MAJOR TECTONIC INTERPRETATIONS AND CONSTRAINTS FOR THE NEW SIBERIAN ISLANDS REGION, RUSSIAN ARCTIC

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ABSTRACT

Traditional fixist interpretations of the tectonic evolution of the New Siberian Islands and adjacent offshore areas in terms of geosynclinal theory were presented in detail during the early 1980's. They were based on data obtained through systematic geologic mapping and geophysical surveys completed mostly by the staff of VNIIOkeangeologiya, including the author, prior to the end of the 1970's. Mobilistic interpretations based on later field observations at various localities within the islands have recently been published. None of these interpretations have properly incorporated constraints provided by results of gravity and magnetic surveys and observations of converted seismic waves recorded during the time that the interpretations were presented. In addition, some paleoenvironmental and structural interpretations, which were presented as arguments to support competing paleotectonic models, are, at best, ambiguous.

The review of existing data discrepancies and the incorporation of new data should allow us to come to a practical understanding of the geology and tectonic evolution of the New Siberian Islands region. This is accomplished by developing tectonic zonations and paleogeodynamic reconstructions that are compatible with all available data, and through the investigation of the characteristics of low-angle faults both at an outcrop scale and through calculations based on results of recently completed detailed magnetic and gravity surveys.

INTRODUCTION

The New Siberian Islands are located on the Russian Arctic continental shelf off northeastern Siberia between 135° 26'-158° 05' E. longitude and 73° 10'-77° 06' N. latitude. The archipelago is divided into three island groups: the De Long Islands in the north and east, the Anjou Islands in the center, and the Lyakhov Islands in the south. Various interpretations of the tectonics, geodynamic evolution, and position of the archipelago with respect to regional and global structures have been published. The objective of this paper is to briefly familiarize scientists with the basic geology of the area (see also Kos'ko et al., 1990; Fujita and Cook, 1990) and with the published tectonic interpretations and to indicate which problems should have high priority for future work. The discussion is limited to three models that have been presented by authors who conducted field observations within the region and for whom understanding of its structure and geodynamic evolution was a primary goal and not a subsidiary issue within more regional compilations.

SUMMARY OF REGIONAL GEOLOGY

The De Long Islands usually have been regarded as a relict block of the hypothetical Hyperborean platform, while the rest of the archipelago has been considered parts of various Phanerozoic fold systems. The region was subjected to rifting and the development of sedimentary basins during the Late Cretaceous and Cenozoic.

Early Paleozoic, Middle Paleozoic, Cretaceous, and Neogene formations are observed within the De Long Islands. Cambrian and Ordovician clastics with some carbonate content outcrop on Bennett Island (Vol'nov and Sorokov, 1961; Vol'nov et al., 1970; Kos'ko et al., 1975). Middle Paleozoic volcaniclastics, volcanics, dikes, and sills of predominantly basic and transitional basalt - andesite composition were studied in detail on Henrietta Island by Vinogradov et al. (1975). Cretaceous coal-bearing argillites and sandstones have been reported from Bennett Island (Vol'nov and Sorokov, 1961). Cretaceous to Neogene basalts and alkaline basalts are widely distributed on Bennett and Zhokhov Islands. Most strata are flat-lying with dips not usually exceeding 10°. However, Middle Paleozoic rocks on Henrietta Island have been folded and faulted.

Ordovician to Recent strata have been studied within the Anjou Islands. Ordovician to Middle Devonian carbonates, Upper Devonian to Lower Carboniferous clastics (including slates), Upper Paleozoic carbonates and terrigenous rocks, Triassic and Jurassic slates, and Cretaceous coal-bearing deposits and acidic volcanics have been studied in outcrops on Kotel'nyi and Bel'kov islands. Basic dikes and small intrusions of Paleozoic and Mesozoic age are widely distributed. Pre-Cretaceous rocks are folded and faulted. An Upper Cretaceous to Recent sedimentary cover is uniformly distributed on Faddeevskiy and Novaya Sibir' Islands. It overlaps deformed Jurassic and/or Cretaceous clastic formations which are known from drill holes in some localities. The sedimentary cover has locally been folded and faulted.

Graded bedded siliciclastics of Permian to Early Cretaceous age are widely distributed within the Lyakhov Islands. They are folded, faulted, and intruded by Cretaceous granites. Melanocratic schists and orthoamphibolites have been mapped in southeastern Bol'shoi Lyakhov Island. These have traditionally been considered as Riphean to Vendian in age. Ultramafics and pillow basalts are known from the same area. The age of these associations is Late Paleozoic according to Drachev and Savostin (1993).

TECTONIC ZONATION INTERPRETATIONS

The first tectonic interpretation is that of Kos'ko et al. (1983, 1990) and is shown in Fig.1. It is an advanced and more elaborate version of a concept developed by scientists of VNIIOkeangeologiya in terms of classic geosynclinal theory (Vinogradov et al., 1974, Egiazarov, 1977). This version was incorporated into a recent comprehensive publication summarizing the knowledge of the Arctic geology of the former USSR (Gramberg and Pogrebitsky, 1984, Zhamoida et al., 1989). This model suggests that the Late Mesozoic folded basement is widely distributed over most of the New Siberian Islands region. Precambrian to Late Paleozoic folded basement has been identified or inferred in the De Long Islands area. Due to the lack of direct data, the age of the basement provides constraints on tentative ages assigned to the lowermost strata of the sedimentary cover in accordance with the tectonic zonation of the basement. Because the existence of an ancient Hyperborean Platform and a superposed Phanerozoic fold belt have been agreed upon, it is reasonable to hypothesize that there is a Mesozoic foredeep basin that stretches along the boundary between the Anjou and De Long Islands that is important in the assessment of hydrocarbon prospects.

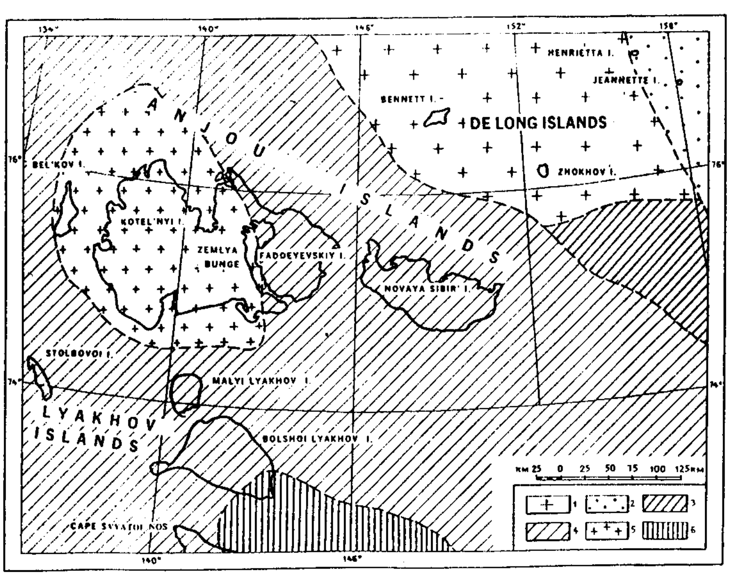

Fig.1. Tectonic zonation of New Siberian islands area simplified from Kos'ko et al. (1983). 1 - Hyperborean craton, 2 - Late Paleozoic Henrietta rift-type fold system, 3 - Riphean South-Hyperborean fold system, 4 - Late Mesozoic New-Siberian miogeosynclinal fold system, 5 - Kotel'nyi massif, 6 - Late Mesozoic South Anyui-Lyakhov eugeosynclinal fold system.

The two mobilistic interpretations were published recently by Drachev (1989) and Aulov et al. (1991). Drachev (1989) has distinguished a Cretaceous to Recent sedimentary cover and an accretionary folded basement of Precambrian to Mesozoic age (Fig.2). The basement is composed of five tectonostratigraphic units, some of which have been classified as terranes. The West Anjou unit is considered part of the Siberian passive margin from the Ordovician to the Late Devonian. It was converted to a marginal plateau during the Late Devonian to Early Carboniferous as a result of rifting. It stayed this way through the Late Paleozoic to Early Mesozoic. The East Anjou and Henrietta units were transported to their present positions as part of the opening of the Amerasia Basin in Late Jurassic to Neocomian time. The Henrietta unit was formerly part of a Late Paleozoic North American active margin. The Stolbovoi unit is considered to represent part of the Late Paleozoic passive margin of Siberia. Finally, the Svyatoi-Nos - Lyakhov unit is proposed to be a remnant of a Late Paleozoic ocean basin that closed and collided in the Early Cretaceous. The interpretation of Aulov et al. (1991) is based mostly on tensional and compressional structural features with a mobilistic philosophy (Fig.3). It is evident that most

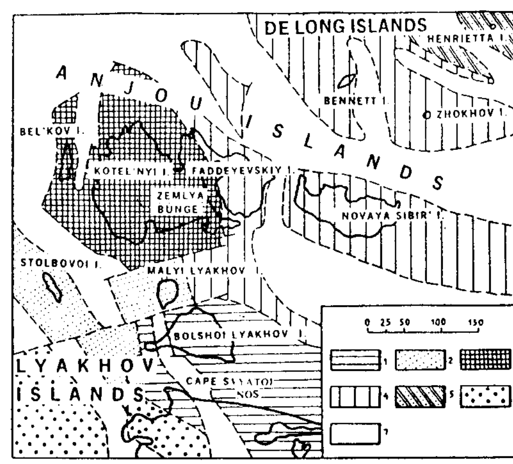

Fig.2. Tectonic zonation of New Siberian islands area after Drachev (1989). 1-6 Tectonostratigraphic basement units: 1 - Svyatoi Nos - Lyakhov unit composed of Late Paleozoic ocean floor, Mesozoic island arc and turbiditic continental slope sequences, and Cretaceous collisional granites; 2 - Stolbovoi unit composed of a passive continental rise association; 3 - West Anjou unit with an early and middle Paleozoic passive margin association, Devonian rift-type association, and Late Paleozoic and Mesozoic geodynamically ambiguous sequences; 4 - East Anjou unit with a Early Paleozoic passive continental margin association, terrigenous folded Jurassic sequence, Early Cretaceous intraplate tholeiites and late Tertiary picritic alkaline basalts; 5 - Henrietta unit with late Paleozoic island arc association; 6 - Verkhoyansk-Kolyma fold system; 7 - Late Cretaceous and Tertiary basins and grabens.

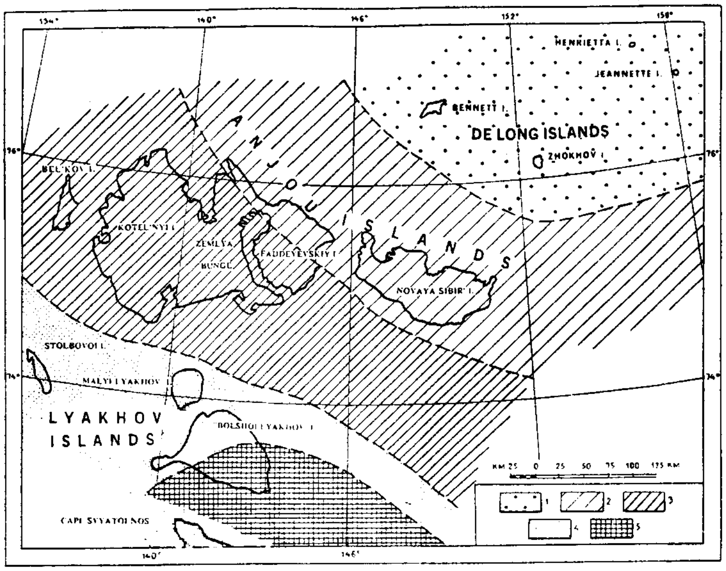

Fig.3. Tectonic zonation of New Siberian islands area after Aulov et al. (1991). 1 - Cretaceous to late Tertiary De Long rift zone, 2 - Miocene Novaya Sibir' zone of tectonic compression, 3 - Lower Cretaceous Anjou zone of tectonic compression, 4 - Late Jurassic to Early Cretaceous North Lyakhov zone of forearc basins, 5 - Early Cretaceous South Lyakhov zone of tectonic compression.

of the tectonic zones identified by Aulov et al. (1991) are based on the most recent tectonic event as indicated by the structural style and the stratigraphic column. The De Long, Novaya Sibir', and Anjou zones are all considered part of the Arctida craton, which was destroyed in the opening of the Amerasia Basin in the Late Mesozoic (Zonenshain et al., 1990). The North and South Lyakhov zones were emplaced in front of a Middle Jurassic to Early Cretaceous island arc that existed to the south. This island arc is not shown on the tectonic zonation scheme in Aulov et al. (1991) but is described within the text. Within the area of Fig.3, the island arc zone includes the Cape Svyatoi Nos region with its calc-alkaline lavas and tuffs. Early Cretaceous granitoid bodies with the North and South Lyakhov zones and calc-alkaline volcaniclastics within the Anjou and Novaya Sibir' zones are taken to be evidence for a collisional event that culminated the pre-Cenozoic evolution of the region. The island arc association of Henrietta Island, within the De Long zone, is considered an active continental margin which formed the New Siberian Islands and Chukotka side of Arctida in the Late Paleozoic

Obvious Constraints

None of the above schemes accurately corresponds to known features defined by aeromagnetic and gravity surveys, or seismology, and both mobilistic models are distinctly at variance with these data.

A series of crustal sections were produced by Avetisov (1983) using the method of converted seismic waves. In most of these sections, terrigenous and carbonate units were inferred "consolidated crust." The thick carbonate unit can be reliably correlated with Lower to Middle Paleozoic carbonate strata exposed on Kotel'nyi Island. The distribution of this unit provides an important constraint and must be incorporated into any tectonic interpretation, or its occurrence must at least be explained. These data were available when the three models discussed here were first presented. A thick terrigenous unit underlying the lower Paleozoic carbonates is identified in the sections for Kotel'nyi island, and it can be easily correlated to the Cambrian to Ordovician clastics and slates on Bennett island if both regions are not considered separate terranes. Fig.4 illustrates the distribution of magmatic bodies inferred from airborne, onshore, and offshore magnetic surveys, gravity data, and outcrops (Litinsky et al., 1978). Shallowly emplaced granites bound Kotel'nyi and Bel'kov islands on the southwest and west and lie between Zemlya Bunge and Faddeyevskiy Island. Shallow granites are also widely distributed between Bol'shoi Lyakhov

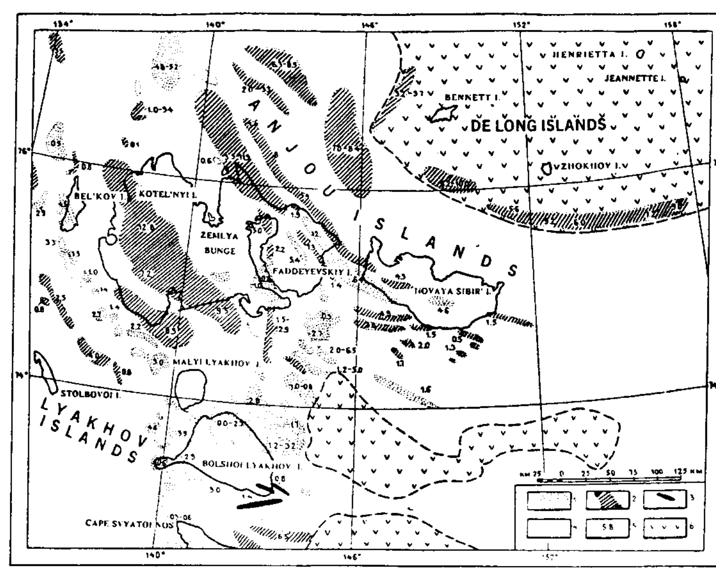

Fig.4. Magmatic rocks in New Siberian Islands area interpreted from magnetic and gravity surveys. Simplified from Litinsky at al. (1978). 1-4 - Intrusive bodies of (1) silicic and intermediate, (2) mafic, (3) ultramafic, and (4) unidentified composition; 5 - depth of intrusive bodies in km; 6 - extrusive volcanics.

and Novaya Sibir' islands. According to recent interpretations using a paleogeodynamic environment approach, these granites are believed to be indicative of a Cretaceous accretionary collision and island arcs within the Bol'shoi Lyakhov area. However, they are almost always ignored when defining the geodynamic regime elsewhere within the area of the New Siberian Islands.

An extensive, geophysically defined domain, interpreted to be the result of large basic intrusions at depths of 7 to 12 km, occurs throughout the Anjou Islands and south of the De Long Islands and has a complex southern boundary that can be considered as an entity in terms of deep structure and paleogeodynamics. These data were also available earlier, but the existing interpretations all divide this domain into smaller pieces and place it within different tectonic zones.

Some Ambiguous Arguments

There are also examples of subjective interpretations of facies and paleotectonic environments that are used as fundamental data for tectonic schemes and paleogeodynamic reconstructions.

Cambrian to Ordovician strata on Bennett Island have traditionally been considered as facies of the Hyperborean platform. Drachev (1989) assigns them to an ancestral continental rise. This interpretation is in agreement with his view that Kotel'nyi and Bennett islands belong to different terranes and were not connected in the Early Paleozoic. Aulov et al. (1991) consider Early Paleozoic strata on Bennett Island as an outer shelf facies. The second option seems more plausible and is at least compatible with the paleobiogeoraphy of fossil trilobites; the presence of carbonate seams and high carbonate content in some siltstone and sandstone layers; and the occurrence of thick, quartz-rich, light-colored sandstone layers. Thus, it is possible to suggest a continuous lateral transition of the Bennett Island section to the Kotel'nyi Island section.

Two environmental interpretations have been presented for the Triassic of Kotel'nyi Island. In the first, it was proposed to be an open, deep-water, marine basin; in the second, it was hypothesized to be a shallow basin with restricted circulation. The first option was used to explain the separation of the west Anjou block from the passive margin of Siberia, its remoteness from Siberia, and its submergence. The second option is used as an argument for existence of a stable tectonic high within a submerging sedimentary basin.

The most difficult problem in structural geology is the identification and assessment of the role and scale of gently dipping faults and thrusts. Until recently, no specific studies of individual faults and fault patterns in the New Siberian Islands had been carried out. Compressional structures were reported in the course of geological mapping in the 1970's, but no comprehensive analysis was performed. Gently dipping thrusts were first documented on southeast Bol'shoi Lyakhov island a few years ago (Drachev, 1989, Aulov et al., 1991).

There is a dramatic ambiguity in the understanding of fault patterns on Kotel'nyi Island (Figs.5 and 6). Geological maps produced in the 1970's present virtually no information on thrusts and compressional structures and generally only identified a few strike-slip faults, although small, steep, thrusts; local compressional folding; cleavage; and zones of schistosity were reported by the field geologists. Some problems were encountered while compiling geologic cross-sections, but interpretations using low-angle thrust faults were not used to resolve these difficulties, because no gentle thrusts had been documented in outcrops. Aulov et al.

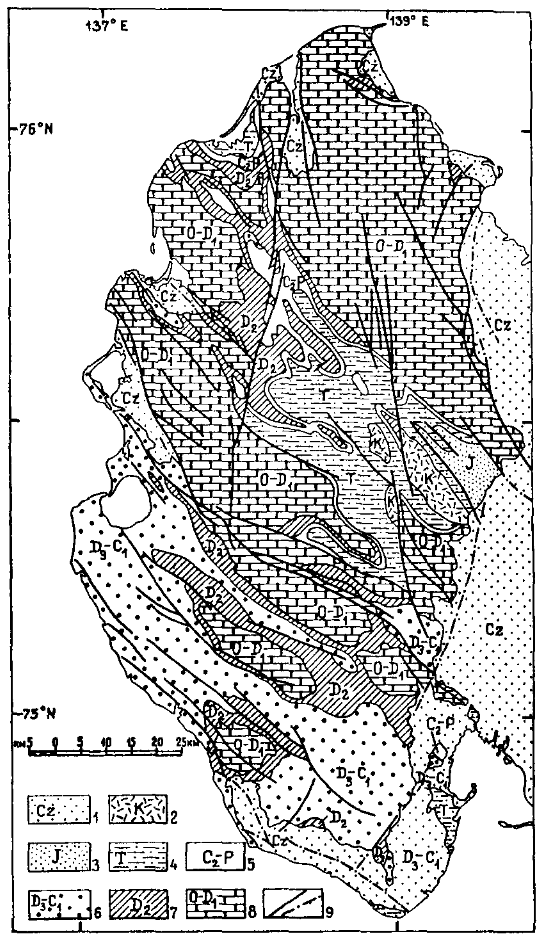

Fig. 5 - Simplified geological map of Kotel'nyi island (from Kos'ko et al, 1990). 1 - terrigenous Cenozoic; 2 - coal-bearing Lower Cretaceous with silicic volcanics; 3 - terrigenous Jurassic; 4 - Triassic with minor clastics and carbonates; 5 - terrigenous Middle Carboniferous to Upper Permian with carbonates; 6 - predominantly terrigenous Upper Devonian to Lower Carboniferous with carbonates; 7 - predominantly carbonate Middle Devonian; 8 - predominantly carbonate Lower Ordovician to Lower Devonian; 9 - mapped and inferred faults.

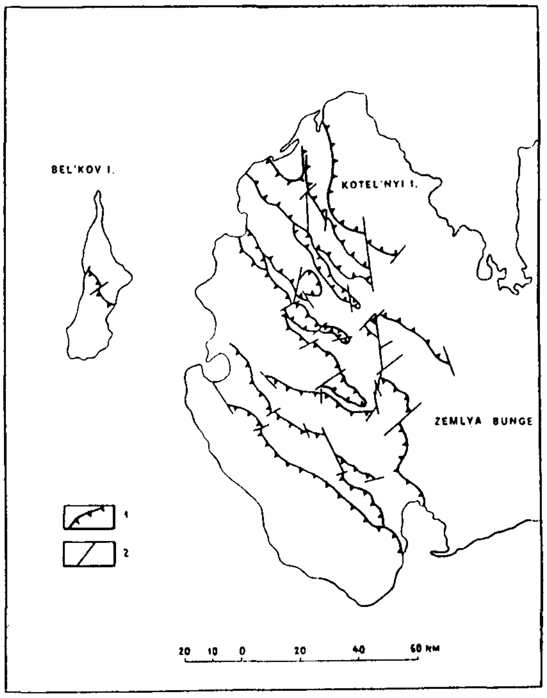

Fig. 6 - Major faults and thrusts on Kotel'nyi and Bel'kov islands. Simplified after Aulov et al. (1991). 1 - thrusts; 2 - other faults.

(1991; Fig.6), however, on the basis of new observations of some outcrops, reinterpreted most of the faults and many stratigraphic boundaries on Kotel'nyi Island as thrust faults (compare Fig.5 to Fig.6). Although I have some reservations about some of the interpretations presented by Aulov et al. (1991), they have clearly identified a major problem and the possible existence of gentle thrusts, probable decollement structures, and compressional structures, throughout the Kotel'nyi Island domain.

CONCLUSIONS: PRIORITIES FOR FUTURE RESEARCH

The above discussion provides a better understanding of priorities for future tectonic studies within the New Siberian Island region. They are (1) to formulate a tectonic zonation and paleogeodynamic reconstruction compatible with all available data (both should then be incorporated into, and provide constraints for, more comprehensive circum-Arctic hypotheses) and (2) to investigate suspected gently dipping faults with more thorough observations of micro-structures at an outcrop scale to examine their thrust nature. In addition, the results of recently completed detailed gravity and magnetic surveys provide an opportunity to perform calculations to check whether thrusts observed in outcrops are detectable deeper in the crust.

The anticipated results will give a better understanding of tensional and compressional events within the tectonic evolution of the region and will hopefully be of practical value in providing a basis for forecasting the structural position of potential hydrocarbon fields in the adjacent continental shelf areas.

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