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A re-examination of the age of Hunchun Flora, Jilin Province, China

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ABSTRACT. The Pritumangan Basin in East Asia is very rich in commercial coals. It occupies parts of the territories of China, North Korea and Far East Russia. The sequence of sediments with coals in Khasan, the Russian part of the basin, ranges in age from Eocene (Nazimov Formation) to Miocene (Khasan Formation). The coal bearing strata of the basin in Onsong and Yusong of Korea are assigned to Eocene while in Saeboyl they are of Miocene age. The floral analysis of all the three parts of the basin suggests that the age of the coal-bearing Hunchun Formation at Hunchun in the Chinese part of the basin is most probably of Middle Eocene age. In this paper, also newly recovered specimens of *Alnus shestakovae* Ablaev are described.

KEY WORDS: fossil leaves, Hunchun flora, Eocene, Pritumangan basin, China, North Korea, Far East Russia

INTRODUCTION

The Pritumangan Basin is the biggest coal-bearing continental deposit of East Asia. It stretches over the territories of Hunchun in north-eastern China, Yusong, Onsong, Haengyeong, Saeboyl, Undok and Chonghak in northern part of the Korean Peninsula, and Khasan in southern Far East Russia (Figs 1, 2). Studies of these sediments, particularly with commercially important coals, have been carried out since long. Inspite of rich data available pertaining to geology and palaeontology, no serious attempts have been made to solve the problems with regard to the age and correlation of different coal-bearing strata of the basin.

MATERIAL

We have visited the exposures of the Hunchun Formation, studied a geological section at Damiao (a temple, 42°53.13'N, 130°20.98'E), North Hill, Hunchun City and collected a good representation of plant remains (macrofossils) from the locality where the former collection was made by earlier workers. According to the data provided by local geologists, the total thickness of terrigenous-coal deposits of the Hunchun Formation developed here is 600 m. This formation, on the basis of lithological composition, is divided into 3 members (approximately equal in thickness): the lower coal-bearing, the middle terrigeneous and the upper coal-bearing. Sampling of fossil plants was conducted in the lower coal-bearing member in a layer of yellow-grey, weakly consolidated aleurolites, interbedded with thin coal seamlets up to 20 cm in thickness.

STRATIGRAPHY OF THE PRITUMANGAN BASIN

Until recently, in Primorye of Russian Far East, including the Khasan (= Kraskino) depression, all Cainozoic coal-bearing sediments were dated to Palaeogene (Bersenev et al. 1969, Nazarenko & Bazhanov 1987). One of the authors of the present paper (Ablaev & Solomonovskaya 1975) showed the fallacy of this view. However, both Palaeogene and Neogene deposits are now recognized as being rich in commercial coals. The Khasan depression con-

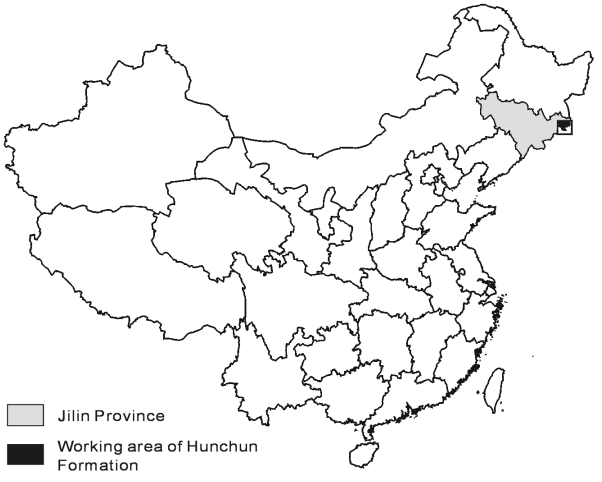

Fig. 1. Map of China and working area of Hunchun Formation

tains layers of coals both in the Palaeogene (Eocene Nazimov Formation) and Neogene (Miocene Khasan Formation). But the question of correlation of the coal-bearing deposits has not yet been resolved and the stratigraphic chart of the Cainozoic of Primorye needs refining.

There are different opinions about the stratigraphy of the Tertiary deposits occupying the northern part of Korea. Previously, the widely spread Palaeogene and Neogene coal-bearing beds were assigned to Palaeogene (Ustinovskyi et al. 1966). However, the majority of Korean geologists and palaeontologists (Jo & Kim 1993) believe that the Cainozoic sedimentation in the Pritumangan Basin started during Neogene times, and therefore the coal-bearing sediments are of Miocene age. According to Ablaev and Tashchi (1992) and Ablaev et al. (1993, 1994) here, as well as in the south of Primorye, the Palaeogene and Neogene sediments are coal-bearing. The floras of coal-bearing sediments of the Onsong and Yusong depressions are Eocene, whereas the flora of similar deposits of the Saeboyl depression are of Miocene age. But, erroneously, both Palaeogene and Neogene sediments are still considered as one stratigraphic unit within rank of formation or sub-formation Hamen.

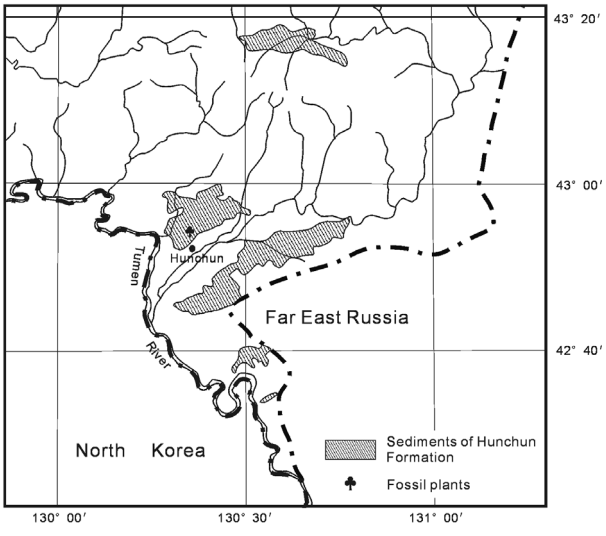

Fig. 2. Map of working area of Hunchum Formation

We have little information about the Hunchun Formation of the same depression occurring north of Pritumangan Basin (Bureau of Geology and Mineral Resources of Jilin Province 1989). The sediments of this formation consist of conglomerates, sandstones, siltstones and claystones with two groups of coal seams. It is 1000 m in thickness, unconformably rests on the Upper Cretaceous Longjing Formation and is overlain by the Miocene Timenzi Formation. In the stratigraphic chart and geological map (scale 1: 500 000) of the Jilin Province, the Hunchun Formation is dated as Palaeogene (Palaeocene-Oligocene), whereas, on the basis of spores and pollen grains, it is considered to be of Oligocene age. Liu (1987) provided palynological assemblages of the Hunchun coal-field and assigned Late Eocene to Early Oligocene age to the Hunchun Formation.

PALAEOBOTANICAL DATA OF HUNCHUN FORMATION

The macrofossils found in the Hunchun Formation were studied by Guo and Li (1979). They thought that the whole sequence belongs to Upper Cretaceous. The plant assemblage of the Hunchun locality, according to Guo and Li includes *Glyptostrobus europaeus* (A.Br.) Heer, *Metasequoia cuneata* (Newb.) Chaney, *Populites* cf. *litigiosus* (Heer) Lesq., *Juglandites poliophyllum* Guo & Li, *Trochodendroides vassilenkoi* Iljinskaja & Romanova, *Protophyllum multinerve* Lesq., *P. haydenii* Lesq., *P. cordifolium* Guo & Li, *P. microphyllum* Guo & Li, *P. ovatifolium* Guo & Li, *P. renifolium* Guo & Li, *P. rotundatum* Guo & Li, *Leguminosites* sp., *Graminophyllum* sp. The flora is characteristic in having 7 species of *Protophyllum* out of 14 species of plants. Of

the listed 7 species of *Protophyllum*, five were described as new. This flora was considered to be comparable to the Cretaceous floras of East Asia and North America. In view of close similarity between the floral assemblages of the two, the Hunchun flora was regarded to be Senonian or even older in age. *Protophyllum*, one of the most common elements of the plant assemblages, might have penetrated to North America from East Asia or vice versa through land bridges during Late Cretaceous.

Guo (2000) described additional specimens of fossil plants from the same depression. The flora of the Hunchun depression now consists of 24 species, belonging to horse-tails (1 sp.), ferns (1), conifers (4) and angiosperms (18). Of the recognized 24 species, 13 are new and belong to Ceratophyllaceae, Platanaceae, Betulaceae, Tiliaceae, Myrtaceae, and Vitaceae. According to Guo, this flora can be dated as Cenomanian – Coniacian. Re-investigation of some of the leaves of this flora by Guo (2000) has resulted in the reduction of the number of species of *Protophyllum* from seven to two, viz. *P. multinerve* Lesq. and *P. zaisanicum* Romanova and the exclusion of the species of *Trochodendroides* from the list of Guo and Li (1979). On the other hand, some more new taxa were added to the list, such as *Taxodium* and *Sequoia* within taxodioids and *Arthollia* of extinct platanoids. The new angiosperm leaves added to these floral assemblages are *Corylites hunchunensis* Guo, *Betuliphyllum hunchuniphyllum* Guo, sp. nov. (Betulaceae), *Vitiphyllum jilinense* Guo, *Cissites hunchunensis* Guo, (Vitaceae), *Ceratophyllum jilinensis* Guo, (Ceratophyllaceae), *Stephanofolium ovatiphyllum* Guo, gen. et sp. nov. (Menispermaceae), *Corylopsiphyllum jilinense* Guo, (Hamamelidaceae), *Tiliaephyllum jiliniphyllum* Guo, (Tiliaceae), and *Myrtophyllum penzhinense* Herman (Myrtaceae).

LEAVES OF *ALNUS SHESTAKOVAE* ABLAEV IN THE HUNCHUN FLORA

The current study shows with certainty that the Hunchun flora is not analogous to any among the Upper Cretaceous floras nor to any of the ecological-vegetation type. This flora is characterized by a dominance of Betulaceae (*Alnus*, *Betula*). Quantitavely, the leaves of alder predominate, forming so-called “leaf beds” or plant-bearing seams, followed by foliage of *Osmunda*, and *Metasequoia*. Representatives of *Liquidambar* and *Cyclocarya* have been met only as single specimens.

The present studies on the Hunchun flora led to the establishment of various morphological types of leaves within a single alder species (Fig. 3). Leaves orbicular and obovate, ranging in size from 4.5–5.2 × 4.2–5.5 cm (middle size) to 11–13 × 10–11 cm (maximum size); apex obtuse or slightly acuminate, base rounded, rounded-cuneate, truncate, weakly sinuate or pierceed / peltate; secondary veins relatively regularly spaced on the somewhat thicker midvein, in lower part of lamina opposite and approximate, near apex alternate, sometimes forking, to 6–7 pairs, usually with 1–2, seldom 3 abaxial branches departing near the margin; range of diverging of veins widely varies – in lower part of lamina secondaries veins (usually 2 pairs, veins more shortened in comparison with above spaced ones) diverging almost at right or wider angles, whereas in the upper part of lamina diverging at acute angles; some branches of secondary veins in the lower part of lamina connected between itself and with tertiary veins by means of angular loops, ending towards margin a shortest veins; tertiary veins forming concentric network, 5–6 per 1 cm, distinct, percurrent, sometimes forking, space between them is filled by small polygonal areoles, 0.1–0.15 mm across, are formed of fifth order veins, ultimate veinlets once to twice branched; margin variable from dentate to denticulate and entire near base, teeth from distinct broad triangular with short acuted tips to inconspicuous; peltate base semi orbicular with entire margin and thin veins radially spreading from the point of the petiole insertion; maximum length of preserved petiole reaching 15 mm.

DISCUSSION ON THE AGE OF THE HUNCHUN FLORA

The species *Alnus shestakovae* was described for the first time from the Eocene flora of Shestakov, northern Priokhotye (Ablaev 1985). Later we succeeded in finding *Alnus shestakovae* in the Eocene flora of Yusong and Onsong, North Korea (Ablaev & Tashchi 1992, Ablaev 2001). In these floras, leaves of alder can be distinguished in their broad and vari-

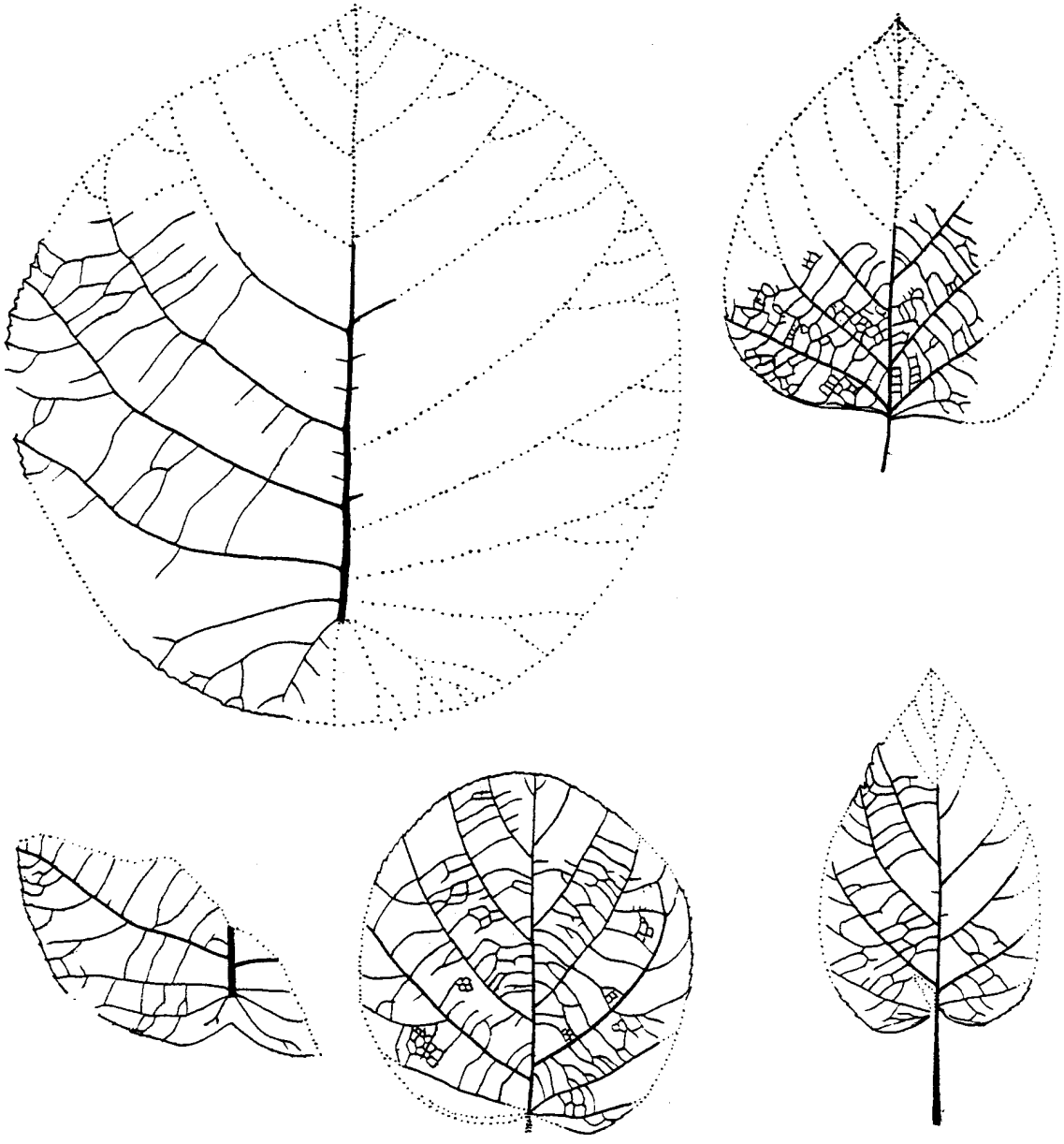

Fig. 3. *Alnus shestakovae* Ablaev, natural size

able size, and some of the biggest leaves can be wrongly referred to other species, such as Upper Cretaceous platanoids having leaves with the peltate base.

In our opinion, fossil leaves assigned to different species of *Protophyllum* and *Arthollia* of the Hunchun flora belong to a single polymorphic species of *Almus shestakovae*. Some other species of the Hunchun flora, viz. *Betuliphyllum hunchuniphyllum, Corylites hunchunensis, Vitiphyllun jilinense, Tiliaephyllum jiliniphyllum, Populites litigiosus*, and also, pro parte, *Corylopsiphyllum jilinense* (Guo 2000, p. 232, Pl. 4, fig. 7) and *Cissites hunchunensis* (ibid., p. 237, Pl. 4, fig. 8, Pl. 8, fig. 3) undoubtedly belong to the genus *Alnus*. Peltate leaves of *Protophyllum* from the Upper Cretaceous flora with entire, wave, and emarginated-dentate margin, thick secondary veins, and forking, including the lower pair of secondaries are sharply differed; leaves of another platanoid genera (*Platanus, Psedoprotophyllum, Paraprotophyllum, Arthollia*) differ by pinnate-palmate venation, the outstanding basal lateral primaries. The opinion that the leaves assigned to various species of the so-called "*Protophyllum*" found in Hunchun are different from the type species of *Proto-*

phyllum of North America has rightly pointed out in 1989 (Bureau of Geology and Mineral Resources of Jilin Province, 1989).

Morphologically differentiated leaves of *Alnus shestakovae* (with peltate, deeply cordate, reniform, truncate, and cuneate base) preserving single type of venation and character of the margin form a single morphologic row; the extreme leaves form are wrongly considered as an independent species within extinct organ-genera of the family Betulaceae, Tiliaceae, Vitaceae. Such morphological variations of leaves of alder in the Tertiary floras from East Asia are not seldom. They have been described from a numbers of localities under different species. The leaf, of *Alnus shestakovae,* is indeed very similar to *A. protophylloides* Budantsev & Golovneva from Eocene Irgyrnin-Kynkil flora of Western Kamchatka (Budantsev & Golovneva 1986, Budantsev 1997). In their morphological features of leaves, both species, *A. shestakovae* and *A. protophylloides* are similar, however, leaves from Kamchatka can be distinguished in having denticulate margin while the leaves in our collection are variable from crenate to dentate margin. Almost similar features are exhibited by the Eocene species of *A. savitskii* (Sych.) Chelebaeva from the Lower Snezhinkin plant complex of the Uglegorskii district from Southern Sakhalin (Chelebaeva & Bratzeva 1985). This species includes the peltate and unpeltate leaves originally described by Sychova (1977) as *Protophyllum savitskii* Sych. and *Alnus hokkaidoensis* Tanai. According to Budantsev (1997), leaves of *A. savitskii* belong to *A. protophylloides*. In the form of impressions, all three species of alder from North Priokhotye, Western Kamchatka, North Korea and Northeast China are similar, although it does not preclude of considering them as vicarious species.

CONCLUSION

From the above palaeofloristic study, it is evident that there is a close similarity between the Hunchun flora and the floras of the Yusong and Onsong depressions of the Pritumangan coal basin. The Middle Eocene flora of Hunchun also compares to that of the Nazimov flora in the Khasan depression from the same coal-bearing basin with plants like *Platanus*, *Trochodendroides* and also magnolia, fig and laurel. Unfortunately, this flora, which has been known since long (Shtempel' 1926, 1963), has not been fully worked out, and little information available is not sufficient for correlation of various strata. A monographic study of the whole collection of fossil plants from the Hunchun locality would provide sufficient data to enable a comparison with the other Eocene floras of East Asia. Views regarding the age of some coal-bearing beds within the Hunchun depression of the Pritumangan basin as Neogene needs to be further studied, as the coal accumulation within the Hunchun depression does not show any difference from situations in the territories of Primorye and North Korea. The latter two areas possess coal layers dated to both Palaeogene and Neogene. This problem would be precisely discussed when the biostratigraphy of the coal-bearing Tertiary sediments is developed both section-wise and area-wise. For a detailed comparison with other floras of China and Far East Russia, the Tertiary floras of Pritumanganye in the Korean territories needs reinvestigation.

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REFERENCES

ABLAEV A.G. 1985. Flory Kamchatsko-Korjakskovo regiona i voprosy stratigrafii kontinental'novo kainozoya: 1–80 (Floras of the Kamchatka-Korjakian Region and problems of the continental Cainozoic stratigraphy). FES Centre Acad. Sci. USSR Publishers, Vladivostok.

ABLAEV A.G. 2001. Paleogen Tumanganskovo uglenosnovo basseina, yug Dal'nevo Vostoka (summary: Palaeogene of the Tumangan Carboniferous basin, southern Far East): 1–67. FEB RAS, Vladivostok.

ABLAEV A.G. & SOLOMONOVSKAYA V.P. 1975. Stratigrafiya floronosnykh sloev Khasanskovo rayona v yugo-zapadnom Primorye (Stratigraphy of floral beds of Khasan district in southwestern Primorye): 5–15. In: Ablaev A.G. & Smirnov A.M. (eds) Materials on the palaeobotany and stratigraphy, soviet Far East. FES Centre Acad. Sci. USSR Publishers, Vladivostok. (in Russian).

ABLAEV A.G. & TASHCHI S.M. 1992. Kainozoi Pritumanganya yuga Dal'nevo Vostoka: stratigrafiya, morfostruktury, geologicheskoe razvitie (Caino-

zoic of Pritumanganye, southern Far East : stratigraphy, morphostructures, geological development). FEB RAS. Depot VINITI., 2558-B92: 1–140. (in Russian).

ABLAEV A.G., TASHCHI S.M. & VASSILIEV I.V. 1994. New data on Cainozoic stratigraphy in Pritumanganye, southern Far East (Russia). Newsl. Stratigr., 30(2): 91–104.

ABLAEV A.G., SIN E.U., VASSILIEV I.V. & LYU Z.M. 1993. Miotsen severa Korei i yuga Primorya: sloi s *Engelhardia* (summary: Miocene of north Korea and south Primorye: *Engelhardia* beds): 1–136. FEB RAS Publishers, Vladivostok.

BERSENEV I.I., USTINOVSKI YU.B., BURYANOVA I.Z., NEVOLINA S.I., & MEDVEDEV V.V. 1969. Kainozoiskaya systema. (Cainozoic system): 317–373. In: Bersenev I.I. (ed.) Geology of USSR: Primorye Territory. Geological description. Nedra Publishers, Moscow. 32(Part 1). (in Russian).

BUDANTSEV L.YU. 1997. Pozdneeotsenovaya flora zapadnoy Kamchatki (Late Eocene flora of Western Kamchatka). Proceed. Botan. Inst. RAS., 19: 1–115. (in Russian).

BUDANTSEV L.YU. & GOLOVNEVA L.B. 1986. Novyi vid roda *Alnus* (Betulaceae) s peltatnymi list'yami v pozdneeotsenovoi flore severo-zapadnoi Kamchatki (A new species of the genus *Alnus* (Betulaceae) with peltate leaves in the Late Eocene flora from North-Western Kamchatka). Bot. Zhurn., 71(2): 246–254. (in Russian).

BUREAU OF GEOLOGY AND MINERAL RESOURCES OF JILIN PROVINCE 1989. Regional geology of Jilin province. Geological Memoirs. Ser. 1. No. 10. Geological Publishing House, Beijing. (in Chinese, with English summary).

CHELEBAEVA A.I. & BRATZEVA G.M. 1985. K klimatostratigrafii paleogena po paleofloram: sever Tikhookeanskoi oblasti i smezhnye regiony (On climatostratigraphy of Palaeogene from palaeofloras: north of Pacific Region and adjacent areas): 157–209. In: Gladenkov Yu. B. (ed.) Correlation of Cainozoic bodies of Far East. Part 2. Geol. Inst. Acad. Sci. USSR, Moscow. (in Russian).

GUO SHUANGXING & LI HAOMIN 1979. Late Cretaceous flora from Hunchun of Jilin. Acta Palaeontologica Sinica, 18(6): 547–560. (in Chinese).

GUO SHUANGXING. 2000. New material of the Late Cretaceous flora from Hunchun of Jilin, Northeast China. Acta Palaeontologica Sinica, 39(Suppl.): 226–250.

JO IL WON & KIM CHANG GON 1993. Cainozoic era: 198–221. In: Pack Ryong Jun, Kan Hyong Gap, Jon Guk Pu, Kim Yong Muk & Kim Yong Hyon (eds) Geology of Korea. Foriegn Languages Book Publishing House, Pyongyang.

LIU MULING. 1987. Early Tertiary palynological assemblages of Hunchun coal-field, Jilin Province. Professional Papers of Stratigraphy and Palaeontology, 17: 167–192

NAZARENKO L.F. & BAZHANOV V.A. 1987. Geologiya Primorskovo kraya. Chast' 1. Stratigrafiya. (Geology of Primorye. Part 1. Stratigraphy): 1–65. Preprint / Geol. Inst. FES Centre Acad. Sci. USSR Publishers, Vladivostok. (in Russian).

SHTEMPEL' B.M. 1926. Uglovskii rayon. Otchet o geologicheskom issledovanii osen'yu 1924 (Uglovskii district. Account on geological researches in autum 1924). Materials on geology and minerals of Far East, 45: 1–88. (in Russian).

SHTEMPEL' B.M. 1963. Paleobotanicheskaya kharakteristika paleogenovykh otlozhenii (Palaeobotanical description of the Palaeogene deposits): 68–100. In: Martinson G.G. (ed.) History of the Palaeogene coal accumulation on territory of Sakhalin. Acad. Sci. USSR Publishers, Moscow-Leningrad. (in Russian).

SYCHOVA O.A. 1977. Rannepaleogenovaya flora Uglegorskovo rayona Sakhalina i eye znacheniye dlya stratigrafii (Lower Palaeogene flora of Uglegorsk district of Sakhalin and its significance for stratigraphy): 1–38. In: Il'ev A.Ya. (ed.) Fauna and flora Cainozoic of North-West Pacific Region: southern Sakhalin. FES Centre Acad. Sci. USSR Publishers, Vladivostok. (in Russian).

USTINOVSKYI YU.B., KHAN D.S., BOLOTNIKOVA M.D., BE G.Z. & KARASEV M.S. 1966. Stratigrafiya i usloviya formirovaniya kainozoiskikh otlozhenii (Stratigraphy and condition of formation the Cainozoic deposits): 162–261. In: Radkevich E.A. (ed.) Geological structure of northeastern Korea and southern Primorye. "Nedra" Publishers, Moscow. (in Russian).