Paleontological Research

Vol. 4 No.4
December 2000

Cover: Idealized sketch of *Nipponites mirabilis* Yabe, a Late Cretaceous (Turonian) nostoceratid ammonite. Various reconstructions of the mode of life of this species have been proposed, because of its curiously meandering shell form (after T. Okamoto, 1988).

Gyronautilus, a new genus of Triassic Nautilida from South Primorye, Russia

YURI D. ZAKHAROV[1] and YASUNARI SHIGETA[2]

[1]*Federal Far Eastern Geological Institute, Far Eastern Branch, Russian Academy of Science, Vladivostok 690022,*
Russia (e-mail: zakharov@fegi.ru)

[2]*Department of Geology and Paleontology, National Science Museum, 3-23-1 Hyakunincho, Shinjuku-ku,*
Tokyo, 169-0073 Japan (e-mail: shigeta@kahaku.go.jp)

Abstract. A new genus of Triassic Nautilida, *Gyronautilus*, is proposed for material from the Lower Triassic of South Primorye, Russia. The new genus differs from previous known genera of the family Grypoceratidae by its gyroconic shell with subrectangular whorl sections and a near-marginal siphuncle. A new subfamily, Gyronautilinae, within the Grypoceratidae is also proposed.

Key words: Early Triassic, *Gyronautilus*, Nautilida, Olenekian, South Primorye

Introduction

The Triassic deposits in South Primorye, Far East of Russia, yield well-preserved nautilids, some of which species have been described by previous authors (Diener, 1895; Kiparisova, 1954, 1961; Zakharov, 1978). *Syringoceras praevolutum* was proposed by Kiparisova (1961) on the basis of a single small specimen collected by N.K. Trifonov in 1948 from the Lower Triassic of the Abrek Bay area, about 45 km southeast of Vladivostok. The exact locality and horizon of the specimen were not described, but recently we found a large and complete specimen identified as *S. praevolutum* from the type locality (Figure 1). In this paper we describe the early to adult features of the species, and propose a new subfamily and genus based on the specimen.

The specimen utilized herein is deposited in the National Science Museum, Tokyo (NSM).

Note on Stratigraphy

The Lower Triassic strata exposed along the eastern coast of Abrek Bay are lithostratigraphically divided into two formations, the Lazurnaya Bay and Zhitkov Formations in upward sequence, as defined by Zakharov (1996, 1997) along the shore of Lazurnaya (= Shamara) Bay and the east coast of Russian Island near Vladivostok.

The Lazurnaya Bay Formation unconformably overlies the Permian Abrek Formation and consists of basal conglomerate and gray, fine-grained, bedded sandstone with lenses of coquinoid calcareous sandstone. Its thickness is 57.9 m in the section surveyed. It contains the ammonoids *Gyronites*

subdharmus Kiparisova and *Koninckites?* sp., the brachiopod *Lingula* sp., the bivalves *Promyalina vetusta* Bencke and *Eumorphotis multiformis* (Bittner) in the middle part, and the cephalopods *Hedenstroemia* sp., *Meekoceras boreale* Diener, *M. subcristatum* Kiparisova, *Ambites* sp. indet., and *Gyronautilus praevolutum* (Kiparisova), as well as the brachiopods *Abrekia sulcata* Dagys and *Lingula borealis* Bitner in the upper part (Zakharov and Popov, 1999). These fossils suggest the Upper Induan in the middle part and the Lower Olenekian (lower part of the *Hedenstroemia bosphorensis* Zone) in the upper part of the formation. The Induan/Olenekian boundary is located at 55 m above the base of the formation.

The overlying Zhitkov Formation consists mainly of dark grey siltstone with calcareous nodules and intercalations of fine-grained sandstone. The formation is more than 87.3 m thick in the section studied. The ammonoids *Inyoites spicini* Zakharov, *Parahedenstroemia conspicienda* Zakharov, *Prosphingitoides magnumbilicatus* (Kiparisova), *Dieneroceras* sp., *Meekoceras boreale* Diener, *M. subcristatum* Kiparisova, *Koninckites* aff. *timorense* Wanner, *K. varaha* (Diener), *Arctoceras septentrionale* (Diener), and *Flemingites* sp., as well as the bivalves *Phaedrysmocheilus* sp. and *Promyalina putiatinensis* (Kiparisova) were found in the lower part of the formation, suggesting an early Olenekian age (upper part of the *Hedenstroemia bosphorensis* Zone).

Paleontological description

Order Nautilida Agassiz, 1847
Superfamily Trigonocerataceae Hyatt, 1884
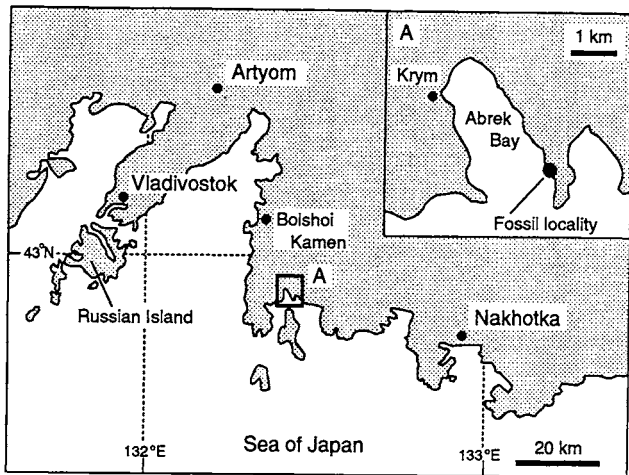Family Grypoceratidae Hyatt in Zittel, 1900

Figure 1. Map showing the fossil locality in South Primorye, Far East Russia.

Subfamily Gyronautilinae, subf. nov.

Diagnosis. — Gyroconic shell with flattened venter. Suture with distinct ventral and lateral lobes.

Composition.—One genus: *Gyronautilus* Zakharov and Shigeta.

Remarks.—Kiparisova (1961) described "*Syringoceras*" *praevolutum* in 1961 from the Lower Triassic of South Primorye and included it in the family Syringonautilidae. Shimansky (1962) recognized four subfamilies in the family Grypoceratidae: Domatoceratinae, Grypoceratinae, Syringonautilinae and Clymenonautilinae. During our investigation of Kiparisova's species we experienced problems with determination of its subfamily assignment, and concluded that it seems to be a representative of a new, previously unknown subfamily of the family Grypoceratidae. However, the nomenclatural and taxonomic history around the type genus of Grypoceratidae, *Grypoceras* Hyatt, 1883 is very complicated (T. Engeser, 2000, personal communication) and was not completely correctly investigated by Engeser and Reitner (1992).

Distribution.—Lower Triassic in South Primorye, Russia.

Genus *Gyronautilus*, gen. nov.

Type species.—*Gyronautilus praevolutum* (Kiparisova).

Diagnosis.—Gyroconic shell with subrectangular whorl-sections and a near-marginal siphuncle. Suture with shallow ventral lobe, broad lateral lobe, and deep dorsal lobe.

Discussion.—The new genus is discussed with *Gyronautilus praevolutum*.

Geological distribution.—Lower Olenekian.

Gyronautilus praevolutum (Kiparisova, 1961)

Figures 2–4

Syringoceras praevolutum Kiparisova, 1961, p.25, pl.4, fig. 2.
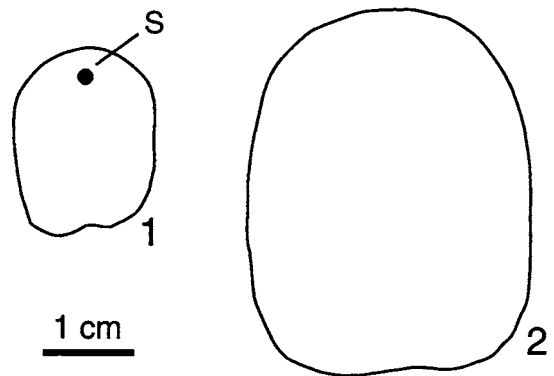
Figure 2. Whorl cross sections of *Gyronautilus praevolutum* (Kiparisova), NSM PM16132, at whorl height of 18.0 mm (1) and 39.3 mm (2). S: siphuncle.

Figure 3. Suture line of *Gyronautilus praevolutum* (Kiparisova), NSM PM16132, at whorl height of 25 mm.

Holotype.—CGM 12/5504 figured by Kiparisova (1961, pl.4, fig.2) from the Lower Triassic (Olenekian?) of Abrek Bay in South Primorye, Russia.

Material.—One specimen, NSM PM16132.

Description.—Shell moderately large, reaching 92.6 mm in diameter, rapidly expanding gyroconic conch, consisting of 1.7 whorls. Embryonic shell 18.2 mm long, exogastrically curved, consisting of 0.4 whorl, attaining 7.4 mm height and 7.0 mm width at nepionic constriction. First whorl subquadrate in cross section, with near-marginal siphuncle, attaining 18.1 mm height and 14.7 mm width: umbilical opening 8.2–13.4 mm across. Adult whorl subrectangular in cross-section with rounded-inflated venter, well-rounded shoulder and concave dorsal side, with near-marginal siphuncle, attaining 39.7 mm height and 36.1 mm width at last septum. Body chamber partly preserved, attaining 45.2 mm height and 36.6 mm width at adoral end. Shell surface not preserved. Suture consisting of shallow ventral lobe, broad lateral lobe, and deep dorsal lobe.

Discussion. — Kiparisova described the only previously known middle stage of *Gyronautilus praevolutum* on the basis of a fragment of the phragmocone reaching 17.0 mm height and 15.0 mm width at the last septum. The specimen described herein is a large and nearly complete one from the embryonic shell to a part of the adult body chamber. Characteristic features described by Kiparisova (1961) are also observed in the middle stage of specimen NSM PM16132.

Gyronautilus praevolutum is placed within the family Grypoceratidae because of its flattened venter and suture with ventral and lateral lobes. Among the previously de-
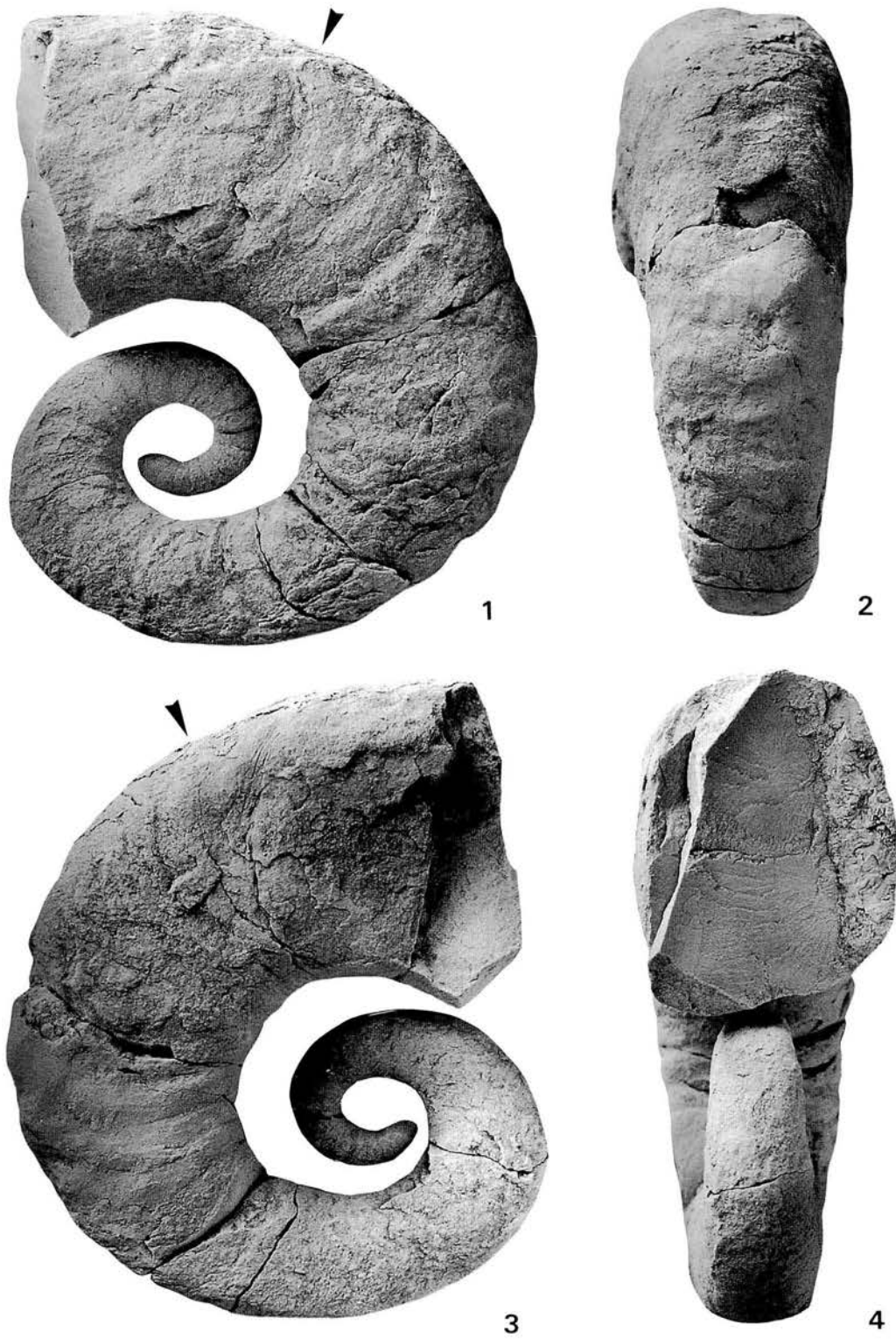
Fugure 4. *Gyronautilus praevolutum* (Kiparisova), NSM PM16132. Right lateral (1), back (2), left lateral (3) and frontal (4) views, ×1.0. Arrow marks indicate the position of the preserved last septum.

scribed genera of the family, the shape of the conch and the suture of *Gyronautilus* show closest affinities with the Permian *Domatoceras*. The sutures of both are similar, with rounded ventral and lateral lobes (Kummel, 1964). *Gyronautilus* shows some affinities to Triassic *Grypoceras* and *Menuthionautilus*, but the latter two differ in the proportions of sutural elements, in general forms of the conch, and in the siphuncle position (Kummel, 1953, 1964). It seems best to consider that Gyronautilinae is an offshoot of Domatoceratinae.

Occurrence.—NSM PM16132 was collected from the uppermost part of the Lazurnaya Bay Formation in the Abrek Bay area, *Hedenstroemia bosphorenses* Zone of the Lower Olenekian.

Acknowledgments

References

Diener, C., 1895: Triadische Cephalopoden der ostsibirischen Küstenprovinz. *Mémoires Comité Géologique St. Pétersbourg*, vol. 14, no. 3, p. 1–59, pls. 1–5.

Engeser, T and Reitner, J., 1992: Description of the first Rhaetian nautiloid (*Grypoceras rhaeticum* n.sp.) from the Kössen Beds of the Fonsjoch area near Achensee (Austria). *Neues Jahrbuch für Geologie und Paläontologie Monatshefte*, 1992, p. 231–241.

Kiparisova, L. D., 1954: *Polevoj atlas kharakternykh kompleksov fauny i flory triasovykh otlozhenij primorskogo kraya.* 125 p. Gosgeoltekhizdat, Moscow. [Field atlas of typical complexes of fauna and flora of Triassic deposits in Primorye region.] (*in Russian*)

Kiparisova, L. D., 1961: Paleontologicheskoe obosnovanie stratigrafii triasovykh otlozhenij primorskogo kraya. 1. Golovonogie mollyuski. *Transactions of All-Union Geological Research Institute (VSEGEI), New Series*, vol. 48, p. 1–278. [Paleontological basis of Triassic stratigraphy of Primorye region. 1. Cephalopods.] (*in Russian*)

Kummel, B., 1953: American Triassic coiled nautiloids. *U.S. Geological Survey Professional Paper*, 250, p. 1–104, pls. 1–19.

Kummel, B., 1964: Nautiloidea-Nautilida. *In*, Moore, R. C. ed., *Treatise on Invertebrate Paleontology. Part K. Mollusca 3*, p. K383–457, The Geological Society of America and the University of Kansas Press.

Shimansky, V.N. 1962: Order Nautilida. *In*, Orlov, Y. A. ed., *Osnovy paleontologii. Mollyuski-golovonogiye.1*, p. 115–154, Izdatel'stvo Akademii Nauk SSSR, Moscow. [Fundamentals of Paleontology. Mollusca-Cephalopoda. 1.] (*in Russian*)

Zakharov, Y. D., 1978: *Rannetriasovye ammonoidei Vostoka SSSR.* 224 p, Nauka, Moscow. [Lower Triassic ammonoids of East USSR.] (*in Russian*)

Zakharov, Y. D./ 1996: The Induan-Olenekian boundary in the Tethys and Boreal realm. *Supplemento agli Annali dei Musei Civici di Rovereto Sezione Archeologia, Storia e Scienze Naturali*, vol. 11, p. 133–156.

Zakharov, Y. D., 1997: Ammonoid evolution and the problem of the stage and substage division of the Lower Triassic. *Mémoires de Géologie (Lausanne)*, vol. 30, p. 121–136.

Zakharov, Y. D. and Popov, A. M., 1999: New data on Induan/Olenekian boundary in South Primorye. *Albertiana*, vol. 22, p. 19.

Discovery of Early Cretaceous (Barremian) decapod Crustacea from the Arida Formation of Wakayama Prefecture, Japan

HIROAKI KARASAWA

Mizunami Fossil Museum, Yamanouchi, Akeyo, Mizunami, Gifu 509-6132, Japan (e-mail: GHA06103@nifty.ne.jp)

Abstract. *Hoploparia* sp. (Astacidea, Nephropidae) and *Callianassa* (s. l.) *sakakuraorum* sp. nov. (Thalassinidea, Callianassidae) are described from the Lower Cretaceous Arida Formation in Wakayama Prefecture, Japan. Both genera are recognized for the first time from Lower Cretaceous (Barremian) deposits of Japan. These occurrences indicate that *Hoploparia* and *Callianassa* reached Japan—the west side of the North Pacific region—by the Barremian.

Introduction

Early Cretaceous decapod Crustacea from Japan previously were only known from the Aptian Miyako Group, northwestern Japan (Takeda and Fujiyama, 1983). The purpose of this paper is to describe two species of decapods, *Hoploparia* sp. (Astacidea, Nephropidae) and *Callianassa* (s. l.) *sakakuraorum* sp. nov. (Thalassinidea, Callianassidae) from the Lower Cretaceous Arida Formation of Wakayama Prefecture, southwestern Japan. Hitherto, *Hoploparia* from the Lower Cretaceous of the North Pacific region has been known from the Hauterivian of Oregon (Feldmann, 1974), while *Callianassa* (s. l.) has not been found in Lower Cretaceous deposits of that region.

The specimens were collected from sandy mudstone exposed at Suhara [Loc. 02 of Komatsu (1999)], Yuasa-cho, Wakayama Prefecture. Obata and Ogawa (1976) and Matsukawa and Obata (1993) indicated that the geologic age of the formation is Barremian. Komatsu (1999) studied the depositional environments and molluscan assemblages of the Arida Formation in the area and divided the formation into four depositional facies. The decapod fossils occurred in his facies 3, which is characterized by the predominant occurrence of *Nanonavis yokoyamai* and seems to indicate an inner-shelf paleoenvironment (Komatsu, 1999).

The described specimens are deposited in the Mizunami Fossil Museum (MFM).

Systematic paleontology

Infraorder Astacidea Latreille, 1802
Superfamily Nephropoidea Dana, 1852
Family Nephropidae Dana, 1852
Subfamily Homarinae Huxley, 1879
Genus *Hoploparia* McCoy, 1849

Hoploparia sp.

Figure 1.1, 1.2

Description. — *Hoploparia* with small-sized body. Carapace laterally compressed. Anterior half of carapace poorly preserved. Rostrum lacking. Surface finely granulated. Postcervical groove deep dorsally, obliquely extending ventrally. Hepatic groove obscurely defined, curving to join antennal and cervical grooves. Cervical groove deep, slightly arcuate, extending ventrally to join antennal groove. Antennal groove nearly straight. Gastro-orbital groove shallow, extending to near upper part of cervical groove. Antennal region with antennal ridge. Dorsal and supraorbital ridges well developed. Intermediate carina weakly developed. Branchial region finely punctuate.

Abdominal somites 1-6 smooth. Pleuron of somite 1 somewhat reduced; posteroventral corner with posteroventrally directed spine. Pleuron of somite 2 subrectangular; anteroventral corner rounded; ventral margin gently convex; posteroventral corner with posteroventrally directed spine; posterior margin gently concave; surface with marginal furrows joining transverse furrow on anterior part of tergum. Pleura of somites 3 and 4 with sharp, posteroventral corners; surfaces with shallow, broad marginal furrow along posterior margin. Pleuron of somite 6 reduced. Telson, uropod and pereiopods unknown.

Discussion.—The carapace with dorsal, supraorbital and antennal ridges readily distinguishes the species from two known Japanese species, *Hoploparia miyamotoi* Karasawa, 1998 from the Maastrichtian Izumi Group and *Hoploparia kamuy* Karasawa and Hayakawa, 2000 from the Turonian-Santonian part of the Upper Yezo Group. *Hoploparia* sp. possesses characters most like those of *Hoploparia collignoni* (Van Straelen, 1949) from the Albian of Madagascar and *Hoploparia riddlensis* Feldmann, 1974
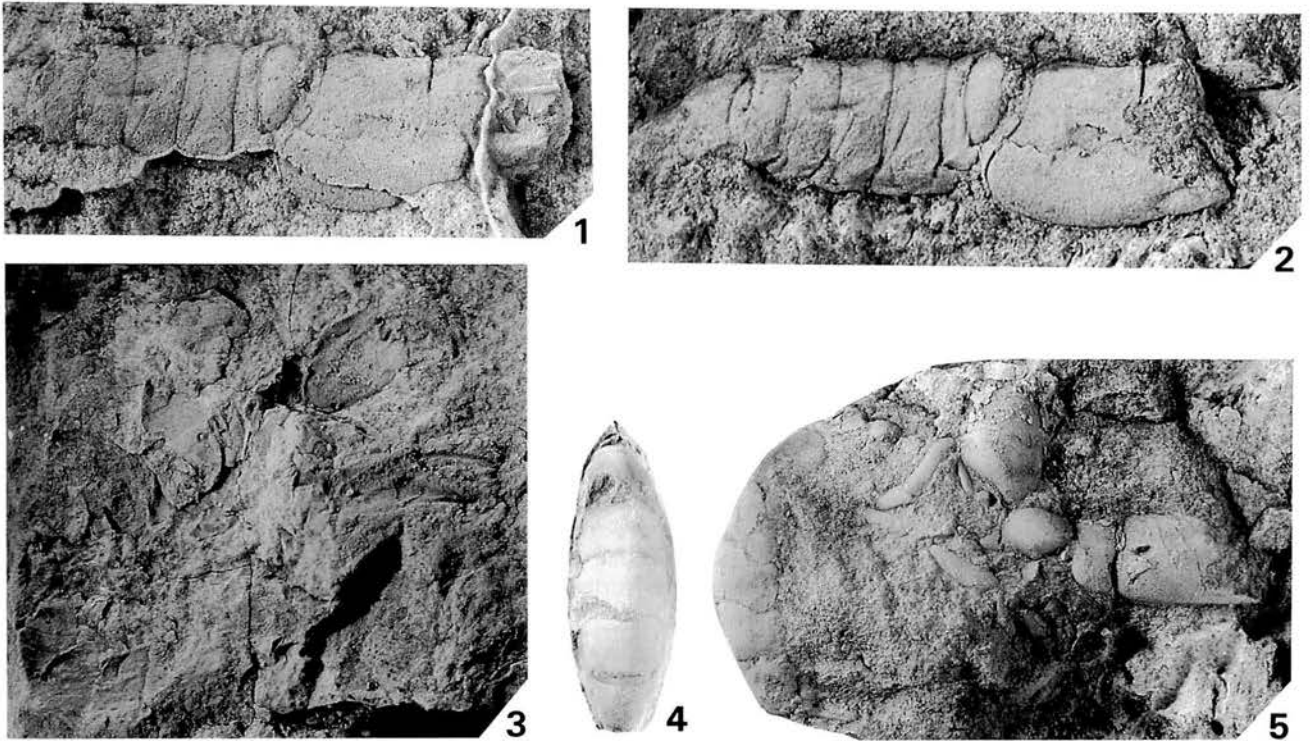
Figure 1. **1, 2.** *Hoploparia* sp., MFM247111, carapace and abdomen. ×2.0. **1:** Latex cast of external mould of the specimen; **2:** lateral view. **3–5.** *Callianassa* (s. l.) *sakakuraorum* sp. nov. **3:** MFM247016 (paratype), external mould of both chelipeds and abdomen, ×2.0, lateral view. **4:** MFM247015 (holotype), abdomen, ×2.0, dorsal view. **5:** MFM247015 (holotype), carapace, cheliped, pereiopods and abdomen, ×2.0, lateral view.

from the Hauterivian of Oregon. However, the present species has well developed supraorbital and antennal ridges on the carapace. *Hoploparia* sp. is similar to *Hoploparia longimana* (Sowerby, 1826) from the Barremian of Argentina and the Aptian-Cenomanian of England, and *Hoploparia mesembria* Etheridge, 1917 from the Albian of Australia, but differs in the presence of an obscurely defined hepatic groove and a well developed antennal ridge. *Hoploparia longimana* and *H. mesembria* possess a dentate supraorbital ridge and an antennal region with three large projections.

Hoploparia, earliest known from the Neocomian of Europe, U. S. A and Argentina (Aguirre-Urreta, 1989), has been recorded from Cretaceous-Palaeogene deposits in Europe, U. S. A, Japan, Argentina, Australia, New Zealand, and Antarctica (Aguirre-Urreta, 1989; Karasawa and Hayakawa, 2000).

Material examined.—MFM247111 collected by Y. Mizuno.

Infraorder Thalassinidea Latreille, 1831
Superfamily Callianassoidea Dana, 1852
Family Callianassidae Dana, 1852
Genus *Callianassa* Leach, 1814

Callianassa (s. l.) *sakakuraorum* sp. nov.

Figure 1.3–1.5

Diagnosis.—Moderate-sized callianassid. Pereiopods 1 chelate, equal-sized, dissimilar. Palm of right cheliped, equal to fixed finger length, slightly longer than high; carpus short, about 1/4 propodus length, height 3/4 length; merus slightly longer than carpus, rhomboidal in lateral view, dorsal and ventral margins strongly convex without meral hook and spines. Propodus of left cheliped about equal to right propodus length, rather slender; palm slightly longer than fixed finger, height about 4/5 length.

Description.—Moderate sized callianassid. Only right branchial region of carapace preserved. Abdominal somite 1 poorly preserved. Somite 2 slightly longer than 3. Pleura of somites 2–5 well developed with rounded posteroventral corner. Pleuron of somite 6 reduced with convergent lateral margins. Telson about equal to length of somite 6 with longitudinal ridge on dorsal surface. Uropod unknown.

Pereiopods 1 chelate, equal-sized, dissimilar. Dactylus of right cheliped strongly curved ventrally with acutely pointed tip; dorsal and occlusal margins smooth. Fixed finger slightly longer than dactylus with acutely pointed tip; occlusal and ventral margins smooth. Palm rectangular in lateral view, equal to fixed finger length, slightly longer than high, with longitudinally convex lateral surface; dorsal and ventral margins smooth. Carpus short, about 1/4 propodus length, height 3/4 length, with nearly straight dorsal margin and strongly curved ventral margin. Merus slightly longer

than carpus, rhomboidal in lateral view, dorsal and ventral margins strongly convex without meral hook; lateral surface strongly vaulted. Ischium poorly preserved, slender without marginal teeth or spines. Propodus of left cheliped about equal to major propodus length, rather slender in outline, occupying about 3/4 major propodus height. Dactylus gently curved ventrally with acutely pointed tip; dorsal and occlusal margins smooth. Fixed finger slightly shorter than dactylus with acutely pointed tip; occlusal and ventral margin smooth. Palm rectangular in lateral view, slightly longer than fixed finger, height about 4/5 length, with smooth dorsal and ventral margins.

Pereiopod 2 not preserved. Carpus and merus of pereiopod 3 preserved; carpus flattened, slender, tapering proximally; merus flattened, about twice length of carpus with straight dorsal and gently convex ventral margins. Propodus, carpus, merus and ischium of pereiopod 4 preserved; propodus small, broken; carpus slender; merus about twice length of carpus; ischium about half carpus length. Pereiopod 5 unknown.

Discussion.—Manning and Felder (1991) recognized two families, seven subfamilies and 21 genera for taxa previously assigned to the extant Callianassidae, whilst Sakai (1999) reexamined all known extant members in the family and recognized four subfamilies and 10 genera. The generic placement of the present species awaits the discovery of better material bearing the maxilliped 3 and the telson, and it is considered best to place the specimen in *Callianassa* (s. l.) for the time being.

The genus *Callianassa* from the Cretaceous of Japan is represented by two species, *"Callianassa" ezoensis* Nagao, 1932 from the Maastrichtian Hakobuchi Sandstone and *Callianassa* (s. l.) *masanorii* Karasawa, 1998 from the Maastrichtian Izumi Group. *Callianassa* (s. l.) *sakakuraorum* differs from *"C." ezoensis* in that pereiopods 1 have dissimilar chelipeds, smooth ventral margins of propodi, and a rhomboidal merus. Equal-sized pereiopods 1 with short fingers and carpi readily distinguish *C.* (s. l.) *sakakuraorum* from *C.* (s. l.) *masanorii.* The new species most resembles *"Callianassa" valida* Rathbun, 1935 from the Lower Cretaceous of Texas, but differs in having a shorter propodus of pereiopod 1 with a smooth dorsal margin and a rhomboidal merus of pereiopod 1. In *C.* (s. l.) *sakakuraorum* the dactylus of pereiopod 1 has a smooth dorsal margin whilst in *"C." valida* it has a serrated dorsal margin.

The earliest known members of *Callianassa* (s. l.) have been recorded from the Neocomian of Europe (Glaessner, 1929) and the Valanginian of Argentina (Aguirre-Urreta, 1989). The Jurassic members of the genus were removed to the axiid genus *Etallonia* Oppel, 1861, by Förster (1977). The known distribution of *Callianassa* (s. l.) is from Upper Cretaceous-Recent worldwide (Glaessner, 1969).

Etymology.—The name is dedicated to Fujio and Norihiko Sakakura.

Material examined.—MFM247015 (holotype) collected by M. Chiba; MFM247016 (paratype) collected by N. Sakakura.

References

Aguirre-Urreta, M. B., 1989: The Cretaceous decapod Crustacea of Argentina and the Antarctic Peninsula. *Palaeontology*, vol. 32, p. 499–552.

Dana, J. D., 1852: Crustacea. *In, United States Exploring Expedition during the Years 1838, 1839, 1840, 1841, 1842 Under the Command of Charles Wilkes, U.S.N.*, vol. 13, 1620 p.

Etheridge, R., 1917: Description of some Queensland Palaeozoic and Mesozoic fossils. 1. Queensland Lower Cretaceous Crustacea. *Publications, Geological Survey of Queensland*, no. 260, p. 7–10.

Feldmann, R. M., 1974: *Hoploparia riddlensis*, a new species of lobster (Decapoda: Nephropidae) from the Days Creek Formation (Hauterivian, Lower Cretaceous) of Oregon. *Journal of Paleontology*, vol. 48, p. 586–593.

Förster, R., 1977: Untersuchungen an jurassischen Thalassinoidea (Crustacea, Decapoda). *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie*, vol. 17, p. 137–156.

Glaessner, M. F., 1929: Crustacea Decapoda, *In*, Pompeckji, F. J. *ed., Fossilium Catalogus*, p. 1–464, W. Junk, Berlin.

Glaessner, M. F., 1969: Decapoda, *In*, Moore, R. C. *ed., Treatise on Invertebrate Paleontology, Part R, Arthropoda 4*, p. R399–651, Geological Society of America and University of Kansas Press.

Huxley, T. H., 1879 [1878]: On the classification and the distribution of the crayfishes. *Proceedings of the Scientific Meetings of the Zoological Society of London*, vol. for 1878, p. 752–788.

Karasawa, H., 1998: Two new species of Decapoda (Crustacea) from the Upper Cretaceous Izumi Group, Japan. *Paleontological Research*, vol. 2, no. 4, p. 217–223.

Karasawa, H. and Hayakawa, H., 2000: Additions to Cretaceous decapod crustaceans from Hokkaido, Japan—Part 1. Nephropidae, Micheleidae and Galatheidae. *Paleontological Research*, vol. 4, no. 2, p. 139–145.

Komatsu, T., 1999: Depositional environments and bivalve fossil assemblages of the Lower Cretaceous Arida Formation, southwest Japan. *The Journal of the Geological Society of Japan*, vol. 105, p. 643–650.

Latreille, P. A., 1802–1803: *Histoire naturelle, générale et particulière, des crustacés et des insectes,* volume 3, 468 p. F. Dufart, Paris.

Latreille, P. A., 1831: *Cours d'Entomologie, ou de l'histoire naturelle des Crustacés, des Arachnides, des Myriapodes et des Insectes, etc.* Annales I. Atlas, 26 p. Roret, Paris.

Leach, W. E., 1814: Crustaceology. *In*, Brewster, D., *Edinburgh Encyclopedia*, vol. 7, p. 385–437.

McCoy, F., 1849: On the classification of some British fossil Crustacea with notices of new forms in the University Collection at Cambridge. *Annals and Magazine of Natural History, Series 2*, vol. 4, p. 161–179, 330–335.

Manning, L. B. and Felder, D. L., 1991: Revision of the American Callianassidae (Crustacea: Decapoda: Thalassinidea). *Proceedings of the Biological Society of Washington*, vol. 104, p. 764–792.

Matsukawa, M. and Obata, I., 1993: The ammonites *Crioceratites* and *Shasticrioceras* from the Barremian of southwest Japan. *Palaeontology*, vol. 36, p. 249–266.

Nagao, T., 1932: Two new decapod species from the Upper Cretaceous deposits of Hokkaidô, Japan. *Journal of the Faculty of Science, Hokkaido Imperial University, series 4*, vol. 2, p. 207–214.

Obata, I. and Ogawa, Y., 1976: Ammonites biostratigraphy of the Cretaceous Arida Formation, Wakayama Prefecture. *Bulletin of the National Science Museum, Series C (Geology & Paleontology)*, vol. 2, p. 93–110.

Oppel, A., 1861: Die Arten der Gattungen *Eryma, Pseudastacus, Magila* und *Etallonia*. *Jahreshefte des Vereins für Vaterländische Naturkunde in Württemberg*, vol. 17, p. 355–364.

Rathbun, M.J., 1935: Fossil Crustacea of the Atlantic and Gulf coastal plain. *Geological Society of America, Special Papers*, no. 2, p. 1–160.

Sakai, K., 1999: Synopsis of the family Callianassidae, with keys to subfamilies, genera and species, and the description of new taxa (Crustacea: Decapoda: Thalassinidea). *Zoologische Verhandelingen*, no. 326, 152 p.

Sowerby, J., 1826: Description of a new species of *Astacus*, found in a fossil state at Lyme Regis. *Zoological Journal*, vol. 2, p. 493–494.

Takeda, M. and Fujiyama, I., 1983: Three decapod crustaceans from the lower Cretaceous Miyako Group, northern Japan. *Bulletin of the National Science Museum, Series C (Geology & Paleontology)*, vol. 9, p. 129–136.

Van Straelen, V., 1949: Crustacés. *In*, Collignon, M., *Recherches sur les faunes albiennes de Madagascar. I. L'Albien d'Ambarimaninga. Annales Géologiques du Service des Mines Madagascar*, vol. 16, p. 99.

Palaeogene decapod Crustacea from the Kishima and Okinoshima Groups, Kyushu, Japan

HIROAKI KARASAWA[1] and YASUHIRO FUDOUJI[2]

[1]Mizunami Fossil Museum, Yamanouchi, Akeyo, Mizunami, Gifu 509-6132, Japan (e-mail: GHA06103@nifty.ne.jp)
[2]Kouda 1754-2-214, Karatsu, Saga 847-0824, Japan

Abstract. Twelve species in 11 genera of decapod crustaceans are recorded from Palaeogene rocks of Nagasaki and Saga Prefectures, Kyushu, Japan. *Carinocarcinoides* gen. nov. (Goneplacidae) is proposed to accommodate *Carinocarcinoides carinatus* sp. nov. and *Varuna angustifrons* Karasawa from the lower Oligocene Kishima Group. A new monotypic genus, *Cicarnus* (Portunidae), is erected with *Cicarnus fumiae* sp. nov. from the middle Eocene Okinoshima Group. *Neocallichirus sakiae* sp. nov. (Callianassidae) is described from the lower Oligocene Kishima Group. *Axius* (s. l.) sp. and *Euphylax*? sp. from the Kishima Group represent the first records for both genera from the Oligocene of Japan. The occurrence of *Minohellenus macrocheilus* Kato and Karasawa extends the known geologic range of this species back to the lower Oligocene. A new description is given for *Collinsius simplex* Karasawa.

Introduction

Previous contributions describing and illustrating decapod species from Palaeogene rocks of Kyushu are rather limited. Yokoyama (1911) was the first to describe two new species, *Xanthilites pentagonalis* and *Homolopsis japonicus*, from the Palaeogene of the Miike Coalfield. Nagao (1941) recorded and illustrated an unnamed *Callianassa* sp. indet. from the Palaeogene of the Asakura Coalfield. Five species in five genera were described from the lower Oligocene Kishima Group in Saga and Nagasaki Prefectures by Imaizumi (1958) and Karasawa (1993, 1997). Inoue (1972) introduced an abundant occurrence of unnamed crabs from the lower Oligocene Kishima Group distributed in the Karatsu Coalfield. Karasawa (1992) described five species from the middle Eocene Manda Group, moved *Xanthilites pentagonalis* to *Branchioplax* Rathbun, 1916 and erected a new monotypic genus *Prohomola* for *Homolopsis japonicus*. Kato and Karasawa (1994) described a new portunid, *Minohellenus macrocheilus* from the upper Oligocene Ashiya Group and additional material of the species was recorded (Kato and Karasawa, 1996).

The purpose of this paper is to describe 12 species in 11 genera, including two new genera and three new species, of decapods from the middle Eocene-lower Oligocene rocks in Saga and Nagasaki Prefectures, Kyushu. New descriptions are given for *Carinocarcinoides angustifrons* (Karasawa, 1993) comb. nov. and *Collinsius simplex* Karasawa, 1993.

The specimens described in the paper are housed in the Mizunami Fossil Museum (MFM).

Localities

Kosasa area (Figure 1A)

Imaizumila sexdentata Karasawa, 1993 occurred in sandstone of the Nagashima Sandstone Member, Haiki Formation, Kishima Group exposed at Takasakiyama (Loc. KSM-1), Usunoura, Kosasa-cho, Kitamatsura-gun, Nagasaki Prefecture. The Haiki Formation was correlated with the Hatatsu Sandstone Member and Yukiaino Sandstone Member of the Kishima Group distributed in the Karatsu-Taku areas (Matsui et al., 1989). According to Okada (1992), the Hatatsu Sandstone Member and Yukiaino Sandstone Member are assigned to Zone CP17 (early Oligocene) of Okada and Bukry's (1980) scale of nannofossils.

Karatsu-Taku areas (Figure 1B)

Eight species in seven genera of decapods (Figure 2) were collected from the Kishima Formation and Yukiaino Sandstone Member of the Kishima Group from 15 localities distributed in the eastern part of Saga Prefecture. Okada (1992) assigned the Kishima Formation to Zone CP16a of Okada and Bukry's nannozones and the Yukiaino Sandstone to Zone CP17. Details of localities are shown in Table 1.
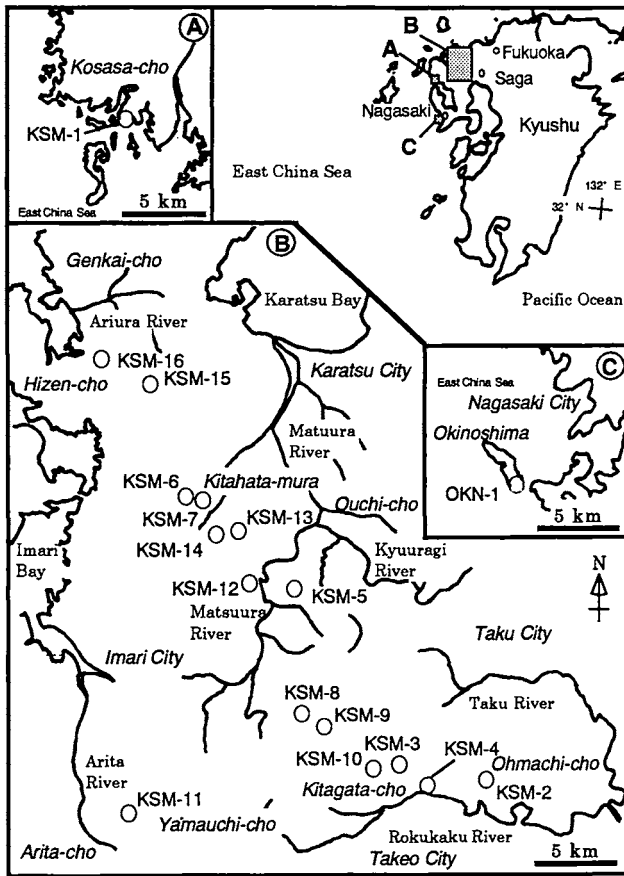
Figure 1. Map showing decapod localities of the studied areas.

Okinoshima area (Figure 1C)

Three species in three genera of decapods (Figure 2) were collected from sandstone of the Okinoshima Formation of the Okinoshima Group exposed at Aze, Iojima-cho, Nagasaki City. The Okinoshima Formation is correlated with the lower part of the Sakasegawa Group in the Amakusa Coalfield and the Nougata Group in the Chikuho Coalfield (Ozaki and Hamasaki, 1991). According to Ozaki and Hamasaki, the formation seems to be assigned to Zones CP13–14 (middle Eocene) by Okada and Bukry's (1980) nannozone.

Summary of the Palaeogene decapod fauna of Kyushu

The decapod fauna from the Okinoshima Group comprises three species, *Callianassa* (s. l.) sp., *Raninoides nodai* Karasawa, 1992 and *Cicarnus fumiae* gen. et sp. nov. (Figure 2). Previously known decapods from the middle Eocene rocks are recorded from the Dosi and Kawamagari Formations (Nagao, 1941) and the Manda Group (Yokoyama, 1911; Karasawa, 1992). *Callianassa* (s. l.) sp. is known from the Dosi and Kawamagari Formations and *R. nodai* from the Manda Group. *Cicarnus* is only known from the Okinoshima Group. The middle Eocene decapod fauna has close affinities with those of the western-central Tethys region, based on the occurrences of *Prohomola*, *Portunites* and *Branchioplax* from the Manda Group (Karasawa, 1992, 1999).

The early Oligocene decapod fauna from the Kishima Group is represented by nine species in eight genera (Figure 2). The fauna from the Kishima Formation is characterized by the abundant occurrence of *Collinsius simplex* Karasawa, 1993, whilst from the Yukiaino Sandstone Member it is char-

Age	Middle Eocene	Early Oligocene															
Nanno Zone by Okada & Bukry (1980)	CP13-14	CP16a										CP17					
Formation	Okinoshima G.	Kishima Group															
	Okinoshima F.	Kishima Formation										Yukiaino Sandstone M.					Haiki F.
Locality		KSM-															
Species	OKN-1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1
Axius (s.l.) sp.						X											
Ctenocheles sujakui Imaizumi, 1958		X	X	X		X											
Callianassa (s.l.) sp.	X																
Neocallichirus sakiae sp. nov.												X	X	X	X	X	
Raninoides nodai Karasawa, 1992	X																
Imaizumila sexdentata Karasawa, 1993																	X
Cicarnus fumiae gen. et sp. nov.	X																
Minohellenus macrocheilus Kato and Karasawa, 1994						X										X	
Euphylax ? sp.		X															
Carinocarcinoides angustifrons (Karasawa, 1993) comb. nov.	X																
Carinocarcinoides carinatus gen. et sp. nov.										X							
Collinsius simplex Karasawa, 1993		X	X	X	X	X	X	X	X	X							

Figure 2. List of fossil decapods from the studied areas. Locality numbers are shown in Figure 1.

Table 1. List of decapod-bearing localities of the Karatsu-Taku areas.

Loc. no.	Locality	Formation
KSM-2	Hatada, Ohmachi, Ohmachi-cho, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-3	Magami, Osaki, Kitagata-cho, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-4	SE of Magami, Osaki, Kitagata-cho, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-5	Tatsugawa, Okawa-cho, Imari City, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-6	Shimohirano, Kitahata-mura, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-7	Shimohiranotoge, Kitahata-mura, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-8	Sarajuku, Takeo City, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-9	Wakagi, Takeo City, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-10	Takatori, Kitagata-cho, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-11	Oubounotoge, Arita-cho, Saga Prefecture	Sandy mudstone of the Kishima Formation, Kishima Group
KSM-12	Komanaki, Okawa-cho, Imari City, Saga Prefecture	Sandstone of the Yukiaino Sandstone Member, Kishima Group
KSM-13	Shige, Kitahata-mura, Saga Prefecture	Sandstone of the Yukiaino Sandstone Member, Kishima Group
KSM-14	Tuzumi, Minamihata-cho, Imari City, Saga Prefecture	Sandstone of the Yukiaino Sandstone Member, Kishima Group
KSM-15	Kirigo, Hizen-cho, Saga Prefecture	Sandstone of the Yukiaino Sandstone Member, Kishima Group
KSM-16	Sosorogawachi, Genkai-cho, Saga Prefecture	Sandstone of the Yukiaino Sandstone Member, Kishima Group

acterized by the frequent occurrence of *Neocallichirus sakiae* sp. nov. Among the known genera from the Kishima Group, *Carinocarcinoides* and *Collinsius* are Japanese early Oligocene endemic genera; *Imaizumila* is only known from the Oligocene of Japan and the Eocene-Miocene of Chile (Schweitzer and Feldmann, 2000); *Minohellenus* occurs outside of Japan in Oligocene-Miocene rocks of Washington and Oregon (Schweitzer and Feldmann, 2000). *Axius* (s. l.), *Ctenocheles*, *Callianassa* (s. l.) and *Neocallichirus* are cosmopolitan. *Euphylax* occurs in the Caribbean and East Pacific Ocean at the present day, but the fossil record seems to extend to the lower Oligocene of Japan. Karasawa (1999) suggested that the Tethyan genera *Prohomola*, *Portunites* and *Branchioplax* disappeared by the Oligocene and that the decapod fauna of southwest Japan appears to become endemic in the early Oligocene.

Systematic paleontology

Infraorder Thalassinidea Latreille, 1831
Superfamily Axioidea Huxley, 1879
Family Axiidae Huxley, 1879
Genus *Axius* Leach, 1814

Type species.—*Axius stirhynchus* Leach, 1814 by monotypy.
Geologic range.—Oligocene to Recent.

Axius (s. l.) sp.

Figure 3.1a–c

Description. — Anterior half of carapace preserved but lacks rostrum. Anterolateral margin unarmed. Gastric region convex; median carina smooth, well marked, extending from anterior margin to posterior fourth of gastric region; lat-

eral carinae weak, extending from anterior margin to anterior third of gastric region. Cervical groove well developed, reaching anteroventrally to hepatic region. Postcervical region of carapace glabrous. Pereiopods 1-3 preserved. Meri of both pereiopods 1 flattened laterally, lateral surface smooth, dorsal and ventral margins pitted, without spines. Palm and carpus of pereiopod 2 compressed laterally; lateral surface, dorsal and ventral margins smooth. Carpus and merus of pereiopod 3 cylindrical in cross section, without marginal spines.

Discussion.—Poore (1994) recognized four families and 32 genera for taxa previously assigned to the extant Axiidae. The definition of the extant axiids includes detailed characters of eyes, antennae, pleopods, and uropods, which are not available for study in fossil specimens. The present species is assigned to *Axius* (s. l.) by having a carapace with a well defined cervical groove and without *linea thalassinicae*. The single incomplete specimen renders generic placement obscure and it is considered best to place the specimen in *Axius* (s. l.).

Previously known fossil members of *Axius* (s. l.) are recorded from the Oligocene of Panama and the Pliocene of France (Glaessner, 1969).
Material examined.—MFM218633 from KSM-6.

Superfamily Callianassoidea Dana, 1852
Family Ctenochelidae Manning and Felder, 1991
Subfamily Ctenochelinae Manning and Felder, 1991
Genus *Ctenocheles* Kishinoue, 1926

Type species. — *Ctenocheles balssi* Kishinoue, 1926 by monotypy.
Geologic range.—Late Cretaceous to Recent.
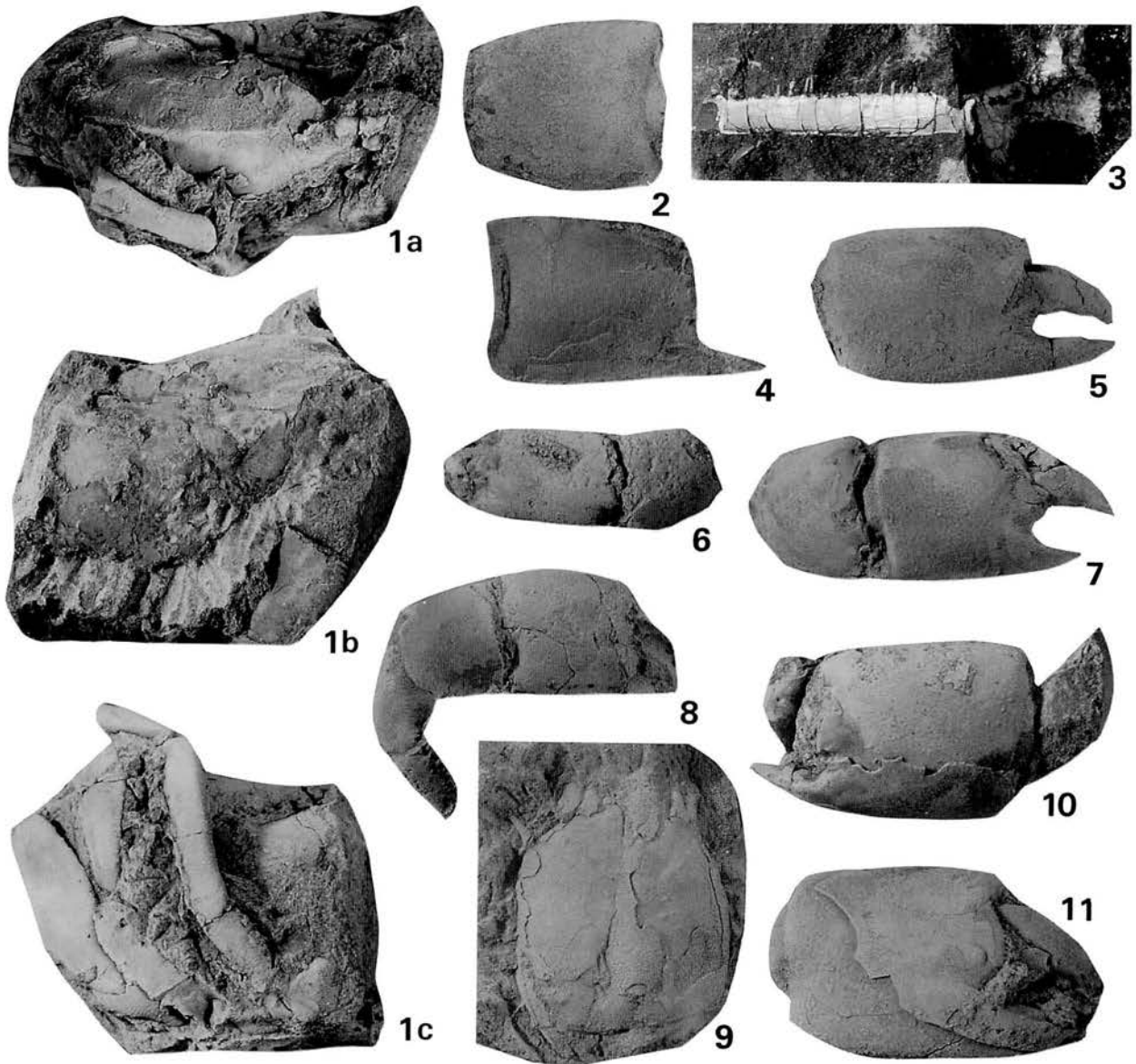
Figure 3. **1a–c**. *Axius* (s. l.) sp., MFM218633, ×1.8; **1a**: carapace, dorsal view; **1b**: carapace and pereiopod 1, lateral view; **1c**: carapace and pereiopods 1–3, lateral view. **2, 4**. *Callianassa* (s. l.) sp., ×1.2; **2**, carpus of major cheliped, lateral view; **4**: propodus of major cheliped, mesial view. **3**. *Ctenocheles sujakui* Imaizumi, 1958, MFM218631, fixed finger of major cheliped, ×1.8, lateral view. **5–8, 10, 11**. *Neocallichirus sakiae* sp. nov.; **5**: MFM218516 (paratype), major cheliped, ×1.5, lateral view; **6**: MFM218515 (holotype), minor cheliped, ×2.5, lateral view; **7**: MFM218519 (paratype), major cheliped, ×1.5, lateral view; **8**, MFM218515 (holotype), major cheliped, ×1.5, lateral view; **10**: MFM218518 (paratype), major cheliped, ×1.5, lateral view; **11**, MFM218517 (paratype), major cheliped, ×1.5, lateral view. **9**: *Raninoides nodai* Karasawa, 1992, MFM218636, carapace, ×1.5, dorsal view.

Ctenocheles sujakui Imaizumi, 1958

Figure 3.3

Ctenocheles sujakui Imaizumi, 1958, p. 301, pl. 44, figs. 2–5; Karasawa, 1997, p. 31, pl. 3, figs. 5, 7.

Remarks.—Imaizumi (1958) originally described the species from the lower Oligocene Kishima Formation of Nagao, Taku City, Saga Prefecture.

Material examined. — MFM218631 and 218632 from KSM-3; referred specimens from KSM-2, 4, 7.

Family Callianassidae Dana, 1852
Subfamily Callianassinae Dana, 1852

Remarks.—Manning and Felder (1991) recognized two families, seven subfamilies and 21 genera for taxa previously assigned to the extant Callianassidae. According to Manning and Felder's (1991) classification, Poore (1994) gave keys to 20 genera in the extant Callianassidae. Since then, four genera, *Grynaminna* Poore, 2000, *Necallianassa* Heard and Manning, 1998, *Nihonotrypaea* Manning and Tamaki, 1998, and *Pseudobiffarius* Heard and Manning, 2000, have been described. Fossil taxa have traditionally been assigned to *Callianassa* (s. l.); however, recent studies have employed the classification of Manning and Felder (Karasawa, 1992, 1993, 1997; Karasawa and Goda,1996; Kato, 1996; Schweitzer Hopkins and Feldmann,1997; Stilwell *et al.*, 1997; Vega *et al.*, 1995). Sakai (1999) reexamined all known extant members in the family Callianassidae and recognized four subfamilies and 10 genera in the family. The classification of Callianassidae by Sakai is quite different from Manning and Felder's (1991) system. After that, Sakai and Türkay (1999) erected a new subfamily Bathycalliacinae with a new genus *Bathycalliax*. Therefore, the fossil species referred to the Callianassidae are in need of reexamination.

Genus *Callianassa* Leach, 1814

Type species.—*Cancer* (*Astacus*) *subterraneus* Montagu, 1808 by monotypy.
Geologic range.—Cretaceous to Recent.

Callianassa (s. l.) sp.

Figure 3.2, 3.4

Callianassa sp. indet.; Nagao, 1941, p. 85, pl. 26, figs. 8, 9.

Description.—Propodus and carpus of major cheliped preserved. Fixed finger short, about 0.3 propodus length, with acutely pointed tip. Palm subrectangular in lateral view, longer than high, with distally convergent dorsal and ventral margins. Carpus subrectangular in lateral view, equal to palm length; dorsal and ventral margins divergent distally.

Discussion.—The generic placement of the present species awaits the discovery of better material and it is considered best to place the species in *Callianassa* (s. l.). The known Japanese Palaeogene species formerly placed in the genus *Callianassa* comprise five species, *Callianassa elongatodigitata* Nagao, 1941, *Callianassa isikariensis* Nagao and Ôtatume, 1938, *Callianassa kushiroensis* Nagao, 1941 and *Callianassa muratai* Nagao, 1932 of Hokkaido, and *Callianassa* sp. indet. (Nagao, 1941) of Kyushu. Among these, *C. muratai* and *C. elongatodigitata* were moved to the genus *Callianopsis* De Saint Laurent, 1973 in the family Ctenochelidae by Kato and Karasawa (1994). The present species differs from *C. ishikariensis* and *C. kushiroensis* in that the major cheliped has a short fixed finger and a palm with distally convergent dorsal and ventral margins. The species is identical with *Callianassa* sp. indet. described from the middle Eocene Dosi and

Kawamagari Formations of Fukuoka Prefecture by Nagao (1941).
Material examined. — MFM218634 and 218635 from OKN-1.

Subfamily Callichirinae Manning and Felder, 1991
Genus *Neocallichirus* Sakai, 1988

Type species. — *Neocallichirus horneri* Sakai, 1988 by original designation.
Geologic range.—Oligocene to Recent.

Neocallichirus sakiae sp. nov.

Figure 3.5-3.8, 3.10, 3.11

Etymology.—The specific name is in honor of Miss Saki Fudouji.
Diagnosis.—Chelipeds large, unequal, dissimilar. Dorsal margin of dactylus of major cheliped smooth; occlusal margin with broad tooth on midlength. Fixed finger shorter than dactylus; occlusal margin with broad tooth on proximal half. Palm rectangular, about 1.3 times longer than high, 1.3 propodus length, with serrated distal margin. Carpus subrectangular, about 0.6 palm length, slightly higher than long. Merus equal to palm length, about 0.6 times higher than long; ventral margin strongly convex without ventral hook. Ischium with dentate ventral margin.
Description.—Chelipeds large in size, unequal, dissimilar. Dactylus of major cheliped curved ventrally with acutely pointed tip; dorsal margin smooth with 4 setal pits; occlusal margin bearing broad tooth at midlength; lateral surface inflated with 4 setal pits parallel to occlusal margin. Fixed finger about 0.75 dactylus length with acutely pointed tip; occlusal margin bearing broad tooth on proximal half; ventral margin smooth; lateral surface slightly convex with row of setal pits parallel occlusal and ventral margins. Palm rectangular in lateral view, about 1.3 times longer than high, 1.3 propodus length; dorsal margin slightly convex; ventral margin nearly straight; distal margin gently convex, serrate; lateral surface longitudinally inflated with row of setal pits parallel to ventral margin. Carpus subrectangular in lateral view, about 0.6 palm length, slightly higher than long, tapering proximally, with convex lateral surface. Merus equal to palm length, about 0.6 times higher than long; dorsal margin gently convex; ventral margin strongly convex without ventral hook; lateral surface with longitudinal ridge. Ischium poorly preserved, about as long as merus, ventral margin dentate.

Fingers of minor cheliped poorly preserved. Palm rectangular in lateral view, occupying about half palm length of major cheliped, slightly longer than high, with convex lateral surface; dorsal margin smooth, ventral margin pitted. Carpus rectangular, about 0.75 palm length, with convex lateral surface, its length equal to height.

Discussion.—The Japanese fossil *Neocallichirus* is represented by three species, *Neocallichirus bona* (Imaizumi, 1959) from the Miocene Moniwa Formation and Mizunami Group (Karasawa, 1993, 1997), *Neocallichirus grandis* Karasawa and Goda, 1996, from the middle Pleistocene Atsumi Group (Karasawa and Goda, 1996) and the middle-

upper Pleistocene Shimosa Group (Kato and Karasawa, 1998), and *Neocallichirus okamotoi* (Karasawa, 1993) from the upper Oligocene Hioki Group (Karasawa, 1993, 1997). Among these, the new species most resembles *N. okamotoi* but differs in that the major cheliped has broad teeth on the occlusal margin of both fingers, a longer palm with a serrated, convex distal margin and a shorter carpus. The merus on the major cheliped without marginal denticules and a short merus readily distinguish *N. sakiae* from *N. bona* and *N. grandis.*

Material examined.—MFM218515 (holotype) and 218516 (paratype) from KSM-12; MFM218517 (paratype) and 218518 (paratype) from KSM-16; MFM218519 (paratype) from KSM-14; referred specimens from KSM-13, 14, 15.

Infraorder Brachyura Latreille, 1802
Section Podotremata Guinot, 1977
Superfamily Raninoidea De Haan, 1841
Family Raninidae De Haan, 1841
Subfamily Raninoidinae Lörenthey in Lörenthey
and Beurlen, 1929
Genus *Raninoides* H. Milne Edwards, 1837

Type species.—Ranina loevis Latreille, 1825 by monotypy.
Geologic range.—Palaeocene to Eocene.

Raninoides nodai Karasawa, 1992

Figure 3.9

Raninoides nodai Karasawa, 1992, p. 1252, figs. 4.2 – 4.8; Karasawa, 1997, p. 39, pl. 7, figs. 7, 9, 11.
Laeviranina nodai (Karasawa); Tucker, 1998, p. 351.

Remarks. — Tucker (1998) provisionally placed *Raninoides nodai* in *Laeviranina* Lörenthey in Lórenthey and Beurlen, 1929. However, this species should be assigned to *Raninoides* based upon the absence of the postfrontal ridge on the carapace.
Material examined.—MFM218636 from OKN-1.

Section Heterotremata Guinot, 1977
Superfamily Portunoidea Rafinesque, 1815
Family Portunidae Rafinesque, 1815
Subfamily Carcininae MacLeay, 1838
Genus *Cicarnus* gen. nov.

Type species.—Cicarnus fumiae sp. nov. by monotypy.
Etymology.—Cicarnus is an anagram of *Carcinus* Leach, 1814; masculine gender.
Diagnosis.—Carapace transversely hexagonal in outline, length about 0.8 its width. Orbitofrontal margin wide. Front with 3 rounded lobes, separated from small, bluntly triangular supraorbital angle by shallow V-shaped notch. Upper orbital margin with 2 open fissures. Anterolateral margin convex, bearing 4 well developed teeth. Dorsal surface smooth, moderately convex. Regions well defined. Epigastric region transversely raised anteriorly. Protogastric region inflated with transverse ridge on each side. Mesogastric region bearing anterior transverse ridge.

Cervical groove well defined. Epibranchial region more inflated. Branchiocardiac grooves poorly defined.
Discussion.—The subfamily Carcininae is defined by the following characters: The carapace is not broad with four or five anterolateral teeth; chelae are short; pereiopods 2-5 are similar and rather stout, and the pereiopod 5 has a lanceolate dactylus [modified from Glaessner (1969)]. Although carapace characters of Carcininae overlap those of the subfamily Polybiinae Ortmann, 1893, Polybiinae are distinguished from Carcininae by having a paddle-like pereiopod 5 (Glaessner, 1969; Schweitzer and Feldmann, 2000).

The Recent Carcininae comprises six genera, *Benthochascon* Alcock and Anderson, 1899, *Brusinia* Stevčić, 1991, *Carcinus* Leach, 1814, *Nectocarcinus* A. Milne Edwards, 1860, *Portumnus* Leach, 1814 and *Xaiva* MacLeay, 1838 (Moosa, 1996). Three extinct genera, *Portunites* Bell, 1858, *Pleolobites* Remy, 1960 and *Mioxaiva* Müller, 1979, were previously assigned to the subfamily (Glaessner, 1969; Müller, 1979). Schweitzer and Feldmann (2000) and Schweitzer *et al.* (2000) removed *Portunites* to Polybiinae based upon the presence of a paddle-like pereiopod 5. The position of *Pleolobites* and *Mioxaiva* within Carcininae is doubtful (Glaessner,1969; Müller, 1984).

The present new genus and species are represented by a single carapace specimen, and chelipeds and pereiopods are not preserved. However, *Cicarnus* possesses carapace characters most like those of *Benthochascon, Carcinus* and *Nectocarcinus,* and may be assigned to Carcininae. *Cicarnus* is most similar to *Nectocarcinus,* but differs in having well developed anterolateral teeth, the frontal margin composed of three rounded lobes, and a smooth dorsal carapace. The mesogastric region in *Cicarnus* has a transverse ridge interrupted by a shallow median groove. With respect to the front which is composed of three rounded lobes, the new genus resembles *Benthochascon* and *Carcinus. Cicarnus* differs from *Carcinus* in having four anterolateral teeth and well defined dorsal regions. Although *Cicarnus* together with *Benthochascon* bears four anterolateral teeth, in *Cicarnus* the dorsal regions are well defined and a wide anterolateral margin bears well separated teeth.
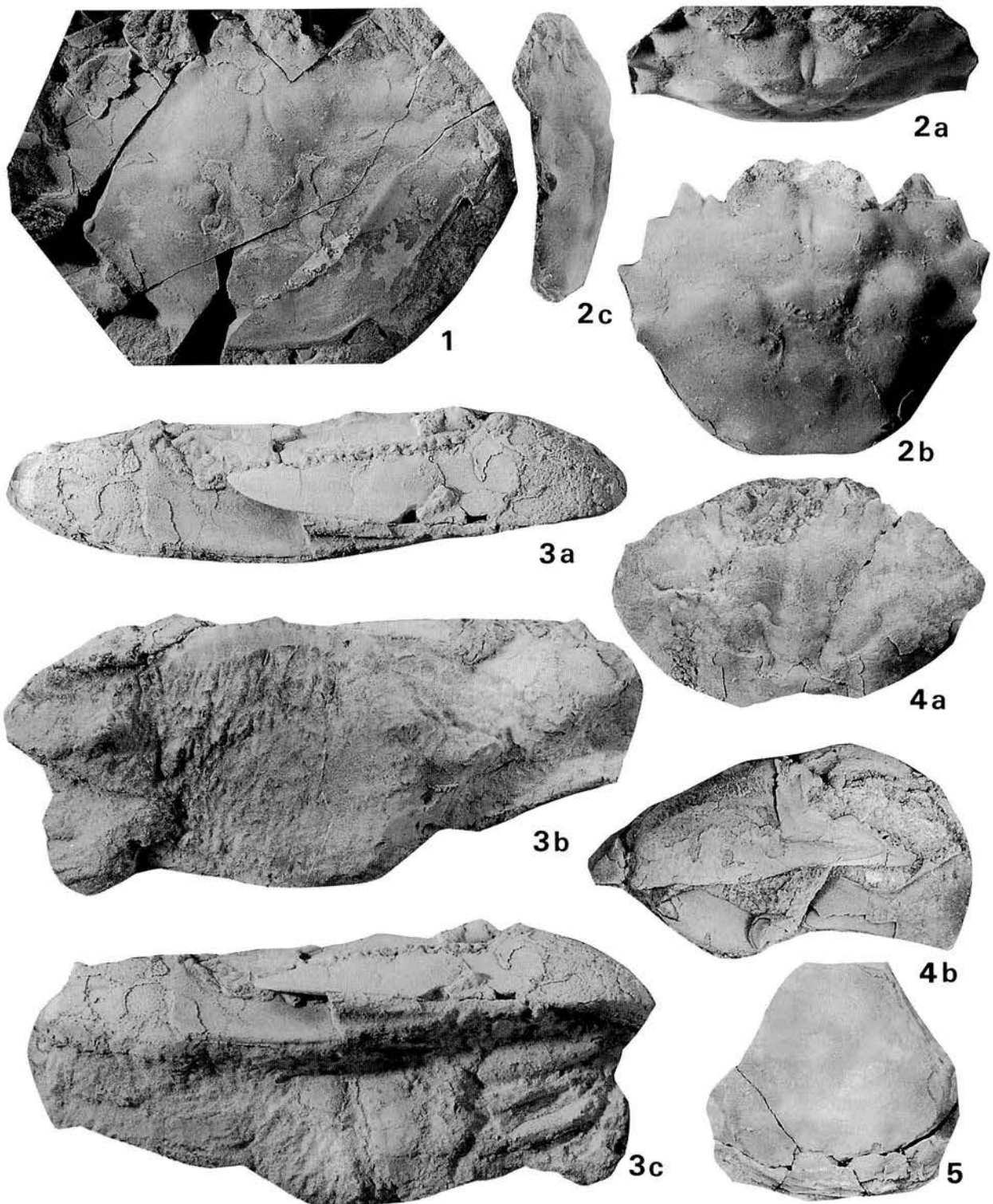
Cicarnus fumiae sp. nov.

Figure 4.2a–c

Etymology.—The specific name is in honor of Mrs. Fumie Karasawa.
Diagnosis.—As for the genus.
Description.—Carapace hexagonal in outline, length about 0.8 its width. Orbitofrontal margin wide, occupying 0.6 carapace width. Front composed of 3 rounded lobes, occupying about 0.3 carapace width, separated from small, bluntly triangular supraorbital angle by shallow V-shaped notch; median frontal lobe small and laterals broad. Upper orbital margin concave, bearing shallow fissure at about midwidth of orbit and shallower fissure anterior to outer orbital tooth. Anterolateral margin convex, occupying about 0.45 carapace width, bearing 4 well separated teeth including outer orbital tooth; outer orbital tooth acutely triangular,

Figure 4. **1.** *Imaizumila sexdentata* Karasawa, 1993, MFM218507 (holotype), carapace, ×1.2, dorsal view. **2a–c.** *Cicarnus fumiae* gen. et sp. nov., MFM218512 (holotype), ×1.5, **2a**: frontal view; **2b**: dorsal view; **2c**: lateral view. **3a–c.** *Euphylax* ? sp., MFM218639, ×1.0; **3a**: both chelipeds, lateral view; **3b**: carapace, cheliped and pereiopods, dorsal view; **3c**: thoracic sternum, chelipeds and pereiopods, ventral view. **4a, b, 5.** *Minohellenus macrocheilus* Kato and Karasawa, 1994, ×1.2; **4a**: MFM218637, carapace, dorsal view; **4b**: MFM218637, right cheliped, lateral view; **5**: MFM218638, carapace, dorsal view.

directed anteriorly; second broadly triangular, slightly directed anterolaterally and dorsally; third acutely triangular, directed anterolaterally and dorsally; last lacking tip, but directed laterally and dorsally. Posterolateral margin sinuous, slightly longer than anterolateral margin. Posterior margin nearly straight, slightly longer than posterolateral margin.

Dorsal surface smooth, moderately convex, with well defined regions. Epigastric region transversely raised anteriorly. Protogastric region inflated, well separated from narrow anterior mesogastric process, with transverse ridge on each side. Mesogastric region convex, pentagonal in outline, bearing anterior transverse ridge divided into two by shallow median depression. Urogastric region narrow, depressed. Cervical groove well defined. Cardiac region slightly convex, hexagonal in outline, bearing two nodes transversely arranged. Intestinal region depressed. Hepatic region slightly convex. Epibranchial region more inflated, shallowly separated from mesobranchial region. Meso- and metabranchial regions also inflated. Branchiocardiac grooves poorly defined.

Discussion.—As for the genus.

Material examined.—MFM218512 (holotype) from OKN-1.

Subfamily Polybiinae Ortmann, 1893
Genus *Imaizumila* Karasawa, 1993

Type species.—*Imaizumila sexdentata* Karasawa, 1993 by monotypy.

Geologic range.—Eocene to Middle Miocene.

Imaizumila sexdentata Karasawa, 1993

Figure 4.1

Imaizumila sexdentata Karasawa, 1993, p. 52, pl. 11, figs. 1-3; Karasawa, 1997, p. 48, pl. 11, figs. 8, 12.

Remarks.—Previously specimens were recorded only from the lower Oligocene Haiki Formation of the Kishima Group (Karasawa, 1993). Schweitzer and Feldmann (2000) described an additional species, *Imaizumila araucana* (Philippi, 1887) from the Eocene-Miocene of Chile.

Material examined.—MFM218507 (holotype) and 218508 (paratype) from KSM-1.

Genus *Minohellenus* Karasawa, 1990

Type species.—*Charybdis* (*Minohellenus*) *quinquedentata* Karasawa, 1990 by monotypy.

Geologic range.—Early Oligocene to Middle Miocene.

Minohellenus macrocheilus Kato and Karasawa, 1994

Figure 4.4a, b, 4.5

Minohellenus macrocheilus Kato and Karasawa, 1994, p. 55, fig. 2; pl. 4, figs. 1-4; Kato and Karasawa, 1996, p. 31, pl. 10, figs. a-c; Karasawa, 1997, p. 49, pl. 14, figs. 2-7.

Remarks.—Previously known specimens were recorded from the upper Oligocene Ashiya Group (Kato and

Karasawa, 1994, 1996). The discovery of *M. macrocheilus* from the Kishima Group extends the geologic range for the species back to the early Oligocene.

Material examined.—MFM218637 from KSM-16; MFM 218638 from KSM-6.

Subfamily Podophthalminae Miers, 1886
Genus *Euphylax* Stimpson, 1860

Type species.—*Euphylax dovii* Stimpson, 1860 by monotypy.

Geologic range.—Oligocene to Recent.

Euphylax ? sp.

Figure 4.3a-c

Description.—Right half of carapace poorly preserved; upper orbital margin wide, gently convex; anterolateral margin narrow with laterally directed stout spine; posterolateral margin sinuous. Thoracic sternum wide, sternites 4-7 preserved.

Chelipeds similar. Dactylus slender, elongate, with smooth dorsal margin and irregularly dentate opposing margin. Fixed finger elongate, about 0.3 times higher than long proximally, with acutely pointed tip; occlusal margin straight, irregularly dentate; ventral margin convex, smooth. Palm short, about 0.75 fixed finger length, about 0.6 times longer than high, converging proximally; dorsal surface tuberculated; ventral margin smooth.

Meri of pereiopods 2 and 3 ovate in cross section.

Discussion.—There is, in the general outline of chelipeds, similarity between the species and *Euphylax domingensis* (Rathbun, 1919) from the lower Miocene? of Haiti, but this species has a slender dactylus and a short palm without carinae on the lateral margin. However, a well preserved carapace of this species is needed to qualify the systematic position.

Material examined.—MFM218639 from KSM-3.

Superfamily Xanthoidea MacLeay, 1838
Family Goneplacidae MacLeay, 1838
Subfamily Carcinoplacinae H. Milne Edwards, 1852
Carinocarcinoides gen. nov.

Type species.—*Carinocarcinoides carinatus* sp. nov. by present designation.

Etymology.—The genus is named in allusion to its close resemblance to *Carinocarcinus* Lörenthey, 1898; masculine gender.

Diagnosis.—Carapace transversely hexagonal to roundly quadrate in outline, widest at anterolateral angle. Orbitofrontal margin wide. Front nearly straight with sharply squared corners. Upper orbital margin concave with triangular, forwardly directed outer orbital spine and without fissures. Inner suborbital tooth sharp, projecting anteriorly. Anterolateral margin strongly convex with 2 small, anterolaterally directed spines exclusive of outer orbital spine. Dorsal surface smooth, moderately vaulted transversely and weakly vaulted longitudinally. Regions distinct. Protogastric, cardiac and epigastric ridges present.

Anterior mesogastric process poorly defined. Cervical and branchiocardiac grooves well defined. Thoracic sternum narrow, longer than wide, tapering anteriorly and posteriorly. Chelipeds large; dactylus, palm and carpus finely granulate on dorsal and lateral surfaces.

Discussion. — *Carinocarcinoides* possesses characters most like those of the extant genera *Carcinoplax* H. Milne Edwards, 1852 and *Homoioplax* Rathbun, 1914. However, *Carinocarcinoides* has a dorsal carapace with well defined regions and several ridges. The thoracic sternum of the new genus is much narrower than that of *Carcinoplax*. Of the extinct genera within Carcinoplacinae, *Carinocarcinoides* is most similar to *Carinocarcinus* Lórenthey, 1898, a monotypic genus from the middle Eocene of Hungary, but differs in having a straight front with sharp lateral corners, three anterolateral teeth including the outer orbital spine, and a protogastric ridge.

The new genus is represented by two species, *Carinocarcinoides angustifrons* (Karasawa, 1993) comb. nov. and *Carinocarcinoides carinatus* sp. nov., from the lower Oligocene Kishima Group.

Carinocarcinoides angustifrons
(Karasawa, 1993) comb. nov.

Figure 5.3

Varuna angustifrons Karasawa, 1993, p. 81, pl. 23, fig. 13; Karasawa, 1997, p. 69, pl. 27, fig. 8.

Revised diagnosis. — *Carinocarcinoides* with rounded-quadrate carapace and with epigastric, protogastric, cardiac and epibranchial ridges.

Revised description. — Carapace roundly quadrate in outline, about as long as wide, widest at midlength. Orbitofrontal margin 0.75 carapace width. Front straight, occupying about 0.3 carapace width, with sharp lateral corners. Upper orbital margin wide, concave, rimmed, with small, forwardly directed outer orbital spine. Anterolateral margin gently convex, about 0.4 carapace width, with two small spines excluding outer orbital spine. Posterolateral margin also strongly convex, about 1.4 times as long as anterolateral margin. Posterior margin straight, about 0.4 carapace width.

Dorsal surface smooth, moderately vaulted transversely and weakly vaulted longitudinally. Regions somewhat distinct. Epigastric region with weak, transverse ridge on each side. Protogastric regions inflated with broad, transverse ridge interrupted by narrow anterior mesogastric process. Anterior mesogastric process poorly defined. Mesogastic region slightly convex. Cervical groove distinct, sinuous. Cardiac region gently inflated transversely, hexagonal in outline, bearing two nodes transversely arranged, with anterior transverse ridge. Intestinal region poorly defined. Hepatic region depressed. Branchiocardiac grooves shallow. Branchial regions convex; each epibranchial region inflated with broad ridge extending in convex-forward arc from mesogastric region to last anterolateral spine.

Discussion. — The present species was originally placed in *Varuna* H. Milne Edwards, 1852 in the family Grapsidae. However, the species is moved here from *Varuna* to *Carinocarcinoides* on the basis of its inflated dorsal carapace with several ridges and three anterolateral spines. Members of *Varuna* have a flattened dorsal surface with a wider frontal margin and three broadly triangular anterolateral teeth.

Material examined.—MFM218501 (holotype) from KSM-2.

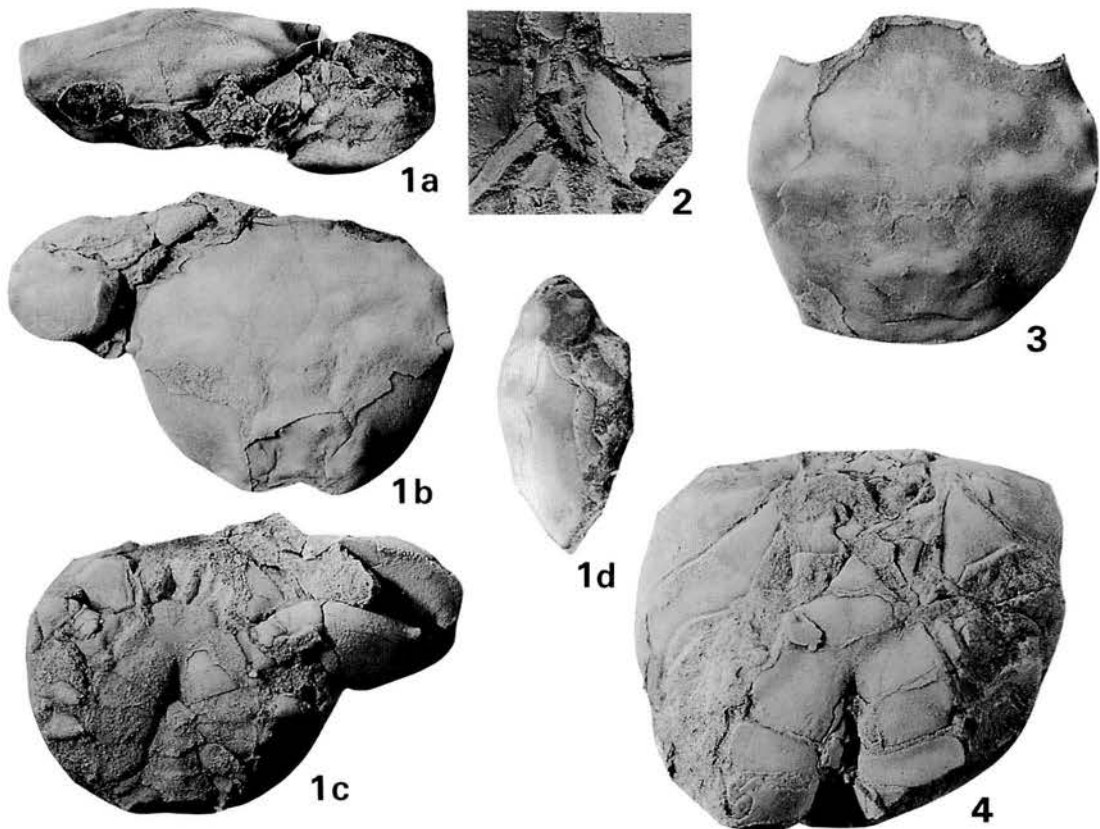## *Carinocarcinoides carinatus* sp. nov.

Figure 5.1a–d, 5.2, 5.4

Diagnosis.—*Carinocarcinoides* with transversely hexagonal carapace and with anterior frontal, protogastric, urogastric, cardiac and epigastric ridges dorsally.

Etymology.—From Latin *carina* (= keel), in reference to dorsal ridges on the carapace.

Description.—Carapace transversely hexagonal in outline, length 0.8 its width, widest at anterolateral angle. Orbitofrontal margin occupying about 0.75 carapace width. Front nearly straight, about 0.4 carapace width, weakly protruded medially, with well developed ridge parallel to anterior margin and with sharply squared corners. Upper orbital margin concave, rimmed, with weak, central projection and broadly triangular, forwardly directed outer orbital spine. Inner suborbital spine sharp, projecting anteriorly, visible in dorsal view. Anterolateral margin strongly convex, about 0.35 carapace width, with two small, anterolaterally directed spines exclusive of outer orbital spine. Posterolateral margin also strongly convex, about 1.8 times as long as anterolateral margin. Posterior margin short, about 0.3 carapace width.

Dorsal surface smooth, moderately vaulted transversely and weakly vaulted longitudinally. Regions distinct. Protogastric region inflated with broad, arcuate ridge on each side. Anterior mesogastric process poorly defined. Mesogastic region slightly convex. Urogastric region with transverse ridge. Cervical groove well defined, sinuous. Cardiac region gently vaulted transversely, hexagonal in outline, bearing two nodes transversely arranged, with transverse ridge anteriorly. Intestinal region small, poorly defined. Hepatic region flattened. Branchiocardiac grooves fairly deep. Branchial regions convex; each epibranchial region most strongly inflated with broad ridge extending in convex-forward arc from mesogastric region to last anterolateral spine. Infraorbital region with weak, granulated ridge parallel to lower orbital margin. Pterygostomian region bearing finely granulated ridge below and parallel to pleural suture. Maxilliped 3 poorly preserved.

Thoracic sternum longer than wide, tapering anteriorly and posteriorly, occupying about 0.4 carapace width, widest at sternite 6. Sternites 1 and 2 fused, triangular. Sternite 3 twice as wide as long with shallow median depression; anterior margin weakly concave, posterior margin broadly V-shaped, lateral margin straight, converging anteriorly. Sternites 4–7 with blunt episternal projections. Sternite 4 about 1.5 times wider than long, narrower anteriorly, wider posteriorly; anterior and posterior margins broadly V-shaped, lateral margins convex. Sternite 5 wider than long, becoming narrower anteriorly; anterior margin broadly V-

Figure 5. **1a–d.** *Carinocarcinoides carinatus* gen. et sp. nov., MFM218513 (holotype) , ×2.0; **1a**: carapace and left cheliped, frontal view; **1b**: carapace and left cheliped, dorsal view; **1c**: carapace, thoracic sternum, abdomen of male, and left cheliped, ventral view; **1d**: carapace, lateral view. **3**. *Carinocarcinoides angustifrons* (Karasawa, 1993) comb. nov., MFM218501 (holotype), carapace, ×2.5, dorsal view. **2, 4**. *Carinocarcinoides carinatus* gen. et sp. nov., MFM218514 (paratype) , **2**: pleopods, ×3.0, ventral view; **4**: carapace and thoracic sternum, ×1.5, ventral view.

shaped, posterior margin sinuous, lateral margin convex. Sternites 6 and 7 wider than long, narrowing posteriorly; anterior and posterior margins sinuous, lateral margin convex. Sternite 8 directed strongly posterolaterally with weak lateral projections. Pleopods poorly preserved.

Abdomen of male narrow. Telson triangular, as long as wide at base. Somites 4–6 preserved, widest at posterior part of somite 4, with straight, anteriorly convergent lateral margins; somite 6 about as long as wide; somites 4 and 5 wider than long.

Left cheliped large, poorly preserved. Dorsal surface of dactylus and lateral surface of palm finely granulate. Lateral surface of carpus also finely granulate with finely granulated ridge parallel to proximal margin; dorsal margin with forwardly directed spine.

Discussion. — A transversely hexagonal carapace with transverse frontal and urogastric ridges readily distinguishes *C. carinatus* from *C. angustifrons*. In *C. carinatus* the carapace length occupies about 80 % of the width, while in *C. angustifrons* a roundly quadrate carapace is about as long

as wide.

Material examined.—MFM218513 (holotype) and 218514 (paratype) from KSM-9.

Subfamily Chasmocarcininae Serène, 1964
Genus ***Collinsius*** Karasawa, 1993

Type species. — *Collinsius simplex* Karasawa, 1993 by monotypy.

Geologic range.—Early Oligocene.

Revised diagnosis.—Carapace slightly wider than long, widest at posterolateral angle. Orbitofrontal margin occupying about half carapace width. Front narrow, bilobed, projecting anteriorly, with squared lateral corner. Upper orbital margin narrow, concave, rimmed, with broadly triangular outer orbital angle. Lateral margin rounded, divergent posteriorly. Posterior margin short, straight. Dorsal surface smooth, gently convex longitudinally and transversely. Epigastric region poorly defined. Cervical groove becoming obsolete in advance of hepatic region. Urogastric region

narrow, depressed. Cardiac region transversely convex. Intestinal region narrow. Branchiocardiac grooves well defined. Branchial regions inflated. Thoracic sternum wide, wider than long, widest at sternite 6. Sternite 8 of male with supplementary sternal plate. Abdomen of male narrow; somites 3–5 fused. Chelipeds unequal.

Discussion. — Karasawa (1993) originally placed the genus in the family Goneplacidae, but did not assign it to any known subfamily. Later, Karasawa (1997) assigned *Collinsius* to the subfamily Chasmocarcininae by recognising the presence of supplementary sternal plates of the thoracic sternite 8 in the male. The subfamily Chasmocarcininae comprises five extant genera, *Chasmocarcinus* Rathbun, 1898, *Camatopsis* Alcock and Anderson, 1899, *Chasmocarcinops* Alcock, 1900, *Hephthopelta* Alcock, 1899 and *Scalopidia* Stimpson, 1858, and the Eocene *Falconoplax* Van Straelen, 1933 (Davie and Guinot, 1996). Among these genera, *Collinsius* resembles *Chasmocarcinus, Hephthopelta* and *Falconoplax* in that abdominal somite 3 of the male fuses to somites 4 and 5. However, the genus differs from *Chasmocarcinus* by having a narrow front and lacking the posterolateral expansion of the carapace; *Hephthopelta* has a wider front and a strongly inflated dorsal carapace; the carapace of *Falconoplax* has well defined epibranchial regions, protogastric tubercles, deep branchiocardiac grooves and epibranchial ridges.

Collinsius is only known from the lower Oligocene Kishima Formation of Kyushu, Japan.

Collinsius simplex Karasawa, 1993

Figure 6.1–6.9

Collinsius simplex Karasawa, 1993, p. 73, pl. 21, figs. 3–8; Karasawa, 1997, p. 61, pl. 23, figs. 4–6, 8–10.

Revised description.—Carapace slightly wider than long, widest at posterolateral angle. Orbitofrontal margin occupying about half of carapace width. Front narrow, projecting anteriorly with shallow median depression dorsally; anterior margin nearly straight, interrupted by weak median notch with sharply squared lateral corner; lateral margin rimmed. Upper orbital margin concave, rimmed, occupying about 0.2 carapace width, with weak, central projection and broadly triangular outer orbital angle. Lateral margin rounded, divergent posteriorly. Posterior margin short, straight. Dorsal surface smooth, gently convex longitudinally and transversely. Epigastric region poorly defined, but visible. Protogastric region separated from anterior mesogastric process by shallow groove. Cervical groove becoming obsolete in advance of hepatic region. Urogastric region narrow, depressed. Cardiac region transversely hexagonal in outline, transversely convex. Intestinal region narrow. Branchiocardiac grooves well defined. Branchial regions inflated.

Thoracic sternum wide, wider than long, widest at sternite 6. Sternites 1 and 2 fused, narrow, broadly triangular in outline, with deep median depression. Sternite 3 about 0.3 as long as wide with median depression; anterior margin nearly straight, posterior margin broadly V-shaped, lateral margin straight, strongly converging anteriorly. Sternites 4–7 with

blunt episternal projections. Sternite 4 about 0.4 times longer than wide, narrower anteriorly, wider posteriorly; anterior and posterior margins broadly V-shaped; lateral margins convex. Sternite 5 wider than long, narrower anteriorly, wider posteriorly; anterior margin broadly V-shaped, posterior margin sinuous, lateral margin convex. Sternite 6 wider than long; anterior and posterior margins sinuous, lateral margin convex. Sternite 7 wider than long, wider anteriorly, narrower posteriorly; anterior and posterior margins sinuous, lateral margin convex. Sternite 8 wider than long, wider anteriorly, narrower posteriorly, directed posterolaterally; supplementary sternal plate developed in male; shallow, transverse groove in female surface.

Abdomen of male narrow. Telson triangular, slightly longer than wide at base. Somite 6 wider than long with straight, anteriorly convergent lateral margins. Somites 3–5 fused, wider than long, widest at base, with slightly concave, anteriorly convergent lateral margins; posterior lateral expansions covering mesial ends of supplementary plates. Somite 2 narrow. Somite 1 unknown. Telson of female abdomen rounded, wider than long at base. Somites 1–6 narrow, much wider than long, widest at somite 3, longest at somite 6.

Chelipeds unequal. Fixed finger short on major cheliped; palm with smooth, inflated lateral surface. Dactylus elongate on minor cheliped, curving ventrally, with acutely pointed tip; fixed finger also elongate, about as long as dactylus, occupying about half of propodus length, slightly deflexed ventrally, with acutely pointed tip; palm longer than high, distal margin much wider than proximal margin, with smooth, inflated lateral surface.

Pereiopods 1–4 of female poorly preserved. Propodi of pereiopods 2–4 elongate, cylindrical in cross section. Coxa and ischium fused to basis short.

Discussion.—As for the genus.

Material examined. — MFM218502 (holotype), 218503 (paratype), and 218601–218610 from KSM-2; MFM218505 (paratype), 218506 (paratype), and 218613–218620 from KSM-4; MFM218504 (paratype), 218621–218630, 218640, 218641 from KSM–5; MFM218612 from KSM–3; MFM 218642, 218643 and 218644 from KSM-6; referred specimens from KSM-7, 8, 9, 10, 11.

Acknowledgements

References

Alcock, A., 1899: *An Account of the Deep-sea Brachyura Collected by the Royal Indian Marine Survey Ship 'Investigator'.* 86 p. Calcutta.
Alcock, A., 1900: Materials for a carcinological fauna of India. No. 6. The Brachyura Catametopa, or Grapsoidea.
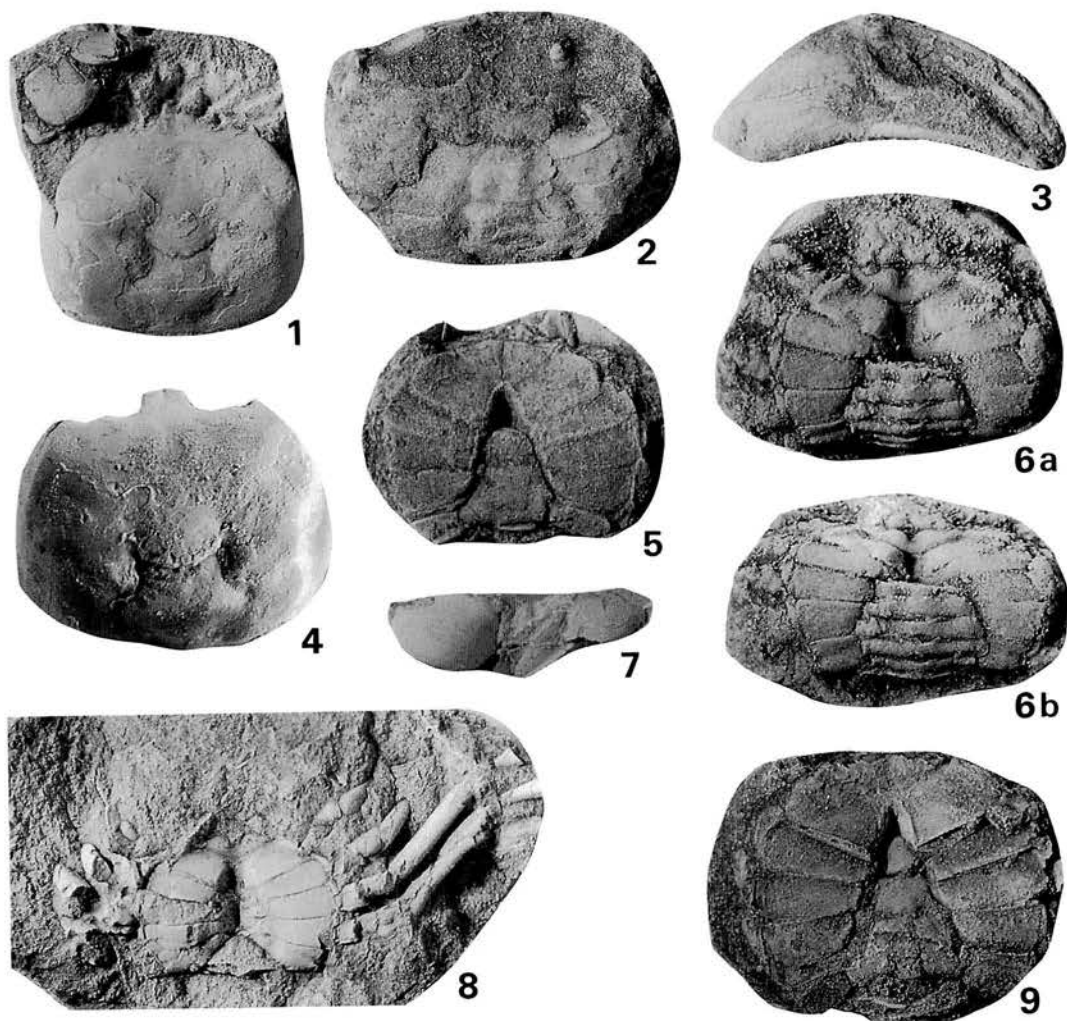
Figure 6. 1–9. *Collinsius simplex* Karasawa, 1993; **1**: MFM218502 (holotype), carapace and left cheliped, ×3.0, dorsal view; **2**: MFM218642, thoracic sternum and abdomen of female, ×3.0, ventral view; **3**: MFM218640, right cheliped, ×3.0, lateral view; **4**: MFM218504 (paratype), carapace, ×4.0, dorsal view; **5**: MFM218505 (paratype), thoracic sternum and abdomen of male, ×3.0, ventral view; **6a, b**: MFM218643, thoracic sternum and abdomen of female, ×3.0, ventral view; **7**: MFM218503 (paratype), both chelipeds, ×2.5, lateral view; **8**: MFM218641, thoracic sternum and pereiopods of female, ×3.0, ventral view; **9**: MFM218644, thoracic sternum and abdomen of male, ×3.0, ventral view.

Journal of the Asiatic Society of Bengal, vol. 69 (part. 2, no. 3), p. 279–456.

Alcock, A. and Anderson, A. R. S., 1899: Natural history notes from H. M. Royal Indian marine survey ship 'Investigator', Commander T. H. Heming, R., commanding.— Series III., No. 2. An account of the deep-sea Crustacea dredged during the surveying-season of 1897–98. *The Annals and Magazine of Natural History, 7th series*, vol. 3, no. 13, p.1–27.

Bell, T., 1858: *A Monograph of the Fossil Malacostracous Crustacea of Great Britain. Part 1, Crustacea of the London Clay.* Palaeontographical Society Monograph, 44 p. London.

Dana, J. D., 1852: Crustacea. *In, United States Exploring Expedition during the Years 1838, 1839, 1840, 1841, 1842 Under the Command of Charles Wilkes, U.S.N.*, vol. 13, 1620 p.

Davie, P. J. F. and Guinot, D., 1996: Two new freshwater crabs in *Australocarcinus* Davie, with remarks on Trogoplacinae Guinot and Goneplacidae MacLeay (Crustacea: Decapoda: Brachyura). *Memoirs of the Queensland Museum*, vol. 39, no. 2, p. 277–287.

De Haan, W., 1833–1850: Crustacea. *In,* Siebold, P. F. von, *Fauna Japonica, sive, Descriptio animalium, quae in itinere per Japoniam, jussu et auspiciis superiorum, qui summun in India Batava Imperium tenent, suscepto, annis 1823–1830 collegit, notis, observationibus et adumbrationibus illustravit.* p. I–xvii + I–xxxi + ix–xvi + 1–

243, pls. A–J + L–Q + 1–55. Ludguni-Batavorum.

De Saint Laurent, M., 1973: Sur la systématique et la phylo-géne des Thalassinidea: définition des familles des Callianassidae et des Upogebiidae et de cinq genres nouveaux (Crustacea Decapoda). *Comptes Rendus Hebdomaires des Séances de l'Académie des Sciences, Paris, série D*, vol. 277, p. 513–516.

Glaessner, M. F., 1969: Decapoda, *In*, Moore, R. C. ed., *Treatise on Invertebrate Paleontology, Part R, Arthropoda 4*, p. R399–R533, R626–R628. Geological Society of America and University of Kansas Press.

Guinot, D., 1977: Propositions pour une nouvelle classification des Crustacés, Décapodes, Brachyoures. *Comptes Rendus Hebdomaires des Séances de l'Académie des Sciences, Paris, série D*, vol. 285, p. 1049–1052.

Heard, R. W. and Manning, R. B., 1998: A new genus and species of ghost shrimp (Crustacea: Decapoda: Callianassidae) from the Atlantic Ocean. *Proceedings of the Biological Society of Washington*, vol. 111, p. 883–888.

Heard, R. W. and Manning, R. B., 2000: A new genus and species of ghost shrimp from Tobago, West Indes (Crustacea: Decapoda: Callianassidae). *Proceedings of the Biological Society of Washington*, vol. 113, p. 70–76.

Huxley, T. H., 1879 [1878]: On the classification and the distribution of the crayfishes. *Proceedings of the Scientific Meetings of the Zoological Society of London*, vol. for 1878, p. 752–788.

Imaizumi, R., 1958: An interesting crustacean remain, *Ctenocheles sujakui* n. sp. from the Palaeogene of Kyushu, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 32, p. 299–304.

Imaizumi, R., 1959: *Callianassa bona* n. sp. from near Sendai, Miyagi Prefecture. *Japanese Journal of Geology and Geography*, vol. 30, p. 30–37.

Inoue, E., 1972: Lithofacies, fossil assemblages and sedimentary environment of Oligocene Kishima Formation in Karatsu Coalfield, northwest Kyushu, southwest Japan. *Geological Survey of Japan, Report*, no. 245, 68 + 4 p.

Karasawa, H., 1990: Decapod crustaceans from the Miocene Mizunami Group, central Japan. Part 2. Section Oxyrhyncha, Cancridea and Brachyrhyncha. *Bulletin of the Mizunami Fossil Museum*, no. 17, p. 1–33.

Karasawa, H., 1992: Fossil decapod crustaceans from the Manda Group (middle Eocene), Kyushu, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 167, p. 1247–1258.

Karasawa, H., 1993: Cenozoic decapod Crustacea from southwest Japan. *Bulletin of the Mizunami Fossil Museum*, no. 20, p.1–92.

Karasawa, H., 1997: A monograph of Cenozoic stomatopod, decapod, isopod and amphipod Crustacea from west Japan. *Monograph of the Mizunami Fossil Museum*, no. 8, 81 p.

Karasawa, H., 1999: The Cenozoic decapod crustacean fauna of southwest Japan. *In*, Schram, F. R. and Vaupel Klein, J. C. von, eds., *Crustaceans and the Biodiversity Crisis. Proceedings of the Fourth International Crustacean Congress, Amsterdam, The Netherlands, July 20–24, 1998, vol. I.* p. 29–44. Brill, Leiden.

Karasawa, H. and Goda, T., 1996: Two new species of decapod crustaceans from the middle Pleistocene Atsumi

Group, Japan. *Science Reports of the Toyohashi Museum of Natural History*, no. 6, p. 1–4.

Kato, H., 1996: Miocene decapod Crustacea from the Chichibu Basin, Central Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 183, p. 500–521.

Kato, H. and Karasawa, H., 1994: *Minohellenus macrocheilus* sp. nov. (Decapoda: Crustacea) from the Oligocene Ashiya Group, Kyushu, Japan. *Bulletin of the Kitakyushu Museum of Natural History*, no. 13, p. 51–58.

Kato, H. and Karasawa, H., 1996: An additional record of *Minohellenus macrocheilus* Kato & Karasawa, 1994. (Crustacea, Decapoda, Portunidae). *Bulletin of the Kitakyushu Museum of Natural History*, no. 15, p. 31–33.

Kato, H. and Karasawa, H.,1998: Pleistocene fossil decapod Crustacea from the Boso Peninsula, Japan. *Natural History Research, Special Issue*, no. 5, p. 1–31.

Kishinoue, K., 1926: Two rare and remarkable forms of macrurous Crustacea from Japan. *Annotationes Zoologicae Japonenses*, vol. 11, p. 63–70.

Latreille, P. A., 1802–1803: *Histoire naturelle, générale et particulière, des crustacés et des insectes*, volume 3, 468 p. F. Dufart, Paris.

Latreille, P. A., 1825: *Familles naturelles du règne animal, ex posées succinctement et dans un ordre analytique, avec l'indication de leurs genres.* 570 p. Paris.

Latreille, P. A., 1831: *Cours d'Entomologie, ou de l'histoire naturelle des Crustacés, des Arachnides, des Myriapodes et des Insectes, etc.* Annales I. Atlas, 26 p. Roret, Paris.

Leach, W. E., 1814: Crustaceology. *In*, Brewster, D., *Edinburgh Encyclopedia*, vol. 7, p. 385–437.

Lörenthey, E.,1898: Beiträge zur Decapodenfauna des ungarischen Tertiärs. *Természetrajzi Füzetek*, vol. 21, p. 1–133.

Lörenthey, E. *in* Lörenthey, E. and Beurlen, K.,1929: Die fossilen Dekapoden der Länder der ungarischen Krone. *Geologica Hungarica, Series Palaeontologica*, pt. 3, 420 p.

MacLeay, W. S., 1838: On the brachyurous decapod Crustacea brought from the Cape by Dr. Smith. *In, Illustrations of the Annulosa of South Africa; being a Portion of the Objects of Natural History Chiefly Collected during an Expedition into the Interior of South Africa, under the Direction of Dr. Andrew Smith, in the Years 1834, 1835, and 1836; Fitted out by "The Cape of Good Hope Association for Exploring Central Africa".* p. 53–71. London.

Manning, R. B. and Felder, D. L., 1991: Revision of the American Callianassidae (Crustacea: Decapoda: Thalassinidea). *Proceedings of the Biological Society of Washington*, vol. 104, p. 764–792.

Manning, R. B. and Tamaki, A.,1998: A new ghost shrimp from Japan (Crustacea: Decapoda: Callianassidae). *Proceedings of the Biological Society of Washington*, vol. 111, p. 889–892.

Matsui, K., Furukawa, T. and Sawamura, K., 1989: *Geology of the Sasebo district. Geological Sheet Map at 1:50,000.* 92 p. Geological Survey of Japan. (*in Japanese with English abstract*)

Milne Edwards, A., 1860: Histoire des crustacés podophtalmaires fossiles. *Annales des Sciences Naturelles, Zoologie, série 4*, vol. 14, p. 129–293.

Milne Edwards, H., 1837: *Histoire naturelle des Crustacés.*

252   Hiroaki Karasawa and Yasuhiro Fudouji

vol. II, 532 p. Paris.

Milne Edwards, H., 1852: Observations sur les affinités zoologiques et la classification naturelle des crustacés. *Annales des Sciences Naturelles, Zoologie, série 3*, vol. 18, p. 109-166.

Miers, E. J., 1886: Report on the Brachyura Collected by H. M. S. *Challenger* during the Years 1873-1876. *Report on the Scientific results of the Voyage of H. M. S. Challenger during the Years 1873-76, Zoology*, vol. 17, xii + 363 p.

Montagu, G., 1808: Description of several marine animals found on the south coast of Devonshire. *Transactions of the Linnean Society of London*, vol. 9, p. 18-114.

Moosa, M. K., 1996: Crustacea Decapoda: Deep-water swimming crabs from the South-West Pacific, particularly New Caledonia (Brachyura, Portunidae). *In*, Crosnier, A. ed., *Résultats des Campagnes MUSORSTOM, Volume 15. Mémoires du Muséum national d'Histoire Naturelle, Tome 168, Zoologie*, p. 503-530.

Müller, P.,1979: Decapoda (Crustacea) fauna a budapesti miocénbol (5). *Földtani Közlöny*, no. 108, p. 272-312.

Müller, P., 1984: Decapod Crustacea from the Badenian. *Geologica Hungarica, Series Palaeontologica*, pt. 42, 317 p.

Nagao, T., 1932: Two Tertiary and one Cretaceous Crustacea from Hokkaidô, Japan. *Journal of the Faculty of Science, Hokkaido Imperial University, series 4*, vol. 2, p. 15-22.

Nagao, T., 1941: On some fossil Crustacea from Japan. *Journal of the Faculty of Science, Hokkaido Imperial University, series 4*, vol. 6, p. 86-100.

Nagao, T. and Ôtatume, K., 1941: A new *Callianassa* from the Palaeogene Isikari Series of Hokkaidô. *The Journal of the Geological Society of Japan*, vol. 45, no. 541, p. 101-102.

Ortmann, A.,1893: Die Decapoden-Krebse des Strassburger Museums, VI. Theil. Abtheilung: Brachyura (Brachyura genuina Boas). 1. Unterabtheilung: Majoidea und Cancroidea, 1. Section Portuninea. *Zoologische Jahrbücher*, vol. 7, p. 23-88.

Okada, H., 1992: Calcareous nannofossils and biostratigraphy of the Paleogene sequences of the northern Kyushu, Japan. *The Journal of the Geological Society of Japan*, vol. 98, no. 6, p. 509-528.

Okada, H. and Bukry, D., 1980: Supplementary modification and introduction of code numbers to the low-latitude Coccolith Biostratigraphic Zonation (Bukry, 1973; 1975). *Marine Micropaleontology*, vol. 5, 321-325.

Ozaki, M. and Hamasaki, S., 1991: Fission track ages of the Paleogene strata in the northern part of Fukuoka Prefecture, Southwest Japan. *The Journal of the Geological Society of Japan*, vol. 97, no. 3, p. 251-254.

Philippi, R. A., 1887: *Los fósiles terciarios i cuarterios de Chile.* 256 p. Brockhaus, Leipzig and Santiago.

Poore, G. C. B., 1994: A phylogeny of the families of Thalassinidea (Crustacea: Decapoda) with keys to families and genera. *Memoirs of the Museum of Victoria*, vol. 54, p. 79-120.

Poore, G. C. B., 2000: A new genus and species of callianassid ghost shrimp from Kyushu, Japan (Crustacea: Decapoda: Thalassinidea). *Journal of Crustacean Biology, Special Number*, 2, p. 150-156.

Rafinesque, S. C. S., 1815: *Analyse de la nature, ou tableau de l'univers et des corps organisés.* 224 p. Palermo.

Rathbun, M. J., 1898: The Brachyura of the biological expedition to the Florida Keys and the Bahamas in 1893. *Bulletin from the Laboratories of Natural History of the State University of Iowa*, vol. 4, p. 250-294.

Rathbun, M. J., 1914: A new genus and some new species of the family Goneplacidae. *Proceedings of U. S. National Museum*, vol. 48, no. 2067, p. 137-154.

Rathbun, M. J., 1916: Description of a new genus and species of fossil crab from Port Townsend, Washington. *American Journal of Science*, vol. 41, p. 344-346.

Rathbun, M. J., 1919: West Indian Tertiary decapod crustaceans. *Carnegie Institution of Washington Publication*, no. 291, p. 159-184.

Remy, J. M., 1960: Études paléontologiques et géologiques sur les falaises de Fresco (Côte d'Ivoire) 2. Crustacés. *Annales de la Faculté des Sciences, Université de Dakar*, vol. 5, p. 55-64.

Sakai, K., 1988: A new genus and five new species of Callianassidae (Crustacea: Decapoda: Thalassinidea) from northern Australia. *The Beagle*, vol. 5, p. 51-69.

Sakai, K., 1999: Synopsis of the family Callianassidae, with keys to subfamilies, genera and species, and the description of new taxa (Crustacea: Decapoda: Thalassinidea). *Zoologische Verhandelingen*, no. 326, 152 p.

Sakai, K. and Türkay, M., 1999: A new subfamily, Bathycalliacinae n. subfam., for *Bathycalliax geomar* n. gen., n. sp. from the deep water cold seeps off Oregon, USA (Crustacea, Decapoda, Callianassidae). *Senkenbergiana Biologica*, vol. 79, p. 203-209.

Schweitzer, C. E. and Feldmann, R. M., 2000: New fossil portunids from Washington, USA, and Argentina, and a re-evaluation of generic and family relationships within the Portunoidea Rafinesque, 1815 (Decapoda: Brachyura). *Journal of Paleontology*, vol. 74, no. 4, p. 636-653.

Schweitzer, C. E., Feldmann, R. M., Tucker, A. B. and Berglund, R. E., 2000: Eocene decapod crustaceans from Pulari Point, Washington. *Annals of Carnegie Museum*, vol. 69, no. 1, p. 23-67.

Schweitzer Hopkins, C. and Feldmann, R. M., 1997: Sexual dimorphism in fossil and extant species of *Callianopsis* De Saint Laurent. *Journal of Crustacean Biology*, vol. 17, no. 2, p. 236-252.

Serène, R., 1964: Redescription du genre *Magasthesius* Rathbun et définition des Chasmocarcininae, nouvelle sous-famille des Goneplacidae (Decapoda, Brachyura). *Crustaceana*, vol. 7, no. 3, p.175-187.

Stimpson, W., 1858: Prodromus descriptionis animalium evertebratorum, quae in Expeditione ad Oceanum Pacificum Septentrionalem, a Republica Federata missa, Cadwaladaro Ringgold et Johanne Rodgers Ducibus, observavit et descripsit W. Stimpson. Pars. V. Crustacea Ocypodoidea. *Proceedings of the Academy of Natural Sciences of Philadelphia*, vol. 10, p. 93-110.

Stimpson, W., 1860: Notes on North American Crustacea in the Museum of the Smithsonian Institution, no. 2. *Annals of the Lyceum Museum of Natural History of New York*, vol. 7, p. 176-246.

Stevčić, Z., 1991: Note on some rare and aberrant Australian crabs. *The Beagle*, vol. 8, p. 121-134.

Stilwell, J. D., Levy, R. H., Feldmann, R. M. and Harwood, D. M., 1997: On the rare occurrence of Eocene callianassid decapods (Arthropoda) preserved in their burrows, Mount Discovery, East Antarctica. *Journal of Paleontology*, vol.

71, no. 2, p. 284-287.

Tucker, A. B.,1998: Systematics of the Raninidae (Crustacea: Decapoda: Brachyura), with accounts of three new genera and two new species. *Proceedings of the Biological Society of Washington*, vol. 111, no. 2, p. 320-371.

Van Straelen, V., 1933: Sur les Crustacés Décapodes cénozoïques du Venezuela. *Bulletin du Musée Royal d'Histoire Naturelle de Belgique*, vol. 9, no. 10, p. 1-14.

Vega, F. J., Feldmann, R. M. and Sour-Tovar, F., 1995: Fossil crabs (Crustacea: Decapoda) from the late Cretaceous Cárdenas Formation, East-Central Mexico. *Journal of Paleontology*, vol. 69, no. 2, p. 340-350.

Yokoyama, M., 1911: Some Tertiary fossils from the Miike coalfield. *Journal of the College of Science, Imperial University of Tokyo*, vol. 27, p. 1-16.

New cephalopod material from the Bashkirian (Middle Carboniferous) of the Ichinotani Formation, Central Japan

SHUJI NIKO

Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University,

Higashihiroshima, 739–8521, Japan (niko@hiroshima-u.ac.jp)

Abstract. Three Bashkirian (Middle Carboniferous) species of orthocerid cephalopods, the orthoceratid *Hidamichelinoceras bandoi* gen. et sp. nov. and the pseudorthoceratids *Mooreoceras* sp. and *Adnatoceras ichinotaniense* Niko and Hamada, 1987, are described (or redescribed) from the Ichinotani Formation, Central Japan based on new material. The siphuncular structure of *Hidamichelinoceras* is shared with *Michelinoceras*, but this new genus is characterized by its broadly cone-shaped initial camera and rapid shell expansion. The discovery of *Mooreoceras*, which previously had been known only from the Hikoroichi Formation in Japan, supports a paleobiogeographic link between the Fukuji and southern Kitakami areas in the Carboniferous. The apical shell diagnosis of *Adnatoceras ichinotaniense* is added.

Key words: Bashkirian (Middle Carboniferous), *Hidamichelinoceras* gen. nov., Ichinotani Formation, Orthocerida.

Introduction

Recent research on Far Eastern Carboniferous orthocerids and bactritids has shown that at least two isolated faunal provinces were present through the period in the area, i. e., the Taishaku-Akiyoshi-South China Province with the *Bogoslovskya* and *Bactrites* lineage (Niko *et al.*, 1987, 1991, 1995, 1997; Niko and Ozawa, 1997) and the southern Kitakami-Fukuji Province with the *Adnatoceras* lineage (Niko and Hamada, 1987; Niko, 1990). Nevertheless, our knowledge of Carboniferous orthoconic cephalopods is too limited to permit detailed paleobiogeographic reconstruction. Descriptive works are still critical also for providing phylogenetic information about these groups. As an additional account of orthocerid cephalopods in the Fukuji area, Central Japan, this work documents a new collection from the Bashkirian (Middle Carboniferous) limestone of the Ichinotani Formation. Details of the geologic setting and stratigraphic position of the collection have already been given by Niko and Hamada (1987).

The abbreviation UMUT for the repository stands for the University Museum of the University of Tokyo.

Systematic paleontology

Order Orthocerida Kuhn, 1940
Superfamily Orthocerataceae M'Coy, 1844
Family Orthoceratidae M'Coy, 1844
Subfamily Michelinoceratinae Flower, 1945
Genus *Hidamichelinoceras* gen. nov.

Type species.—*Hidamichelinoceras bandoi* sp. nov., by monotypy.

Diagnosis.—Orthoconic michelinoceratinid with rapid shell expansion, 9°–13° in angle, for subfamily, circular cross section, and probably endogastric early juvenile portion; shell surface ornamented by transverse lirae; initial camera broadly cone-shaped with rounded apex, shallow; early siphuncle central then becoming subcentral in position; septal necks very long and orthochoanitic, forming very wide septal foramen; cameral deposits weakly developed, episeptal-mural and hyposeptal; auxiliary deposits absent.

Etymology.—The generic name is derived from Hida, which is a historic provincial name of the type locality, and *Michelinoceras.*

Hidamichelinoceras bandoi sp. nov.

Figures 1.1–1.6, 2.1

Diagnosis.—Same as for the genus.

Description.—Based on single incomplete phragmocone of orthoconic shell with circular cross section; early juvenile shell indicates probable endogastric curvature; shell expansion rapid as for subfamily, its angle approximately 13° apically, then decreases to approximately 9° adorally; diameter of adoral shell attains 6.2 mm. Surface ornamentation consists of transverse and somewhat distant lirae forming weak sinuations. Sutures not observed, but obvious obliquity not recognized in dorsoventral section. Initial camera broadly cone-shaped with rounded apex, shallow and relatively small with 0.9 mm+ (slightly deformed) in maximum diameter and 0.3 mm in length between both apexes of initial and second camerae; cameral length abruptly increases in following camerae, then re-shortened adorally; maximum diameter/length ratios of adoral camerae range from 1.7 to 2.2; septal curvature moderate to relatively deep in seven apical septa, then becomes shallower in adoral septa. Siphuncular position nearly central in early juvenile shell, then slightly shifts in ventral direction, subcentral; minimum distance of central axis of siphuncle from shell surface versus shell diameter decreases to 0.4; caecum weakly inflated; siphuncle consists of orthochoanitic septal necks and nearly cylindrical connecting rings in second to seventh camerae; connecting rings missing in adoral camerae where septal necks are orthochoanitic, very long, 0.65–0.79 mm in length, attaining 0.3 in ratio of septal neck length/cameral length; diameters of septal necks are 0.61–0.71 mm; septal foramen cylindrical, very wide for subfamily, 0.52–0.63 mm in diameter; ratio of septal neck diameter to corresponding dorsoventral shell diameter attains 0.13. Cameral deposits weakly developed, restricted to apical 10 camerae, episeptal-mural and hyposeptal, slightly thicker in venter than dorsum; circumsiphuncular ridges of episeptal and hyposeptal deposits partly extend onto ventral side of connecting rings and septal necks, respectively. Endosiphuncular deposits, including auxiliary ones, are absent.

Discussion.—The siphuncular structure of *Hidamichelinoceras bandoi* gen. et sp. nov. suggests a close relationship to the widespread genus *Michelinoceras* (Foerste, 1932; type species *Orthoceras michelini* Barrande, 1866). The most important distinctive feature is the morphology of the initial camera. In contrast to the broadly cone-shaped initial camera of this new genus, the longitudinally elongated bulbous form of the type species of *Michelinoceras* was confirmed by Ristedt (1968, pl. 1, fig. 1). The rapid shell expansion (9°–13° in angle) of *Hidamichelinoceras* in comparison with the much slenderer shell shape of *Michelinoceras* (1°–2° in angle of shell expansion of *M. michelini*) is also regarded as enough to be of generic significance. *Hidamichelinoceras* differs from the Devonian to Carboniferous genus *Bogoslovskya* (Zhuravleva, 1978; type species, *B. perspicua* Zhuravleva, 1978) in having a less eccentric siphuncular position with a wider septal foramen and in lacking auxiliary deposits. The Triassic genus *Trematoceras* (Eichwald, 1851, not seen by the author; its generic diagnosis, including apical shell morphology, comes from citation by Schindewolf, 1933; type species, *Orthoceratites elegans* Münster, 1841) has a cone-shaped initial camera but the shape of the septal necks of *Hidamichelinoceras* is

quite unlike that of *Trematoceras*, whose septal necks are very short and suborthochoanitic. In addition, the cameral deposits of *Trematoceras* are characterized by the prominent lamellae. The circular shell cross section of *Hidamichelinoceras* clearly separates it from the Devonian genus *Arkonoceras* (Flower, 1945; type species, *Orthoceras arkonense* Whiteaves, 1898), which has a much slenderer shell characterized by its subquadrangular cross section.

The Ordovician genus *Sinoceras* (Shimizu and Obata, 1935; type species, *Orthoceras chinense* Foord, 1888) was erroneously assigned to the Michelinoceratinae (e. g., Sweet, 1964) owing to its orthoconic shell shape and its *Michelinoceras*-like very long septal necks indicating orthochoanitic forms. However, the enveloping cameral-endosiphuncular deposits on the septal neck and on both the adoral and apical surfaces of the septum, recognized in the type species of *Sinoceras* in Woodward's (1856, pl. 6, fig. 1) illustration, undoubtedly place *Sinoceras* in the family Lituitidae within the order Tarphycerida.

Material examined and occurrence.—Holotype, UMUT PM 27849, 28.0 mm in length from the uppermost part of the Lower Member, Ichinotani Formation.

Etymology.—The specific name refers to the late Dr. Yuji Bando, in recognition of his contributions to the study of fossil cephalopods.

Superfamily Pseudorthocerataceae Flower
and Caster, 1935
Family Pseudorthoceratidae Flower and Caster, 1935
Subfamily Pseudorthoceratinae Flower and Caster, 1935
Genus *Mooreoceras* Miller, Dunbar and Condra, 1933

Type species.—*Mooreoceras normale* Miller, Dunbar and Condra, 1933.

Mooreoceras sp.

Figures 1.7–1.9, 2.7

Description.—Orthoconic phragmocone with gradual shell expansion and dorsoventrally depressed, oval cross section; diameter of apical end is 5.2 mm in dorsoventral direction and 5.8 mm in lateral direction, giving a form ratio of approximately 1.1. Surface ornamentation absent. Sutures transverse, nearly straight, or strongly oblique in rare cases; septal curvature shallow. Cameral length moderate for genus, cameral ratios of maximum dorsoventral diameter/ maximum length are 0.2–0.4. Siphuncle subcentral, consists of cyrtochoanitic septal necks and subcylindrical connecting rings whose inflation is weak for genus. Cameral deposits not detected. Endosiphuncular deposits form annulosiphonate rings.

Discussion.—Although this species is known from a single specimen of a probable juvenile shell judging from the relatively weak inflation of the connecting rings, the oval cross section of the shell, subcentral siphuncular position with the cyrtochoanitic septal necks, annulosiphonate rings formed of endosiphuncular deposits and the lack of cameral deposits warrant generic assignment to *Mooreoceras*. Unsuccessful attempts to make a well-oriented thin section preclude a specific determination.

Figure 1. 1–6. *Hidamichelinoceras bandoi* gen. et sp. nov., holotype, UMUT PM 27849. **1**: Lateral view of silicone rubber cast, venter on right, ×4; **2**: Details of shell surface, showing ornamentation of transverse lirae, ×8; **3**: Polished cross section, venter down, ×4; **4**: Longitudinal thin section of apical shell, venter on left, slightly deformed, ×14; **5**: Longitudinal thin section of adoral shell, venter on left, ×14; **6**: Details of the three most apical camerae, note cone-shaped initial camera, ventral shell slightly deformed, ×30. **7–9.** *Mooreoceras* sp., UMUT PM 27850. **7**: Dorsal view, ×4; **8**: Septal view of apical end, venter down, ×4; **9**: Longitudinal thin section, venter on right, ×5.
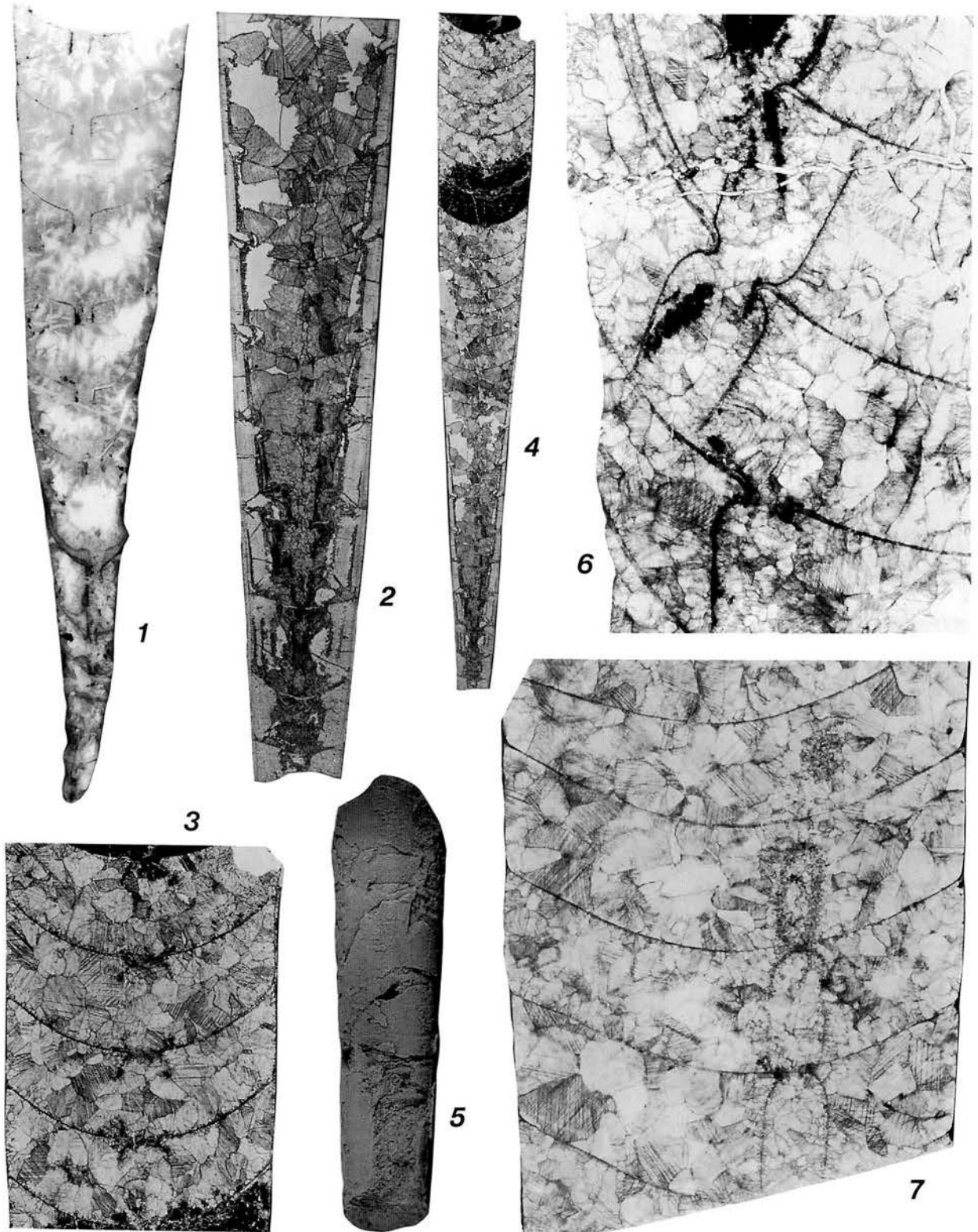
Figure 2. **1**. *Hidamichelinoceras bandoi* gen. et sp. nov., holotype, UMUT PM 27849, longitudinal thin section, venter on left, ×5. **2–6**. *Adnatoceras ichinotaniense* Niko and Hamada, 1987. **2–4**: UMUT PM 27852; **2**: Longitudinal thin section of apical shell, venter on right, ×14; **3**: Longitudinal thin section of adoral shell, venter on right, ×14; **4**: Longitudinal thin section, venter on right, ×5; **5, 6**: UMUT PM 27851; **5**: Ventral view, ×2; **6**: Longitudinal thin section, details of adoral siphuncular structure, venter on left, ×14. **7**. *Mooreoceras* sp., UMUT PM 27850, longitudinal thin section, venter on right, showing siphuncular structure, ×14.

Previously, this genus had been represented in Japan solely by *Mooreoceras kinnoi* Niko, 1990, from the Visean (Early Carboniferous) of the Hikoroichi Formation in the southern Kitakami area, Northeast Japan. The present discovery of *Mooreoceras* sp. from the Fukuji area supports a paleobiogeographic link in the Carboniferous between the Fukuji and southern Kitakami areas, of which the similarity has also been suggested by the common occurrence of *Adnatoceras* in both areas.

Material examined and occurrence.—Single incomplete phragmocone, UMUT PM 27850, 15.0 mm in length. Stratigraphic horizon is identical with *Hidamichelinoceras bandoi*.

Subfamily Spyroceratinae Shimizu and Obata, 1935
Genus ***Adnatoceras*** Flower, 1939

Type species.—*Orthoceras spissum* Hall, 1879.

Adnatoceras ichinotaniense Niko and Hamada, 1987

Figure 2.2–2.6

Adnatoceras ichinotaniensis Niko and Hamada, 1987, p. 225, 227, figs. 3-1-6.
Adnatoceras ichinotaniense Niko and Hamada. Niko, 1990, p. 557; Kamiya and Niko, 1992, fig. 1-E.

Additional diagnosis.—Early siphuncle central in position with suborthochoanitic septal necks and cylindrical connecting rings. See Niko and Hamada (1987, p. 225) for diagnosis of adult shell.

Description.—Orthoconic shells with dorsoventrally depressed subcircular cross section up to nearly 4 mm in diameter and with a mean form ratio of approximately 1.1, then circular cross section attaining 9.1 mm in diameter; shell expansion moderate for genus, its angle approximately 4° in apical shell, then decreases to 2°–3° in adoral shell. Surface ornamentation absent; ventral wall slightly thicker than dorsal wall. Sutures straight, slightly oblique with approximately 5° to rectangular direction of shell axis, toward aperture on venter; septa relatively shallow; cameral length moderate to relatively short for genus; maximum width/length ratio of apical camerae ranges from 1.3 to 2.0, and ratio increases to 2.9–5.8 with 3.9 mean in adoral camerae. Early siphuncle central in position, composed of very short suborthochoanitic septal necks, 0.13 mm in length for a well-preserved one, and cylindrical connecting rings having weak constrictions at septal foramen; siphuncular position shifts towards a ventral one as shell grows, subcentral; ratio of minimum distance of central axis of the most adoral siphuncle from shell surface per shell diameter decreases to 0.3, where septal necks are asymmetrical, suborthochoanitic to cyrtochoanitic on dorsal side, with a length of 0.31 mm, and strongly recurved cyrtochoanitic on ventral side, with a length of 0.22 mm; adoral connecting rings subcylindrical, nearly parallel-sided and abruptly constricted at septal foramen; maximum diameter/length ratio of adoral siphuncle 0.5 –0.7; adnation area very wide for family. Cameral deposits usually episeptal-mural and hyposeptal, but the latter are absent in some camerae, thicker in venter than dorsum.

Endosiphuncular parietal deposits restricted on ventral siphuncular wall, thin, not fused. Adoral camerae lack both cameral and endosiphuncular deposits.

Discussion.—The description above is the same as in Niko and Hamada (1987) except that the apical shell morphology and most adoral siphuncular structures are added based on new specimens. The weaker cameral and endosiphuncular deposits of one specimen (UMUT PM 27852), compared to the holotype, probably result from its immaturity.

Material examined and occurrence.—Holotype, UMUT PM 18068; paratype, UMUT PM 18069. In addition, two newly collected incomplete phragmocones were examined: UMUT PM 27851, which includes more of the adoral shell than the type specimens, 38.3 mm in length, and UMUT PM 27852, which represents more of the apical shell than the type specimens, 23.0 mm in length. Stratigraphic horizon is identical with *Hidamichelinoceras bandoi*.

Acknowledgments

References

Barrande, J., 1866: *Systême silurien du centre de la Boheme, Première Partie: Recherches paléontologiques. Volume 2, Classe des Mollusques, Ordre des Céphalopodes*, part 7, pls. 108–244, Praha.
Eichwald, E. von, 1851: Naturhistorische Bemerkungen, als Beitrag zur vergleichenden Geognosie, auf einer Reise durch die Eifel, Tyrol, Italien, Sizilien und Algier gesammelt. *Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou*, vol. 9, p. 1–464, pls. 1–4. (*not seen*)
Flower, R.H., 1939: Study of the Pseudorthoceratidae. *Palaeontographica Americana*, vol. 2, p. 1–214, pls. 1–9.
Flower, R.H., 1945: Classification of Devonian nautiloids. *American Midland Naturalist*, vol. 33, p. 675–724, pls. 1–5.
Flower, R.H. and Caster, K.E., 1935: The stratigraphy and paleontology of northeastern Pennsylvania. Part II: Paleontology. Section A: The cephalopod fauna of the Conewango Series of the Upper Devonian in New York and Pennsylvania. *Bulletins of American Paleontology*, vol. 22, p. 199–271.
Foerste, A.F., 1932: Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario (Part 1). *Denison University Bulletin, Journal of the Scientific Laboratories*, vol. 27, p. 47–136, pls. 7–37.
Foord, A.H., 1888: *Catalogue of the Fossil Cephalopoda of the British Museum (Natural History)*, part 1, 344 p., London.
Hall, J., *Palaeontology of New York. Volume 5, Descriptions of the Gastropoda, Pteropoda and Cephalopoda of the Upper Helderberg, Hamilton, Portage and Chemung Groups*, part 1, 492 p., part 2, 113 pls., New York Geological Survey, C. van Benthysen and Sons, Albany.
Kamiya, T. and Niko, S., 1992: Color markings on Devonian

orthochonic cephalopod from Fukuji, Gifu Prefecture. *Chigakukenkyu*, vol. 41, p. 149–153. (*in Japanese*)

Kuhn, O., 1940: *Paläozoologie in Tabellen*, 50 p. Fischer, Jena.

M'Coy, F., 1844: *A Synopsis of Characters of the Carboniferous Limestone Fossils of Ireland*, 274 p. Privately published. (reprinted by Williams and Norgate, London, 1862).

Miller, A.K., Dunbar, C.O. and Condra, G.E., 1933: The nautiloid cephalopods of the Pennsylvanian System in the Mid-Continent region. *Nebraska Geological Survey*, Bulletin 9, Second Series, p. 1–240, pls. 1–24.

Münster, G., 1841: *Beiträge zur Geognosie unt Petrefacten-Kunde des südöstlichen Tirols vorzüglich der Schichten von St. Cassian, Volume 4*, 152 p., 16 pls., Buchner, Bayreuth. (*not seen*)

Niko, S., 1990: Early Carboniferous (Viséan) cephalopods from the Hikoroichi Formation, southern Kitakami Mountains. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 159, p. 554–561.

Niko, S. and Hamada, T., 1987: *Adnatoceras* from Middle Carboniferous of the Ichinotani Formation, Fukuji district, Central Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 148, p. 223–227.

Niko, S., Nishida, T. and Kyuma, Y., 1987: Middle Carboniferous Orthoceratidae and Pseudorthoceraceae (Mollusca: Cephalopoda) from the Akiyoshi Limestone, Yamaguchi Prefecture (Molluscan paleontology of the Akiyoshi Limestone Group-VIII). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 148, p. 335–345.

Niko, S., Nishida, T. and Kyuma, Y., 1991: Middle Carboniferous Bactrioidea (Mollusca: Cephalopoda) from the Akiyoshi Limestone Group, Yamaguchi Prefecture (Molluscan Paleontology of the Akiyoshi Limestone Group-X). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 161, p. 714–719.

Niko, S., Nishida, T. and Kyuma, Y., 1995: A new Carboniferous cephalopod *Bogoslovskya akiyoshiensis* from Southwest Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 179, p. 193–195.

Niko, S., Nishida, T. and Kyuma, Y., 1997: Moscovian (Carboniferous) orthoconic cephalopods from Guizhou and Guangxi, South China. *Paleontological Research*, vol. 1, p. 100–109.

Niko, S. and Ozawa, T., 1997: Late Gzhelian (Carboniferous) to early Asselian (Permian) non-ammonoid cephalopods from the Taishaku Limestone Group, Southwest Japan. *Paleontological Research*, vol. 1, p. 47–54.

Ristedt, H., 1968: Zur Revision der Orthoceratidae. *Abhandlungen der Mathematisch Naturwissenschaftlichen Klasse*, no. 4, p. 211–287, pls. 1–5.

Schindewolf, O.H., 1933: Vergleichende Morphologie und Phylogenie der Anfangskammern tetrabranchiater Cephalopoden. Eine Studie über Herkunft Stammesentwicklung und System der niederen Ammoneen. *Abhandlungen der Preussischen Geologischen Landesanstalt, Neue Folge*, no. 148, p. 1–115, pls. 1–4.

Shimizu, S. and Obata, T., 1935: New genera of Gotlandian and Ordovician nautiloids. *The Journal of the Shanghai Science Institute, Section 2, Geology, Palaeontology, Mineralogy and Petrology*, vol. 2, p. 1–10.

Sweet, W.C., 1964: Nautiloidea-Orthocerida. *In*, Moore, R.C. ed., *Treatise on Invertebrate Paleontology*. p. K216–K261. The Geological Society of America and the University of Kansas Press.

Whiteaves, J.F., 1898: On some additional or imperfectly understood fossils from the Hamilton Formation of Ontario, with a revised list of the species therefrom. *Geological Survey of Canada, Contributions to Canadian Paleontology*, vol. 1, p. 361–427, pls. 48–50.

Woodward, S.P., 1856: On an *Orthoceras* from China. *The Quarterly Journal of the Geological Society of London*, vol. 12, p. 378–381, pl. 6.

Zhuravleva, F.A., 1978: Devonskiye ortoserodei, Nadotryad Orthoceratoidea (Devonian orthoceratids, superorder Orthoceratoidea). *Akademiya Nauk SSSR, Trudy Paleontologicheskogo Instituta*, vol. 168, 223 p. (*in Russian*)

Further notes on the turrilitid ammonoids from Hokkaido–Part 1 (Studies of the Cretaceous ammonites from Hokkaido and Sakhalin–LXXXIX)

TATSURO MATSUMOTO[1] and TAKEMI TAKAHASHI[2]

[1]c/o Kyushu University Museum, Fukuoka 812-8581, Japan

[2]28-109 Hanazono-cho, Mikasa, 068-2124, Japan

Abstract. This paper contains the descriptions of *Ostlingoceras* (*Ostlingoceras*) *bechei* (Sharpe, 1857), *O.* (*O.*) aff. *bechei*, and *Neostlingoceras carcitanense* (Matheron, 1842), all from the lower Cenomanian of the Mikasa and Kotanbetsu areas; also those of two new species *Neostlingoceras asiaticum* and *N. cobbani* from the middle Cenomanian of the Mikasa area. A new genus *Hypostlingoceras* is established, with descriptions of two new species, *H. japonicum* (type species) and *H. mikasaense*, from the lower Cenomanian of the same area.

Key words: *Carthaginites*, Cenomanian, *Hypostlingoceras*, *Neostlingoceras*, *Ostlingoceras*, Turrilitidae

Introduction

Recently ten species of *Mariella* and a few species of *Mesoturrilites*, *Hypoturrilites* and *Pseudhelicoceras* from the Cretaceous of Hokkaido have been described (Matsumoto et al., 1999; Matsumoto and Kawashita, 1999; Matsumoto and Kijima, 2000; Matsumoto and Inoma, 1999; Matsumoto et al., 2000). Sources of the material for these investigations are collections from the upper Albian and lower Cenomanian of the Soeushinai area of northwestern Hokkaido and the Shuparo and Hobetsu areas of central Hokkaido.

In this and succeeding papers additional species of the Turrilitidae are to be described. The material for this paper depends mainly on the collections from the celebrated Ikushunbetsu Valley of the Mikasa area. For a general account of the stratigraphy and the locality data readers may refer to Matsumoto (1991, p. 3–5; 21–24). Supplementary notes may be added to the particular cases concerned.

The purpose of our series of papers is to present precisely the systematic descriptions of the turrilitid ammonoids from the Cretaceous Yezo Group of Hokkaido, with confirmation or revision of previously known species and also establishment of new taxa. The described species could be useful for biostratigraphic subdivision and interregional correlation. As the faunal characteristics of the subdivided units of the Albian and the Cenomanian in the North Pacific region become clearer, the results could improve the knowledge of its palaeogeography and palaeoenvironments.

Repository.—The specimens described in this paper are to be stored in the Kyushu University Museum, Fukuoka, 812-8581, Japan, which is indicated by the letters GK at the head of a register number. To each specimen collected by T. T. a personal number was provisionally given. This numbering was set in accordance with the date of his field work. Although not official register numbers, they should not be ignored, because they are written clearly in red ink on each specimen and because they are tied to his field notes and will enable readers to get useful information. In this paper such numbers are indicated in brackets, as for instance, GK. H8531 [= previous S. 37·7·17] (Figure 1 D–F). Herein S. means *Showa*, a reign style in Japan and S. 37 = 1962.

A few specimens which were housed in the Geological Collections, Faculty of Culture and Education, Saga University, Saga, 840-8502, Japan (abbreviated as GS), are transferred to GK.

Systematic descriptions

Order Ammonoidea Zittel, 1884
Suborder Ancyloceratina Wiedmann, 1966
Superfamily Turrilitaceae Gill, 1871
Family Turrilitidae Gill, 1871
Genus *Ostlingoceras* Hyatt, 1900
Subgenus *Ostlingoceras* (*Ostlingoceras*) Hyatt, 1900

Type species.—*Turrilites puzosianus* d'Orbigny, 1842 (p. 587, pl. 143, figs. 1, 2) by original designation (Hyatt, 1900,

p. 587).

Diagnosis.—See Wright and Kennedy, 1996, p. 320.

Remarks.—Wright and Kennedy (1996, p. 320) treated *Parostlingoceras* Breistroffer (1953, p. 1350) as a subgenus of *Ostlingoceras*. No example of *O.* (*Parostlingoceras*) has been found in Hokkaido. In addition to *O.* (*O.*) *puzosianum* ten species were assigned to *O.* (*Ostlingoceras*) by Wright and Kennedy (1996, p. 321). Moreover, *Turrilites* cf. *colcanapi* of Pervinquière (1910, p. 50, pl. 14, fig. 4) from Algeria was revised to *O.* (*O.*) *collignoni* Wright and Kennedy (1996, p. 340, text-fig. 138E), although it deviates from the normal species of *O.* (*Ostlingoceras*) in its larger apical angle.

The available material of *O.* (*Ostlingoceras*) from Hokkaido is not numerous but fairly good in showing the characters that enable us to define more clearly previously named species. There are a few other indefinite taxa which are temporarily placed in this subgenus. One of them is described in this paper.

Ostlingoceras (Ostlingoceras) bechei (Sharpe, 1857)

Figures 1A–C, D–F; 2A, B

Turrilites bechei Sharpe, 1857, p. 66, pl. 26, fig. 13 [as *bechii* on p. 66]

Ostlingoceras bechei (Sharpe, 1857). Wright and Wright, 1951, p. 18; Marcinowski, 1970, p. 435, pl. 3, fig. 5; Kennedy, 1971, p. 25 (*pars*), pl. 8, figs. 9, 13.

Ostlingoceras (*Ostlingoceras*) *bechii* (Sharpe, 1857). Atabekian, 1985, p. 50, pl. 14, fig. 6.

Ostlingoceras (*Ostlingoceras*) *bechei* (Sharpe, 1857). Wright and Kennedy, 1996, p. 321, pl. 96, figs. 6, 14–16, 18, 23.

Name of the species.—Two names have been used for this single species since Sharpe's (1857) original paper: *Turrilites Bechii* in the heading of the description (p. 66) and *Turrilites Bechei* in the explanation to plate 26, fig. 13a, b. Sharpe noted that the specimen was found by Sir H. T. de la Beche, and that it was named in his memory. We agree with Wright and Wright (1951, p. 18) in regarding *T. Bechii* as an obvious misprint for *T. Bechei*.

Holotype. — By monotypy, BMNH 88, the original of Sharpe, 1857, pl. 26, fig. 13, from the 'Cenomanian Limestone' near Lyme Regis, Devon (southern England).

Material.—GK.H8529 (Figure 1A, B, C), found by Tamotsu Omori near Loc. Ik1065b of the Shimo-ichino-sawa, a tributary of the River Ikushunbetsu; GK. H1381 (not figured), obtained in 1955 by T. M. at Loc. Ik1065b; GK.H8531 [previous
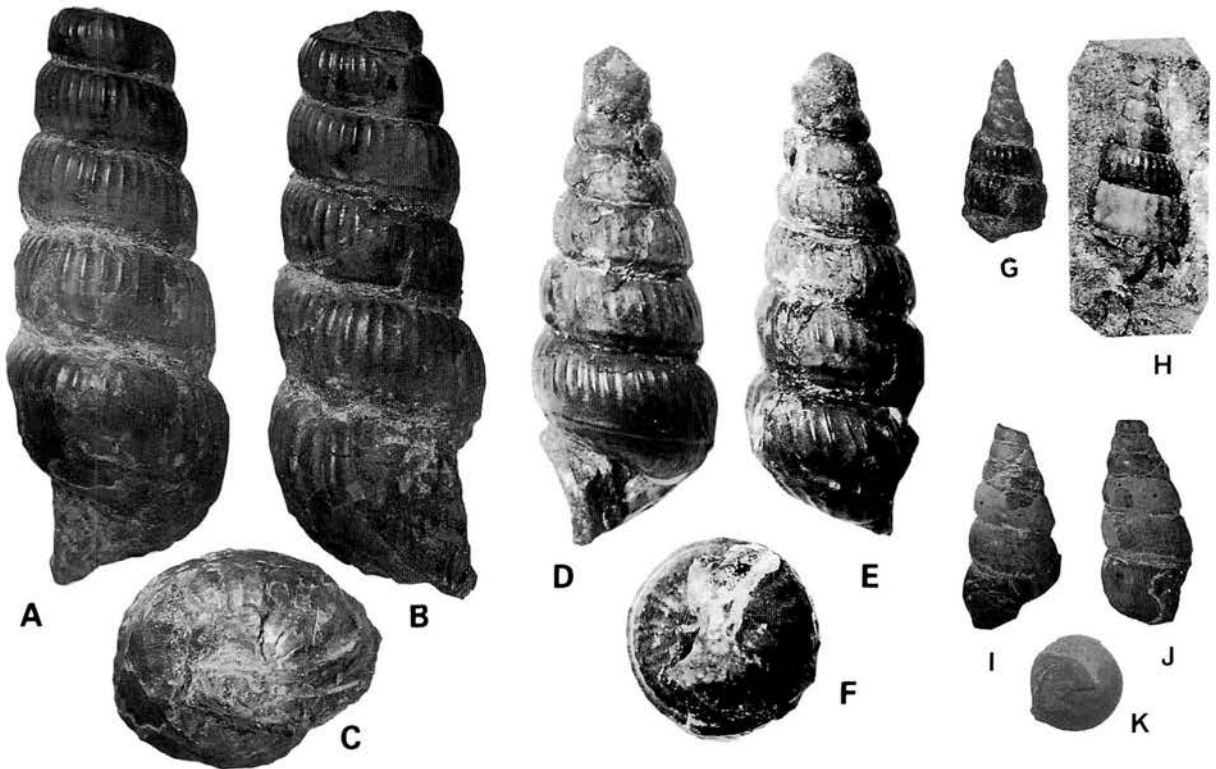
Figure 1. **A–C, D–F.** *Ostlingoceras* (*Ostlingoceras*) *bechei* (Sharpe, 1857). Two lateral (A and B, 180° apart) and basal (C) views of GK.H8529; similar views (D, E, F) of GK. H8531. **G–H, I–K.** *Ostlingoceras* aff. *bechei* (Sharpe, 1857). Extracted (G) and undeveloped (H) states of GK. H8530; two lateral (I, J) and basal (K) views of GK. H8555. All figures are ×2, except for H (×2.5). Photos courtesy of M. Noda (D–F, H) and T. Nishida (others).

Table 1. Measurements of *Ostlingoceras (O.) bechei* (Sharpe).

Specimen	NW	Hp	Ht	D	ap	h	d	h/d	R	r/h
GK. H8529	5	38.0	58.0	17.5	20°	7.4	13.8	0.54	32	6-7
GK. H8531	5	27.0	40.0	12.5	23°	6.1	11.5	0.53	30	6
BMNH88	4	50.0	75.0	29.8	20°	11.5	21.5	0.53	—	7

NW = number of the preserved whorls, Hp = total height of the preserved whorls, Ht = total shell height from the preserved last whorl to the estimated apex, D = diameter of the preserved last whorl, ap = estimated apical angle, h = height of an exposed outer face [= flank] of a late whorl, d = diameter of the same whorl, R = number of ribs on the same whorl, r/h = number of ribs in the interval equal to h. Linear dimension is in mm.

S. 37·7·17] (Figure 1D, E, F), collected by T. T. in 1962 at a locality on the Onkonosawa, a branch of the River Ponbetsu, which is a major tributary of the River Ikushunbetsu.

Description.—The two illustrated specimens preserve five whorls but are dissimilar in size. Their dimensions are shown in Table 1. As the youngest part is lacking, the apical angle is estimated from the preserved part. It is fairly low but seems to vary to some extent between individuals (20°-23°).

The shell is turreted, sinistral, and the whorls are tightly in contact. The outer exposed whorl face is rounded, and its main part (= flank) is gently inflated and has a weak shoulder on its upper margin. Transverse ribs are numerous, somewhat prorsiradiate, and moderately distinct. They are much weakened at (or interrupted by) a shallowly concave, narrow spiral zone in the lower part of the flank. They may be faintly swollen above this zone, showing sinuous curvature. Still lower, parallel to the lower whorl seam, there are two rows of spirally elongated tubercles, that correspond in number to the transverse ribs. The two rows tend to form narrow ridges, with an intervening, narrow groove between them. The lower ridge runs along the lower whorl seam. In other words it forms the outer outline of the basal surface, where the ribs extend to run with an anteriorly convex curvature to the narrow umbilicus. On the marginal part of the basal surface close to the second row of clavate tubercles there is another (i. e., fourth) row of small tubercles resting on the basal ribs.

The number of ribs seems to vary to some extent with growth and also between individuals. Where the shelly layer is preserved the ribs are more distinct than on the internal mould.

In the preserved last part of GK. H8529, the largest specimen of the three, a few ribs tend to strengthen and curve more markedly than the other ones (Figure 1B, C). This could be inferred as flaring near the peristome, although the interpretation is uncertain.

Septal sutures are exposed on some parts of the flank, showing a fairly broad E-L saddle, L, and a narrower L-U saddle. These elements show minor incisions (Figure 2).

Comparison.—The specimens from Hokkaido are essentially similar to the holotype and other specimens from the 'Lower Chalk'. GK.H8529 surprisingly resembles the partly restored illustration of the holotype (Sharpe, 1857, pl. 26, fig. 13). Actually the holotype was in part enclosed by rock matrix, when one of us (T. M.) examined it at the Natural History Museum, London. Its characters are, however, well expressed by Sharpe's figure. The differences from the two illustrated specimens from Hokkaido are in the somewhat larger size and more delicate ribbing of the holotype. As the shelly layer is not preserved in the British specimen and as the number of ribs tend to increase with growth, the above differences are quite natural and would not invalidate the identification.

Discussion.—As described above, GK. H8529 may be almost adult, whereas the holotype, despite its larger shell, does not show the feature that should occur near the adult apertural end. This may suggest a difference in size. Wright and Kennedy (1996) pointed out the presence of size dimorphs in many species of the Turrilitidae, although they did not discuss this problem with respect to *O. (O.) bechei.*
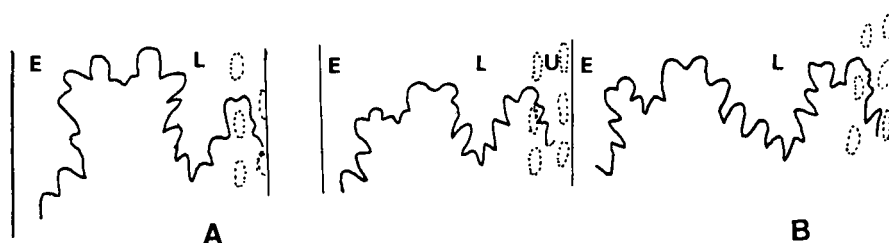
Figure 2. A, B. *Ostlingoceras bechei* (Sharpe, 1857). A: External suture on the whorl flank of GK. H8531 at h = 4.5 mm. Figure is about ×7.5. B: Ditto on the flank of successive whorls of GK. H8529 at h = 4.5 mm and 6.0 mm. Figure is about × 7. Straight line: whorl seam, dotted line: tubercles; E: external lobe; L: lateral lobe; U: umbilical lobe. Drawing by T. M.

Table 2. Measurements of *Ostlingoceras* (*O.*) aff. *bechei* (Sharpe).

Specimen	NW	Hp	Ht	D	ap	h	d	h/d	R	r/h
GK. H8530	6	12.0	13.3	5.5	30°	2.2	5.0	0.44	25	4-5
GK. H8537	5	13.3	16.5	6.2	30°	3.0	6.2	0.48	27	5

Legend as for Table 1.

In fact, the available specimens are not numerous enough to determine whether the size difference mentioned above is an indication of individual variation or implies dimorphism. The question is left for further investigation.

Occurrence.—As for material. On the basis of the location, lithology and associated species, the described three specimens came from the lower part of the Member IIb of the Mikasa Formation and are of early Cenomanian age.

Distribution. — *Ostlingoceras* (*O.*) *bechei* has been reported to occur in the lower Cenomanian of England, Poland and Azerbaidjan (see Wright and Kennedy, 1996, p. 322). Its occurrence in Hokkaido of the North Pacific region suggests a more extensive distribution of this species.

Ostlingoceras (*Ostlingoceras*) aff. *bechei* (Sharpe, 1857)

Figure 1G, H; I-K

Material.—Two small specimens: GK.H8530 (Figure 1G, H) collected by T. M. at Loc. Ik1065b of the Shimo-ichino-sawa, a tributary of the River Ikkushunbetsu; GK. H8555 [= previous GS.G058] (Figure 1I, J, K) collected by Tamio Nishida and T. M. at Loc. R735 pl in the upper reaches of the River Oku-futamata, a branch of the River Kotanbetsu (see Nishida *et al.*, 1993, fig. 1 for the location). The second specimen is probably derived from the upper part of the lower Cenomanian on the basis of its location and associated *Inoceramus* cf. *virgatus* Schlüter.

Description.—These two specimens are generally similar to the typical specimens of *Ostlingoceras* (*O.*) *bechei* (Sharpe, 1857) described above, but the young part, at the same size as the former, is lacking or poorly preserved in the latter. As is shown in Table 2, the estimated apical angle is somewhat larger and the ribs are less numerous and seem to be relatively coarser and shorter in the former in comparison with the latter. Moreover, the preserved earliest whorl (diameter = 1.3 mm in GK. H8530) shows an inflated flank. Tentatively, we call this taxon *Ostlingoceras* (*O.*) aff. *bechei* (Sharpe), although the above difference might imply a change with growth in *O.* (*O.*) *bechei.* It seems to resemble the taxon from Germany which was described under '*O.* (*O.*) aff. *bechii*' by Lehmann (1998, p. 37, without figure), but as we have not examined the actual specimen, we hesitate to confirm the identity.

Genus *Neostlingoceras* Klinger and Kennedy, 1978

Type species. — *Turrilites carcitanensis* Matheron, 1842 -(p. 267, pl. 41, fig. 4) by original designation (Klinger and Kennedy, 1978, p. 14).

Diagnosis.—Sinistrally coiled turrilicone, with low apical angle (less than 20°) and roughly flat flank of the whorl; or-namented by coarse tubercles in an upper row and more numerous finer tubercles in lower 2 or 3 approximated or coalesced rows, with a shallowly concave zone below the upper row; faint transverse riblets may extend upward and/-or downward and scarcely cross the concave belt. Siphuncle runs along the upper shoulder or still higher immediately below or along the upper whorl seam, depending on the species.

Discussion.—The type species and its allied species *N. oberlini* (Dubourdieu, 1953) have been regarded as being well defined. The available specimens are, however, mostly fragmentary, without showing the details of the early growth stage or those of the last stage. The origin of this genus has been sought in *Ostlingoceras* (Klinger and Kennedy, 1978, p. 15).

In addition to the above two species from the lower Cenomanian, Cobban and Hook (1981) and Cobban *et al.* (1989) described five species from the middle and upper Cenomanian of New Mexico, of which one species, *N. virdenense* Cobban, Hook and Kennedy, occurs also in the upper Cenomanian of England (Wright and Kennedy, 1996). Furthermore, there are two new species (described below) in the middle Cenomanian of Hokkaido. Some of these species are represented by very small specimens, as shown by *N. procerum* Cobban, Hook and Kennedy, 1989 (p. 60, figs. 62, 95, O, P) and *N. asiaticum* sp. nov. (to be established below). They are, in their early growth stage, very similar to *Carthaginites kerimensis* (Pervinquière, 1907) (p. 101, pl. 4, figs. 18, 19) or *C. krorzaensis* Dubourdieu, 1953 (p. 66, pl. 4, figs. 49–52). Hence, the question might arise that *Neostlingoceras* is a junior synonym of *Carthaginites.* Until the characters of the later growth stages in *Carthaginites* can be made clear, *Neostlingoceras* should be used in accordance with the current difinition.

Occurrence.—The genus has been recorded to occur in the Cenomanian of France, England, Germany, Poland, Romania, Turkmenistan, Kazakstan, Iran, Israel, Tunisia, Algeria, Madagascar, South Africa, New Mexico, Colorado, Wyoming, Texas and Japan. Although the type species and its allied species occur characteristically in the lower Cenomanian, other species are recorded from the middle and upper parts of the Cenomanian.

Neostlingoceras carcitanense (Matheron, 1842)

Figure 3A-C, D-F

Turrilites carcitanensis Matheron, 1842, p. 261, pl. 41, fig. 4; Fabre, 1940, p. 242, pl. 5, fig. 7.

Turrilites morrisii Sharpe, 1857, p. 65 (*pars*), pl. 26, figs. 4, 6-7.

Hypoturrilites carcitanensis (Matheron). Kennedy, 1971, p. 59 (*pars*), pl. 6, figs. 1, 2, 4-6, 9, 10.
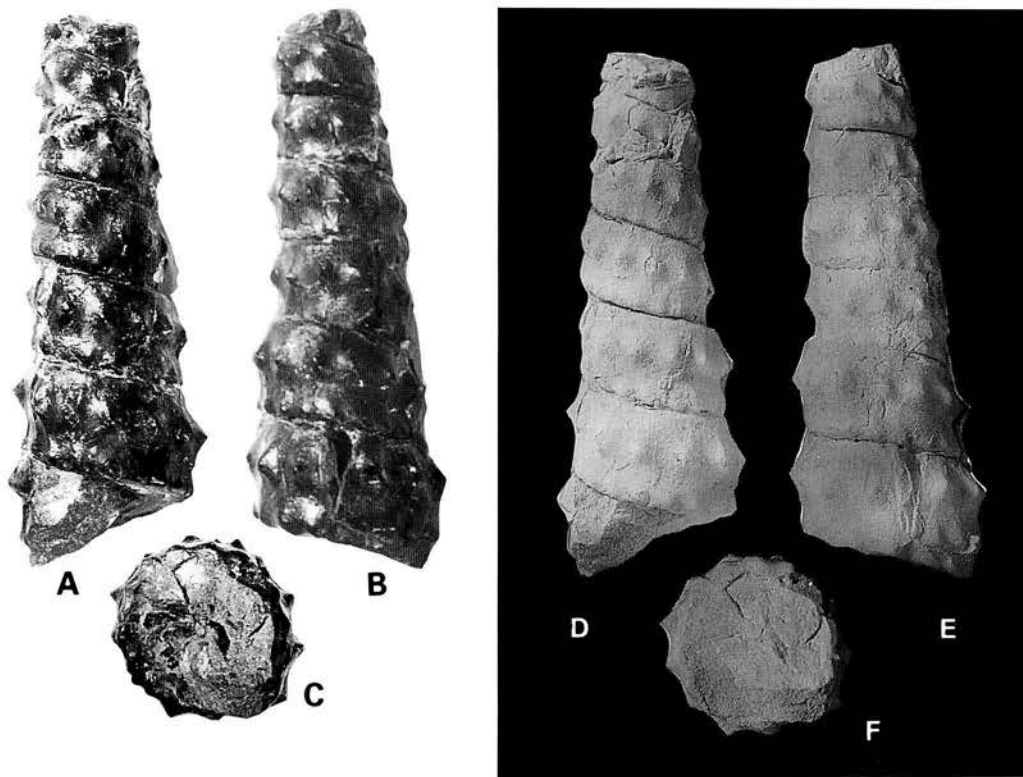
Figure 3.   A–C, D–F. *Neostlingoceras carcitanense* (Matheron, 1842).   Two lateral (A and B, 180° apart) and basal (C) views of GK. H8534, without whitening; similar views (D, E, F) of the same specimen with whitening.   ×1.   Photos courtesy of M. Noda (A–C) and T. Nishida (D–F).

Turrilites (Hypoturrilites) carcitanensis (Matheron).   Immel, 1979, p. 635, pl. 4, fig. 1.

Neostlingoceras carcitanense (Matheron).   Klinger and Kennedy, 1978, p. 15 (*pars*), pl. 3, fig. G; Wright and Kennedy, 1996, p. 326, pl. 99, figs. 1–7, 9–15, 18, 19, 22; pl. 100, fig. 8; text-fig. 140B (with full synonymy).

Holotype.—By monotypy, the original of Matheron, 1842, pl. 41, fig. 4.   We have not seen the specimen, which seems to be fragmentary as shown by Fabre's (1940, pl. 5, fig. 7) reillustration.   The type locality is in southern France.   Its present repository is uncertain (see Wright and Kennedy, 1996, p. 327).

Material.—GK. H8534 [= previous S. 40·8·15] (Figure 3A–C, D–F), collected by T. T. in 1965 at Loc. Ik1054 below the bridge called 'Katsura-Ohashi'.   It was found in the dark green silty fine-grained sandstone of the Zone of *Mantelliceras japonicum*.   Another crushed specimen, GK. H8556, was found by T. M. at Loc. R82 of the Soeushinai-Kontanbetsu area (for the location see Matsumoto and Okada, 1973, fig. 7).   It was from the mudstone in the lower part of the Member My5.   One of us (T. M.) examined the specimens from England (see above synonymy) at the Natural History Museum, London to compare them with ours.

Description.—Six continuous whorls are preserved in GK. H8534, which is 47 mm high altogether and 15.6 mm in diameter of the last whorl.   The ratio of height to diameter in the exposed part of each whorl is roughly 5:9.   The apical angle estimated from the preserved part of the shell is as low as 13°.   The early part of the shell is lacking.

Each whorl is ornamented by an upper row of larger tubercles, 13 to a whorl, and a lower row of smaller, double tubercles 18 or 19 per whorl, above the lower whorl seam.   The upper tubercle is pointed at the top and its base is bullate upward, whereas a concave spiral zone runs at about the
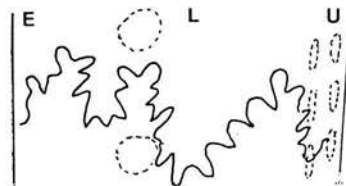
Figure 4.   *Neostlingoceras   carcitanense*   (Matheron, 1842).   External suture of GK. H8534 on the flank at h = 7.8 mm.   Figure is about ×5.5.   Symbols as for Figure 2.   Drawing by T. M.

midflank immediately below the row of major tubercles. The double tubercle of the lower row consists of a small subrounded upper one and rather clavate lower one which are closely set. Some of the upper ones are bullate upward, whereas the lower ones form the outer edge of the basal surface.

The suture is exposed on a part of the flank, showing L in the middle part of the flank, with saddles on either side of L. They are moderately incised at the middle growth stage (Figure 4).

Remarks.—When the genus *Neostlingoceras* was introduced, Klinger and Kennedy (1978, p. 15) considered that *N. carcitanense* (Matheron, 1842) is so variable that *N. oberlini* (Dubordieu, 1953) and some others were within its variation or might be subspecies in a successive sequence. Such an interpretation has been recently denied by Wright and Kennedy (1996, p. 327-328), with whom we agree.

Comparison.—The described specimen shows clearly the morphological characters of this species. It quite well resembles a specimen called SAS SM (Klinger and Kennedy, 1978, pl. 3, fig. G) from the Mzinene Formation, Cenomanian II, of the Skoenburg, Zululand.

Occurrence.—As for material. This species marks the basal zone of the Cenomanian in England, but it occurs in the beds of the next and still higher levels in Hokkaido.

Neostlingoceras asiaticum sp. nov.

Figures 5 A–C, D–F, G–I; 6

Material.—Holotype is GK. H8536 [= previous S. 36·8·26] (Figure 5A, B, C) collected by T. T. in 1961 at Loc. Ik1103 from the middle part of the Cenomanian in the Mikasa area on the western wing of the Ikushunbetsu anticline. Two other specimens (paratypes) are GK. H8537 [= previous S.
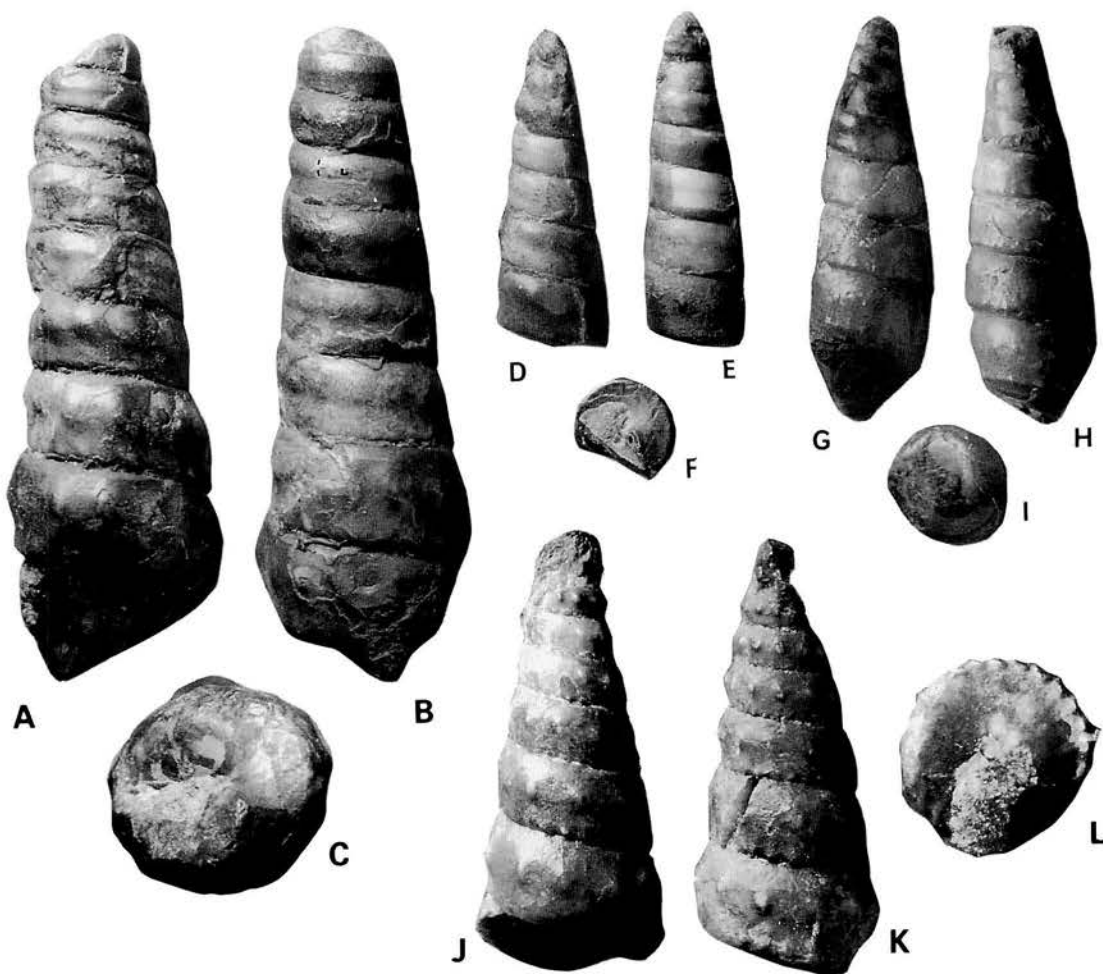
Figure 5. **A–C, D–F, G–I.** *Neostlingoceras asiaticum*, sp. nov. Two lateral (A and B, 180° apart) and basal (C) views of GK. H8536 (holotype). Similar views (D, E, F) of GK. H8537 and ditto (G, H, I) of GK.H8538. **J–L.** *Neostlingoceras cobbani* sp. nov. Two lateral (J and K, 180° apart) and basal (L) views of GK. H8535 (holotype). Figures are all ×3. Photos courtesy of M. Noda.

Table 3. Measurements of *Neostlingoceras asiaticum* sp. nov.

Specimen	NW	Hp	Ht	D	ap	h	d	h/d	T	t
GK. H8536	7.5	28.0	45.3	10.0	13°	3.8	8.7	0.44	15	30
GK. H8537	6 + a	14.2	21.0	4.7	14°	2.2	4.7	0.47	—	—
GK. H8538	7	16.2	26.0	5.3	15°	2.5	5.5	0.48	16	32

T = number of upper tubercles, t = number of lower tubercles, 6 + a = somewhat over 6. See Table 1 for other abbreviations.
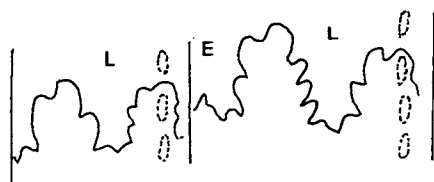
Figure 6. *Neostlingoceras asiaticum* sp. nov. External suture on the flank of two successive young whorls of GK. H8537 at h = 1.4 mm and 1.9 mm. Figure is about ×16. Symbols as for Figure 2. Drawing by T. M.

55·3·10A] (Figure 5D, E, F) and GK. H3538 [= S. 55·3·10B] (Figure 5G, H, I) collected by T. T. in 1980 at the type locality (Ik1103). This locality belongs to the Abunance Zone of *Calycoceras* (*Newboldiceras*) *asiaticum*.

Diagnosis.—Shell slender with a low apical angle; whorl at early growth stage rather flat-sided, with rounded upper shoulder and shallow groove at midflank. Later, blunt nodes are developed on the upper shoulder and numerous minute tubercles are aligned along the lower edge of the flank. Suture fundamentally similar to that of *Ostlingoceras* (*O.*) *bechei*, but apparently simple on account of the small size of the shell (Figure 6).

Description.—The three specimens are all small as shown in Table 3. They preserve the shell layer for the most part. In GK.H3537, the smallest specimen, the suture is well shown at its preserved middle stage (2.3 mm in whorl height). It is rather simple, but the elements (L and the saddles on either side) exposed on the next whorl show more clearly minor indentations. L is situated on the concave zone of the midflank.

The holotype is the largest of the three specimens. Its earlier part is lacking. If its preserved last part be assumed to reach a part of the last whorl, the restored outline of the shell would be roughly 45 mm in height.

In every specimen the whorl junction is clearly impressed. The ratio of height to diameter in each whorl is low (less than 0.5). A gradual change of ornament with growth is evidently shown by the holotype. Two paratypes generally follow the holotype in this regard.

In young whorls a shallow and narrow, spiral groove runs at about the midflank and a low, spiral elevation above the groove forms a rounded shoulder in the upper part of the flank.

In the next step of growth, the upper elevation is faintly undulated and the lower edge of the whorl has numerous, tiny tubercles. Soon this is followed by broadening of the upper

elevation on which bluntly raised and upward bullate nodes are developed. The spiral groove below the upper elevation is somewhat shifted downward from the midflank and numerous small tubercles become distinct on the lower edge. The upper tubercles are 15 or 16 per whorl and the lower ones are twice as numerous as the upper ones. Both tubercles become gradually distinct with growth and a short riblet extends upward from each of the lower tubercles. Finally on the preserved last whorl narrow transverse ribs run obliquely downward (i. e., adorally) from some of the upper tubercles. Underneath the row of lower tubercles there is a train of narrowly clavate tubercles, which defines the margin of the basal surface of the whorl.

Comparison.—This species is unique among the nine species of *Neostlingoceras* in that its younger part is similar to *Carthaginites krorzaensis* Dubourdieu, 1953 (p. 66, pl. 4, figs. 49–52, text-fig. 20), from the upper Cenomanian of eastern Algeria, also to *C.* cf. *krorzaensis*, from the upper Cenomanian of England (Wright and Kennedy, 1996, p. 361, pl. 98, fig. 11), whereas its later whorls show the general characters of *Neostlingoceras*.

The present species somewhat resembles *N. bayardense* Cobban, Hook and Kennedy, 1989 (p. 60, figs. 95R, 96R), from the Zone of *Calycoceras canitaurinum* in New Mexico, but the latter has a still lower apical angle (11°), distinctly flatter flank and finer and more numerous tubercles in the upper row.

N. procerum Cobban, Hook and Kennedy, 1989 (p. 60, figs. 62, 95 O–Q, S), from the upper Cenomanian *Metoicoceras mosbyense* Zone in New Mexico, is also similar to the younger part of the present species. Its shell is, however, more slender with a lower apical angle (10°). In later growth stages the nodes in the upper row are more distinct and coarser in *N. asiaticum*. It should be noted that transverse ribs occur at the late growth stage in both species.

Occurrence.—As for material. It should be noted that the present species is fairly close in geological age to *N. bayardense* mentioned above.

Neostlingoceras cobbani sp. nov.

Figure 5J–L

Material.—Holotype, designated herein, is GK. H8535 [= previous S.36·3·28] (Figure 5J, K, L), collected by T. T. in 1961 at loc. Ik1103 of Nishikatsurazawa, from the middle Cenomanian part of the Mikasa Formation on the western wing of the Ikushunbetsu anticline. At present it is the sole available material for this rare but noteworthy species.

Specific name.—In honor of William A. Cobban, who has

Table 4. Measurements of *Neostlingoceras cobbani* sp. nov.

Specimen	NW	Hp	Ht	D	ap	h	d	h/d	T	t
GK. H8535	6 + a	20.0	25.5	8.8	20°	3.5	7.5	0.47	10	25

Abbreviations as for Table 3.

made a remarkable contribution to palaeontology and biostratigraphy.

Diagnosis.—A species of *Neostlingoceras* that shows a comparatively less acute apical angle for the genus, distantly disposed and rather bluntly elevated tubercles of the upper row, shallower concave zone at midflank and numerous, small tubercles of the lower row. Small size of the shell appears to be diagnostic, but is not necessarily definite.

Description.—This specimen preserves six whorls, but its very apex and late whorls are unpreserved. It is small, as shown in Table 4, although the true size of the completely preserved original shell is not known. The proportion of height to diameter of each whorl is less than 0.5. The apical angle as estimated from the preserved part of the shell is 20°.

The upper part of the outer exposed whorl face slopes down to the upper row of tubercles where a shoulder is formed. The tubercles of this row are distant and not numerous; 10 per whorl on average. Each of them is a bluntly pointed node which is broadened but lowered upward. A shallowly concave spiral zone runs below the upper row of major tubercles. Minor tubercles of the lower row are numerous, 25 per whorl. They are arranged in a single row immediately above the lower whorl seam, but each of them seems to be double, as it is granular in lateral view but is rather clavate in lower view, forming the outer edge of the lower face of the whorl. In other words the lower tubercles may be those of united 2nd and 3rd rows. Sometimes faint riblets may extend upward from the lower tubercles across the concave zone below the row of major tubercles. On the lower face of the whorl ribs are scarcely discernible.

The suture is not well traced. The preserved last whorl is still septate, showing minor indentation on the lobes of L, U and adjacent saddles.

Comparison.—Although the specimen is small, it shows the generic charcters of *Neostlingoceras*. It is distinguished from *N. carcitanense* by the diagnosis (see above). Although the ratio of height to diameter of each whorl may vary to some extent within a species, it is generally smaller in the present species than in the cases of *N. carcitanense*, *N. oberlini* and also *N. kottlowskii* Cobban and Hook, 1981 (p. 26, pl. 4, figs. 1–28; Cobban, 1984, p. 17, pl. 4, fig. 9; Cobban *et al.*, 1989, p. 60, fig. 95 A–F). *N. kottlowskii* is closer in geological age to the present species than the other two.

Occurrence and distribution.—As for material; unique at present.

Genus **Hypostlingoceras** nov.

Type species.—*Hypostlingoceras japonicum* sp. nov. (described below).
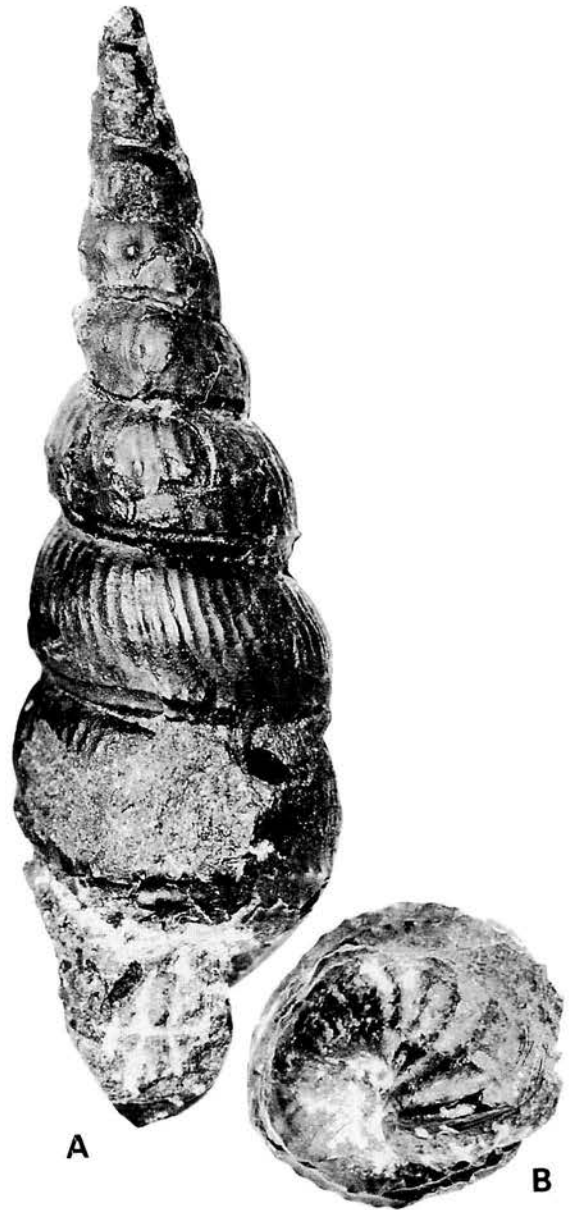
Figure 7. A, B. *Hypostlingoceras japonicum* gen. et. sp. nov. Lateral (A) and basal (B) views of GK.H8542 (holotype). Figures are ×2. Photos courtesy of M. Noda.

Diagnosis.—Turrilitid ammonoids which show peculiar change of characters with growth. Whorls in early growth stages have coarse or strong tubercles at about the midflank and numerous, minute tubercles in at least two lower rows. Sooner or later the tubercles at midflank gradually weaken and become sparse, whereas transverse ribs intervene between the tubercles. Finally the midflank tubercles disappear, while numerous transverse ribs predominate, and thus the ornamentation as well as the whorl shape becomes quite similar to that of *Ostlingoceras*.

Discussion.—On account of its more or less slender shell shape and small size, this genus resembles *Neostlingoceras* rather than *Hypoturrilites* in its youth. In more or less later growth stages it is quite similar to *Ostlingoceras*. The stage at which the characters of the *Neostlingoceras* type change to those of the *Ostlingoceras* type varies to some extent, and the change occurs more or less gradually. Based on the above facts, we presume that *Hypostlingoceras* may have been derived from *Ostlingoceras* in parallel with *Neostlingoceras*. The type specimens are never artificial chimeras.

Occurrence.—At present this genus is represented by two species from the lower Cenomanian in the Mikasa area of Hokkaido. More material should be searched for to determine clearly the geological and geographical distribution as well as the phylogenetic relationships of this genus.

Hypostlingoceras japonicum sp. nov.

Figures 7A, B; 8A–E; 9A–E; 10

Material.—Holotype, designated herein, is GK. H8542 [= previous S. 36·7·25] (Figures 7A, B; 8A, B, C, D, E), collected by T. T. in 1961 from the lower part of the Mikasa Formation exposed on the Ganseki-zawa, i. e., the eighth branch of the Kami-ichino-sawa, a tributary of the River Ikushunbetsu. Paratype is GK. H8541 [= previous S. 39· 9·11] (Figure 9A, B, C, D, E) collected by T. T. in 1964 at Loc. 7045 of T. T. in the Suido-no-sawa, a short branch of the River Ikushunbetsu. The beds at the above two localities are referred to the *Mantelliceras japonicum* Zone, and are early Cenomanian in age.

Diagnosis.—Shell shape is slender, with low apical angle, and rather small. Whorls in youth subtrapezoid in lateral view, with square shoulder at midflank where coarse and strong tubercles are disposed at intervals. Then comes a transitional stage, where whorl is subrounded, midflank tubercles weaken and extend upward to ribs and additional intervening ribs occur. Whorls in later growth stages gently inflated on side and ornamented densely by numerous transverse ribs. Minute tubercles are aligned on the lower two narrow ridges throughout growth.

Description.—The two specimens, GK. H8542 and GK. H8541, are much different in size but similar in their slender
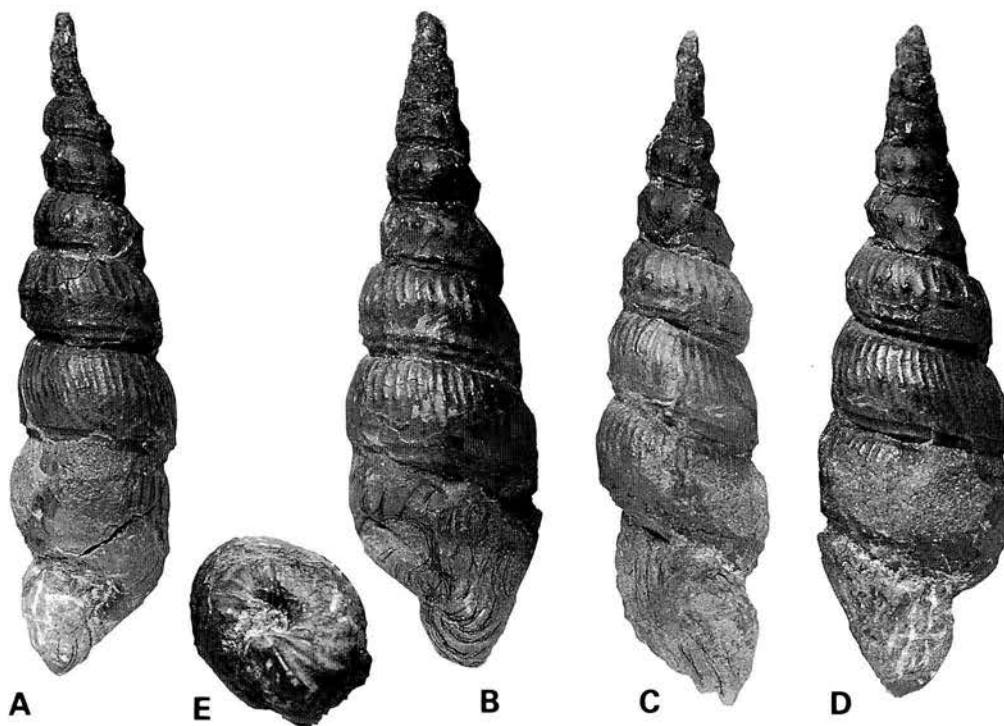
Figure 8. A–E. *Hypostlingoceras japonicum* gen et sp. nov. Four lateral (A, B, C, D, successively 90° apart clockwise) and basal (E) views of GK.H8542 (holotype). Figures are ×1.2. Photos courtesy of T. Nishida.

Table 5. Measurements of *Hypostlingoceras japonicum* sp. nov.

Specimen	NW	Hp	Ht	D	ap	h	d	h/d	R	T	t
GK. H8542	8 + a	69.0	80.0	20	18°	11.0	19.0	0.58	40	16	30
GK. H8541	7 + a	26.5	34.0	8.5	18°	4.2	7.4	0.57	32	15	—

Abbreviations as for Tables 1 and 4. T and t are measured on the whorl at 2 volutions earlier than that where h, d, and R are measured.
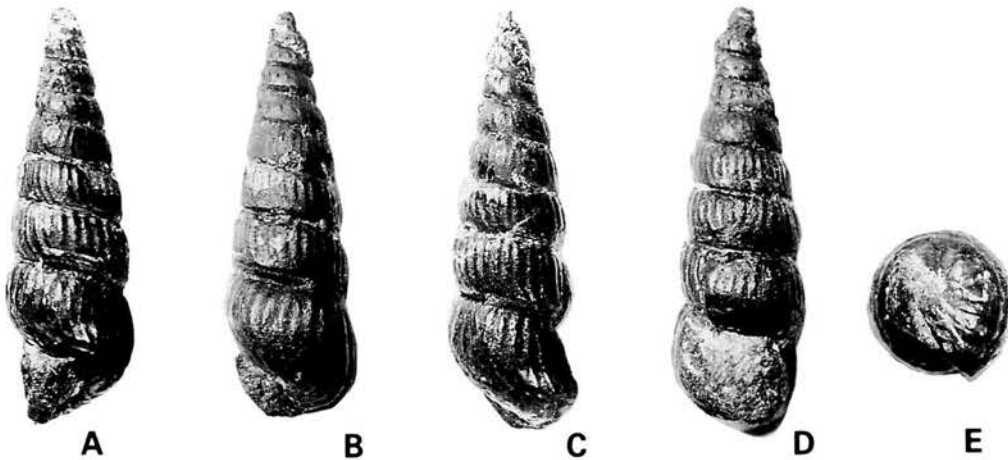
Figure 9.   A–E. *Hypostlingoceras japonicum* gen. et sp. nov. Four lateral (A, B, C, D, successively 90° apart clockwise) and basal (E) views of GK.H8541 (paratype).   Figures are ×2. Photos courtesy of M. Noda.

shell shape with a low apical angle (about 18°) and the proportion of the flank height and diameter of each whorl is slightly above 0.5 (see Figures 7–9 and Table 5).   The stage characterized by strong midlateral tubercles is manifested by several young whorls in the two specimens, although the youngest part is destroyed or unpreserved.   The change in the whorl shape and ornamentation is evident in both specimens, but it occurs in the whorl at a diameter of about 15 mm in GK. H8542, whereas it occurs at a diameter of about 5 mm in GK. H8541.   An *Ostlingoceras*-like late stage continues for fully 3 whorls in the smaller specimen (GK. H8541) and for 2.5 whorls in the larger one (GK. H8542).

In the larger specimen the longitudinal ribs become denser and more numerous on the whorl of the later growth stage (Figure 8).   However, near the preserved last part a few ribs strengthen and markedly curve on the convex basal surface (Figure 7B).   However, as the last whorl is partly destroyed, we cannot confirm the real peristome.   In the smaller specimen the ribs do not become particularly dense and numerous in the preserved last whorl.   They curve rather moderately on the convex lower surface (Figure 9).

Almost throughout growth, in both specimens, small tubercles are aligned in two rows on the narrowly raised ridges which are separated by a narrow groove.   At first these minor tubercles correspond in number and disposition to the major ones, but soon they become more numerous and clavate.   These two rows of minor tubercles correspond to
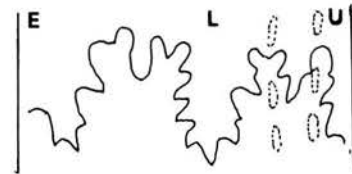
Figure 10. *Hypostlingoceras japonicum* gen. et sp. nov. External suture of GK. H8541 (paratype) on the preserved last whorl at h = 5 mm and d = 8.2 mm.   Figure is about ×9. Symbols as for Figure 2.   Drawing by T. M.

the second and third rows in certain species of *Ostlingoceras* (*Ostlingoceras*).   The second row forms the lower edge of the flank and the third row runs along the lower whorl seam.

In the early stages there is a concave spiral zone below the subangular zone of strong tubercles.   In the transitional and later stages, the concave zone shifts downward and the ribs have more or less weakened smaller tubercles above this zone.   These minor tubercles may be so reduced that they may be sometimes expressed as faint swellings.   The ribs extend further to run across the concave zone with gentle sinuosity and weakening and are connected with minor tubercles of the second row.   In addition to the tubercles of
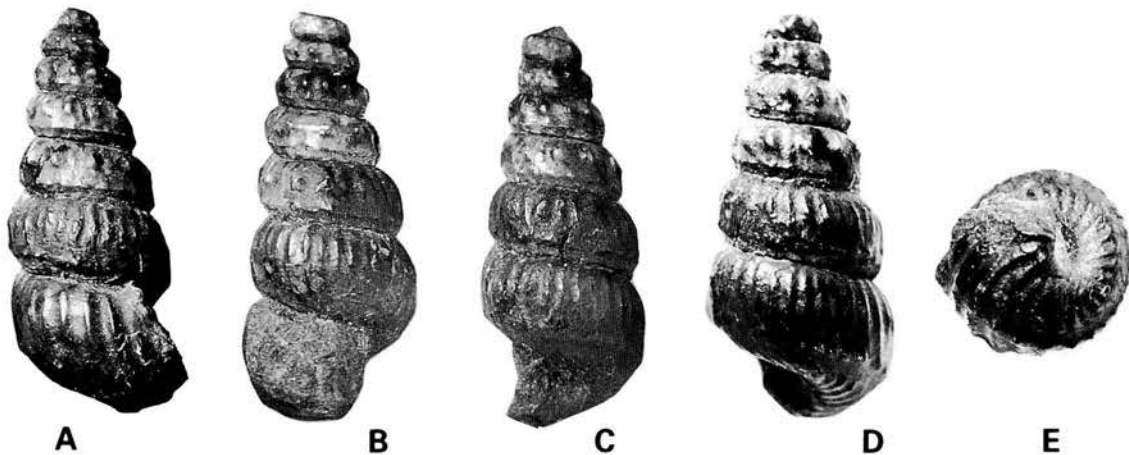
Figure 11. A-E. *Hypostlingoceras mikasaense* gen. et sp. nov. Four lateral (A, B, C, D, successively 90° apart clockwise) and basal (E) views of GK.H8540 (holotype). All figures are × 2.1. Photos courtesy of T. Nishida (A–C) and M. Noda (D, E).

Table 6. Measurements of *Hypostlingoceras mikasaense* sp. nov.

Specimen	NW	Hp	Ht	D	ap	h	d	h/d	R	T	t
GK. H8540	6	26.0	32.0	13.0	30°	4.6	10.3	0.45	30	14	23

Abbreviations as for Table 5.

the third row, those of the fourth row may be discernible on some ribs of the basal surface.

A septal suture is observed on the preserved last whorl of the smaller specimen (see Figure 10).

Discussion.—The specimen, OM.II–497, illustrated as ' *Turrilites* cf. *costatus* Lamarck' by Ikegami and Omori (1957, pl. 14, fig. 3), from their Unit MK1 (= Member IIb of Matsumoto, 1965, fig. 4; 1991, p. 22–24), was listed under *Ostlingoceras* (*O.*) aff. *colcanapi* (Boule, Lemoine and Thévenin, 1907) by Wright and Kennedy (1996, p. 323). Its figure shows, however, a more slender shell shape with a lower apical angle and its younger whorls have a row of coarse tubercles at about midflank. It is probably another example of this species. Regrettably, the original specimen is missing at present.

Occurrence.—As for material.

Hypostlingoceras mikasaense sp. nov.

Figure 11A–E

Material.—Holotype is GK. H8540 [= previous S. 51·7·4] (Figure 11A, B, C, D, E), collected by T. T. in 1976 at a locality on the northeastern rivulet ['Migimata'] of the Ganseki-zawa, i. e., the eighth branch of the Kami-ichi-no-sawa, a tributary of the River Ikushunbetsu. The exposed rock of the type locality is referred to the *Mantelliceras japonicum* Zone of the Mikasa Formation.

Diagnosis.—Shell small, with a moderate apical angle, about 30° as estimated from the preserved part. Whorls in
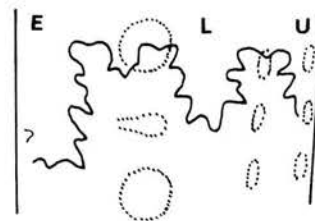
Figure 12. *Hypostlingoceras mikasaense* gen et sp. nov. External suture of a young stage at h = 4.2 mm. Figure si about ×9.5. Symbols as for Figure 2. Drawing by T. M.

youth subtrapezoid in lateral view with shoulder at about the midflank, where coarse and strong tubercles are aligned. Change of ornament at transitional growth stage generally follows that of the type species. Later whorls show moderately to gently convex flanks and ornamentation like that of *Ostlingoceras* (*O.*) *bechei* (Sharpe, 1857).

Description.—The holotype consists of about 6 whorls, but its apical part is lacking. The preserved part of the shell is 26 mm high and its diameter at the last whorl is 13 mm. The apical angle estimated from the preserved part of the shell is about 30°. Whorls are tightly in contact, with a fairly deeply impressed junction. The ratio between flank height and diameter in each whorl is about 0.45 (see Table 6).

The shape of a young whorl in lateral view is trapezoid, with an angular shoulder at about the midflank, where strong tubercles are aligned at moderate intervals, numbering 12 per whorl. Another row of smaller tubercles runs on a narrow ridge slightly above the lower whorl seam. On the preserved first whorl these lower tubercles are fairly coarse and correspond in number and disposition to the upper tubercles. Soon the upper strong tubercles are bullate and the lower tubercles become finer and tend to be clavate.

In the transitional stages the upper tubercles are weakened, transversally elongated and distantly arranged, whereas a few nodeless ribs occur in the intervening space. The minor tubercles on the lower spiral ridge are disposed approximately on the extension of the elongated tubercles and intervening ribs. Throughout the above-described stages there is another row of clavate tubercles along the lower whorl seam. There is a narrow but distinct spiral groove between the two lower rows of minor tubercles.

In the late stages, including the late transitional substage, the whorl develops a more rounded shape, showing a gently convex flank. It is ornamented by numerous transverse ribs, numbering 32 in the preserved last whorl. Above the second row of minor tubercles there is a shallowly concave spiral zone. The ribs run across this concave zone with slight weakening and sinuousity. In the preserved last whorl the third row of minor tubercles is not clavate but elevated at the markedly curved point of the ribs on the marginal part of the basal surface. Some of the tubercles seem to be doubled, suggesting incorporation of the remnants of the tubercles of the fourth row (Figure 11E). The ribs extend further toward the narrow umbilicus with a gentle curvature.

The septal suture is partly exposed on the flank of a rather young whorl, showing half of E, the E–L saddle, entire L and a part of the L–U saddle. L is situated on the concave zone below the upper row of the tubercles. These elements are indented (Figure 12).

Comparison.—With respect to the general change of characters with growth, this species is assigned to the genus *Hypostlingoceras*. It is distinguished from *H. japonicum* in having a larger apical angle, smaller ratio of h/d in each whorl, stronger midflank tubercles in youth and somewhat coarser and less numerous ribs on the later whorls.

The whorls of this species in late growth stages are fairly similar to *Ostlingoceras (Ostlingoceras) bechei* (Sharpe) in shell shape and ornamentation, although this does not necessarily imply a direct phylogenetic relationship.

Occurrence and distribution.—As for material. At present this species is known solitarily in the lower part of the Cenomanian of Hokkaido.

Acknowledgments

References

Atabekian, A. A., 1985: Turrilitids of the late Albian and Cenomanian of the southern part of the USSR. *Academy of Sciences of the USSR, Ministry of Geology of the USSR, Transactions*, vol. 14, p. 1–112, pls. 1–34. (*in Russian*)

Boule, M., Lemoine, P. and Thévenin, A., 1907: Céphalopodes crétacés des environs de Diégo Suarez. *Annales de Paléontologie*, vol. 2, p. 1–58, pls. 1–8.

Breistroffer, M., 1953: L'evolution des Turrilitides albiens et cénomaniens. *Compte Rendus Hebdomadaires des Sciences de l'Académie des Sciences*, vol. 237, p. 1349–1351.

Cobban, W. A., 1984: Molluscan record from a mid-Cretaceous borehole in Western County, Wyoming. *U. S. Geological Survey, Professional Paper*, no. 1271, p. 1–24.

Cobban, W. A. and Hook, S. C., 1981: New turrilitid ammonite from the mid-Cretaceous (Cenomanian) of southwestern New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Circular 180*, p. 22–29.

Cobban, W. S., Hook, S. C., and Kennedy, W. J., 1989: Upper Cretaceous rocks and ammonite faunas of southwestern New Mexico. *New Mexico Bureau of Mines and Mineral Resources, Memoir 45*, p. 1–137.

Dubourdieu, G., 1953: Ammonites nouvelles des Monts du Mellègue. *Bulletin du Sérvice de la Carte Géologique de l'Algérie. 1re Série, Paléontologie*, no. 16, p. 1–76, pls. 1–4.

Fabre, S., 1940: Le Crétacé supérieur de la Basse-Provence occidentale. 1. Cénomanien et Turonien. *Annales de la Faculté de Sciences de Marseille, série 2*, vol. 14, pl 1–355, pls. 1–10.

Gill, T., 1871: Arrangements of the families of Mollusks. *Smithsonian Miscellaneous Collections*, no. 227, p. i–xvi, 1–49.

Hyatt, A., 1900: Cephalopoda, *In*, Zittel, K. A. : *Text book of Palaeontology*, 1st English edition translated by C. R. Eastman, p. 502-592. Macmillan, London and New York.

Ikegami, S. and Omori, T., 1957: On the so-called "Mikasa Formation" in the Katsurazawa-dam site area near the Ikushunbetsu River, Mikasa, Hokkaido. *Journal of the Hokkaido Gakugei University, ser. 2*, vol. 8, no. 1, p. 70–89, pls. 1–14. (*in Japanese with English explanation of plates*)

Immel, H., 1989: Cenoman-Ammoniten aus den Losensteiner Schichten der Bayerischen Alpen. *In*, Wiedmann, J., ed., Aspekte der Kreide Europas. *International Union of Geological Sciences, ser. A*, no. 6, p. 607-644, pls. 1-4. Schweizerbartische Verlagsbuchhandlung, Stuttgart.

Kennedy, W. J., 1971: Cenomanian ammonites from southern England. *Special Papers in Palaeontology*, vol. 8, p. 1–133, pls. 1–64.

Klinger, H. C. and Kennedy, W. J., 1978: Turrilitidae (Cretaceous Ammonoidea) from South Africa, with a discussion of the evolution and limits of the family. *Journal of Molluscan Studies*, vol. 44, p. 1–48, pls. 1–9.

Lehmann, J., 1988: Systematic palaeontology of the ammonites of the Cenomanian-Lower Turonian (Upper Cretaceous) of northwestern Westphalia, north Germany. *Tübinger Geowissenschaftliche Arbeiten, Reihe A*, vol.

37, p. 1-58, pls. 1-5.

Marcinowski, R., 1970: The Cretaceous transgressive deposits east of Czestochowa (Polish Jura Chain). *Acta Geologica Polonica*, vol. 20, p. 413-449, pls. 1-6.

Matheron, P., 1842: *Catalogue méthodique et descriptif des corps organises fossiles du Departement des Bouche-du-Rhone et lieux circonvoisins*, 269 p., 41 pls. Marseille.

Matsumoto, T., 1965: A monograph of the Collignoniceratidae from Hokkaido. Part 1. *Memoirs of the Faculty of Science, Kyushu University, ser. D*, vol. 16, no. 1, p. 1-80, pls. 1-18.

Matsumoto, T. (compiled), 1991: The mid-Cretaceous ammonites of the family Kossmaticeratidae from Japan. *Palaeontological Society of Japan, Special Papers*, no. 33, p. i-vi, 1-143, pls. 1-31.

Matsumoto, T. and Inoma, A., 1999: The first record of *Mesoturrilites* (Ammonoidea) from Hokkaido, *Paleontological Research*, vol. 3, no. 1, p. 36-40.

Matsumoto, T., Inoma, A. and Kawashita, Y., 1999: The turrilitid ammonoid *Mariella* from Hokkaido-Part 1. *Paleontological Research*, vol. 3, no. 2, p. 106-120.

Matsumoto, T. and Kawashita, Y., 1999: The turrilitid ammonoid *Mariella* from Hokkaido-Part 2. *Paleontological Research*, vol. 3, no. 3, p. 162-172.

Matsumoto, T. and Kijima, T., 2000: The turrilitid ammonoid *Mariella* from Hokkaido-Part 3. *Paleontological Research*, vol. 4, no. 1, p. 33-38.

Matsumoto, T. and Okada, H., 1973: Saku Formation of the Yezo geosyncline. *Science Reports of the Department of Geology, Kyushu University*, vol. 11, no. 2, p. 275-309. (*in Japanese with English abstract*)

Matsumoto, T., Takashima, R. and Hasegawa, K., 2000: Some turrilitid ammonites from the Cretaceous of the Shuparo Valley, central Hokkaido. *Bulletin of the Mikasa City Museum, Natural Science*, no. 4, p. 1-13.

Nishida, T., Matsumoto, T., Yao, A. and Maiya, S., 1993: Towards the integrated mega- and micro- biostratigraphy on the Cenomanian (Cretaceous) sequence in the Kotanbetsu Valley, Hokkaido, including the C-T boundary problem. *Journal of the Faculty of Education, Saga University*, vol. 40, no. 3, p. 95-125. (*in Japanese with English abstract*)

Orbigny, A. d', 1842: *Paléontologie française. Terrains crétacés. 1. Céphalopodes*, p. 431-662. Masson, Paris.

Pervinquière, L., 1907: Études de paléontologie tunisienne. 1. Céphalopodes des terrains secondaires. *Carte Géologique de la Tunisie*, 438p., atlas (27 pls.). Rudeval, Paris.

Pervinquière, L., 1910: Surquelques ammonites du Crétace algérien. *Mémoires de la Sociéte Géologique de France*, vol. 17, mémoir 42, p. 1-86, pls. 1-7.

Sharpe, D., 1857: Description of the fossil remains of Mollusca found in the Chalk of England. Cephalopoda, part 3. *Palaeontographical Society*, London, 1856, p. 37-70, pls. 17-27.

Wiedmann, J., 1966: Stammesgeschichte und System der posttriadischen Ammonoideen, ein Überblick, 1 Teil. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, vol. 125, p. 49-79, pls. 1-2.

Wright, C. W. and Kennedy, W. J., 1996: The Ammonoidea of the Lower Chalk, part 5. *Monograph of the Palaeontographical Society*, London, 1996, p. 320-403, pls. 95-124.

Wright, C. W. and Wright, E. V., 1951: A survey of the fossil Cephalopoda of the Chalk of Great Britain. *Palaeontographical Society*, London, 1950, p. 1-40.

Zittel, K. A. von, 1884: Cephalopoda, *In*, K. A. Zittel: *Handbuch der Paläontologie*, vol. 1, p. 329-522, Oldenbourg, München & Leibzig.

Late Paleocene to early Eocene planktic foraminiferal biostratigraphy of the Dungan Formation, Sulaiman Range, central Pakistan

MUHAMMAD YOUSAF WARRAICH[1], KENSHIRO OGASAWARA[1] and HIROSHI NISHI[2]

[1]Institute of Geoscience, University of Tsukuba, Tennodai 1-1-1, 305-8571 Japan

(yousaf56@strati.geo.tsukuba.ac.jp; ogasawar@arsia.geo.tsukuba.ac.jp)

[2]Department of Earth Science, Graduate School of Social and Cultural Studies, Kyushu University

4-2-1 Ropponmatsu, Chuo-Ku, Fukuoka, 810-8560 Japan (hnishi@rc.kyushu-u.ac.jp)

Abstract. The Paleogene marine sequences of the Dungan, Shaheed Ghat, Baska and Kirthar Formations are exposed at several places in the Sulaiman fold and thrust belt in central Pakistan. The lowermost Dungan Formation unconformably overlies the open marine Maastrichtian Pab Sandstone, being distributed widely along both limbs of the Zinda Pir Anticline area and in the Rakhi Nala area. The Dungan Formation is composed mainly of black-colored siltstone with some intercalations of sandstone in the base and many interbeds of limestone in the upper part. The strata from all three sections have yielded abundant and well-preserved Paleocene-Eocene planktic foraminifers and about 50 species belonging to nine genera are identified from this sequence. Zones P3 to P7 of the tropical zonal schemes were recognized, furthermore, Zones P3 and P4 are subdivided into two subzones (Subzones A and B), respectively. These assemblages contain a new species *Globanomalina rakhiensis* in the Rakhi Nala section. A late Paleocene through early Eocene age is assigned to the Dungan Formation. The quantitative data of each species indicates that the Dungan Formation was deposited in a relatively deep to open marine environment, probably forming a continental slope dipping from east to west.

Introduction

A Mesozoic to Paleogene sedimentary sequence is widely exposed along the northwestern margin of the Indian Subcontinent in central Pakistan. These strata were deposited during the closing of the Tethys Ocean and form several fold-and-thrust belts of over 100 km width along a series of lobes in the Kirthar, Sulaiman, and Salt Ranges from south to north (Cheema et al., 1977; Humayon et al., 1991; Warwick et al., 1998). The Paleogene sequence of the Sulaiman Range which overlies the Mesozoic marine shelf sediments consists of the Paleocene to Eocene Dungan Formation, the early Eocene Shaheed Ghat and Baska Formations, and the middle to late Eocene Kirthar Formation. Latif (1961) and Samanta (1973) reported many Paleocene-Eocene planktic foraminifers and their zonation from the Rakhi Nala section located in the eastern Sulaiman Range (Figure 1). Jones (1997) also showed the age of the Dungan Formation using the planktic foraminifers recovered

from three samples from the northern part of the Sulaiman Range. Warraich and Natori (1997) also established the Paleocene-Eocene planktic foraminiferal biostratigraphy on the western side of the Zinda Pir Anticline region, and recognized the following nine zones: the *Morozovella angulata*, *Globanomalina pseudomenardii*, *Morozovella velascoensis*, *M. subbotinae*, *M. formosa formosa*, *M. aragonensis*, *M. spinulosa/Truncorotaloides topilensis*, *Catapsydrax howei* and *Globigerina officinalis* zones. However, this biostratigraphic work is still preliminary and further detailed work is needed for correlation with the recently revised standard zonal schemes of Berggren et al. (1995) and Olsson et al. (1999).

The main objectives of this paper are to establish a complete biostratigraphic zonation of the Dungan Formation distributed in the Zinda Pir Anticline and the Rakhi Nala regions of the Sulaiman Range, and to correlate zones established in these regions with standard zones of the tropical-subtropical latitudes, and with those recognized in the other
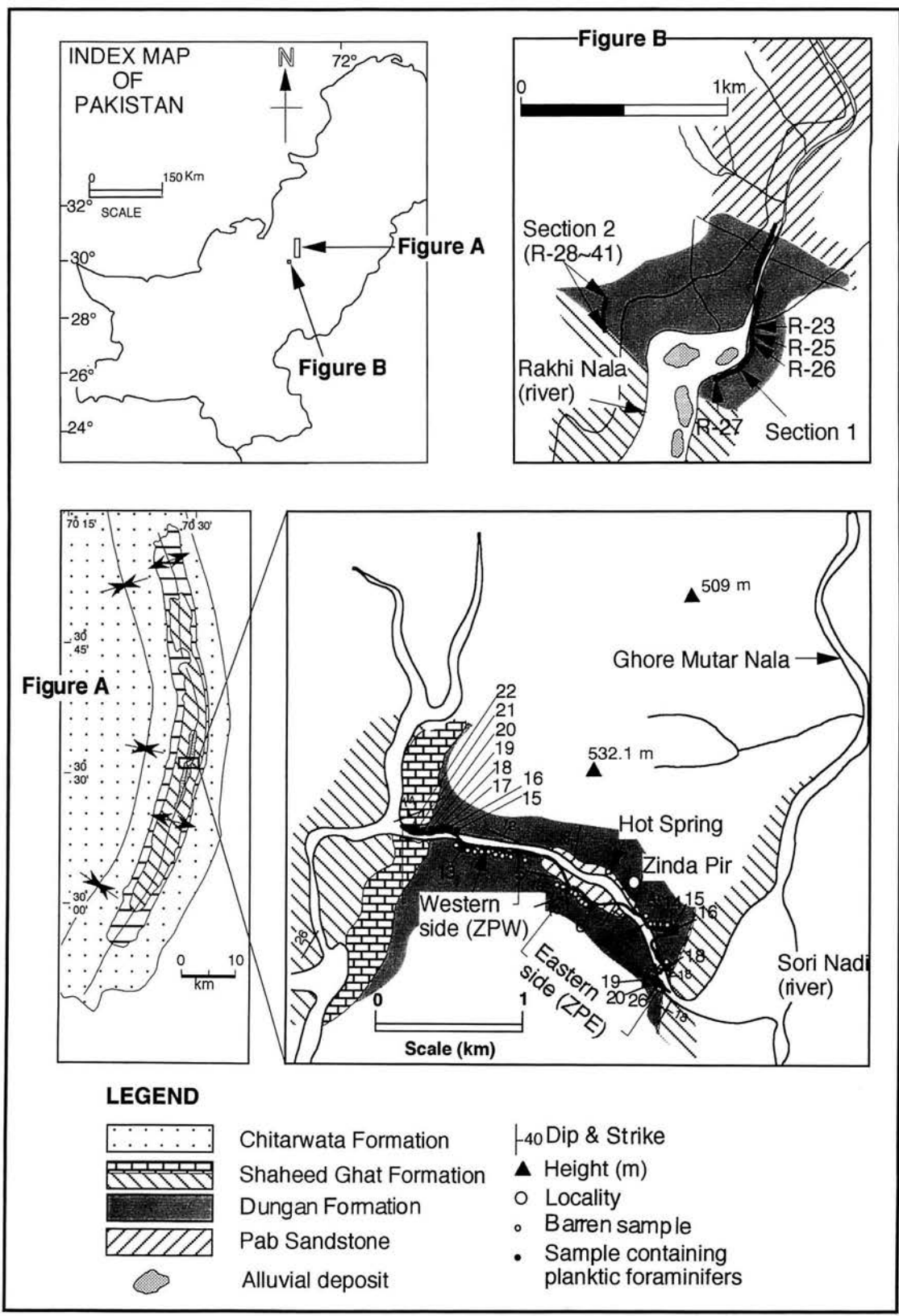
Figure 1. Route maps of the Rakhi Nala and the Zinda Pir sections of the eastern Sulaiman Range, central Pakistan.

regions of the Indus Basin. We also discuss the faunal changes and depositional environment of the Dungan Formation using quantitative foraminiferal data.

Materials and methods

We carried out systematic sampling along both sides of the Zinda Pir Anticline and in the Rakhi Nala section covering the entire sequence of the Dungan Formation (Figure 1). Some 54 samples (22 samples coded ZPW and 32 samples coded ZPE) were obtained along the western and the eastern limbs of the Zinda Pir Anticline, and 41 samples (coded R) were collected from the Rakhi Nala section. These samples were collected at 1-to 5-meter intervals. Because siltstone samples were very hard, all samples (each weighing 100g) were first treated with sodium sulfate (Na₂So₄), and later with tetraphenylborate (NaTPB). The disaggregated samples were washed using a 63 μm sieve.

Population counts for planktic foraminifers are based on random splits of 200 to 300 specimens. To remove juvenile forms, specimens over 150 μm were picked and identified; however, the smaller fractions were also scanned for recognition of small-sized species. The faunal reference list is given in Appendix 1.

Lithostratigraphy

The Paleogene sequences exposed in the Zinda Pir and Rakhi Nala sections of the investigated areas consist of the Dungan and the Shaheed Ghat Formations in ascending order (Figure 1). The Dungan Formation forms the basal part of the Paleogene sequence, unconformably overlying the Maastrichtian Pab Sandstone (Kazmi, 1995, Nomura and Brohi, 1995, this study). Eames (1952) was the first who described the lithostratigraphy of the lower Paleogene strata of both the Zinda Pir and Rakhi Nala areas in detail. He divided this sequence into four lithological units in both areas (Figure 2). Cheema et al. (1977) and Kazmi (1995) summarized his several units and gave the name of the Dungan Formation to the mudstone-dominated sequences. For example, Kazmi (1995) included many lithological units

defined by many previous workers into the Dungan Formation (Figure 2).

We divided the strata distributed in the studied area into three formations according to the lithology of Kazmi (1995). The lowermost strata of the Maastrichtian Pab Sandstone consist of white, cream-to brown-colored, thick- to massive-bedded, medium to coarse-grained quartzose sandstone with intercalations of shale and argillaceous limestone in the study areas. The Dungan Formation overlying the Pab Sandstone represents dark-black colored siltstones interbeded with hard quartzitic-glauconitic sandstone beds in the lower part and thin-to thick-bedded, dark-gray limestone weathering brown-buff in the upper part. The interbeds of sandstone are abundant in the Rakhi Nala, while those of limestone are common in the Zinda Pir.

It is noteworthy that the thickness of the Rakhi Nala section (312 m) is twice that of the Zinda Pir sections (135 m). In the Sulaiman Range, while contact of the Dungan Formation with the overlying Shaheed Ghat Formation is described as conformable (Cheema et al., 1977; Shah, 1990, Kazmi, 1995). However, we describe this contact as unconformable based on the presence of the conglomeratic to brecciated limestone bed in the lowermost part of the Shaheed Ghat Formation (Figures 3-6). Previous workers (Eames, 1952; Cheema et al., 1977; Shah, 1990, Kazmi, 1995) did not report this conglomeratic to brecciated limestone bed. Moreover, this result is also supported by the nonexistence of Zone P6 (Figures 3-6). Thickness of the conglomeratic to brecciated limestone bed is 16 m in the Zinda Pir sections that pinches out at Rakhi Nala. However, in the Rakhi Nala section, there is another conglomeratic to brecciated bed (1 m) which is stratigraphically younger than those of the Zinda Pir sections (Figure 6). This limestone contains shallow marine fossils such as larger foraminifers and bivalves (Vasticardium and Chlamys species) embedded in a calcareous matrix containing a pelagic fauna.

Biostratigraphy

Among 32 and 22 samples collected from the Dungan

Eames (1952)		Cheema et al. (1977)	Kazmi (1995)	This work
Rakhi Nala	Zinda Pir			
Upper Rakhi Gaj Shales	Ghazij Shales	Ghazij Fm.	Shaheed Ghat Formation	Shaheed Ghat Formation
	Zinda Pir Ls. (upper part)			
Lower Rakhi Gaj Shales	Zinda Pir Ls. (lower part)	Dungan Fm.	Dungan Formation	Dungan Formation
	Zinda Pir Shales			
Gorge Beds	Quartzose Sandstone	Bara Fm.		
Venericardia Shales		Khadro Fm.		
Pab Sandstone		Pab Sandstone	Pab Sandstone	Pab Sandstone

Figure 2. Lithostratigraphic subdivisions and correlation of the early Tertiary strata exposed in the Sulaiman Range proposed by different workers.
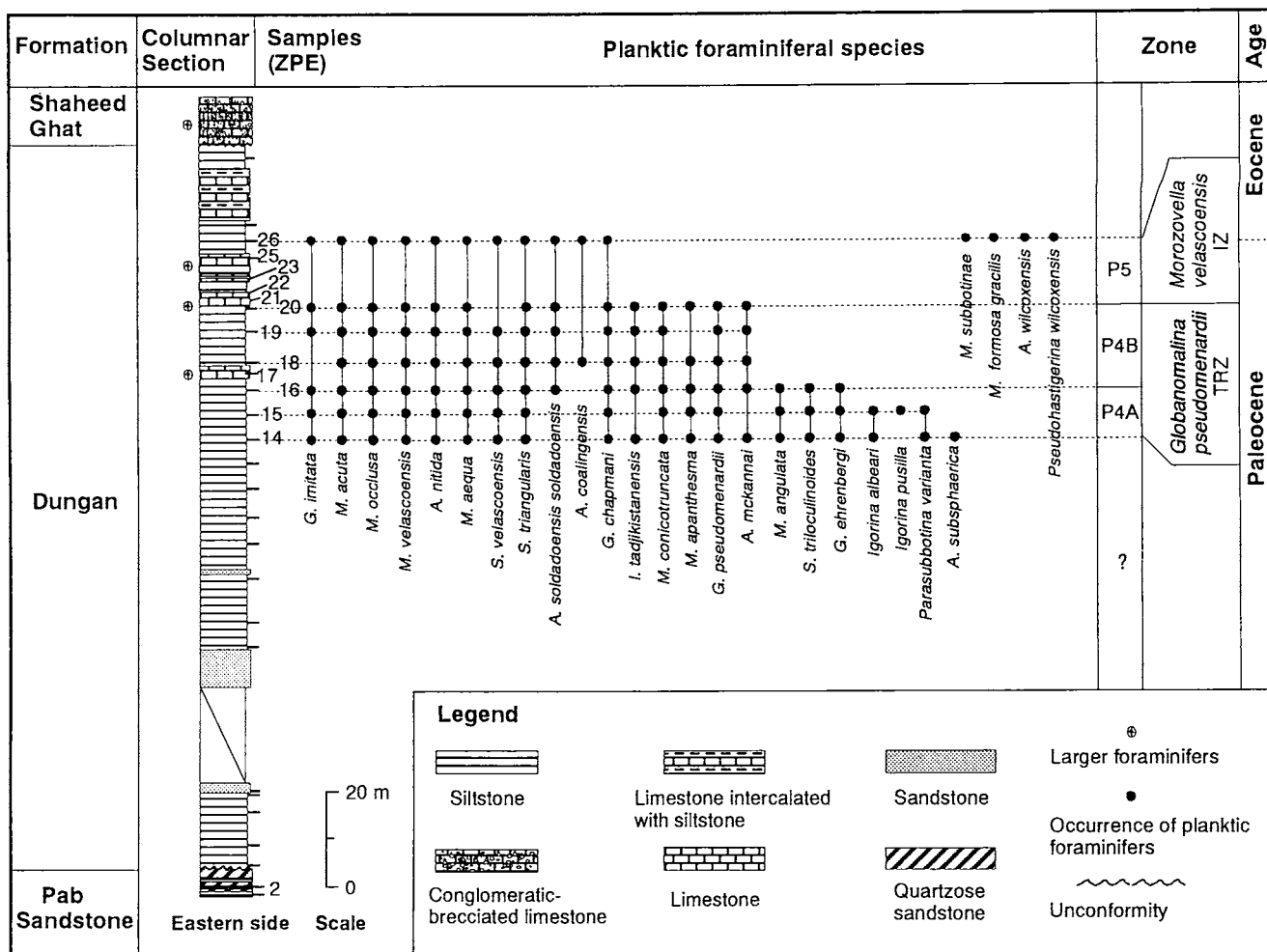
Figure 3. Measured columnar section along the eastern limb of the Zinda Pir Anticline showing lithostratigraphic sequences, sample locations, and biostratigraphic distribution of the recovered planktic foraminifers. The numbers indicate the samples containing planktic foraminifers.

Formation along the eastern and western limbs of the Zinda Pir Anticline, 7 and 11 samples yielded planktic and benthic foraminifers, respectively. The individual specimens of the planktic foraminifers recovered from the western side of the Zinda Pir Anticline are abundant and better preserved than those from the eastern side. Some 30 species belonging to 7 different genera of planktic foraminifers were identified in the Zinda Pir sections (Appendix 3).

In the Rakhi Nala section, 16 samples out of 41 yielded abundant and well-preserved foraminifers. The planktic foraminiferal assemblage recovered from this section comprised 51 species belonging to 10 genera (Appendix 3).

Two standard Paleogene zonal schemes have been established in the low-latitude regions. One is represented by Bolli's zonation and its revisions (Bolli, 1957, 1966; Toumarkine and Luterbacher, 1985). The other one is the P-zonation of Blow (1979) and its modifications (Berggren and Miller, 1988; Berggren *et al.*, 1995). Recently, Berggren and Norris (1997) and Olsson *et al.* (1999) have

published updated versions of the Paleocene P-zonal system and the phylogeny.

The Paleogene fauna recovered from the Dungan Formation included abundant tropical and subtropical indicators, suggesting a habitat of tropical-subtropical Tethyan waters. Hence, the Paleogene international zonal schemes proposed by Berggren *et al.* (1995) and Olsson *et al.* (1999) are basically applicable to the faunal assemblage of the Dungan Formation (Figure 7). This formation is divided into five biostratigraphic intervals that correspond to Zones P3 to P7 of Berrgren's zonation (Figure 7). However, we have subdivided Zone P4 of Berggren and Norris (1997) and Olsson *et al.* (1999) into two subzones instead of three as an extension of the stratigraphic range of *A. subsphaerica* is recorded in this region. Moreover, we have used some different datum levels as boundaries of subzones due to sporadic occurrence of index species in the lower portions of all three sections.
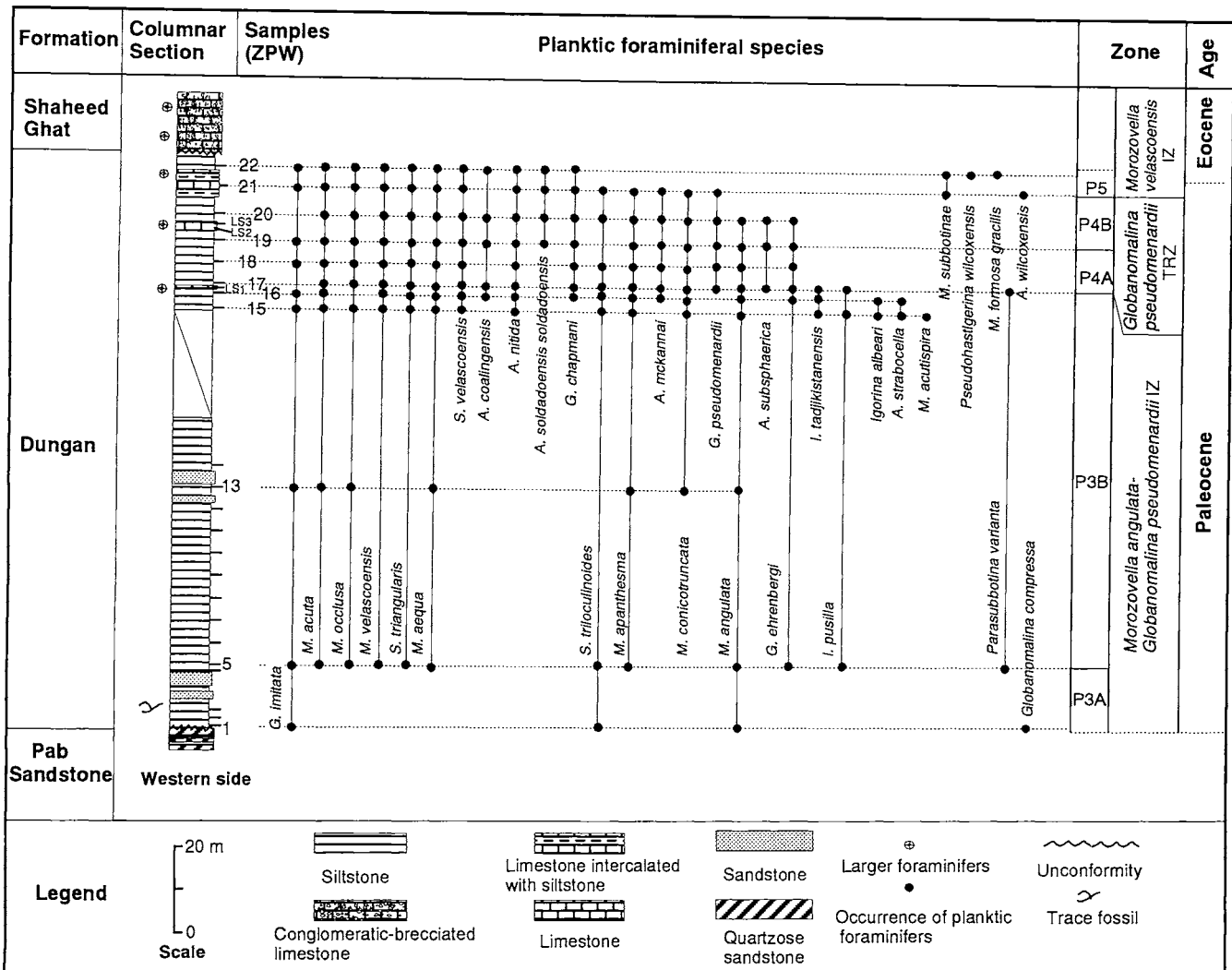
Figure 4. Measured columnar section along the western limb of the Zinda Pir Anticline showing lithostratigraphic sequences, sample locations and biostratigraphic distribution of the recovered planktic foraminifers. The numbers indicate the samples containing planktic foraminifers.

Paleocene Zones of the Dungan Formation

P3. *Morozovella angulata/Globanomalina pseudomenardii* Interval Zone

Zone P3 of Berggren and Norris (1997) and Olsson *et al.* (1999) is defined as the interval zone between the first appearance datum (FAD) of *Morozovella angulata* and the FAD of *Globanomalina pseudomenardii*. They also have subdivided Zone P3 into Subzones P3a and P3b using the FAD of *Igorina albeari*. In this paper, however, we cannot use their subzones because of the sporadic occurrence of *I. albeari* (Figures 3–5). Instead, we defined two regional subzones as described below, using the FAD of *M. acuta*.

P3A. *Morozovella angulata -M. acuta* Interval Subzone

Definition.—The lower boundary of this zone is not defined because of the missing sequence in the Zinda Pir and nonoccurrence of any planktic foraminifers in the Rakhi Nala. The upper boundary is placed at the FAD of *Morozovella acuta* (Figure 4).

Occurrence.—This subzone is found restrictedly in the western section of the Zinda Pir Anticline (Figures 1, 4). Planktic foraminifers in this zone are not abundant, with the total number of specimens per sample ranging from 20 to 76 per sample. The rare occurrence of *M. angulata* is observed in Sample ZPW-1, associated with *Globanomalina imitata, G. compressa,* and *Subbotina triloculinoides.*

Correlation and age.—The FAD of *M. acuta* is a reliable datum in the tropical regions, being placed within Subzone P3b of Berggren and Norris (1997) and within the *Planorotalites pusilla pusilla* Zone of Toumarkine and Luterbacher (1985). The other index species of the Dungan Formation is *G. compressa*, which disappears within Zone P3a of Berggren and Norris (1997). The absence of *M. acuta* and cooccurrence of *M. angulata* and *G. compressa*
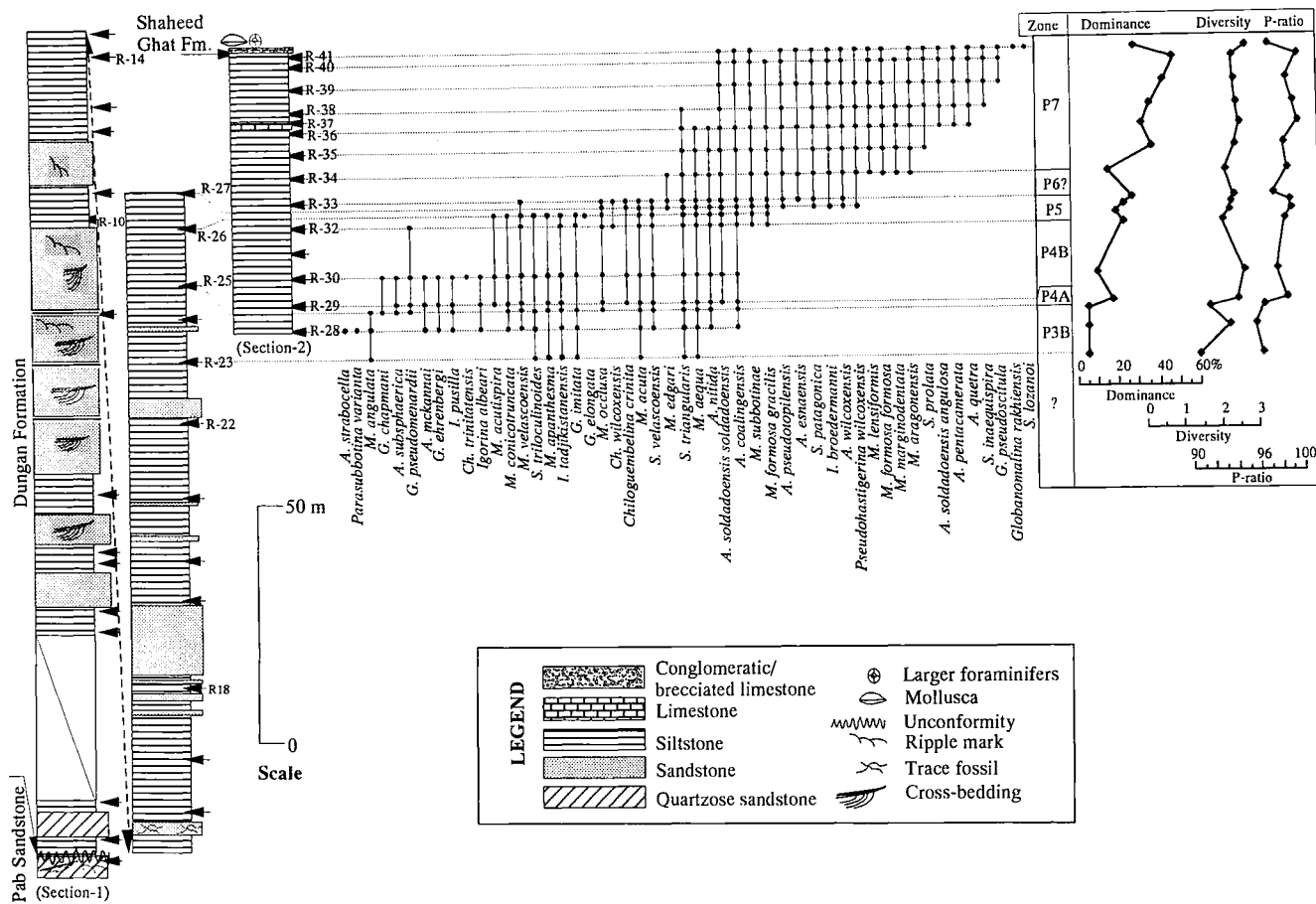
Figure 5. Measured columnar section along the Rakhi Nala (river) showing lithostratigraphic sequences, sample locations and biostratigraphic distribution of the recovered planktic foraminifers. The numbers indicate the samples containing planktic foraminifers. In addition, the results of quantitative analysis consisting of dominance (the most abundant species), diversity and the P-ratio are shown in this figure.

indicate that Subzone P3A corresponds to the interval from Subzone P3a to the lower part of Subzone P3b of Berggren and Norris (1997) (Figure 7). Hence, the age of Subzone P3A is assigned to the late Paleocene (Selendian).

P3B. *Morozovella acuta-Globanomalina pseudomenardii* Interval Subzone

Definition.—The interval of this zone ranges from the FAD of *M. acuta* to the FAD of the *Globanomalina pseudomenardii*.

Occurrence.—This subzone is observed in the interval from Samples ZPW–5 to ZPW–16 in the western section of the Zinda Pir Anticline and from Samples R23 to R28 in the Rakhi Nala (Figures 4, 5).

Correlation and age.— The dominant faunas of this subzone are *Morozovella* forms (*acuta*, *apanthesma*, *occlusa*, and *velascoensis*). These species and another three species (*Globanomalina ehrenbergi*, *Igorina pusilla*, and *Subbotina triangularis*) appear first in Sample ZPW–5 of the Zinda Pir west section and R23 of the Rakhi Nala. This

subzone is correlated with the upper part of Subzone P3b of Berggren and Norris (1997), Olsson *et al.* (1999), and with the *P. pusilla pusilla* Zone of Toumarkine and Luterbacher, 1985 (Figure 7). The age of this zone is late Paleocene (Selendian).

P4. *Globanomalina pseudomenardii* Total Range Zone

The total range of *Globanomalina pseudomenardii* (Zone P4) is recognized as an excellent stratigraphic marker in many tropical regions (e.g. Bolli and Krasheninnikov, 1977; Toumarkine and Luterbacher, 1985). In the studied sections, the FAD of *Globanomalina pseudomenardii* has been placed at Sample ZPW–15 in the western section of the Zinda Pir Anticline, and at Sample R25 from the Rakhi Nala (Figures 4, 5). The last appearance datum (LAD) of *G. pseudomenardii* was observed in all three sections. Samples ZPE–20, ZPW–21 of the Zinda Pir Anticline and Sample R32 of the Rakhi Nala show the LAD of *G. pseudomenardii*. Some 25 species belonging to five genera were identified in this zone.
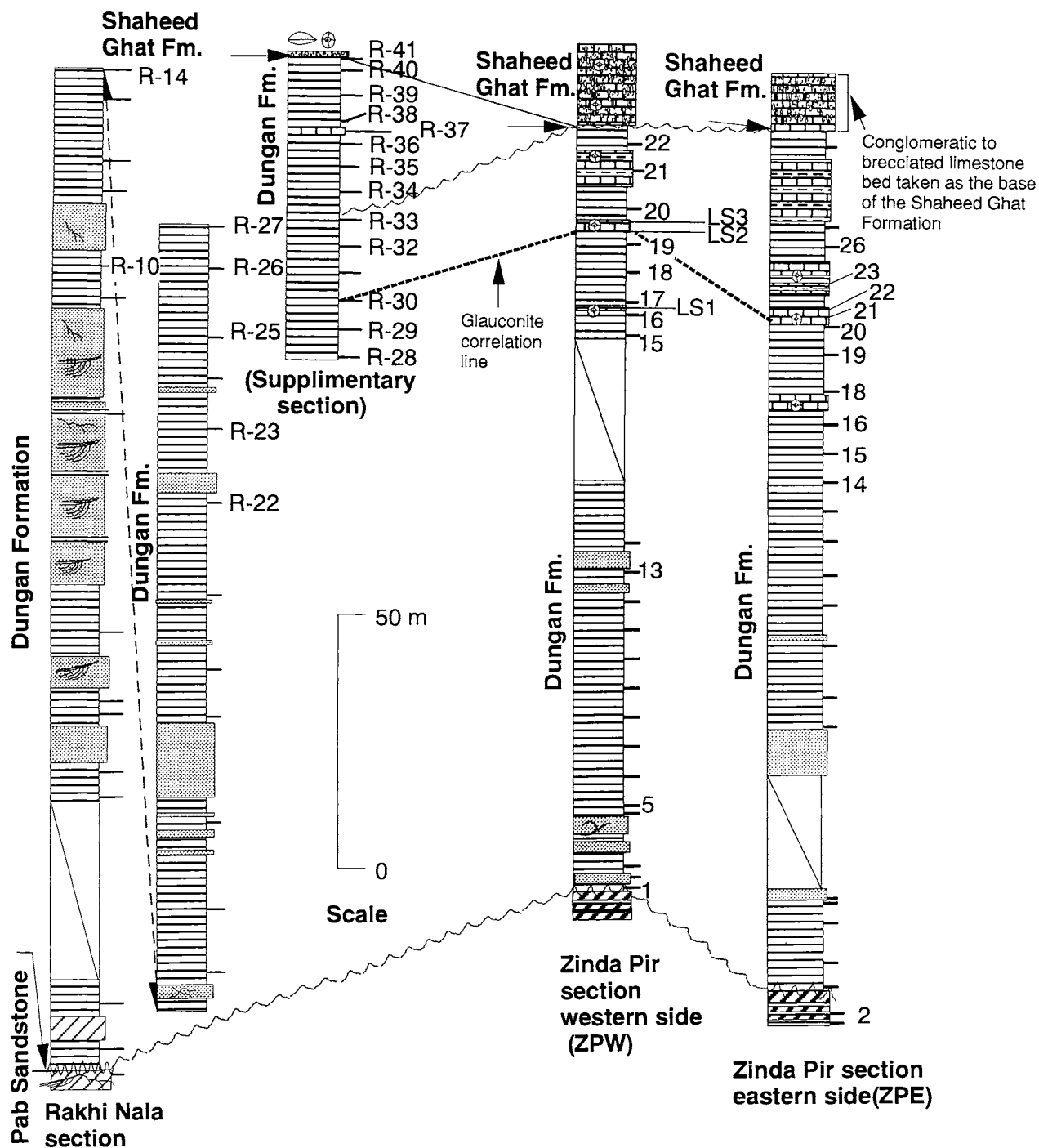
Figure 6. Lithostratigraphic and biostratigraphic correlation between measured columnar sections from the Rakhi Nala and the Zinda Pir area. The numbers indicate the samples containing planktic foraminifers.

Berggren and Norris (1997) have used the FADs of *Acarinina subsphaerica* and *A. soldadoensis soldadoensis* to subdivide their Zone P4 into three subzones (P4a, P4b and P4c). We cannot apply their definition in this area, because the stratigraphic ranges of both *A. subsphaerica* and

A. soldadoensis soldadoensis overlap in the Zinda Pir west section and in the Rakhi Nala (Figures 3-5). Olsson *et al.* (1999) has demonstrated that the stratigraphic range of *Acarinina subspaerica* may extend upwards, close to Zone P4/P5 boundary. Therefore, we used only the FAD of *A.*
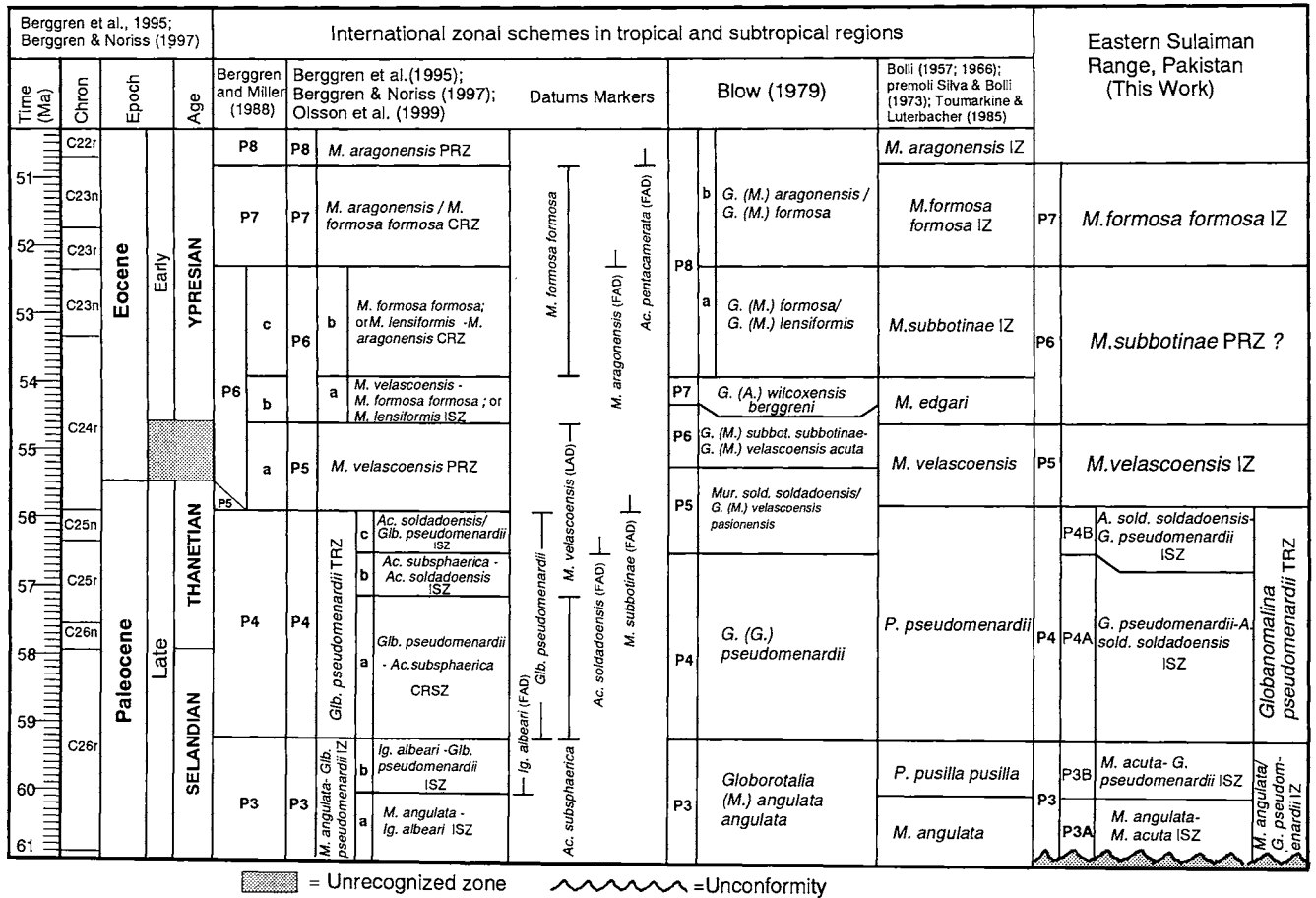
Figure 7. Correlation of planktic foraminiferal zones of the studied area with international low latitude zones. Here IZ: Interval Zone, TRZ: Total Range Zone, PRZ: Partial Range Zone, CRSZ: Concurrent Range Subzone, ISZ: Interval Subzone. A; Ac. Acarinina, Glb; G: Globanomalina, Ig; I: Igorina, M: Morozovella, P: Planorotalites; S: Subbotina. Age and epoch boundaries are adopted from Berggren et al. (1995) and Berggren and Norris (1997).

soldadoensis soldadoensis as an index marker, and subdivided Zone P4 into two subzones P4A and P4B as follows (Figure 7).

P4A. *Globanomalina pseudomenardii-Acarinina soldadoensis soldadoensis* Interval Subzone

Definition.—This subzone is defined as the interval zone between the FAD of *G. pseudomenardii* and the FAD of *A. soldadoensis soldadoensis*.

Occurrence.—This subzone is recognized in both sides of the Zinda Pir Anticline (Samples ZPE-14 to 15 in the east and ZPW-17 to 18 in the west) and in the Rakhi Nala (Samples R25 to R29).

Correlation and age.—The FAD of *A. soldadoensis soldadoensis* is one of the distinctive bioevents in the late Paleocene and is placed at Zones P4a/P4b boundary by Berggren and Norris (1997) and Olsson *et al.* (1999) or within the *Planorotalites pseudomenardii* (= *Globorotalia pseudomenardii*) Zone by Toumarkine and Luterbacher (1985). This subzone corresponds to the joint interval of

P4a and P4b (Figure 7) of Berggren and Norris (1997), and Olsson *et al.* (1999). The age span of this zone is late Paleocene, from the latest Selendian to early Thanetian. In the Dungan Formation, two species of *Igorina* (*albeari, pusilla*) and *Parasubbotina varianta* disappear within this subzone.

P4B. *Acarinina soldadoensis soldadoensis/Globanomalina pseudomenardii* Concurrent range Subzone

Definition.—Subzone is defined as the interval between the FAD of *A. soldadoensis soldadoensis* and the LAD of *G. pseudomenardii*.

Occurrence.—This subzone ranges from Samples ZPE-15 to 20 in the east section of the Zinda Pir Anticline, ZPW-19 to 21 in the west section of the Zinda Pir Anticline, and R29 to R32 in the Rakhi Nala (Figures 3-5).

Correlation and age.—This subzone is equivalent to Subzone P4c of Berggren and Norris (1997) and Olsson *et al.* (1999). The age of this subzone is late Paleocene (Thanetian). In the Dungan Formation, *Morozovella*
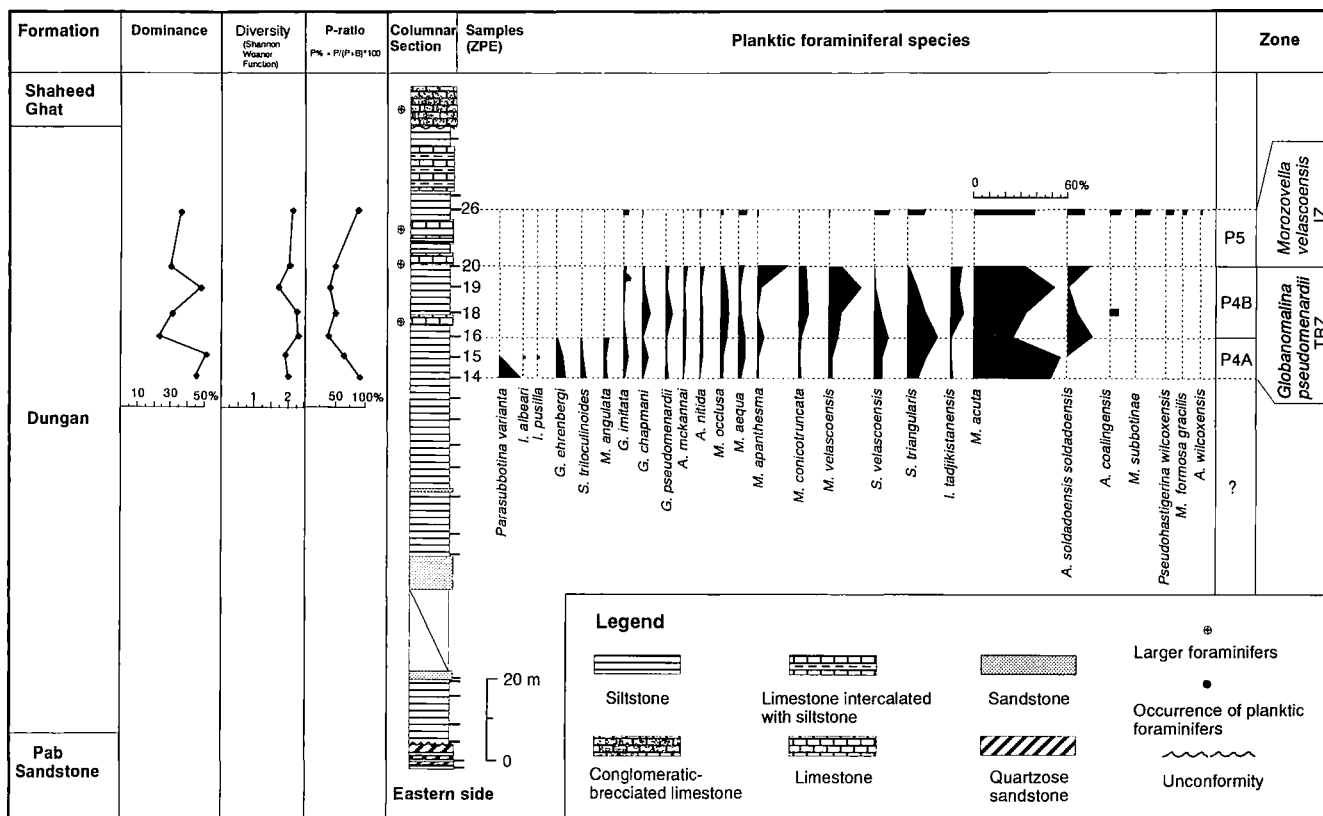
Figure 8. Results of the quantitative analysis of dominance (the most abundant species), diversity, P-ratio and the relative abundances of the characteristic planktic foraminiferal species along the eastern limb of the Zinda Pir Anticline. The numbers indicate the samples containing planktic foraminifers.
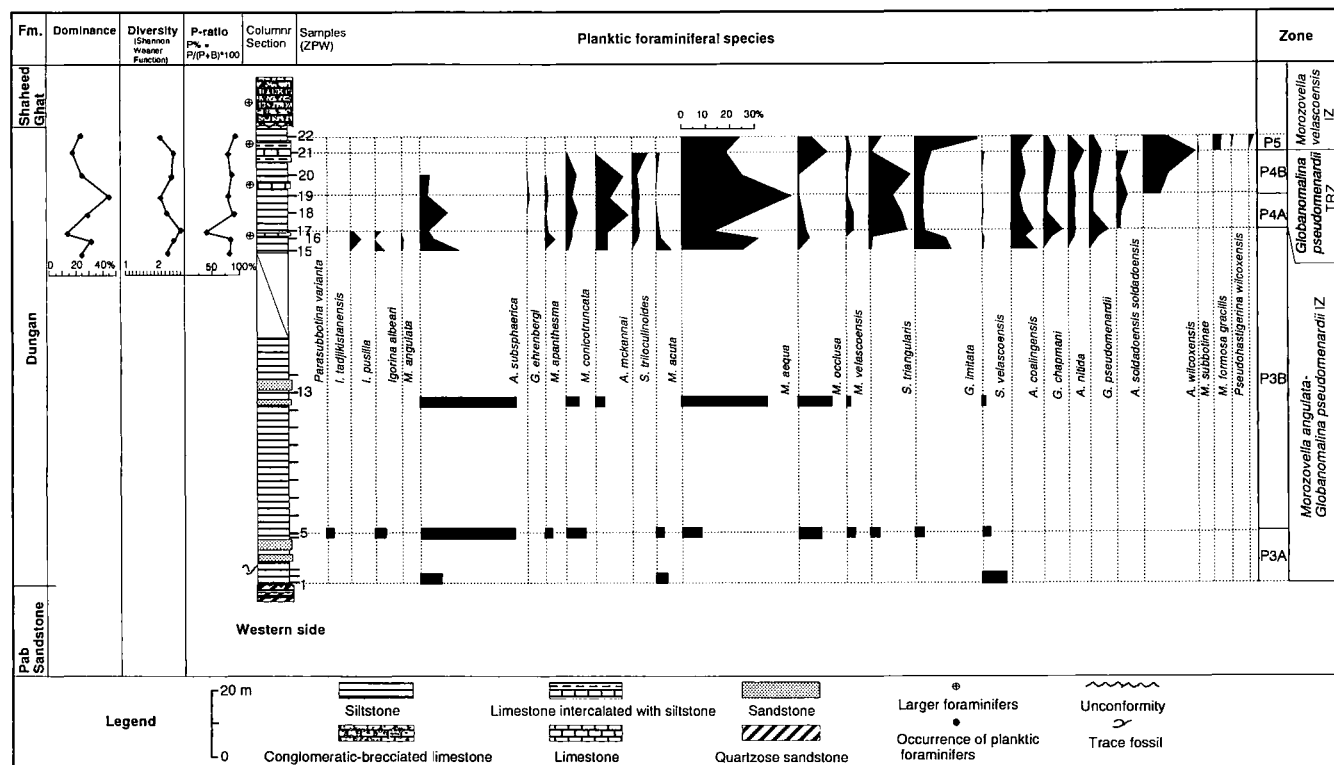
Figure 9. Results of the quantitative analysis of dominance, diversity, P-ratio and relative abundances of the most abundant characteristic planktic foraminiferal species along the western limb of the Zinda Pir Anticline. The numbers indicate the samples containing planktic foraminifers.
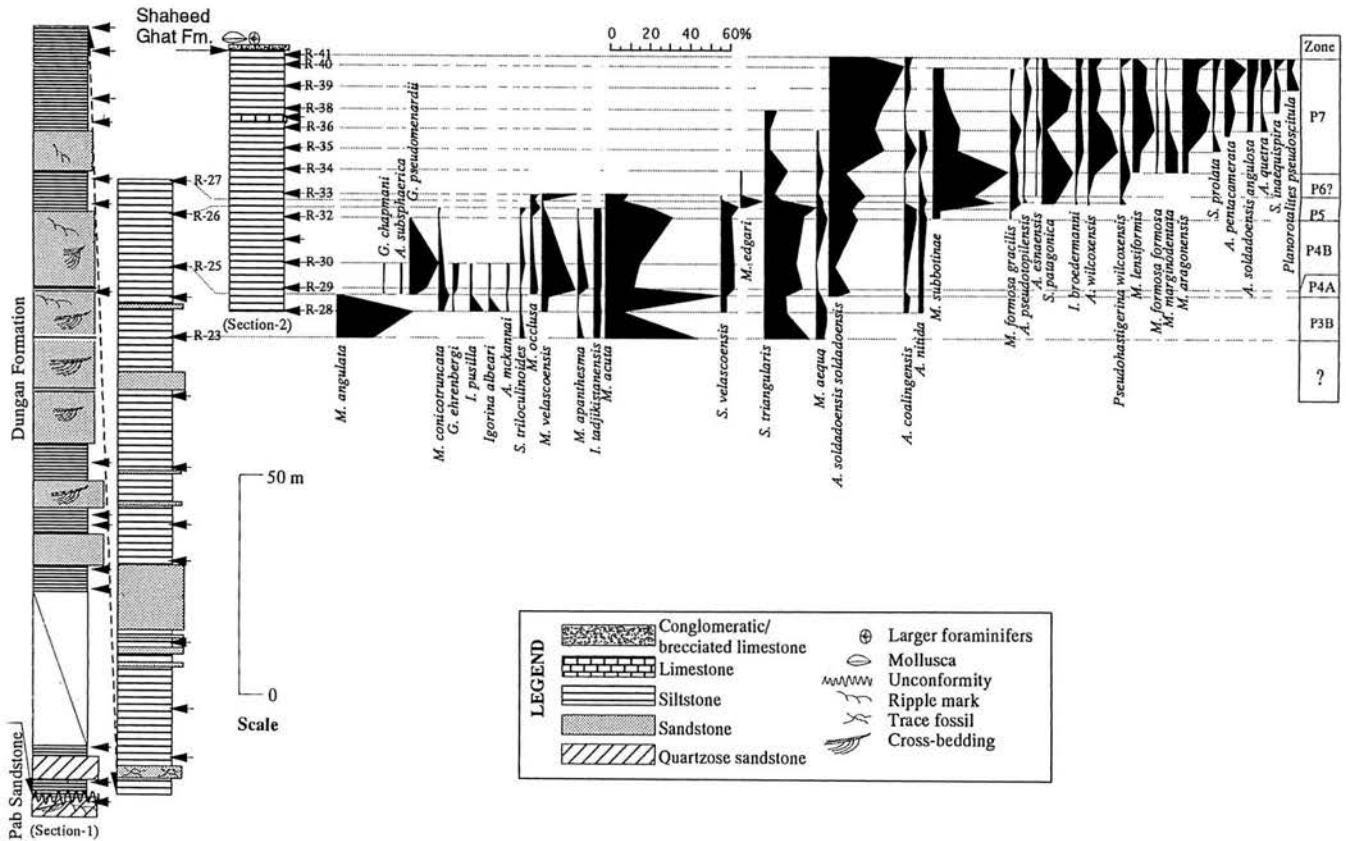
Figure 10. Results of the quantitative analysis of the relative abundances of the most abundant characteristic planktic foraminiferal species from the Rakhi Nala section. The numbers indicate the samples containing planktic foraminifers. For quantitative results of dominance, diversity, and the P-ratio see Figure 5.

angulata and *Globanomalina ehrenbergi* disappear within Subzone P4B.

P5. *Morozovella velascoensis* Interval Zone

Definition.—The definition of Zone P5 is the interval zone between the LAD of *G. pseudomenardii* and the LAD of *Morozovella velscoensis* (e.g. Berggren and Norris, 1997). The base of this zone has been found in all three sections. The upper limit of this zone was placed at the level of Sample R26 in the Rakhi Nala, but its boundary is not clear in the Zinda Pir Anticline, because the hard siltstone of the uppermost part of the Dungan Formation contains no planktic foraminifers (Figures 3, 4).

Occurrence.—This zone ranges from Samples ZPE-20 to 26 in the east and from Samples ZPW-21 to 22 in the west of the Zinda Pir Anticline, and from Sample R32 to R33 in the Rakhi Nala.

Correlation and age.—This zone corresponds exactly to Zone P5 of Berggren and Norris (1997) and Olsson *et al.* (1999). The assemblages of planktic foraminifers in the Dungan Formation contain abundant index species of latest Paleocene to early Eocene age such as *Morozovella subbotinae*, *M. formosa gracilis*, *Acarinina wilcoxensis* and *Pseudohastigerina wilcoxensis*. In particular, the last species is a marker for recognizing the Paleocene/Eocene (P/E)

boundary, appearing first just above the P/E boundary (Berggren, 1969; Stainforth *et al.*, 1975; Berggren and Aubry, 1998). The FAD of this species has been recorded in Samples ZPW-21 and ZPE-26 in the Zinda Pir, and in Sample R27 in the Rakhi Nala.

The chemo- and biostratigraphic events of a negative excursion of $\delta^{13}C$ (CIE) and the benthic foraminiferal extinction event (BEE) are used as the P/E boundary markers by many workers (e. g. Berggren and Aubry, 1998; Berggren *et al.*, 1998). The BEE in the investigated area is recognized between Samples R32 and R33 of the Rakhi Nala section (personal communication by Ritsuo Nomura, Shimane University, Japan). Hence, the P/E boundary can be placed between Samples R27 and R26 in the Rakhi Nala section. The P/E boundary in the Zinda Pir sections can be drawn tentatively between the Samples ZPE-20 and 26 in the east and ZPW-21 and 22 in the west, respectively. The age of this zone ranges from the latest Paleocene to earliest Eocene.

Eocene Zones of the Dungan Formation

In the study area, the siltstone sequence of the Dungan Formation is overlain by the conglomeratic to brecciated limestone beds present in the basal part of the Shaheed Ghat Formation. This field observation implies an
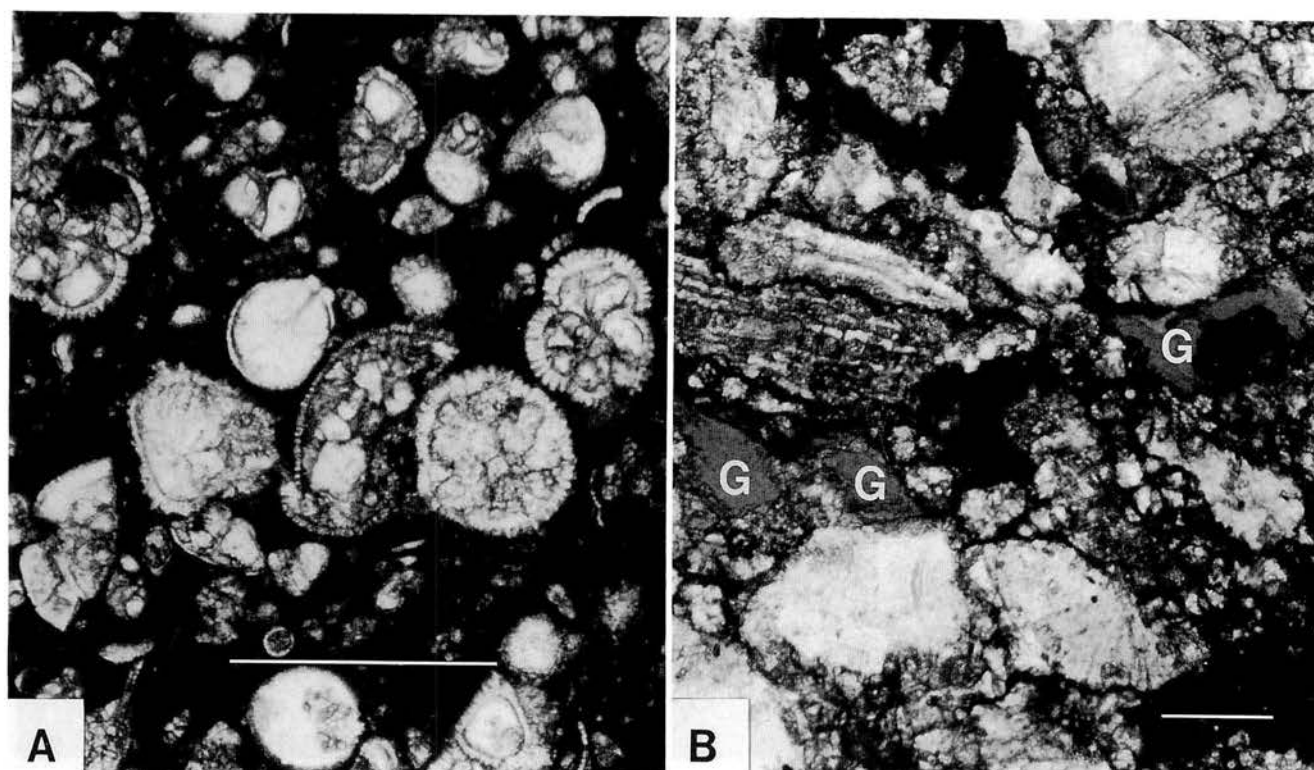
Figure 11. A. Pelagic limestone (wakestone) containing abundant planktic foraminifers from the Rakhi Nala section, Sample R37 (scale bar = 0.5mm). **B.** Limestone (wakestone) showing squashed (compacted) larger foraminifers and glauconitic grains from the Zinda Pir western section, Sample LS3 (scale bar = 0.5mm). G stands for glauconite grain.

unconformable relationship between the two formations. The biostratigraphic data from the Dungan Formation supports this interpretation because the age of the siltstone beds in the uppermost part of the Dungan Formation in the Zinda Pir sections is latest Paleocene to earliest Eocene (Zone P5), whereas such beds in the Rahki Nala section are early Eocene in age (Zone P7). Two early Eocene zones described here are recognized from the Rakhi Nala section.

P6. *Morozovella subbotinae* Partial Range Zone

Definition.—This zone is defined as an interval zone between the LAD of *M. velascoensis* and the FAD of *M. aragonensis*.

Occurrence.—None occurred in the intervening samples between the Sample R27 and the Sample R34 in the study area.

P7. *Morozovella aragonensis/M. formosa formosa* Concurrent-Range Zone

Definition.—This zone is defined by the interval from the FAD of *M. aragonensis* to the LAD of *Morozovella formosa formosa*. The upper boundary of this zone probably lies within the overlying Shaheed Ghat Formation.

Occurrence.—The interval of this zone is recognized between the Samples R34 and R41 that include many early Eocene species such as *Morozovella aragonensis, M.*

formosa formosa, Subbotina inaequispira, and *S. lozanoi.* Two species (*Acarinina nitida* and *Morozovella aequa*) disappear close to the top of this interval (Figure 5).

Correlation and age.—Zone P7 of Blow (1969, 1979) has been revised by Berggren and Miller (1988), who used the FAD of *M. aragonensis* as the lower boundary of this zone and the LAD of *M. formosa formosa* as the top. This zone corresponds to the joint interval of the *M. formosa formosa* Zone and the lower part of the *Acarinina pentacamerata* Zone of Toumarkine and Luterbacher (1985). The age of this zone is early Eocene (middle to late Ypresian).

Quantitative analysis of planktic assemblages

For calculation of quantitative indices (plankton ratio, dominance and species diversity), we used the samples containing over 100 individuals. In the Rakhi Nala, all samples from Zone P3 to P7 yielded abundant and well-preserved foraminifers (Appendix 2). However, the total number per samples of individuals recovered from Zone P3 of the Zinda Pir sections amounted to less than 100. The number of specimens in the other samples in the Zinda Pir exceeded 200 individuals per sample.
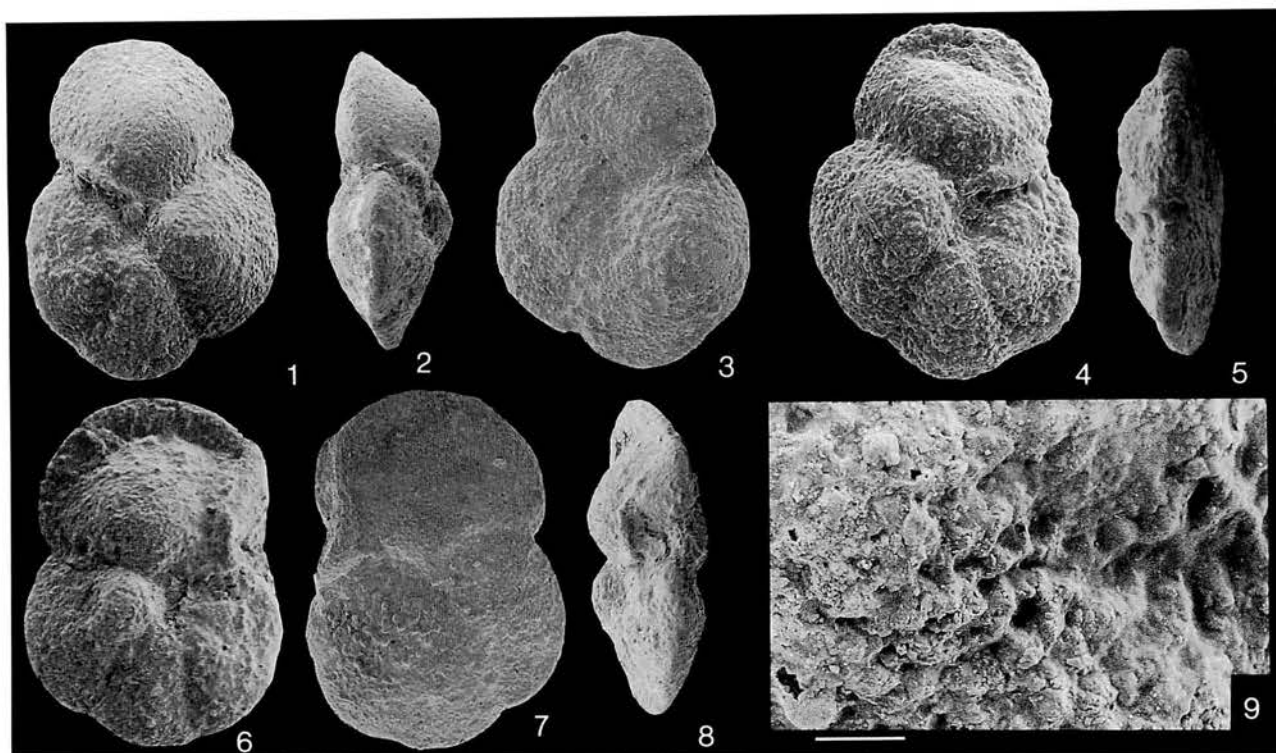
Figure 12. *Globanomalina rakhiensis* sp. nov. **1–3**: Holotype, (IGUT coll. cat. no. 50101) umbilical, side and spiral views, Sample R41, all ×270. **4, 5**: Paratype, (IGUT coll. cat. no. 50102), umbilical and side views, Sample R41, all ×330. **6–8**: Paratype, (IGUT coll. cat. no. 50103) side, spiral and umbilical views. This specimen has more compressed peripheral margin on umbilical side, more limbate intercameral sutures on spiral side and more developed keel in side view, Sample R41, all ×300. **9**: An enlarged view of specimen (as illustrated in Figure 4) shows smooth wall surface with some pustules (scale bar = 10µm)

Results and discussion

1. Plankton-ratio

The plankton-ratio (P–ratio) is expressed by the following formula:

$$\text{P–ratio} = [P/(P+B)] \times 100$$

Here P and B represent the number of specimens of planktic and benthic foraminifers, respectively. The trend of P-ratios differs between the eastern and western sections of the Zinda Pir Anticline (Figures 8, 9). In the east, the P-ratios of Zone P4A are as high as 90%, decreasing gradually to a minimum (39%) in Zone P4B, and then recovering to 89% in Zone P5. In the west, the P-ratios are consistently high (80–90%) during Zones P3B to P5, except for a figure of 31% in Sample ZPW–17 in the lowermost part of Zone P4A. In the Rakhi Nala section, the P-ratios of all samples show high values of more than 95% (Figure 5).

2. Species compositions

The morozovellid species are common to abundant throughout the studied sequences, exceeding about 30–40% of the total number of specimens (Figures 8–10). The dominant morozovellids are *M. angulata* in Zone P3B, *M. acuta* and *M. velascoensis* in Zone P4 and three species (*M.*

acuta, M. subbotinae, and *M. aequa*) in Zone P5 in the Zinda Pir area. In the Rakhi Nala region, the assemblage of Zone P3B is dominated by *M. acuta* and *M. angulata* (40–60%), whereas that of Zones P4 and P5 is dominated by *M. acuta, M. conicotruncata, M. occlusa*, and *M. velascoensis* (30–35%). The relative abundance of *Acarinina* and *Subbotina* during Zones P3 to P5 is relatively high, fluctuating between 10 and 20% of the total for each genus. Those of the other genera (*Igorina, Globanomalina*, and *Parasubbotina*) are less than 10% for each genus.

The replacement of the Paleocene morozovellid group (*M. velascoensis, M. angulata, M. conicotruncata* and *M. apanthesma*) by early Eocene forms (*M. formosa gracilis, M. formosa formosa, M. lensiformis, M. subbotinae, M. marginodentata* and *M. edgari*) occurred during Zones P5 to P6 (Figure 5). The acarininids (*A. pentacamerata, A. solda-doensis soldadoensis, A. wilcoxensis*) and subbotinids (*S. patagonica, S. inaequispira, S. prolata*) increased within Zone P7, accompanied by a decrease in the abundances of the morozovellid forms (Figure 10). This increase in the abundance of acarininid and subbotinid forms is probably related to a temperature decrease after the Paleocene-Eocene boundary. In the late Paleocene, the period spanning latest zone P4 to P5 is of maximum warmth (LPTM), with Zones
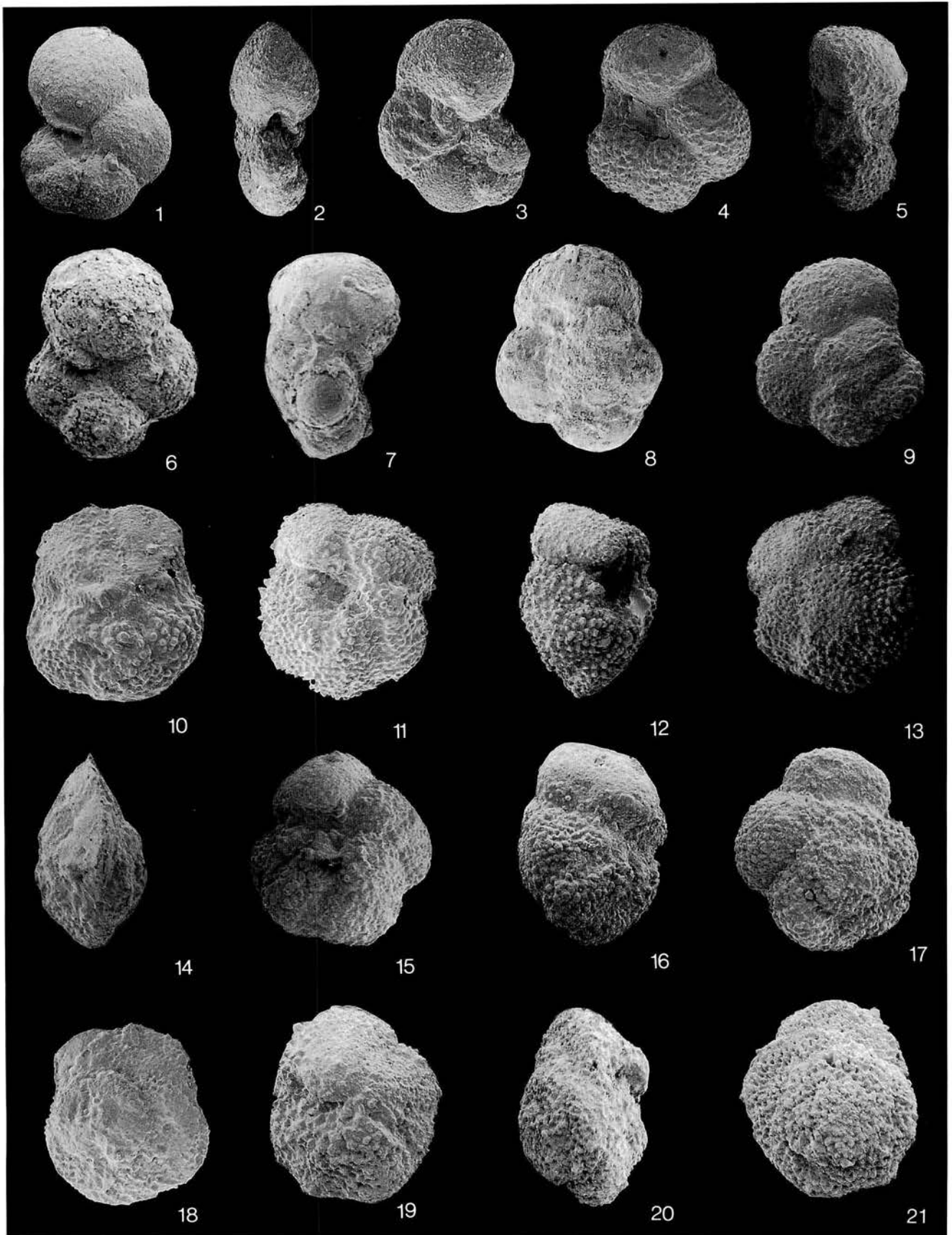
Figure 13.
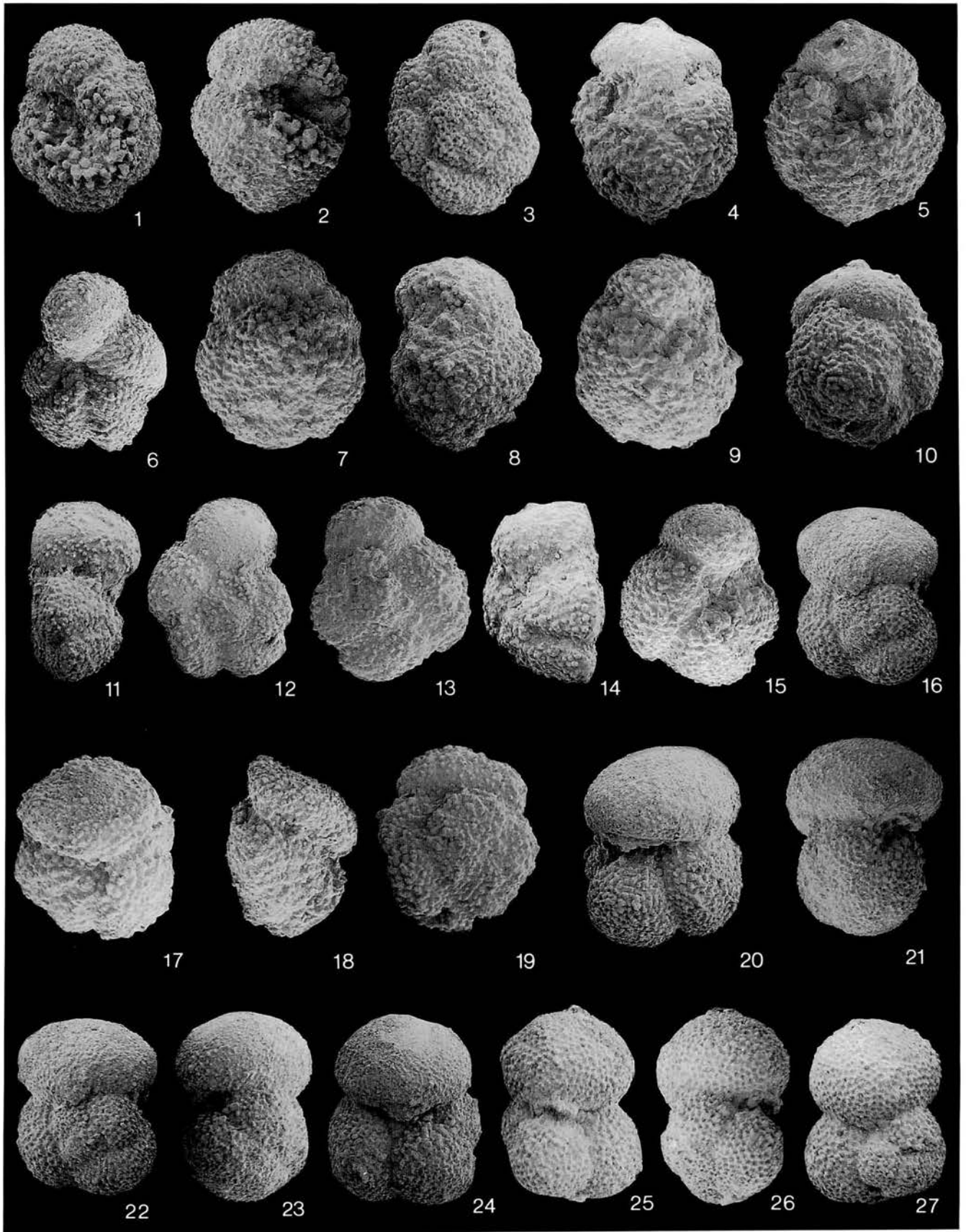
Figure 14.
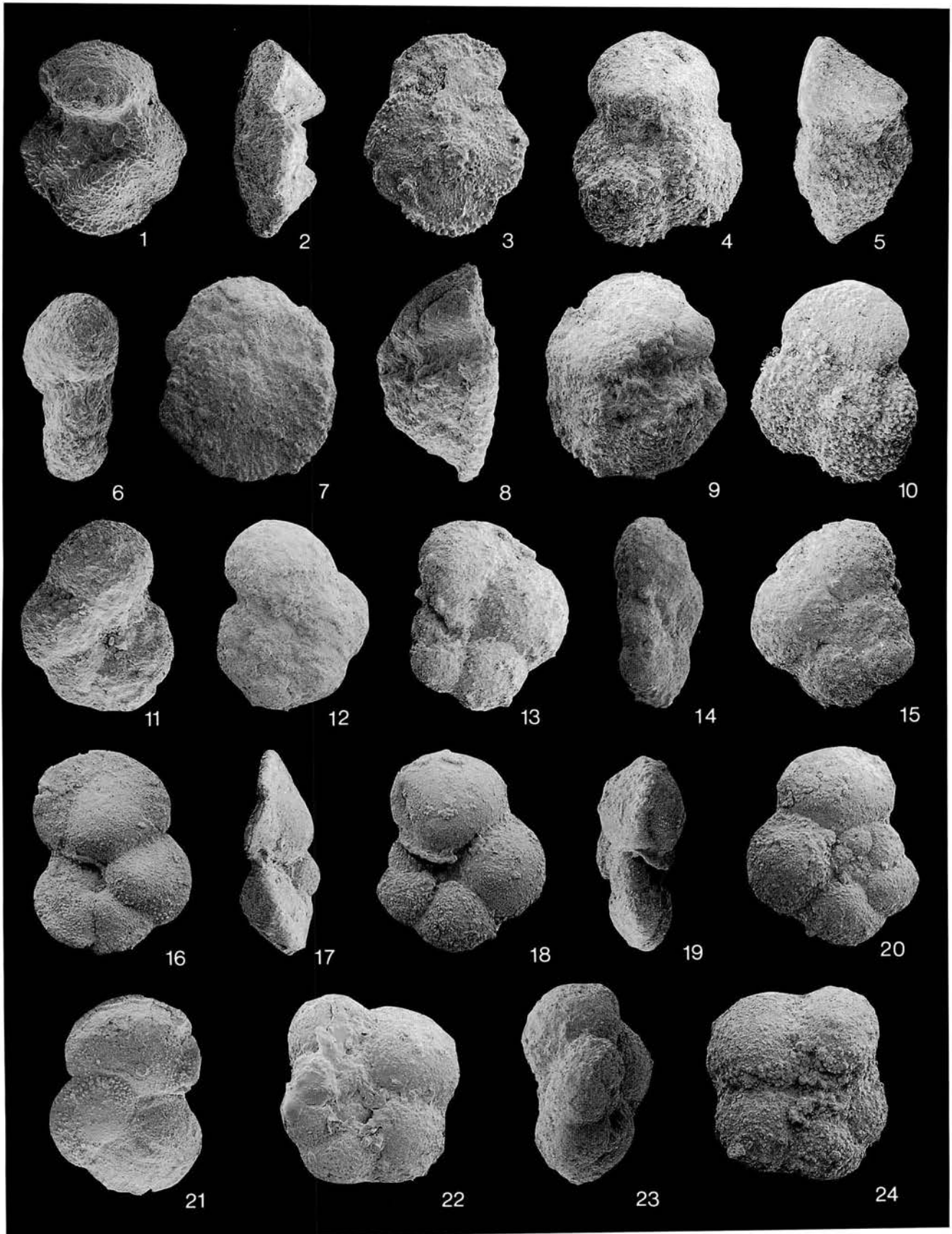
Figure 15.
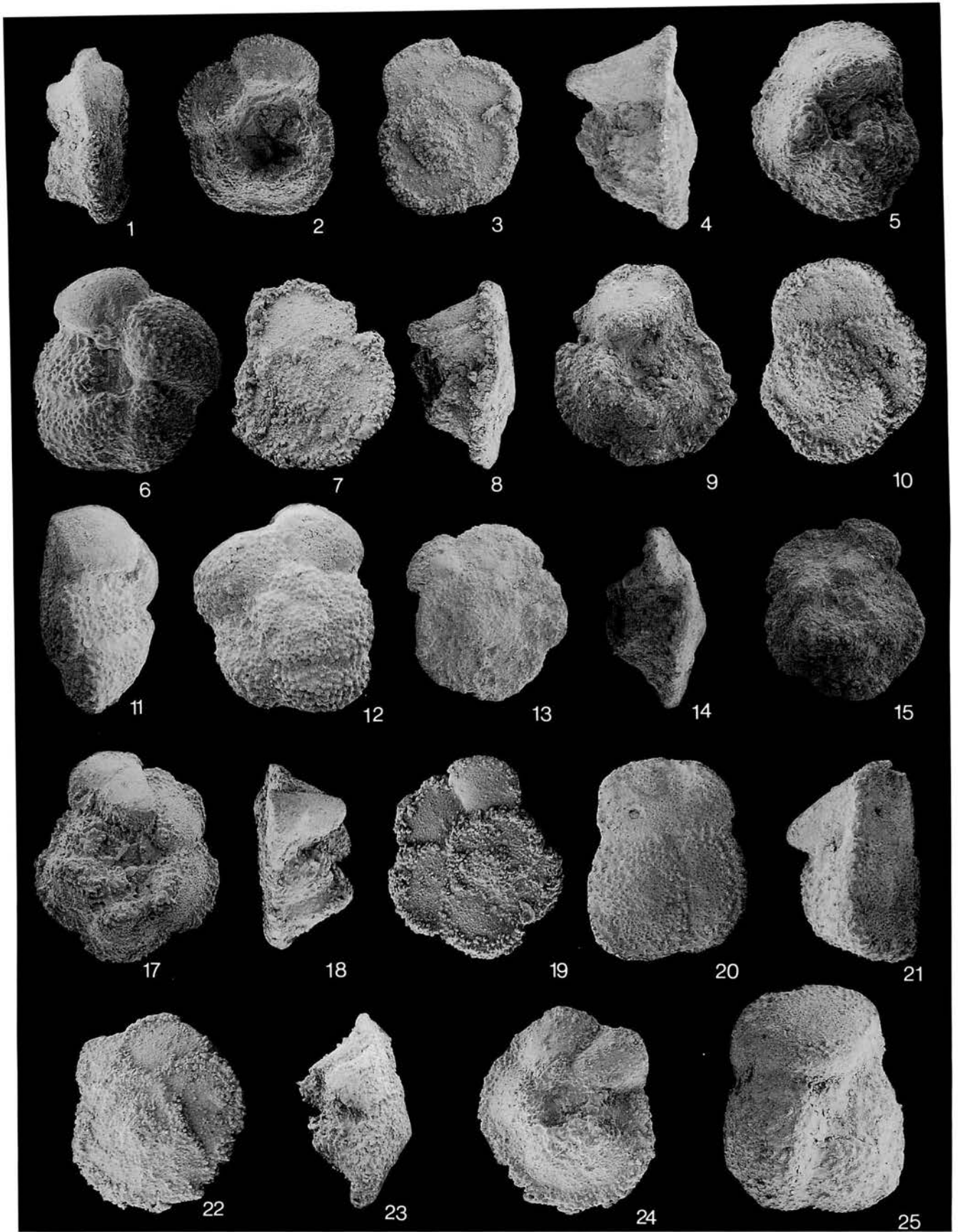
Figure 16.
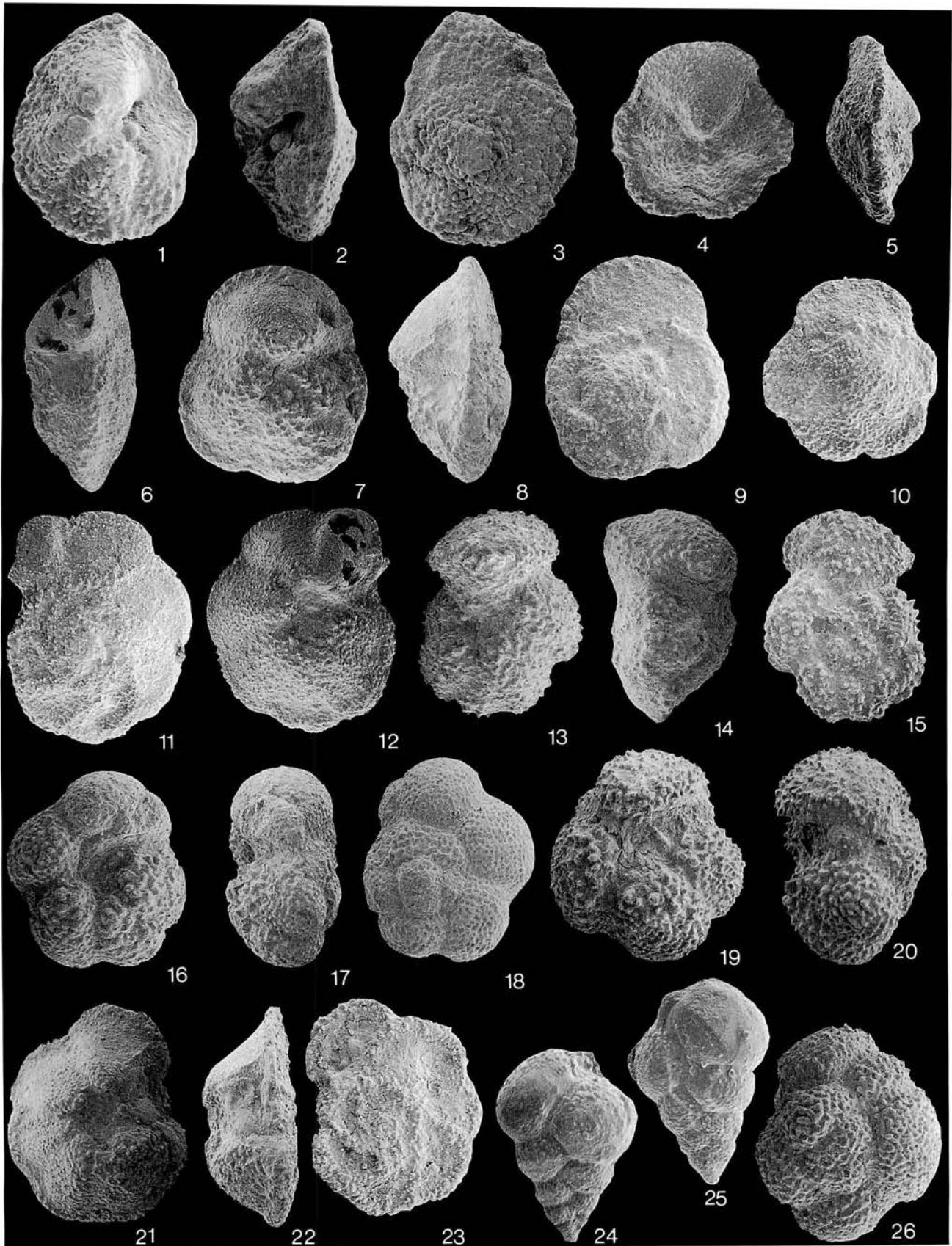
Figure 17.
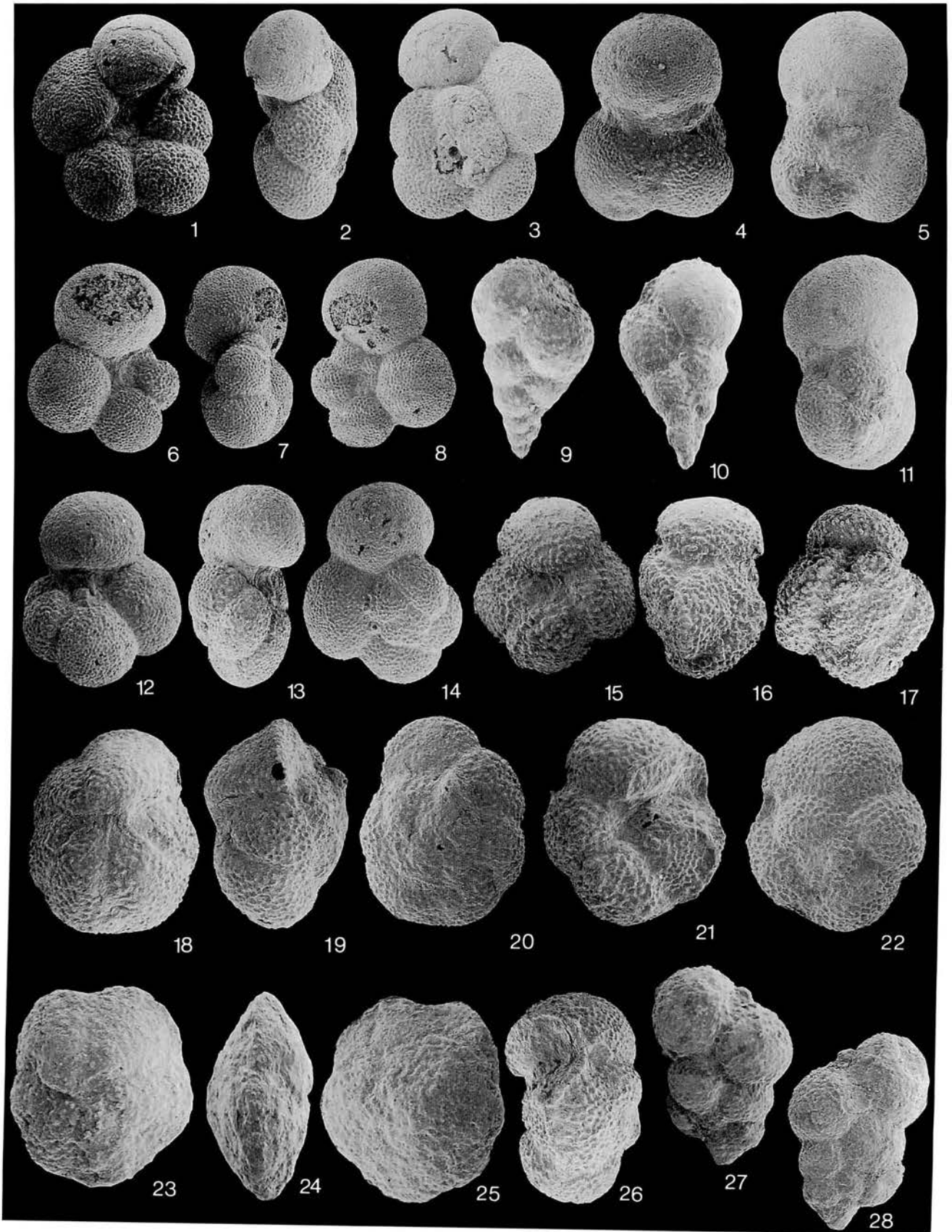
Figure 18.

P6b and P7 becoming slightly cooler (e.g., Stott *et al.*, 1990; Bralower *et al.*, 1995). This cooling event is probably responsible for the increase in percentage of *Acarinina* and *Subbotina* species in Zone P7.

3. Diversity and dominance trends

We calculated the species diversity in both sections of the Zinda Pir (Zones P3B to P5) and in the Rakhi Nala section (Zones P3 to P7) using the Shannon-Wiener Function by the following mathematical expression.

$$H\ (S) = \Sigma_{i=1}^{s}\ pi \ln pi \text{ (from } i = 1 \text{ to } S)$$

Where *pi* is the relative abundance of the *i*-th species in a

sample and *S* is the number of species. Dominance index is expressed as percentages of the most abundant species. The relationship between the Shannon-Wiener diversity index and dominance index display distinct opposite trends (Figures 8–10).

In the east of the Zinda Pir, the species richness decreases gradually from 20 to 15 species during Zones P4A to P5 (Appendix 2). The diversity index is, however, relatively constant (1.9 and 2.0), with generally lower values than in the western samples. The lowest value (15 species) was recorded from the earliest Eocene Sample ZPE-26, but this figure is not the overall minimum (Figure 8).

Figure 13. (p.287) 1–3. *Globanomalina chapmani* (Parr), umbilical, side and spiral views, Sample ZPW-17, all x250. **4, 5, 9.** *Acarinina wilcoxensis* (Cushman and Ponton), umbilical, side and spiral views, Sample ZPW-21, all x230. **6–8.** *Parasubbotina varianta* (Subbotina), umbilical, side and spiral views, Sample ZPW-5, all x500. **10, 14, 18.** *Igorina albeari* (Cushman and Bermudez), umbilical, side and spiral views, Sample ZPW-15, all x230. **11–13.** *Igorina tadjikistanensis* (Bykova), umbilical, side and spiral views, Sample ZPW-17, all x220. **15–17.** *Acarinina strabocella* (Loeblich and Tappan), umbilical, side and spiral views, Sample ZPW-16, all x230. **19–21.** *Igorina pusilla* (Bolli), umbilical, side and spiral views, Sample ZPW-17, all x300.

Figure 14. (p.288) **1–3.** *Acarinina mckannai* (White), umbilical, side and spiral views, Sample ZPW-17, all x180. **4–5, 10.** *Acarinina nitida* (Martin), side, umbilical and spiral views, Sample ZPW-20, all x220. **6, 11–12.** *Acarinina soldadoensis soldadoensis* (Bronnimann), umbilical, side and spiral views, Sample ZPW-20, all x170. **13–15.** *Acarinina soldadoensis soldadoensis* (Bronnimann) spiral, side and umbilical views, Sample ZPW-20, all x200. **7–9.** *Acarinina subsphaerica* (Subbotina), spiral, side and umbilical views, Sample ZPW-19, all x220. **16, 20, 21.** *Subbotina velascoensis* (Cushman), spiral, umbilical and side views, Sample ZPW-17, all x200. **17–19.** *Acarinina coalingensis* (Cushman and Hanna), umbilical, side and spiral views, Sample ZPW-20, all x200. **22–24.** *Subbotina triangularis* (White), spiral, side and umbilical views, Sample ZPW-17, all x180. **25–27.** *Subbotina triloculinoides* (Plummer), umbilical, side and spiral views, Sample ZPW-17, all x300.

Figure 15. (p.289) **1–3.** *Morozovella angulata* (White), umbilical, side and spiral views, Sample ZPE-15, all x150. **4, 5, 10.** *Morozovella subbotinae* (Morozova), umbilical, side and spiral views, Sample ZPE-26, all x150. **6, 11, 12.** *Pseudohastigerina wilcoxensis* (Cushman and Ponton), apertural face, lateral views, Sample ZPW-22, all x270. **7–9.** *Morozovella conicotruncata* (Subbotina), spiral, side and umbilical views, Sample ZPW-16, all x200. **13–15.** *Globanomalina imitata* (Subbotina), umbilical, side and spiral views, Sample ZPW-18, all x250. **16, 17, 21.** *Globanomalina pseudomenardii* (Bolli), umbilical, side and spiral views, Sample ZPW-17, all x170. **18–20.** *Globanomalina ehrenbergi* (Bolli), umbilical, side and spiral views, Sample ZPW-17, all x170. **22–24.***Globanomalina imitata* (Subbotina), spiral, side and umbilical views, Sample ZPW-18, all x200.

Figure 16. (p.290) **1–3.** *Morozovella acuta* (Toulmin), side, umbilical and spiral views, Sample ZPW-17, all x100. **4–5, 10.** *Morozovella acuta* (Toulmin), side, umbilical and spiral views, Sample ZPW-19, all x160. **6, 11, 12.** *Morozovella apanthesma* (Loeblich and Tappan), umbilical, side and spiral views, Sample ZPW-21, all x200. **7–9.** *Morozovella acutispira* (Bolli and Cita), spiral, side and umbilical views, Sample ZPW-15, all x150. **13–15.** *Morozovella gracilis* (Bolli), spiral, side and umbilical views, Sample ZPE-26, all x130. **17–19.** *Morozovella velascoensis* (Cushman), umbilical, side and spiral views, Sample ZPE-15, all x140. **20, 21, 25.** *Morozovella aequa* (Cushman and Renz), spiral, side and umbilical views, Sample ZPW-21, all x220. **22–24.** *Morozovella occlusa* (Loeblich and Tappan), spiral, side and umbilical views, Sample ZPW-15, all x160.

Figure 17. (p.291) **1–3.** *Morozovella edgari* (Primoli Silva and Bolli), umbilical, side and spiral views, Sample R33, all x270. **4, 5, 10.** *Morozovella marginodentata* (Subbotina), umbilical, side and spiral views, Sample R40, all x200. **6, 11, 12.** *Morozovella aragonensis* (Nuttall), side, spiral and umbilical views, Sample R41, all x130. **7–9.** *Morozovella lensiformis* (Subbotina), umbilical, side and spiral views, Sample R40, all x170. **13–15.** *Acarinina quetra* (Bolli), umbilical, side and spiral views, Sample R41, all x180. **16–18.** *Acarinina pentacamerata* (Subbotina), umbilical, side and spiral views, Sample R40, all x150. **19, 20, 26.** *Acarinina soldadoensis angulosa* (Bolli), umbilical, side and spiral views, Sample R38, all x200. **21–23.** *Morozovella formosa formosa* (Bolli), umbilical, side and spiral views, Sample R41, all x130. **24, 25.** *Chiloguembelina trinitatensis* (Cushman and Renz), lateral views, Sample R30, all x350.

Figure 18. (p.292) **1–3.** *Subbotina lozanoi* (Colom), umbilical, side and spiral views, Sample R41, all x170. **4, 5, 11.** *Subbotina patagonica* (Todd and Knicker), umbilical, spiral and side views, Sample R38, all x150. **6–8.** *Subbotina inaequispira* (Subbotina), umbilical, side and spiral views, Sample R41, all x150. **9–10.** *Chiloguembelina crinita* (Glaessner), lateral views, Sample R30, all x370. **12–14.** *Subbotina prolata* (Bolli), umbilical, side and spiral views, Sample R41, all x170. **15–17.** *Acarinina pseudotopilensis* (Subbotina), umbilical, side and spiral views, Sample R39, all x160. **18–20.** *Igorina broedermanni* (Cushman and Bermudez), umbilical, side and spiral views, Sample R41, all x200. **21, 22, 26.** *Acarinina esnaensis* (LeRoy), umbilical, spiral and side views, Sample R41, all x190. **23–25.** *Planorotalites pseudoscitula* (Glaessner), umbilical, side and spiral views, Sample R39, all x450. **27, 28.** *Chiloguembelina wilcoxensis* (Cushman and Ponton), lateral views, Sample R33, all x180.

In the western section, the species richness during Zones P3B to P4 is consistently high (17 to 20 species), except for sample ZPW-18 (Zone P4A, 16 species) (Appendix 3). The species diversity fluctuates between 2.1 and 2.6. The minimal values of both richness (15 species) and diversity (2.1) are yielded by the earliest Eocene Sample ZPW-22 (Figure 9).

In the Rakhi Nala section, the species richness during the Paleocene (Zones P3B to P4) is high and nearly constant (19 to 22 species), excepting Sample R23 (8 species, Zone P3B). The diversity of two samples (Samples R23 and R25) of Zone P3B-P4 is about 1.6 but varies to 2.5 in Sample R30 (Zone P4B). The Eocene species richness during Zones P5 to P7 ranges from 16 to 20 species, and the diversity index is constant at close to 2.5 (Figure 10). The diversity during the earliest Eocene is consistently high (2.2-2.3), differing from the trends in the Zinda Pir.

4. Depositional environment

The sequence of the Dungan Formation is characterized by a remarkable change of lithology in the studied regions. During the late Paleocene (Zone P3), the strata of both regions (Zinda Pir and Rakhi Nala) consist of siltstone subordinate to sandstone. The interbeds of sandstone show the westward-thickening trend as sandstone beds are abundant and thick in the Rakhi Nala (Figure 6). In Zone P4, two basins were filled with siltstone, with rarely intercalating thin limestone beds containing larger foraminifers. After Zone P5, the limestones became thicker in the eastern section of the Zinda Pir, and the lithology changed from a siltstone-dominant facies to a limestone-dominant one in the eastern area. As a whole, limestone deposits thinned to the westward from the Zinda Pir to the Rakhi Nala, while siltstone deposition went on in the Rakhi Nala basin, located in the western region.

As a rule, plankton-ratios (P-ratios) increase from the shelf to the open-ocean environment, and exceed 50% in the deeper environment beyond the outer shelf in both modern and ancient sediments (e.g. Ingle, 1980; Gibson, 1989). The high P-ratios of all three sections of the Dungan Formation strongly indicate an open marine environment in the studied area. The highest P-ratios (98 to 99%), high values of species richness and diversity index in the Rakhi Nala suggest that the paleodepth of the Rakhi Nala basin was greater than that of the Zinda Pir. Furthermore, the planktic foraminiferal assemblage of the western section in the Zinda Pir Anticline also represents higher species richness and P-ratios than does that of the eastern one. Hence, the sedimentary basin of the Dungan Formation, as a whole, is thought to constitute a continental slope dipping from east to west.

The westward-deepening basin is ascertained by lithological evidence, as mentioned above, namely, that the thickness of the limestone beds intercalated with the Paleocene siltstone in the Zinda Pir area are thinner in the western section than in the eastern ones (Figure 6). Moreover, petrographic studies of these intercalated limestones from the Rakhi Nala show an abundant pelagic faunas (Figure 11A), while some limestone bands from the Zinda Pir area contain deformed or broken specimens of larger foraminifers along with many glauconite grains (Figure 11B), indicating a shallow marine environment. Actually, these thin limestone bands are of turbidite origin and were emplaced in the deep-water siltstone sequence, possibly due to unstable tectonics in tectonic episodes. Our interpretation is also supported by Humayon *et al.* (1991), who have reported the westward-deepening-basin structure of the Sulaiman fold belts using seismic reflections and drilling core data.

Conclusions

Five biostratigraphic zones P3 to P7 of the tropical zones were recognized in the Dungan Formation exposed in the eastern Sulaiman Range. Zones P3 and P4 are subdivided into two subzones (Subzones A and B). The Dungan Formation is assigned to the late Paleocene to early Eocene. Based on quantitative analysis of planktic species of P-ratios, species richness and species diversity, the Dungan Formation is thought to have been deposited in a relatively deep-water environment, forming a westward-dipping continental slope during the late Paleocene to early Eocene.

Systematic description

Superfamily Rotaliporacaea Sigal, 1958
Family Hedbergellidae Loeblich and Tappan, 1961
Genus *Globanomalina* Haque 1956
Globanomalina rakhiensis sp. nov.

Figure 12

Description.—Test very small, spiral side flat to slightly convex, umbilical side low convex; equatorial periphery elongate, distinctly lobulate; peripheral margin acute, strongly to moderately compressed with a keel; 14 or 15 chambers arranged in 3 whorls, all visible from spiral side; commonly five (rarely six) chambers in the last whorl increase very rapidly in size; on umbilical side intercameral sutures depressed and weakly curved whereas strongly recurved and limbate on spiral side; surface finely perforate; umbilicus narrow and shallow; aperture low arch-shaped, interiomarginal, umbilical- extraumbilical with distinct lip.

Type and material.—Holotype, IGUT (Institute of Geosciences, University of Tsukuba) coll. cat. no, 50101, from Sample R41, Dungan Formation, Rakhi Nala section, maximum diameter 0.27 mm, width 0.20 mm. Paratype, IGUT coll. cat. no. 50102, Sample R41, Dungan Formation, Rakhi Nala section, maximum diameter 0.27 mm, width 0.20 mm. Paratype, IGUT coll. cat. no. 50103, Sample R41, Dungan Formation, Rakhi Nala section, maximum diameter 0.26 mm, width 0.21 mm.

Remarks.—The species is common in Sample R41. The largest specimen is 0.27 mm in diameter, but specimens are usually less than 0.15 mm. *Globanomalina rakhiensis* sp. nov. is a small but very distinctive species and might have been overlooked previously due to its small size. It can be missed if using the 150 μm size fraction. This species shows variation in size and degree of compression of the peripheral margin. The holotype (Figure 12.1-12.3) is less

compressed than the paratype (Figure 12.6 - 12.8). *Planorotalites pseudoscitula* (Glaessner, 1937) is very similar to *G. rakhiensis* sp. nov. but differs in having more chambers in the last whorl (6 or 7) and a circular periphery, and in being more lenticular.

Globanomalina rakhiensis sp. nov. is a homeomorph of the late Paleocene *Globanomalina pseudomenardii* (Bolli, 1957) as both forms possess a compressed planoconvex test, 5 chambers in the last whorl, and a low-arched umbilical-extraumbilical aperture that bears a lip. *G. rakhiensis* sp. nov. is easily distinguished from *G. pseudomenardii* by its small size and relatively weak keel.

The stratigraphic range of *G. pseudomenardii* is restricted to Zone P4 (late Paleocene) in many works (Toumarkine and Luterbacher, 1985; Berggren and Miller, 1988, Berggren *et al.*, 1995; Berggren and Norris, 1997; Olsson *et al.*, 1999, etc). However, Blow (1979) extended the age range of this species to his Zone P7 (early Eocene). We suggest that *Globorotalia (G.) pseudomenardii* identified by Blow (1979) from his Zone P7 (pl. 111, figs. 1-4; pl. 112, figs. 2, 3; 9-10) is quite similar to our new species (*G. rakhiensis*). Therefore, he might have misidentified *G. rakhiensis* sp. nov.

This new species is named after a local river, Rakhi Nala, along which this section is exposed.

Stratigraphic range.—*Globanomalina rakhiensis* sp. nov. yielded by Sample R41 is assigned to the *M. formosa formosa* Zone (P7), corresponding to Zone P7 of Berggren and Miller (1988) and Berggren *et al.* (1995). Therefore, the stratigraphic range of this species is within the middle lower Eocene.

Acknowledgments

References

Berggren, W. A., 1969: Rates of evolution in some Cenozoic planktonic Foraminifera. *Micropaleontology*, vol. 15, no. 3, p. 351-365.

Berggren, W. A. and Miller, K. G., 1988: Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology. *Micropaleontology*, vol. 34, no. 4, p. 362-380.

Berggren, W. A., Kent, D. V., Swisher, C. C., III and Aubry, M. -P., 1995: A revised Cenozoic geochronology and chronostratigraphy. *In*, Berggren, W. A., *et al.*, eds., *Geochronology, Time Scales and Global Stratigraphic Correlation. Society of Economic Paleontologists and Mineralogists, Special Publication*, no. 54, p. 129-212.

Berggren, W. A. and Norris, N. D., 1997: Biostratigraphy, phylogeny and systematics of Paleocene trochospiral planktic foraminifera. *Micropaleontology*, vol. 43, supplement 1, p. 1116, pls. 116.

Berggren, W. A. and Aubry, M.-P., 1998: The Paleocene/Eocene epoch/Series boundary: chronostratigraphic framework and estimated geochronology. *In*, Aubry, M.-P., Lucas, S. and Berggren, W. A. eds., *Late Paleocene-Early Eocene Climatic and Biotic Events in the Marine and Terrestrial Records*, p. 18-35. Columbia University Press, New York.

Berggren, W. A., Lucas, S. and Aubry, M.-P., 1998: Late Paleocene-Early Eocene climatic and biotic evolution: An overview. *In*, Aubry, M.-P., Lucas, S. and Berggren, W. A., eds., *Late Paleocene-Early Eocene Climatic and Biotic Events in the Marine and Terrestrial Records*, p. 1-17. Columbia University Press, New York.

Blow, W. H., 1969: Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *Proceedings of the First International Conference on Planktonic Microfossils, Geneva*, 1967, vol. 1, p. 199-422.

Blow, W. H., 1979: *The Cainozoic Globigerinidea*, 1413 pages, 3 volumes. Leiden, The Netherlands: E. J. Brill.

Bolli, H. M., 1957: The genera *Globigerina* and *Globorotalia* in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad, B. W. I. *In*, Loeblich, A. R. ed., *Studies in Foraminifera. Bulletin of the United States National Museum*, vol. 215, p. 61-81.

Bolli, H. M., 1966: Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. *Boletín Informativo de la Asociación Venezolana de Geología, Minería y Petróleo*, vol. 9, p. 3-32.

Bolli, H. M. and Cita, M. B., 1960: *Globigerine e Globorotalie* del Paleocene di Paderno d' Ada (Italia). *Rivista Italiana di Paleontologia e Stratigrafia*, vol. 66, no. 3, p. 361-408.

Bolli, H. M. and Krasheninnikov, V. A., 1977: Problem in Paleogene and Neogene correlation based on planktonic foraminifera. *Micropaleontology*, vol. 23, no. 4, p. 436-452.

Bralower, T. J., Zachos, J. C. and Thomas, E., 1995: Late Paleocene to Eocene paleoceanography of the equatorial Pacific Ocean: Stable isotopes recorded at Ocean Drilling Program Site 865, Allison Guyot. *Paleoceanography*, vol. 10, p. 841-865.

Bronnimann, P., 1952: Trinidad Paleocene and Lower Eocene Globigerinidae. *Bulletins of American Paleontology*, vol. 34, no. 143, p. 134.

Bykova, N. K., 1953: Foraminifery Suzakskogo yarusa Tadzhikskoi depressii. *Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta (VNIGRI), Mikrofauna SSSR, Sbornik*, vol. 69, p. 5-105. (*in Russian*)

Cheema, M. R., Raza, S. M. and Ahmad, H., 1977: Cainozoic. *In*, Shah, S. M. I., ed., *Stratigraphy of Pakistan. Memoirs of the Geological Survey of Pakistan, Quetta*, vol.12. p. 1-138.

Colom, G., 1954: Estudio de las biozonas con foraminíferos del Terciario de Alicante. *Boletín del Instituto Geológico Y Minero de España*, vol. 66, p. 1-279, pls. 135.

Cushman, J. A., 1925: Some new foraminifera from the Velasco Shale of Mexico. *Contributions from the Cushman Laboratory for Foraminiferal Research*, vol. 1, p. 18-23, pl. 3.

Cushman, J. A. and Bermudez, P. J., 1949: Some Cuban spe-

cies of *Globorotalia. Contributions from the Cushman Laboratory for Foraminiferal Research,* vol. 25, p. 26–45.

Cushman, J. A. and Hanna, G. D., 1927: Foraminifera from the Eocene near Coalinga, California. *Proceedings of the California Academy of Sciences, 4th Series,* vol. 16, no. 8, p. 205–229, pls. 13–14.

Cushman, J. A. and Ponton, G. M., 1932: An Eocene foraminiferal fauna of Wilcox age from Alabama. *Contributions from the Cushman Laboratory for Foraminiferal Research,* vol. 8, p. 51–72.

Cushman, J. A. and Renz, H. H., 1942: Eocene, Midway, foraminifera from Soldado Rock, Trinidad. *Contributions from the Cushman Laboratory for Foraminiferal Research,* vol. 18, p. 1–20.

Eames, F. E., 1952: A contribution to the study of the Eocene in western Pakistan and western India: A. The geology of standard sections in the western Punjab and in the Kohat district. *Quarterly Journal of the Geological Society of London,* vol. 107, p. 159–171.

Glaessner, M. F., 1937: Planktonforaminiferen aus der Kreide und dem Eozaen und ihre stratigraphische Bedeutung. *Studies in Micropaleontology, Publications of the Laboratory of Paleontology, Moscow University.* vol. 1, p. 27–46.

Gibson, T. G., 1989: Planktonic–benthonic foraminiferal ratios: Modern patterns and Tertiary applicability. *Marine Micropaleontology,* vol. 15, p. 29–52.

Haque, A. F. M., 1956: The foraminifera of the Ranikot and the Laki of the Namal Gorge, Salt Range. *Memoirs of the Geological Survey of Pakistan, Paleontologia Pakistanica,* vol. 1, p. 1–300.

Humayon, M., Lillie, R. J. and Lawrence, R. D., 1991: Structural interpretation of the eastern Sulaiman foldbelt and foredeep, Pakistan. *Tectonics,* vol. 10, no. 2, p. 299–324.

Ingle, J. C., 1980: Cenozoic paleobathymetry and depositional history of selected sequences within the southern California continental borderland. *Cushman Laboratory for Foraminiferal Research, Special Publication,* no. 19, p. 163–195.

Jones, R. W., 1997: Aspects of the Cenozoic stratigraphy of the Northern Sulaiman Ranges, Pakistan. *Journal of Micropaleontology,* vol. 16, p. 51–58.

Kazmi, A. H., 1995: Sedimentary sequence. *In,* Bender, F. K. and Raza, H. A. eds., *Geology of Pakistan.* Borntraeger, Berlin, p. 162–181.

Latif, M. A., 1964: The use of pelagic foraminifera in the subdivision of the Paleocene–Eocene of the Rakhi Nala, West Pakistan. *Geological Bulletin of the Punjab University, Lahore,* vol. 1, no. 4, p. 31–45.

LeRoy, L. W., 1953: Biostratigraphy of Maqfi section, Egypt. *Geological Society of America, Memoir* 54, p. 1–73, pls. 1–13.

Loeblich, A. R., Jr. and Tappan, H., 1957: Planktonic foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic Coastal Plains. *In,* Loeblich, A. R. eds., *Studies in Foraminifera. Bulletin of the United States National Museum,* vol. 215, p. 173–198, pls. 40–64.

Martin, L. T., 1943: Eocene foraminifera from the type Lodo Formation, Fresno County, California. *Stanford University Publications. Geological Sciences,* vol. 3, p. 93–125.

Morozova, V. G., 1939: K stratigrafii verkhnego mela i paleogena Embenskoi oblasti po faune foraminifer [On the

stratigraphy of the Upper Cretaceous and Paleogene of Emba region according to the foraminiferal fauna]. *Biulleten Moskovskogo obshchestva ispytatelei prirody, Otdel geologicheskii,* vol. 17, no. 45, p. 59–86. (*in Russian*)

Nomura, R. and Brohi, I. A., 1995: Benthic foraminiferal fauna during the time of the Indian–Asian contact, in southern Baluchistan, Pakistan. *Marine Micropaleontology,* vol. 24, p. 215–238.

Nuttall, W. L. W., 1930: Eocene foraminifera from Mexico. *Journal of Paleontology,* vol. 4, p. 271–293, pls. 23–25.

Olsson, R. K., Hemleben, C., William A, B. and Huber, B. T., eds., 1999: Atlas of Paleocene planktonic foraminifera. *Smithsonian Contributions to Paleobiology,* no. 85, p. 1–106, pls. 1–71.

Parr, W. J., 1938: Upper Eocene foraminifera from deep borings in King's Park, Perth, Western Australia. *Journal of the Royal Society of Western Australia,* vol. 24, p. 69–101, pls. 1–3.

Plummer, H. J., 1926: Foraminifera of the Midway Formation of Texas. *University of Texas Bulletin,* Austin, no. 2644, p. 1–206, pls. 1–15.

Primoli Silva, I. and Bolli, H. M., 1973: Late Cretaceous to Eocene planktonic foraminifera and stratigraphy of Leg 15 Sites in the Caribbean Sea. *In,* Edgar, N. T., *et al., Initial Reports of Deep Sea Drilling Project.* vol. 15, p. 449–547.

Samanta, B. K., 1973: Planktonic foraminifera from the Paleocene-Eocene succession in the Rakhi Nala, Sulaiman Range, Pakistan. *Bulletins of the British Museum (Natural History) Geology,* vol. 22, p. 433–481, pls. 1–15.

Shah, S. M. I., 1990: Coal resources of Baluchistan. *In,* Kazmi, A. H. and Siddiqui, R. A. eds, *Significance of the coal resources of Pakistan, Geological Survey of Pakistan/ United States Geological Survey, Quetta/ Restonva,* p. 93–63.

Sigal, J., 1958: La classification actuelle des familles de foraminiferes planktoniques du Cretace. *Compte Rendu des Seances, Societe Geologique de France,* p. 262–265.

Stainforth, R. M., Lamb, J. L., Luterbacher, H., Beard, J. H. and Jeffords, R. M., 1975: Cenozoic planktonic foraminiferal zonation and characteristics of index forms. *University of Kansas Paleontological Contributions, Article* 62, p. 1–425.

Stott, L. D., Kennett, J. P., Shackleton, N. J. and Corlfield, R. M., 1990: The evolution of Antarctic surface waters during the Paleogene: Inferences from the stable isotopic composition of planktonic foraminifers, ODP Leg 113. *In,* Barker, P. F. *et al., Proceedings of the Ocean Drilling Program: Scientific Results,* vol. 113, College Station, TX: Ocean Drilling Program, P. 849–863.

Subbotina, N. N., 1947: Foraminifery datskikh i paleogenovykh otlozhenii severnogo Kavkaza [Foraminifera of the Danian and Paleogene deposits of the northern Caucasus]. *In,* Mikrofauna neftyanykh mestorozhdenii Kavkaza, Emby I Srednei Azii. *Trudy Vesesoyuznogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Neftyanogo Instituta, Novaya Seriya (VNIGNI),* p. 39–160, pls. 1–9. (*in Russian*)

Subbotina, N. N., 1953: Iskopaemye foraminifery SSSR (Globigerinidy, Khantkenininidy i Globorotaliidy) [Fossil foraminifera of the U.S.S.R., Globigerinidae, Hantkeninidae and Globorotaliidae]. *Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta (VNIGRI),* vol. 76, p. 1–296. (*in*

Russian)

Todd, R. and Kniker, H. T., 1952: An Eocene foraminiferal fauna from the Agua Fresca shale of Magallanes province, southernmost Chile. *Cushman Foundation for Foraminiferal Research Special Publication*, no. 1, p. 26.

Toulmin, L. D., 1941: Eocene smaller foraminifera from the Salt Mountain limestone of Alabama. *Journal of Paleontology*, vol. 15, 567-611.

Toumarkine. M. and Luterbacher. H., 1985: Paleocene and Eocene planktic foraminifera. *In*, Bolli, H. M., Saunders, J. B. and Perch-Nelson, K. eds., *Plankton Stratigraphy*, p. 87-154. Cambridge University Press, Cambridge.

Warraich, M. Y. and Natori, H., 1997: Geology and planktonic foraminiferal biostratigraphy of the Paleocene-Eocene succession of the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. *Bulletin of the Geological Survey of Japan*, vol. 48, p. 595-630, pls. 1-15.

Warwick, P. D., Johnson, E. A. and Khan, I. H., 1998: Collision-induced tectonism along the northwestern margin of the Indian subcontinent as recorded in the Upper Paleocene to Middle Eocene strata of central Pakistan (Kirthar and Sulaiman Ranges). *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 142, p. 201-216.

White, M. P., 1928: Some index foraminifera of the Tampico embayment area of Mexico, Part I and Part II. *Journal of Paleontology*, vol. 2, p. 177-215, 280-317.

Appendix 1: Faunal reference list

The classification of the planktic foraminifera adopted in this paper is based on Berggren *et al.* (1995), Berggren and Norris (1997) and Olsson *et al.* (1999). The synonymies of the planktic foraminifers are restricted to original descriptions. The SEM photographs of marker species are presented in Figures 13 to 18.

Acarinina coalingensis (Cushman and Hanna) (Figure 14.17-14-19)
Globigerina coalingensis Cushman and Hanna, 1927, p. 205, pl.14, fig. 4.
Acarinina esnaensis (LeRoy) (Figure 18.21, 18.22, 18.26)
Globigerina esnaensis LeRoy, 1953, p. 31, pl. 6, figs. 8-10.
Acarinina mckannai (White) (Figure 14.1-14.3)
Globigerina mckannai White, 1928, p. 194, pl. 27, figs. 16a-c.
Acarinina nitida (Martin) (Figure 14.4-14.5, 14.10)
Globigerina nitida Martin, 1943, p. 115, pl. 7, figs. 1a-c.
Acarinina quetra (Bolli) (Figure 17.13-17.15)
Globorotalia quetra Bolli, 1957, p. 79-80, pl. 19, figs. 1-6.
Acarinina pentacamerata (Subbotina) (Figure 17.16-17.18)
Globorotalia pentacamerata Subbotina, 1947, p. 128-129, pl. 12-17, figs. 24-26.
Acarinina pseudotopilensis Subbotina (Figure 18.15-18.17)
Acarinina pseudotopilensis Subbotina, 1953, p. 227-228, pl. 21, figs. 13.
Acarinina soldadoensis angulosa (Bolli) (Figure 17.19-17.20, 17.26)
Globigerina soldadoensis angulosa Bolli, 1957, p. 71, pl. 16, figs. 46.
Acarinina soldadoensis soldadoensis (Bronnimann) (Figure 14.6, 14.11-14.15)
Globigerina soldadoensis Bronnimann, 1952, p. 7, 9, pl. 1, figs. 19
Acarinina strabocella (Loeblich and Tappan) (Figure 13.15-13.17)
Globorotalia strabocella Loeblich and Tappan, 1957, p.195, pl. 61, figs. 6a-c.
Acarinina subsphaerica (Subbotina) (Figure 14.7-14.9)
Globigerina subsphaerica Subbotina, 1947, p. 108, pl. 5, figs. 26-28.
Acarinina wilcoxensis (Cushman and Ponton) (Figure 13.4, 13.5, 13.9)
Globorotalia wilcoxensis Cushman and Ponton, 1932, p. 71, pl. 9, figs.10a-c.
Chiloguembelina crinita (Glaessner) (Figure 18.9-18.10)
Guembelina crinita Glaessner, 1937, p. 383, pl.4, figs. 34a, *b.*
Chiloguembelina trinitatensis (Cushman and Renz) (Figure 17.24-17.25)
Guembelina trinitatensis Cushman and Renz, 1942, p. 8, pl. 2, figs. 8a, b
Chiloguembelina wilcoxensis (Cushman and Ponton) (Figure 18.27-18.28)
Guembelina wilcoxensis Cushman and Ponton, 1932, p. 66, pl. 8, figs. 16, 17.
Globanomalina chapmani (Parr) (Figure 13.1-13.3)
Globorotalia chapmani Parr, 1938, p. 87, pl. 3, figs. 8, 9.
Globanomalina compressa (Plummer)
Globigerina compressa Plummer, 1926, p. 135, pl. 8, figs. 11a-c.
Globanomalina ehrenbergi (Bolli) (Figure 15.18-15.20)

Globorotalia ehrenbergi Bolli, 1957, p. 77, pl. 20, figs. 18-20.
Globanomalina elongata (Glaessner)
Globanomalina pseudoscitula var. *elongata* Glaessner, 1937, p. 33, pl. 1, figs. 3d-f.
Globanomalina imitata (Subbotina) (Figure15.13 - 15.15; 15.22-15.24)
Globorotalia imitata Subbotina, 1953, p. 206-207, pl. 16, figs. 14-16.
Globanomalina pseudomenardii (Bolli) (Figure 15.16-15.17, 15.21)
Globorotalia pseudomenardii Bolli, 1957, p. 77, pl. 20, figs. 14-17.
Igorina albeari (Cushman and Bermudez) (Figure 13.10, 13.14, 13.18)
Globorotalia albeari Cushman and Bermudez, 1949, p. 33, pl. 6, figs. 13-15.
Igorina broedermanni (Cushman and Bermudez) (Figure 18.18-18.20)
Globorotalia (Truncorotalia) broedermanni Cushman and Bermudez, 1949, p. 40, pl. 7, figs. 22-24.
Igorina pusilla (Bolli) (Figure 13.19-13.21)
Globorotalia pusilla pusilla Bolli, 1957, p. 78, pl. 20, figs. 8-10.
Igorina tadjikistanensis (Bykova) (Figure 13.11-13.13)
Globorotalia tadjikistanensis Bykova, 1953, p. 86, pl. 3, figs. 5a-c.
Morozovella acuta (Toulmin) (Figure 16.1-16.3; 16.4-16.5, 16.10)
Globorotalia wilcoxensis Cushman and Ponton var. *acuta* Toulmin, 1941, p. 608, pl. 82, figs. 68.
Morozovella acutispira (Bolli and Cita) (Figure 16.7-16.9)
Globorotalia acutispira Bolli and Cita, 1960, p. 15, pl. 33, figs. 3a-c.
Morozovella aequa (Cushman and Renz) (Figure 16.20-16.21, 16.25)
Globorotalia crassata (Cushman) var. *aequa* Cushman and Renz, 1942, p. 12, pl. 3, figs. 3a-c.
Morozovella aragonensis (Nuttall) (Figure 17.6, 17.11, 17.12)
Globorotalia aragonensis Nuttall, 1930, p. 288, pl. 24, figs. 6-11.
Morozovella angulata (White) (Figure 15.1-15.3)
Globigerina angulata White, 1928, p. 191, 192, pl. 27, figs. 13a-c.
Morozovella apanthesma (Loeblich and Tappan) (Figure 16.6, 16.11, 16.12)
Globorotalia apanthesma Loeblich and Tappan, 1957, p. 187, pl. 48, figs. 1a-c, pl. 55, figs.1a-c, pl. 58, figs. 4a-c; pl. 59, figs. 1a-c.
Morozovella conicotruncata (Subbotina) (Figure 15.7-15.9)
Globorotalia conicotruncata Subbotina, 1947, p. 115-117, pl. 4, figs. 11-13; pl. 9, figs. 9-11.
Morozovella edgari (Primoli Silva and Bolli) (Figure 17.1-17.3)
Globorotalia edgari Primoli Silva and Bolli, 1973, p. 526, pl. 7, figs. 10-12, pl. 8, figs. 1-12.

Morozovella formosa formosa (Bolli) (Figure 17.21-17.23)
Globorotalia formosa formosa Bolli, 1957, p. 76, pl. 18, figs. 1-3.
Morozovella formosa gracilis (Bolli) (Figure 16.13-16.15)
Globorotalia formosa gracilis Bolli 1957, p. 75, 76, pl. 18, figs. 4-6.
Morozovella lensiformis (Subbotina) (Figure 17.7-17.9)
Globorotalia lensiformis Subbotina, 1953, p. 214, pl. 18, figs. 4, 5.
Morozovella marginodentata (Subbotina) (Figure 17.4, 17.5, 17.10)
Globorotalia marginodentata Subbotina, 1953, p. 212, 213, pl. 17, figs. 14-16, pl.18, figs. 1-3.
Morozovella occlusa (Loeblich and Tappan) (Figure 16.22-16.24)
Globorotalia occlusa Loeblich and Tappan, 1957, p. 191, pl. 64, figs. 3a-c.
Morozovella subbotinae (Morozova) (Figure 15.4, 15.5, 15.10)
Globorotalia subbotinae Morozova, 1939, p. 80, pl. 2, figs. 16,17.
Morozovella velascoensis (Cushman) (Figure 16.17-16.19)
Pulvinulina velascoensis Cushman, 1925, p. 19, pl. 3, figs. 5a-c.
Parasubbotina varianta (Subbotina) (Figure 13.6-13.8)
Globigerina varianta Subbotina, 1953, p. 63, pl. 3, figs. 5-7, 10-12.
Planorotalites pseudoscitula (Glaessner) (Figure 18.23-18.25)
Globorotalia pseudoscitula Glaessner, 1937, p. 32, figs. 3a-c.

Pseudohastigerina wilcoxensis (Cushman and Ponton) (Figure 15.6, 15.11, 15.12)
Nonion wilcoxensis Cushman and Ponton, 1932, p. 64, pl. 8, figs. 11a, b.
Subbotina inaequispira (Subbotina) (Figure 18.6-18.8)
Globigerina inaequispira Subbotina, 1953, p. 69, pl. 6, figs. 1-4.
Subbotina lozanoi (Colom) (Figure 18.1-18.3)
Globigerina lozanoi Colom, 1954, p.149, pl. 2, figs. 1-48.
Subbotina patagonica (Todd and Kniker) (Figure 18.4, 18.5, 18.11)
Globigerina patagonica Todd and Kniker, 1952, p. 26, pl. 4, figs. 32a-c.
Subbotina prolata (Bolli) (Figure 18.12-18.14)
Globigerina prolata Bolli, 1957, p. 72, pl. 15, figs. 24-26.
Subbotina triangularis (White) (Figure 14.22-14.24)
Globigerina triangularis White, 1928, p. 195, pl. 28, figs. 1a-c.
Subbotina triloculinoides (Plummer) (Figure 14.25-14.27)
Globigerina triloculinoides Plummer, 1926, p. 134, 135, pl. 8, figs. 10a-c.
Subbotina velascoensis (Cushman) (Figure 14.16, 14.20, 14.21)
Globigerina velascoensis Cushman, 1925, p. 19, pl. 3, figs. 6a-c.
Turborotalia praecentralis Blow
Globorotalia (Turborotalia) praecentralis Blow, 1979, p. 1094, pl. 135, figs. 7-9; pl. 136, figs. 1-6; pl. 233, fig. 6.

Muhammad Yousaf Warraich *et al.*

Appendix 2: Stratigraphic distribution and relative abundance (%) of planktic foraminiferal species in the Dungan Formation exposed at the Rakhi Nala section. Here x = less than 1 %.

R23	R28	R25	R29	R30	R32	R26	R27	R33	R34	R35	R36	R38	R39	R40	R41	Samples	Planktic foraminiferal species
	2	3	1	2	6	6	x	1	x	6	1		3	2	4		Acarinina coalingensis
							x	x		2			1		1		A. esnaensis
	1		1	1		2											A. mckannai
	2	2	2	2	4	2	4	2		4	2						A. nitida
											3	5	3	10	4		A. pentacamerata
						2	x	1	1	1	2	4	1		3		A. pseudotopilensis
											3	1	1	5	4		A. quetra
			10	3	13	11	14	18	8	28	22	25	31	36	19		A. sold. soldadoensis
											2	3	3	5	5		A. soldadoensis angulosa
	4																A. strabocella
		1	1	1													A. subsphaerica
							1		3	13	11	4	6	4	7		A. wilcoxensis
		1					1	1									Chiloguembelina crinita
				2													Ch. trinitatensis
					x			1									Ch. wilcoxensis
		1		1													Globanomalina chapmani
	1		2	3													G. ehrenbergi
					1												G. elongata
x	1	1		1	x	1											G. imitata
		2	8	14	1												G. pseudomenardii
															5		G. rakhiensis
	6		1	1													Igorina albeari
							1		1	4	3	2	3	2	4		I. broedermanni
	7	1	1	1													I. pusilla
3	4	3	4	4	4	3											I. tadjikistanensis
46	9	58	14	17	33	23	9	11									Morozovella acuta
		x	1		x												M. acutispira
4	6	2	1	x	5	3	3	1	3	1	1		x				M. aequa
18	37	1															M. angulata
3		1	5	3		1											M. apanthesma
									3	3	11	13	7	8	14		M. aragonensis
	2	5	3	2		1											M. conicotruncata
							11	1	1								M. edgari
								1	1	1	1	x	x	1			M. formosa formosa
					1	1	5	4	4	2	5		2				M. formosa gracilis
								3	4	10	9	6	7	2			M. lensiformis
								6	6	2	2		1				M. marginodentata
		3	4	2	1	5	2	5									M. occlusa
					4	4	30	20	35	12	14	9	6	5	x		M. subbotinae
	2	3	16	11	3	1		17									M. velascoensis
	1																Parasubbotina varianta
													6	2	4		Planorot. pseudoscitula
							3	1	5	2	1	2	2		4		Pseudohasti. wilcoxensis
												2	3	1	5		Subbotina inaequispira
															6		S. lozanoi
										3		1	1	2	4		S. prolata
							6	8	14	8	2	12	14	3	2		S. patagonica
2	1	1		2		3											S. triloculinoides
23	12	11	19	16	19	26	8	5	12	3	3	7					S. triangularis
	3	3	7	7	5	9	x	1									S. velascoensis
												3					Turborotalia praecentralis
226	393	308	383	409	298	343	316	288	305	187	262	199	304	243	301		Total Counts
8	18	19	20	22	15	18	17	19	16	17	20	18	19	18	20		Species Number
P3B			P4A	P4B		P5		P7									Zones

Appendix 3: Stratigraphic distribution and relative abundance (%) of planktic foraminiferal species in the Dungan Formation exposed along the eastern and western lims of the Zinda Pir Anticline. Here x = less than 1 %.

Dungan Formation — Planktic foraminiferal Species

Side	Samples	Acarinina coalingensis	A. mckannai	A. nitida	A. soldadoensis soldadoensis	A. strabocella	A. subsphaerica	A. wilcoxensis	Globanomalina chapmani	G. compressa	G. ehrenbergi	G. imitata	G. pseudomenardii	Igorina albeari	I. pusilla	I. tadjikistanensis	Morozovella acuta	M. acutispira	M. aequa	M. angulata	M. apanthesma	M. conicotruncata	M. formosa gracilis	M. occlusa	M. subbotinae	M. velascoensis	Parasubbotina varianta	Pseudohastigerina wilcoxensis	Subbotina triloculinoides	S. triangularis	S. velascoensis	Total Counts	Species Number	Zones
Western side	ZPW-22	1		2	9			x			2						24		6			x	x	4		6		2		31	9	361	15	P5
Western side	ZPW-21	5	2	5	21		x	7			1		5				19		12			1	x		2	3	1		2	7	4	250	18	P4B
Western side	ZPW-20	2	2	4	11	x		3		1	2						25		1	4	4	11		1		24			1	4	6	271	18	P4B
Western side	ZPW-19	x	1	2	7		1	4		2	x		5				46		1	4	3	6		1		10				4	4	284	18	P4B
Western side	ZPW-18		1	2				3		1	1		2				30		3	12	5	14		3		14			1	4	5	278	16	P4A
Western side	ZPW-17	1	1	9			1	4		2			2	2	2		17		4	4	3	6		4		18	x		2	5	11	264	20	P4A
Western side	ZPW-16	2	1	3		15		3		4	1			1		4	28		4	5	3	4				1			2	11	6	267	18	P4A
Western side	ZPW-15		1			2						1		1	3	1	25	8	1	16	2	5		1		2			7	15	11	313	17	P3B
Western side	ZPW-13											1					35	14	39	5	4			1								79	7	P3B
Western side	ZPW-5									3	3					4	7	9	39	8				4		4	3			3	4	67	13	P3A
Western side	ZPW-1						5					10							5											5		5	4	P3A
Eastern side	ZPE-26	7		1	10		1	1					3				36		5				1	2	9	1		5		11	7	352	15	P5
Eastern side	ZPE-20		3	3	14			2			2	2				7	30		3		20	5		2	8					1		191	14	P4B
Eastern side	ZPE-19		1	1	1			2				1	1			5	48		1		2	6		4	21					6	1	166	15	P4B
Eastern side	ZPE-18	5	3	2	6			5					5			8	31		2					6	5	8				11	5	69	14	P4B
Eastern side	ZPE-16		3	2	15			1			1	2	1			1	23		4	4	4	2		4	6				1	18	9	112	18	P4A
Eastern side	ZPE-15			2				4			4	3	1	1	1	1	51		4	2	1	1		2	3	1			2	12	5	178	19	P4A
Eastern side	ZPE-14		x	x			x	1				6	1	2	x	2	45		2	2	1	1		2	3	14			4	7	5	367	20	P4A

The Palaeontological Society of Japan has revitalized its journal. Now entitled **Paleontological Research,** and published in English, its scope and aims have entirely been redefined. The journal now accepts and publishes any international manuscript meeting the Society's scientific and editorial standards. In keeping with the journal's new target audience the Society has established a new category of membership **(Subscribing Membership)** which, hopefuliy, will be especially attractive to new and existing overseas members. The Society looks forward to receiving your applications. Thank you.

APPLICATION FOR OVERSEAS MEMBERSHIP TO THE PALAEONTOLOGICAL SOCIETY OF JAPAN

1. NAME: _____
                   Last (Surname)   First (Given name)   Middle Initial

2. POSTAL ADDRESS: _____

   _____

   _____

3. TELEPHONE AND FAX (please include country code if known):
   TEL _____
   FAX _____
          country code   area code   number

4. E-MAIL: _____

5. MEMBERSHIP CATEGORY (please check one):
   ☐**Full Member** receives four issues of **Paleontological Research** · · · · · · · · · · · · · · · ·**8,500 JP Yen**
      and two issues of **Kaseki** (a Japanese language journal of paleontology)
      in a year and all privileges of the Society including voting rights and
      conference programs
   ☐**Subscribing Member of PR** receives four issues of ·**6,000 JP Yen**
      Paleontological Reasearch in a year   (Current JP Yen is 0.009 U.S. $)

6. METHOD OF PAYMENT (Please check one box):
   ☐I enclose a bank draft made payable to the PSJ.
   ☐I will remit/have remitted the above amount on_____JP Yen through my bank to the
      account of JPS, a/c #062-0211501, The Bank of Tokyo-Mitsubishi, Kasuga-cho Branch, Tokyo.
   ☐I agree to pay the amount of_____JP Yen by my credit card.
        ☐Master   ☐VISA   ☐American Express
        ☐Diners Club   ☐Access   ☐Euro
        Card Account Number ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐
        Signature (required) _____ Card Expiration _____

7. SIGNATURE _____ DATE _____

8. MAIL TO: Palaeontological Society of Japan
             c/o Business Center for Academic Societies, Japan
             5-16-9 Honkomagome, Bunkyo-ku, Tokyo, 113-8622 Japan

A GUIDE FOR PREPARING MANUSCRIPTS

PALEONTOLOGICAL RESEARCH is dedicated to serving the international community through the dissemination of knowledge in all areas of paleontological research. The journal publishes original and unpublished articles, normally not exceeding 24 pages, and short notes, normally less than 4 pages, without abstract. Manuscripts submitted are subject to review and editing by reviewers and a language editor. Manuscripts accepted for publication will generally be published in order of submission. Authors submit three copies of their manuscript to: Dr. Kazushige Tanabe, Editor of Paleontological Research, Department of Earth and Planetary Science, University of Tokyo, Hongo 7-3-1, Tokyo 113-0033, Japan. After review, two copies of the revised manuscript are to be returned for copy editing.

Text: Paleontological Research is intended to be read by an international audience, therefore it is particularly critical that language be clear and concise. Manuscripts should be written in English. Either British or American usage style is acceptable. The editors strongly recommend the author(s) whose mother language is not English to ask critical reading and stylistic corrections of the manuscript before submission by specialist(s) who are familiar with English. Use SI (Systeme International d' Unités) units wherever possible.

Text should be typed always in double space on one side of white paper of not less than either 210×280 mm (A4 size) or 8 1/2×11 inches in the following order.

Cover sheet. Cover sheet should contain (1) full name, address, phone and fax numbers, and e-mail address of the author taking responsibility for the galley proofs, (2) running title composed of less than 40 characters, and (3) the numbers of tables and figures.

Title page. Title of the paper, names of authors and their professional affiliations with postal and e-mail addresses (or residential address, if an author is unaffiliated). Titles are to be brief and simple. Spell out one or more of the authors' first names.

Abstract. Abstract should be a condensation and concentration of the essential qualities of the paper. All the papers, excluding Short Notes, are to be accompanied by an abstract not exceeding 500 words. New taxonomic or stratigraphic names should be mentioned in the abstract.

Key words. Select keywords (not more than six words or phrases) which identify the most important subjects covered by the paper and arrange them in alphabetical order.

Main text. Use three or fewer levels of heading. No footnotes are to be used. Bibliographical references are to be identified by citing the authors' names, followed, in parentheses, by the date of publication, with a page number if desired. All citations must have a corresponding entry in the reference list. Acknowledgments should be placed at the end of the text, before References. Do not use honorifies such as Dr., Prof., Mrs., etc. Footnotes should be avoided. Stratigraphic nomenclature must follow the International Stratigraphic Guide.

The typical format for arrangement of systematic paleontology can be learned from current issues of the Journal. All descriptions of new taxa must include a diagnosis, and, as appropriate, stratigraphic and geographic indications, designation of a type or types, depository information, and specification of illustrations. In synonymies use an abbreviated form of the reference, consisting only of authors of reference, date of publication, and number of pages, plates, figures and text-figures referring to the organism or organisms in question.

References. Heading for the bibliography can be "References." Entries are to be listed alphabetically. No abbreviations will be used in article and book titles. Journal titles are written out, not abbreviated. Series, volume, and number or part are to be given, with the appropriate word abbreviated in each case("ser.", "vol.", etc.;

see the examples).

Illustrations. All illustrations, including maps, geologic sections, and half-tone illustrations (including "plates") are to be called figures and must be numbered in the same sequence as they are first cited in the text. Citations of illustrations in the text are to be spelled out in full (e. g., Figure 2 or Figure 2.1). Figure captions are to be typed separately. Plan the illustrations so that they take up either the entire width of the printed page (170 mm) or the width of one column (80 mm). Originals should not be smaller than the final intended size for printing. No foldouts will be accepted. Mark all originals clearly with authors' names and figure number. Photographs of all specimens except sections must be illuminated from the upper left side, as is conventional.

Manuscripts on disk. Authors are encouraged to deliver final, revised manuscript copy on disk, but disks should be sent only after the paper has been accepted. 3.5 inch disk with the RTF file (not the text file) written by a recent version of Word Perfect or Microsoft Word (ver. 5.1 or higher) for Windows 3.1 or higher, or Mac OS is acceptable. Be sure to specify, in a covering note, the hardware and the word-processing package used.

Galley proofs and offprints. Galley proofs will be sent to authors about one month before the expected publication date and should be returned to the editors within 3 days of receipt. The authors are responsible for reading the first galley proof. Minor changes submitted by the author will be permitted while a paper is in galleys, but a charge will be made for substantial alterations.

The authors receive 50 free of charge offprints without covers. Additional copies and covers can be purchased and should be ordered when the proofs are returned.

Charges. If a paper exceeds 24 printed pages, payment of page charges for the extra pages is a prerequisite for acceptance. Illustrations in color can also be published at the authors' expense. For either case, the editors will provide infomation about current page charges.

Return of published figures. The manuscripts of the papers published will not be returned to the authors. However, figures will be returned upon request by the authors after the paper has been published.

Ager, D. V., 1963: *Principles of Paleoecology*, 371p. McGraw-Hill Co., New York.

Barron, J. A., 1983: Latest Oligocene through early Middle Miocene diatom biostratigraphy of the eastern tropical Pacific. *Marine Micropaleontology*, vol. 7, p. 487-515.

Barron, J. A., 1989: Lower Miocene to Quaternary diatom biostratigraphy of Leg 57, off northeastern Japan, Deep Sea Drilling Project. *In*, Scientific Party, *Initial Reports of the Deep Sea Drilling Project*, vols, 56 and 57, p. 641-685. U. S. Govt. Printing Office, Washington, D. C.

Burckle, L. H., 1978: Marine diatoms. *In*, Haq, B. U. and Boersma, A. eds., *Introduction to Marine Micropaleontology*, p. 245-266. Elsevier, New York.

Fenner, J. and Mikkelsen, N., 1990: Eecene-Oligocene diatoms in the western Indian Ocean: Taxonomy, stratigraphy, and paleoecology. *In*, Duncan, R. A., Backman, J., Peterson, L. C., *et al., Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 115, p. 433-463. College Station, TX (Ocean Drilling Program).

Kuramoto, S., 1996: Geophysical investigation for methane hydrates and the significance of BSR. *The Journal of the Geological Society of Japan*, vol. 11, p. 951-958. (*in Japanese with English abstract*)

Zakharov, Yu. D., 1974: Novaya nakhodka chelyustnogo apparata ammonoidey (A new find of an ammonoid jaw apparatus). *Paleontologicheskii Zhurnal* 1974, p. 127-129. (*in Russian*)

List of reviewers

The coeditors are indebted to the following persons who acted as reviewers during the editing of volumes 3–4 of *Paleontological Research*.

Aitchison, J.	Amano, K.	Anderson, O. R.	Ando, H.
Bandel, K.	Chiba, S.	Chinzei, K.	Collette, B. B.
Crick, R. E	Debenay, J. -P.	Endo, K.	Engeser, T.
Farrell, J.	Feldmann, R. M.	Fryxell, G. A.	Furutani, H.
Gröcke, D. R.	Haggart, J.	Hayami, I.	Hirano, H.
Hirayama, R.	Histon, K.	Hottinger, L.	Houart, R.
Igo, H.	Iryu, Y.	Ishizaki, K.	Kaiho, K.
Kato, H.	Kennedy, W. J.	Kidwell, S. M.	King, A.
King, G. M.	Kitazato, H.	Kuwahara, K.	Landman, N. H.
Maas, M. C.	Maeda, H.	Majima, R.	Marincovich, L.
Martin, T.	Matoba, Y.	Matsuoka, A.	McLean, D.
Muller, P. H.	Nishida, H.	Nishida, T.	Nomura, R.
Oba, T.	Ogasawara, K.	Oji, T.	Orchard, M.
Padian, K.	Reif, W.-E.	Reisz, R. R.	Reitner, J.
Revets, S. A.	Reyment, R. A.	Sasaki, T.	Shigeta, Y.
Suzuki, M.	Takayanagi, Y.	Takeda, M.	Tanai, T.
Tanimura, Y.	Thomas, R. D. K	Ting, S.-Y.	Tomida, Y.
Ubukata, T.	Uemura, K.	Ueno, T.	Ujiié, H.
Utting, J.	Yamamoto, M.	Yun, C.	Weidrich, O.

SYSTEMATIC INDEX

(vol. 3, no. 1–vol. 4, no. 4: 1999–2000)

The 53 papers published in volumes 3–4 of *Paleontological Research* are listed under major systematic divisions of fossils. Entries in each category are arranged in alphabetical order of authorship, with two or more papers by the same author (s) in chronological order of publication. The volume number, part number (in parentheses), page numbers are given for each paper.

PALEOZOOLOGY

Protoctista

Porifera

Cnidaria

Mollusca

PALEOBOTANY

TERRESTRIAL ORGANIC MATTER

310

INDEX OF GENERA AND SPECIES

Genera and species described in volumes 3-4 of *Paleontological Research* are listed in alphabetical order. The volume number, part number (in parentheses), page numbers, and figure numbers are given for each taxon. Newly proposed taxa are in bold type.

312

CONTENTS

Vol. 3 No. 1 (April 30, 1999)

Vol. 3 No. 2 (June 30, 1999)

Vol. 3 No. 3 (September 30, 1999)

Vol. 3, No.4 (December 30, 1999)

314

Vol. 4, No. 1 (April 28, 2000)

Vol. 4, No. 2 (June 30, 2000)

Vol. 4, No. 3 (September 29, 2000)

Vol. 4, No. 4 (December 30, 2000)

━━━ 行 事 予 定 ━━━

◎第150回例会は，2001年1月27日（土）と28日（日）に「茨城県自然博物館」で開催されます．27日にシンポジウム「新生代軟体動物古生物学の最近の動向（世話人：野田浩司・天野和孝・島本昌憲・間嶋隆一」が行われます．個人講演の申し込み締切日は2000年12月1日（金）です．

◎2001年年会・総会は，2001年6月29日（金），6月30日（土），7月1日（日）に「国立オリンピック記念青少年総合センター」で開催されます．21世紀最初の年会ですので，「21世紀の古生物学」を統一テーマとし，29日に統一シンポジウム，30日と1日に17件の課題別シンポジウムが行われる予定です．現在，学会の「将来計画委員会」によってプログラムの詳細を立案中です．一般講演はポスター講演だけに限って受け付けます．口答発表形式による一般講演はありませんのでご注意下さい．ポスター講演の申し込み締切日は2001年5月9日（水）です．

◎第151回例会（2002年1月下旬開催予定）には鹿児島大学理学部からの開催申し込みがありました．

◎2002年年会・総会（2002年6月下旬開催予定）には福井県立博物館から開催申し込みがありました．

◎古生物学会では，小人数で実施されるワークショップやショートコースを主催しております．学会から金銭を含む援助を行なうことができますので，企画をお持ちの方は行事係までお問い合せ下さい．

個人講演・シンポジウム案の申し込み先
　個人講演の申し込みは予稿集原稿を直接お送り下さい．e-mail やファックスでの申し込みは，原則として受け付けておりません．
　　　　　〒240-0067 横浜市保土ケ谷区常盤台79-2
　　　　　横浜国立大学教育人間科学部自然環境講座
　　　　　TEL 045-339-3349（直通）　FAX 045-339-3264（学部事務室）
　　　　　E-mail majima@edhs.ynu.ac.jp
　　　　　間嶋隆一（行事係）
　お問い合せは，行事係か下記の行事幹事までお寄せ下さい．
　　　　　〒250-0031 小田原市入生田499
　　　　　神奈川県立生命の星・地球博物館
　　　　　TEL 0465-21-1515　FAX 0465-23-8846
　　　　　E-mail taru@pat-net.ne.jp
　　　　　樽　創（行事幹事）

Paleontological Research

Vol. 4, No. 4   December 30, 2000

CONTENTS