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GEOLOGY

Early Paleozoic Tectonics for the New Siberian Islands Terrane (Eastern Arctic)[1]

D. V. Metelkin[a,b,*], A. I. Chernova[a,b], Academician V. A. Vernikovsky[a,b], and N. Yu. Matushkin[a,b]

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Abstract—The New Siberian Islands archipelago is one of the few research objects accessible for direct study on the eastern Arctic shelf. There are several models that have different interpretations of the Paleozoic tectonic history and the structural affinity of the New Siberian Islands terrane. Some infer a direct relationship with the passive continental margin of the Siberian paleocontinent. Others connect it with the marginal basins of Baltica and Laurentia, or the Chukotka-Alaska microplate. Our paleomagnetic investigation led us to create an apparent polar wander path for the early Paleozoic interval of geological history. Based on it we can conclude that the New Siberian Islands terrane could not have been a part of these continental plates. This study considers the possible tectonic scenarios of the Paleozoic history of the Earth, presents and discusses the corresponding global reconstructions describing the paleogeography and probable mutual kinematics of the terranes of the Eastern Arctic.

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The New Siberian Islands archipelago is one of the few research objects accessible for direct geological observations in the Eastern Arctic. Although active studies of this territory have been renewed during the last decade, the geology, tectonic structure and the evolution history of the New Siberian Islands terrane, as well as the entire Eastern Arctic region, are still debated [1, 2]. The continental origin of the New Siberian Islands terrane is no longer doubted [2, 3]. Its Precambrian crystalline basement is mostly overlain by deformed Paleozoic and early Mesozoic deposits [4]. The lower Paleozoic section forming the New Siberian Islands is usually described as a typical passive continental margin shelf with a mostly carbonate sedimentation on the Anjou territory and flysch on the De Long Islands [4]. At the same time, the north-easternmost De Long islands: Henrietta and Jeannette islands are still poorly studied, and the main information on the geology of this island group was based on data from Bennett Island (Fig. 1). The mentioned lithological differences of the lower Paleozoic sections have been explained in a series of publications by their tectonic dissociation. The De Long flysch complexes are compared to the Chukotka-Alaska continental margin, while the characteristic carbonate sedimentation of the Anjou Islands is compared to the Verkhoyansk shelf. New data on the geology of Henrietta and Jeannette islands indicate a suprasubductional formation setting for their late Precambrian – early Paleozoic sedimentary-volcanogenic and igneous complexes, as well as their possible continuation in the southern part of Mendeleev Rise [5–7]. Our paleomagnetic investigations led us to the creation of an apparent polar wander path (APWP, Fig. 1, Table 1), which quite distinctly indicates that the Anjou and De Long sedimentary basins are facially different parts of a single marginal basin [8–11]. Correspondingly, the characteristic type of sections of Jeannette and Henrietta islands in the extreme north-east was probably formed in a marginal sea located on a continental crust in the back-arc region of an active margin. From this it follows that in the late Precambrian – early Paleozoic the Chukotka-Alaska continental structures could not have been oriented towards the De Long Islands in the same configuration as today.

The tectonic connection of the New Siberian Islands terrane with other adjacent paleocontinents: Siberia, Laurentia, Kara, Baltica, can be verified by the convergence of their early Paleozoic APWP intervals. However, the abrupt change in direction of the New Siberian Islands apparent polar wander path in the Early Ordovician (Fig. 1) significantly differentiates this APWP and indicates that the New Siberian Islands continental unit had an independent, terrane (!) tectonic history. Therefore, in the early Paleozoic, the New Siberian Islands terrane could not have been

[1] The article was translated by the authors.

[a] *Novosibirsk State University, Novosibirsk, 630090 Russia*
[b] *Trofimuk Institute of Petroleum Geology and Geophysics SB RAS, Novosibirsk, 630090 Russia*
**e-mail: metelkindv@ipgg.sbras.ru*

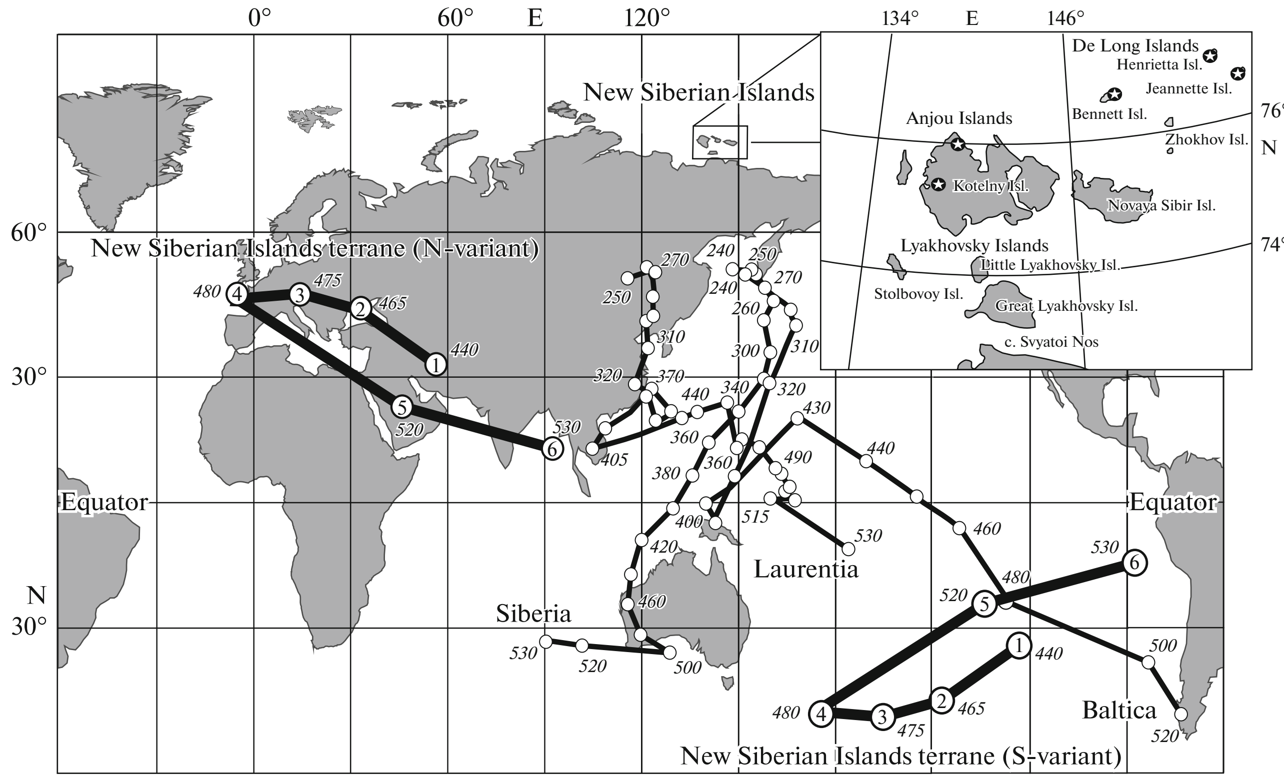

Fig. 1. Two variants of the apparent polar wander path for the New Siberian Islands terrane compared to the APWPs for Siberia, Laurentia and Baltica. Numbers near the poles show the age in m.y. ago; lines show confidence ovals for the average paleomagnetic poles. Numbers in circles correspond to the determination numbers in Table 1. On the inset, stars mark the locations of the studied sites.

part of the continental plates listed above, but must have had active tectonic boundaries with them [8]. However, obtained paleomagnetic data display some similarity with available singular determinations for the Omulevka-type continental blocks that are located along the Kolyma structural loop. Considering the similarity of the Anjou and Omulevka carbonate sections, it is not excluded that in addition to the common origin of the basins, a tectonic coherence could have taken place [8].

The drift kinematics of the New Siberian Islands terrane calculated from the APWP for the early Paleozoic is characterized by an insignificant latitudinal drift, about 4 cm per year and by rotation of up to 2 degrees per million years. We can deduce that in the early Paleozoic the terrane was gradually and slowly moving in the tropical and sub-tropical region of the Earth, below 40 degrees latitude. The uncertainty in tectonic interpretation of the obtained paleomagnetic data is due to the uncertainty of the true polarity and, correspondingly, the geographic hemisphere in which the terrane was located when the paleomagnetic signal was recorded. Therefore, two possible scenarios are considered for the geological history of the New Siberian Islands in the early Paleozoic, which are reflected in reconstructions (Fig. 2). In addition to the tectonic interpretation of the paleomagnetic determinations themselves, which is usually based on the principle of minimization of horizontal motions, when arguing for one or another scenario one must take into account other facts most important for the paleogeography. These are first and foremost – biofacial information, indicating a single sea basin, which connected the Verkhoyansk margin of Siberia and the New Siberian Islands at least in the Cambrian – Early Ordovician [12]. Also, results of detrital zircons studies must be considered, since, according to the researchers who made the determinations, the zircons were transported to the New Siberian Islands sedimentary basin from the Timan margin of Baltica [13].

For the time of the reconstruction global tectonics has several important tectonic features. In the middle–late Cambrian (~520 Ma) the laurentian continents, with which the New Siberian Islands unit could have interacted, were located southerly of the equator and relatively close to each other (Fig. 2a). The Early Ordovician epoch (~480 Ma) is characterized by intense growth of the Iapetus oceanic space, which caused Laurentia and Siberia to drift northwards, and Baltica to occupy intermediate latitudes of the southern hemisphere (Fig. 2b). In the Late Ordovician – Silurian (~440 Ma) the Iapetus Ocean was actively

Table 1. Average paleomagnetic directions, coordinates for paleomagnetic poles and paleolatitudes resulting from studies of the early Paleozoic rocks of the Anjou and De Long archipelagos

No.	Site, age, Ma	n/N	Geographic coordinates				Stratigraphic coordinates				Paleomagnetic pole			PL	Reference
			D	I	k	α_{95}	D	I	k	α_{95}	*Plat*	*Plong*	A_{95}		
1	Kotelny Isl., limestones, 440	43/45 (4)	208.3	81.5	87.0	9.9	272.0	53.9	558.5	3.9	33.7	55.7	5.1	34.4	[8]
2	Bennett Isl., sandstones, 465	25/33 (3)	298.5	54.1	109.3	11.9	307.7	57.4	178.4	9.3	45.5	31.9	11.0	38.0	[8]
3	Kotelny Isl., dolomites, 475	23/25 (2)	278.3	77.5	25.7	51.4	315.6	59.1	414.0	12.3	48.9	13.8	18.1	39.9	[8]
4	Jeannette Isl., dolerites, 480	39/45 (3)	308.7	44.8	55.5	16.7	344.4	56.0	468.7	5.7	49.2	357.4	5.9	36.5	[9]
5	Henrietta Isl., sandstones, tuffs, basalts, 520	56/65 (6)	294.5	25.4	19.0	14.2	295.5	34.0	282.0	3.6	23.7	45.7	3.2	18.6	[10]
6	Bennett Isl., sandstones, 530	18/22 (2)	247.8	46.5	184.3	18.5	249.2	37.0	265.1	15.4	15.5	83.6	18.0	20.6	[11]

No corresponds to the pole number on the APWP for the New Siberian Islands terrane for the N-variant (Fig. 1); n/N—ratio of the number of samples used in the statistics to the total number of studied samples, number of sites in brackets; D – declination, I – inclination, k – precision parameter, α_{95} (A_{95}) – radius of the 95% confidence oval for the average vector (for poles), *Plat* – pole latitude, *Plong* – pole longitude, *PL* – paleolatitude for the site.

closing. As a result, Baltica returned to the tropical and sub-tropical latitudes, rotated counterclockwise significantly, and ended up in front of the Greenland margin of Laurentia (Fig. 2c). During this time Siberia continued to drift northwards and crossed the equator completely. One of the main features of its drift was clockwise rotation, which conditioned the strike-slip mode in the evolution of its marginal continental structures [14].

On the reconstructions we present here, the first variant (N) assumes that the geomagnetic field had a normal polarity when the lower Paleozoic rocks of the New Siberian Islands archipelago recorded their magnetization, and therefore, that the New Siberian Islands terrane was in the northern hemisphere. This variant has the advantage of minimal amount of horizontal drift for the terrane, which follows from the integrated analysis of all paleomagnetic data. However, the terrane itself was located at considerable distance from the Verkhoyansk margin of Siberia, with which we infer a distinct biogeographic connection at this time [12]. We assume that this space could have been occupied by the Omulevka and, possibly, the Chukotka-Alaska continental terranes, which provided the shallow sea settings necessary for fauna migration. In the Ordovician we assume that this terrane system "broke apart", the terranes fragmented completely and gradually further approached the Verkhoyansk margin of Siberia (Figs. 2a, 2b, N-variant). The location of the New Siberian Islands terrane proposed in this model is not in agreement with the ambiguous views on Baltica-generated sediment sources [13]. Nor does it agree with the dominating reversed geomagnetic field polarity in the Ordovician [15]. However, the latter does not exclude the possibility that the recorded magnetization could have formed in relatively short intervals of normal polarity.

The second variant (S) infers a reversed geomagnetic field polarity, which was more typical for the early Paleozoic, and the southern position of the New Siberian Islands terrane. Paleomagnetic data indicate that it could have been located close to its present-day location together with the Omulevka terrane, but with a different relative orientation. The latter would explain the biofacial connection of the Verkhoyansk and New Siberian Islands sedimentary basins. In this configuration, the New Siberian Islands terrane also could have been located directly close to western Scandinavia, which could explain the presence of detrital material from Baltica in its sections. However, tectonic facts that follow from global paleogeographic reconstructions, correspond much worse to this model. In the Early Ordovician due to the opening of the Iapetus Ocean, we reconstruct the "break up" of

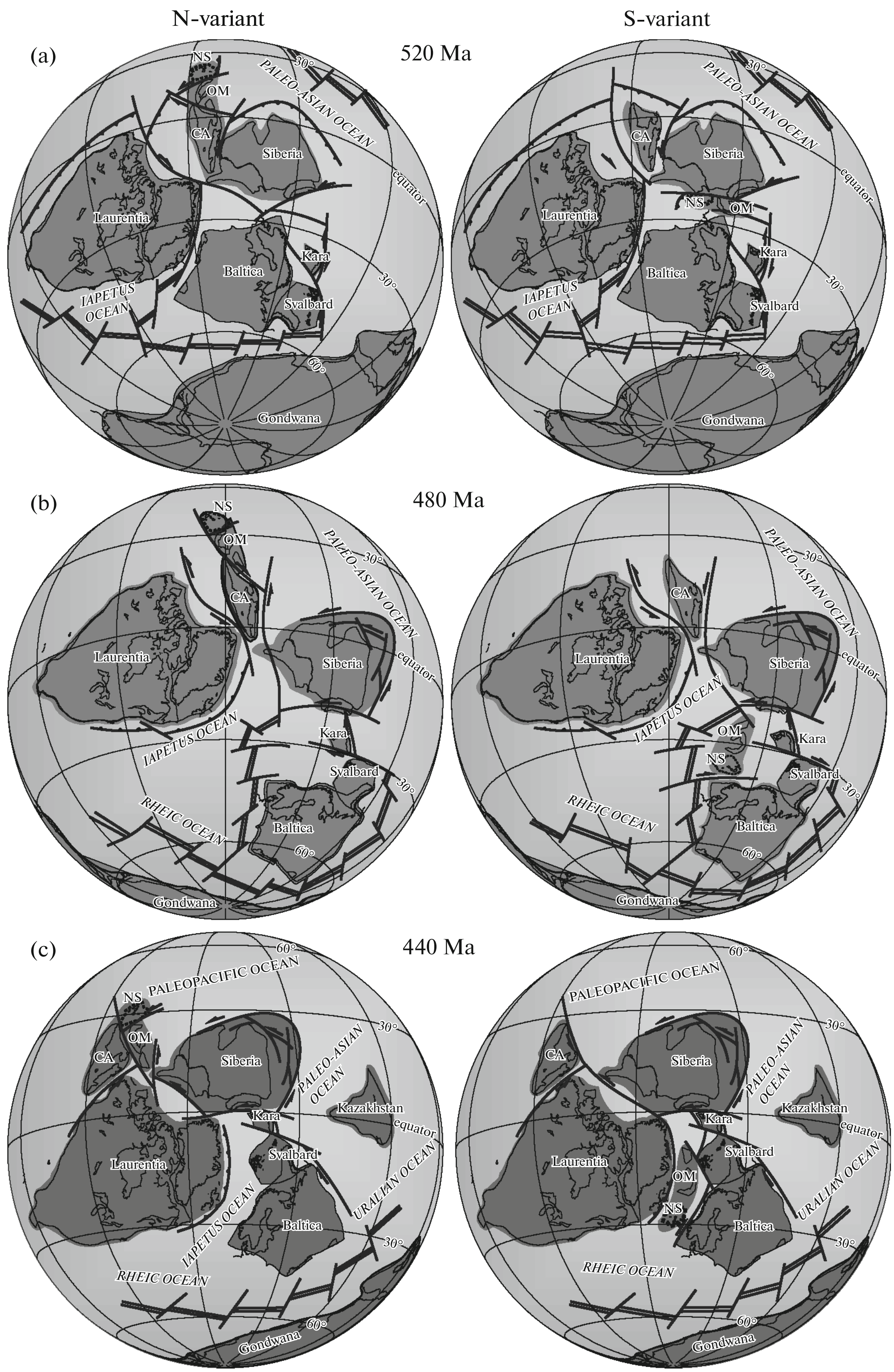

Fig. 2. Paleotectonic reconstructions showing the two variants of the location of the New Siberian Islands terrane in the early Paleozoic. The N-variant is on the left, the S-variant – on the right. Explanations in the text. Letters show terranes: NS – New Siberian Islands, CA – Chukotka-Alaska, OM – Omulevka.

the New Siberian Islands-Omulevka terranes group, which is recorded in the abrupt change in direction of the apparent wander path of paleomagnetic poles. It is inferred that they subsequently drifted together close to the Scandinavian margin of Baltica (Figs. 2a, 2b, S-variant). The main problem with this variant is that paleomagnetic data indicate that the New Siberian Islands terrane was located "too far" to the south during the closing of the Iapetus Ocean. Even at 440 Ma, when this ocean was smallest, the New Siberian Islands terrane finds itself deep in this convergent system, and in the global kinematic setting its subsequent drift to its present-day position is challenging (Fig. 2c, S-variant). The speeds of the presumed late Paleozoic drift become very high (~20 cm/year). To occupy its present-day position the New Siberian Islands unit would have had to "catch up" with Siberia, which drifted northwards and rotated clockwise this whole time.

In conclusion, the total of geological and geophysical facts available today proves the unity of the Anjou and De Long sedimentary basins, the sub-tropical position of the New Siberian Islands terrane in the beginning of the Paleozoic, and, from our point of view, better argues towards its position in the northern hemisphere (N-variant).

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