RECONNAISSANCE PALEOMAGNETISM OF THE OLYUTORSKY SUPERTERRANE, NE RUSSIA

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ABSTRACT

A reconnaissance paleomagnetic investigation of Campanian to Paleocene-aged basalts and sediments from the Olyutorsky Peninsula (three localities: Upper Apuka River [lat. 61.5° N., long. 170.5° E.], Machevna Bay [60.8° N., 171.6° E.], and Javevyn Bay [60.2° N., 170.4° E.]) reveals a prefolding, characteristic remanent magnetization during careful stepwise thermal and alternating field demagnetization.

Analysis of the magnetizations observed at these localities gives characteristic remanent magnetizations in stratigraphic coordinates of D=141.4°, I= -70.8°, and α_{95}=10.8°; D=338.6°, I=66.5°, and α_{95}=10.4°; and D=297.1°, I=51.3°, and α_{95}=11.7°, respectively. The Fisher estimate of kappa changes from 1.06 in geographic coordinates to 13.4 in stratigraphic (ratio 13.4, N=15), suggesting that the characteristic magnetization of the Upper Apuka locality was acquired before folding. A positive fold test, coherence of characteristic magnetizations in stratigraphic coordinates when comparing the three localities, and removal of lower temperature magnetic components during thermal demagnetization suggest that these magnetizations represent a prefolding, characteristic magnetic remanence. Interpretation of the Machevna Bay and Javevyn Bay reconnaissance study results show 21° to 26° of northward motion for the Late Maastrichtian and 46° of northward motion for the Campanian rocks from these localities with respect to the North American plate. The observed paleolatitudes agree well with terrane trajectories calculated using previously published Izanagi-North America and Kula-North America finite rotations. They provide evidence that the Izanagi and Farallon plates were bounded by an island-arc system in the western Pacific and that fragments of this plate boundary are preserved today as tectonostratigraphic terranes.

INTRODUCTION

Detailed geological studies in the central and southern Koryak (Mitrofanov, 1977; Aleksandrov et al., 1980; Bogdanov et al., 1982; Astrahantzev et al., 1987; Vishnevskaya, 1987; Stavsky et al., 1990) and Kamchatka regions (Raznitsin et al., 1986; Zinkevich et al., 1988) show that large portions of the three Eurasian continent consist of allochthonous terranes. As in southern Alaska and other portions of the Northern Pacific rim, the structure of this region may be understood with the use of the allochtonous terrane paradigm (Ben-Avraham and Cooper, 1981; Fujita and Newberry, 1982).

However, questions concerning the geometry, structure, geological evolution, and the age of accretion of these terranes remain unclear. Additionally, an island arc system between the ancient Farallon and Izanagi plates in the western Pacific has been hypothesized (Engebretson et al., 1985); but no previous paleomagnetic or geologic evidence has been presented to support or reject the existence of this boundary. If there was such an island arc system, evidence for its existence well might be found in the accretionary terranes of this part of northeastern Russia.

In this paper, we present the first reconnaissance paleomagnetic results from sediments of Maastrichtian-Paleocene age and basalt flows of Campanian age from the Olyutorsky superterrane. Our results, reconnaissance in nature, and based on a relatively small number of sites and a small number of samples per site, show that this region consists of tectonostratigraphic terranes that have been displaced poleward by between 21° and 46° of latitude. In combination with the finite rotation plate kinematic data, the paleomagnetic results suggest that the terranes of the Olyutorsky peninsula represent an island arc system, or subduction boundary, between the Farallon and Izanagi plates. These terranes appear to have migrated across the ancient Northern Pacific basin and accreted to this region during the early Tertiary.

GEOLOGY AND TECTONICS OF THE OLYUTORSKY SUPERTERRANE

The Olyutorsky superterrane is the most outboard of tectonostratigraphic terranes that make up northeast Russia. A major southwestward-dipping thrust-fault boundary, the Vatyna thrust, juxtaposes the Olyutorsky superterrane to the south and Santonian to Paleogene-aged Ukelayat flysch belt to the north (Mitrofanov, 1977; Aleksandrov et al., 1980; Mitrofanov and Sheludchenko, 1981) (Fig.1A). The Olyutorsky superterrane has been interpreted to represent an accretionary prism composed of at least thrust-fault-bounded tectonic zones northeastern (Astrahantzev et al., 1987). These zones are thrust over trench-slope deposits of the Ukelayat Flysch (Mitrofanov, 1977; Aleksandrov et al., 1980), and olistostromes of Maastrichtian age (Mitrofanov and Sheludchenko, 1981). Because we are not sure whether these zones represent distinct terranes or are complexly deformed but depositionally related portions of a single terrane, we refer to them as "structural zones."

Within the Olyutorsky superterrane, the upper part of each thrust-fault-bounded structural zone is similar. This upper stratigraphic section is composed of late Santonian-Danian tuff, sandstone, mudstone, chert, clino-pyroxene basalt, and andesite-composition flows, which collectively are known as the Achaivayam structural unit (Aleksandrov et al., 1980). The mollusk and radiolaria-based stratigraphy (see Vishnevskaya, 1987, for details) has been confirmed by K/Ar date of 67 m.y. obtained from the clino-pyroxene-plagioclase basalt by A.N. Sukhov (reference in Vishnevskaya [1987]); no uncertainities for this K/Ar age are available).

The stratigraphically lower part of each structural zone consists of basalt flows and jasper in different proportions referred to as Vatyna structural unit (Alekseyev, 1979, 1981; Aleksandrov et al., 1980). While the Achaivayam structural unit tuff, sandstone, mudstone, basalt, and andesite flows are very similar within all three structural zones, there is a variation in the relative proportion of basalt flows and jasper within the Vatyna structural unit between the structural zones (Fig.1D). Geochemical data also show differences in the composition of basalt among these zones (Sukhov, 1987; Fedorchuk, 1987).

Within the southeasternmost region structural zone, farthest from the Vatyna thrust, the Vatyna structural unit consists of pillow and massive basalt flows. In the central zone, it consists of pillow basalt flows interbedded with thin layers and lenses of jasper. The jasper contains fragments of thick-walled macroscopic pelecypods which in the upper part of the sequence were determined as *Inoceramus ex gr. Schmidti Mich., In. pinniformis Willet, In. cf. orientalis Sok.* (Dundo, 1974), of Santonian-Campanian age. The presence of distinct pillow and massive basalt layers and shallow-water fauna suggest that the jasper was deposited in a shallow-water environment. Radiolaria complexes with *Pseudodictyomitra pseudomacrocephala* and *Archaeospongoprunum bipartitum* from the lower horizons (Vishnevskaya, 1987) suggest the initial deposition of this complex in the Albian. In the northwestern structural zone, immediately next to the terrane bounding Vatyna thrust, the Vatyna structural unit consists of jasper, mud jusper, and red mudstone layers. Only a few thin flows of pillow basalt are observed here. The lithologic transition from jasper to mudstone in the most northwestern zone and its lithological similarity to units in the Ukelayat flysch suggest that the Vatyna structural unit and the Ukelayat flysch may be related. A characteristic feature of the sedimentary rocks of this zone is the widespread presence of the *Inoceramus* prismatic layers. *Inoceramus ex gr. Schmidti Mich., In. pinniformis Willet, In. cf sachaliensis Sok., In. cf. orientalis Sok., In. ex gr. patootensis Lor., Patella (Helcon) gigantea Schm., P. gigantea var. nasuta Schm., P. centralis Schm.*, of Santonian-Campanian age (Dundo, 1974; Zhamoida, 1972; refs. in Vishnevskaya, 1987). Findings of *Pseudoaulophacus praeflorensis, Halesium sexanmitra, Pseudodictyomitra pseudomacrocephala, Dictiomitra veneta, D. maleolla,* as well as *Cenosphaera magna, Patellula planoconvexa, Dictiomitra napaensis, Archaeospongoprunum bipartitum* (Vishnevskaya, 1987) in different parts of this sequence widen the age to Albian-Campanian.

The vergence of the thrust faults that bound these structural zones is opposite to the vergence of the Vatyna thrust. Because of this difference in orientation of thrust faults, Astrahantzev et al. (1987) suggested that these zones were amalgamated to form a composite Olyutorsky superterrane before the composite terrane collided with the continental margin.

Stratigraphic relationships can be used to constrain the time of collision between the Olyutorsky superterrane and the continental plate margin. The Olyutorsky superterrane is underlain by an olistostrome. The clastic part of the olistostrome is made up of Triassic and Late Jurassic basalt and jasper and Cretaceous basalt and jasper, similar to those of the Vatyna structural unit. Tuff, clinopyroxene basalt, and andesite characteristic of the Achaivayam structural unit are absent. The matrix consists of sandstone and mudstone similar to these of the Ukelayat flysch. The age of the olistostrome is Maastrichtian, based on fossils in the matrix (Mitrofanov and Sheludchenko, 1981). The presence of the intensively deformed Vatyna rocks within the olistostrome and absence of Achaivayam rocks suggest that the olistostrome was deposited at an early stage in the development of a subduction zone, before Achaivayam island-arc volcanism began.

The olistostrome marks the beginning of an overthrust contact between the Olyutorsky superterrane and the Eurasia margin. The age of the final accretion of this terrane is constrained by the deposition of shallow-water sandstones and mudstones of late Eocene-Miocene age overlapping the terrane-bounding thrust fault.

PALEOMAGNETISM OF CRETACEOUS TO PALEOCENE ROCKS OF THE OLYUTORSKY SUPERTERRANE

Within the Olyutorsky superterrane, two main lithologic complexes were sampled for paleomagnetic study: The Campanian-aged Vatyna basalt and the late Maastrichtian to early Paleocene Achaivayam tuff, sandstone, and mudstone.

Either of two demagnetization techniques was used for the collection: (1) Thermal demagnetization up to 550 °C or (2) a combination of thermal heating to 350 °C followed by alternating field demagnetization up to 400 Oe.

To determine the remanent magnetization, we prepared at least three 2-cm cubes from each oriented hand sample. We generally worked with at least two specimens to average interlayer discrepancies and rejected samples with substantial angular differences.

The upper Apuka River sites are situated at the northern boundary of the Olyutorsky superterrane (Fig.1) 30 to 40 km to the south of the Vatyna thrust, at the intersection of the Apuka and Mine-Achikanjauvayam Rivers (61.5° N., 170.5° E.). In this zone, Late Cretaceous to early Paleogene terrigeneous turbidites are exposed along a regional antiform. The antiform deforms thrust sheets of the Campanian-age Vatyna jasper and Maastrichtian to early Paleocene volcanoclastic breccia, conglomerate, tuff, lava, and sand- and mudstone (Fig.1B) (Astrahantzev et al., 1987). The limbs of the antiform are isoclinally folded and often overturned. A total of 23 oriented samples with a stratigraphic sample spacing of 0.7 to 5 m were collected from both upright and overturned layers of Maastrichtian-early Paleocene tuff and mudstone. The age of the units is constrained by the observation of the late Maastrichtian radiolaria found within these rocks (K.A. Krylov, Geological Institute, Moscow, pers. commun., 1988). This stratigraphic sequence correlates well with the extensive belt of andesitic-basaltic lavas and tuffs observed to the southeast. We also obtained a K/Ar age of 66 ± 4 m.y. for these rocks in agreement with the radiolarian age (K%=0.623, (^{40}Ar)=2.91*10^{-9}, (^{40}Ar)/(^{40}K)=0.00392, T=66 ± 4 m.y.; determination by N. Sochevanov, Institute of Geology of Precambrian, St. Petersburg).

Of the 23 samples collected, 6 samples were broken while being prepared. The remaining 17 samples were demagnetized in a stepwise manner using standard thermal demagnetization techniques. Orthogonal vector diagrams (Zijderveld, 1967) were used to identify components of magnetization (Fig.2).

After a viscous component was removed, usually after heating to temperatures less than 150 °C, the characteristic magnetic vectors from samples, collected from different sides of the fold grouped into two different directions in the geographic frame. The angle between these two groups was 130°. After correcting for the tilt of the sampled beds, the dispersion decreased, but *k* (the best estimate of the Fisher precision parameter [Fisher, 1953]) remained low (3.5). At higher thermal demagnetization temperatures, clustering of the mean stratigraphic magnetic directions improved significantly. Characteristic components of magnetization successfully were isolated by temperatures of 400°-550 °C, and 450 °C was determined to be the optimum temperature for thermal demagnetization. Two samples behaved chaotically during thermal demagnetization and were rejected. For the remaining 15 samples, the mean direction of the characteristic component after tilt correction and associated statistical parameters were: D=141.4°, I= -70.8° ; ks, the Fisher estimate of kappa in stratigraphic coordinates, was 13.4, α_{95}=10.8°, N=15 (Fig.3A). The ratio of the Fisher estimate of kappa in stratigraphic and geographic coordinates, ks/kg was 12.6. This ratio indicates that the characteristic magnetization was acquired before folding occurred.

The magnetic component removed by thermal remagnetization is near the direction of the modern field or on a plane connecting the present-day field (pdf) and observed characteristic direction, suggesting that the secondary component is due to the modern field.

The Machevna Bay locality sampling sites are on the southeast side of the Olyutorsky peninsula (60.8° N., 171.6° E., Fig.1A,B). A large syncline, overturned to the southwest, is present in the mountains to the south of Machevna Bay. The core zone of the syncline consists of black and green-black, gray tuffaceous mudstone with rare layers of sandstone and andesite-basalt tuff. The thickness of the layers varies from 5 cm to 5 m for mudstone, and from 3 to 10 cm for tuff. We collected 25 samples, mainly tuff and tuffaceous sand- and mudstone.

From these strata, 5 to 10 km to the south, A.V. Fedorchuk from the Institute of Lithosphere (Moscow) collected radiolaria *Cromyosphaera vivenkensis* Lipman, *Stylosphaera minor* Cambell and Clark, *Amphibrachium cf. mucronatum* Lipman, *Theocampe altamontensis* (Cambell and Clark), *Amphipyndax alamedaensis* (Cambell and Clark) of Maastrichtian-Danian age (Vishnevskaya, 1987). Found in the same layers about 5 km west, *Inoceramus shicotaensis* also date Maastrichtian-Danian (Vishnevskaya, 1987). In the northern part of the terrane, this part of the sequence contains more tuff and some pyroxene basalt flows.

Pillow lava of the Vatyna structural unit is present at this locality. It is well exposed but could not be sampled because no well-constrained bedding planes were visible within the massive outcrops.

Most of our samples from the Machevna Bay rocks show chaotic demagnetization behavior after heating to 350°-420 °C. The combined AF and thermal demagnetization technique described above was not successful in isolating a linear prefolding characteristic magnetic component. During demagnetization, however, magnetization directions commonly changed between 15° and 30°. This allowed the use of demagnetization plane techniques (Bingham, 1974; Hoffman and Day, 1978). For single samples, the 95-percent confidence limit in determining the pole did not surpass 10°. The mean direction calculated from the intersection of demagnetization planes, in stratigraphic coordinates, is D=336.0° , I=66.5°, α_{95} max=10.5°, α_{95} min=9.7°, N=16 (Fig.3B, Table 1).

Table 1. Poles to the demagnetization planes of the sandstone and tuff samples from the Machevna Bay locality (in stratigraphic coordinates).

Num	Sample#	D_{pole} (°)	I_{pole} (°)
1	3	68.5	1.9
2	5	26.8	1.4
3	6	292.0	-2.7
4	8	1.2	-38.0
5	9	73.8	-4.7
6	10	46.2	-12.9
7	12	301.3	-7.0
8	13	297.4	-30.6
9	14	30.7	-14.1
10	16	44.8	-5.5
11	19	43.4	-2.6
12	20	357.3	-30.8
13	21	345.9	-10.5
14	23	16.5	-18.8
15	24	31.2	-11.3
16	25	314.0	-35.4
Bingham [1974] direction		336.0	66.5
α_{95} max (°)			10.5
α_{95} min (°)			9.7
Oval Azimuth (°)		38.6	

9 samples were rejected: 2 samples had no definite planes,
3 samples behaved chaotically and
4 samples gave planes with very strange directions

At the Javevyn Bay locality, 70 km to the south from Machevna Bay (60.2° N., 170.4° E.), Vatyna basalt flows of Campanian age were sampled (Fig.1A,B,D). Thick flows of pillow basalt are interbedded with layers of massive basalt and lenses and very rare layers of red chert. Chert lenses and bedded chert provide us good structural control for the paleomagnetically sampled pillow lava.

Age control for these samples is provided by abundant late Campanian radiolaria from this site (Vishnevskaya, 1987). The age estimate also is supported by our radiolaria collection that consists of *Orbiculiforma* sp. *Phaseliforma subcarinata,* Pessagno cf. *Pseudoaulophacus florensis,* Pessagno cf. *Amphipyndax stocki* var. B (Campbell, Clark), *Dictiomitra aff. densicostata* Pessagno. This collection corresponds in age to Campanian to Maastrichtian (determination by I. Pral'nikova, Geological Institute, Moscow, pers. commun., 1989).

Twenty oriented samples of pillow and massive basalt were collected from layers with dip vector azimuths of between 180° and 280° and dip angles between 30° and 80° to the northwest. For these 20 samples, the combined AF and thermal demagnetization technique described above was used. Unfortunately, it was successful in isolating the prefolding characteristic magnetic component in only about half of the samples (Fig.2B). Demagnetization planes analysis (Hoffman and Day, 1978) was used to isolate a characteristic magnetic component. Two samples were rejected because demagnetization did not change the direction of their magnetic vectors. For the remaining samples the change in direction during demagnetization was between 10° and 35°, so that demagnetization planes were well defined and 95-percent confidence limits in the uncertainties about the calculated poles to demagnetization planes were, in most cases, less than 10° (Table 2).

Table 2. Poles to the demagnetization planes of the samples of basalt rom the Javevyn Bay locality (in stratigraphic coordinates).

Num	Sample#	D_{pole} (°)	I_{pole} (°)	$\alpha95_{max}$ (°)	$\alpha95_{min}$ (°)
1	1	317.0	-45.5	7.46	1.07
2	2	315.4	-18.5	4.91	1.05
3	3	309.8	-27.0	3.03	0.48
4	4	252.2	-19.5	16.11	1.51
5	5	332.7	-45.6	7.83	0.18
6	6	357.4	-23.2	17.30	0.04
7	8	231.6	-35.5	0.47	0.05
8	9	318.6	-43.9	0.15	0.04
9	10	287.9	-30.6	3.05	0.44
10	11	12.0	-16.9	3.64	0.79
11	13	22.3	- 0.3	3.30	0.29
12	14	232.3	- 7.4	2.69	0.42
13	15	339.9	-47.6	1.09	0.16
14	16	293.5	-22.9	8.74	1.43
15	17	285.6	-50.5	11.97	4.47
16	18	285.6	-55.8	2.80	0.22
17	20	4.5	-4.3	0.49	0.34
Bingham [1974] direction		297.6	49.9		
α_{95} max (°)		12.9			
α_{95} min (°)		10.8			
Oval Azimuth (°)		77.2			

3 samples were rejected: 2 samples had no definite planes and 1 sample gave a far-removed direction.

In geographic coordinates, the poles to demagnetization planes for samples collected at Machevna Bay and Javevyn Bay do not well define a great circle. A best-fit pole to these poles of demagnetization planes has a 95-percent uncertainty of greater than 40°.

This contrasts with a fairly well-defined great-circle trend to the poles to demagnetization data in stratigraphic coordinates. In the stratigraphic coordinates the mean result, which we interpret to represent the prefolding characteristic remanent magnetization, is D=297.6°, I=49.9°, α_{95} max=12.9°, α_{95} min=10.8°, N=17 (Fig.3C, Table 2).

DISCUSSION

Constraints from the estimated rates of poleward motion of lithospheric oceanic plates in the ancient Pacific basin suggest that the reversely magnetized rocks from the upper Apuka locality were deposited in the northern hemisphere during a reverse polarity period. A southern hemisphere origin requires an unrealistic latitudinal component of plate velocity that does not agree with present estimates of Izanagi, Kul, Farallon, or Pacific plate rates of ancient motion (Engebretson et al., 1985; Zonenshain et al., 1987). After the observed characteristic magnetization direction is inverted through the origin to a corresponding normal polarity direction (D=321.4°, I=70.8°); the difference between the Upper Apuka locality and the Machevna Bay locality direction is insignificant. Nevertheless, the model in which these fault-bounded structural units were initially deposited at significant distance from each other may not be rejected. We will assume a northern hemisphere formation for these units in our interpretation. However, the paleomagnetic data alone does not constrain these terranes to have been deposited in the northern hemisphere.

Using the 61 m.y. apparent polar wander path (APWP) reference pole for Eurasia 72° N., 156° E., A95=15° (Irving and Irving, 1982), the expected paleolatitude for the Upper Apuka locality is 78.2° N. with corresponding expected declination and inclination of D=337.9° and I=84.0°, respectively. Using this APWP for the Machevna Bay rocks, the expected declination and inclination versus Eurasian 61 m.y. pole are D=340.5° and I=83.6°. Comparing our study with this reference, we find a latitude anomaly of 23.0° ± 18.0° for the Upper Apuka and 28.3° ± 17.0° for the Machevna Bay locality, suggesting that Maastrichtian tuff and tuffaceous sandstone originated significantly to the south of their present-day position on the Eurasian continent. Rotational and flattening statistics (Demarest, 1983) are given in Table 3.

The Eurasian APWP reference pole for 79 m.y. is approximately the age of the Vatyna structural unit basalts (Irving and Irving, 1982). If the Javevyn Bay block already had collided to Eurasia by this time, the expected paleolatitude is 75° N. Our result is significantly shallower, assuming the northern hemisphere of deposition, with an observed paleolatitude of 32° and a difference between expected and observed paleolatitudes of 43° ± 22° (Table 3).

The North America APWP reference paleomagnetic pole for 77 m.y. (Irving and Irving, 1982) was used for comparision with the Vatyna basalts data. The observed difference in paleolatitude is 48° ± 13°.

To model the Apuka River, Machevna Bay, and Javevyn Bay paleomagnetic results, we constructed model apparent polar wonder paths (MAPWP) using the techniques of Debiche et al. (1987). This method consists of rotating APWP reference points into a terrane frame of reference using finite rotations between the Eurasian and the ancient Ioceanic plates. We used the finite rotations of the Izanagi and Farallon oceanic plates to calculate the corresponding terrane trajectories. We then compared our model of expected paleolatitude versus time with the paleomagnetically observed paleolatitudes.

Table 3. Paleomagnetic results from the Olyutorsky superterrane.

Locality	Upper Apuka	Machevna Bay	Javevyn Bay
Lat/Long	61.5/170.5	60.8/171.6	60.2/170.4
Age	66±4 Ma	66±4 Ma	K_2cp (84 -74.5 Ma)
Declination (°)	321.4	336.0	297.6
Inclination (°)	70.8	66.5	49.9
α_{95} (°)	10.8	10.5	12.9
Observed paleolatitude (°)	55.2	49.0	32.0
Eurasian			
Paleomagnetic	72, 156, 15	72, 156, 15	74, 145, 24
Reference Pole	61 Ma	61 Ma	79 Ma
R±ΔR (°)	-16.5±24.8	1.9±19.1	-38.1±13.1
F±ΔF (°)	13.2±10.4	17.1±10.2	31.2±14.2
Δλ (°)	23.0±18.0	28.3±17.0	42.6±21.8
N. America			
Paleomagnetic	74, 190, 7	74, 190, 7	68, 191, 7
Reference Pole	67 Ma	67 Ma	77 Ma
R±ΔR (°)	-16.9±33.8	4.1±29.3	-22.3±31.4
F±ΔF (°)	11.9±8.9	16.0±8.7	34.1±10.5
Δλ (°)	20.5±14.7	26.2±13.4	47.5±12.5

Lat/Long refer to coordinates of the sampled localities in degrees northern latitude and eastern longitude, age is the approximate age of the sampled units (constrained using fossil and radiometric estimates in Upper Apuka and Machevna Bay localities and by fossil estimates in the Javevyn Bay locality), α_{95} refer to the radius of the 95% cone of confidence about observed paleomagnetic direction; for paleomagnetic reference poles shown are: location - latitude (degrees northern latitude), longitude (degrees eastern longitude), radius of the 95% cone of confidence about this pole, age in Ma; R±ΔR is rotation and associated uncertainity, F±ΔF is flattening and assotiated uncertainity, Δλ is latitudinal anomaly and assotiated uncertainity (Beck, 1980; Demarest, 1983). Paleomagnetic reference poles are from Irving and Irving (1982). Data for the Upper Apuka locality are inverted to normal polarity.

A key parameter in the terrane modelling technique of Debiche et al. (1987) is the location and age of accretion of the tectonostratigraphic terrane on the other plate. Since the age of accretion of the Olyutorsky superterrane is estimated to be late Eocene to Miocene, we constructed terrane trajectory models assuming an age of accretion to be 40 m.y. or 50 m.y. The results change only slightly using North America or Eurasia MAPWP. Accretion at 50 m.y. better fits the paleomagnetic data (Fig.4). Assuming the North American MAPWP and 50 m.y. accretion time, we calculate an expected paleolatitude for the superterrane of between 46° N. and 58° N. at 70 to 60 m.y. and 39° N. to 52° N. at 90 to 80 m.y. Our results of 55° ± 15° N. paleolatitude for the upper Apuka, 49° ± 13° paleolatitude for the Machevna Bay, and 32° ± 13° for the Javevyn Bay localities closely match the predicted position for the Olyutorsky superterrane.

CONCLUSIONS

Together, these new paleomagnetic results and their agreement with the calculated terrane trajectories suggest that an island arc system moving with the Kula plate collided with this region of the North American plate approximately 50 m.y. (middle Eocene). Engebretson et al. (1985) and Debiche et al. (1987) inferred that the boundary between the Izanagi and Farallon plates was a subduction zone based on the relative plate motions between these two plates. In the model of Engebretson et al. (1985), this region becomes part of the Kula plate at 85 m.y., after initiation of Kula-Farallon motion. Our data show that fragments of an island arc are present in the Olyutorsky Peninsula. Further, more detailed, paleomagnetic investigations in this region will provide a more accurate picture both of the paleomagnetism of these units and their tectonic implications.

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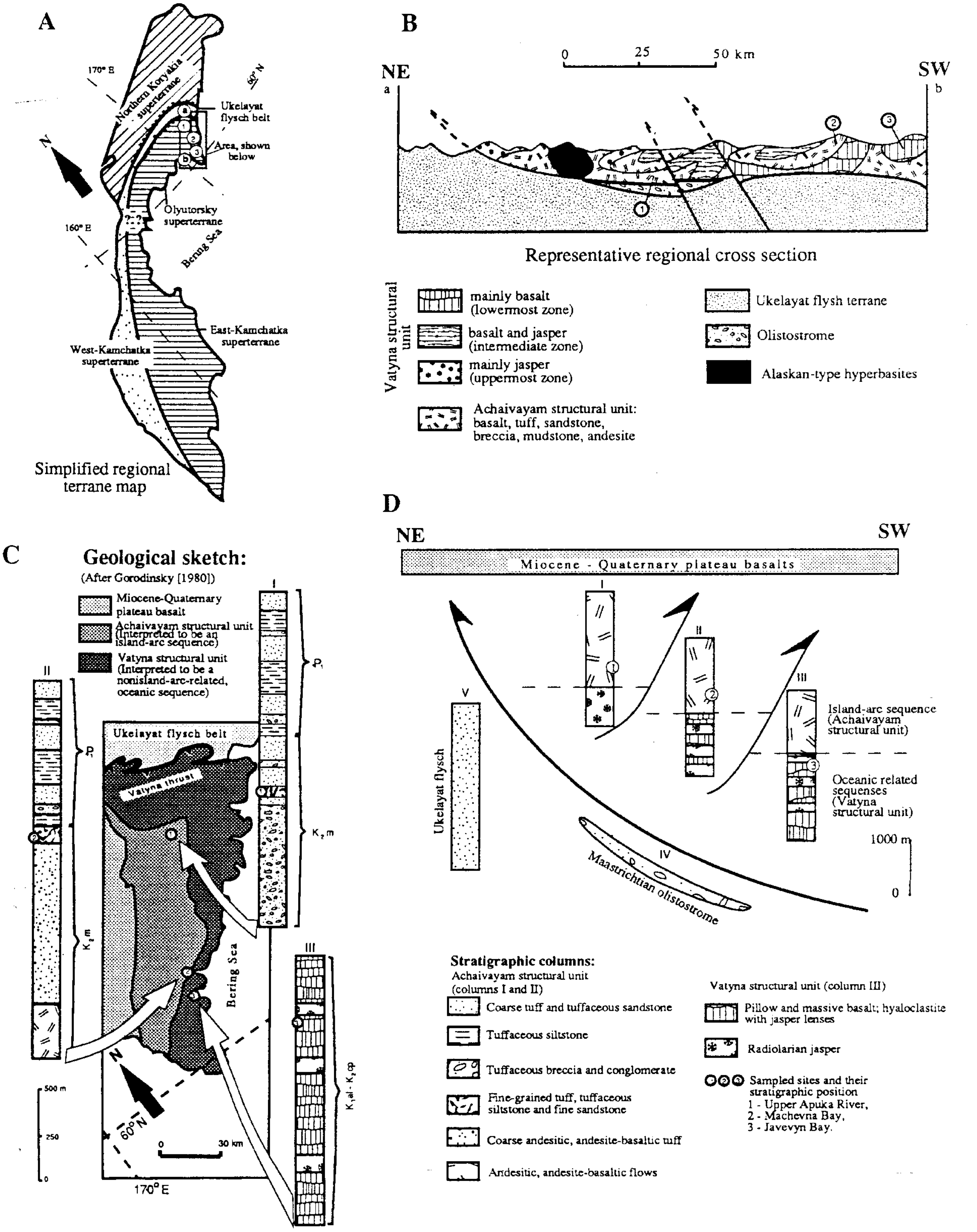

Fig.1. A--Location map of the Olyutorsky terrane within NE Russia, B--simplified geological cross-section of the region (after Astrahantsev et al., 1987), C--geological sketch (after Gorodinsky, 1980) and stratigraphic columns of the studied area, and D--scheme of structural relations between some of the structural units within the Olyutorsky terrane.

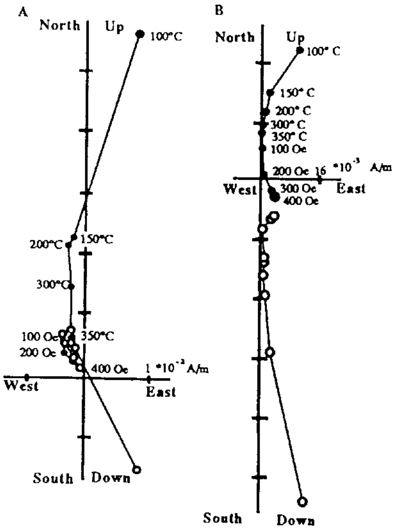

Fig.2. Representative orthogonal vector plots of two specimens during alternating field and thermal demagnetization. Solid circles = horizontal component; open circles = vertical component. Note the removal of a secondary component and measurement of a higher coercivity component in Fig.2A, a specimen from the Apuka River. In Fig.2B, no primary single characteristic magnetic component is isolated. For this type of sample, great-circle analysis was used to estimate the underlying magnetic direction.

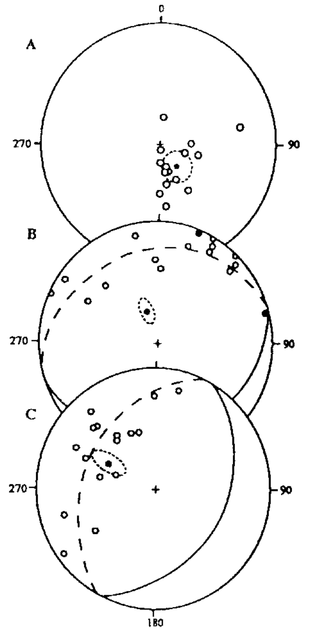

Fig.3. A--Projection of the characteristic components of the samples from the Upper Apuka locality on the Lambert equal-area plot. Circles = characteristic magnetization of the basalt flows, star = Fisher's mean. B--Estimate of the underlying component for the Machevna Bay samples using the poles to demagnetization planes, numeric data are given in the Table 1. C--Estimate of the underlying magnetic component from Javevyn Bay using poles to demagnetization data; numeric data are given in the Table 2. In A, B, and C, solid symbols represent lower hemishere and dashed line shows α_{95} cone of confidence. In B and C, circles show poles to demagnetization planes of the samples.

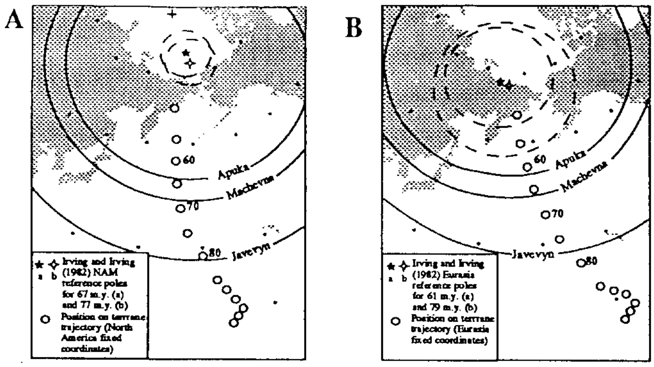

Fig.4. Terrane trajectory and observed paleolatitudes for the Apuka River and Javevyn Bay localities assuming accretion at 50 m.y. Circles show the displacement of a terrane moving on the Izanagi (90-85 m.y.) and Kula (85-50 m.y.) plates. Numbers near the circles along the terrane trajectory correspond to the age of the modelled position. Solid curves = observed paleolatitudes (from paleomagnetic data); dashed curves = 95-percent cones of confidence about reference poles. Note the correspondence between the observed paleolatitude, represented by small circles about the appropriate reference pole of Irving and Irving (1982) and the expected terrane position along this trajectory.