Bull. Mizunami Fossil Mus., no. 22 (1995), p. 73-102, 8 figs.

Paleogene Nuculanidae (Bivalvia) of South Sakhalin: Composition and Distribution

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Abstract

The paper presents a review of taxa of a generic group of the family Nuculanidae registered in Cenozoic deposits of Northern-Western Pacific.

In this paper, *Nuculana s. s.* Link, 1807, *N.* (*Thestyleda*) Iredale, 1929, *N.* (*Tenuileda*) Habe, 1977 and *N.* (*Crassoleda*) Savizky, 1969, *Jupiteria s. s.* Bellardi, 1875, *J.* (*Saccella*) Woodring, 1925; *J.* (*Epacroleda*) Savizky, 1969 and *J.* (*Costanuculana*) Habe, 1951 are established to belong to Nuculaninae; *Propeleda* Iredale, 1924 to Poroledinae; *Yoldia s. s.* Möller, 1842, *Y.* (*Cnesterium*) Dall, 1898; *Y.* (*Kalayoldia*) Grant *et* Gale, 1931, *Y.* (*Orthoyoldia*) Verrill *et* Buch, 1897, *Y.* (*Sachalinella*) Savizky, 1969, *Y.* (*Tepidoleda*) Iredale, 1939, *Y.* (*Nampiella*) subgen. nov., *Y.* (*Praesachalinella*) subgen. nov., *Megayoldia s. s.* Verrill *et* Bush, 1897, *M.* (*Portlandella*) Stewart, 1930, *M.* (*Hataiyoldia*) Kamada, 1962, *M.* (*Praeportlandia*) Savizky, 1969 and *Portlandia* Mörch, 1857 to Yoldiinae; *Malletia* Des Moulins, 1832 and *Spineilo* (*Multidentata*) L. Krishtofovich, 1964 to Malletiinae; *Neilonella s. s.* Dall, 1881 and *N.* (*Borissia*) Slodkewitsch, 1938 to Neilonellinae.

Diagnoses and key to genera and subgenera are given. Subgenus *Acilana* L. Krishtofovich, 1964 has been reduced to a synonym of *Hataiyoldia* Kamada, 1962.

The mode of distribution of Nuculanidae in the Paleogene section of South Sakhalin permits to identify five complexes corresponding to the established stratigraphic classification. Complex I: "lona" *Jupiteria* (*Saccella*) *gabbii*, reported from the Lower Eocene (most early in Sakhalin) marine formations of lower-Krasnopolyev sub-suite. Complex II is distinguished rather hypothetically on the basis of availability of the rare "*Nuculana*" *snatolensis* and *Nuculana* (*Thestyleda*) sp. in the upper member of Krasnopolyev suite. Investigation into complex III indicates synchrony between the Aral, Takaraday and uppermost portion of Nizhneduy suite at the Western coast of Southern Sakhalin. Complex IV; "lona" *Yoldia* (*Y.*) *longissima-Megayoldia* (*Portlandella*) *nitida* corresponds to flourishing stage of Yoldiinae in the Far Eastern region of Russia, and in Southern Sakhalin it characterizes the deposits of the lower and middle Members of Arakay suite and Gennoyshi suite. Commonly traced is the base of deposits (Kholmsk and lentil II of Khoylldzhi suites) characterized by complex V-"lona" *Megayoldia* (*Hataiyoldia*) *tokunagai-Nuculana* (*Crassoleda*) *crassotelloides*.

Key words: Bivalvia, Nuculanidae, systematics, biostratigraphy, Cenozoic, Northwest Pacific.

Introduction

In 1978, Chief Geologist of the Central Laboratory of the stratigraphical Party of the Sakhalin Territorial Geological Administration (presently known Informgeocentre of "Vostokgeologiya" Research and Production Association, Yuzhno-Sakhalinsk), Dr. Viktor O. Savizky had proposed Dr. Alex. I. Kafanov (Institute of Marine Biology, Vladivostok) to cooperate in the analysis of Bivalvia fauna from the Sakhalin Cenozoic formations, preserved at this institution in excellent condition. The purpose of this analytical effort was a better understanding of the key formation stages of Cenozoic molluscan faunas of the North Pacific. The cooperative effort was successfully started and permitted to publish certain information on the family Cardiidae (Kafanov *et* Savizky, 1982a, b; 1983). Unfortunately, untimely death of V. Savizky of November 5, 1988 stopped this joint initiative.

Separate notes, not supplied by references, regarding the stratigraphic distribution of the Sakhalin Paleogene Nuculanidae were prepared by V. Savizky already in 1979. However, due to various reasons, it is only at present that this contribution could be prepared for print. All the stratigraphic conclusions containing in this article may to a certain extent be adjusted to the updated information on the Paleogene stratigraphy of South Sakhalin (Zidkova *et al.*, 1982; Avkhipova *et al.*, 1992 etc.) and Kamchatka (Gladenkov *et al.*, 1989, 1991). As a synonym of "provincial zone" we use here the term "lona" proposed by Krimholz (1972) and approved by Stratigraphical Code of the USSR (1977). Lona is a regional stratigraphical classification relating to a part of horizon and integrating mono- and polyfascial strike deposits within the limits of paleobiogeographical region or province. The latter deposits are characterized by a definite set of organic residues and the inherent single or several index species. The key Sakhalin toponyms cited in the text are designated in Fig. 1.

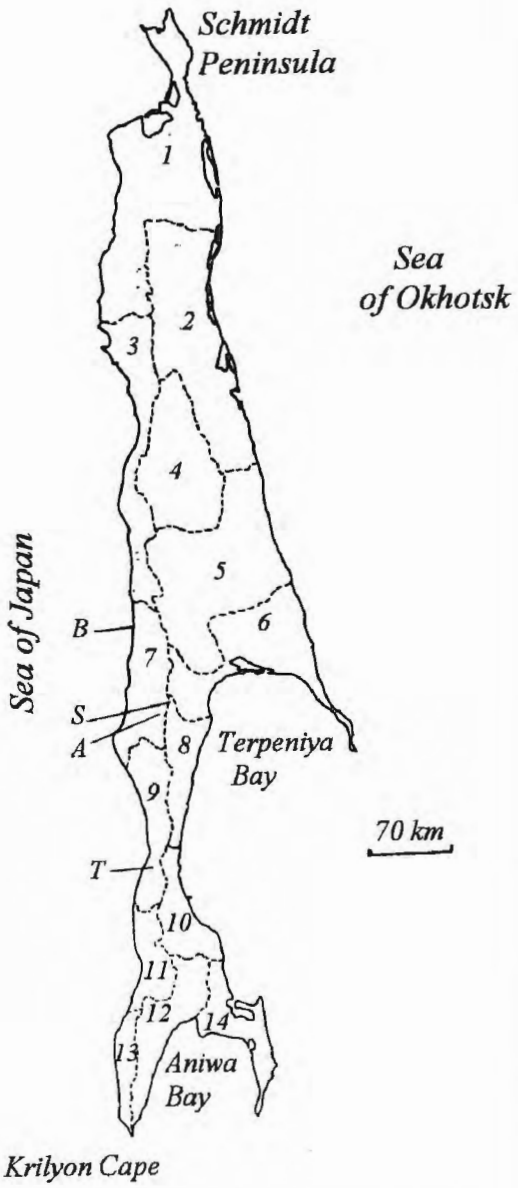


Fig. 1. Localities of the Sakhalin's Paleogene Nuculanidae mentioned in the text. Districts: 1—Okha, 2—Nogliki, 3—Aleksandrovsk—Sakhalinsky, 4—Tymov, 5—Smirnykhov, 6—Poronaysk, 7—Uglegorsk, 8—Makarov, 9—Tomari, 10—Dolinsk, 11—Kholmsk, 12—Aniwa, 13—Nevel'sk, 14—Korsakov. Localities: S—Snezhinka River, A—Aral'skaya River, B—Boshnyakovo, T—Tomarinka River.

Taxonomic comments

Representatives of the family Nuculanidae forming the basis of the subclass Paleotaxodonta (Newell, 1969) constitute one of most frequent groups of bivalve molluscs in the Lower Cenozoic formations of Sakhalin, Kamchatka, Japan and Pacific coast of North America (Uozumi, 1955, 1957; Krishtofovich, 1964; Gladenkov, 1970a, b, 1972; Moore, 1963). Despite one and a half century history of studies of Nuculanidae (*see* historical survey in Gladenkov, 1972), their taxonomy cannot be admitted stabilized. Some researchers tend to incorporate into this family but two or three large genera with the relevant subgenera and sections (Puri, 1969); others (Dell, 1955; Ludbrook, 1961) are treating most of the valid taxa of this generic group as individual genera.

Meanwhile Savizky (1958, 1969a, b, 1971, 1978, 1980) and Gladenkov (1971c, 1972) presented strong evidence in favor of taxonomic importance of generic (peculiarities of hinge structure and type of dentition; shape of resilifer pit and its ornamentation; presence or absence of rib-form welt on the inner side of rostrum characterising the effect of siphon tube confluence) and subgeneric (type of shell external sculpture and shape of its posterior edge) characters of Cenozoic Nuculanidae of the Far East. Among Nuculanidae, 9 genera and over 20 subgenera may be distinguished here. In this case several subgenera (*Ilpinella, Majnella, Karaginskiella*) mentioned by Gladenkov (1971c, 1972) are so far considered formally undescribed. So split a system, though looking cumbersome, permits to represent most adequately the stages of phylogenesis of Nuculanidae, and to use various sets of fossil representatives of the family when developing stratigraphical schemes for various areas of Northern Pacific and for comparison between the schemes. Numerous representatives of the family are inhabiting bathyal and abyssal sea zones, thus possessing very wide ranges (*see* Kafanov 1991). This enhanced the stratigraphical importance of Nuculanidae for wide interregional correlations. It is particularly this approach that was used by Gladenkov (1970a, b, 1971a, b, c, 1972, 1973), using *Yoldia* as an example. To a certain extent the present effort is a further development of Gladenkov's concepts as demonstrated by an example of Paleogene Nuculanidae of South Sakhalin. In a manner similar to Gladenkov (1971c), the present authors have paid attention to the presence of "parallel" subgenera with close characters in each of the studied genera (see key to the genera and subgenera). It is not improbable that this phenomenon is an illustration of the law of homologous series in variation by Vavilov (1922).

However, in his subsequent research Gladenkov (Gladenkov *et al.*, 1984) returns to Puri's concepts (1969), making in this case some curious errors. Thus, with respect to the same collection specimen (GIN no 411/3612) and in reference to the same original drawing (Gladenkov *et al.*, 1984, pl. 29, fig. 25) he describes *Portlandia sublischkei* Gladenkov "sp. nov." (1. c., p. 163) and *Yoldia sublischkei* Gladenkov "sp. nov." (1. c., p. 173), though the presented drawing of the shell should be rather referred to *Megayoldia* (*Portlandella*).

The taxonomy of Nuculanidae was chiefly developed by paleontologists. It is based on morphological characters of shell whose correlation with the structure of soft parts of molluscs is not always evident. Still, following Schileyko (1989) who paid basic attention to anatomic characters in identifying the taxonomic status of various forms, we treat Nuculanidae as composed of five or six subfamilies: Nuculaninae H. *et* A. Adams, 1858; Malletiinae H. *et* A. Adams, 1858; Neiloiellinae Schileyko, 1989; Poroledinae Scarlato *et* Starobogatov, 1979; Yoldiinae Glibert *et* Van de Poel, 1965 (the authorship of which is erroneously described by Habe (1977) to himself), and probably Adraninae Scarlato *et* Starobogatov, 1979.

In this publication, we adopt the following system of Paleogene Nuculanidae of North-Western Pacific:

Nuculaninae H. *et* A. Adams, 1858
- *Nuculana* Link, 1807
  - *Nuculana s. s.*
  - *Thestyleda* Iredale, 1929
  - *Tenuileda* Habe, 1977 (= *Tenuinucula* Habe, 1977)
  - *Crassoleda* Savizky, 1969

Jupiteria Bellardi, 1875
Jupiteria s. s.
Saccella Woodring, 1925
Epacroleda Savizky, 1969
Costanuculana Habe, 1951
Poroledinae Scarlato *et* Starobogatov, 1979
Propeleda Iredale, 1924 (=*Lamellileda* Cotton, 1930)
Yoldiinae Glibert *et* Van de Poel, 1965
Yoldia Möller, 1842
Yoldia s. s.
Cnesterium Dall, 1898
Kalayoldia Grant *et* Gale, 1931
Orthoyoldia Verrill *et* Bush, 1997
Sachalinella Savizky, 1969
Tepidoleda Iredale, 1939
Nampiella Kafanov *et* Savizky subgen. nov.
Praesachalinella Kafanov *et* Savizky subgen. nov.
Megayoldia Verrill *et* Bush, 1897
Megayoldia s. s.
Portlandella Stewart, 1930
Hataiyoldia Kamada, 1962 (=*Acilana* L. Krishtofovich, 1964)
Praeportlandia Savizky, 1969
Portlandia Mörch, 1857
Malletiinae H. *et* A. Adams, 1858
Malletia Des Moulins, 1832
Spineilo Finlay *et* Marwick 1937
Multidentata L. Krishtofovich, 1964 (=*Mennerocotenia* Kalishevich, 1973)
Neilonellinae Schileyko, 1989
Neilonella Dall, 1881
Neilonella s. s.
Borissia Slodkewitsch, 1938

The identification key and diagnoses of all listed taxa of the generic group are given below with indication (in the original writing) of some of most typical representatives from the Cenozoic of Northern Pacific for each of the taxa.

Review of Cenozoic Nuculanidae of North-Western Pacific

Key to the genera and subgenera

In the following key, proceed to the subsequent number if the character of a number is enough; if not, there is need to proceed to the number in parantheses.

1(44). Resilifer of various degree of development; ligament mostly internal.
2(43). Dentition mostly vertical.
3(18). Posterior branch of hinge commonly containing large number of teeth; resilifer pit narrow, chamfered or straight, with smooth surface—(Nuculaninae H. *et* A. Adams, 1858).
4(11). Shell elongated, inequilateral to a various degree; resilifer pit located in the plane of linkage of valves, pallial sinus acute-apexed; rib-form welt commonly present at internal side of rostrum—(*Nuculana* Link, 1807).
5(8). Shell oblong-ovate, subequilateral, with faint rostrum.
6(7). External surface of valves smooth; edge-form welt commonly present at the internal side of rostrum—*Nuculana s. s.*
7(6). External surface of valves covered by thin concentric comb-shaped widely spaced ribs, and concentric lines of growth; no rib-form welt present on internal side of rostrum—*Crassoleda* Savizky, 1969.
8(5). Shell sharply inequilateral, definitely rostrate, curved towards the lower edge.
9(10). External surface mostly smooth—*Tenuileda* Habe, 1977.
10(9). External surface with strong concentric sculpture—*Thestyleda* Iredale, 1929.
11(4). Shell oval, subequilateral; resilifer pit not located in the plane of linkage of valves; pallial sinus with wide U-shaped apex; no rib-form welt present on internal side of rostrum—(*Jupiteria* Bellardi, 1875).
12(13). External surface of valves smooth and represented only by thin concentric lines of growth traceable across the whole surface—*Jupiteria s. s.*

13(12). External surface of valves with concentric sculpture developed across the whole surface or at its separate portions.

14(15). Rib-form welt present on inner surface of rostrum—*Epacroleda* Savizky, 1969.

15(14). No rib-form welt present on inner surface of rostrum.

16(17). External sculpture with strong concentric rugae on major surface of valves—*Saccella* Woodring, 1925.

17(16). External sculpture with conspicuous circular furrow on anterior half; posterior one-third flat and smooth—*Costanuculana* Habe, 1951.

18(3). Anterior branch of hinge commonly possessing a larger number of teeth, or at least the length of anterior and posterior branches mostly equal; resilifer pit wide, triangular-oval, ornamented by concentric or radial furrows—(Yoldiinae Glibert *et* Van de Poel, 1965).

19(34). Shell lanceolate, oblong-ovate, oval or drop-shaped; no keels present on external surface; teeth fine, long, acute-apexed, densely enclosed into each other, anterior branch commonly longer than posterior one; resilifer pit tapered, obliquely arranged, mostly without radial striation—(*Yoldia* Möller, 1842).

20(21). Shell drop-shaped, its posterior edge sharply constricted—*Tepidoleda* Iredale, 1939.

21(20). Shell differently shaped.

22(23). Shell ovate, without distinct rostrum—*Orthoyoldia* Verrill *et* Bush, 1897.

23(22). Shell lanceolate or oblong-ovate, variously rostrate.

24(25). External surface mostly smooth—*Yoldia s. s.*

25(24). External surface sculptured.

26(27). External sculpture represented by oblique crests intersecting with concentric lines of outgrowth—*Cnesterium* Dall, 1898.

27(26). No oblique crest present on external surface.

28(29). External surface sculptured by fairly crude growth lines or striae observed mainly on anterior and near-top areas—*Nampiella* Kafanov *et* Savizky subgen. nov.

29(28). External surface with concentric crests developed across the whole shell or its part.

30(31). Concentric sculpture gradually fading towards edges present only in lower part of valves—*Praesachalinella* Kafanov *et* Savizky subgen. nov.

31(30). Most part of external surface covered by concentric crests.

32(33). External surface completely covered by concentric crests; posterior part of valves short—*Kalayoldia* Grant *et* Gale, 1931.

33(32). Regular concentric crests slightly not reaching the hinge margin; posterior part of valves drawn off, acute-peaked—*Sachalinella* Savizky, 1969.

34(19). Shell oblong-rectangular, often with extended posterior edge; one or several keels present on external surface; teeth relatively short; hinge branches of almost equal length or the anterior one somewhat longer; resilifer pit conspicuous, straight, often with radial striation.

35(42). One or several keels; posterior edge of valve commonly expanded; resilifer pit conspicuous, wide, sometimes with radial striation; pallial sinus deep—(*Megayoldia* Verrill *et* Bush, 1897).

36(37). Posterior edge of valve pronouncedly angular expanded—*Megayoldia s. s.*

37(36). Posterior edge of valve differently shaped.

38(39). External surface of valve smooth—*Portlandella* Stewart, 1930.

39(38). External surface of valve sculptured.

40(41). External surface with oblique crests intersecting with concentric lines of growth across most part of valve—*Praeportlandia* Savizky, 1969.

41(40). External surface at medial area bearing fine, irregular divaricate-cellular sculpture—*Hataiyoldia* Kamada, 1962.

42(35). Shell with double keels, divided by constriction; posterior portion of valve with minute constricted rostrum; resilifer pit modest-sized, with radial striation; pallial sinus shallow—(*Portlandia* Mörch, 1857).

43(2). Dentition distinctly skewed; sometimes teeth with almost lengthwise arrangement—(Poroledinae Scarlato *et* Starobogatov, 1979), *Propeleda* Iredale, 1924.

44(1). Resilifer extremely small or absent; ligament external.

45(48). Shell thin, irregular in outline; resilifer

absent—(Malletiinae H. *et* A. Adams, 1858).

46(47). Umbones faintly prosogyrate; external surface smooth or only with concentric growth lines—*Malletia* Des Moulins, 1832.

47(46). Umbones orthogyrate; external surface sculptured by thin, not completely regular, concentric ribs separated by wider interspaces—*Spineilo* (*Multidentata*) L. Krishtofovich, 1964.

48(45). Shell moderately thick, veneroid in shape; resilifer faint or missing—(Neilonellinae Schileyko, 1989).

49(50). External sculpture formed only by concentric growth lines inconspicuous or vanishing on posterior area—*Neilonella* Dall, 1881.

50(49). External sculpture in the form of wide, low, often twisting concentric ribs located either across the whole surface of valves except posterior area or only at near-umbo triangle—*Borissia* Slodkewitsch, 1938.

Family Nuculanidae H. *et* A. Adams, 1858
Subfamily Nuculaninae H. *et* A, Adams, 1858

Genus *Nuculana* Link, 1807

Type species: *Arca rostrata* Bruguière, 1789 (=*Mya pernula* Möller, 1779 [OD] ; Recent, North Atlantic.

Diagnosis: Shell minute, oblong, sharply inequilateral, limited by smooth curve from below and sharply rounded from the front. Posterior tip long, tapered into rostrum, and truncated. Teeth numerous, chevron-shaped, interrupted under umbo by oblique irregular-triangular pit for internal ligament. Resilifer pit located in plane of valve linkage. Posterior branch of hinge bearing twice as much teeth as anterior branch. No lunule present, escutcheon long, clearly delimited. External surface smooth or of concentric sculpture, faint or sharp, evenly distributed across the whole external surface of valve or only on its separate areas. Umbones commonly minute, arranged in anterior portion of shell. Keel extending between umbones and base of posterior edge. Muscle scars minute, faintly impressed. Pallial sinus distinct, narrow and relatively deep. Rib-form welt commonly present on internal surface of rostrum.

Subgeneric composition: *Nuculana s. s.*, *Tenuileda* Habe, 1977; *Thestyleda* Iredale, 1929; *Crassoleda* Savizky, 1929.

Subgenus *Nuculana* Link, 1807

Miocene through Recent; circumboreal and Arctic.

Some representatives:

Nuculana (*N.*) *pernula* (Möller, 1779)—Pliocene Fernando Formation of California; living in North Pacific and Arctic Oceans;

Leda sadoensis Yokoyama, 1926—Pliocene Sawane Formation of Niigata Prefecture, and Wakimoto Formation of Akita Prefecture, Honshu; Miocene Arakawa Formation of Tochigi Prefecture, Honshu;

Nuculana (*Nuculana*) *majamraphensis* var. *tumiensis* Lautenschlager *in* L. Krishtofovich, 1964—Miocene Tumsk and Daekhuriin suites of North Sakhalin.

Subgenus *Thestyleda* Iredale, 1929

Type species: *Leda ramsayi* Smith, 1885 [OD] ; Recent, New South Wales, Australia.

Diagnosis: Shell rostrate with strong concentric sculpture curving at rostral sinus. Posterior truncate, often with a keel at inflection of concentric ribs. Resilifer comparatively large.

In the opinion of E. V. Coan (pers. comm.), the characters that have been used to separate *Nuculana* s. s. from *Thestyleda*—length and degree of truncation of rostrum—do not "work" well, and he synonymizes these two taxa. We believe that *Thestyleda* is also distinguished from *Nuculana s. s.* by more conspicuous resilifer, and character of sculpture more resembling that in *Nuculana* (*Crassoleda*), and admit a possibility of retaining *Thestyleda* in the subgeneric rank.

Neogene through Recent in North Pacific; Recent in South Pacific.

Some representatives:

Leda hamata Carpenter, 1846—Pliocene Niguel Formation, Pliocene and Pleistocene Fernando and San Pedro Formations of California;

Nuculana yokoyamai Kuroda, 1936—Pliocene of

Honshu, Japan: Hamada Formation of Aomori Prefecture, Nishiyama Formation of Niigata Prefecture; Omma Formation of Ishikawa Prefecture.

There are also known some so far undescribed species from Cenozoic formations of Sakhalin.

Subgenus *Tenuileda* Habe, 1977

Type species: *Nuculana conceptionis ikebei* Suzuki *et* Kanehara, 1936 [OD] ; Pliocene Hasumi Formation of Chiba Prefecture, Honshu.

Establishing a new genus *Tenuileda*, Habe (1977, p, 21, 22) designates its type species and presents diagnosis in Japanese. However, in captions to the drawings on page 22, the type species is given as "*Tenuinucula ikebei* (Suzuki *et* Kanehara)". Therefore the name *Tenuinucula* is invalid, and refers to *Tenuileda*. Besides, the issue of relationship between *Tenuileda* Habe, 1977 and *Thestyleda* Iredale, 1929 requires special consideration.

Diagnosis: Shell sharply inequilateral, with posterior part oblong and somewhat curved upward. Posterior end of valve sharpened. Prominently outlined keel stretching between minute sharpened umbo and posterior end of valve. Resilifer pit vague, but anterior and posterior branches of hinge evidently cut beneath umbo; the anterior branch 1.5-2 times shorter than the posterior one. External surface of valve smooth.

Neogene through Recent in Japan.

So far registered in the composition of the subgenus is the type species reported from Pliocene Hasumi and Iioka Formations of Chiba Prefecture, Honshu, and presently inhabiting near the South-Western Honshu at depths between 700 to 1030 m.

Subgenus *Crassoleda* Savizky, 1969

Nuculana (*Crassoleda*) Savizky, 1969a, 27.

Crassoleda Savizky, "gen. nov."; Zhidkova *et al.*, 1972, 93.

Type species: *Nuculana* (*Sacella*) *crassotelloides* Lautenschlager *in* L. Krishtofovich, 1964 [OD] ; Miocene Pilsk suite of the Schmidt Peninsula, Northern Sakhalin.

Diagnosis: Shell moderate-sized, thin, oblong, sharply inequilateral, moderately convex. Umbones wide, opisthogyrate. Anterior portion of valve short, dilated; posterior portion elongate, tapered, drawn off into oblique-truncated rostrum. External sculpture carries thin crest-shaped widely spaced concentric ribs and growth lines, possibly smoothed to various degree. Thin sharp keel stretching between umbo and base of posterior edge of valve. Hinge carries short anterior and long posterior branches of teeth separated beneath umbo by narrow deep resilifer strongly truncated backward. No rib-form welt present on inner surface of rostrum.

Neogene of Northwest Pacific.

Some representatives:

Nuculana (*Saccella*) *crassotelloides* Lautenschlager *in* L. Krishtolovich, 1964—Oligocene and Miocene Kholmsk, Pilsk, Kaskad, Kurasi and Dagi (upper part) suites of Sakhalin; Kuybyshev suite of Iturup Island, Kurile Islands; Miocene Shumnov (lower part) and Okruglov suites of Paramushir Island, Kurile Islands;

Leda pennula Yokoyama, 1925—Miocene of Honshu, Japan: Yamanouchi and Maki Formations of Gifu Prefecture, Kamenoo Formation of Fukushima Prefecture, Fuyube Formation of Aomori Prefecture, Ohno Formation of Aichi Prefecture; Miocene Taiki Formation of Hokkaido; Miocene Pilsk and Oligocene Kholmsk suites of Sakhalin (?).

Genus *Jupiteria* Bellardi, 1875

Type species: *Nuculana concava* Bronn, 1831 [SD] Dall, 1893; Pliocene of Italy.

Diagnosis: Shell elongate to ovate, subequilateral, inflated. Anterior and posterior hinge branches carry almost equal number of teeth, and are separated by triangular resilifer pit, the latter outside the plane of valve linkage. Posterior tip of valve either pointed or truncated, or rounded, no rib-form welt commonly present on its inner side. Pallial sinus with wide U-shaped apex.

Paleocene through Recent; cosmopolitan but mostly in warm shallow waters.

Subgeneric composition: *Jupiteria s. s.*, *Saccella*

Woodring, 1925; *Epacroleda* Savizky, 1969; *Costanuculana* Habe, 1951.

Subgenus *Jupiteria* Bellardi, 1875

Paleocene though Recent; cosmopolitan.

Some representatives:

Jupiteria (*Ledina*) *duttonae* Vokes, 1939—Paleocene and Eocene Cerros shale Member of the Lodo Formation of California;

Nuculana (*Saccella*) *pilvoenica* Lautenschlager *in* L. Krishtofovich, 1964—Miocene and Oligocene Kaskad and Kholmsk suites of Sakhalin.

Subgenus *Saccella* Woodring, 1925

(nom. nov. pro *Ledina* Sacco, 1898 Dec. *non* Dall, 1898 Apr.)

Type species: *Arca fragilis* Deshayes, 1858 (=*Leda commutata* Philippi, 1844;=*Nucula deltoidea* Lamarck, 1805) [OD] ; Recent, Mediterranean.

Diagnosis: Shell rostrate. Rostrum pointed. External sculpture with strong concentric rugae. Posterior and anterior branches of teeth mostly equal. Resilifer triangular and symmetrical. Shallow groove extending from umbo to ventral margin at both ends of valves.

Paleocene through Recent; cosmopolitan in warm waters.

Some representatives:

Leda gabbii "Conrad" Gabb, 1859—Paleocene of California; Las Virgenes Sandstone. Martinez and Meganos Formations; Eocene of California: Avenal and Matilija Sandstones, Domengine, Llajas and Tejon Formations; Eocene Napan suite of Western Kamchatka; Eocene Lower-Krasnopolyev sub-suite of Sakhalin;

Leda taphria Dall, 1896—Oligocene through Recent in California (*see* Moore, 1983);

Leda gordonis Yokoyama, 1920—Pliocene Omma Formation of Ishikawa Prefecture, Honshu; living off Southwestern Honshu.

Subgenus *Epacroleda* Savizky, 1969

Epacropleda Savizky, 1969a, 29.

Type species: *"Nuculana" epacris* Moore, 1963 [OD]; Miocene Astoria Formation of Oregon.

Diagnosis: Shell mostly equilateral. Posterior end pointed; rib-form welt commonly present on its inner surface. External sculpture concentric in the umbo part of valve.

Oligocene and Miocene of Northern Pacific.

Some representatives:

"Nuculana" epacris Moore, 1963—Miocene Astoria Formation of Oregon;

Nuculana (*Nuculana*) *slodkewitschi* Kogan *in* Slodkewitsch, 1938—Oligocene Viventek suite of Western Kamchatka; Miocene Sertunay, Aleksandrov, Vengeri and Mayamraf suites of Sakhalin.

Subgenus *Costanuculana* Habe, 1951

Type species: *Nuculana husamaru* Nomura, 1940 [OD] ; Recent off Pacific side of Honshu, Japan.

Diagnosis: Shell medium-sized, moderately thick. External surface with conspicuous circular furrow on anterior half; posterior one-third flat and smooth. Hinge teeth large, few.

Neogene through Recent; Japan.

Within the subgenus only the type species is known: *Nuculana husamaru* Nomura, 1940—Pliocene Iioka Formation of Chiba Prefecture, Honshu; living off Pacific side of North Honshu.

Recognizing the need of retaining in Nuculaninae an independent genus *Lembulus* Leach *in* Risso, 1826, Savizky (1969a, p. 301) proposes the establishment of new subgenus *Lembulina* with the type species *Arca rostrata* Montagu, 1803 *non* Bruguiere, 1789 (Savizky, 1969a, text-fig. on p. 28); however, since no diagnosis is given, the name *Lembulina* should be considered invalid.

Subfamily Poroledinae Scarlato *et* Starobogatov, 1979

Genus *Propeleda* Iredale, 1924
(*syn. Lamellileda* Cotton, 1930)

Type species: *Leda ensicula* Angas, 1877 [OD]; Recent; Australia.

Diagnosis: Shell sickle-shaped. Resilifer backwardly sloping. Hinge thin. Pallial sinus deep.

Some representatives:

Nuculana (*Nuculana*) *schmidti* L. Krishtofovich, 1964—Miocene Pilsk and Dagi suites of North Sakhalin; Tyushev suite of Eastern Kamchatka (?);

Poroleda sp. Shibata *in* Itoigawa *et al.* 1974—Miocene Oidawara Formation of Gifu Prefecture, Honshu.

The present-day fauna knows *Nuculana soyomaruae* Okutani, 1962; South China Sea to Kyushu, Japan, at depth 730-760 m.

Subfamily Yoldiinae Glibert *et* Van de Poel, 1965

Genus *Yoldia* Möller, 1842

Type species: *Yoldia hyperborea* Torell, 1859 (= *Yoldia arctica* Möller, 1842 *non Nucula arctica* Gray, 1824) [SD ICZN, 1966, Opinion 769] ; Recent, North Atlantic and Arctic.

Diagnosis: Shell elongate-oval, devoid of keels at posterior area of valve. Teeth thin, relatively elongate, pointed, tightly enclosed into each other; anterior branch of hinge margin commonly longer than posterior one. Resilifer pit large-sized, tapered, obliquely arranged, without radial striation. Umbo minute, opisthogyrate, central or somewhat shifted backward. External surface of valve smooth or sculptured by concentric ribs or oblique crests, cutting the concentric growth lines.

Cretaceous through Recent; cosmopolitan, mostly in frigid and cold-temperate waters.

Subgeneric composition: *Yoldia s. s.*; *Cnesterium* Dall, 1898; *Kalayoldia* Grant *et* Gale, 1931; *Orthoyoldia* Verrill *et* Bush, 1897; *Sachalinella* Savizky, 1969; *Tepidoleda* Iredale, 1939; *Nampiella* subgen. nov., *Praesachalinella* subgen. nov.

Subgenus *Yoldia* Möller, 1842

Cretaceeus through Recent; cosmopolitan.

Some representatives:

Yoldia longissima Slodkewitsch, 1936—Paleogene of North Western Pacific: Amanin and Gakkhin suites of Western Kamchatka; Tyushev suite of Eastern Kamchatka; Alugin and Nallen suites of Koryak Upland; Poronai Formation of Hokkaido;

Yoldia (*Yoldia*) *epilongissima* Gladenkov, 1972—Neogene of Kamchatka (Mysa Ploskogo, Yunyunvayam, Ilyushin and Kakert suites) and Sakhalin (? Okobykay suite);

Yoldia hyperborea Torell, 1859—Pliocene of Eastern Kamchatka: Llmimtevayam and Ust-limimtevayam suites; living in North Atlantic, Arctic and Northern Pacific;

Yoldia kovatschensis Slodkewitsch, 1938 (described as *Yoldia cooveri* var.)—Paleogene of Sakhalin: Takaraday (upper part) and Gastello suites;

Yoldia (*Yoldia*) *gretschishkini* L. Krishtofovich, 1964—Paleogene of Sakhalin: Gennoyshi and Takaraday (upper part) suites;

Yoldia caudata Khomenko, 1937—Paleogene of Sakhalin (Machigar, Gastello, Mutnov and Tumsk suites) and Hokkaido (Poronai Formation);

Yoldia (*Yoldia*) *tschekhoyi* L. Krishtofovich, 1964 (described as *Y.* (*Y.*) *caudata* var.)—Oligocene Kholmsk suite of Sakhalin;

Yoldia (*Yoldia*) *akanensis* Uozumi, 1957—Oligocene Onbetsu Formation of Hokkaido;

Yoldia (*Yoldia*) *saitoi* Uozumi, 1957—Paleogene Poronai Formation of Hokkaido.

Subgenus *Cnesterium* Dall, 1898

Type species: *Yoldia scissurata* Dall, 1897 (=*Nucula arctica* Broderip *et* Sowerby, 1829 *non* Gray, 1824) [OD] ; Recent, Pacific coast of North America.

Diagnosis: Shell elongate to ovate, faintly convex, with posterior part somewhat tapered, Umbo small-sized. External sculpture carrying oblique crests, cutting concentric growth lines. Crest slopes directed to umbo are steeper than the opposite ones.

Neogene through Recent; North Pacific and North Atlantic.

Some representatives:

Yoldia kuluntunensis Slodkewitsch, 1936—Miocene of Western Kamchatka: Kakert, Etolon and Ermanov suites; Pliocene Nutov and Maruyama (upper part) suites of Sakhalin;

Yoldia (*Cnesterium*) *nabiliana* Simonova *in* L. Krishtofovich, 1964—Miocene Dagi (upper part) and Okobykay suites of Sakhalin.

Subgenus *Kalayoldia* Grant *et* Gale, 1931

Type species: *Yoldia cooperi* Gabb, 1865 [OD] ; Recent, Pacific coast of North America.

Diagnosis: Posterior part of valves short, narrowed, recurved. The whole external surface of valve carries concentric crests.

Gladenkov (1972, p, 198) synonymizes *Kalayoldia* and *Sachalinella*; in our opinion, this synonymy is incorrect.

Some representatives:

Yoldia (*Kalayoldia*) *macroschema* Uozumi, 1957—Pliocene Honbetsu Formation of Hokkaido.

Subgenus *Orthoyoldia* Verrill *et* Bush, 1897

Type species: *Yoldia scapania* Dall, 1889 [OD] ; Recent, Brazil.

Diagnosis: Shell oblong, blunt or rounded at both ends, without distinct rostrum, no carina. Teeth numerous in both hinge branches. Pallial sinus broad.

Eocene through Recent; North Pacific and Caribbean.

Some representatives:

Yoldia iwatensis Hatai, 1940—Miocene Kadonosawa Formation of Iwate Prefecture and Kaisekizan Formation of Mie Prefecture, Honshu;

Yoldia (*Orthoyoldia*) *haboroensis* Uozumi, 1957—Miocene Chikubetsu Formation of Hokkaido.

Subgenus *Sachalinella* Savizky, 1969

Sachalinella Savizky, 1969a, 31.

Type species: *Yoldia vasiljevskii* Slodkewitsch, 1938 [OD] ; Eocene Amanin suite of Western Kamchatka.

Diagnosis: Shell medium-sized, elongate-ovate. Anterior tip of valve rounded, posterior one drawn off, pointed. External sculpture represented by regular concentric crests, almost reaching the hinge margin.

Some representatives:

Yoldia (*Cnesterium*) *nairoensis* Evseev *in* L. Krishtofovich, 1964—Paleogene of Sakhalin: Arakay and Gastello suites;

Yoldia (*Kalayoldia*) *matschigarica* L. Krishtofovich, 1964—Paleogene Machigar suite of the Schmidt Peninsula, Northern Sakhalin.

Subgenus *Tepidoleda* Iredale, 1939

Type species: *Tepidoleda lata orion* Iredale, 1939 [OD] ; Recent, Australia.

The question of Independence of this taxon and its volume remains open (*see* Gladenkov, 1972). This subgenus incorporates species with peculiar drop-like shape of shell, and sharply tapered posterior edge of valve. According to Gladenkov (1972, Table 26), in the north of the Pacific region—it is distributed in deposits of the Machigarian and Sakhalin provincial horizons.

Some representatives:

Yoldia (*Tepidoleda*) *sobrina* Takeda, 1953—Paleogene Poronai, Pepeshiru and Momijiyama Formations of Hokkaido.

Yoldia kawadai Hirayama, 1954—Miocene Kobana Formation of Tochigi Prefecture, Honshu.

Subgenus *Nampiella* Kafanov *et* Savizky, subgen. nov.

Type species: *Yoldia takaradaensis* L. Krishtofovich, 1957; Oligocene Takaraday suite of Sakhalin.

Diagnosis: Shell small-sized, thin-walled, faintly convex, subequilateral. Posterior edge of valve somewhat narrowed, blunt or pointed, Umbones minute, almost non-projecting, located in the middle or past-middle of hinge margin. Lunule commonly lanceolate, explanate, almost vertical, relatively short and straight, delimited by sharp keel. Over 30 teeth, their

number on anterior branch somewhat exceeding that on the posterior branch. External surface smooth, sculptured by fairly crude growth lines or striae, best visible on anterior and umbonal areas of valve.

This subgenus was established by Savizky, and is sometimes cited in biostratigraphic and malacological literature (Gladenkov, 1971c, 1972). No formal description of this subgenus and designation of the type species is available, though Gladenkov (1972, p. 199, Table 25) mentions the presence of jet sculpture on portion of valve external surface as a diagnostic character. *Nampiella* here is formally described as new taxon.

Paleogene of Northwestern Pacific.

Composition:

Yoldia asagaiensis Makiyama, 1934—Paleogene Asagai Formation of Fukushima Prefecture, Honshu;

Yoldia laudabilis Yokoyama, 1924—Paleogene Poronai, Naibuchi, Charo, Shitakara, Onbetsu, Ushikubitoge and Momijiyama Formations of Hokkaido; Asagai Formation of Fukushima Prefecture, Honshu, and Taishu Formation of Nagasaki Prefecture, Kyushu;

Yoldia takaradaensis L. Krishtofovich, 1957—Oligocene Takaraday suite of Sakhalin.

Subgenus *Praesachalinella* Kafanov *et* Savizky subgen. nov.

Type species: *Yoldia* (*Yoldia*) *biremis* Uozumi, 1957; Miocene Chikubetsu Formation of Hokkaido.

Diagnosis: Shell medium-sized, oblong-ovate, with drawn off posterior edge. Regular concentric crests developed only on lower surface of valve, gradually smoothing towards its edges.

This taxon is mentioned by Gladenkov (1971c, 1972) without description. In discussion of taxonomic status of *Sachalinella*, Savizky (1969a, p. 31) writes: "there also are transitional forms between *Yoldia s. s.* and *Sachalinella* subgen. nov., like *Yoldia biremis* Uozumi characterized by the presence of concentric sculpture only in the lower part of valve, gradually fading out towards edges, and which may also be separated into independent subgenus" (no name of the subgenus given). The formal description of the subgenus is presented here.

Paleogene through Miocene; Northern West Pacific.

Composition:

Yoldia (*Yoldia*) *biremis* Uozumi, 1957—Miocene Takinoue, Chikubetsu, Sankebetsu, Asahi and Horomui Formations of Hokkaido; Miocene Okazaki Formation of Aichi Prefecture, Honshu.

Besides the type species, several other undescribed species are known from Miocene and Upper Oligocene Formations of Sakhalin and Kamchatka.

Genus *Megayoldia* Verrill *et* Bush, 1897

Type species: *Nucula thraciaeformis* Storer, 1838 [OD] ; Recent, Northern Atlantic.

Diagnosis: Shell oblong-trapezoidal with angular-expanded posterior edge. Posterior area of valve commonly delimiting one distinct keel, another keel passing in the middle of posterior area. Teeth relatively short, prominent. Hinge branches of equal length, or anterior branch somewhat longer. Resilifer pit large-sized, wide, straight, covered by radial striation. Umbo wide, opisthogyrate, shifted toward anterior edge of valves. External surface smooth or sculptured by concentric crests, or with divaricate sculpture.

Cretaceous through Recent; circumboreal.

Subgeneric composition: *Megayoldia s. s.*, *Portlandella* Stewart, 1930; *Hataiyoldia* Kamada, 1962; *Praeportlandia* Savizky, 1969.

Subgenus *Megayoldia* Verrill *et* Bush, 1897

Paleogene through Recent; circumboreal.

Some representatives:

Nucula thraciaeformis Storer, 1838—Neogene of Kamchatka: Ilyin, Kakert, Etolon, Mysa Ploskogo, Yunyunvayam and Llmimtevayam suites; Neogene of Sakhalin: Aleksandrov, Okobykay, Kurasi, Maruyama (lower part), Mayamraf and Nutov suites Miocene Chikubetsu Formation of Hokkaido; Miocene Hazama Formation of Gifu Prefecture and Miocene Tottori Group of Tottori Prefecture and Oligocene-Miocene Akahira Formation of Saitama

Prefecture, Honshu; Recent, circumboreal;

Portlandia (*Megayoldia*) *yotsukurensis* Uozumi, 1957—Paleogene Asagai Formation of Fukushima Prefecture and Oligocene or Miocene Oga Formation of Shizuoka Prefecture, Honshu;

Portlandia (*Portlandella*) *ovata* Takeda *in* Hayasaka *et* Uozumi, 1954—Paleogene Momijiyama and Onbetsu Formations of Hokkaido.

Subgenus *Portlandella* Stewart, 1930

Type species: *Leda rosa* Hanna, 1927 [OD] ; Eocene Ardath shale of California.

Diagnosis: Shell relatively faintly oblong, of somewhat rectangular outlines. Posterior area of valve wide, with concave surface, anterior area shorter, faintly convex. Lower edge arch-shaped. Teeth relatively short, massive. Hinge branches of approximately equal length, or anterior branch somewhat longer than posterior. Resilifer pit large-sized, straight. Umbones convex, almost central or shifted forward, orthogyrate. Lunule long, narrow. Escutcheon lanceolate, delimited by distinct keel. External surface smooth or sculptured only by thin concentric growth lines.

Cretaceous through Recent; Northern Pacific.

Some representatives:

Yoldia (*Yoldia*) *watasei* Kanehara, 1937—Paleogene Poronai Formation of Hokkaido; Oligocene-Miocene Akahira Formation of Saitama Prefecture, Honshu; Paleogene of Sakhalin: Khandasin, Arakay and Kholmsk (lower part) suites; Oligocene of Western Kamchatka: Amanin and Gakkhin suites; Paleogene of Koryak Upland: Kovachin, Alugin (lower part) and Ionay suites;

Yoldia nitida Slodkewitsch, 1936—Oligocene Gakkhin suite of Western Kamchatka; Oligocene Takaraday (upper part) and Arakay uppermost parts suites of Sakhalin;

Yoldia (*Portlandella*) *karaginskiensis* Gladenkov, 1972—Neogene of Eastern Kamchatka: Mysa Ploskogo, Limimtevayam (lower part); Pakhachi and Ilyin suites;

Portlandia sublischkei Gladenkov *in* Gladenkov *et al.*; 1984, p. 173, p. 129, fig. 25) (= *Yoldia sublischkei* Gladenkov *in* Gladenkov *et al.*, 1984, p. 173, pl. 29, fig. 25)—Miocene Kakert suite of Western Kamchatka; Miocene Mysa Ploskogo (?) and Mayamraf (?) suites of Karaginsky Island, Eastern Kamchatka, and Sakhalin.

Subgenus *Hataiyoldia* Kamada, 1962
(*syn. Acilana* L. Krishtofovich, 1964)

Type species: *Yoldia tokunagai* Yokoyama, 1925 [OD] ; Miocene Kamenoo Formation of Iwaki Prefecture, Honshu.

Diagnosis: Shell of medium size or sufficiently large, oblong-trapezoidal, swollen. Umbo wide, somewhat shifted anteriorly. External surface of valve on its medial area carries a thin, irregular divaricate-cellular sculpture, close to that in *Acila*. Fine striation, perpendicular to posterior edge of valve, present on posterior area. Lunule and escutcheon narrow lanceolate, sharply demarkated.

The group *Acilana* has been established as section of the genus *Yoldia* by Khomenko (1937), and is well characterized morphologically. On page 7, Khomenko [l.c.] enumerates four sections of the genus (*Yoldia s. s.*, *Cnesterium*, *Portlandia* and *Acilana*) and accompanies a short diagnosis of each section by making reference to their typical representatives (respectively *Y. caudata* Khom., *Y. scissurata* Dall, *Y. thraciaeformis* Stor. and *Y. tokunagai* Yok.), and on page 22 in the section *Acilana* he describes *Yoldia subtokunagai* "sp. n.". Therefore in a strict sense (ICZN, Article 67(b)), the type species of *Acilana* has not been originally registered, and the name proposed by Khomenko should be considered invalid (*see* also: Vokes, 1980, p. 221).

The type species of the section—*Yoldia tokunagai* Yokoyama, 1925—was formally designated by Krishtofovich (1964, p. 112); simultaneously she also presented a widened diagnosis of the section. Therefore the authorship of *Acilana* should be given to L. Krishtofovich (1964).

However, two years before Kamada (1962, p. 55) established new subgenus *Hataiyoldia* with the same type species, therefore *Acilana* L. Krishtofovich, 1964 should be considered a synonym of *Hataiyoldia*

Kamada, 1962.

Oligocene through Miocene; Northern West Pacific.

Some representatives:

Yoldia tokunagai Yokoyama, 1925—Miocene and Oligocene Pilsk, Kaskad, Vengeri, Nevelsk, Dagi, Okobykay and Kholmsk suites of Sakhalin; Miocene Ainaigawa Formation of Aomori Prefecture and Miocene Kamenoo Formation of Iwaki Prefecture, Honshu;

Acilana paramushiraensis Savizky *in* Zhidkova *et al.*, 1972—Miocene Shumnov (lower part) suite of Paramushir Island, Northern Kurile Islands.

Subgenus *Praeportlandia* Savizky, 1969

Praeportlandia Savizky, 1969a, 32.

Type species: *Portlandia* (subgen. nov. indet.) *furcata* Ichikawa *et* Maeda, 1958 [OD]; Upper Cretaceous (Cenomanian) Izumi Group of Japan.

Diagnosis: Shell small-sized, trapezoidal, convex. Anterodorsal margin inclined; posterior margin more lengthy, horizontal. Umbones convex, shifted towards anterior tip of shell. Keel-shaped constriction extending between umbones and base of posterior margin; this constriction separating posterior explanate section of valve from moderately convex medial area covered by thin oblique crests. Hinge plate bow-shaped. Numerous teeth, their number approximately equal at anterior and posterior branches. Lunule very narrow, escutcheon long, lanceolate.

Ichikawa *et* Maeda (1958) indicated the presence in the Japanese Upper Cretaceous of the representatives of *Portlandia* with the external surface covered by oblique crests, like *Yoldia* (*Cnesterium*). In their opinion, new subgeneric name should be assigned to these species.

Late Cretaceous through Paleogene in Sakhalin and Japan.

Composition: Besides the type species, several so far undescribed species are known from Paleogene formations of Sakhalin.

Genus *Portlandia* Mörch, 1857

Type species: *Nucula arctica* Gray, 1824 [SD], ICZN, 1966, Opinion 769, name n. 1705; Recent, Arctic seas.

Diagnosis: Shell oblong-rectangular, with small constricted rostrum in posterior areas. Two keels separated by constriction present on posterior surface. Umbo convex. Teeth relatively short, hinge branches of almost equal length. Resilifer pit minute, straight, with radial striation. Pallial sinus faintly developed.

In the understanding of taxonomy of this genus, we follow Schileyko (1985) who, using a set of conchological and anatomic characters, identified *Yoldiella* Verrill *et* Bush, 1897 to belong to the family Ledellidae Allen *et* Sanders, 1982 and established the actual status of a set of contemporary forms conventionally attributed to "*Portlandia*" or "*Yoldiella*".

? Upper Pliocene-Pleistocene through Recent; Arctic and circumboreal.

Some representatives:

Nucula arctica Gray, 1824 and *Yoldia intermedia* M. Sars, 1865—Pleistocene of Kamchatka, Chukotka, Iceland, England, the Netherlands, Norway, Alaska, Arctic coast of Russia and Canada; Recent in Arctic seas and northern parts of Atlantic and Pacific (*see* Petrov, 1982).

Subfamily Malletiinae H. *et* A. Adams, 1858

Genus *Malletia* Des Moulins, 1832

Type species: *Malletia chilensis* Des Moulins, 1832 (Monotypy), Chile, Recent.

Diagnosis: Shell commonly moderate-sized, oblong-ovate, with expanded gaping posterior end. Umbones devoid of projection, almost. Centrals orthogyrate. Dental margin possessing two branches of minute teeth, converging beyond umbo. Only external ligament, disposed behind umbones, present. Resilifer minute or missing. External surface smooth, with concentric lines and rugae of growth. Pallial line with deep sinus.

Mesozoic through Recent, cosmopolitan.

Some representatives:

Leda inermis Yokoyama, 1925—Miocene Takinoue, Atsunai and Hikatagawa Formations of Hokkaido; Miocene of Honshu: Itsukaichi Formation of Tokyo, Oi Formation of Mie Prefecture, Okazaki and Ohno

Formations of Aichi Prefecture; Oligocene and Miocene Kholmsk, Pilsk and Nevelsk suites of Sakhalin;

Malletia longa L. Krishtofovich, 1954 [1957]— Oligocene and Miocene Kholmsk, Pilsk and Nevelsk suites of Sakhalin; Miocene lower part of Shumnov suite of Paramushir Island, northern Kurile islands;

Malletia wajampolkensis L. Krishtofovich, 1972— Miocene Kuluven suite of Western Kamchatka; Miocene Kuybyshev and Rybakov suites of Iturup Island, Kurile Islands.

Genus *Spineilo* Finlay *et* Marwick, 1937

Type species: *Malletia elongata* Marshall, 1917 [OD]; Danian Stage of New Zealand.

Puri (1969) placed this genus in synonymy to *Nuculana* Link, 1807. Savizky (1980) presented strong evidence against this through detailed study of the taxonomic status of *Spineilo* (*Multidentata*). Considerable geographic separation between the ranges of *Spineilo s. s.* and *Spineilo* (*Multidentata*) should not be embarrassing since the representatives of both these taxa, like most Malletiinae, belong to components of relatively deep water fauna characterized by wide inhabitance ranges.

Subgenus *Multidentata* L. Krishtofovich, 1964
(*syn. Menneroctenia* Kalishevich, 1973)

Type species: *Yoldia multidentata* Khomenko, 1937 [OD] ; Miocene Kaskad suite of the Schmidt Peninsula, Northern Sakhalin.

Diagnosis: Shell small-sized, convex, inequilateral, of peculiarly irregular trapezoidal outline. Anterior tip short, narrowly rounded, drawn off upward; posterior tip blunted, with somewhat tapered bluntly pointed upper angle. Umbones straight, low but swollen, located in anterior one-third of almost straight dental margin. Sculpture of external surface carrying thin, not completely regular concentric ribs, vertical crests separated by wider flat interspaces.

From the same type species, Kalishevich (1973, p. 22) established the new genus *Menneroctenia* within the family Ctenodontidae Wohrmann, 1893. Savizky (1980) demonstrated the inaccuracy of such taxonomic decision, and reduced *Menneroctenia* into synonymy of *Multidentata*. Later Kalishevich (Kalishevich *et al.*, 1981) approved this interpretation. Simultaneously she presented a sufficiently complete list of species of *Multidentata* and described a number of new species from Cretaceous-Paleogene formations of Sakhalin.

Upper Cretaceous through Neogene; Northwest Pacific and, possibly Northeast Pacific-*Spineilo* (*Multidentata*) *evansi* (Meek *et* Hayden, 1876).

Some representatives:

Yoldia multidentata Khomenko, 1937—Oligocene and Miocene Khoimsk, Pilsk, Kaskad, Engizpal (lower part) and Tum suites of Sakhalin; Ilpin (upper part) suite of Eastern Kamchatka;

Yoldia (*Multidentata*) *epimultidentata* Gladenkov, 1972—Miocene Mysa Ploskogo suite of Karaginzky Island, Eastern Kamchatka;

Portlandia (*Portlandella*) *kakimii* Uozumi, 1957— Miocene Morai, Tokomuro and Nupinaigawa Formations of Hokkaido.

Subfamily Neilonellinae Schileyko, 1989

Genus *Neilonella* Dall, 1881

Type species: *Leda* (*Neilonella*) *corpulenta* Dall, 1881 [Monotypy] ; Recent, Cuba.

Diagnosis: Shell minute or medium-sized, egg-form. Umbo disposed in anterior part of shell. The external valve surface carries sharp growth lines, on posterior area; they become indeterminate or completely vanish. Numerous teeth; anterior and posterior branches of hinge joining beyond umbo, though in some cases faint resilifer pit is present between them. Pallial line with small sinus.

Cenozoic through Recent in warm and warm-temperate waters of North Pacific, Indo-West Pacific.

Subgeneric composition: *Neilonella s. s.*, *Borissia* Slodkewitsch, 1938.

Subgenus *Neilonella* Dall, 1881

Cenozoic through Recent in North Pacific and Indo-

West Pacific.

Some representatives:

Neilonella coix Habe, 1951—Pliocene Nakazato Formation of Kanagawa Prefecture and Pliocene Hijikata and Tamari Formations of Shizuoka Prefecture, Honshu; living off Japan;

Nucula poronaica Yokoyama, 1890—Paleogene Poronai Formation of Hokkaido; Muro Formation of Wakayama Prefecture, Honshu;

Neilonella soyoae Habe, 1958—Miocene Oidawara Formation of Gifu Prefecture, Honshu; living off Japan.

Subgenus *Borissia* Slodkewitsch, 1938

Type species: *Nuculana* (*Borissia*) *alferovi* Slodkewitsch, 1938 [OD]; Miocene Tyushev suite of Eastern Kamchatka.

The taxonomic position is comprehensively described by Savizky (1978).

Diagnosis: Shell oblong-ovate, markedly convex; almost subequilateral. Posterior margin of valve wider than anterior one. Umbones protruding. External sculpture in the form of wide, low, often twisting ribs. Ribs either disposed across the whole surface except posterior area or limited by umbonal triangle. At separated areas of valve, ribs transverse lines of growth.

Cenozoic of Northern West Pacific.

Some representatives:

Nuculana (*Borissia*) *alferovi* Slodkewitsch, 1938—Miocene Tyushev suite of Eastern Kamchatka;

Nuculana (*Borissia*) *sakhalinensis* L. Krishtofovich, 1964 (described as subspecies of *N.* (*B.*) *alferovi*)—Oligocene Kholmsk and Nevelsk (lower part) suites of Sakhalin;

Nuculana (*Borissia*) *vengeriensis* Kogan *in* L. Krishtofovich, 1964 (described as subspecies of *N.* (*B.*) *alferovi*)—Miocene Vengeri, Pagi, Okobykay (lower part) and Pileng suites of Sakhalin.

Distribution of Nuculanidae in Paleogene section of South Sakhalin

Until recently the subject of stratigraphy of Paleogene of Southern Sakhalin hardly seemed to be a debated topic and it did not attract much attention of researchers. It was assumed obvious that Paleogene strata of the Zapadnokamyshev Series developed only at the West Coast of the island, were characterized by consistency of facial composition, thickness and age across the whole area of distribution. Basic motions of earth crust in Cenozoic appeared on the territory of Sakhalin almost simultaneously and uniformly (Ratnovsky, 1961, 1969). These prerequisites were basically responsible for identification in Paleogene section of the Konglomerat, Nizhneduy, Krasnopolyev and Takaraday suites (Kozyrev *et al.*, 1960; Zhidkova, 1961; Decisions... 1961). It is only in the northern part of the Island (Aleksandrovsk District) that the Zapadnokamyshev Series disintegrated into Konglomerat, Nizhneduy and Gennoyshi suites. In this case the latter suite was compared with Takaraday (Decisions... 1961; Ratnovsky, 1969).

However, the lithological-stratigraphical studies undertaken by geologists of the Sakhalin Territorial Geological Service introduced corrections into the structural picture of the Zapadnokamyshev Series. It was demonstrated that previously identified difference in types of Paleogene sections between Northern, Central and Southern parts of the west coast of Sakhalin (Zhidkova *et al.*, 1974) was caused by accumulation of sediments in various structural-fascial zones of the West Sakhalin sedimentation basin. Independent stratigraphic divisions were proposed for these zones (Savizky *et al.*, 1974): Snezhinka and Aral suites. And a footnote herein: Aral suite is an equivalent of "Nishisakutan schists with gennoishi (Kawasaki, 1935) and "Nishisakutan dark gray or black shale" (Uwatoko, 1937).

Age substantiation, intercomparison between sedimentary continental formations of Paleogene, and conclusions about diverse age of their basal formations in various parts of the West Sakhalin sedimentation basin were based on key geological concepts and analytical evidence from the leaf flora, spores and pollen (Akhmet'ev *et al.*, 1978; Zaklinskaya, 1976). And correlation of marine sediments of the Zapadnokamyshev Series and its roof, besides survey of tracer horizons, was based on the evidence from studies of

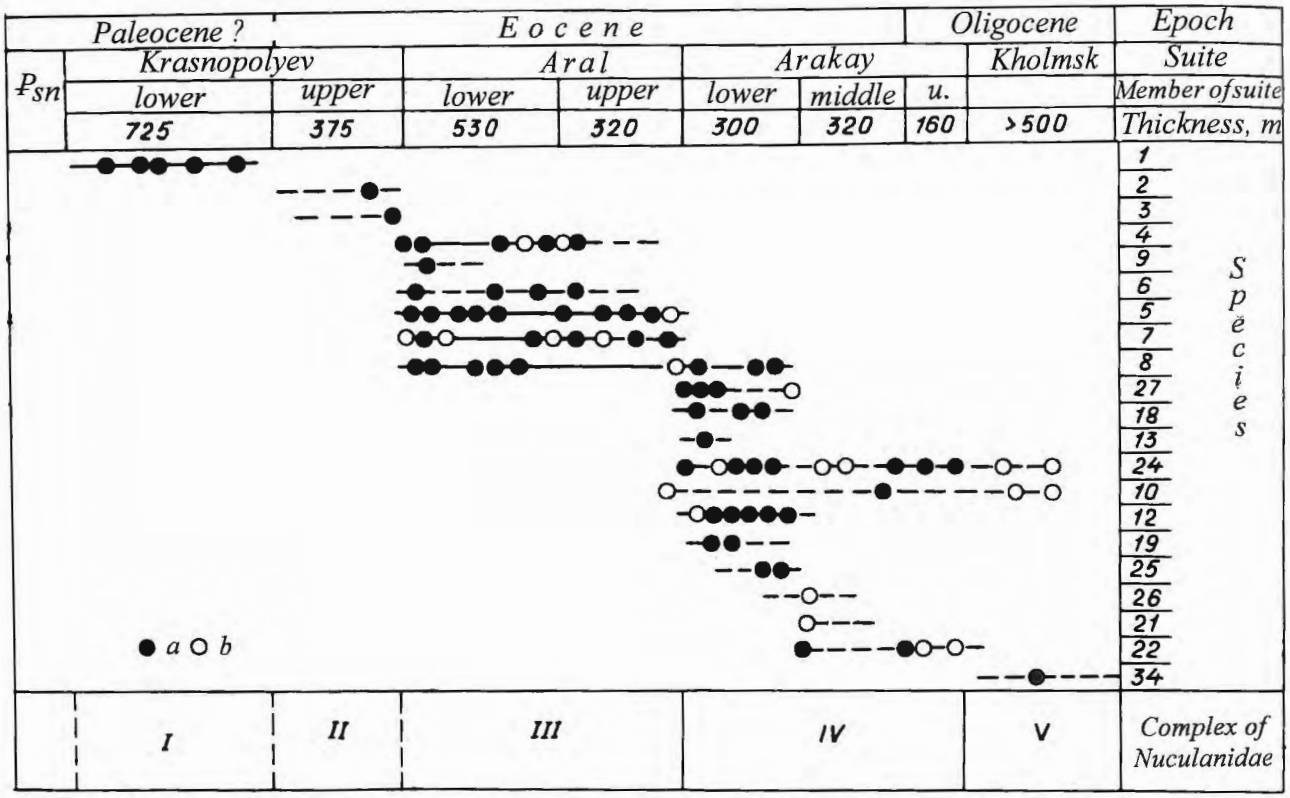


Fig. 2. Distribution of Nuculanidae in the Paleogene section of Uglegorsk District (Snezhinka, Aral'skaya and Dubovka/Stukolka rivers), Central structural-fascial zone. Identification of species: a—exact, b—aff. or cfr. Psn—Snezhinka suite. About species explanation *see* Fig. 6.

molluscan assemblages (Savizky *et al.*, 1974; Zhidkova *et al.*, 1974). Important biostratigraphic conclusions on sediment intercomparison have been obtained from the studies of the Nuculanidae. Therefore, below we outline the peculiarities of distribution of Nuculanidae in the Paleogene Section of South Sakhalin, and their stratigraphic importance.

Evidently, the distribution of Nuculanidae, like other molluscs, is determined by both evolutionary and ecological features. In quantitative respect, representatives of the subfamily Yoldiinae are predominant in the studied sections. Most diversified are Nuculanidae of the basins of the Late Paleogene; in marine formations they are sparse and less diverse. The distribution analysis of nuculanids in sections of separate districts (Figs. 2-6) has permitted to understand the nuculanids interchangeability pattern and identify five complexes and the relevant stratigraphic divisions in the Paleogene section of South Sakhalin.

Complex I —lona *Jupiteria* (*Saccella*) *gabbii* characterizes the Lower-Krasnopolyev sub-suite. It is established by the presence of *J.* (*S.*) *gabbii*, and separate *Yoldia* sp. of seldom occurrence. This complex, as well as the first representatives of the family Nuculanidae in general, is known only from Eocene marine deposits of Uglegorsk District (Fig. 2). Here, in the sections of Krasnopolyev suite in the rivers Snezhinka, Chernomorka, Kama of frequent occurrence are *J.* (*S.*) *gabbii* together with *Brachidontes esutoruensis, Crassostrea* sp., *Sanguinolaria* cfr. *townsendensis, Cyclocardia expansa, Ampulina* cfr. *andersoni* and "*Genota*" *snatolensis* (Savizky *et al.*, 1974). Narrow vertical distribution makes *J.* (*S.*) *gabbii* one of the leading species of the Krasnopolyevsk stratigraphic horizon. It is significant that *Jupiteria* (*Saccella*) *gabbii* is not reported from the upper part of the Lower-Krasnopolyev suite, though its lithological composition is everywhere monotonous, and disappearance of the species is evidently independent to paleoclimatic features, since the representatives of the

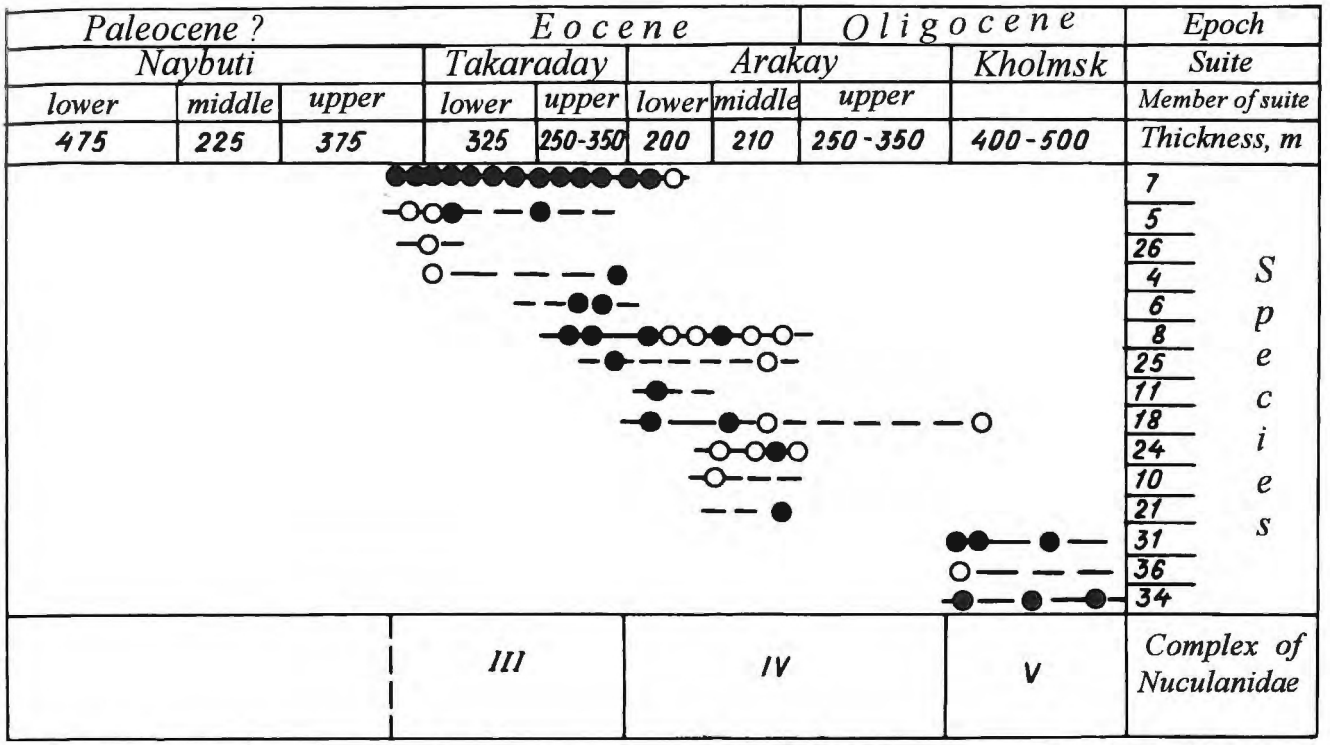


Fig. 3. Distribution of Nuculanidae in the Paleogene section of Kholmsk District (Serpyanka and Pravda rivers), Southern structural-fascial zone. About species explanation *see* Figs. 2, 6.

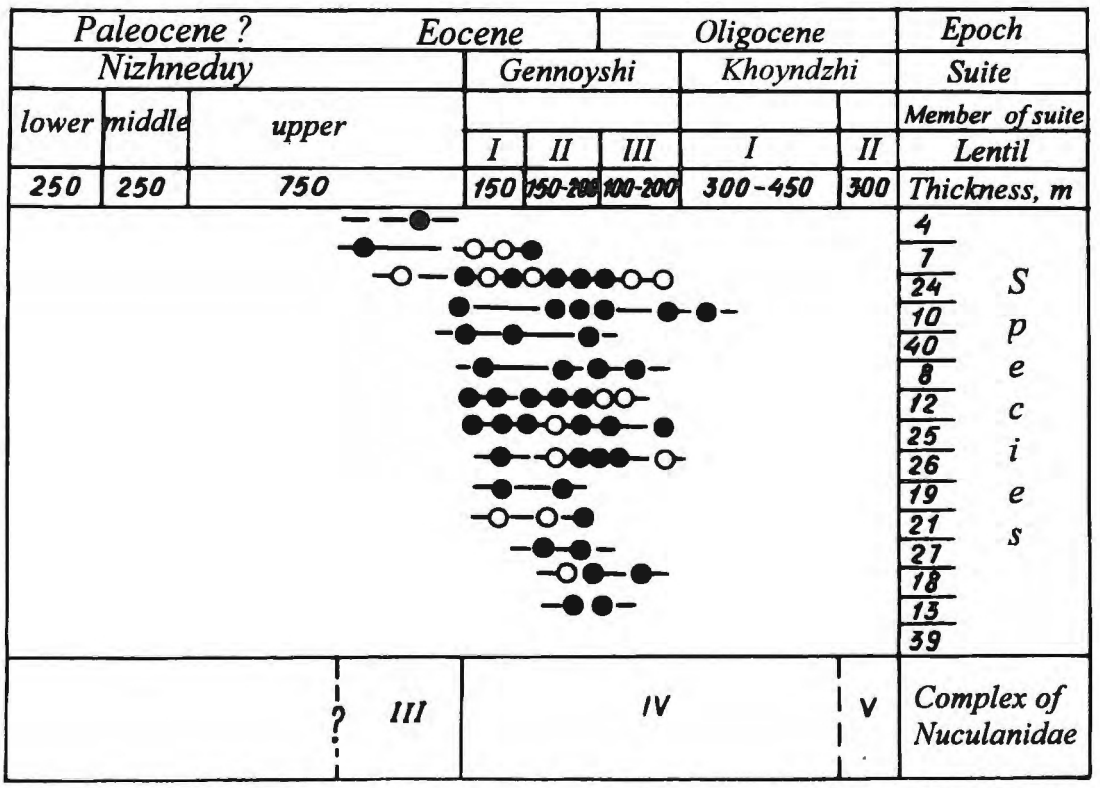


Fig. 4. Distribution of Nuculanidae in the Paleogene section of Boshnyakovo (Avgustovka, Nikiforovka, Onnay, Chernomorka/Lesogorka rivers), Northern structural-fascial zone. About explanation *see* Figs. 2, 6.

subgenus *Saccella* are relatively stenothermal organisms distributed in warm waters (Savizky, 1979). This agrees with characteristic features of generic composition of other molluscs: in the formations of the Lower-Krasnopolyev sub-suite remnants of relatively headloping *Crassostrea, Brachidontes, Macrocallista, Calyptraea* and "*Genota*" have been reported.

Jupiteria (*Saccella*) *gabbii* is also important for interregional correlations. This is a characteristic form of the Napanian horizon of Kamchatka (Krishtofovich, 1969), it is also widely distributed in Eocene formations of North America—Meganos and Tejon formations of California (*see* Moore, 1983). Therefore, it may be considered valid to distinguish separate lona *Jupiteria* (*Saccella*) *gabbii* in the lower Cenozoic section of the North Pacific Region. Recognizing the importance of this species in correlation of Paleogene strata of the Far East, let us suggest the following reason of its lack in the Paleogene of Northern and Southern structural-fascial zones of the West Sakhalin sedimentation basin.

The analysis of nuculanid distribution in the Boshnyakovo section (Fig. 4) together with considerations of consistent relations of the Lower Cenozoic formations is suggestive of the fact that the marine formations of lona *Jupiteria* (*Sacella*) *gabbii* are evidently substituted here by continental and coastal-marine formations (middle and lowermost parts of upper member of Nizhneduy suite). The above reasoning is confirmed by finding marine sublayers in lowermost part of upper member of Nizhneduy suite of the Avgustovka River, yielding characteristic molluscan assemblage for the Krasnopolyevskian horizon: *Ostrea esutoruensis, Mytilus littoralis, Ciliatocardium asagaiense, Macrocallista* cfr. *andersoni, Calyptraea* cfr. *diegoana*, "*Genota*" *snatolensis*, (Savizky *et al.*, 1974). The absence of *Jupiteria* (*Sacella*) *gabbii* in the sections of southwestern coast (Fig. 3) is evidently conditioned by fascial substitution. The consistent relations between Takaraday and Naybuti suites specified by research in the seventies permit to accept the fact that here marine sediments of lona *Jupiteria* (*Saccella*)

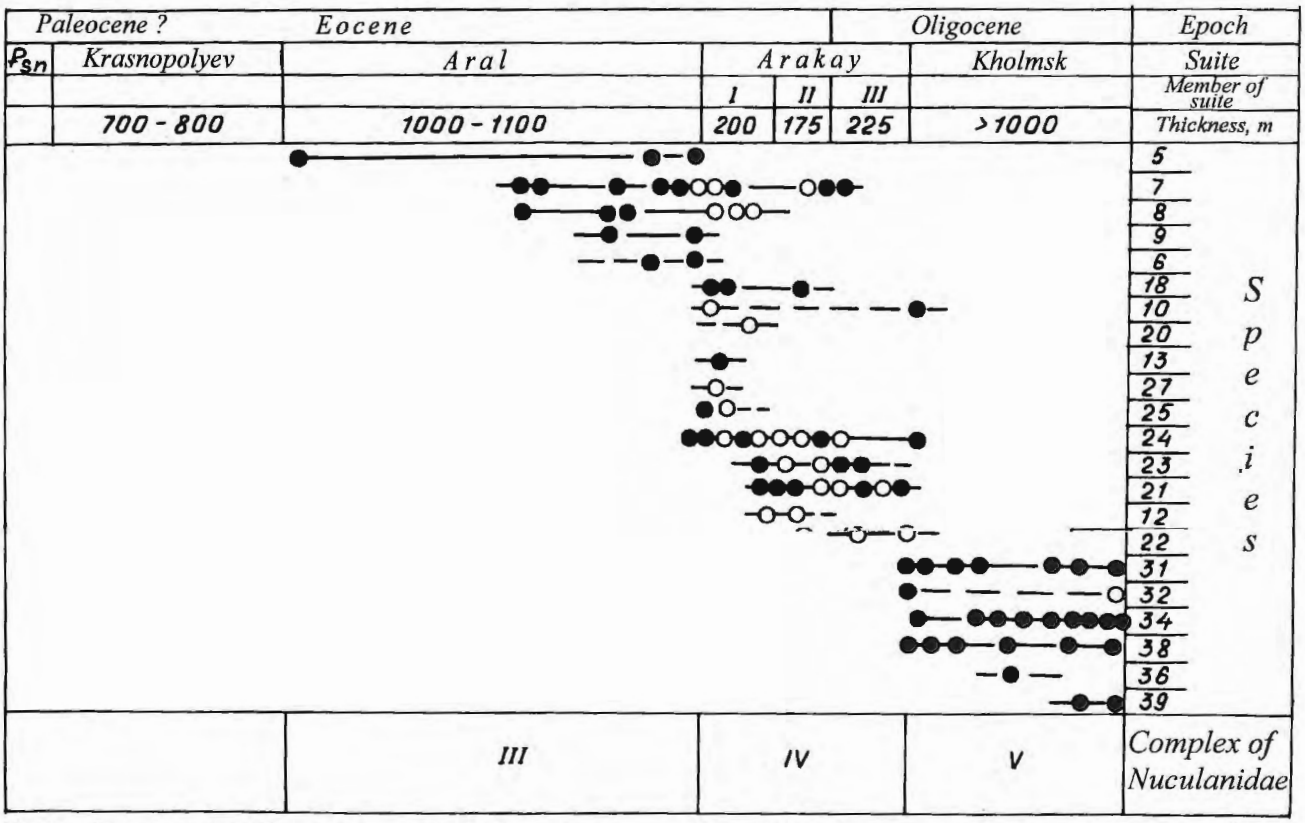


Fig. 5. Distribution of Nuculanidae in the Paleogene section of Tomarinka River, Central structural-fascial zone. About explanation *see* Figs. 2, 6.

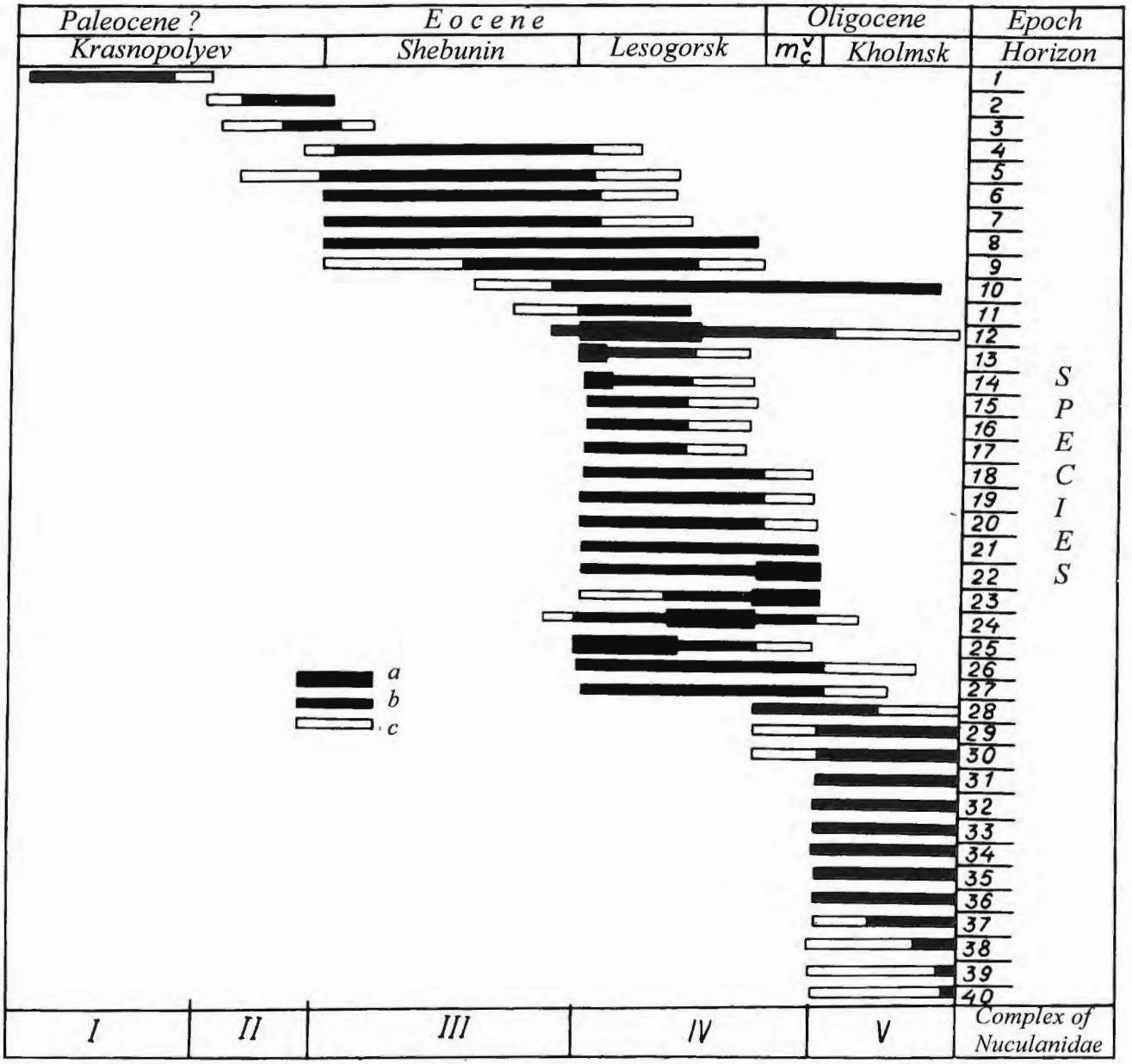


Fig. 6. Distribution of Nuculanidae in the summary Paleogene section of South Sakhalin: 1—*Jupiteria* (*Saccella*) *gabbii* (Conrad), 2—*Nuculana* (*s. l.*) *snatolensis* Slod., 3—*Nuculana* (*Thestyleda*) sp. 1, 4—*N.* (*T.*) sp. 2, 5—*Yoldia* (*Cnesterium*) *saitoi* Uozumi, 6—*Y.* (*Y.*) *akanensis* Uozumi, 7—*Y.* (*Nampiella*) *takaradaensis* L. Krisht., 8—*Megayoldia* (*Portlandella*) *watasei* (Kanehara), 9—*M.* (*P.*) *watasei ogasawarai* Uozumi, 10—*M.* (*P.*) *nitida* (Slod.), 11—*Yoldia* (*Nampiella*) sp. 1, 12—*Y.* (*Yoldia*) *longissima* Slod., 13—*Y.* (*Praesachalinella*) *biremis* Uozumi, 14—*Y.* (*P.*) sp. 1, 15—*Y.* (*P.*) sp. 2, 16—*Megayoldia* (*Praeportlandia*) sp. 1, 17—*M.* (*P.*) sp. 2, 18—*M.* (*Megayoldia*) *ovata* (Uozumi), 19—*Yoldia* (*Nampiella*) *laudabilis* Mak., 20—*Y.* (*N.*) *asagaiense* Mak., 21—*Y.* (*Sachalinella*) *matschigarica* Khom., 22—*Y.* (*S.*) *vasiljevskii* Slod., 23—*Y.* (*S.*) *nairoensis* Evseev, 24—*Y.* (*Yoldia*) *caudata* Khom., 25—*Y.* (*Y.*) *gretschishkini* L. Krisht., 26—*Yoldia* (*Y.*) *kovatschensis* Slod., 27—*M.* (*M.*) *yotsukurensis* (Uozumi), 28—*Nuculana* (*Thestyleda*) sp. 3, 29—*Propeleda schmidti* (L. Krisht.), 30—*Yoldia* (*Y.*) *tschekhovi* L. Krisht., 31—*Nuculana* (*Crassoleda*) *crassotelloides* (Laut.), 32—*N.* (*C.*) *pennula* (Yok.), 33—*Neilonella* (*Borissia*) sp. 1, 34—*Megayoldia* (*Hataiyoldia*) *tokunagai* (Yok.), 35—*M.* (*H.*) sp. 1, 36—*Nuculana* (*N.*) *tumiensis* L. Krisht., 37—*Megayoldia* (*Hataiyoldia*) sp. 2, 38—*M.* (*H.*) sp. 3, 39—*Neilonella* (*Borissia*) *alferovi* (Slod.), 40—*Megayoldia* (*Portlandella*) *khandasensis* (Kogan); m—Machigarian horizon, Abundance of species: a—maximal, b—ordinary, C—occasional (or assumed).

gabbii are also substituted by continental coal bearing Naybuti suite. This supports the assumption of the presence of most ancient strata of the Sakhalin Paleogene in Uglegorsk District general (Savizky *et al.*, 1969; Zhidkova *et al.*, 1969) as well as of most ancient marine formation of Krasnopolyev suite (Savizky *et al.*, 1974).

Complex II is distinguished rather hypothetically on the basis of availability of rare "*Nuculana*" *snatolensis* and *Nuculana* (*Thestyleda*) sp., in the upper member of Krasnopolyev suite. Similarly to complex I, this complex has been identified in Paleogene formations of the Central structural-fascial zone where "*Nuculana*" *snatolensis* is registered in the Uglegorsk section from the upper member of Krasnopolyev suite (Fig. 2). However, rare occurrence and ambiguity of taxonomic position prevent from estimating biostratigraphic value of this species. Simultaneously in the uppermost part of the suite the site-representative *Nuculana* (*Thestyleda*) were registered for the first time. The absence of these nuculanids in the Paleogene sections in Southern structural-fascial zone (as well as in the Northern zone) is assumingly due to specific features of paleogeographic conditions of Krasnopolyevsk sedimentation pattern (Margulis *et* Savizky, 1974).

The two above complexes have been identified on the basis of the presence of rare representatives of the subfamily Nuculaninae in the sections. However, in the overlying formations of Paleogene sections the leading role shifts to representatives of the subfamily Yoldiinae. It is a most thoroughly studied group of Nuculanidae in the Far East (Krishtofovich, 1964; Gladenkov, 1970a, b, 1971a, 1972, 1973; etc.). Frequent occurrence of these biofossils in Paleogene formations, richness of species and high evolutionary plasticity specify supreme biostratigraphic value of the Yoldiinae species, though representatives of the subfamily Nuculaninae are still of certain importance. Distinct variability of a whole number of nuculanids in Paleogene section of South Sakhalin (Fig. 6) serves a basis for identification of the III, IV and Vth complexes.

Complex III—*lona Yoldia* (*Cnesterium*) *saitoi*-*Y.* (*Nampiella*) *takaradaensis*—has been distinguished in Paleogene section of Southern Sakhalin (Fig. 6) by the presence of *Nuculana* (*Thestyleda*) sp. 2, *Yoldia* (*Cnesterium*) *saitoi*, *Y.* (*Nampiella*) *takaradaensis*, *Y.* (*Y.*) *akanensis*, *Megayoldia* (*Portlandella*) *watasei*. Of joint occurrence are rare *Y. takaradaensis* and the associated *Acila* cfr. *sinnaensis*, *Conchocele snatolensis oligocenica*, *Ciliatocardium asagaiense*, *Periploma iesakai*, and *Ancistrolepis modestoideus*.

Unlike the two previous, the present complex is generally identified in Paleogene formations of Takaradayan stratigraphic horizon: in the Aral, Takaraday and uppermost part of Nizhneduy suites. Its characteristic feature is a small amount of generic and subgeneric taxa of *Yoldia*. The complex incorporates only 5-6 species of *Yoldia* belonging to the subgenera *Yoldia s. s.*, *Nampiella* and *Portlandella*, though the ecological conditions of Takaraday sea, as earlier described (Margulis *et* Savizky, 1974), were generally favorable for existence of Palaeotaxodont Bivalvia. Despite inexpressive species composition, the complex is of positive importance for correlations between diversifascial strata of the Zapadnokamyshev Series of South Sakhalin and for regional intercomparison between Paleogene strata.

In the Central structural-fascial zone (sections of Uglegorsk and Tomari District), the complex characterizes the normal marine sediments of Aral suite, predominantly composed of aleurites. It contains *Nuculana* (*Thestyleda*) sp. 2, *Megayoldia* (*Portlandella*) *watasei ogasawarai*, *M.* (*P.*) *watasei*, *Yoldia* (*Y.*) *akanensis*, *Y.* (*Nampiella*) *takaradaensis* (Figs. 2, 5). Practically the same species composition is also characteristic for complex III in the section of Takaraday suite of the South structural-fascial zone: *Nuculana* (*Thestyleda*) sp. 2, *Megayoldia* (*Portlandella*) *watasei*, *Yoldia* (*Nampiella*) *takaradaensis*, *Y.* (*Cnesterium*) *saitoi*, *Y.* (*Y.*) *akanensis*, *Y.* (*Y.*) *kovatschensis* (Fig. 3). Tracing of the complex within the bounds of Southern Sakhalin validates registration of the lower bound of the Takaradayian horizon along the base of the ingression (argillite-aleurite) lentil of Takaraday suite in the Kholmsk/Nevelsk District and along the base of the Aral suite of the Tomari and Uglegorsk Districts. Identification of complex III in the section of upper member of Nizhneduy suite of Boshnyakovo

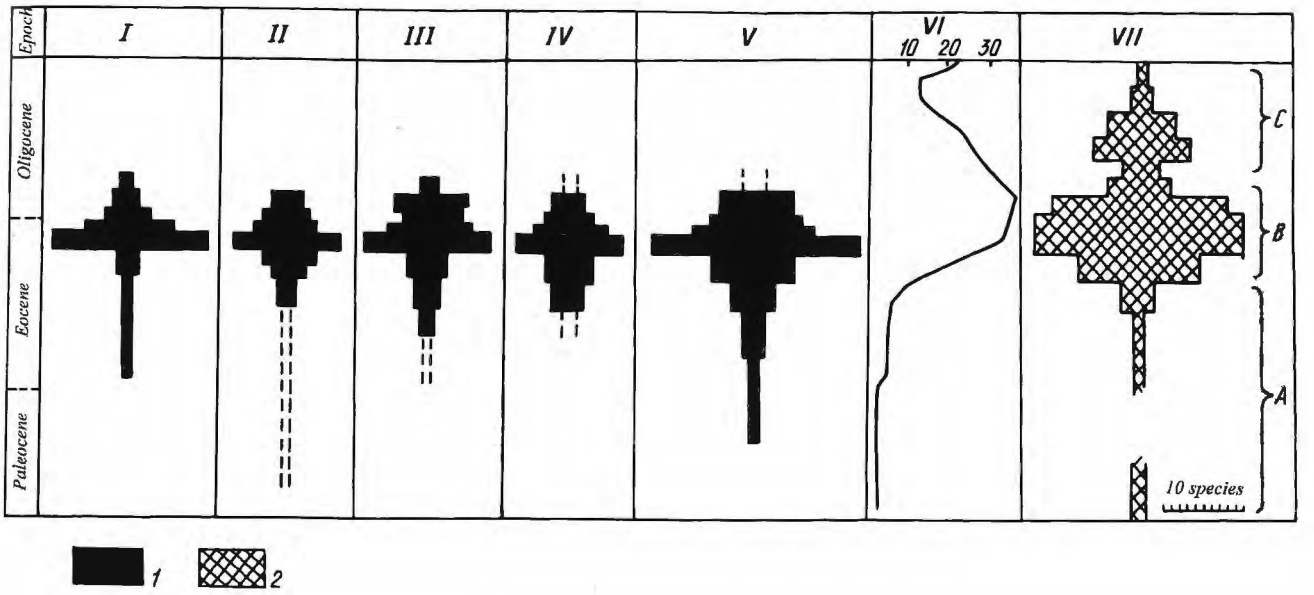


Fig. 7. Quantitative distribution of Yoldiinae species in the Paleogene sections of South Sakhalin and North Pacific region. South Sakhalin; I—Boshnyakovo section, II—section of Uglegorsk District, III—section of the Tomarinka River, IV—section of Kholmsk District, V—summary Paleogene section of South Sakhalin, North Pacific region (based on Gladenkov, 1970a): VI—summary species number, VII—quantitative change of the appeared species number; 1—summary species number, 2—appeared species number. Stages of the development: A—grow, B—acme, C—dying away.

section confirms the validity of attribution of these strata also to Takaradayian horizon since here there are present *Nuculana* (*Thestyleda*) sp. 2, *Y.* (*Nampiella*) *takaradaensis,* and *Y.* (*Y.*) *caudata* (Fig. 4). The same conclusion may be drawn from the analysis of quantitative distribution of Yoldiinae in the above sections (Fig. 7).

The comparison between complex III and nuculanids assemblages from similarly aged formations of Kamchatka and Japan indicated that this complex corresponds to the stabilization stage of Yoldiinae in the north of the Pacific area (Gladenkov, 1970a). The taxonomic composition of complex III may be compared with that of the Kovachinian horizon of Western Kamchatka with respect to common species: *Y.* (*Nampiella*) *takaradaensis, Megayoldia* (*Portlandella*) *watasei, M.* (*Portlandella*) *olympiana* (Krishtofovich, 1961, 1969). In Japan *M.* (*Portlandella*) *watasei* is known from Upper Ishikari and Poronai faunas (Takeda, 1953).

The study of the *Yoldia* complex which successfully replaced complexes I and II in Early Paleogene gives substantial ground for identification of lona *Yoldia* (*Cnesterium*) *saitoi*-*Y* (*Nampiella*) *takaradaensis.* With respect to age and volume, in Sakhalin this set corresponds to diversifascial formations of Takaradayian horizon (Takaraday, Aral and upper member of Nizhneduy suites).

Complex IV—lona *Yoldia* (*Y.*) *longissima*-*Megayoldia* (*Portlandella*) *nitida*—is distinguished by mass development of the *Yoldia* s. s. species, frequent development of *Megayoldia* (*Portlandella*), appearance of *Praesachalinella, Sachalinella* and *Megayoldia* s. s. in Arakay suite and its age analogues. The following forms are characteristic for this complex: *Y.* (*Nampiella*) *asagaiense, Y.* (*Praesachalinella*) *biremis, Y.* (*Y.*) *gretschischkini, Y.* (*Y.*) *longissima, Y.* (*Sachalinella*) *matschigarica, Y.* (*Sachalinella*) *nairoensis, Y.* (*Sachalinella*) *vasiljevskii, Megayoldia* (*Portlandella*) *nitida, M.* (*Megayoldia*) *ovata, M.* (*Megayoldia*) *yotsukurensis.* Some forms (*Y. takaradaensis, M. watasei, M. watasei ogasawarai*) are transient and are

known from under lying formations of the Takaradayian horizon. The complex also incorporates more rarely occurring Nuculaninae: *Nuculana* (*Thestyleda*) *khandasensis* (in lowermost parts) and *N.* (*Thestyleda*) sp. 3 (in the upper part) of Arakay suite. In general, the complex under consideration is distinguished from complex III by a notable rise in the number of species *Yoldia* and *Megayoldia* (Fig. 6). This complex is particularly characterized by large amount of smooth lanceolate *Yoldia s. s.*, representatives of the subgenus *Portlandella* (*M.*) *watasei semiovata, M. nitida.* It is for the first time that sculptured *Yoldia* (*Sachalinella, Praesachalinella* and *Nampiella*) make their appearance on the boundary of Takaraday and Arakay suites and gain wide development. Those features characteristic for the complex, are helpful for its identification in Paleogene section of South Sakhalin among formations of Lesogorskian and Machigarian stratigraphic horizons not only in the bounds of West Sakhalin Paleogene deflection but in other areas of the Island as well. The present complex corresponds to the stage of development of Yoldiinae (Fig. 7), and represents a most consistent set in Paleogene section of South Sakhalin. It retains basically similar subgeneric and species composition in Paleogene formations of the Uglegorsk, Tomari, Kholmsk Districts (Figs. 2, 3, 5) and on Krilyon peninsula.

In the Central part of Western coast of the Island complex IV may be identified in Arakay suite of Uglegorsk and Tomari sections (Figs. 2, 5) by the following common species: *Yoldia* (*Praesachalinella*) *biremis, Y.* (*Y.*) *caudata, Y.* (*Y.*) *longissima, Y.* (*Y.*) *gretschishkini, Y. matschigarica, Y. vasilievskii, Megayoldia* (*Megayoldia*) *ovata, M.* (*M.*) *yotsukurensis, M.* (*Portlandella*) *nitida.*

In Paleogene section of the Kholmsk District (Fig. 3) complex IV also characterizes volcanogenic-sedimentary yields of Arakay suite.

The distribution analysis of Nuculanidae within complex IV in the mentioned sections permits to specify in the Arakay suite of South Sakhalin the individual biostratigraphic zones distributed within the West-Sakhalin deflection. These zones, identified according to specific distribution features of separate species of Yoldiinae within the section, are approximately correspondingin volume to three members (sub-suites of Arakay suite).

Thus, almost all species of subgenus *Praesachalinella* are characterized by narrow vertical distribution and basically occur in sediments of the lower member of Arakay suite. Also abundant here are lanceolate representatives of subgenus *Yoldia s. s.* ((*Y.*) *longissima, Y. caudata, Y. gretschishkini*, etc.), and first occurrence of *Megayoldia s. s.* (*Megayoldia ovata, M, yotsukurensis*) is reported.

Despite index species, lona *Yoldia* (*Praesachalinella*) *biremis-Y.* (*Y.*) *gretschishkini* is characterized by versatility of lanceolate (*Yoldia* (*Y.*) *longissima, Y. caudata, Y. gretschishkini, Y. salvationemense*) as well as representatives of the genus *Megayoldia*: *M.* (*Megayoldia*) *yotsukurensis, M.* (*M.*) *ovata, M.* (*Portlandella*) *watasei.* The associated forms from other bivalve mollusc groups are: *Ciliatocardium asagaiense, Profulvia matschgarica, Liocyma furtiva, Conchocele smekhovi kriljonensis, Macoma asagaiense, Mya grewingki.* The lona is commonly traced within the bounds of Southern Sakhalin and is identified in all the sections of Arakay suite in the Central and Southern structural-fascial zones. Most characteristic here is *Praesachalinella. Yoldia* (*Praesachalinella*) *biremis* is reported only from lower member of Arakay suite. *Praesachalinella* is also known from Kamchatka (*Y. oblukovinens*) and Japan (*Y. biremis*) justifying subsequent possibility of interregional comparisons.

Conversely, the strata of the upper member of Arakay suite are characterized by abundance of representatives of subgenus *Sachalinella* (*Yoldia nairoensis, Y. vasilievskii*). This is mostly associated with fascial situation and connection of these forms with more coarse-fragmentary sand fascia compared with other subgenera of *Yoldia.*

The *Yoldia* (*Sachalinella*) *nairoensis* biozone identified here is characterized by mass appearance of index species, presence of *Nuculana* (*Thestyleda*) sp. 3, *Y.* (*Y.*) *longissima, Y.* (*Y.*) *caudata* and *Megayoldia* (*Portlandella*) *nitida.* In the absence of some of the specified leading Nuculanidae species in some sections, this biozone is characterized by the associated forms of other mollusc groups: *Profulvia matschigar-*

ica, Laevicardium tristiculum (= *L. esutoruense*), *Macoma simizuensis* and *Laternula yokoyami.* The biozone is distinctly traced in most sections of the upper member of Arakay suite of Southern Sakhalin. In its volume it is evidently coincident with previously specified faunistic horizon *Laevicardium esutoruense* (Krishtofovich, 1954; Margulis *et* Savizky, 1969) which serves a marker for the correlation between Arakayian volcanic formations of Southern Sakhalin.

The above considered biozones are rather definitely distinguished in the sections of lower and upper members of Arakay suite of Uglegorsk, Tomari and Kholmsk Districts. Conversely, the biozone *Yoldia caudata-Y. asagaiense*, corresponding in volume to middle member of Arakay suite is poorly identifiable. It is characterized by predominance of *Yoldia s. s.* and *Nampiella*, or most frequent occurrence are, *Yoldia* (*Y.*) *caudata, Y.* (*Y.*) *praecaudata, Y.* (*Nampiella*) *laudabilis, Y.* (*Nampiella*) *asagaiense*; from *Megayoldia* reported are *M.* (*Portlandella*) *watasei* and *M.* (*P.*) *nitida.* This biozone was earlier studied (Margulis *et* Savizky, 1969) in the volume of faunistic horizon *Yoldia caudata.*

All the distinguished biozones give opportunity (along with the information on other Bivalvia groups) to make a sufficiently definite tracing of Arakay suite within the Central and Southern structural-fascial zones, and identify the consistency of complex IV across the whole of the analyzed territory. In this connection of certain interest is the information on the distribution of complex IV in the studied sections of southern part of the Northern structural-fascial zone (Fig. 4). Here it is represented by *Yoldia* (*Y.*) *caudata, Y.* (*Praesachalinella*) *biremis, Y.* (*Y.*) *longissima, Y.* (*Y.*) *gretschishkini, Y.* (*Y.*) *kovatschensis, Y.* (*Nampiella*) *laudabilis, Megayoldia* (*Portlandella*) *nitida, M.* (*P.*) *khandasensis, M.* (*P.*) *watasei, M.* (*Megayoldia*) *yotsukurensis* and *M.* (*M.*) *ovata.* It is peculiar that this complex, identical in systematic composition to complex IV from Arakay suite of more southerly regions, has been identified here in the Gennoyshi suite. This phenomenon seems important for correct understanding of the structure of Paleogene strata and exact tracing of roof of Zapadnokamyshev Series on the west coast of Sakhalin, since so far there exists an opinion of age identity between Takaraday and Gennoyshi suites (Zhidkova *et al.*, 1974).

The lower boundary of Miocene had been earlier identified on the Sakhalin (Decisions..., 1961) along the base of the Arakay suite. Therefore it is important to trace on the west coast a marker level in the base of volcanogenic-sedimentary formations of Sergeev Series. The volume of the Arakay suite in various regions of the west coast of South Sakhalin is differently understood by various authors (Margulis *et* Savizky, 1969, 1974). This was first noticed by Krishtofovich (1954, 1964), she identified in the Cenozoic section of the island the strata with *Acila sinaensis* (Krilyon strata) previously referred either to Takaraday or to Arakay suites.

Essentially Krishtofovich was the first to arrive at correct conclusion concerning the replacement in the western direction of coarse fragmentary volcanogenic yields of Arakay suite by normal sedimentary yields included by most geologists into Takaraday suite. Sudden fascial replacements of volcanogenic formations of Sergeev Series were also noted by Shilov (1957, 1958).

Radically different information on this subject has been reported by researchers of the Sakhalin Territorial Geological Service. Coarse fragmentary volcanogenic formations of Sergeev Series developed in the northern part of the Uglegorsk Districts were previously separated into Verkhnearakay suite (faunistic horizon *Laevicardium esutoruense* and *Laternula yokoyamai*) which by its volume corresponds to upper member of Arakay suite (Margulis *et* Savizky, 1974). The underlying formations (Takaraday or Gennoyshi suite of precursors) were treated here as an integral Takaraday-Nizhnearakay unit which assumed age dissimilarity between Takaraday and Gennoyshi suites. This concept is completely supported by practical data (Margulis *et* Savizky, 1969, 1974; Savizky *et al.*, 1974). It was ascertained that with respect to paleontological data, Gennoyshi suite together with Nikiforov beds should be compared to lower part of Arakay suite. This is evidenced by the above comparison between complexes of Nuculanidae, and comparison between quantitative

distribution of Yoldiinae in the sections of west coast of Southern Sakhalin (Fig. 7). In fact, in Gennoyshi suite present are practically all the species of complex IV known in Arakay suite of Southern Sakhalin: *Yoldia (Y.) caudata, Y. (Y.) longissima, Y. (Y.) kovatschensis, Y. (Y.) salvatiorlernense, Y. (Y.) gretschishkini, Y. (Nampiella) laudabilis, Y. sobrina, Y. (Sachalinella) matschigarica, Y. (Praesachalinella) biremis, Megayoldia (M.) ovata, M. (Portlandella) watasei.* This set sharply distinguishes from complex III (Takaradayian) by a large number of Yoldiinae species. In the formations of Takaradayian horizon no occurrence has so far been reported of *Yoldia longissima, Y. gretschishkini, Y. laudabilis, Y. sobrina, Y. matschigarica, Y. biremis, Megayoldia ovata, M. yotsukurensis*, characteristic, on the other hand, for Gennoyshi and lower part of Arakay suites of Southern Sakhalin.

The validity of comparison between Gennoyshi and Arakay suites is supported by data on other species of molluscs. Besides, observations of the specified *Yoldia* biozones within complex IV permit to make a more accurate comparison between Gennoyshi and Arakay suite. So, the established biozone *Yoldia biremis-Y. gretschishkini* in the section of the 1st and 2nd lentils of Gennoyshi suite in the northern part of the Uglegorsk District permits to correlate them with the lower part of Arakay suite of more southerly regions. In the section of the upper part of Gennoyshi suite (3rd lentil) biozone *Yoldia caudata-Y. asagaiense* is also specified; a younger biozone (*Yoldia valiljevskii-Y. nairoensis*) has been established here in the lower part of the overlying Khoyndzhi suite.

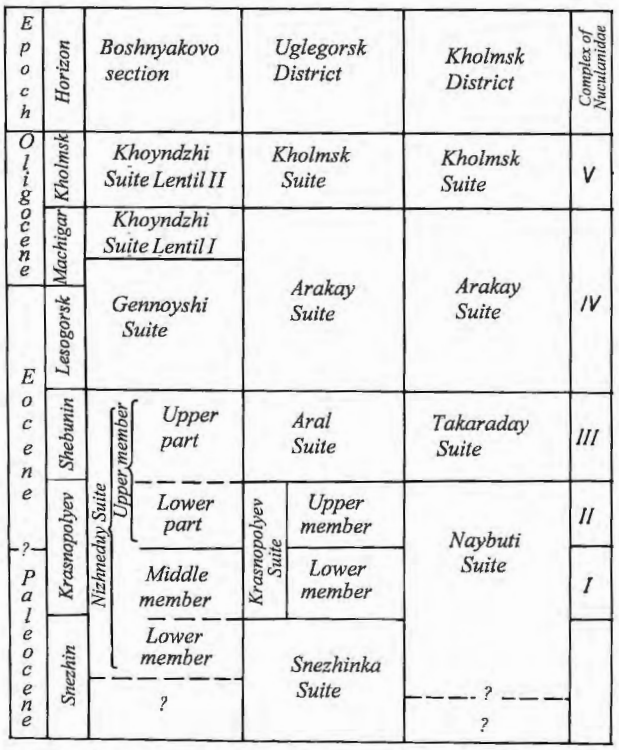


Fig. 8. Stratigraphic correlation of South Sakhalin.

Thus, the overall consistency of complex IV in the section Paleogene of the three structural-fascial zones reaffirms the validity of previously assumed (Margulis *et* Savizky, 1968, 1974; Savizky *et al.*, 1974) correlation scheme of Paleogene formations of Southern Sakhalin (Fig. 8). This complex is also important for interregional correlations. In taxonomic composition it may be compared with Amaninian *Yoldia* set of the Western and Eastern Kamchatka (Gladenkov, 1972). The common species for those sets are: *Yoldia (Y.) longissima, Y. (Y.) kovatschensis, Y. (Sachalinella) matschigarica, Y. (Y.) gretschishkini, Megayoldia (Portlandella) watasei, M. nitida* and many others. The comparison of the Arakay and Gennoyshi suites of Southern Sakhalin with the formations of Amaninian horizon of Western Kamchatka is also confirmed by other groups of molluscs (Gladenkov, 1988).

Similarity is almost evident between the analyzed set and Nuculanidae from Poronai and Asagai Formations of Japan (Takeda, 1953; Uozumi, 1957; Oyama *et al.*, 1960, etc.). Large number of common species — *Yoldia (Nampiella) asagaiense, Y. (N.) laudabilis, Y. sobrina, Megayoldia (Portlandella) watasei, M. (P.) watasei semiovata, M. (P.) watasei ogasawarai, Megayoldia (M.) ovata, M. (M.) yotsukurensis*—make it reasonable to assume the age similarity of these formations. Uozumi (1957) believed that it was exactly during accumulation of sediments in the Poronai Formation that group of bivalve molluscs was most versatile in composition subgenera and species. In Gladenkov's opinion (1970a), *Yoldia longissima, Megayoldia watasei, M. nitida* and closely related species entered into the composition of lower subtidal/bathyal sets of Machigarian time practically

across the whole of the Northern part of the Pacific Ocean (from Japan to America).

Observation of complex IV in Sakhalin, Kamchatka and Japan suggests its wide distribution across the North-Western part of the Pacific Region. It gives ground for separating out lona *Yoldia longissima-Megayoldia* (*Portlandella*) *nitida*. It evidently coincides with horizon I in volume, and temporally corresponds to the period of flourishing of Yoldiinae (Gladenkov, 1970a) in Cenozoic of North Pacific (Fig. 7).

Complex V—lona *Megayoldia* (*Hataiyoldia*) *tokunagai-Nuculana* (*Crassoleda*) *crassotelloides* abruptly distinguishes from the previous complexes by appearance of a number of new subgenera of *Megayoldia* enjoying here wide development. The complex also incorporates *Megayoldia* (*Portlandella*) *nitida* and *Yoldia* (*Y.*) *caudata*, known from more ancient formations, *Yoldia saggitaria*, *Y.* (*Y.*) *tschekhovi*, occurring for the first time. However, most characteristic are *Megayoldia* (*Hataiyoldia*) *tokunagai*, *Nuculana* (*Crassoleda*) *crassotelloides*, *N.* (*C.*) *pennula*, *Propeleda schmidti* as well as a number of leading species Malletiinae: *Spineilo* (*Multidentata*) *multidentata*, *Neilonella* (*Borissia*) *alferovi*, *Malletia* (*M.*) *inermis*, *M.* (*M.*) *longa*.

With respect to age, complex V is characterizing sediments of Kholmsk and Nevelsk suites of South Sakhalin, however, the question of upper limit of distribution remains open. The occurrence of this complex in Cenozoic section of South Sakhalin records the shift of coastal-marine situations of Arakayian time to a relatively deep water conditions of Kholmskian/Nevelskian time.

This transgression is undoubtedly the most extensive in Paleogene covering a large portion of the territory of South Sakhalin. The predominance of fine fragmentary formations and the composition Bivalvia of Kholmsk suite suggest the depths of basin up to 2000 m and prevalence of silty fascia favorable for mass settlement of *Nuculana*, *Megayoldia* and *Malletia*. Representatives of *Nuculana* (*Crassoleda*), *Megayoldia* (*Hataiyoldia*) and peculiar *Multidentata* also settle there for the first time and quickly inhabit vast spaces of Kholmsk basin.

Subsequently, when similar relatively deep water conditions of vast transgression became repeated in the Cenozoic section of South Sakhalin, occurrence of a part of those species is resumed. Thus in the section of lower part of Kurasi suite, numerous leading forms in the set are distinguished: *Nuculana* (*Crassoleda*) *crassotelloides*, *Neilonella* (*Borissia*) *alferovi*, *Spineilo* (*Multidentata*) *multidentata*, though in the upper member of Kurasi suite the first occurrence, *Megayoldia* (*M.*) *thraciaeformis* and disappearance of a number of leading species, *Megayoldia* (*Hataiyoldia*) *tokunagai*, *Malletia longa*, of complex V is recorded. This data is helpful for identifying the Kurasi suite in most regions of South Sakhalin. However, in a number of sites of the east coast where in the Cenozoic section the Kholmsk/Nevelsk suites are not separated from Kurasi suite by Coal-bearing layers, their identification presents a complicated problem which is beyond the scope of the present contribution.

Over the western coast where this problem does not look so keen, complex V is characteristic of Kholmsk and Nevelsk suites, and can be positively traced in the sections of the Central and southern structural-fascial zones, thus, complex V in the section of Kholmsk District (Fig. 3) incorporates *Nuculana* (*Crassoleda*) *crassotelloides*, *Nuculana* (*N.*) *tumiensis*, and *Megayoldia* (*H.*) *tokunagai*.

Its composition in the Tomari section is quite similar: *Nuculana* (*Crassoleda*) *crassotelloides*, *N.* (*C.*) *pennula*, *Nuculana* (*N.*) *tumiensis*, *Megayoldia* (*Hataiyoldia*) *tokunagai*, *M.* (*H.*) sp. 3, *Neilonella* (*Borissia*) *alferovi* (Fig. 5).

In the Northern zone (Fig. 4) complex V is identified in the section of 2nd lentil of Khoyndzhi suite composed of siliceous tuff-aleurolites, more seldom of tuffogenic sandstones containing *Neilonella* (*Borissia*) *alferovi*, *Malletia inermis* and the associated *Mytilus* cfr. *tichanovitschi*, *Macoma simizuensis*. The age of Khoyndzhi suite is recently identified from leaf flora and marine Bivalvia as Late Oligocene (Khudik *et* Ablaev, 1991).

Stratigraphic importance of a number of characteristic species complex V in the Far East region was time and again noted in the previous literature. Thus, *Nuculana* (*Crassoleda*) *crassotelloides*, *Megayoldia*

(*Hataiyoldia*) *tokunagai*, *Spineilo* (*Multidentata*) *multidentata* are acknowledged leading species of the Sakhalinian stratigraphic horizon of provincial scale (Krishtofovich, 1969). This set has previously been reported also from Kamchatka, the Kurile Islands, the Islands of Honshu and Hokkaido, and is of great importance for interregional correlations. Complex V can be distinctly identified in the lower part of Tyushev suite of Eastern Kamchatka where the following species are common with Southern Sakhalin; *Nuculana* (*Crassoleda*) *crassotelloides*, *Megayoldia* (*Hataiyoldia*) *tokunagai*, *Spineilo* (*Multidentata*) *multidentata*, and *Neilonella* (*Borissia*) *alferovi*.

In the Kurile Islands, similar composition is displayed by the North Kurile set. The latter set is most completely represented in the Shumnov suite of the Paramushir island, incorporating *Nuculana* (*Crassoleda*) *crassotelloides*, *M.* (*C.*) *pennula*, *Megayoldia* (*Hataiyoldia*) *tokunagai*, *M.* (*H.*) *paramushiraensis*, *Malletia longa*, and *M. inermis* (Zhidkova *et al.*, 1972). Gladenkov (1978) also points to high stratigraphic value of temporal level with *Megayoldia* (*Hataiyoldia*) *tokunagai*. It is referred to the Early Miocene and is identified in Northern Japan, Sakhalin and Kamchatka.

Therefore, there is full evidence for identifying lona *Megayoldia* (*Hataiyoldia*) *tokunagai*—*Nuculana* (*Crassoleda*) *crassotelloides* within the Far Eastern region; at the same time, the question of its upper limit so far remains unresolved requiring further detailed biostratigraphic studies of Nevelsk, Uglegorsk and Kurasi suites of Southern Sakhalin.

The above biostratigraphic considerations may seem somewhat obsolete in the light of updated studies (*see*: Gladenkov, 1988; Arkhipova *et al.*, 1992) concerning correlations of stratigraphic schemes of Far Eastern-regions of Russia, North America and Japan. At the same time they are indicative of great importance of Nuculanidae for separation and correlation of marine Cenozoic formations of the North Pacific. It is hoped that the above information on distribution of nuculanids in Paleogene section of Southern Sakhalin may prove useful for subsequent stratigraphic studies.

Acknowledgements

The authors are sincerely grateful to Dr. Kazutaka Amano (Joetsu University of Education, Joetsu, Niigata Prefecture, Japan), Dr. Liliya I. Mitrofanova (Informgeocentre of "Vostokgeologiya" Research and Production Association, Yuzhno-Sakhalinsk, Russia) and Dr. Lidiya S. Zhidkova (All-Russia Petroleum Scientific-Research Geological-Exploration Institute, St. Petersburg, Russia) for critical review of the manuscript and valuable comments which were taken into account in the preparation of the manuscript for print, Dr. Kazutaka Amano and Dr. Yoshikazu Noda (Institute of Geology and Paleontology, Tohoku University, Sendai, Japan) were extremely helpful in supplying the Japanese literature missing in the libraries of Russia. Technical assistance in the preparation of the manuscript for print was rendered by Miss Galina Ryabukha (Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok, Russia). The English translation is made by Mr. Sergei V. Solovyev (Research Institute for Nature Conservation of the Arctic and North, St. Petersburg, Russia). The author extends his acknowledgments to all these persons.

The research described in this publication was made possible in part by Grant No. 773100 from the International Science Foundation and Russian Government.

The present work is a contribution to the International Geological Correlation Program (IGCP-355 Project). The research described in this publication was made possible in part by grants no. 95-01-11134 and 95-05-14997 from the Russian Foundation for Basic Research.

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Manusoript received on 26th, July, 1995; accepted on 28th, September, 1995.

サハリン南部の古第三紀シワロウバイ科（二枚貝綱）：その構成と分布

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要　　旨

北・西部太平洋の第三系より知られるシワロウバイ科の属・種について再検討する．*Nuculana s. s.* Link, 1807, *N.* (*Thestyleda*) Iredale, 1929, *N.* (*Tenuileda*) Habe, 1977, *N.* (*Crassoleda*) Savizky, 1969, *Jupiteria s. s.* Bellardi, 1875, *J.* (*Saccella*) Woodring, 1925, *J.* (*Epacroleda*) Savizky, 1969, *J.* (*Costanuculana*) Habe, 1951はシワロウバイ亜科に，*Propeleda* Iredale, 1924はヤナギバソデガイ亜科に，*Yoldia s. s.* Möller, 1842, *Y.* (*Cnesterium*) Dall, 1898, *Y.* (*Kalayoldia*) Grant *et* Gale, 1931, *Y.* (*Orthoyoldia*) Verrill *et* Buch, 1897, *Y.* (*Sachalinella*) Savizky, 1969, *Y.* (*Tepidoleda*) Iredale, 1939, *Y.* (*Nampiella*) subgen. nov., *Y.* (*Praesachalinella*) subgen. nov., *Megayoldia s. s.* Verrill *et* Bush, 1897, *M.* (*Portlandella*) Stewart, 1930, *M.* (*Hataiyoldia*) Kamada, 1962, *M.* (*Praeportlandia*) Savizky, 1969, *Portlandia* Mörch, 1857はナギナタソデガイ亜科に，*Malletia* Des Moulins, 1832, *Spineilo* (*Multidentata*) L. Krishtofovich, 1964はスミゾメソデガイ亜科に，*Neilonella s. s.* Dall, 1881, *N.* (*Borissia*) Slodkewitsch, 1938はハトムギソデガイ亜科に所属する．

シワロウバイ科各属・亜属の定義と検索を用意した．*Acilana* L. Krishtofovich, 1964は *Hataiyoldia* Kamada, 1962の新参客観シノニムである．

サハリン南部の古第三系セクションでのシワロウバイ科属・種の層序分布は，同地域の層序区分に相当する5つのコンプレックスに区分することが可能である．Complex Ⅰ：下部始新統海成層 Krasnopolyev 層下部では "Iona" *Jupiteria* (*Saccella*) *gabbii* が産出する．Complex Ⅱ は Krasnopolyev 層の上部で "*Nuculana*" *snatolensis*, *Nuculana* (*Thestyleda*) sp. の稀な産出に基づき区別されるだろう．Complex Ⅲはサハリン南部の西岸での Takaraday 層，Aral 層と Nizhneduy 層上部に相当する．Complex Ⅳの "Iona" *Yoldia* (*Y.*) *longissima*-*Megayoldia* (*Portlandella*) *nitida* はロシアの極東地域でナギナタソデガイ亜科の繁栄期に相当し，サハリン南部では Arakay 層とGennoyshi 層の下部・中部で特徴的である．Complex Ⅴの "Iona" *Megayoldia* (*Hataiyoldia*) *tokunagai*-*Nuculana* (*Crassoleda*) *crassotelloides* によって特徴づけられる堆積物の基底（Khoyndzhi 層の lentil Ⅱ Kholmsk層）は普通に追跡される．