COMPARATIVE GEOLOGY OF NORTHERN CHUKOTKA AND THE NORTHERN CANADIAN CORDILLERA

Yu.M. Bychkov, North East Interdisciplinary Scientific Research Institute, 16 Portovaya St., Magadan 685000, Russia
M.E. Gorodinsky, PGO "Sevvostgeologiya," Proletarskaya St., Magadan 685000, Russia

ABSTRACT

Comparison of geologic sequences and magmatism in northern Chukotka and the northern Canadian Cordillera shows that the geologic history of these regions was similar during the Proterozoic and the early and middle Paleozoic. In contrast, their comparative history differed greatly during the late Paleozoic, Mesozoic, and Cenozoic.

INTRODUCTION

Northern Chukotka, located along the coast of the East Siberian and Chukchi Seas, consists of the Chukotka foldbelt, the East Chukchi (Eskimos) massif, and the northeastern part of the Okhotsk-Chukotsk volcanic belt. To the south, this region is bordered by the South Anyui foldbelt (or "suture") and the Koryak-Kamchatka foldbelt (Fig.1).

The oldest rocks of Archean and Proterozoic ages occur in the East Chukchi massif. Lower and middle Paleozoic rocks are exposed in uplifts within the Chukotka foldbelt and in the East Chukchi massif. There are Late Proterozoic rocks in the Wrangel uplift and probably at the base of the section of the subsurface Kuyul uplift (north-central Chukotka foldbelt).

Basins in the Chukotka foldbelt almost exclusively contain Triassic sediments while orogenic and postorogenic troughs include Late Jurassic, Cretaceous, and Cenozoic strata. The Okhotsk-Chukotsk volcanic belt consists of Albian and Late Cretaceous volcanic rocks. Silicic and mafic intrusive magmatism occurs in the northern Chukotka foldbelt, East Chukchi massif, and the Okhotsk-Chukotsk volcanic belt. The Jurassic Kimmerian orogeny had a strong effect on the region.

Geologists working in the northern Canadian Cordillera (Lerand, 1973; Norris, 1974, 1983; Norris and Yorath, 1981) have identified several uplifts, depressions,

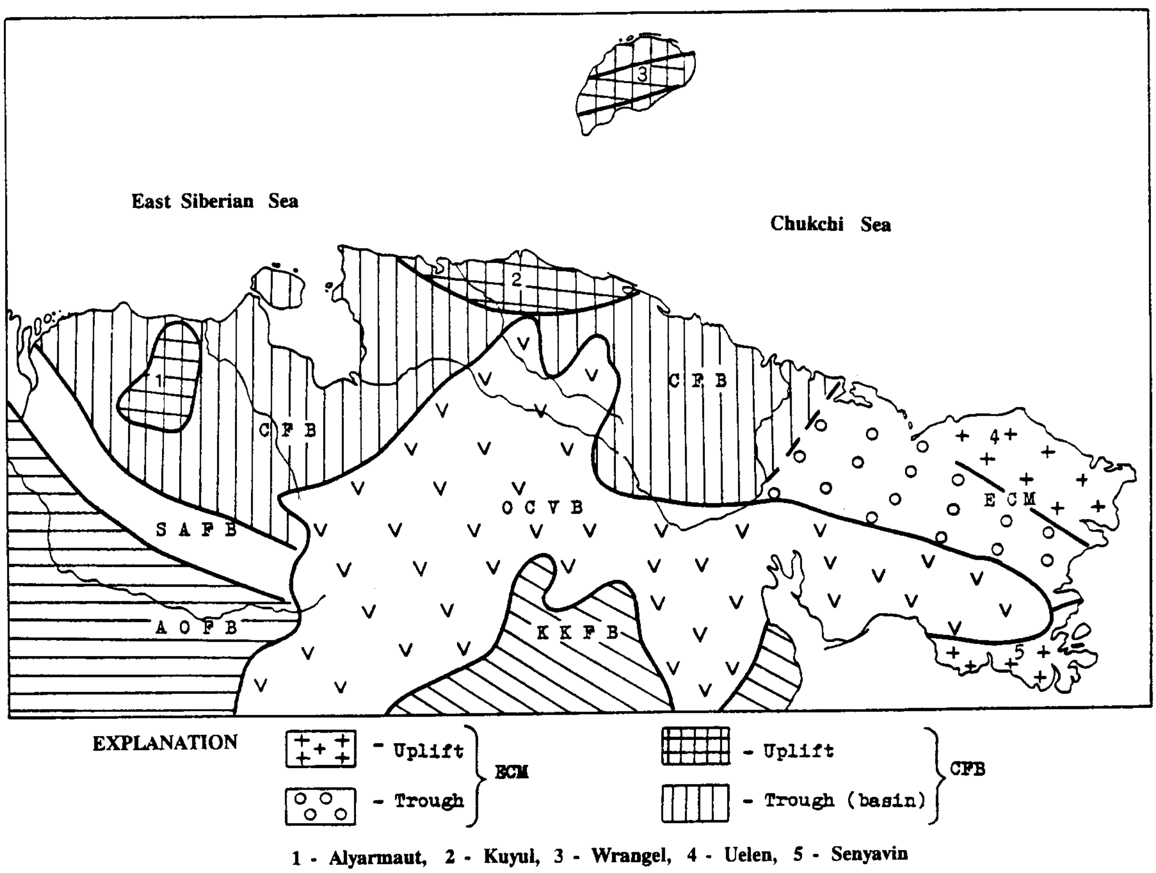

Fig.1.Major geologic divisions in the Northern Chukotka. CFB=Chukotka foldbelt, ECM=Eastern Chukotka Massif, AOFB=Alasea-Oloi foldbelt, OCVB=Okhotsk-Chukotsk volcanic belt, SAFB=South Anyui foldbelt, KKFB=Koryak-Kamchatka foldbelt.

and basins. Proterozoic, Paleozoic, and Triassic rocks are exposed in the uplifts, while Jurassic, Cretaceous, and Cenozoic rocks predominate in the depressions and basins. Proterozoic and Phanerozoic rocks in the northern Canadian Cordillera are almost exclusively sedimentary clastic and carbonate strata, with the exception of Cambrian basalts and volcanic conglomerates in the northwestern portion of the region near the boundary with Alaska. The middle Paleozoic Ellesmerian orogeny had the strongest effects in the region, and granitic magmatism occurred during the middle Paleozoic.

In Fig.2, we compare the sequences of rocks in northern Chukotka and the northern Canadian Cordillera in order to estimate similarities and differences in the geologic history of these regions.

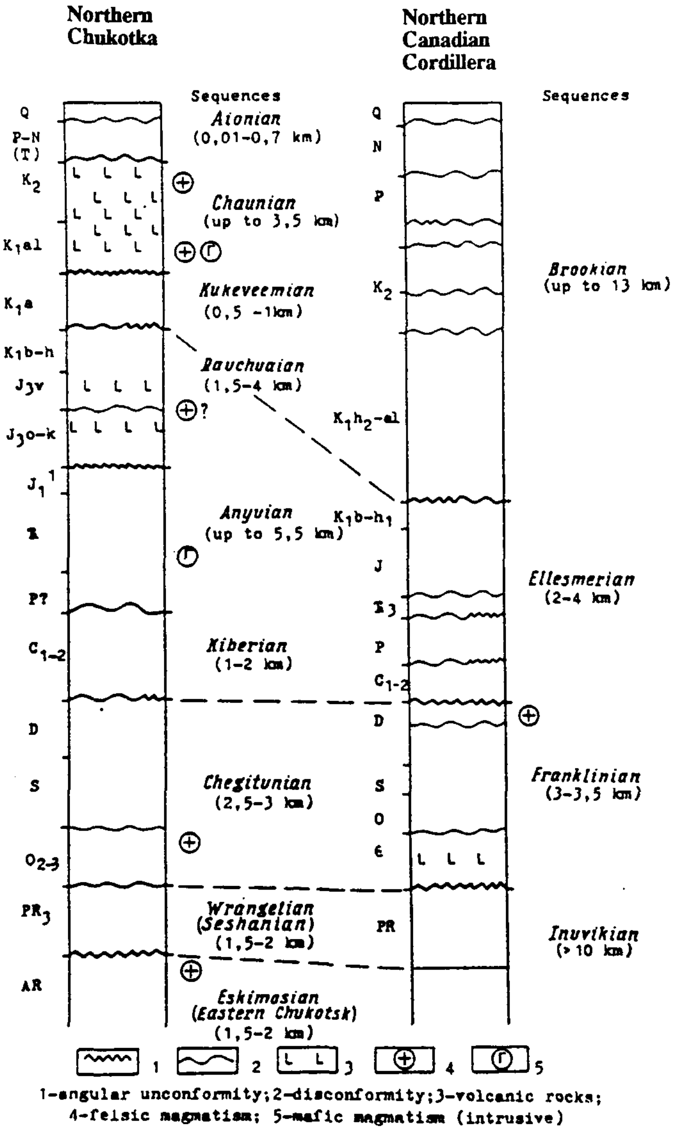

Fig.2. Comparisons of sequences of rocks in the Northern Chukotka and the Northern Canadian Cordillera

SEQUENCES AND MAGMATISM OF NORTHERN CHUKOTKA

The succession of Precambrian and Phanerozoic rocks in northern Chukotka can be divided into nine sequences (complexes):

(1) Archean gneisses, schists, quartzites, amphibolites, and marbles, approximately 10 km thick, are placed in the Eskimoan sequence by Shuldiner and Nedomolkin (1976) and in the Eastern Chukotkan sequence by Ivanov and Kryukov (1973). These rocks are highly metamorphosed and deformed (Zhulanova, 1990).

(2) The late Proterozoic Wrangelian (Ivanov and Kryukov, 1973) or Seshanian (Bychkov and Gorodinsky, 1992) sequence consists of phyllites, biotite-muscovite and chlorite-sericite schists, quartzites, and limestones. Kameneva, Dittman, and Ivanov (1975) suggested a Riphean age for this complex based on acritarch and algal remains, and Cecile et al. (1991) determined a Late Proterozoic age using U/Pb isotopes. Thicknesses range from 1.5 to 2 km. The Wrangelian sequence unconformably overlies the Eskimoan sequence in the East Chukchi massif.

(3) The Chegitun'ian sequence in the Uelen uplift of the East Chukchi massif contains predominantly carbonate rocks: limestones, dolomites, and marbles. However, there are shales, coaly shales, and calcareous shales that increase toward the top of the section. Numerous fossils, characteristic of the Middle Ordovician to Middle Devonian (Oradovskaya and Obut, 1977) are found.

Terrigenous rocks (sandstones, siltstones, shales, and turbidites) predominate in the Chegitun'ian sequence in the Kuyul (north-central Chukotka foldbelt) and Alyarmaut uplifts and limestones are rare (Gorodinsky, 1963; Rogozov and Vasil'eva, 1968). The rocks are Devonian in age and some may be older. The Chegitun'ian sequence is 2.5 to 3 km thick. The rocks of this complex are structurally complicated by repeated folding and faulting.

A disconformity separates the Chegitun'ian sequence from the Wrangelian (Seshanian) sequence, and there is another disconformity within the Chegitun'ian sequence.

(4) The Early to Middle Carboniferous Kiberian sequence consists of shales, sandstones, siltstones, and limestones. Conglomerates at the base of the section establish the position of a disconformity and, locally, a low-angle unconformity. The Kiberian sequence is 1 to 2 km thick.

(5) The Anyuian sequence (Tilman and Egorov, 1957) is widespread in the basins of the Chukotka foldbelt, where it is locally up to 5.5 km thick. This sequence is represented by sandstones, siltstones, shales, and turbidites (Bychkov, 1958, 1991). In the western part of the belt, there are rare layers of mafic tuffs and

tuffites at the base of the section. The sequence is predominantly of Triassic age. The earliest Early Jurassic rocks (Hettangian to Sinemurian) occur in the upper part of the sequence west of Chaun Bay, and Permian rocks are locally found in the lower part of the sequence. The Middle Triassic disconformity is defined by its occurrence in the Kuyul uplift and may also be present where the sequence fills basins (Tibilov et al., 1982). The Anyuian sequence is separated from Kiberian strata by a disconformity.

(6) The Rauchuanian sequence consists of sandstones, argillites, and siltstones and reaches thicknesses of 1.5 to 4 km. There are beds and members of tuffaceous argillites, tuffaceous sandstones, tuffites, andesitic tuffs, and rarely andesite and rhyolite flows in the middle part of the section. The age of the sequence is Oxfordian to Valanginian and locally Hauterivian. There is a disconformity at the base of the Volgian (Tithonian) section. The Rauchuanian sequence overlies the Anyuian sequence with great angular unconformity (Paraketsov and Paraketsova, 1989).

Sequences 3 through 6 (Ordovician to Early Cretaceous) are almost exclusively marine. They contain brachiopods, mollusks, graptolites, and coral remains. Fossil plants are found in presumed Permian rocks in the Cape Schmidt area, which may indicate that these are nonmarine.

(7) The Kukeveemian coal-bearing sequence is 0.5 to 1 km thick and outcrops locally in orogenic troughs in the central and eastern parts of the Chukotka foldbelt. It consists of sandstones, siltstones, argillites, coaly argillites, conglomerates, and coals. An Aptian or early to middle Albian age is established on the basis of numerous fossil plants. The Kukeveemian sequence represents deposition in a fluvial and lacustrine setting. This sequence overlies the Anyuian sequence with angular unconformity (Paraketsov and Paraketsova, 1989).

(8) The Chaunian sequence is 1.5 to 3.5 km thick and consists of rhyolites, andesites, basalt flows, their tuffs, and ignimbrites of the Okhotsk-Chukotsk epicontinental volcanic belt (Belyi, 1977). A late Albian to Late Cretaceous age is established for this sequence based on fossil plants. The beds of the Chaunian sequence are relatively undeformed, although dips of 20-40°, and sometimes as high as 60°, are found at the edges of volcanic troughs and near fault zones. The Chaunian sequence overlies all older sequences with angular unconformity.

(9) The Cenozoic Aionian sequence has its largest thickness (up to 0.7 km) in nearshore depressions where it is composed of Tertiary (Paleogene and Neogene) and Quaternary sediments. The sequence consists of sands, silts, clays, and gravels with beds of peat and lignite. Basaltic and andesitic flows of presumably Paleogene age, up to 250 m thick, occur in the eastern part of the region. The Aionian sediments are mainly nonmarine; rarely do beds contain marine mollusks. This sequence overlies older sequences with angular unconformity.

Granitic magmatism occurred in northern Chukotka during the Archean, early Paleozoic, Jurassic (pre-Volgian), and Early and Late Cretaceous.

It is difficult to separate the Archean granite-gneiss intrusions from metamorphics of the same age (Gel'man, 1970). Radiogenic (K/Ar) dates on the intrusives of 1,583 m.y. (Shilo and Zagruzina, 1965) probably reflect the age of later metamorphism.

Early Paleozoic intrusions are rare. Carboniferous conglomerates contain clasts of an intrusive body of microline granite that occurs in the Cape Kiber area. The age of the intrusion as defined by radiometric dating (Rb/Sr) is 439 ± 32 m.y. (Tibilov et al., 1986).

Jurassic and Early and Late Cretaceous intrusions are numerous in northern Chukotka (Ivanov, 1969; Gel'man, 1970; and Sosunov et al., 1982), where there are large batholiths. Intrusions of quartz-diorites, syenite-diorites, monzonites, diorites, granodiorites, adamellites, and other rocks occurred during the Jurassic and Early Cretaceous. Nepheline syenites and alkaline syenites are known in the East Chukchi massif. Age determinations of the intrusions by radiogenic means (K/Ar) indicate a date of 110 to 150 Ma. Gnibidenko (1969). Intrusive bodies of biotite granites, granodiorites, and diorites were formed during the Late Cretaceous and have been radiogenically dated (K/Ar) at 85 to 105 Ma.

Mafic magmatism occurred during the Early to Middle Triassic and the Early and Late Cretaceous. Early to Middle Triassic diabase, gabbro-diabase, rarely gabbro, quartz-diabase, and quartz-gabbro sills, dikes, and stocks are numerous in some districts of the Chukotka foldbelt and in the East Chukchi massif. The Early and Late Cretaceous intrusions of gabbro-diabase and quartz-diabase occurred mainly in the eastern part of the region.

SEQUENCES AND MAGMATISM OF THE NORTHERN CANADIAN CORDILLERA

Lerand (1973) and Norris and Yorath (1981) divided the Proterozoic and Phanerozoic of the northern Canadian Cordillera into four predominantly marine sequences (Fig.2): Inuvikian, Franklinian, Ellesmerian, and Brookian.

(1) The late Proterozoic Inuvikian sequence reaches thicknesses of 10 km and consists of phyllites, shales, sandstones, quartzites, limestones, and dolomites. It covers mainly the western part of the region: British Mountains and Old Crow Flats.

(2) The Cambrian to Devonian Franklinian sequence is 3 to 3.5 km thick and contains limestones, shales, cherts, quartzites, and siltstones. There are turbidites in the upper part of the section. Cambrian

rocks are absent in many districts, and there is a widespread pre-Devonian disconformity.

(3) The Carboniferous to Early Cretaceous Ellesmerian sequence is divided, based on lithology, into two parts. In the lower part (Carboniferous to Triassic), limestones and marls predominate with lesser amounts of calcareous sandstones, grits, conglomerates, argillites, and siltstones. Near the base of the section, a coal-bearing member is present that locally reaches a thickness of 400 m. In the upper part of the Ellesmerian sequence (Jurassic-Hauterivian), argillites prevail in the western districts and sandstones prevail in the eastern districts of the region. The Ellesmerian sequence is 2 to 4 km thick. Numerous marine fossils are found in the strata of the sequence.

Several disconformities are present in the Ellesmerian sequence from the late Carboniferous, Early-Middle Triassic, and earliest Jurassic levels. In some areas, the entire Permian or Triassic is missing at the disconformity. The Ellesmerian sequence is separated from the Franklinian Sequence by an unconformity. Locally, the Permian and Upper Triassic rocks overlie pre-Carboniferous rocks with great angular unconformity.

(4) The age of the Brookian sequence is Late Hauterivian to Holocene. In its lower part (early Late Cretaceous), it consists predominantly of turbidites, sandstones, siltstones, and shales that reach thicknesses of 8 to 10 km. Upper Cretaceous and Paleogene deposits consist of sandstones, conglomerates, argillites, and siltstones and contain predominantly marine fossils. However, some strata are composed of continental sediments with beds of coal. Neogene and Quaternary rocks are unconsolidated and consist of sand, clay, silt, gravel, and peat. The Brookian sequence is up to 13 km thick. There are several disconformities in the Brookian sequence, which is separated from the underlying Ellesmerian sequence by a disconformity or unconformity.

In the northern Canadian Cordillera, rare stocks of granites, tonalites, quartz-monzonites, and syenite-diorites occur in the Barn and Eastern British Mountains. Granitic batholiths are abundant in the Old Crow Flats. Probably the largest amount of granite was intruded during the Ellesmerian orogeny (Late Devonian to Early Carboniferous). Pebbles and clasts of the granites are found in conglomerates of the Kekituk Formation. Although the age of the granites has been dated at 95 to 431 Ma, a more reliable age of 354 to 406 Ma has been established (Norris, 1983).

CONCLUSIONS

The following conclusions can be drawn in the comparison of northern Chukotka and northern Canadian Cordillera sequences, magmatism, and orogenic events:

- The Inuvikian sequence of Northern Canada corresponds lithologically to the Wrangelian sequence of Chukotka but is much thicker. The Franklinian sequence closely resembles the Chegitun'ian sequence. The Ellesmerian sequence corresponds to the Kiberian, Anyuian, and Rauchuanian sequences, which have a combined thickness almost three times greater than the Ellesmerian sequence. The Ellesmerian sequence also includes many carbonate rocks that are rare or absent in northern Chukotka, but volcanic rocks found in the Rauchuanian sequence are absent in the Ellesmerian. The Anyuian sequence consists mainly of Triassic rocks, whereas very few Triassic rocks are found in the Ellesmerian that contain only the Norian and Rhaetian stages. In contrast, while Jurassic rocks predominate in northern Canada, Middle Jurassic sediments are absent in northern Chukotka. The ages of angular unconformities and disconformities in northern Canada during the Ellesmerian usually differ from those of northern Chukotka.
- The Brookian sequence is analogous to the Kukeveemian, Chaunian, and Aionian sequences. These Canadian and Chukotkan sequences differ greatly in facies and thicknesses. In northern Chukotka, there are abundant volcanic rocks that are absent from the northern Canadian Cordillera.
- The ages of granitic magmatism differ between Chukotka and Canada and mafic magmatism is absent in the northern Canadian Cordillera.
- The geologic history of northern Chukotka and the northern Canadian Cordillera have some similarities during the Proterozoic and early and middle Paleozoic. However, they differ during the late Paleozoic, Mesozoic, and Cenozoic.

ACKNOWLEDGMENTS

The authors are grateful to O.N. Ivanov for his consultations, V.M. Kuznets for reviews, and M.A. Trumpe for his enormous help in computer work.

REFERENCES

Belyi, V.F., 1977. Stratigrafiya i struktury Okhotsko-Chukotskogo vulkanogennogo poyasa. Nauka, Moscow, 171 pp. (in Russian).

Bychkov, Y.M., 1958. K stratigrafii tsentral'noi chast Chaunskogo raion. Materialy po Geologii i Poleznym Iskopaemym Severo-Vostka SSSR. 12: 29-34 (in Russian).

Bychkov, Y.M., 1991. Sravnitel'naya kharakteristika triasa severnoi Chukotki i severnogo Yukona. In: I.S. Gramberg and M.K. Kos'ko (Editors), Geologiya Skladchatogo Obramleniya Ameraziiskogo Subbaseina. NPO "Sevmorgeologiya", St. Petersburg, pp. 84-93 (in Russian).

Bychkov, Y.M. and M.E. Gorodinsky, 1992. Comparative

geology of the Northern Chukotka and the Northern Canadian Cordillera. Abs., International Conference on Arctic Margins, 1992, Anchorage, AK, p. 22.
Cecile, M.P., Harrison, J.C., Kos'ko, M.K. and Parrish, R. 1991. U-Pb Geochronology of Plutonic rocks, Wrangel Island Complex, Wrangel Island, USSR. Canadian Journal of Earth Sciences, v. 28, pp. 1340-1348.
Gel'man, M.L., 1970. Pozdnemezozoiskii magmatizm, Chukotskaya skladchataya oblast'. In: I.E. Drabkin (Editor), Geologiya SSSR, v. 30, Severo-Vostok SSSR, Geologicheskoe Opisanie, book 2. Nedra, Moscow, pp. 126-141 (in Russian).
Gnibidenko, G.S. 1969. Metamorficheskie kompleksy v strukturakh severo-zapadnogo sektora Tikhookeanskogo poyasa. Akademiya Nauk SSSR, Sibirskoe Otdelenie. Izdatel'stva Nauka, Moskva, 132 pp.
Gorodinsky, M.E., 1963. Geologicheskii ocherk tsentral'nykh raionov Chukotki. Materialy po Geologii i Poleznym Iskopaemym Severo-Vostka SSSR. 16: 54-66 (in Russian).
Ivanov, O.N., 1969. Ovozmozhnosti vydeleniya giperbasit- gabbro-granitnogo formatsionogo ryada na vostochnoi Chukotke. Geologiya i Geofizika, (7): 72-78 (in Russian).
Ivanov, O.N. and Kryukov, Y.V., 1973. Dokembrii vostochnogo sektora Sovetskoi Arktiki. Geologiya i Geofizika, (9): 50-59 (in Russian).
Kameneva, G.I. Dittmar, and Ivanov. 1975. Struktura tsentral'noi chasti o. Vrangelya. In: D.A. Vol'nov (Editor), Geologiya i Poleznye Iskopaemye Novosibirskikh Ostrovov i Ostrova Vrangelya. NIIGA, Leningrad, pp. 72-77 (in Russian).
Lerand, M., 1973. Beaufort Sea. In: The Future Petroleum Provinces of Canada - Their Geology and Potential. Can. Soc. Petrol. Geol. Mem. 1, pp. 315-386.
Norris, D.K., 1974. Structural Geometry and geological history of the Northern Canadian Cordillera. In: Proceedings of the 1973 National Convention, Calgary. Canad. Soc. Expl. Geophysicists, pp. 18-45.
Norris, D.K., 1983. Geotectonic correlation chart - operation Porcupine project area. Geol. Surv. of Canada, Map 1532-A, 1 pp.
Norris, D.K. and Yorath, C.J., 1981. The North American Plate from the Arctic Archipelago to the Romanzof Mountains. In: The Ocean Basins and Margins, v. 5, The Arctic Ocean. Plenum Press, New York, pp 37-103.
Oradovskaya, M.M. and Obut, A.M., 1977. Stratigrafiya, korrelyatsiya, paleogeografiya ordovikskikh i siluriiskikh otlozhenii na Chukotskom poluostrove. In: A.M. Obut (Editor), Stratigrafiya i Fauna Ordovika i Silura Chukotskogo Poluostrova. Nauka, Novosibirsk, pp. 4-42 (in Russian).
Paraketsov, K.V. and Paraketsova, G.I., 1989. Stratigrafiya i fauna verhneyourskikh i nizhnemelovykh otlozhenii Severo-Vostoka SSSR; Ministerstvo Geologii SSSR, Severo-Vostochnoe proizvodstvennoe geologicheskoe ob-edinenie "Sevvostgeologiya"; Moskva "Nedra," 297 pp. (in Russian).
Rogosov, Y.G. and Vasil'eva, N.M., 1968. Devonskie otlozheniya poberezh'ya proli va Longa (Tsentral'naya Chukotka). Uchen. Zap. NIIGA, Regional'naya Geologiya, 13: 151-157 (in Russian).
Shilo, N.A. and Zagruzina, I.A. 1965. Magmaticheskie kompleksy i metallogenniya vostochnoi Chukotke. In: Pozdnemezozoiskie Granitoidy Chukotki (Trudy SVKNII, v. 12). SVKNII, Magadan, pp. 188-206 (in Russian).
Shul'diner, V.I. and Nedomolkin, V.F., 1977. The crystalline basement of the Eskimos Massif. Int. Geol. Rev., 19: 891-902.
Sosunov, G.M., Pavlova, O.K., and Gel'man, M.L., 1982. Geologicheskaya karta Severo-Vostoka SSSR. Scale 1:1,500,000. Tables. Ministerstvo Geologii SSSR, Magadan, 39 pp . (in Russian).
Tibilov, I.V., Begunov, S.F., Larionov, Y.S., and P'yankov, A.Y., 1982. K stratigrafii triasa Chukotskoi strukturno-fatsial'noi oblasti. Materialy po Geologii i Poleznym Iskopaemym Severo-Vostka SSSR. 26: 15-22. (in Russian).
Tibilov, I.V., Milov, A.P., and Davydov, I.A., 1986. O proyavlenii demezozoiskog o granitoidnogo magmatizma na Chukotke. Tikhookeanskaya Geologiya, (4): 95-98 (in Russian).
Tilman, S.M. and Egorov, D.F., 1957. Novye dannye po stratigrafii i tektonike pravoberezh'ya r. Kolyma v ee nizhnem techenie. Doklady Akad. Nauk SSSR, 113: 421-423 (in Russian).
Zhulanova, I.L., 1990. Zemnaya kora Severo-Vostoka Azii v Dokembrii i Fanerozoe. Nauka, Moskva, 302 pp. (in Russian).