alternative assumes that the accumulation of the Anabar Riphean deposits occurred during the interruption, which divides the Uchur and Aimchan series (Fig. 2b, to the left). The second alternative requires that the Riphean of the Anabar Uplift to have been formed earlier than the Uchur series (Fig. 2b, to the right).

There are two paleomagnetic arguments, which at present impede the adoption of the second alternative of the correlation:

1) There are metachronous directions in the Uchur series ("Om-A", "Om-C", "Om-30"), whose poles correspond with the poles of the Anabar Riphean, which implies a more ancient age of the Uchur series;

2) the adoption of the second alternative, other conditions being equal, substantially complicates and lengthens the curve of the apparent pole migration of the Siberian Platform, i.e., contradicts the principle of minimization of the displacements.

The closeness of the Konder (the Late Uchur in our interpretation) pole to the poles of the Ilinskaya and Burdur Formations, which compose the lower part of the Riphean of the Anabar region, is also the reason in favor of the fact that the Anabar Riphean was formed after the Uchur series.

These arguments enable us to consider the first alternative of the correlation as more preferable.

The data obtained in the present work together with the already published results (Table 4) can be used for determining the latitudinal drift of the Siberian Platform during the Mesoproterozoic period. For constructing the reconstructions, the coordinates of the paleomagnetic poles of the Anabar block were corrected taking into account the outcrops in the Middle Paleozoic era of the Vilyui rift system [Pavlov and Petrov, 1997; Pavlov et al., 2007] by their clockwise rotation at an angle of 25° around the pole, located in the region with coordinates of 117° E and 62° N. The paleomagnetic poles are obtained with the use of the "nontraditional" option of the polarity of paleomagnetic directions, which assumes (for the Riphean) the position of the northern paleomagnetic poles in the Eastern Hemisphere. This selection is confirmed by the latest works of V.E. Pavlov and A.V. Shatsillo [Pavlov et al., 2002; Shatsillo et al., 2006]. For reconstruction of the position of Siberia in the Paleo-Proterozoic (Fig. 11) the Late Paleo-Proterozoic poles of the basement [Pavlov, 2006; Savrasov, 1990; Paleomagnetic…, of 1971] of the Chaya Formation and Shumikha granitoid rocks [Didenko and Vodovorov, 2004] (the Shumikhin pole corrected for the opening of the Vilyui rift system) were used.

The paleomagnetic data, given in Tables 3 and 4, indicate that in the interval of 1.9–1.5 Ga, Siberia experienced quasi-vibrational displacements in the equatorial region, being considerably displaced towards the comparatively higher latitudes of the northern hemisphere only during the Konder, Burdur, and Kotuykan periods (Fig. 11). With the approach of the boundary of 1.5 Ga, which is distinguished by the emplacement of the intrusive bodies of the Anabar Uplift, Siberia again approached the equator and was turned counterclockwise to an angle of the order of 45° relative to the paleomeridian in comparison with its position during the Gonam period.

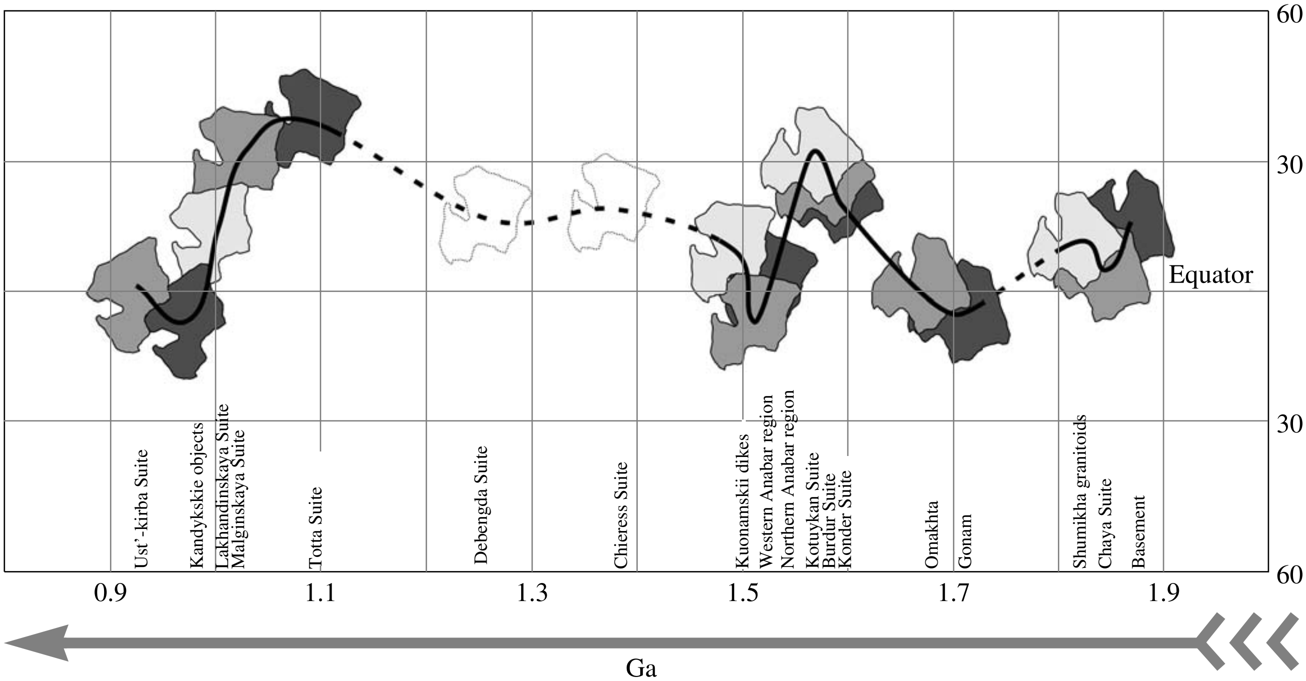

Fig. 11. Paleo-latitudinal position of the Siberian craton within an interval of 1.9–0.9 Ga.

The absence of the key paleomagnetic determinations for the time interval of 1.5–1.1 Ga makes it impossible to carry out confidently the paleo-reconstructions of Siberia within this time interval; therefore, for an indication of the approximate position of the Siberian craton in this "window" we used the preliminary poles of the Debengda Formation (the determination of A.G. Iosifidi [Paleomagnetic…, 1986]) and the Chieress dike [Ernst et al, 2000]. On the basis of these data, 1.4–1.2 Ga ago the Siberian Platform was located in the 10–15th latitudes of the northern hemisphere. Beginning from the Totta period, i.e., about 1.1 Ga ago [Khudoley et al., 2007], and up to the Kandyks-Ust'-kibra period the Siberian Platform was displaced from the middle latitudes of the northern hemisphere to the equator, and again experienced a counterclockwise rotation at an angle of approximately 35° relative to the meridian [Pavlov et al., 2002].

CONCLUSIONS

The data obtained in the course of this work give grounds to assume that:

1) The accumulation of the Riphean of the Anabar Uplift occurred after the formation of the Uchur series of the Uchur-Maya region;

2) The accumulation of the entire or almost entire Riphean section of the Anabar region was completed approximately 1.5 Ga ago;

3) The Konder layers, which are compared according to the correlation scheme accepted at the present time [Semikhatov and Serebryakov, 1983] with the bottoms of the Totta Formation, could relate to a considerably more ancient time level;

4) The emplacement of Proterozoic sills and dikes of the northern and western slopes of the Anabar Uplift occurred nonsimultaneously, although in the time intervals close to approximately 1.5 Ga ago.

5) During the Paleo-Mesoproterozoic, the Siberian craton was located, mainly, in the equatorial or low northerly latitudes, experiencing considerable rotations relative to the meridian throughout this time. From the end of the Paleoproterozoic [Didenko et al., 2004] up to the beginning of the Neoproterozoic [Pavlov et al., 2002] the Siberian Platform was turned counterclockwise relative to the meridian at an angle of the order of 90°.

The results obtained considerably supplement the database of Siberian paleomagnetic data for the Precambrian and, corresponding in general to the up-to-date criteria of paleomagnetic reliability [Van der Voo, 1993], can be used for the solution of different stratigraphic, geochronological, and paleogeographic problems.

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