Early Anisian (Aegean) ammonoids from the Fukkoshi Formation (Inai Group) with special reference to the Olenekian/Anisian boundary in the South Kitakami Belt, Northeast Japan

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Masayuki Ehiro

The Tohoku University Museum, Sendai 980-8578, Japan

Abstract: The Triassic Fukkoshi Formation is integral to clarifying the Olenekian/Anisian boundary in the South Kitakami Belt, Northeast Japan, because it overlies conformably the Olenekian Osawa Formation and one hand is covered by the Anisian Isatomae Formation. The middle and upper parts of the Fukkoshi Formation distributed in the Kamiwarizaki area yield abundant ammonoids consisting of over 30 species belonging to 21 genera, including one new genus *Psilokhvalynites* and four new species, *Parapopanoceras involutum*, *Psilokhvalynites takaizumii*, *Paracrochordiceras watanabei* and *Paradanubites ozashiense*. The Fukkoshi ammonoid fauna is dominated in the genera *Leiophyllites* (very abundant), *Paradanubites*, *Danubites* and *Paracrochordiceras*, and, in addition, characterized common occurrences of those belonging to the families Parapopanoceratidae, Japonitidae and Longobarditidae. Although it includes some Olenekian-type genera, such as *Hemilecanites*, *Pseudosageceras* and *Metadagnoceras*, the majority of the fauna are early Anisian (Aegean) genera and species. Therefore, the fauna is early Anisian in age, and the Olenekian/Anisian boundary is considered to locate somewhere in the lower part of the Fukkoshi Formation. The generic composition of the Fukkoshi Aegean ammonoid fauna has similarities with those of some localities located in the low-latitude regions of the Tethys and Panthalassa, especially with that of Qinghai, west China.

Introduction

The Triassic Fukkoshi Formation is the third formation of the Lower–Middle Triassic Inai Group in the South Kitakami Belt, Northeast Japan, which is distributed widely in the southern part of the Kitakami Massif (Figure 1). The group is composed of a continuous, fossiliferous, shallow marine (partly alluvial to nearshore marine) clastic sediments, and therefore, one of the most important reference sequences of the Lower–Middle Triassic of Japan. It consists of the Hiraiso, Osawa, Fukkoshi and Isatomae formations, in ascending order (Onuki and Bando, 1959: Figure 2). The Osawa and Isatomae formations are rich in ammonoids, and many late Olenekian and Anisian–(Ladinian) ammonoids, respectively, have been known. The Fukkoshi Formation locates stratigraphically between them and, therefore, is important to elucidate the stratigraphic position of the Olenekian/Anisian boundary (OAB) in the South Kitakami Belt. The Fukkoshi Formation is, however, almost baren of ammonoid, since it is dominated in sandstone. Very few ammonoids have been described or reported from the Fukkoshi Formation until now, but it still remains doubtful about the stratigraphic position and taxonomy of these specimens, as discussed below.

Recently, new ammonoid localities of the Fukkoshi Formation were found in the Kamiwarizaki area, the border area of the north-side Minamisanriku Town and south-side Kitakami-cho of Ishinomaki City, Miyagi Prefecture. The ammonoid fauna is rather diverse and were collected definitely from some horizons belong to the middle to upper part of the formation. This paper describes these ammonoids and discusses its biostratigraphical and biogeographical significances.

Stratigraphy of the Fukkoshi Formation and its biostratigraphic problems

The Fukkoshi Formation, 200 to 300 meters in total thickness, consists mostly of sandstone and alternating beds of sandstone and mudstone, with minor amount of

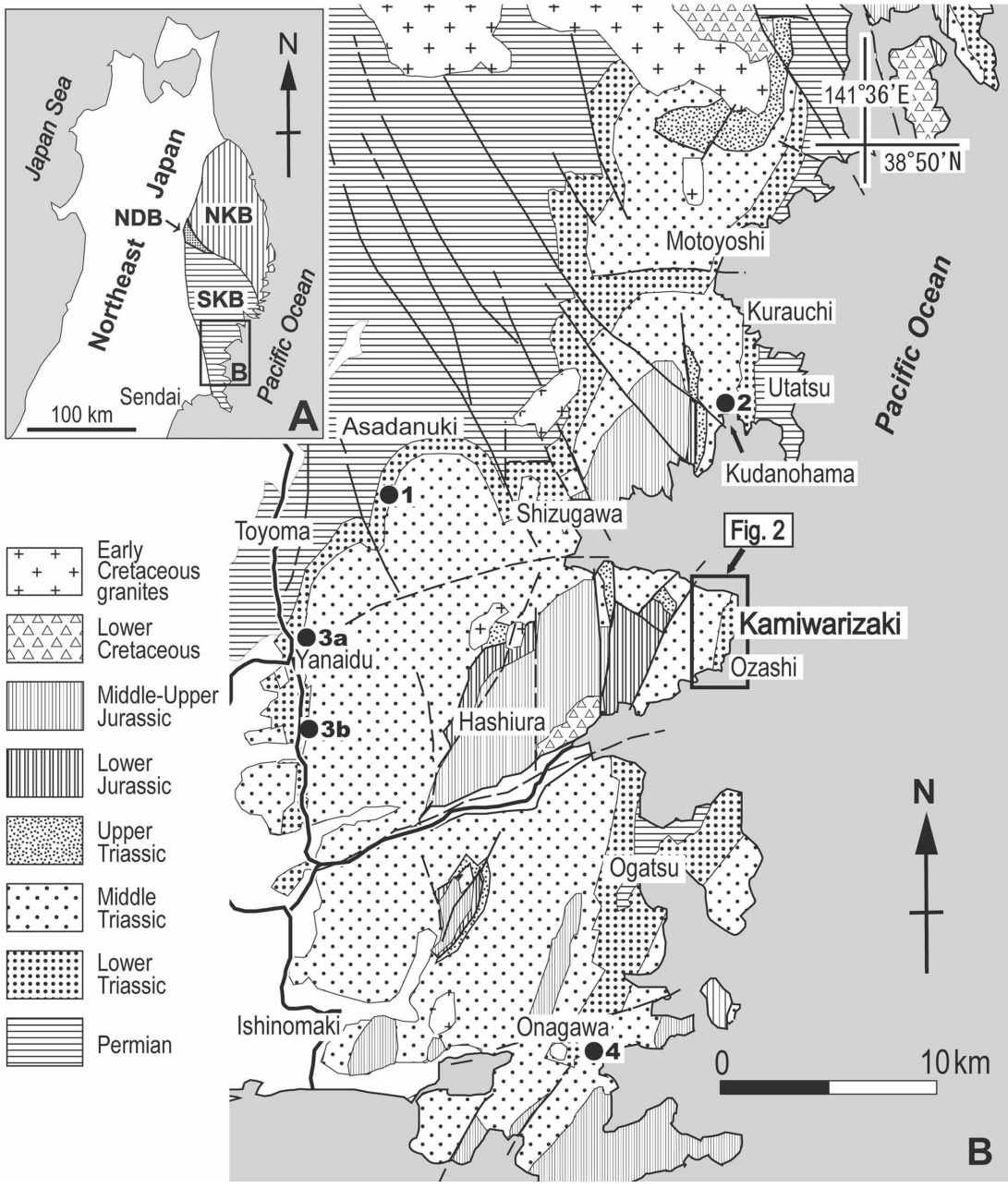

Figure 1. Index map (A) and simplified geologic map of the Southern Kitakami Massif (South Kitakami Belt), Northeast Japan, showing the distribution of the Lower-Middle Triassic Inai Group and study area (Fig. 2) (B). Longitude and latitude are from the International Terrestrial Reference Frame. Thick solid and broken lines are faults. NDB: Nedamo Belt, NKB: North Kitakami Belt, SKB: South Kitakami Belt. Localities 1–4 are related ammonoid localities: see text.

mudstone. It overlies conformably the Osawa Formation, and in turn is covered conformably by the Isatomae Formation.

The Osawa Formation is dominated in laminated mudstone (250 to 350 m thick), and yields rich ammonoids. Twenty-seven ammonoid genera have been described from the formation (e.g. Bando and Shimoyama, 1974; Ehiro et al., 2016; Ehiro, 2022 in press). The lower to middle part of the formation, the *Subcolumbites* Zone of Bando and Shimoyama (1974), yields *Columbites parisianus* Hyatt

and Smith and *Subcolumbites perrinismithi* (Arthaber), associated with such genera as *Hemilecanites*, *Albanites*, *Pseudosageceras*, *Tardicolumbites*, *Yvesgalleticeras*, *Hellenites*, *Metadagnoceras*, *Procarnites*, *Olenekoceras*, *Nordophiceratoides*, etc. The lower part of the upper part, the *Arnautoceltites* Zone of Bando and Shimoyama (1974), contains *Arnautoceltites*, *Nordophiceras*, *Prenkites*, etc. These two zones are correlated with the upper Olenekian (Bando and Shimoyama, 1974; Ehiro et al., 2016). Ehiro (2022 in press) proposed a new ammonoid zone, the *Eodanubites* Zone, in the uppermost part of the formation, based on the section at the south of Asadanuki (Loc. 1 in Figure 1). It consists of Olenekian genera *Eodanubites*, *Pseudosageceras*, *Ceccaisculitoides* and *Procarnites*, associated with *Japonites* and *Procladiscites*. The latter two genera are common in the Anisian, but already appeared in the latest Olenekian strata, and therefore, the *Eodanubites* Zone is correlated with the uppermost Olenekian (Ehiro, 2022 in press).

Recently, Shigeta (2022 in press) re-examined some ammonoid species reported from the lower to middle part (*Subcolumbites* Zone) of the Osawa Formation by Bando and Shimoyama (1974), and concluded that *Columbites parisianus*, *Subcolumbites perrinismithi* and *Eophyllites* cf. *dieneri*, collected from the Motoyoshi area, should be attributed to *Hellenites tchernyschewiensis* Zakharov, *H. inopinatus* Kiparisova, *Neocolumbites grammi* Zakharov, *N. insignis* Zakharov, *Procolumbites ussuriensis* (Zakharov) and *P. subquadratus* Zakharov. Even in such case, this fauna is compared with that of the *N. insignis* Zone of South Primorye, Russian Far East, and correlated to the upper Olenekian (Spathian) as a conventional one.

The Fukkoshi Formation is composed of thick sandstone and alternating beds of sandstone and mudstone, with total thickness of 200–300 m. According to Kamada (1984) these sandstones of the Fukkoshi Formation were deposited as a submarine fan complex. Because of its sandstone dominated facies, the Fukkoshi Formation is almost baren of ammonoids. Only some Anisian species, *Gymnites* cf. *watanabei* (Mojsisovics), *Hollandites* sp. and *Balatonites* cf. *kitakamicus* (Diener), reported by Shimizu (1930), were designated to come from the middle part of the Fukkoshi Formation (Onuki and Bando, 1959). However, there are some doubts about the stratigraphic position and locality of these ammonoids (Ishibashi, 2006) and reexamination is needed. The locality of Shimizu (1930)'s ammonoids was positioned by Onuki and Bando (1959) to the east of Yanaizu (Loc. 3a in Figure 1), where the Fukkoshi Formation is distributed. But, according to the attached label of *Balatonites* cf. *kitakamicus* specimen (IGPS coll. cat. no. 36530) by Shimizu (1930), the locality is "Road side near the southern end of Yanaizu Town". The southern end of Yanaizu Town in 1930 is located about 4 km to the south of Yanaizu (Fig. 1, loc. 3b), not to the east, and therefore exact stratigraphic horizon of these ammonoids is unknown.

On the other hand, ammonoid specimens, *Danubites* aff. *ambica* Diener, *Danubites* sp., *Leiophyllites* cf. *pitamaha* (Diener) and *L.* aff. *pradyumna* (Diener), described from a locality at Konori (Konori-hama), Onagawa Town (Bando, 1970; Loc. 4 in Figure 1), which are considered to come from the Osawa Formation, may actually belong to the Fukkoshi Formation. Bando (1970) stated that these ammonoids were collected from the alternating beds of the uppermost part of the Osawa Formation, but these alternating beds may lithologically belong to the Fukkoshi Formation. In fact, Working Group on the Permian-Triassic Systems (1975, p. 172), the members of which include Y. Bando, regarded the horizon of these ammonoids as the Fukkoshi Formation. The outcrop at Konori, however, was lost when the reconstruction work of "2011 off the Pacific coast of Tohoku Earthquake" was extended, and the effective re-examination is impossible.

Thus, the reliability of the ammonoid stratigraphy, considered to come from the Fukkoshi Formation until now, is insufficient.

The Isatomae Formation is more than 1,000 m thick and consists of sandy laminated mudstone, often with thick sandstones or alternating beds of sandstone and mudstone. Many Anisian ammonoids have been described from the formation by Mojsisovics (1888), Diener (1916a), Shimizu (1930) and others. The fauna comprises such genera as *Hollandites*, *Danubites*, *Gymnites*, *Japonites*, *Sturia*, *Balatonites*, *Ussurites*, *Leiophyllites*, etc. These ammonoids are mostly from the middle part of the formation and those from the lower part are rare. Ishibashi (2006) reported, although not yet described, some species collected from the basal part of the formation at Kudanohama in Utatsu area (Loc. 2 in Figure 1). He set two ammonoid zones in the basal part: the *Grambergia kitakamiensis* Zone below and the *Lenotropites isatomaensis–Leiophyllites* cf. *pseudopradyumna* Zone above. The former zone yields *Grambergia kitakamiensis* Ishibashi (MS), *Grambergia* sp., *Tropigastrites* cf. *lahontanus* Smith and *Ussurites* sp. The latter consists of *Lenotoropites isatomaensis* Ishibashi (MS), *Leiophyllites pseudopradyumna* (Welter) and *Paracrochordicera*s sp. These Kudanohama ammonoid zones probably corresponds to the *Lenotropites–Japonites* Zone (Aegean: lowermost Anisian) of Qinghai, China (He et al., 1986), *Japonites welteri* beds to *Lenotropites caurus* Zone (lower Anisian) of Nevada (Bucher, 1989), *Paracrochordiceras–Japonites* beds (Aegean) of Deşli Caira Hill, Romania (Grădinaru et al., 2007) and Chios (Assereto, 1974; Fantini Sestini, 1981).

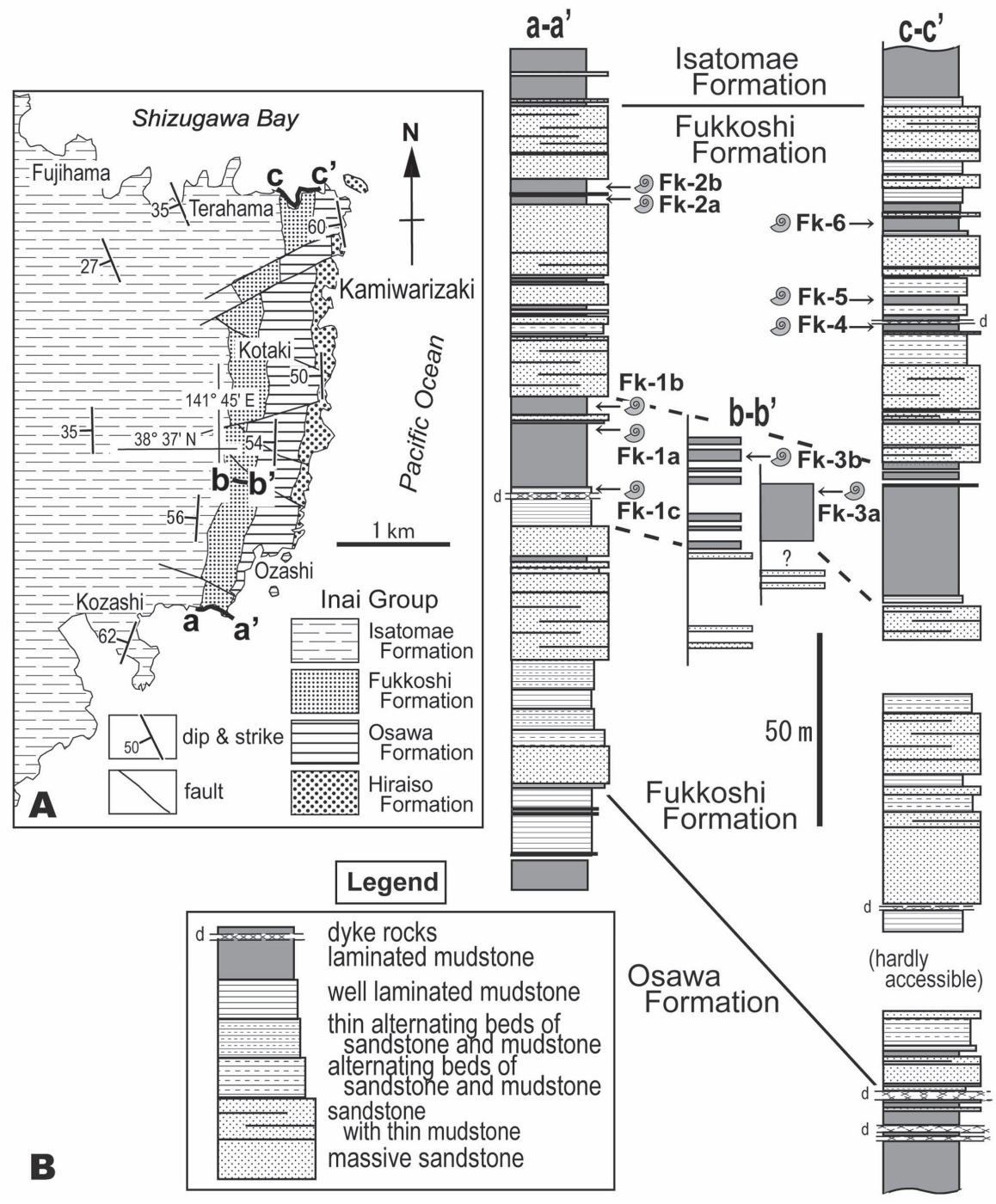

Figure 2. Geologic map of the Kamiwarizaki area (simplified from Kamada and Takizawa, 1992) (A) and columnar sections of the Fukkoshi Formation showing the ammonoid horizons (Fk-1–Fk-6) (B). Routes of the columnar sections (a–a', b–b' and c–c') are shown in figure A.

Materials and the stratigraphy of the new ammonoid localities

Ammonoids specimens described here were collected from the middle to upper part of the Fukkoshi Formation distributed in the Kamiwarizaki area (Figure 1). In this area, strata of the Inai Group, from the middle part of the Hiraiso Formation to the lower part of the Isatomae Formation, distribute parallel to the eastern coast of Kamiwarizaki (Figure 2A), striking nearly N-S and dipping 45˚-70˚ westerly.

Nearly continuous sections of the Fukkoshi Formation crop out along the southern and northern coasts, but the outcrops are rather rare and imperfect in the inland area. Along the southern coast (a-a' section in Figure 2B), the basal part of the Fukkoshi Formation, consisting of the alternating beds of sandstone and mudstone, conformably covers the laminated mudstone of the underlying Osawa Formation. The lower part of the formation (about 65 m thick) is dominated in massive sandstone and sandstone dominated alternating beds of sandstone and mudstone, but intercalating with thin alternating beds or mudstone dominated alternating beds of sandstone and mudstone (about 22 m) in the lower part. The middle part (about 34 m) is composed of laminated or poorly laminated mudstones, intercalating with thin sandstone beds (ca. 1.5 m thick, consisting of alternating beds of sandstone and mudstone, and sandstone) in the uppermost part (from ca. 4.5 m to 3 m below the top). Ammonoid horizons Fk-1a, Fk-1b and Fk-1c are in this mudstone beds (located at 38°36′18″N, 141°30′59″E). Horizon Fk-1c is situated about 7-8 m above the base of the mudstone. Fk-1a and Fk-1b are in the uppermost part of the mudstone beds and separated by the above-mentioned sandstone beds. Fk-1a has an interval (1.5 m thick) from ca. 2 m to 0.5 m below the intercalating sandstones, and Fk-1b has ca. 2 m interval immediately above the sandstone (Figure 2B). The upper part of the formation is about 75 m in thickness and dominated in sandstone. Thin (usually less than 3 m) mudstone beds are often intercalated in the lower part, and about 7 m mudstone dominated part are in the upper part. The last mudstone beds are separated into the lower and upper parts by thin sandstone. The ammonoid horizon Fk-2a and Fk-2b (located at 38°36′19″N, 141°30′56″E) are situated in the lower and upper parts of this mudstone beds, respectively (Figure 2B).

Along the old forest road (b-b' section in Figure 2B) to the northwest of Ozashi, rather thick mudstone beds (20 m+ thick) are sporadically cropped out, dipping steeply to the west. This mudstone beds are situated above the sporadically distributed sandstone beds and are correlated with the mudstone dominated part (middle part) of the a-a' section. From the upper part of this beds, two ammonoids were collected (Horizon Fk-3a and 3b: 38°36′53″N, 141°31′8″E).

Nearly continuous section of the Fukkoshi Formation can also be observed along the northern coast, east of Terahama (c-c' section in Figure 2B). Although some parts are missing or hardly accessible, the total thickness of the formation is estimated to be about 240 m, which is slightly thicker than that along the southern coast. In this section, the lower (about 110 m) and upper (ca. 90 m) parts of the Fukkoshi Formation are composed mainly of sandstone and alternating beds of sandstone and mudstone, with minor amount of mudstone intercalations. The middle part (ca. 35 m thick) consists of laminated mudstone. This mudstone dominated part is stratigraphically correlated with the middle mudstone dominated part along the southern coast, although no ammonoid fossil has been collected here. Some mudstone intercalations in the upper part yield ammonoids: Fk-4 and Fk-5 (38°38′9″N, 141°31′26″E), and Fk-6 (38°38′10″N, 141°31′25″E) (Figure 2B). Fk-4 yields only one poorly preserved, undeterminable specimen, so it will not be covered here.

The precise correlation of thin mudstone intercalations in the upper part of the formation between those distribute along the southern and northern coasts is difficult, because of lateral facies change and thickness change of each bed. But, considering their relative stratigraphic positions, the horizon Fk-2a and Fk-2b seem to be roughly correlated with Fk-6.

Ammonoid specimens studied in this paper were buried in mudstone beds with their plane of symmetry lying mostly parallel to the bedding plane. Many specimens are preserved only their lower half due to probably the synsedimentary erosion. Some specimens having extremely narrow shell, such as ones belong to the genera *Pseudosageceras*, *Psilokhvalynites*, *Arctohungarites* and *Leiophyllites*, sometimes hold both sides of the shell, but it is difficult to measure their exact shell width, because they had suffered from severe tectonic flattening. Thin film-like pyrite crystals are sometimes formed on the outer or inner shell surfaces.

Systematic description

The specimens described here are all kept in the Tohoku University Museum (Institution abbreviation: IGPS = Institute of Geology and Paleontology, Tohoku University, Sendai). Systematic descriptions basically follow the classification established by Tozer (1981, 1994) and terminology of conch shape (umbilical width) follows Korn (2010). The following abbreviations are used in the descriptions: *D* = diameter of whorl, *H* = height of whorl, *W* = width of whorl, *UD* = diameter of umbilicus.

Order Ceratitida Hyatt, 1884
Superfamily Xenodiscoidea Frech, 1902
Family Hemilecanitidae Guex et al., 2010
Genus ***Hemilecanites*** Spath, 1934

Type species.—*Lecanites discus* Arthaber, 1908.

Hemilecanites discus (Arthaber, 1908)
Figures 3.1, 3.2

Lecanites discus Arthaber, 1908, p. 268, pl. 11, figs. 5a–c; Renz and Renz, 1948, p. 55.
Hemilecanites discus (Arthaber), Spath, 1934, p. 135, pl. 13, figs. 7a–7d; Kummel in Arkell et al., 1957, p. L136, fig. 169-3; Chao, 1959, p. 41, pl. 3, figs. 1, 2; Kummel, 1969, p. 374, pl. 25, figs. 9, 10, text-fig. 4-E; Ehiro et al., 2016, p. 93, figs. 2.1–2.3.

Material examined.—Two specimens, IGPS coll. cat. nos. 112546 and 112547.

Descriptive remarks.—The conch is evolute and compressed, with lenticular cross section. They attain more than 23 (no. 112547) and 27 mm (no. 112546) in maximum diameter, but the last volution of each conch is not well preserved. It consists of phragmocone and living chamber, the latter occupies about one volution. In specimen no. 112547, at a diameter of ca. 20 mm, the corresponding height and umbilical diameter are ca. 6.0 and 8.8 mm (*UD*/*D* = 0.44), respectively. In specimen no. 112546, the height and umbilical diameter at *D* = ca. 27 mm are ca. 7.5 and 13.3 mm (*UD*/*D* = 0.49), respectively.

The flanks are broadly convex to nearly flat, with broadly rounded umbilical and ventral shoulders. The maximum width is at about the center of the flank. The venter is not well preserved. The umbilicus is shallow. The shell surface seems to be smooth. The external lateral suture is partly preserved. It is goniatitic and consists of three rounded saddles and three probably rounded lobes. Sides of lobes are nearly parallel. The saddles and lobes diminish in size slightly towards the umbilicus.

Although the sutural trace differs slightly from that of the type specimen of *Hemilecanites discus* (*Lecanites discus* Arthaber, 1908), the general shell shape and dimensions of the present specimens are similar to those of the type specimen from the late Olenekian of Albania (Arthaber, 1908, p. 268, pl. 11, figs. 5a–c). The species of the genus *Hemilecanites* have mostly been known from the late Olenekian strata, but *H*. cf. *paradiscus* Kummel were described from the Lower Anisian *Japonites welteri* beds, NW. Nevada (Bucher, 1989, p. 961, pl.6, figs. 7-8, text fig. 3).

Occurrence.—Both specimens are from the middle part (Fk-1b) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Superfamily Sageceratoidea Hyatt, 1884
Family Sageceratidae Hyatt 1884
Genus ***Parasageceras*** Welter, 1915

Type species.—*Parasageceras discoidale* Welter, 1915.

Parasageceras aff. ***discoidale*** Welter
Figures 3.3, 3.4

aff. *Parasagecers discoidale* Welter, 1915, p. 113, pl. 89, fig. 4; Kutassy, 1932, p. 608; Spath, 1934, p. 62, text-figs. 9a–9c.
Parasagecers aff. *discoidale* Welter, Spath, 1934, p. 62.

Material examined.—Two specimens, IGPS coll. cat. nos. 112548 and 112549.

Description.—The specimen no. 112548 consists largely of a phragmocone with a part of body chamber. The conch diameter attains about 25 mm in the obliquely deformed state. The umbilicus is not well preserved, but very small. Another specimen (no. 112549) is composed of phragmocone and body chamber, the latter of which occupies about three-fourth of the last whorl. It attains a diameter of ca. 21.5 mm, and corresponding height and umbilical diameter are 12.2 and 2.2 mm (*UD*/*D* = 0.10), respectively. The sides of both specimens are nearly flat, with broadly rounded umbilical shoulder and acute ventral shoulder. The venter seems to be flat. Faint, slightly sigmoidal fine ribs, projected and most distinct near the ventral shoulder, are on the sides.

The ventral lobe is shallow and divided into two, simple, pointed prongs by a low, rounded, median saddle. The first lateral lobe is widest and has four irregular denticulations at the base. A denticulation situated on the ventral side is most remarkable. The second to sixth lateral lobes are bifid, and the followings (more than three, probably eight or more) have rounded base. The second lobe has nearly the same width as the first, but slightly small and shallow. The second lateral saddle is as large as the first and highest. The other saddles and lobes diminish in size toward the umbilicus. Almost lateral saddles have rounded crest, except for the sixth, which is slightly wider than the surrounding ones and divided into two parts by a shallow depression.

Comparison.—The shell shape and surface ornamentation of the present species are similar to those of *Parasagecers discoidale* Welter, 1915 from the Anisian of Timor. But the present species differs from the Timor species in having more flexosus ribs, and in having complex first lateral lobe.

Occurrence.—Middle part (Fk-1a: no. 112548 and Fk-

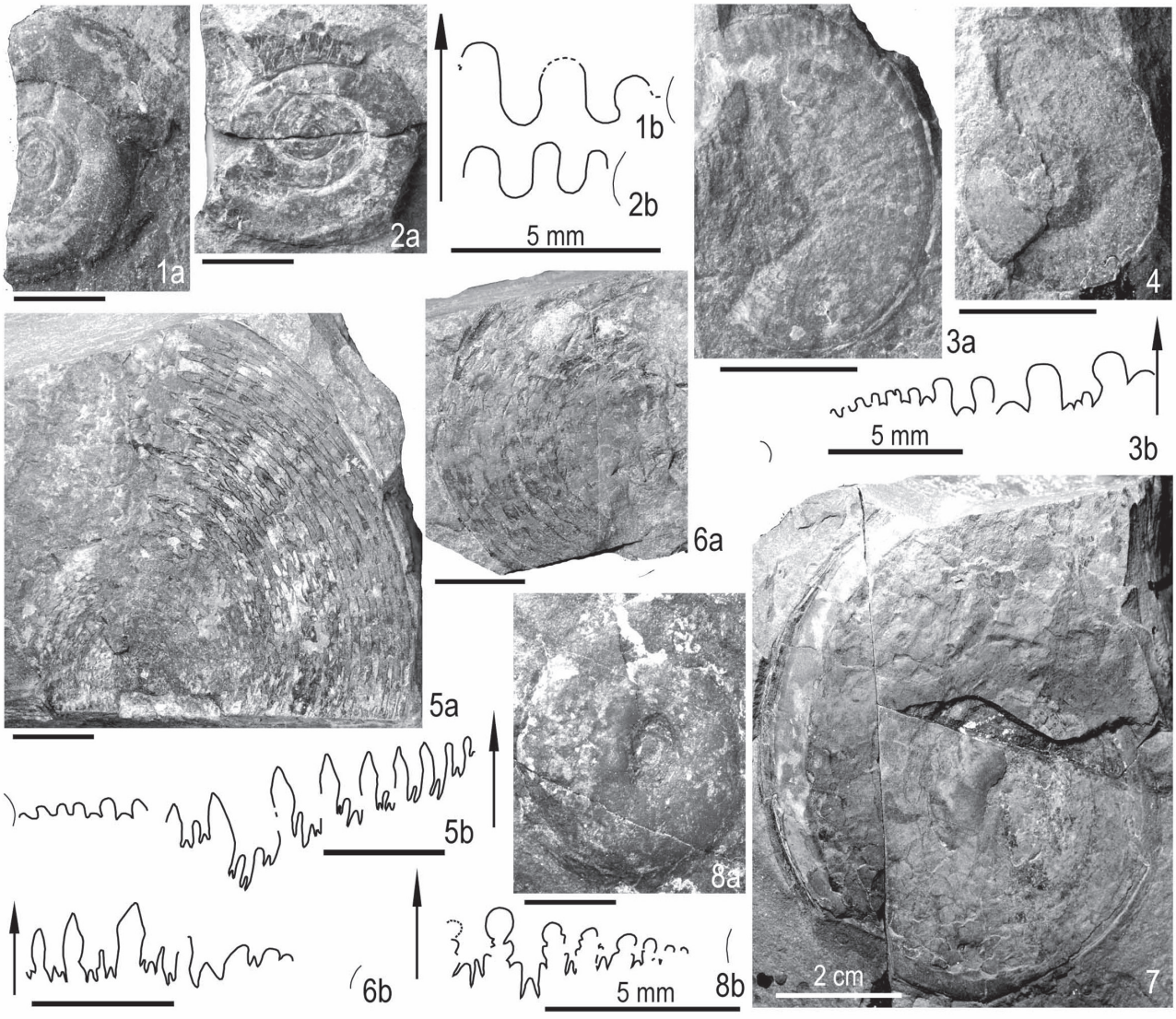

Figure 3. *Hemilecanites*, *Parasageceras*, *Pseudosageceras* and *Megaphyllites* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1 and **2**, *Hemilecanites discus* (Arthaber); 1, IGPS coll. cat. no. 112546; 1a, lateral view; 1b, suture line; 2, IGPS coll. cat. no. 112547; 2a, lateral view; 2b, suture line; **3** and **4**, *Parasageceras* aff. *discoidale* Welter; 3, IGPS coll. cat. no. 112548; 3a, lateral view; 3b, suture line; 4, IGPS coll. cat. no. 112549, lateral view; **5**–**7**, *Pseudosageceras multilobatum* Noetling; 5, IGPS coll. cat. no. 112550; 5a, lateral view; 5b, suture line; 6, IGPS coll. cat. no. 112551; 6a, lateral view; 6b, suture line; 7, IGPS coll. cat. no. 112552, lateral view; 8, *Megaphyllites* sp., IGPS coll. cat. no. 112664; 8a, lateral view; 8b, suture line. Scale bars are 1 cm unless otherwise stated.

1b: no. 112549) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Family Hedenstroemiidae Waagen, 1895
Genus ***Pseudosageceras*** Diener, 1895a

Type species.— *Pseudosageceras* sp., Diener, 1895a.

Pseudosageceras multilobatum Noetling
Figures 3.5–3.7

Pseudosageceras sp., Diener, 1895 a, p. 28, pl. 1, fig. 8.

Pseudosageceras multilobatum Noetling, 1905a, p. 181, pls. 19–27; Noetling, 1905b, pl. 23, fig. 4, pl. 25, fig. 1, pl. 26, fig. 3; Arthaber, 1908, p. 279, pl. 12, fig. 3; Krafft and Diener, 1909, p. 145, pl. 21, fig. 5; Wanner, 1911, p. 181, pl. 7, fig. 4; Welter, 1922, p. 94, text-fig. 3; Diener, 1925, p. 96, fig. 26 ; Smith, 1932, p. 87, pl. 4, figs. 1–3, pl. 5, figs. 1–6, pl. 25, figs. 7–16, pl. 60, fig. 32, pl. 63, figs. 1–6; Collignon, 1933, p. 56, pl. 11, fig 2; Spath, 1934, p. 54, text-fig. 6a; Kiparisova, 1947, p. 127, pl. 25, figs. 3–4; Chao, 1959, p. 31, 183, pl. 1, figs., 9, 12; Jeannet, 1959, p. 30, pl. 6, fig. 1; Tozer, 1961, p. 44, pl. 13, figs. 8, 9; Chao et al., 1965, p. 135, pl. 35, fig. 5; Kummel, 1966, p. 388, pl. 1, figs. 11, 12; Hada, 1966, pl. 4, fig. 6; Kummel and Erben, 1968, p. 112, pl. 19, fig. 9; Shevyrev, 1968, p. 79, pl. 1, figs. 1, 2; Kummel, 1969, p. 361, pl. 34, fig. 6, text-fig. 2; Collignon, 1973, p. 5, pl. 1, fig. 1; Weitschat and Lehmann, 1978, p. 75, pl. 10, fig. 2; Vu Khuc, 1984, p. 26, pl. 1, fig. 1, text-fig. 1; Pakistani-Japanese Research Group, 1985, pl. 12, figs. 5–7, pl. 14, fig. 3; Vu Khuc, 1991, p. 119, pl. 45, figs. 5, 6, text-fig. 2.2; Tozer, 1994, p. 83, pl. 18, fig. 1, text-fig. 17; Brayard and Bucher, 2008, p. 70, pl. 37, figs. 1–5, text-fig. 61; Shigeta and Zakharov, in Shigeta et al., 2009, p. 140, figs. 129, 130; Brühwiler et al., 2010, p. 429, fig. 16.14; Brühwiler and Bucher in Brühwiler et al., 2012a, p. 47, pl. 26, fig. 4; Brühwiler and Bucher, in Brühwiler et al., 2012b, p. 109, figs. 95A–95N; Brayard et al., 2013, p. 208, figs. 77a–77f; Shigeta and Nguyen, in Shigeta et al., 2014, p. 137, figs. 98, 99; Ehiro, 2016, p. 2, fig. 2.1; Ehiro, 2022 in press, figs. 5.2, 5.3.

Pseudosageceras intermontanum Hyatt and Smith, 1905, p. 99, pl. 4, figs. 1–3, pl. 5, figs. 1–6, pl. 63, figs. 1, 2.; Mathews, 1929, p. 3, pl. 1, figs. 18–22; Renz and Renz, 1948, p. 90, pl. 16, figs. 4, 7.

Pseudosageceras drinense Arthaber, 1911, p. 201, pl. 17, figs. 6, 7; Spath, 1934, p. 55, text-fig. 6c; Renz and Renz, 1948, p. 92, pl. 16, fig. 6.

Pseudosageceras clavisellatum Diener, 1913, p. 28, pl. 4, figs. 5, 6.

Pseudosageceras paomochungenense Tien, 1933, p. 24, pl. 3, fig. 7; Chao et al., 1965, p. 137, pl. 35, figs. 12, 13.

Pseudosageceras cf. *clavisellatum* Diener, Renz and Renz, 1948, p. 90, pl. 16, fig. 3.

Pseudosageceras longilobatum Kiparisova, in Kiparisova and Krishtofovich, 1954, p. 20, pl. 11, fig. 3; Kiparisova, 1961, p. 29, pl. 6, fig. 1, 2, text-fig. 2; Popov, 1961, p. 12, pl. 10, fig. 1, text-fig. 2.

Pseudosageceras cf. *longilobatum* Kiparisova, 1961, p. 30, pl. 5, fig. 3, text-fig. 3.

Pseudosageceras longilobatum var. *kwangsiense* Chao, 1959, p. 32, 186, pl. 1, figs. 5, 6, pl. 8, figs. 10, 11, text-fig. 5c; Chao et al., 1965, p. 136, pl. 35, figs. 14–16.

Pseudosageceras tsotengense Chao, 1959, p. 32, 184, pl. 1, figs. 7, 8, text-fig. 5b; Chao et al., 1965, p. 136, pl. 35, figs. 9–11.

Pseudosageceras schamarense Kiparisova, 1961, p. 31, pl. 7, figs. 3a, 3b.

Material examined.—Three specimens, IGPS coll. cat. nos. 112550–112552.

Description.—Three specimens, strongly compressed and involute with almost closed umbilicus, are at hand. The specimen no. 112552 is about 80 mm in diameter and consists of phragmocone and body chamber, the latter occupies about three-fourth of the last whorl. The diameter of the fragmental specimens nos. 112550 and 112551, both consists of phragmocone, exceed 60 and 40 mm, respectively. The sides are almost flat except for the slightly depressed umbilical margin. The venter is not well preserved, but estimated to be acutely rounded. The shell surface appears to be smooth. The suture is ceratitic with numerous adventitious elements. The lateral lobes are essentially bifid, but some of which are again bifid or, rarely, trifid.

Discussion.—Although the present specimens of *Pseudosageceras* are not so well preserved, their general shell morphologies and especially the shape of the suture lines allow to identify it with *Pseudosageceras multilobatum* Noetling.

Occurrence.—Middle part (Fk-1a: no. 112551; Fk-1b: nos. 112550 and 112552) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Superfamily Megaphyllitoidea Mojsisovics, 1896
Family Parapopanoceratidae Tozer, 1971
Genus ***Parapopanoceras*** Haug, 1894

Type species.— *Popanoceras verneuili* Mojsisovics, 1886.

Remarks.—When Popov (1961) proposed a new genus *Stenopopanoceras*, the fundamental difference between the genera *Parapopanoceras* and *Stenopopanoceras* is in the shell shape. However, Dagys and Ermakova (1981) clarified that the shell shape of the genus *Parapopanoceras* is variable not only between species but also in the steps of ontogeny, and shell shape in some of them is similar to that of *Stenopopanoceras*. They considered, instead, that the distinctive feature of the genus *Parapopanoceras* is in the suture line: the species of the genus *Parapopanoceras* have at least four external lateral lobes, which are serrated not only the bases but also their sides, even in their early ontogenetic stage.

Parapopanoceras involutum sp. nov.

Figures 4.1–4.7

Material examined.—Eight specimens, IGPS coll. cat. nos. 112553 (holotype) and 112554–112560 (paratypes).

Etymology.—The species name is from its involute shell form.

Diagnosis.—*Parapopanoceras* having very small umbilicus (*UD*/*D* < 0.11) even in the large specimen (*D* up to 120 mm). The number of lateral lobes, which are strongly denticulate, is four in all ontogenetic stages (*D* from 20 to 120 mm).

Description.—The specimen no. 112554 is a small fragment of the ventral part of the phragmocone. The width of it reaches at least 20 mm. The venter is broadly rounded, but its broadness may partly be caused by the tectonic flattening. The ventral shoulder is rounded. The specimen no. 112557 is a small fragmental phragmocone, and about a half of a volution is preserved. The shell diameter is ca. 20 mm with a small umbilicus, the ratio of *UD*/*D* is estimated to be 0.21-0.25. The flank is broadly convex and continues smoothly with broadly rounded venter. The umbilical shoulder is rounded. Other specimens, including the holotype (no. 112553), consist of phragmocone and body chamber, the latter of which occupies about two-thirds of a volution. The maximum preserved shell diameter ranges from ca. 48 to 124 mm, and the ratios of *H*/*D* and *UD*/*D* at the last whorls range 0.42-0.54 and 0.07-0.11 (mostly 0.10-0.11), respectively. Although the umbilical edge of the body chamber of the largest specimen (no. 112558) is broken off and precise ratio of *UD*/*D* is unknown, the adoral end of the phragmocone is well preserved and the ratio of *UD*/*D* there (*D* = ca. 120 mm) is ca. 0.10. The side is convex with rounded umbilical and ventral shoulders. The maximum shell width is near the center of the flank. In two specimens (holotype and no. 112559), there are faint, slightly sigmoidal growth lines on the shell surface, but the shell surfaces of the rest seem to be smooth.

The ventral lobe is divided into two prongs by a low and narrow median saddle, and the base to lower one-third of the sides of the prong is denticulate. The median saddle is about a half height to the ventrolateral saddles. The first lateral love has nearly the same width and depth as the ventral lobe. There are four lateral lobes in all specimens. All lobes are strongly denticulate in their base to lower one-third of their sides. The first lobe is the largest and they diminish in size toward the umbilicus. There are some auxiliary lobes, except for the smallest specimen, at the umbilical margin. The crests of lateral saddles are all rounded, and the saddles also gradually diminish in size towards the umbilicus.

Discussion.—Based on the general shell shape, having rounded venter and small umbilicus, and the trace of external suture lines, the present specimens are considered to belong to the genus *Parapopanoceras* Haug, 1894. The present species differs from the known species of the genus in having small ratio of *UD*/*D* (0.10 to 0.11) even in the large specimens (*D* = ca. 50 to 120 mm). Small specimens (*D* < 40 mm) of *P. plicatum* Bytschkov have rather small umbilicus (*UD*/*D* = 0.12–0.16), but larger specimens of the species (*D* > 40 mm) have rather large umbilicus (*UD*/*D* = 0.15–0.34) (Bytschkov in Bytschkov et al., 1976, p. 138, pl. 23, figs. 2–4, text-fig. 13; Dagys and Ermakova, 1981, p. 61, pl. 11, figs. 1–7, text-figs. 38–41).

Occurrence.—Middle part of the Fukkoshi Formation at the south of Ozashi (Fk-1c: nos. 112558, 112560; Fk-1a: nos. 112554, 112557; Fk-1b: nos. 112553, 112556, 112559) and at the northwest of Ozashi (Fk-3b: no. 112555) , Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Family Megaphyllitidae Mojsisovics, 1896
Genus ***Megaphyllites*** Mojsisovics, 1879

Type species.—*Ceratites Jarbas* Münster, 1841.

Megaphyllites sp.
Figures 3.8a, b

Material examined.—One specimen, IGPS coll. cat. no. 112664.

Descriptive remarks.—A small, discoidal and involute to sub-involute specimen is examined. It consists of the phragmocone and body chamber, the latter attains about one-thirds of the preserved last whorl. The shell diameter attains 30.4 mm in the elliptically deformed state, and its corresponding height and umbilical diameter are 7.2 and ca. 5.0 mm (*UD*/*D* = 0.16), respectively. The umbilical margin is somewhat indistinct. The side of the phragmocone is broadly convex and the maximum width is at about the center of the side, whereas the side of the body chamber is nearly flat. The ventral shoulder is rounded. The small umbilicus is rather deep and funnel-shaped. The shell surface is smooth without any ornamentation and constriction. The external suture line is imperfectly preserved, but typical for the genus *Megaphyllites*. There are at least seven saddles and six lobes. The crests of saddles are all rounded. The second saddle is highest and saddles gradually diminish in size towards the umbilicus. The deep first lateral lobe is denticulate not only at the base but also on the sides. The basal denticulations are strong. The second lobe is nearly equal in depth with the first and have the same denticulations, the basal two denticulation of which are very long. The third lobe has nearly the same outline as the second, but the depth is about two-thirds of the second. Following lobes gradually diminish in size towards the

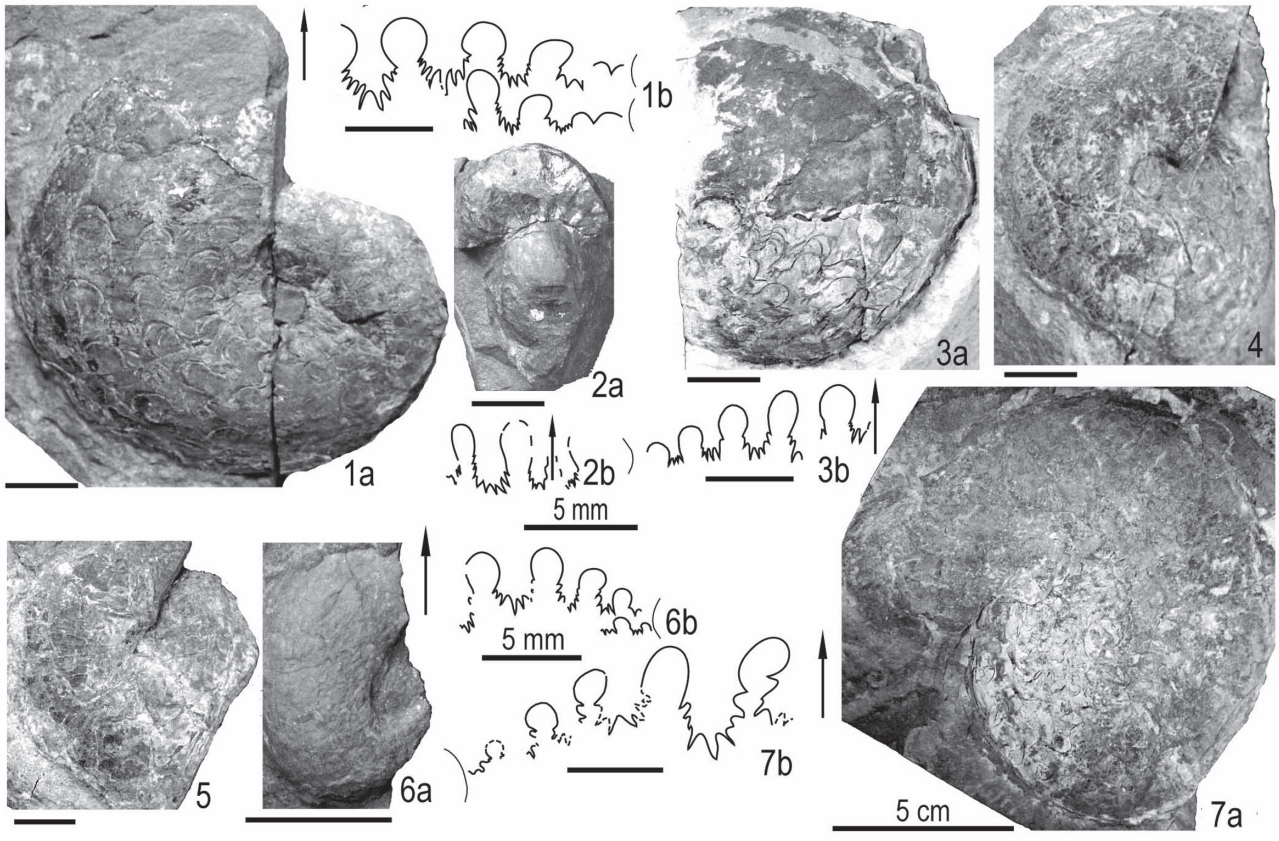

Figure 4. *Parapopanoceras involutum* sp. nov. from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1, IGPS coll. cat. no. 112553 (holotype); 1a, lateral view; 1b, suture line; **2**, IGPS coll. cat. no. 112554; 2a, ventral view; 2b, suture line; **3**, IGPS coll. cat. no. 112555; 3a, lateral view; 3b, suture line; **4**, IGPS coll. cat. no. 112556, lateral view; **5**, IGPS coll. cat. no. 112559, lateral view; **6**, IGPS coll. cat. no. 112557; 6a, lateral view; 6b, suture line; **7**, IGPS coll. cat. no. 112558; 7a, lateral view; 7b, suture line. Scale bars are 1 cm unless otherwise stated.

umbilicus.

The general shell shape of the present specimen, with broadly convex to flat sides and small but distinct umbilicus, is similar to those of *Megaphyllites compressus* Shevyrev from Caucasus (Shevyrev, 1995, p. 123, pl. 22, fig. 4, text-fig. 73), *Megaphyllites evolutus* Welter from Timor (Welter, 1915, p. 114, pl. 7, figs. 2a–2c) and from Qinghai (He et al., 1986, p. 207, pl. 17, figs. 5–7, text-fig. 14c), and *Megaphyllites tenuis* Chen in He et al. from Qinghai (He et al., 1986, p. 207, pl. 17, figs. 14–16, text-fig. 14d). But it is somewhat difficult to identify it at the specific level because of its small size and poor state of preservation.

Occurrence.—Middle part (Fk-1b) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Superfamily Dinaritoidea Mojsisovics, 1882

Family Khvalynitidae Shevyrev, 1968
Genus ***Metadagnoceras*** Tozer, 1965

Type species.—*Metadagnoceras pulchrum* Tozer, 1965.

Metadagnoceras sp. A
Figures 5.2a, b

Material examined.—One specimen, IGPS coll. cat. no. 112561.

Descriptive remarks.—A small specimen is discoidal and involute to sub-involute. The maximum shell diameter may exceed 40 mm, but exact diameter is unclear because its ventral part of the preserved end is missing. The umbilicus is small and the ratio of *UD*/*D* is estimated to be 0. 15 or so. The side is broadly convex to nearly flat with the maximum width at about the center of it. The umbilicus is shallow, but

the umbilical wall is steep with rounded umbilical shoulder. The venter seems to be convex to flat with sharp ventral shoulder. The shell surface looks like smooth, but fine sinuous ribs are preserved near the apertural end. The external suture consists of shallow ventral lobe, narrow first lateral saddle, very large and deep first lateral lobe, large and rounded second lateral saddle and auxiliaries near the umbilical margin. One of the prongs of the ventral lobe is visible and its base has irregular denticulations. The first lateral saddle is rounded, but its crest is incised. The first lateral lobe occupies the center of the side and is denticulate deeply at the base. The denticulations extend up to the ventral side to nearly the top of the first lateral saddle, whereas the umbilical side is almost smooth. The wide rounded second lateral saddle is asymmetric having long ventral side and short umbilical side. The auxiliaries are shallow and pointed.

The present specimen is rather small and not well preserved, so the specific identification is difficult. It somewhat resembles *Metadagnoceras pulchrum* Tozer, 1965 from the upper Olenekian (Spathian) of British Columbia in the general shell shape and outline of the suture, but the shape of the first lateral saddle is different; *M. pulchrum* has a symmetric, equally incised first lateral saddle, whereas the that of the present specimen has irregularly incised ventral side.

Occurrence.—Middle part (Fk-1a) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Metadagnoceras sp. B
Figures 5.1a, b

Material examined.—One specimen, IGPS coll. cat. no. 112562.

Descriptive remarks.—A fragmental phragmocone is at hand. Its height attains more than 30 mm. The venter is not preserved. The side is nearly flat with acutely rounded umbilical shoulder. The umbilicus probably deep with steep wall, but not well preserved. The shell surface seems to be smooth. The external lobe is partly preserved, although the ventral lobe is missing. The probable first lateral saddle is highly denticulate, but may be not well individualized. The large and deep first lateral lobe occupies the central part of the side and strongly denticulate. The denticulations extend up to the ventral side to nearly the top of the first lateral saddle, whereas the umbilical side is almost smooth. The second lateral saddle is large and rounded, and its outline is asymmetrical, having long ventral side and short umbilical side. Near the umbilical edge, there are some pointed auxiliary lobes.

Based on the general shell shape and the outline of the suture, the present specimen is considered to belong to the genus *Metadagnoceras* Tozer, 1965. Its sutural pattern is somewhat similar to that of *M. youngi* Bucher from the lower Anisian of Nevada (Bucher, 1989, p. 963, pl. 1, figs. 2–5, text-fig. 5), but the specific designation is difficult because of the fragmental state of preservation of the present specimen.

Occurrence.—Middle part (Fk-1b) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Genus ***Psilokhvalynites*** gen. nov.

Type species.—*Psilokhvalynites takaizumii* gen. and sp. nov.

Etymology.—The generic name refers to it smooth (Greek, *Psilo*-) shell surface, and a genus name *Khvalynites*, the general shell shape and sutural trace of which resemble those of the present new genus.

Diagnosis.—The shell is involute and extremely discoidal with almost smooth surfaces. The sides are broadly convex and converge slightly to the flat to convex venter. The external suture line is similar to that of the genus *Khvalynites*, consisting a large and deeply denticulate lateral lobe and two rounded lateral saddles. The ventral side of the first lateral saddle is smooth.

Discussion.— *Psilokhvalynites* gen. nov. resembles an Olenekian (Early Triassic) genus *Khvalynites* Shevyrev, 1968 in its general shell shape and sutural traces. However, smooth shell surface of the new genus is the most distinctive character from *Khvalynites*, which has remarkable radial ribs. The smooth ventral side of the first lateral saddle of the new genus is also unique in the family Khvalynitidae. Some species of Anisian genus *Alanites* Shevyrev, 1968, such as *Alanites visendus* Shevyrev 1968 and *A. laevis* Tozer, 1994 have smooth surface, but is easily distinguished from the present new genus in having thickly trapezoidal shell cross section and having serrated saddles.

Psilokhvalynites takaizumii gen. and sp. nov.
Figures 5.3–5.7

Material examined.—Seven specimens, IGPS coll. cat. no. 112563 (holotype) and nos. 112564–112569 (paratypes).

Etymology.—The specific epithet is dedicated to Yukihiro Takaizumi, who donated many ammonoid specimens, including the present new species, from the Fukkoshi Formation.

Diagnosis.—As for the genus.

Description.—The shell is involute and extremely discoidal. The holotype is the largest and its maximum

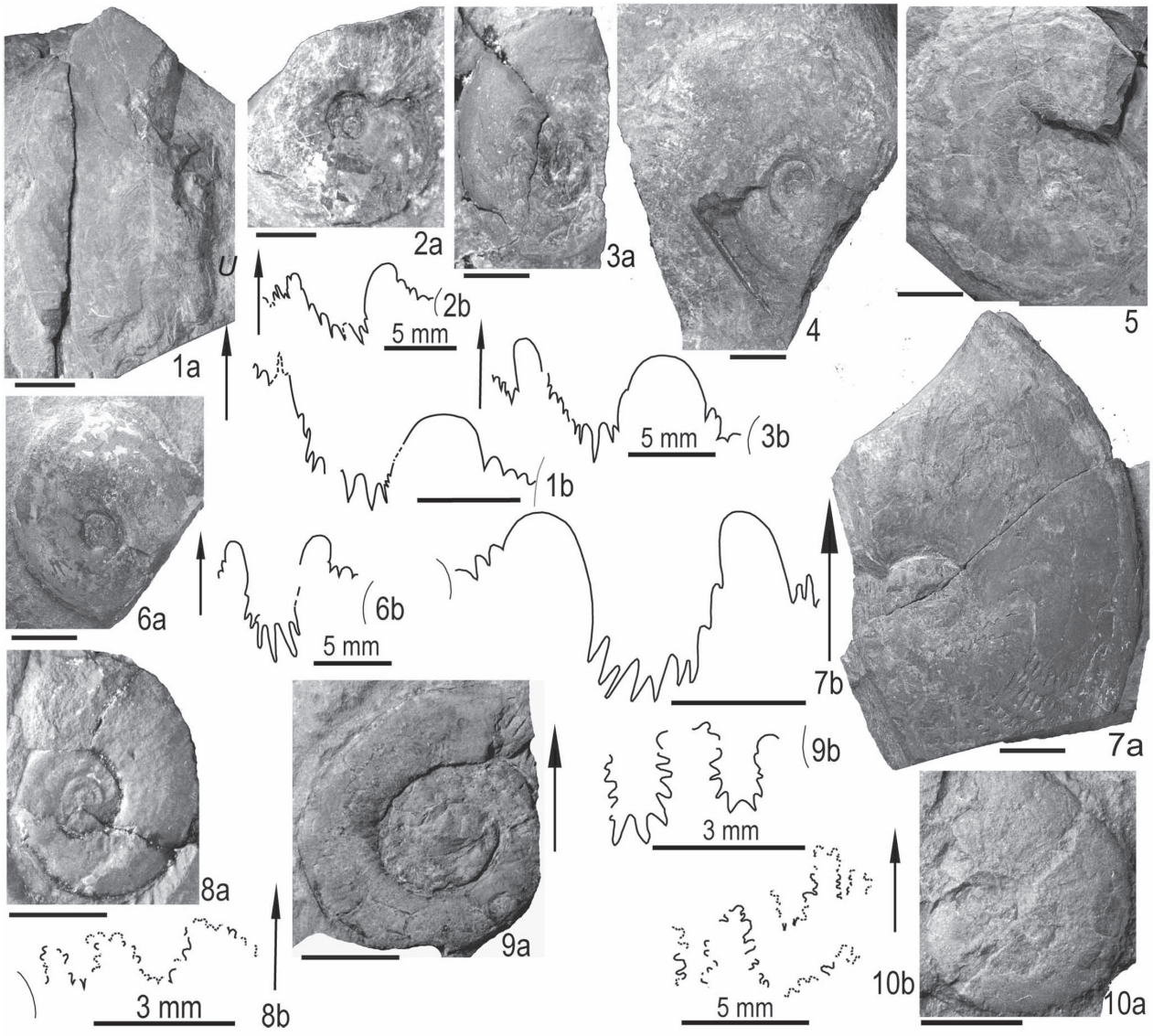

Figure 5. *Metadagnoceras*, *Psilokhvalynites*, *Aegeiceras*?, *Eogymnites* and *Buddhaites*? from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1, *Metadagnoceras* sp. B, IGPS coll. cat. no. 112562; 1a, lateral view (*U*: umbilicus); 1b, suture line; **2**, *Metadagnoceras* sp. A, IGPS coll. cat. no. 112561; 2a, ventral view; 2b, suture line; **3**–**7**, *Psilokhvalynites takaizumii* gen. and sp. nov.; 3, IGPS coll. cat. no. 112565; 3a, lateral view; 3b, suture line; 4, IGPS coll. cat. no. 112564, lateral view; 5, IGPS coll. cat. no. 112569, lateral view; 6, IGPS coll. cat. no. 112566; 6a, lateral view; 6b, suture line; 7, IGPS coll. cat. no. 112563 (holotype); 7a, lateral view; 7b, suture line; **8**, *Aegeiceras*? sp., IGPS coll. cat. no. 112583; 8a, lateral view; 8b, suture line; **9**, *Eogymnites* sp., IGPS coll. cat. no. 112584; 9a, lateral view; 9b, suture line; **10**, *Buddhaites*? sp., IGPS coll. cat. no. 112588; 10a, lateral view; 10b, suture line. Scale bars are 1 cm unless otherwise stated.

diameter may attain to 90 mm, but it lacks part of shell margins. The preserved shell diameters of other specimens range from ca. 30 mm to over 80 mm. The ratio of *UD*/*D* ranges from 0.12 to 0.17, the majority of which is 0.12 to 0.13. The sides are broadly convex to nearly flat with broadly rounded umbilical shoulder. The maximum shell width is at or near the umbilical shoulder and the sides slightly converge to the venter. The venter is not well preserved, but, in the holotype, seems to be nearly flat with acute ventral shoulders. The umbilicus is shallow with low umbilical wall.

The shell surface is almost smooth, except for faint sinuous growth lines.

The general outline of the external suture line is similar to that of the genus *Khvalynites*. The ventral lobe is not well preserved, and only probably a part of its prong is visible. It is shallow and denticulate, with smooth side. A wide and deep, U-shaped lateral lobe occupies the central part of the flank, with two rounded saddles on each side. The base of the lobe is deeply denticulate and some small denticulations are up to the middle part of the ventral side. Crests of two saddles are rounded. The first lateral saddle is symmetrical, whereas the wide second saddle is asymmetrical with short umbilical side, which continue to some pointed small auxiliary lobes on the umbilical shoulder.

Occurrence.—Middle part (Fk-1a: no. 112564; Fk-1b: nos. 112563, 112565–112568) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City and from the upper part (Fk-5: no. 1112569) at the eastern coast of Terahama, Togura, Minamisanriku Town, Miyagi Prefecture.

Superfamily Ceratitoidea Mojsisovics, 1879
Family Acrochordiceratidae Arthaber, 1911
Genus ***Paracrochordiceras*** Spath, 1934

Type species.—*Acrochordiceras anodosum* Welter, 1915.

Paracrochordiceras cf. ***denseplicatum*** Fantini Sestini
Figures 6.1–6.3

cf. *Acrochordiceras* ex aff. *anodosum* Welter, Bender, 1970, p. 439, pl. 2, fig. 9.
Paracrochordiceras denseplicatum Fantini Sestini, 1981, p. 49, pl. 4, figs. 2, 3.

Material examined.—Three specimens, IGPS coll. cat. nos. 112570–112572.

Descriptive remarks.—Specimens are discoidal and sub-evolute. The flanks are nearly flat with acutely rounded umbilical shoulder. The umbilicus is shallow. The venter is not well preserved. Sample no. 112570 attains a maximum diameter of ca. 42.0 mm, and its corresponding height and umbilical diameter are ca.16.0 and 14.0 mm (*UD*/*D* = 0.33), respectively. There are 39–40 ribs on the shell surface. The ribs are rectiradiate and run from the umbilical shoulder to the ventral shoulder, slightly strengthened to the venter, but slightly curve forward at the ventral shoulder. They reach to the venter, but whether they cross the venter or not is unclear because the venter is not well preserved. Very few ribs bifurcate near the ventral shoulder. The maximum shell diameter of sample no. 112571 is 43.5 mm, with corresponding height and umbilical diameter of ca. 13.5 and 15.5 mm (*UD*/*D* = 0.36), respectively. There are 34–35 rectiradiate ribs on the last whorl. The ribs run from the umbilical shoulder, slightly strengthened to the venter and probably cross the venter. About one-thirds of ribs bifurcate or associated with short secondary ribs near the ventral shoulder. No. 112572 is a fragmental and deformed specimen having fine ribs resemble to no. 112571.

The external suture is partly preserved in specimen no. 112570. Three lateral saddles and two lateral lobes are observable, although the first saddle is only preserved on its umbilical side. The saddles are rounded. The lobes are strongly denticulate at the base and small denticulations reach to the middle part of their sides.

The general shell outline and surface ornamentation, especially their flat sides, closely resemble *Paracrochordiceras denseplicatum* Fantini Sestini, 1981, described from the Lower Anisian (Aegean) of Chios Island, Greece. But I refrain from identifying the present specimens definitely at the specific level, because the present specimens are not well preserved and Chios specimen lacks suture line. *Proacrochordiceras kiparisovae* Korchinskaya described from Spitsbergen (Korchinskaya, 1983, p. 110, figs 1a–h, 2a–b) is somewhat similar to the present species in its shell form, surface ornamentation and outline of the suture line. But the former differs from the latter in having umbilical tubercles on the inner whorls and in having coarser ribs.

Occurrence.—Upper part of the Fukkoshi Formation at the southern coast of Ozashi (Fk-2b: no. 112570), Jusanhama, Kitakami-cho, Ishinomaki City, and at the eastern coast of Terahama (Fk-5: nos. 112571, 112572), Togura, Minamisanriku Town, Miyagi Prefecture.

Paracrochordiceras watanabei sp. nov.
Figures 6.4–6.7

Material examined.—Six specimens: IGPS coll. cat. nos. 112573 (holotype) and 112574–112578 (paratypes).

Etymology.—The species name is to honor Yuta Watanabe, who collected important specimens including the holotype, and making them available for this study.

Diagnosis.—*Paracrochordiceras* having coarse radial ribs which are largely rursiradiate. The shell is moderately evolute with oval cross section.

Description.—The shell is discoidal and sub-evolute. It consists of a phragmocone and body chamber, the latter of which occupies about half part of the preserved last volution. The maximum diameter ranges from ca. 30 mm to 52.5 mm. The ratio of *UD*/*D* is in the range of 0.38–0.43 (Table 1). The flanks are nearly flat to broadly convex with acutely rounded umbilical shoulder. The umbilicus is shallow. The venter is not fully preserved, but probably rounded with broadly

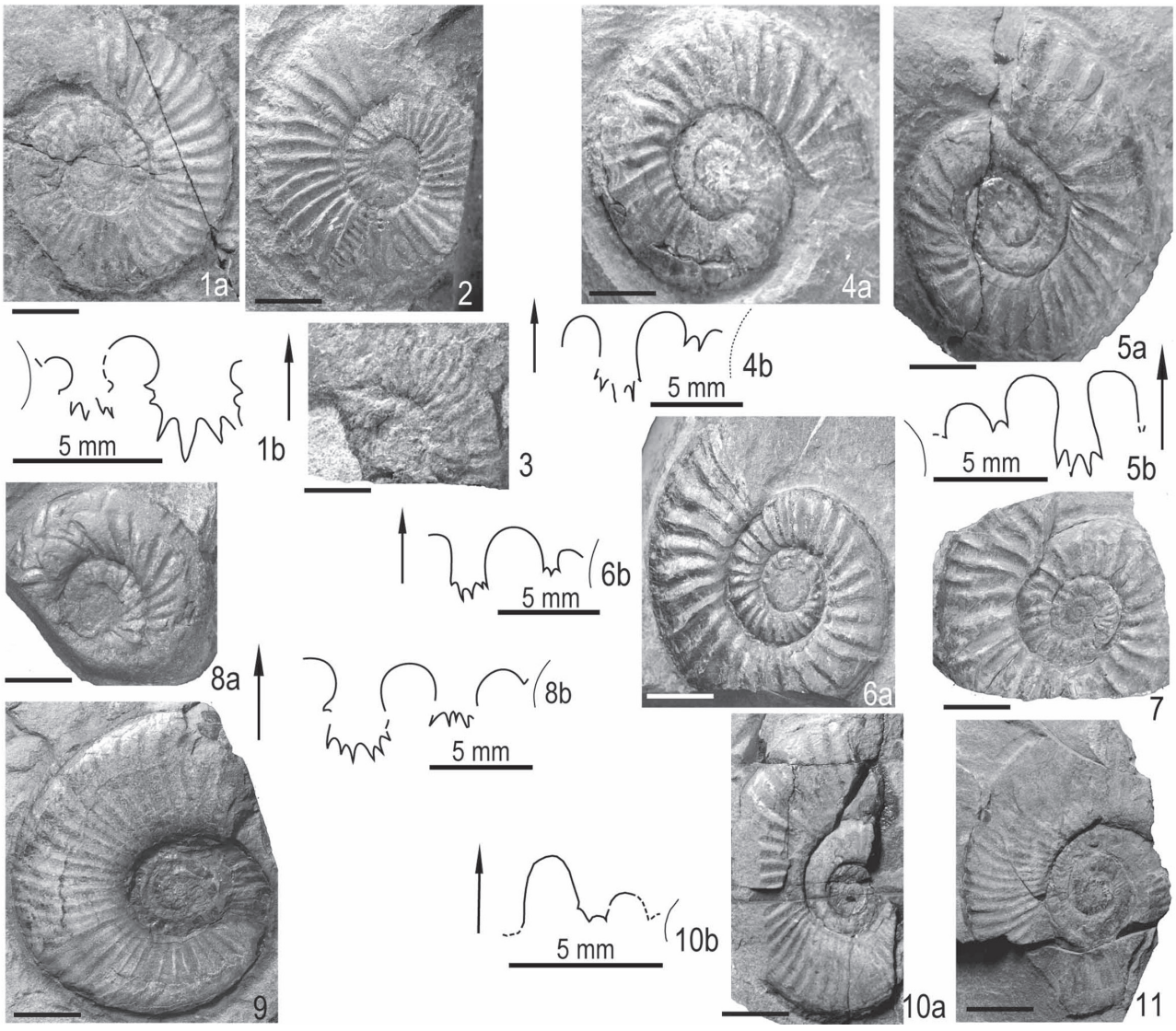

Figure 6. *Paracrochordiceras* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan. **1**–**3**, *Paracrochordiceras* cf. *denseplicatum* Fantini Sestini; 1, IGPS coll. cat. no. 112570; 1a, lateral view; 1b, suture line; 2, IGPS coll. cat. no. 112571, lateral view; 3, IGPS coll. cat. no. 112572, lateral view; **4**–**7**, *Paracrochordiceras watanabei* sp. nov.; 4, IGPS coll. cat. no. 112574, 4a, lateral view; 4b, suture line; 5, IGPS coll. cat. no. 112573 (holotype); 5a, lateral view; 5b, suture line; 6, IGPS coll. cat. no. 112575; 6a, lateral view; 6b, suture line; 7, IGPS coll. cat. no. 112576, lateral view; **8**, *Paracrochordiceras* sp. A, IGPS coll. cat. no. 112579; 8a, lateral view; 8b, suture line; **9**-**11**, *Paracrochordiceras* sp. B; 9, IGPS coll. cat. no. 112580, lateral view; 10, IGPS coll. cat. no. 112581; 10a, lateral view; 10b, suture line; 11, IGPS coll. cat. no. 112582, lateral view. Scale bars are 1 cm unless otherwise stated.

rounded ventral shoulder, which continued from the rounded margin of the side. The maximum shell width is at the center to ventral two-thirds of the flank, and the flanks slightly converge to the umbilicus. There are rursiradiate ribs on the flanks. They are convex and sometimes slightly sigmoidal. They run from the umbilical wall, slightly strengthened and widened to the venter, and probably cross the venter. They seem to be simple on the inner whorls, but, on the last whorl, sometimes bifurcate near the ventral shoulder or associated by intercalary ribs. There are 28 to 32 (rarely 24) primary ribs on the last whorl.

The external lateral suture consists of three rounded

Table 1. Dimensions (in mm) and ratios of *Paracrochordiceras watanabei* sp. nov. from the Fukkoshi Formation. α: the angular position adapical from the preserved end; *D*: diameter of whorl; *H*, height of whorl; *W*: width of whorl; *UD*: diameter of umbilicus.

IGPS no.	α	*D*	*H* (*H*/*D*)	*W*	*UD* (*UD*/*D*)
112573	0°	52.5	19.5 (0.37)		20.0 (0.38)
(holotype)	0°	39.3	15.1 (0.38)		15.6 (0.40)
	-180°	38.9	12.5 (0.32)		15.8 (0.41)
112574	0°	42.6	ca.13.0 (0.30)		18.3 (0.43)
	-90°	41.7	13.9 (0.33)		17.2 (0.41)
	-180°	30.3	12.4 (0.41)		11.5 (0.38)
112575	0°	42.0	15.1 (0.36)		17.8 (0.42)
112576	0°	37.5	ca.12.5 (0.33)		15.8 (0.42)
	-90°	33.9	11.6 (0.34)		14.2 (0.42)
112577	-90°	29.8	ca.10.0 (0.34)		12.1 (0.41)
112578	0°	31.0	10.4 (0.34)		12.6 (0.41)

saddles and two serrated lobes. The ventral lobe is not preserved. The second saddle is widest and the third is small. The first lateral lobe is deep, with smooth sides which are subparallel each other to slightly widened toward the base. The base has four to five strong denticulations. The small and shallow second lobe bifurcates, rarely trifurcates at the base. The auxiliary robe is simple and pointed.

Discussion.—The general shell outline and surface ornamentation, especially their nearly flat sides, of the present species somewhat resembles *Paracrochordiceras denseplicatum* (Fantini Sestini, 1981, p. 49, pl. 4, figs. 2, 3) described from the Lower Anisian (Aegean) of Chios Island, Greece. The present species, however, clearly distinguished from *P. denseplicatum* and other previously known species of *Paracrochordiceras* in having coarser, rursiradiate ribs.

Occurrence.—Middle part (Fk-1a: nos. 112577, 112578; Fk-1b: nos. 112573–112576) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Paracrochordiceras sp. A
Figures 6.8a, b

Material examined.—One specimen, IGPS coll. cat. no. 112579.

Descriptive remarks.—A specimen collected from a float near the locality Fk-1a and Fk-1b is examined. About two-thirds of the conch is preserved. It is discoidal and sub-evolute. The maximum diameter is about 35 mm, and its corresponding height and umbilical diameter are ca. 12 and 12-13 mm (*UD*/*D* = 0.34-0.37), respectively. The broadly rounded flanks continue to the umbilical wall and venter without well-defined umbilical and ventral shoulders. The maximum shell width is at about the center of the flanks. Exact shell width is not known, but, based on the preserved shell thickness, the width at least reaches 10 mm, and probably larger than the corresponding height. The umbilicus is deep and umbilical wall is steep. The shell surface is ornamented with strong radial ribs, which run from the umbilical shoulder, broadened to the venter and probably cross the venter. They are rursiradiate on the inner whorls, but partly falcoid on the last whorl. Although the large part of the shell surface of the last whorl is worn out and not well preserved, many of the ribs on the preserved last whorl seem to bifurcate at the center of the flank or near the ventral shoulder. There are 15-16 primary ribs per half volution.

The external suture is partly preserved, but the ventral lobe and auxiliary ones near the umbilicus are not preserved. The crests of three saddles are all rounded. The first saddle is highest, but narrow, and the second is wide. The first lateral lobe is wide and deep, showing somewhat circular outline. Its base is strongly denticulate and shallow denticulations are up to the middle part of the ventral side. The small second lateral lobe is also denticulate.

Based on its general shell shape and shape of suture line, the present specimen very likely belongs to the genus *Paracrochordiceras*. Although its coarse ribbing and unique rib pattern suggests that the present species is a new species, I refrain from proposing it because of their poor state of preservation.

Occurrence.—From a float at the middle part (Fk-1) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Paracrochordiceras sp. B
Figures 6.9–6.11

Material examined.—Three specimens, IGPS coll. cat. nos. 112580–112582.

Descriptive remarks.—The specimens are discoidal and sub-involute to sub-evolute. The maximum diameters of them are ca. 45 mm, and the ratios of *UD*/*D* are 0.30 (specimen no. 112580), 0.38 (no. 112581) and 0.44 (no. 112582). The flanks are nearly flat to broadly convex with acutely rounded umbilical and ventral shoulders. The venter is not well preserved, but seems to be rounded. The umbilicus is shallow. The maximum width is near the ventral shoulder to the center of the flank. The shell surface is ornamented with slightly sigmoidal to slightly concave, rectiradiate to slightly rursiradiate, fine radial ribs. They run from the umbilical shoulder, slightly broadened to the venter, and fade out short before the venter or probably

cross the venter. Very fine ribs or growth lines, parallel to the primary ribs, are also present in specimen no. 112580. There are about 50 primary ribs per volution. The suture is only preserved in specimen no. 112581. It is rather simple and consists of deep ventral lobe, high and large, rounded first lateral saddle, moderately deep first lateral lobe, small second rounded saddle and small second lobe. Although all lobes are not well preserved, the lower part of the first lateral lobe is pointed at three or four parts.

The general shell shape and rib pattern, and the outline of the suture line of the present specimen resemble with those of the species of the genus *Paracrochordiceras*. The ribs of the present specimens are remarkably finer than those of the known species. However, I refrain from identifying it at the specific level, because they are in poor state of preservation.

Occurrence.—From the middle part (Fk-1a) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Superfamily Pinacoceratoidea Mojsisovics, 1879
Family Gymnitidae Waagen, 1895
Subfamily Japonitinae Tozer, 1971
Genus ***Aegeiceras*** Fantini Sestini, 1981

Type species.—*Gymnites ugra* Diener, 1895b.

Aegeiceras? sp.
Figures 5.8a, b

Material examined.—One specimen, IGPS coll. cat. no. 112583.

Descriptive remarks.—A small specimen is discoidal and sub-evolute. It consists of phragmocone and body chamber, the latter occupies about a half of the last whorl. The shell attains 24.4 mm in diameter and its corresponding height and umbilical diameter are 10.0 and 8.0 mm (*UD*/*D* = 0.33), respectively. The side is broadly convex with maximum width at the center of it. The apparent width is very small and about 2 mm, but this is partly tectonic flattening. The venter is carinate, without remarkable ventral shoulder. The umbilicus is shallow with rounded umbilical shoulder. The shell cross section is lenticular. The shell surface seems to be smooth on the phragmocone, but on the body chamber, there are faint, fine radial ribs, running from just above the umbilical shoulder to near the venter. They are rectiradiate on the inner side of the whorl, but slightly curve adorally on the outer side. There are also seen three, indistinct spiral ridges on the body chamber: at the ventral one-fourth, center and ventral three-fourth. They slightly expand on the radial ribs.

The external lateral suture line is ammonitic and similar to that of *Aegeiceras*, although the ventral lobe is only partly preserved and its details sometimes in distinct because of its small size and ill preservation. The all saddles and lobes are finely frilled. The ventral lobe is shallow than the first lateral lobe. There are three saddles on the lateral side, the second is highest and the third is low. The first lateral lobe is deepest. The second lobe is slightly shallow than the first. Near the umbilical edge, there are some auxiliaries.

The general shell shape and sutural outline are similar to those of the genus *Aegeiceras* Fantini Sestini, 1981, although the ratio of *UD*/*D* of the present species is little smaller than the known species of *Aegeiceras*. The species of *Aegeiceras* have only one spiral ornament constituted by clavi. The present species has three faint spiral ridges on the body chamber. Some specimens of *Aegeiceras ugra* also have additional spiral ornament, although they are very indistinct ridge (Diener, 1895b, pl. 30, fig 5a; Bender, 1970, pl. 3, fig. 6; Fantini Sestini, 1981, pl. 5, fig. 2). The spiral ornaments of the present species are ridge, instead of clavi, but they expand on the radial ribs as nodes. Thus, the present species is thought to belong to the genus *Aegeiceras*, but there remain some questions about the generic assignment due to its small size and poor state of preservation.

Occurrence.—Middle part (Fk-1a) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Genus ***Eogymnites*** Spath, 1951

Type species.—*Japonites arthaberi* Diener, 1915.

Eogymnites sp.
Figures 5.9a, b

Material examined.—One specimen, IGPS coll. cat. no.112584.

Descriptive remarks.—A small specimen, consisting of phragmocone and body chamber, is at hand. The body chamber occupies more than two-thirds of the preserved last whorl. The shell is extremely discoidal and sub-evolute. It attains 32.8 mm in diameter and its corresponding height and umbilical diameter are ca. 12.0 and 14.5 mm (*UD*/*D* = 0.44), respectively. The apparent width is 1.8 mm, but its discoidal form may be partly due to the synsedimentary compaction and tectonic flattening. The sides are broadly convex with broadly rounded umbilical and ventral shoulders. The umbilicus is shallow and the venter is probably acutely rounded. The maximum shell width is at the center of the flank, and the shell cross section is lenticular. The shell surface is almost smooth, but with faint, slightly sinuous, radial ribs.

The external lateral suture consists of large and deep first lateral lobe, high second lateral saddle, deep second lateral lobe and small third lateral saddle on the umbilical shoulder. Ventral lobe is not seen and the first lateral saddle is only preserved on its umbilical side. At maturity all parts of saddles and lobes are serrated, but on the inner whorls the crests of saddles are rounded. The serration of the base of the lobes are rather deep. Sides of lateral lobes are parallel to each other.

Based on the general shell shape and sutural traces, especially in having parallel lobe sides, the present specimen belongs to the genus *Eogymnites* Spath, 1951. But the precise specific identification is difficult, because it is rather small and ill preserved.

Occurrence.—Middle part (Fk-1a) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Genus ***Japonites*** Mojsisovics, 1893

Type species.—*Ceratites planiplicatus* Mojsisovics, 1888.

Japonites cf. ***meridianus*** Welter
Figures 7.5a, b

cf. *Japonites meridianus* Welter, 1915, p. 122, pl. 93. figs. 2a–2c, text-fig. 21; Wang and He, 1976, p. 414, pl. 42, figs. 3–4, pl. 43, figs. 10–11; He et al., 1986, p. 240, pl. 9, figs. 7–14, text-figs. 33c–33d.

Material examined.—One specimen, IGPS coll. cat. no. 112585.

Descriptive remarks.—A fragmental specimen, about a half volution, is at hand. Inner whorls are missing. It largely consists of body chamber, but a part of the phragmocone is also preserved. The shell attains about 54 mm in diameter, and its corresponding height and umbilical diameter are ca. 15.5 and 23.3 mm, respectively. The ratio of *UD*/*D* is 0.43. The shell is compressed and the side is nearly flat to broadly convex. The ventral and umbilical shoulders are not well preserved, but seem to be acutely rounded. The shell surface bears faint fine ribs, which are rursiradiate and partly slightly sinuous. They run from the umbilical shoulder to near the ventral shoulder. The external suture line is rather well preserved, except for ventral lobe and auxiliaries near the umbilical shoulder. It is typical *Japonites*-type. The ventral lobe is probably bifurcated by the median saddle and the serrated prong is moderately deep. There remains three lateral saddles and two lateral lobes, all are fully serrated. The first and second saddles are nearly the same height and the third is low. The first lateral lobe is deeper than the second.

Based on the general shell shape, shell ornamentation and outline of the suture line, the present specimen closely resembles *Japonites meridianus* Welter, but the exact specific identification is difficult, because the present specimen is fragmental and not well preserved. *J*. cf. *meridianus* collected from the underlying Osawa Formation (Ehiro, 2022 in press) has smaller umbilicus.

Occurrence.—Middle part (Fk-1a) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Japonites raphaelizoyae (Tommasi)
Figures 7.7a, b

Gymnites Raphaelis Zoja Tommasi, 1899, p. 41, pl. 6, figs. 5, 6; Renz, 1910, p. 41, pl. 2, figs. 10, 12 (non 2), text-fig. 4.
Japonites Raphaelis Zojae (Tommasi), Welter, 1915, p. 123, pl. 10, figs. 1–4, text-figs. 22–24.
Japonites raphaelis-zojae (Tommasi), Bender, 1970, p. 448, pl. 4, fig. 1.
Japonites raphaelis zojae (Tommasi), He et al., 1986, p. 240, pl. 9, figs. 15–19, text-fig. 33g.
Japonites raphaelis zojae (Tommasi), Wang et al., 1979, p. 46, pl. 11, figs. 11–14, text-fig. 25b–c.

Material examined.—One specimen, IGPS coll. cat. no. 112586.

Description.—The shell is discoidal and evolute. It consists of phragmocone and body chamber, the latter occupies about three-fourth of the last whorl. The shell diameter at the preserved end is 73.5 mm, with corresponding height and umbilical diameter of 25.0 and 34.3 mm (*UD*/*D* = 0.47), respectively. The sides are broadly rounded connecting to the rounded venter and rounded umbilical slope without distinct shoulders. The maximum shell width is near the center of the flank, and it is more than 10 mm. The shell cross section is approximately elliptical. The umbilicus is shallow. There are strong, slightly sigmoidal radial ribs, 26–27 per volution, on the shell surface. They run from the umbilical wall, widening to the venter, to the ventral shoulder and fade out. Fine ribs or growth lines, parallel to the ribs, are also present.

The external suture is preserved except for the ventral lobe. It consists of high, rather narrow first lateral saddle, deep and wide first lateral lobe, wide second lateral saddle, shallow second lateral lobe, small third lateral saddle and some auxiliary lobes on the umbilical shoulder to umbilical wall. All saddles and lobes are serrated irregularly. The first lateral lobe has nearly parallel sides and its base is strongly serrated. The second lateral lobe narrows toward the base.

Comparison.—The general shell shape, especially in having elliptical shell cross section and rather wide

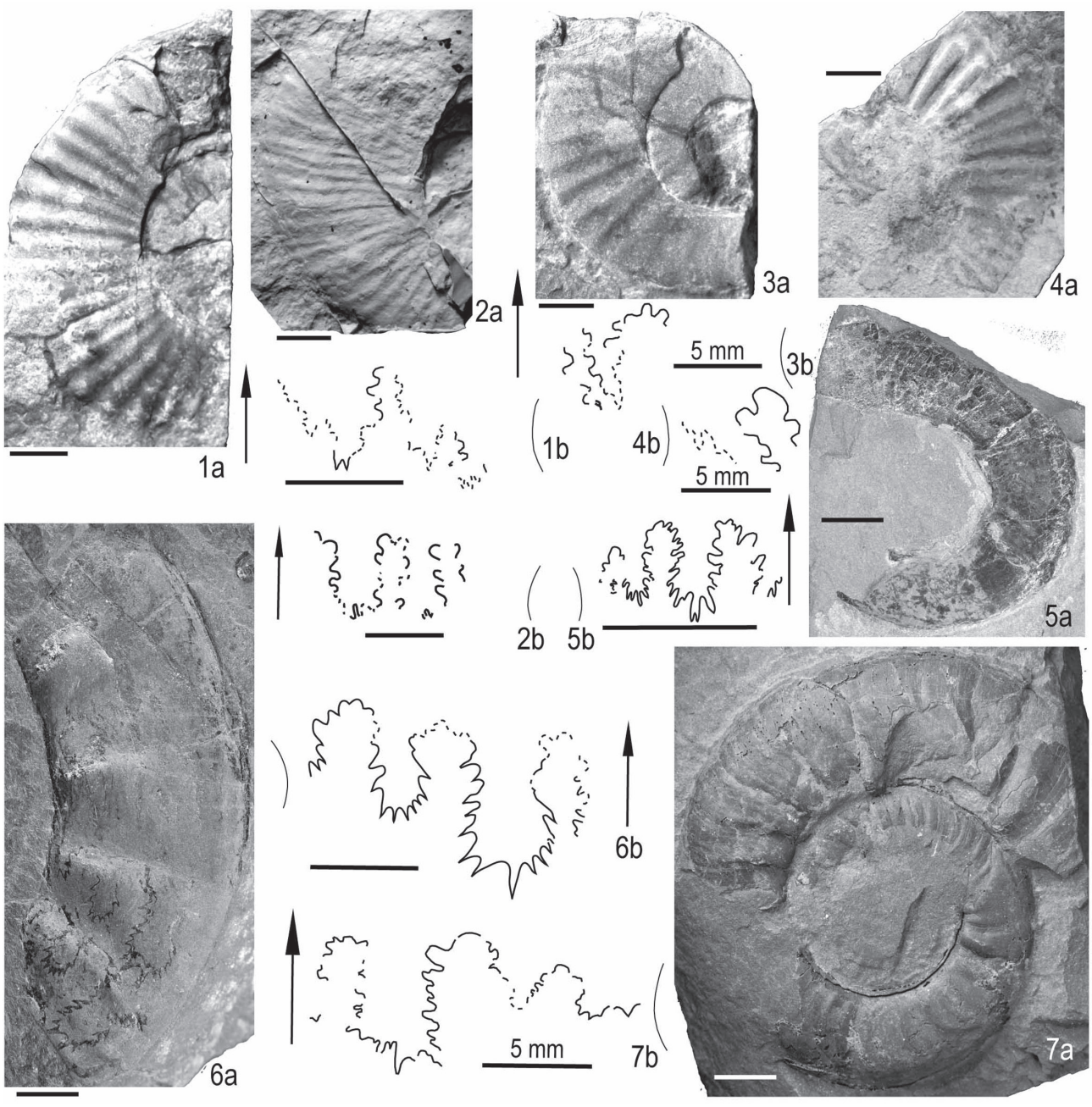

Figure 7. *Japonites* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1, **3**, **4**, *Japonites* sp. B; 1, IGPS coll. cat. no. 112667; 1a, lateral view; 1b, suture line; 3, IGPS coll. cat. no. 112665; 3a, lateral view; 3b, suture line; 4, IGPS coll. cat. no. 112666; 4a, lateral view; 4b, suture line; **2**, *Japonites* sp. C, IGPS coll. cat. no. 112668; 2a, lateral view (rubber cast); 2b, suture line; **5**, *Japonites* cf. *meridianus* Welter, IGPS coll. cat. no. 112585; 5a, lateral view; 5b, suture line; **6**, *Japonites* sp. A, IGPS coll. cat. no. 112587; 6a, lateral view; 6b, suture line; **7**, *Japonites raphaelizoyae* (Tommasi), IGPS coll. cat. no. 112586; 7a, lateral view; 7b, suture line. Scale bars are 1 cm unless otherwise stated.

umbilicus, the present specimen is identified with *Japonites Raphaelis Zojae* (Tommasi), especially very similar to the specimen *J. Raphaelis Zojae* form 2 described by Welter (1915, p. 123, pl. 10, fig. 2, text-fig. 23) from Timor.

Occurrence.—Upper part (Fk-6) of the Fukkoshi Formation at the eastern coast of Terahama, Togura, Minamisanriku Towny, Miyagi Prefecture.

Japonites sp. A
Figures 7.6a, b

Material examined.—One specimen, IGPS coll. cat. no. 112587.

Descriptive remarks—A fragmental specimen, about a quarter of one-volution, consists of phragmocone and body chamber. It is evolute and discoidal, and its maximum diameter is considered to exceeds 100 mm. The side is broadly convex with rounded umbilical shoulder. The venter is not well preserved. The maximum shell width is near the umbilical shoulder, and sides converge to the venter. The shell surface is ornamented with low, but wide, radial ribs, which run from the umbilical wall, bifurcate at the umbilical shoulder, and run to the ventral shoulder. There are four primary ribs per quarter whorl. The external suture is preserved except for the ventral lobe. Three lateral saddles are all serrated from lower to top. The first and second saddles are nearly the same height. The first is narrow, whereas the second is wide. The height of the third is about a half of the second. The first lateral lobe is large and deep with strong denticulations at the base. The lower part of it is slightly expanded. The depth of the second lobe, which is denticulate as with the first, is about two-thirds of the first. There may be some auxiliary lobes near the umbilical shoulder, but only a part is visible.

Based on the general shell shape and outline of the suture line, the present specimen is considered to belong to the genus *Japonites*. Bifurcate rib pattern of the present specimen is unique for the genus *Japonites*, but it is not well preserved enough to propose a new species.

Occurrence.—Middle part (Fk-1b) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Japonites sp. B
Figures 7.1, 7.3, 7.4

Material examined.—Three specimens, IGPS coll. cat. nos. 112665–112667.

Descriptive remarks—Three fragmental specimens are at hand. They are discoidal and sub-evolute. The maximum shell diameter of the specimen no. 112665 exceeds 60 mm. At the estimated diameter is ca. 65.0 mm, its corresponding height and umbilical diameter are ca. 20, and ca. 28 mm (*UD*/*D* = 0.43), respectively, and at *D* = ca. 50.5 (about 180° adapical from the preserved end) the height and umbilical diameter are 17.2 and 19.3 mm (*UD*/*D* = 0.38), respectively. Another specimen (no. 112666) is a fragment of about one-third of a whorl, the height of which is ca. 22 mm. They have nearly flat to very slightly convex side with acutely rounded umbilical and ventral shoulders. The venter probably rounded, but not well preserved. The umbilicus is shallow. There are low but prominent ribs on the shell surface. They are substantially rectiradiate, but slightly rursiradiate and convex, and run from umbilical shoulder to ventral shoulder, slightly strengthened to the venter. On the outer molds there are also fine striae parallel to the ribs, although they are rather obscure. There are nine to ten ribs per quarter volution (ca. 40 ribs per volution) of the whorl.

Specimen no. 112667 moderately large specimen, about a half of outer volution and a part of inner volution is preserved. It is discoidal and sub-evolute. The maximum shell diameter probably attains about 80 mm, with the corresponding height (estimated) and umbilical diameter are 30 and 31.0 mm (*UD*/*D* = 0.39), respectively. The sides are nearly flat to very broadly convex with acutely rounded umbilical shoulder. The umbilical wall is steep. The venter is probably rounded with broadly rounded shoulder. The maximum shell width is near the ventral shoulder and the sides slightly converge toward the umbilicus. On the shell surface, there are 22–23 rectiradiate ribs per half volution. They run from umbilical wall to the venter, strengthened to the ventral shoulder.

The suture lines are only partly preserved and obscure in all specimens. Preserved parts are the ventral side region of the inner whorl in specimen no. 112665, the umbilical side region in specimen no. 112666 and the ventral two-thirds in specimen no. 112667. They are composed of the fully serrated deep lobes and/or high saddles.

The present specimen is considered to belong to the genus *Japonites*, based on the general shape of the suture lines and discoidal and sub-evolute shell shape. The surface ornamentation is somewhat similar to that of *Japonites meridianus*, but the specific identification is difficult because of their poor state of preservation.

Occurrence.—Two specimens (nos. 112665, 112666) come from the middle part (Fk-1c) and one specimen (no. 112667) from the upper part (Fk-2a) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Japonites sp. C
Figures 7.2a, b

Material examined.—IGPS coll. cat. no. 112668.

Descriptive remarks—A fragmental phragmocone, about one-third to one-fourth of a volution, is at hand. It is discoidal and sub-evolute. The diameter near the preserved end is estimated to be 80–85 mm, and its corresponding height and umbilical diameter are ca. 30 and 28 mm (*UD*/*D* = 0.33–0.35), respectively. The side is nearly flat with broadly rounded ventral shoulder and acutely rounded umbilical shoulder. The venter and umbilicus are not well preserved. The maximum shell width is at the ventral shoulder and the sides slightly converge to the umbilicus. On the flanks there are 13 to 15 fine ribs per quarter. They are rectiradiate and slightly concave, and run from the umbilical shoulder to the ventral shoulder. Few ribs bifurcate at about ventral one-third. Fine striae parallel to the ribs are also seen.

The suture lines are obscure and only parts of narrow and high saddles are visible, although some parts are little unreliable. They are fully serrated.

The present specimen is considered to belong to the genus *Japonites*, based on the general shape of the suture lines and discoidal and sub-evolute shell shape. The specific identification is difficult because of the poor state of preservation. It has finer and closely spaced ribs than the above-described *Japonites* sp. B.

Occurrence.—From the middle part (Fk-1a) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Subfamily Gymnitinae Waagen, 1895
Genus ***Buddhaites*** Diener, 1895b

Type species.—*Gymnites* (*Buddhaites*) *rama* Diener, 1895b.

Buddhaites? sp.
Figures 5.10a, b

Material examined.—One specimen, IGPS coll. cat. no. 112588.

Descriptive remarks.—Specimen attains a maximum diameter of ca. 26.5 mm. It is discoidal and involute. The umbilicus is not well preserved but its diameter is probably less than 2 mm. The side is broadly convex with maximum width at the center of the side. The umbilicus is shallow. The venter, with broadly rounded ventral shoulder is not well preserved but seems to be acutely rounded. The shell surface seems to be smooth. The partly preserved external suture line is ammonitic and resembles that of the family Gymnitidae. The first lateral saddle (ventro-lateral saddle) is wide and asymmetrical. Its ventral side, the enveloping surface of which is gently inclined ventrally, has rather deep secondary lobes.

Based on the shell morphology and the sutural outline, the present specimen is considered to belong to the genus *Buddhaites* Diener, 1895b, but there remains a question about the generic assignment due to the poor state of the preservation of the suture line.

Occurrence.—Middle part (Fk-1a) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Superfamily Danubitoidea Spath, 1951
Family Danubitidae Spath, 1951
Genus ***Danubites*** Mojsisovics, 1893

Type species.—*Ceratites Floriani* Mojsisovics, 1882.

Danubites cf. ***ambika*** Diener
Figures 8.1, 8.2

cf. *Danubites ambika* Diener, 1895b, p. 104, Pl. 29, figs. 2a–2c.
Danubites aff. *ambika* Diener, Bando, 1970, p. 347, pl. 38, fig. 1.

Material examined.—Three specimens, IGPS coll. cat. nos. 112589, 112590, 112669.

Descriptive remarks.—Specimens are discoidal and evolute. Conch is slowly increasing in height and shallowly embracing the preceding whorls. The maximum shell diameter of specimen no. 112589 exceeds 35 mm, and at the diameter of 34.9 mm, the corresponding height and umbilical diameter are 10.7 (*H*/*D* = 0.29) and 16.2 mm (*UD*/*D* = 0.46), respectively. The maximum diameter of the specimen no. 112590 exceeds 45 mm, and at a diameter of 44.9 mm the ratios of *H*/*D* and *UD*/*D* are 0.32 and 0.43, respectively. The maximum diameter of the specimen no. 112669 is 47.8 mm, with the corresponding height and umbilical diameter are 17.2 (*H*/*D* = 0.36) and 18.2 mm (*UD*/*D* = 0.38), respectively. The sides are broadly convex to nearly flat and sometimes slightly concave in the outer part. The umbilical and ventral shoulders are acutely rounded. The venter is not well preserved, but seems to be flat to slightly convex. The umbilicus is shallow. The shell surface is ornamented with strong, rectiradiate ribs, which run from umbilical shoulder to near the ventral shoulder and fade out. They become widened forward. There are 28-29 (specimen no. 112589) or about 34 (no. 112590, 112669) ribs on the last whorl. The suture is only preserved in specimen no. 112669. Three lateral saddles and two lateral lobes are observed. The crests of saddles are all rounded. The second is highest and the third is small. The first lateral lobe is wide and deep, with parallel sides and denticulate base. The second lobe has similar shape as the first, but small in size.

The present specimens resemble *Danubites ambika*

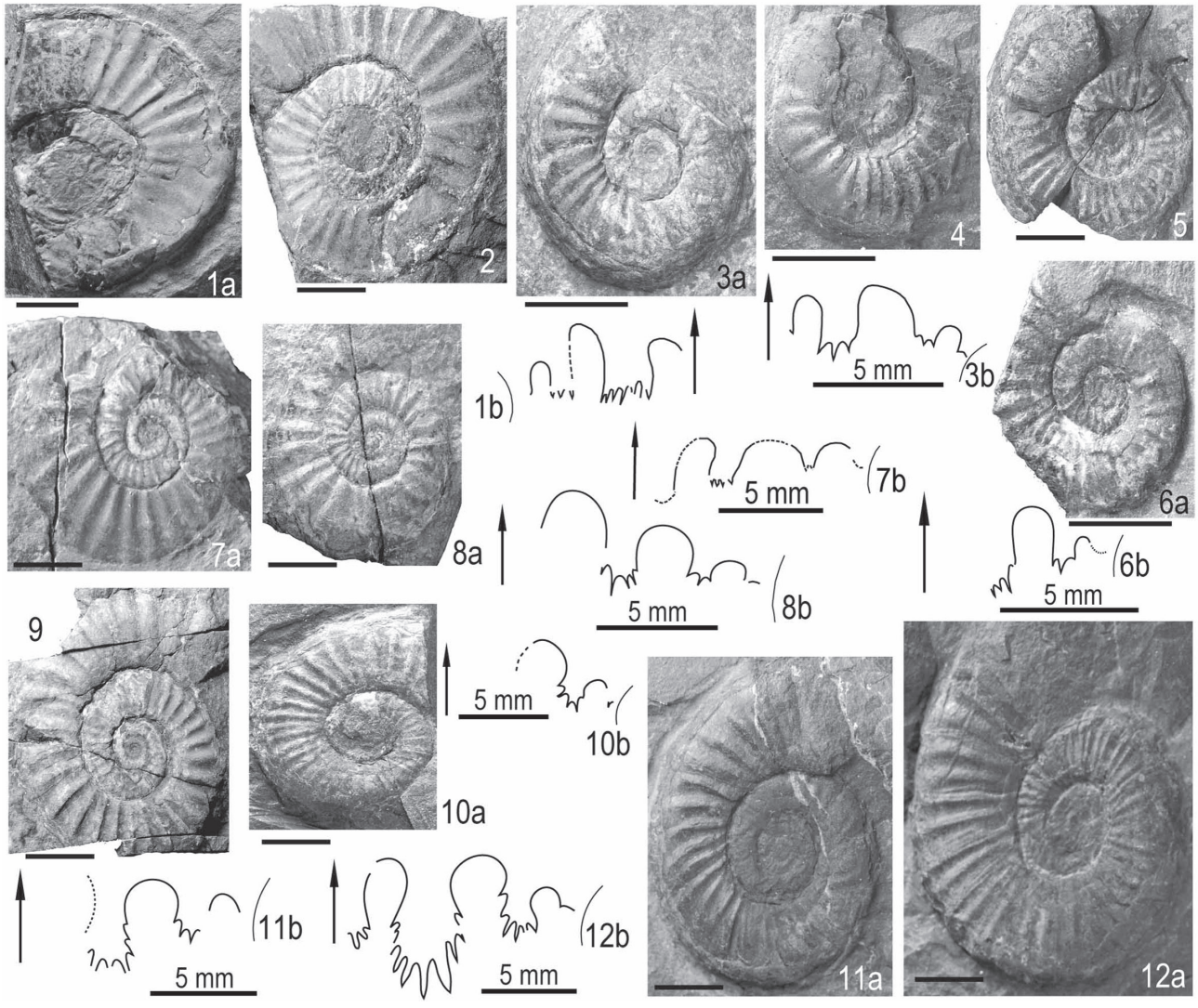

Figure 8. *Danubites* and *Paradanubites* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1–**2**, *Danubites* cf. *ambika* Diener; 1, IGPS coll. cat. no. 112669 ; 1a, lateral view, 1b, suture line; 2, IGPS coll. cat. no. 112590, lateral view; **3**–**6**, *Danubites floriani* (Mojsisovics); 3, IGPS coll. cat. no. 112591; 3a, lateral view; 3b, suture line; 4, IGPS coll. cat. no. 112592, lateral view; 5, IGPS coll. cat. no. 112593, lateral view; 6, IGPS coll. cat. no. 112594; 6a, lateral view; 6b, suture line; **7**–**9**, *Danubites* cf. *tozeri* Korchinskaya; 7, IGPS coll. cat. no. 112595; 7a, lateral view; 7b, suture line; 8, IGPS coll. cat. no. 112596; 8a, lateral view; 8b, suture line; 9, IGPS coll. cat. no. 112597, lateral view; **10**–**12**, *Paradanubites ozashiense* sp. nov.; 10, IGPS coll. cat. no. 112605; 10a, lateral view; 10b, suture line; 11, IGPS coll. cat. no. 112604; 11a, lateral view; 11b, suture line; 12, IGPS coll. cat. no. 112603 (holotype); 12a, lateral view; 12b, suture line. Scale bars are 1 cm unless otherwise stated.

Diener from the lower Anisian of Himalayas (Diener, 1985b) and *Danubites* aff. *ambika* Diener from the late Olenekian Osawa Formation (Bando, 1970), especially the latter, in having evolute shell with rather flat sides and rather coarse ribbing. But its precise comparison is difficult, because present specimens are poorly preserved. As stated in the preceding chapter, there is some doubt on the stratigraphic position of Bando's specimen. The present author considers that it may come from the Fukkoshi Formation.

Occurrence.—All specimens from the middle part (Fk-1a) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi

Prefecture.

Danubites floriani (Mojsisovics)
Figures 8.3–8.6

Celtites Floriani Mojsisovics, 1882, p. 145, pl. 28, figs. 5–7, pl. 31, fig. 4.
Danubites Floriani Mojsisovics, 1893, p. 398; Spath, 1951, p. 13.
Florianites floriani Hyatt, 1900, p. 553.

Material examined.—Four specimens, IGPS coll. cat. nos. 112591–112594.

Description.—Specimens are slightly deformed obliquely and flattened laterally. The shell is composed of the phragmocone and body chamber, the latter occupies about a half of the last whorl. The specimens are moderately evolute. The maximum shell diameter ranges from 24.5 to 39.0 mm, with the ratios of *H*/*D* and *UD*/*D* are 0.31–0.40 and ca. 0.37, respectively (Table 2). The exact shell width is not known, but, judging by the preserved half part, the maximum width of specimen no. 112591 is ca. 8 mm. The sides and venter are both broadly rounded and the umbilicus is rather deep with steep umbilical wall. Both umbilical and ventral shoulders are gradual. The maximum shell width is at the center of the side, and therefore, the shell cross section is nearly circular, although it is suffered from tectonic flattening. The shell surface is ornamented with simple, rectiradiate to slightly rursiradiate ribs, which are slightly strengthened to the venter and fade out before the venter. On the last whorl there are 26 to 30 ribs

The ventral lobe is not preserved. The large first lateral lobe is deep with nearly parallel sides and the base of it has many denticulations. The second lateral lobe is smaller remarkably than the first and trifurcates at the base, the middle branch of which is the deepest. There are three rounded saddles on the side and the second is the widest.

Comparison.—The present specimens from the Fukkoshi Formation closely resemble *Danubites floriani* (Mojsisovics, 1882) (originally described as *Celtites Floriani*) from the Middle Triassic of Austria in the shell shape, surface ornamentation and sutural trace. The ratio of *UD*/*D* of the Austrian specimens ranges from 0.32 to 0.45, increasing as the diameter increase, and those of the present specimens are in this range. The number of ribs of the former is slightly larger than those of the latter, but almost the same. The lateral suture line of the Mojsisovics (1882)'s specimen (figured in pl. 31, fig. 4 ; at about 39 mm in shell diameter) is almost similar to that of the present specimen. The both specimens have the large and deep first lateral lobe with denticulate base and trifurcated small second lateral lobe. Both second saddles are wider than the first.

Table 2. Dimensions (in mm) and ratios of *Danubites floriani* (Mojsisovics) from the Fukkoshi Formation. Abbreviations see Table 1.

IGPS no.	α	*D*	*H* (*H*/*D*)	*W*	*UD* (*UD*/*D*)
112591	0°	26.4	9.0 (0.34)	8+	9.8 (0.37)
112592	0°	24.5	ca.9.5 (0.39)		ca.9.0 (0.37)
112593	0°	ca.39.0	ca.12.0 (0.31)		14.5 (0.37)
	-90°	ca.30.0	11.2 (0.37)		10.7 (0.37)
112594	0°	ca.29.0	ca.11.5 (0.40)		10.2 (0.35)

Occurrence.—Middle part (Fk-1a: nos. 112591, 112592; Fk-1b: nos. 112593, 112594) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Danubites cf. ***tozeri*** Korchinskaya
Figures 8.7–8.9

cf. *Danubites tozeri* Korchinskaya, 1982, p. 60, pl. 16, figs. 7–9, text-figs. в, г; Vavilov and Arkadiev, 1986, p. 41, pl. 3, fig. 3, text-fig. 3a.

Material examined.—Three specimens, IGPS coll. cat. nos. 112595–112597.

Descriptive remarks—The specimens are compressed and sub-evolute. It consists largely of phragmocone with a part of the living chamber. The shell diameter of the preserved end of no. 112595 is 36.4 mm with the corresponding height and umbilical diameter of 13.2 and 15.0 mm (*UD*/*D* = 0.41), respectively. At the diameter of ca. 32 mm, the height and umbilical diameter are 11.4 and 14.2 mm (*UD*/*D* = 0.44), respectively. The shell diameter of no. 112596 exceeds 35 mm in the deformed state. At the diameter of ca. 28.5 mm, about 60° adapical from the preserved end, the corresponding height and umbilical diameter are ca. 9.0 (*H*/*D* = 0.32) and 12.7 mm (*UD*/*D* = 0.45), respectively. At about 180° adapical from the preserved end (D = ca. 29 mm), height and umbilical diameter are 11.8 and 11.5 mm (*UD*/*D* = 0.40), respectively. No. 112597 exceeds 35 mm in diameter and the ratio of *UD*/*D* is ca. 0.41.

The side are broadly convex and the maximum width is about the center of the side. The steeply dipping umbilical wall is low but distinct with rounded umbilical shoulder. The ventral shoulder is rounded but the venter is not well preserved. The shell surface is ornamented with slightly rursiradiate, straight, coarse ribs, running from the umbilical wall to the ventral shoulder. The ribs are slightly broadened to the ventral shoulder, but seem to not cross the venter. There are 24 to 26 ribs per volution.

The ventral lobe is not preserved. There are three

rounded saddles on the lateral side. The second saddle is widest and the third is small. The first lateral lobe, having subparallel smooth sides, is wide and deep, and the base has four denticulations. The second lobe is small and bi- or tri-furcate. The auxiliary lobe is not seen.

The general shell shape, coarse ribbing and outline of the suture line of the present species resembles to those of *Danubites tozeri* Korchinskaya reported from the lower Anisian of Svalbard (Korchinskaya, 1982) and eastern Taimyr (Vavilov and Arkadiev, 1986). But the present forms differ from the latter two in having oval cross section instead of sub-square to sub-rectangular, and in having slightly rursiradiate ribs.

Occurrence.—Middle part (Fk-1a: no. 112595, 112597; Fk-1b: no. 112596) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Genus ***Paradanubites*** Shevyrev, 1968

Type species.—*Ceratites* (*Danubites*) *kansa* Diener, 1895b.

Paradanubites kansa (Diener)
Figures 9.1–9.3

Ceratites (*Danubites*) *kansa* Diener, 1895b, p. 103, pl. 29, fig. 1.
Ceratites (*Florianites*) *kansa* (Diener), Diener, 1907, p. 70, pl. 5, fig. 5.
Danubites kansa Diener, Diener, 1915, p. 116 ; Arkell et al., 1957 , p. 154, fig. 186.6.
Paradanubites kansa (Diener), Shevyrev, 1968, p. 123 ; He et al., 1986, p. 228, pl. 5, figs. 22–30, text-figs. 26c, 26f.

Material examined.—Three specimens, IGPS coll. cat. nos. 112598–112600.

Description.—The compressed shell of no. 112598 is moderately evolute. It consists of phragmocone and body chamber, and the latter occupies the about 3/4 of the preserved last whorl. The maximum shell diameter is about 77 mm and corresponding height and umbilical diameter are ca. 32.0 (*H*/*D* = 0.42) and 28. 2 mm (*UD*/*D* = 0.37), respectively. The ratios of *UD*/*D* of the inner volutions are slightly small (0.35–0.34). The cross section of the shell is elongated oval with convex sides and acutely rounded venter. The umbilical wall is steep with rounded umbilical shoulder. The ventral shoulders are broadly rounded. The maximum shell width is near the center of the flanks, but at the preserved end it is near the center, but a little to the venter. The shell surface is ornamented with strong radial ribs. They run from the umbilical wall, become thickening slightly, to the ventral shoulder and fade out. There are 34 (inner whorl) to 39 (last whorl) ribs per volution. The venter is smooth.

Other two specimens are fragmental. Specimen no. 112599 is a phragmocone, the diameter of which attains 48.8 mm and the ratio of *UD*/*D* is 0.42. On the last whorl, there are 34-35 radial ribs per volution. Specimen no. 112600 consists probably phragmocone and body chamber and its maximum diameter attains 40 mm, but it is ill preserved. It has 17-18 ribs per half volution.

The external lateral suture of no. 112598 consists of three rounded saddles and serrated lobes. The ventral lobe is not preserved. The first lateral lobe is very large and deep with sides slightly widened toward the base. The base of it is strongly serrated with deep denticulations and the lower half of the sides are also serrated. The second lobe is small and its base tri-furcate remarkably. The small auxiliary lobe has two denticulations. The first lateral saddle is narrow, the second is high and wide and the third is small. The external lateral suture of no. 112599 has deep and denticulate first lateral lobe, narrow second lateral saddle, small second lobe with four denticulations and small auxiliary lobe having two small denticulations.

Comparison.—The general shell shape, surface ornamentation and suture line of the present specimen are all very similar to those of the holotype of *Paradanubites kansa* (Diener).

Occurrence.—Middle part (Fk-1a: nos. 112598, 112599; Fk-1b: no. 112600) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Paradanubites cf. ***kansa*** (Diener)
Figures 9.4, 9.5

Synonym list compared see above.

Material examined.—Two specimens, IGPS coll. cat. nos. 112601, 112602.

Description.—Two large, discoidal and subevolute specimens are at hand. One specimen, no. 112601, consists of about two-thirds of inner volutions and a fragmental outer one. Its maximum diameter probably exceeds 120 mm. The body chamber occupies over one volution. The ratio of *UD*/*D* is estimated to be about 0.40. Sides are nearly flat to broadly convex with maximum width at the center of the side. The umbilical shoulder is broadly rounded and low wall is steeply dipping. The venter is probably acutely rounded, though it is not well preserved, with rounded shoulder. The shell surface is ornamented with radial ribs, which run from the umbilical wall to ventral shoulder. There are 15–16 ribs per half volution on the inner whorl. The ribs rarely bifurcate near the umbilical shoulder.

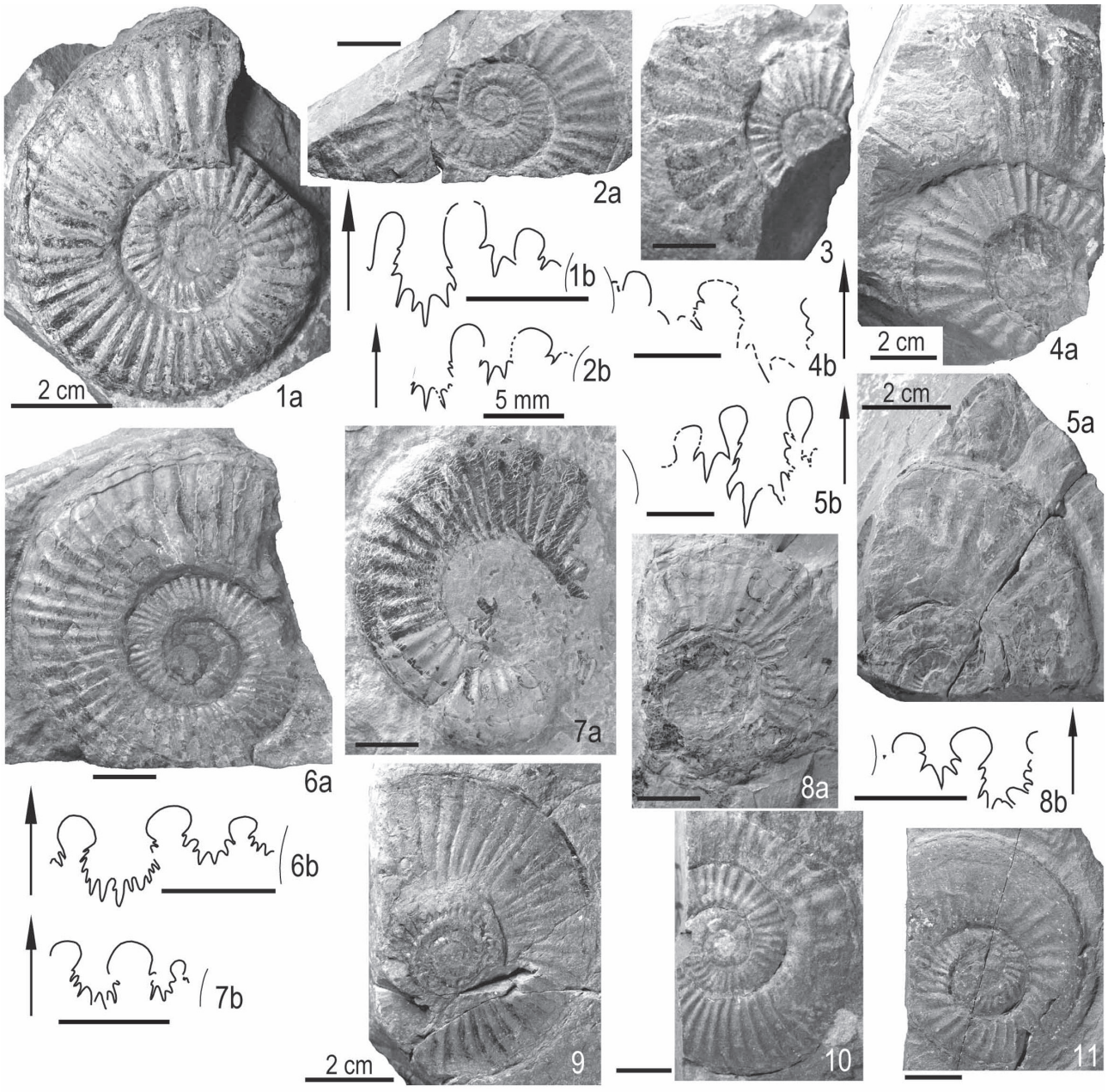

Figure 9. *Paradanubites* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan. **1**–**3**, *Paradanubites kansa* (Diener); 1, IGPS coll. cat. no. 112598; 1a, lateral view; 1b, suture line; 2, IGPS coll. cat. no. 112599; 2a, lateral view; 2b, suture line; 3, IGPS coll. cat. no. 112600, lateral view; **4** and **5**; *Paradanubites* cf. *kansa* (Diener); 4, IGPS coll. cat. no. 112601; 4a, lateral view; 4b, suture line; 5, IGPS coll. cat. no. 112602; 5a, lateral view; 5b, suture line; **6**–**8**, *Paradanubites phyllus* He; 6, IGPS coll. cat. no. 112606; 6a, lateral view; 6b, suture line; 7, IGPS coll. cat. no. 112607; 7a, lateral view; 7b, suture line; 8, IGPS coll. cat. no. 112608; 8a, lateral view; 8b, suture line; **9**–**11**, *Paradanubites* sp.; 9, IGPS coll. cat. no. 112610, lateral view; 10, IGPS coll. cat. no. 112611, lateral view; 11, IGPS coll. cat. no. 112612, lateral view. Scale bars are 1 cm unless otherwise stated.

Another specimen, no. 112602, is fragmental and a quarter of the shell is preserved. Its diameter probably reaches 80 mm. The side is nearly flat with acutely rounded umbilical and ventral shoulders. The umbilicus is shallow. On the shell surface there are rectiradiate ribs, about 12 per quarter (about 40 per volution) on the outer whorl.

The external suture lines are both partly preserved, although somewhat deformed. They consist of three narrow saddles, having rounded crests, and large and wide first lobe, small and shallow second lobe, and small auxiliaries near the umbilical margin. The base of the first lateral lobe has three deep denticulations and short denticulations extend up to the both sides, gradually diminishing in size. The second lobe also deeply denticulate at the base, but the number of denticulations is rather small: three to five? in no. 112601 and three in no. 112602.

Comparison.—The general shell shape, surface ornamentation and suture line of the present specimen are similar to those of *Paradanubites kansa* (Diener). But their shell sizes are larger than the known specimens of *P. kansa* and the details of the suture line somewhat differ from each other. Then, it is difficult to identify them with *P. kansa* definitely.

Occurrence.—Middle part (Fk-1b) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

***Paradanubites ozashiense* sp. nov.**

Figures 8.10–8.12

Material examined.—Three specimens, IGPS coll. cat. nos. 112603 (holotype), 112604 and 112605 (paratypes).

Etymology.—The species name is from the geographic name “Ozashi” near the fossil locality.

Diagnosis.—*Paranubites* having rursiradiate, convex, coarse ribs, the width and interspaces of them are somewhat irregular. The shell is moderately evolute with oval cross section. The umbilical side of the second lateral lobe is smooth.

Description.—Three specimens, slightly deformed obliquely and flattened laterally, are at hand. They consist of the phragmocone and body chamber, the latter occupies at least a half volution. The specimens are compressed and sub-evolute. The sides are broadly convex with acutely rounded umbilical shoulder and broadly rounded ventral shoulder. The maximum shell width is at about the center of the flank. The venter is probably rounded. The umbilicus is shallow, but with steep wall. The shell cross section is elongated oval. In holotype specimen, the maximum shell diameter attains ca. 51.0 mm, and corresponding height and umbilical diameter are 16.7 (*H*/*D* = 0.35) and 18.5 mm (*UD*/*D* = 0.39), respectively. In specimen no. 112604, the maximum shell diameter is ca. 48 mm, with ratios of *H*/*D* and *UD*/*D* are 0.35 and 0.39, respectively. Specimen no. 112605 attains a diameter of 33.5 mm and ratios of *H*/*D* and *UD*/*D* are 0.37 and 0.31, respectively. The shell surface is ornamented with slightly rursiradiate, convex ribs. They are simple and run from the umbilical wall, slightly strengthening to the venter, and reach to the venter. It is uncertain whether they cross the venter or not, because the venter is not fully preserved. The width of ribs and the width of interspaces are rather irregular and partly associated with very fine ribs. On the last whorl there are 39–40 (no. 112603) or 34–35 (no. 112604, 112605) primary ribs.

The ventral lobe is not fully preserved and only a part of one denticulate prong is visible. The depth is about two-thirds of that of the first lateral lobe. The first lateral lobe is deep with laterally expand sides and the outline of the lobe is ellipse. There are numerous strong denticulations on the base of it and shallow denticulations extend upwards, reducing in size, to two-thirds of the sides. The second lateral lobe is small and asymmetrical. The ventral side is long and serrated from the base to near the top, but the umbilical one is short and smooth. The auxiliary lobe is simple. All saddles have rounded crest. The second is widest and the first is rather elongated vertically.

Comparison.—The present new species is easily distinguished from other species of the genus *Paradanubites* in having small number of ribs, which are rursiradiate and have rather irregular widths and interspaces, and in having asymmetrical second lateral lobe.

Occurrence.—Middle part (Fk-1b) of the Fukkoshi Formation at the southern coast of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

***Paradanubites phyllus* He**

Figures 9.6–9.8

Paradanubites phyllus He in He et al., 1986, p. 231, pl. 6, figs. 22–29, text-figs. 26d, 26e.

Material examined.—Four specimens, IGPS coll. cat. nos. 112606–112609.

Description.—The shell is compressed and sub-evolute. The shell dimeter ranges from 42 to 55 mm, and the ratio of *UD*/*D* ranges 0.37 to 0.42. The flanks are broadly convex with rounded umbilical and ventral shoulders. The cross section of the shell is elongated oval and the maximum shell width is at the center to ventral one-thirds of the flanks. The venter is not well preserved. The umbilicus is shallow. The shell surface is ornamented with sharp ribs, which are rectiradiate and straight, but sometimes slightly concave. They run from the umbilical wall, become thickening slightly, to the ventral shoulder and fade out. There are 40 to 46 ribs

per volution.

The external lateral suture consists of three rounded saddles and serrated lobes. The ventral lobe is not preserved. The first lateral lobe is very large. Its sides expand laterally and the outline of the lobe is sub-circular. The base of it is strongly denticulate and the denticulations extend up to the two-thirds of sides. The outline of the second and probably third lateral lobes are similar to the first, but small and shallow. All lateral saddles have small, sub-circular crest.

Comparison.—The general shell shape, surface ornamentation and suture line, especially the external lateral suture line of the present specimens are very similar to those of *Paradanubites phyllus* He in He et al., 1986.

Occurrence.—Middle part (Fk-1a: of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Paradanubites sp.
Figures 9.9–9.11

Material examined.—Three specimens, IGPS coll. cat. nos. 112610–112612.

Descriptive remarks.—The shell is compressed and sub-evolute. The shell dimeter exceeds 50 mm. The ratio of *UD*/*D* is 0.40-0.42 in specimen no. 112611 at *D* = ca. 40 mm, and ca. 0.32 in specimen no. 112610 at *D* = ca. 70 mm. The flanks are broadly convex with rounded umbilical and ventral shoulders. The maximum shell width is near the center of the flank. The venter is not well preserved. The umbilicus is shallow. The shell surface is ornamented with strong rectiradiate ribs. They run from the umbilical wall, become thickening slightly, to the ventral shoulder and fade out. In specimen no. 112610, faint striae or growth lines also run parallel to the ribs. There are 40 to 45 ribs per volution. The suture is not preserved.

Based on the general shell shape and surface ornamentation, the specimens are considered to belong to the genus *Paradanubites*, and they somewhat resemble *Paradanubites phyllus* He. But I refrain from identifying them at the specific level since no suture line is preserved.

Occurrence.—Middle part (Fk-1a) of the Fukkoshi Formation at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Family Longobarditidae Spath, 1951
Subfamily Groenlanditinae Assereto, 1966
Genus ***Groenlandites*** Kummel, 1953

Type species.—*Groenlandites nielseni* Kummel, 1953.

Groenlandites sp.
Figures 9.1a, b

Material examined.—A specimen, IGPS coll. cat. no. 112613.

Descriptive Remarks.—A fragmental conch, about a half of a volution, is compressed and involute. The maximum shell diameter is ca. 23.0 mm and corresponding height and umbilical diameter are ca. 11.0 (*H*/*D* = 0.48) and ca. 2.0 mm (*UD*/*D* = 0.09), respectively. The maximum shell width is at the umbilical third to the central part of the side. The shell is laterally flattened tectonically and, in the deformed state, the maximum width is estimated larger than 6 mm. The sides are slightly convex with rounded ventral shoulder and the venter is rounded. The shell surface seems to be almost smooth.

The external lateral suture consists of five saddles and lobes. The ventral lobe is not preserved. The first lateral lobe is widest and deepest with strongly denticulate base. The second and third lobes, become narrower and shallower than the first, also have denticulate bases. The bases of the fourth and fifth lobes seem to be smooth. All saddles have rounded crests and become smaller to the umbilicus.

Based on the general shell outline and the shape of the suture, the present specimen is considered to belong to the genus *Groenlandites* Kummel, but the specific identification is difficult due to their poor state of preservation.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1a) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Genus ***Lenotropites*** Popov, 1961

Type species.—*Lenotropites solitarius* Popov, 1961.

Lenotropites spp.
Figures 9.2, 9.3

Material examined.—Two specimens, IGPS coll. cat. nos. 112614, 112615.

Descriptive Remarks.—Two small specimens, the conch of which are compressed and involute to sub-involute, are at hand. The smaller one (no. 112614) consists of phragmocone and body chamber, the latter occupies more than a half volution. It attains a maximum diameter of ca. 18.5 mm (at -60° from the preserved end) in the elliptically deformed state. Its corresponding height and umbilical diameter are ca. 9.0 and ca. 3.5 mm (*UD*/*D* = 0.19), respectively. The sides are broadly convex with the maximum width near the center of the side. The shell cross section is oval with broadly rounded umbilical shoulder and rounded ventral shoulder. The venter may be rounded. The umbilicus is shallow. Shell surface is ornamented with

sigmoidal faint ribs or growth lines.

The other specimen (no. 1126105) is also elliptically deformed and composed of phragmocone and body chamber. The body chamber reaches more than a volution. The maximum shell diameter is 25.8 mm (at -30° from the preserved end), and its corresponding height is 14.9 mm. The umbilicus is almost closed. The sides are broadly convex with rounded umbilical and broadly rounded ventral shoulders. The maximum width is near the umbilical shoulder to a little on the outer part, and the sides converge to the venter. The venter is probably rounded. Shell surface is ornamented with sigmoidal, low, faint ribs and/or growth lines.

In the both specimens the ventral suture are not preserved. In specimen no. 112614 the lateral suture consists probably of five set of saddle and lobe. The rounded saddles diminish in size towards the umbilicus. The first and second lateral lobes are deep with parallel sides and serrated base. The rest are small and shallow, and their bases are probably rounded. The lateral suture of the specimen no. 112615 consists of four saddles and at least three, probably four lobes. The crests of saddles are all rounded. The first one is the highest and the second to fourth are gradually diminish in their size. The first lateral lobe is large and deep with parallel sides. Its base is strongly denticulate. The second has a similar shape to the first but smaller in size. The third is small and simple.

Although two specimens slightly differ from each other in shell morphology and sutural traces, based on their general shell morphology and the shape of the suture line, they are considered to belong to the genus *Lenotropites* Popov, 1961. But it is difficult to identify them at the specific level because of their poor state of preservation.

Occurrence.—Both from the middle part of the Fukkoshi Formation (Fk-1b) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Subfamily Longobarditinae Spath, 1951
Genus ***Grambergia*** Popov 1961

Type species.—*Grambergia taimyrensis* Popov, 1961.

Grambergia cf. ***tetsaensis*** McLearn
Figures 9.4–9.8

cf. *Grambergia tetsaensis* McLearn, 1969, p. 36, p1. 7, figs. 1–5, text-fig. 15; He et al., 1986, p. 210, pl. 11, figs. 23–25, 31–33, text-fig. 15a; Tozer, 1994, p. 101, pl. 43, figs. 3, 4, pl. 44, figs. 3, 4, 10, text-figs. 31c, d.

Material examined.—Five specimens, IGPS coll. cat. nos. 112616–112620.

Description.—The specimens are small, ranging their maximum shell diameters from ca. 21 mm to ca. 32 mm. They are compressed with almost flat sides and very involute with the ratios of *UD*/*D* = 0.08–0.13. The specimen no. 112617 and 112619 have acutely rounded to acute ventral shoulder. In the specimen no. 112618, there is a faint spiral ridge near the venter on the flank, which probably corresponds to the ventral shoulder. The surface of the shell is almost smooth, but in the specimen no. 112618, some faint sigmoidal growth lines are present.

The external suture lines consist of shallow ventral lobe, deep and wide first lateral lobe and following 3–4 lobes and rounded saddles, but they vary in detail among specimens. The ventral lobe of the specimen no. 112616 is shallow and divided into serrated prongs by low, rounded median saddle. The first lateral lobe is widest and deepest with remarkable denticulation at the base. The second to fourth lateral lobes are also denticulate, but become considerably shallower and smaller than the first. The small fifth lobe is V-shaped and there is probably an additional lobe at the umbilical shoulder. All lateral saddles are rounded. The ventral lobes of other specimens are also shallow and divided into two prongs, but their precise shapes are not seen. The second lateral lobes of the specimens no. 112617 and 112618 bear denticulations at the base, whereas that of specimen no.112619 seems to be smooth, and the following lobes have smooth bases.

Discussion.—Based on their general shell shapes, having very compressed, nearly flat, smooth sides, and suture lines with shallow ventral lobe, considerably deep first lateral lobe and following 4–5 lobes, the present specimens are considered to belong to the genus *Grambergia* Popov 1961. They closely resemble *Grambergia tetsaensis* McLearn, 1969 in having deep first lateral lobe and high second saddle, but the precise identification is difficult due to the poor state of preservation and small size.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1a: nos. 112616–112618; Fk-1b: no. 112619; Fk-1c: no. 112620) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Subfamily Czekanowskitinae Tozer, 1994
Genus ***Arctohungarites*** Diener, 1916 b

Type species.—*Hungarites triformis* Mojsisovics, 1886.

Arctohungarites sp.
Figures 11.1–11.3

Material examined.—Three specimens, IGPS coll. cat. nos. 112621–112623.

Descriptive remarks.—Three more or less fragmental, imperfect specimens are at hand. The shell is compressed

and involute. Specimen no. 112621 consists of phragmocone and body chamber, but their boundary is not well known. The shell diameter exceeds 55 mm and estimated ratio of *UD*/*D* is ca 0.16. Specimen no. 112622 is a fragment of a shell having small umbilicus. Specimen no. 112623 attains a maximum diameter of ca. 59.0 mm, and its corresponding height and umbilical diameter are ca. 25.0 and 19.0 mm (*UD*/*D* = 0.32), respectively. The sides of the specimens are broadly convex, the maximum width of which is at about the center of the side. The venter is probably acutely rounded with rounded ventral shoulder. The umbilicus is shallow and its shoulder is acutely rounded. The shell cross section is thin lenticular, although its compressed shell shape is partly due to the tectonic deformation. The shell surface is ornamented with widely spaced, low and slightly sinuous ribs, which run from the umbilical shoulder to near the ventral shoulder. There are 12-13 ribs per half volution.

The poorly preserved external suture line consists of large and rounded first lateral saddle, large and deep first lateral lobe, the base of which is denticulate, second rounded saddle, medium-sized, serrated second lateral lobe, small rounded third saddle, small third lateral lobe and small fourth lateral saddle. The base of the third lobe is not well observed.

Based on the general shell shape, surface ornamentation and outline of external suture line, the present specimens are considered to belong to the genus *Arctohungarites* Diener, 1916b with high probability. But it is difficult to identify them at the specific level because of their poor state of preservation.

Occurrence.—All from the middle part of the Fukkoshi Formation (Fk-1b) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Longobarditidae? gen. and sp. indet.
Figure 9.10

Material examined.—One specimen, IGPS coll. cat. no. 112624.

Descriptive Remarks.—A small specimen is at hand. It is compressed and involute. The conch attains about 14.0 mm in diameter and the corresponding umbilical diameter is 2.8 mm (*UD*/*D* = ca. 0.20). The sides are convex and the venter is probably carinate or acutely rounded without remarkable ventral shoulder. The shell surface has rather strong, sinuous ribs. They run from the umbilical shoulder to the ventral one-fourth, with maximum height at the center of the side, and fade out. There are 25 ribs per volution. The suture is not preserved.

The general shell outline and its rib pattern of the present specimen are somewhat similar to those of *Groenlandites silberlingi* Tozer, 1994. But the present specimen is so small in size, poor state of preservation and lacks suture line. Moreover, some species belong to the longobarditid genera, such as *Lenotropites* Popov, 1961 and *Intornites* Assereto, 1966, have similar shell shape and ornamentation in their early ontogenetic stages.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1b) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Superfamily Arcestoidea Mojsisovics, 1875
Family Cladiscitidae Zittel, 1884
Subfamily Procladiscitinae Gamsjäger, 1982
Procladiscites Mojsisovics, 1882

Type species.—*Procladiscites broncoi* Mojsisovics, 1882.

Procladiscites brancoi Mojsisovics
Figures 11.4–11.6

Procladiscites broncoi Mojsisovics, 1882, p. 114, pl. 48, figs. 1–2 ; Arthaber, 1896, p. 85; 1915, p.175, pl. 5, fig. 8; He et al., 1986, p. 233, pl. 18, figs. 6–16, 20–22, text-figs. 28a–b; Germani, 1997, p. 288, pl. 3, figs. 2a–b, text-fig. 11.
Procladiscites brancoi Mojsisovics var., Salopek, 1911, p. 24, pl. 2, figs. 3a–b.
Procladiscites cf. *yasoda* Diener, Welter, 1915, p. 112, pl. 9, fig. 4.

Material examined.—Three specimens, IGPS coll. cat. nos. 112625–112627.

Description.—Two specimens (specimens no. 112625 and no. 112627) are side of the conch and the rest (no. 112626) is a fragment of the venter. The conch is compressed and involute with almost closed umbilicus. The sides are slightly convex with maximum width at half height of the whorl. The umbilical shoulder is rounded. The venter is not well preserved, but seems to be acutely rounded to rounded. The shell surface is ornamented with numerous spiral striae.

The lateral suture consists of phylloid and terminated lateral saddles and denticulate ptychitid lateral lobes. The ventral lobe, only preserved in the fragmental specimen (no. 112626), is divided into two prongs by a moderately high median saddle. The base of the prong has two deep denticulations. The crests of first three lateral saddles are semi-triangular. The second lateral saddle is the highest and then saddles are become smaller to the umbilicus. There are at least six, probably eight to nine, lateral lobes. The bases of these lobes are deeply denticulate. The second lateral lobe is the largest and deepest, and the third has about a half depth of the second and following ones become smaller to the umbilicus.

Discussion.—Based on the general shell shape and

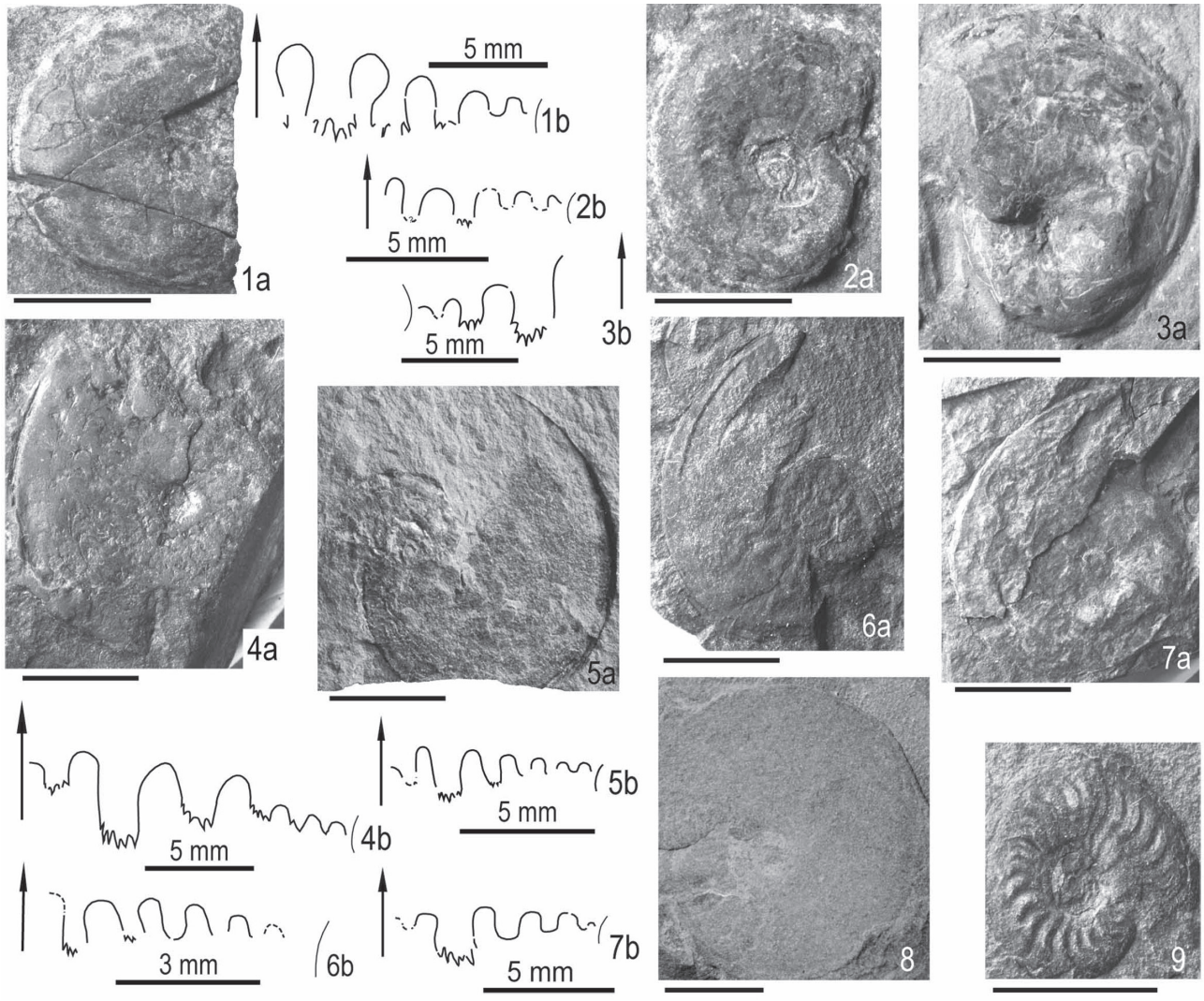

Figure 10. *Groenlandites*, *Lenotropites*, *Grambergia* and Longobarditidae? gen. and sp. indet. from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1, *Groenlandites* sp., IGPS coll. cat. no. 112613; 1a, lateral view; 1b, suture line; **2** and **3**, *Lenotropites* sp.; 2, IGPS coll. cat. no. 112614; 2a, lateral view; 2b, suture line; **3**, IGPS coll. cat. no. 112615; 3a, lateral view; 3b, suture line; **4**–**8**, *Grambergia* cf. *tetsaensis* McLearn; 4, IGPS coll. cat. no. 112616; 4a, lateral view; 4b, suture line; 5, IGPS coll. cat. no. 112617; 5a, lateral view; 5b, suture line; 6, IGPS coll. cat. no. 112618; 6a, lateral view; 6b, suture line; 7, IGPS coll. cat. no. 112619; 7a, lateral view; 7b, suture line; 8, IGPS coll. cat. no. 112620, lateral view; **9**, Longobarditidae? gen. and sp. indet., IGPS coll. cat. no. 112624. Scale bars are 1 cm unless otherwise stated.

surface ornamentation, the present species is well identified with *Procladiscites broncoi* Mojsisovics, 1882. They differ only in details of the median saddle of the ventral lobe: The sides of it is simple in the holotype, but serrated in the Fukkoshi specimen. Welter's (1915) specimen from Timor has similar serrated median saddles. ***P. towaensis*** (Bando and Ehiro) (originally described as *Eosturia towaensis* Bando and Ehiro, 1982) from the uppermostpart of the underlying Osawa Formation is somewhat similar to the present species in the general shape of the suture line, but clearly distingished by having lateral ribs along the ventral margin.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1a: nos. 112625, 112626; Fk-1b: no. 112627) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Procladiscites sp.
Figure 11.7

Material examined.—IGPS coll. cat. no. 112628.

Descriptive remarks.—Two fragments of lateral part and one fragment of ventral part, yield adjoining each other, are at hand. It is unclear whether they are parts of the same individual or not. The largest fragment consists of flat flank with the umbilical margin, which is slightly depressed gently. It attains more than 70 mm in height, and the umbilicus is rather small, probably less than 15 mm. Another small fragment of a part of a flank is also flat and more than 30 mm in height. The ventral fragment has broadly rounded venter and apparent shell width attains more than 27 mm. The shell surface of both the venter and flank are ornamented with numerous spiral striae. The suture is not preserved.

Although the specimens are fragmental, based on the estimated shell shape and surface ornamentation the present species is considered to belong to the genus *Procladiscites*. The specific identification, however, is difficult because of the poor state of preservation.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1b) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Order Phylloceratida Zittel, 1884
Superfamily Ussuritoidea Hyatt, 1900
Family Palaeophyllitidae Popov, in Luppov and Drushchits, 1958
Genus ***Leiophyllites*** Diener, 1915

Type species.—*Monophyllites suessi* Mojsisovics, 1882.

Leiophyllites cf. ***confucii*** (Diener)
Figure 12.1

cf. *Monophyllites Confucii* Diener, 1895b, p. 107, pl. 30, fig. 7, pl. 31, figs. 1, 2; Diener. 1907, p. 107, pl. 13, fig. 10; Arthaber, 1915, p. 151, pl. 13, fig. 6.
Monophyllites cf. *suessi* Toula, 1896, p. 171, pl. 20, fig. 7.
Monophyllites (*Leiophyllites*) *confucii* (Diener), Frech, 1903, p. 17, fig. 4; Diener, 1915, p. 205.
Monophyllites (*Monophyllites*) *confucii* Diener, Diener, 1907, p. 103, pl. 13, fig. 10.
Leiophyllites confucii (Diener), Wang et al., 1979, p. 53, pl. 14, figs, 9, 10, text-fig. 30a.
Leiophyllites visendus Shevyrev, 1968, p. 113, pl. 6, fig. 2, text-fig. 26.
Leiophyllites taramelti (Martelli), 1906, p. 135, pl. 6, figs. 3-4.

Material examined.—One specimen, IGPS coll. cat. no. 112529.

Descriptive remarks.—Small specimen is extremely discoidal and evolute to very evolute, with slowly increasing whorls. Specimen attains a diameter of ca. 17.0 mm, and its corresponding height and umbilical diameter are ca. 4.0 (*H*/*D* = 0.24) and 10.0-10.5 mm (*UD*/*D* = ca. 0.60), respectively. The sides are broadly convex and the maximum shell width is at the center of the flanks. The umbilical and ventral shoulders are rounded. The umbilicus is very shallow. The venter is not well preserved. Suture is not preserved.

Based on in its shell shape, especially having large umbilicus and slowly increasing height, the present species resemble to *Leiophyllites confucii* (Diener) described from Himalayas and eastern Europe. But, the precise identification at the specific level is difficult because it lacks suture line.

Occurrence.—Upper part (Fk-5) of the Fukkoshi Formation at the eastern coast of Terahama, Togura, Minamisanriku Towny, Miyagi Prefecture, Miyagi Prefecture.

Leiophyllites pitamaha (Diener)
Figures 11.2–11.7

Monophyllites pitamaha Diener, 1895b, p. 107, pl. 31, figs. 5, 7, 8.
Xenodiscus middlemissi Diener, 1895b, p. 110, pl. 30, fig. 6.
Monophyllites (*Leiophyllites*) *pitamaha* (Diener), Diener, 1915, p. 205; Kutassy, 1932, p. 595; Mitrova and Nestorovsky, 1960, p. 105, pl. 1, fig. 2.
Xenodiscus indo-australica Welter, 1915, p. 129, pl. 93, fig. 4.
Leiophyllites pitamaha (Diener), Spath, 1934, p. 297; Shevyrev, 1968, p. 112, pl. 6, fig. 3, text-fig. 25; Wang et al., 1979, p. 54, pl. 15, fig.4; Fantini Sestini, 1981, p. 57; He et al., 1986, p. 252, pl. 16, figs. 4–12, 16–22, text-fig. 29.
Leiophyllites? *middlemissi* (Diener). Spath, 1934, p. 308.
Xenaspis laevis Welter. Bender, 1970, p. 429, pl. 2, fig. 8.
Leiophyllites stoecklini Tozer, 1972, p. 37, pl. 5, fig. 5, text-fig. 2B.
Leiophyllites cf. *middlemissi* (Diener). Wang and He, 1976, p. 429, pl. 47, figs. 6–8, text-fig. 73c.
Leiophyllites cf. *pitamaha* (Diener). Wang and He, 1976, p. 430, pl. 47, figs. 14, 15, pl. 48, figs. 8, 9, text-fig. 73e.
Leiophyllites aff. *pitamaha* (Diener). Fantini Sestini, 1988, p. 69, pl.14, fig. 5.

Material examined.—Seven specimens, IGPS coll. cat. nos. 112630–112636.

Description.—The shell is discoidal and evolute. The

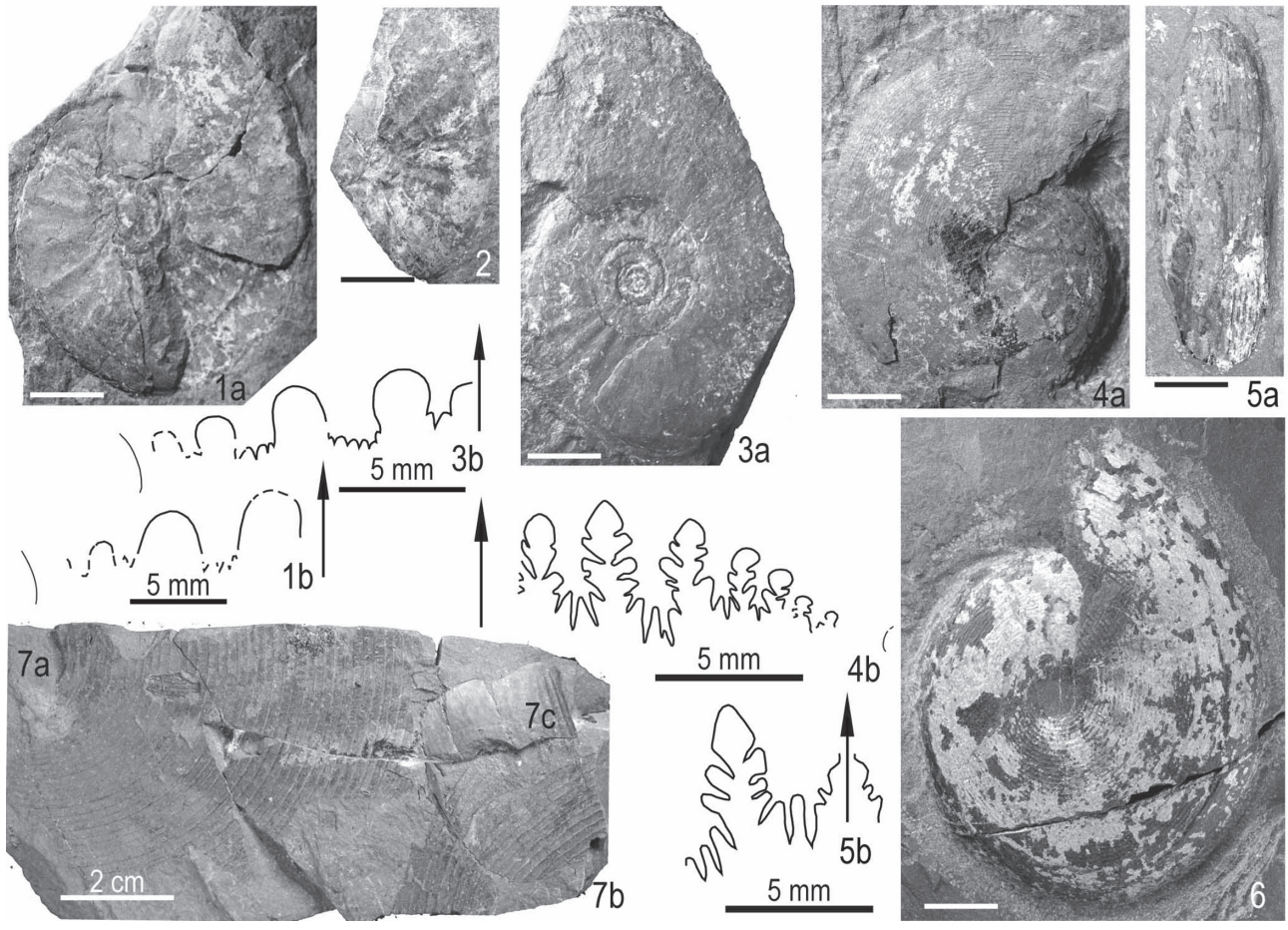

Figure 11. *Arctohungarites* and *Procladiscites* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1–**3**, *Arctohungarites* sp.; 1, IGPS coll. cat. no. 112621; 1a, lateral view; 1b, suture line; 2, IGPS coll. cat. no. 112622, lateral view; 3, IGPS coll. cat. no. 112623; 3a, lateral view; 3b, suture line; **4**–**6,** *Procladiscites brancoi* Mojsisovics; 4, IGPS coll. cat. no. 112625; 4a, lateral view; 4b, suture line; 5, IGPS coll. cat. no. 112626; 5a, ventral view; 5b, suture line; 6, IGPS coll. cat. no. 112627, lateral view; **7**, *Procladiscites* sp., IGPS coll. cat. no. 112628, lateral (7a and 7b) and ventral (7c) views. Scale bars are 1 cm unless otherwise stated.

maximum diameter ranges from 28 mm to more than 75 mm. The larger specimens (D > 40 mm) are composed of phragmocone and body chamber, the latter occupies over a half volution. The ratio of *H*/*D* ranges from 0.26 to 0.39, but mostly about 0.30. The ratio of *UD*/*D* ranges from 0.44 to 0.53, but mostly 0.48 to 0.53 (Table 3). The sides are nearly flat to slightly convex. The umbilicus is shallow with moderately inclined wall and rounded umbilical shoulder. The venter is acutely rounded with broadly rounded umbilical shoulder which continued to the flanks without clear boundary. The cross section is compressed oval. Inner whorls are sometimes ornamented by faint and low, radial to concave ribs or fold. The surface of outer whorls is almost smooth, but often have faint sigmoidal ribs or growth lines. Constrictions parallel to the ribs or growth lines are rarely visible on the last whorl.

The ventral lobe is not well preserved, but shallow. The first lateral lobe is wide and its base has irregular, strong denticulations, seven to eight in number. The second lobe is small, but it also has four to five strong denticulations. Auxiliary lobe is simple and pointed. There are three saddles on the lateral side. The saddles are all rounded and narrowed toward the base. The second saddle is highest and the third is small.

Discussion.—The present specimens are very similar to *Leiophyllites pitamaha* Diener reported from the Anisian

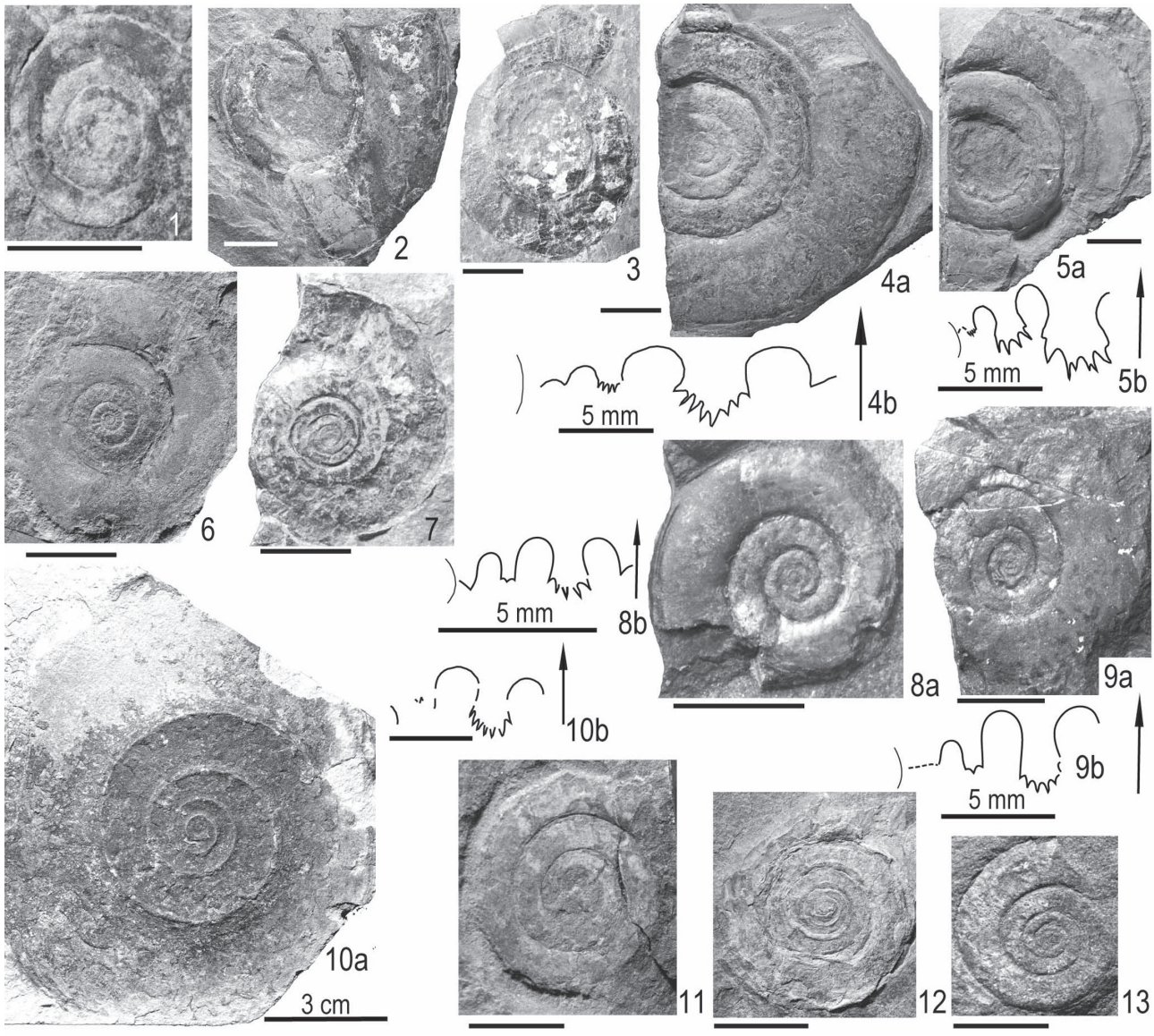

Figure 12. *Leiophyllites* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan. **1**, *Leiophyllites* cf. *confucii* (Diener), IGPS coll. cat. no. 112629, lateral view; **2**–**7**, *Leiophyllites pitamaha* (Diener); 2, IGPS coll. cat. no. 112632, lateral view; 3, IGPS coll. cat. no. 112633, lateral view; 4, IGPS coll. cat. no. 112630; 4a, lateral view; 4b, suture line; 5, IGPS coll. cat. no. 112631; 5a, lateral view; 5b, suture line; 6, IGPS coll. cat. no. 112635, lateral view; 7, IGPS coll. cat. no. 112636, lateral view; **8** and **9**, *Leiophyllites* cf. *praematurus* Kiparisova; 8, IGPS coll. cat. no. 112637; 8a, lateral view; 8b, suture line; 9, IGPS coll. cat. no. 112638; 9a, lateral view; 9b, suture line; **10**, *Leiophyllites* sp. A; 10a, lateral view; 10b, suture line; **11**–**13**, *Leiophyllites* sp. B; 11, IGPS coll. cat. no. 112657, lateral view; 12, IGPS coll. cat. no. 112658, lateral view;13, IGPS coll. cat. no. 112661, lateral view. Scale bars are 1 cm unless otherwise stated.

strata of Himalayas, Qinghai and east Europe, in the general shell shape, surface ornamentation, although the umbilicus of the present specimens is slightly larger than that of the holotype (*UD*/*D* = 0.44).

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1c: no. 112635; Fk-1a: nos. 112630–112634) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, and upper part (Fk-6: no. 112636) at the eastern coast of Terahama, Togura, Minamisanriku Town, Miyagi Prefecture.

Table 3. Dimensions (in mm) and ratios of *Leiophyllites pitamaha* (Diener) from the Fukkoshi Formation. Abbreviations see Table 1.

IGPS no.	α	*D*	*H* (*H*/*D*)	*W*	*UD* (*UD*/*D*)
112630	-90°	ca.53.0	15.5 (0.29)	4-5	26.5 (0.50)
	-180°	ca.38.0	11.5 (0.30)		20.0 (0.53)
112631	0°	ca.55.0	14.5 (0.26)	?	28.5 (0.52)
	-90°	ca.40.5	12.0 (0.30)		20.0 (0.53)
112632	-90°	47.4	ca.18.5 (0.39)		20.8 (0.44)
112633	0°	ca.55.0	ca.15.0 (0.37)		27.5 (0.50)
112634	0°	56.4	16.4 (0.29)		27.5 (0.49)
112635	0°	ca.34.5	9.6 (0.28)		16.4 (0.48)
112636	0°	29.4	10.5 (0.33)		13.7 (0.46)

Leiophyllites cf. ***praematurus*** Kiparisova, 1958
Figures 11.8, 11.9

cf. *Leiophyllites praematurus* Kiparisova, in Kiparisova and Popov, 1958, p. 32, pl. 7, fig. 13, text-fig. 17б; Kiparisova, 1961, p. 134, pl. 28, figs. 5, 6, text-figs. 101, 102.

Leiophyllites pitamaha Diener. Kummel, 1969, p. 531, text-fig. 49B.

Material examined.—Two specimens, IGPS coll. cat. nos. 112637, 112638.

Descriptive remarks.—Two specimens are both phragmocone, and the shell is discoidal and sub-evolute to evolute. The maximum shell diameter of the small specimen (no. 112636) is 19.6 mm and the corresponding height and umbilical diameter are 5.6 (*H*/*D* = 0.29) and 9.0 mm (*UD*/*D* = 0.46), respectively. The larger specimen (no. 112637) attains a maximum diameter of ca. 25 mm and its corresponding height and umbilical diameter are ca. 9.5 (*H*/*D* = 0.38) and 10.2 mm (*UD*/*D* = 0.41), respectively. The sides are rounded in the smaller specimen and broadly convex in the larger one, with the maximum width near the center of the flank. The venter of the small specimen is rounded with a keel. That of the larger specimen is not well preserved. The umbilicus is shallow. Both the ventral and umbilical shoulder are indistinct and rounded to convex side continue to the venter and umbilical wall. The conch section is compressed oval, and that of the larger one is more compressed. There are short, low but wide ribs, slightly curved backward, on the inner side of the flanks of the smaller specimen. The shell surface of the larger specimen is nearly smooth, but similar short ribs are on the inner whorls.

The ventral lobe is not seen. The external lateral suture consists of three saddles, two lobes and auxiliary ones. All saddles have rounded crests and nearly parallel sides. The first and second saddles have nearly the same height, but the third is considerably small. The first lateral lobe is deep with subparallel sides. The base of it has six strong denticulations and the lower part of the sides are also denticulate, though very weak. The second lobe is shallow and its base has three short or indistinct denticules. The auxiliary lobe is simple and pointed.

Although there are some differences in the ratio of *H*/D and *UD*/*D* and surface ornamentation between the two materials described, their general shell form and sutural shape resemble those of *Leiophyllites praematurus* Kiparisova (1958, 1968). But the present species differs from the latter in having a ventral keel. The present species also somewhat resembles *L. laevis* (Welter) form 1 (originally as *Xenaspis laevis*) from the Anisian of Timor (Welter, 1915, p. 130, pl. 10, figs. 7a–7b). The Timor specimen differs from *L. praematurus* in having larger umbilicus and in having downwardly narrowed saddles.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1a: no. 112637; Fk-1b: 112638) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Leiophyllites suessi (Mojsisovics)
Figures 13.1–13.7

Monophyllites Suessi Mojsisovics, 1882, p. 205, pl. 79, fig.4; Hauer, 1887, p. 33; Patte, 1926, p. 185, pl. 12, figs. 6, 7.

Monophyllites (*Mojsvarites*) *Suessi* Mojsisovics, Kraus, 1916, p. 289.

Monophyllites (*Leiophyllites*) *Suessi* (Mojsisovics), Renz, 1931, p. 57; Kutassy, 1932, p. 595.

Leiophyllites suessi (Mojsisovics), Spath, 1934, p. 303, text-fig. 104b; Wiedmann, 1970, p. 969, pl. 1, figs. 1, 2, text-fig. 3.

Leiophyllites pradyumna (Diener), Zakharov, 1968, p. 124, pl. 23, figs. 2, 3, text-fig. 29h.

Leiophyllites suessi (Mojsisovics), Krystyn and Tatzreiter, 1991, p. 142, pl. 2, fig. 7.

Material examined.—Ten specimens, IGPS coll. cat. nos. 112639–112648.

Description.—The shell is discoidal and sub-evolute to evolute. The maximum diameter ranges from 24 mm to more than 70 mm. They are composed of phragmocone and body chamber, the latter occupies over three-fourth of the last whorl. The ratio of *H*/*D* ranges from 0.29 to 0.35 (mostly 0.31-0.35) and that of *UD*/*D* ranges from 0.41 to 0.53 (mostly 0.45-0.48) (Table 4). The sides are broadly convex to rounded with maximum width near the umbilical shoulder to the center of the flank. The venter is acutely rounded with rounded ventral shoulder. The umbilicus is shallow. There

Table 4. Dimensions (in mm) and ratios of *Leiophyllites suessi* (Mojsisovics) from the Fukkoshi Formation. Abbreviations see Table 1.

IGPS no.	α	*D*	*H* (*H*/*D*)	*W*	*UD* (*UD*/*D*)
112639	-90°	47.1	15.8 (0.34)		21.6 (0.46)
112640	-30°	49.8	14.2 (0.29)		22.6 (0.45)
112641	0°	45.4	14.2 (0.31)		21.3 (0.47)
112642	-30°	ca.70.0	23.8 (0.34)		31.5 (0.45)
112643	-90°	ca.61.0	19.0 (0.31)		29.0 (0.48)
112644	0°	ca.24.0	ca.7.0 (0.29)		11.5 (0.48)
112645	0°	ca.58.0	ca.18.0 (0.31)		27.0 (0.47)
112646	0°	ca.55.0	19.2 (0.35)		23.6 (0.43)
112647	-30°	ca.35.0	11.8 (0.34)		14.5 (0.41)
112648	0°	ca.28.0	9.8 (0.35)		14.7 (0.53)

is no remarkable umbilical shoulder and the sides gradually down into the umbilical seam. The cross section of the conch is elongated oval. The shell surface is almost smooth, but on the last whorl there are faint, slightly convex to falcoid ribs or growth lines. Many strong and wide constrictions, which are also convex to falcoid, are also visible on the outer whorl. They number four to eight, mostly six to seven per volution.

The external suture consists of three saddles, two lobes and auxiliary ones. The ventral lobe is not well preserved and only a part of the prong, having at least three denticulations at the base, is visible. The crests of saddles are all rounded. The saddles are vertically elongated and become narrower downward. The second one is the highest. The first lateral lobe is deep and wide, and expanded base has five to seven (mostly five) strong denticulations. The second lobe has a similar shape to the first, including the denticulation, but smaller in size, The auxiliary one is composed of a small, pointed lobe, and low and wide saddle on the umbilical shoulder.

Discussion.—The present specimens from the Fukkoshi Formation are very similar to *Leiophyllites suessi* (Mojsisovics) reported from the Anisian strata of east Europe in the general shell shape, surface ornamentation and the outline of the suture line. A slight deference between them is a number of constrictions. The Fukkoshi specimens have more constrictions than the European specimens. *Leiophyllites pradyumna* (Diener) resembles to *Leiophyllites suessi* (Mojsisovics) in the general shell shape and shape of the suture. But it differs from the latter in having bulges (ribs) instead of constrictions on the shell surface. *L. pseudopradyumna* Welter, 1915 is also distinguished from the present species in having bulges.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1c: nos. 112645–112648; Fk-1a: nos. 112639–112644) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Leiophyllites wakoi Ehiro, Sasaki and Kano
Figures 14.1–14.6

Leiophyllites wakoi Ehiro, Sasaki and Kano, 2016, p. 99, figs. 4.4a–d.

Material examined.—Seven specimens, IGPS coll. cat. nos. 112649–112655.

Descriptive remarks.—Small- to medium-sized shells are discoidal and evolute. They consist of phragmocone and a part of the body chamber. The shell diameter ranges from ca. 25 to 58 mm. The ratio of *H*/*D* ranges from 0.27 to 0.31 and that of *UD*/*D* varies from 0.47 to 0.53 (mostly around 0.50) (Table 5). The sides are broadly convex to flat at maturity, with broadly rounded umbilical and ventral shoulders. The maximum conch width is near the center of the flank. The cross section is flattened oval. The shell surface of the inner whorls seems to be smooth, whereas fine but distinct, biconcave ribs are on the outer whorl. Some shallow constrictions parallel to the ribs are also present.

The ventral lobe is not well preserved and only a part of its prong is visible, which has denticulate base. The first lateral lobe is large and its rounded base has five to seven, slightly irregular denticulations. The second lobe is about half depth of the first and asymmetrical. It has four to six denticulations. Main deep denticulations are at the base. Small, one or two denticulations are up to the lower part of the ventral side, whereas the umbilical side is smooth. The auxiliary lobe is simple and pointed. There are three rounded saddles on the lateral side. The second is largest and highest, and the third is small.

The general shell shape and especially the biconcave ribs on the last volution of the present specimens are closely similar to those of *Leiophyllites wakoi* described by Ehiro

Table 5. Dimensions (in mm) and ratios of *Leiophyllites wakoi* Ehiro, Sasaki and Kano from the Fukkoshi Formation. Abbreviations see Table 1.

IGPS no.	α	*D*	*H* (*H*/*D*)	*W*	*UD* (*UD*/*D*)
112649	0°	ca.39.5	ca.11.0 (0.28)		20.4 (0.52)
	-180°	28.4	ca.8.0 (0.28)		15.1 (0.53)
112650	-70°	ca.34.0	10.2 (0.30)		17.1 (0.50)
112651	0°	ca.30.5	ca.8.8 (0.29)		15.6 (0.51)
112652	0°	ca.33.0	ca.10.0 (0.30)		16.4 (0.50)
112653	-60°	ca.25.4	ca.8.0 (0.31)		12.4 (0.49)
112654	-90°	ca.58.0	15.7 (0.27)	4-	29.0 (0.50)
112655	0°	ca.31.5	ca.9.5 (0.30)		14.8 (0.47)

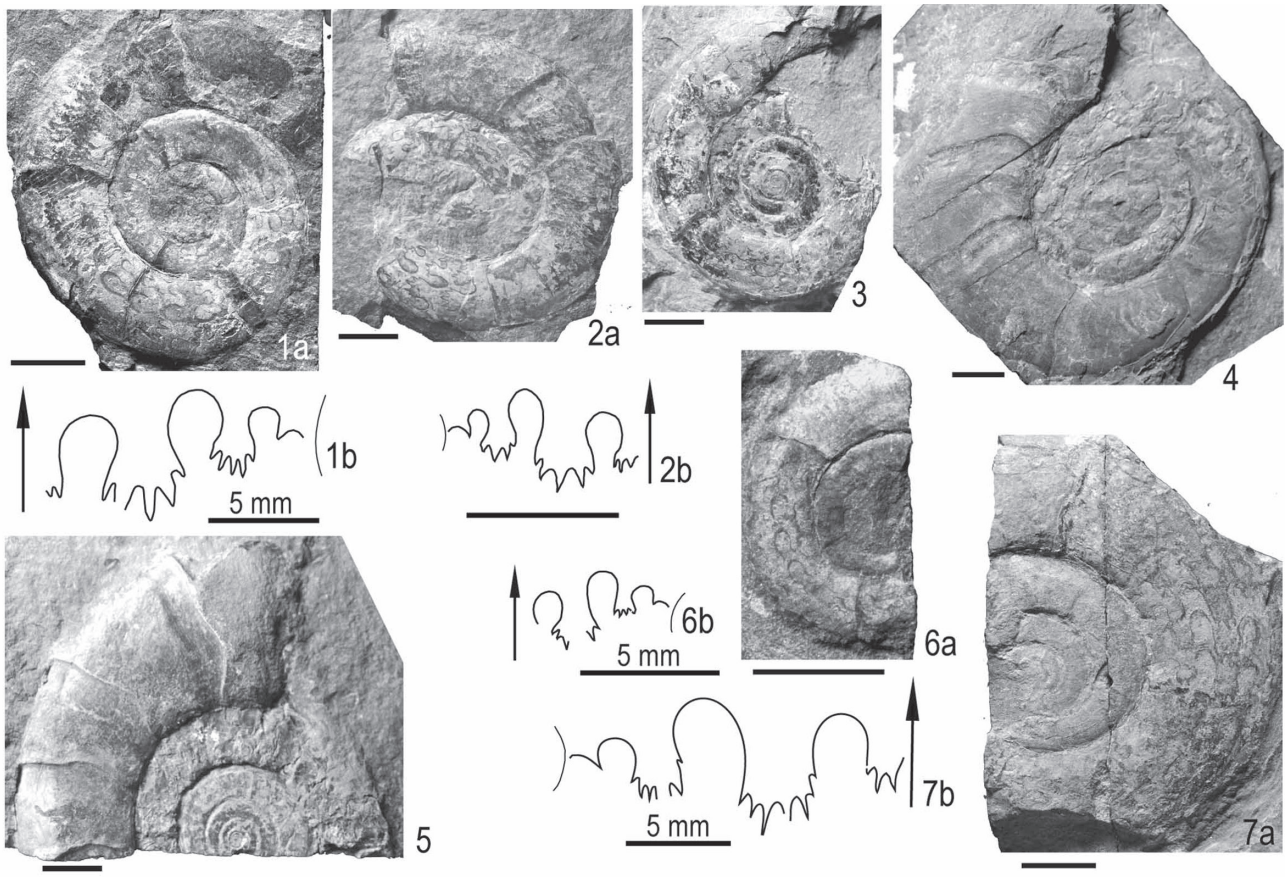

Figure 13. *Leiophyllites suessi* (Mojsisovics) from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1, IGPS coll. cat. no. 112639; 1a, lateral view; 1b, suture line; 2, IGPS coll. cat. no. 112640; 2a, lateral view; 2b, suture line; 3, IGPS coll. cat. no. 112641, lateral view; 4, IGPS coll. cat. no. 112642, lateral view; 5, IGPS coll. cat. no. 112643, lateral view; 6, IGPS coll. cat. no. 112644; 6a, lateral view; 6b, suture line; 7, IGPS coll. cat. no. 112645; 7a, lateral view; 7b, suture line. Scale bars are 1 cm unless otherwise stated.

et al. (2016) from the underlying late Olenekian Osawa Formation. The ratio of *UD*/*D* of the latter is rather small (0.40 at *D* = 65-90 mm), but it is 0.45–0.46 at *D* = 43 mm, and almost the same as the present specimens.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1a: nos. 112649, 112651–112654; Fk-1b: nos. 112650, 112655) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Leiophyllites sp. A
Figure 12.10a, b

Material examined.—One specimen, IGPS coll. cat. no. 112656.

Descriptive remarks.—An outer mold of moderately large specimen with impressions of suture lines are at hand. It consists of phragmocone and body chamber, the latter occupies about a half part of the last volution. The shell is probably extremely discoidal and sub-evolute. The maximum shell dimeter attains more than 97 mm, and at *D* = ca. 81 mm, corresponding height and umbilical diameter are ca. 25.0 and 35. 5 mm (*UD*/*D* = 0.44), respectively. The side is broadly convex with broadly rounded umbilical and ventral shoulders. The maximum shell width is near the umbilical shoulder and the sides slightly converge to the venter. The venter is not well preserved. The shell surface is almost smooth. The external lateral suture, preserved as impressions on the outer mold, consists of the first and second lateral saddles and first and second lateral lobes. The crests of saddles are both rounded and the second lateral saddle is higher than the first. The first lateral lobe is deep and wide, and its base has many denticulations. The

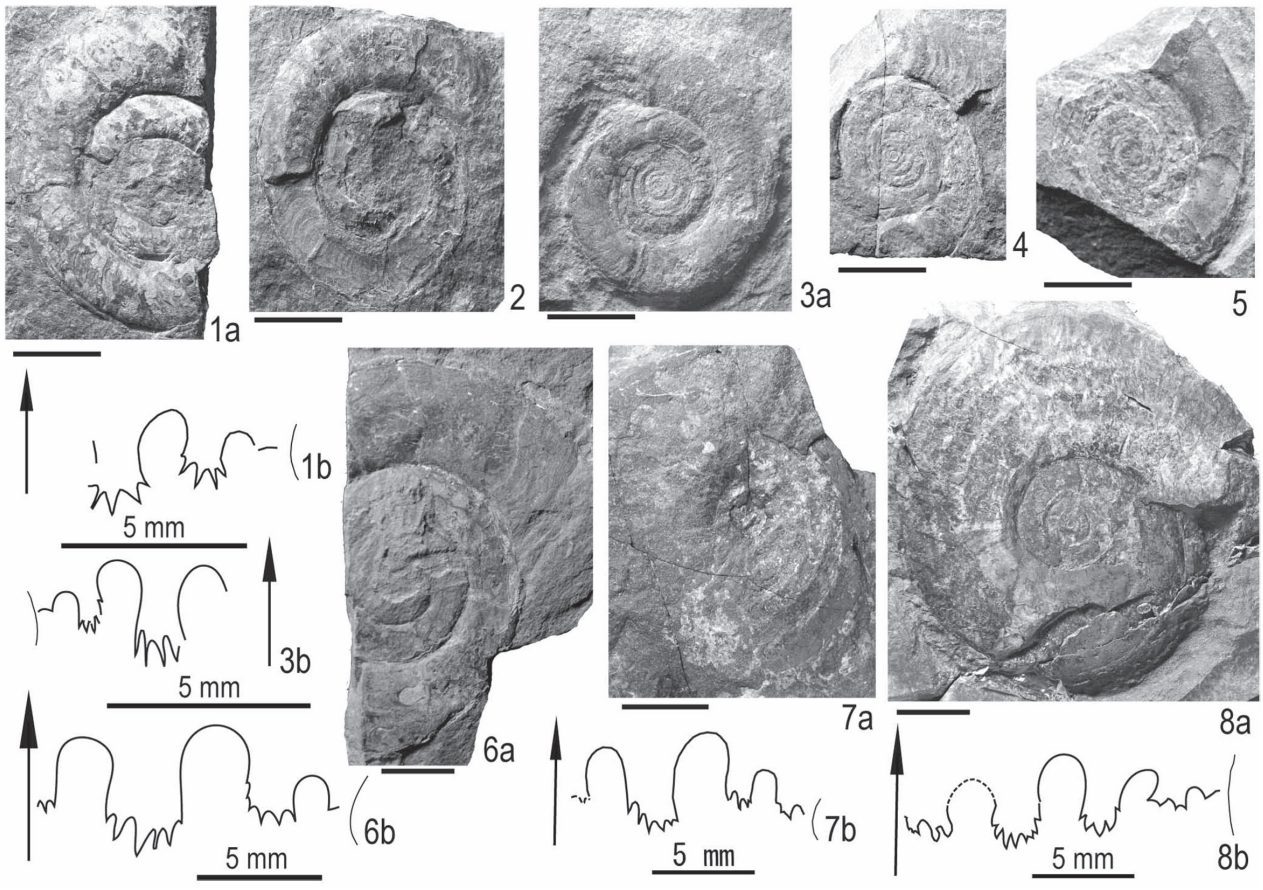

Figure 14. *Leiophyllites wakoi* and *Ussuriphyllites amurensis* from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan.
1–**6**, *Leiophyllites wakoi* Ehiro, Sasaki and Kano; 1, IGPS coll. cat. no. 112649; 1a, lateral view; 1b, suture line; 2, IGPS coll. cat. no. 112650, lateral view; 3, IGPS coll. cat. no. 112651; 3a, lateral view; 3b, suture line; 4, IGPS coll. cat. no. 112652, lateral view; 5, IGPS coll. cat. no. 112653, lateral view; 6, IGPS coll. cat. no. 112654; 6a, lateral view; 6b, suture line; **7** and **8**; *Ussuriphyllites amurensis* (Kiparisova); 7, IGPS coll. cat. no. 112663; 7a, lateral view; 7b, suture line; 8, IGPS coll. cat. no. 112662; 8a, lateral view; 8b, suture line. Scale bars are 1 cm unless otherwise stated.

second lobe is shallow and small, and its base is probably tri-denticulate. The ventral lobe is not preserved and there is some space between the third saddle and the umbilical edge.

Based on the general shell form and suture line, the present specimen is considered to belong certainly the genus *Leiophyllites* Diener, 1915, but the specific identification is difficult because of its poor state of preservation. This specimen is clearly larger than the other *Leiophyllites* species collected from nearly the same horizon at the south of Ozashi (Fk-1a–1c).

Occurrence.—Middle part of the Fukkoshi Formation (Fk-3a) at the west of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Leiophyllites sp. B
Figures 12.11–12.13

Material examined.—Five specimens, IGPS coll. cat. nos. 112657–112661.

Descriptive remarks.—Small shells are discoidal and evolute. The maximum shell diameter ranges from ca. 20 to 40 mm. The ratio of *H*/*D* ranges from 0.20 to 0.32, but mostly around 0.30. The ratio of *UD*/*D* varies from 0.47 to 0.60. They have five to six volutions at *D* = 20 mm. The sides are broadly convex to flat, with broadly rounded umbilical and ventral shoulders. The maximum conch width is near the center of the flank. The umbilicus is very shallow. The cross section is flattened oval. The shell surface is almost smooth.

The suture is not preserved.

Based on the general shell form, the present specimen is considered to belong certainly the genus *Leiophyllites* Diener, 1915 and somewhat similar to the juvenile shell of *L. pitamaha*, but the specific identification is difficult because they lack of suture line and are poor state of preservation.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1c: nos. 112657–112660; Fk-1a: no. 112661) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Genus ***Ussuriphyllites*** Zakharov, 1967

Type species.—*Eophyllites amurensis* Kiparisova, 1961.

Ussuriphyllites amurensis (Kiparisova)
Figures 14.7, 14.8

Eophyllites amurensis Kiparisova, 1961, p. 137, pl. 28, figs. 7, 8, text-fig. 104.

Ussuriphyllites amurensis (Kiparisova), Zakharov, 1967, p. 50, pl. 4, figs. 8–10, text-figs. 1g, 1h, 2; Zakharov, 1968, p. 123, pl. 22, figs. 12, 13, pl. 23, fig. 1; Zakharov et al., 2005a, fig. 3; Zakharov et al., 2005b, fig. 8; Shigeta and Kumagae, 2016, p. 54, figs. 6A, 6B.

Material examined.—Two specimens, IGPS coll. cat. nos. 112662, 112663.

Description.—Two specimens are discoidal and sub-involute, and consists of phragmocone and body chamber, the latter of which occupies about three-fourth of the last whorl. The sides are broadly convex. The maximum width is at about the center of the flank, from where the flank converges to both the venter and umbilicus. The umbilicus is very shallow without distinct umbilical wall. The venter is not well preserved, but seems to be acute or carinated. The shell cross section is lenticular. The maximum shell dimeter of specimen no. 112662 attains more than 60 mm, and at *D* = ca. 58 mm, corresponding height and umbilical diameter are 23.8 and 15.5 mm (*UD*/*D* = 0.28), respectively. Another smaller specimen (no. 112663: max. D > 45 mm) has rather small umbilicus (*UD*/*D* < 0.08). The shell surface is ornamented with faint, slightly sigmoidal, fine radial ribs and fine, sparse, concentric ribs. There are four to five concentric ribs between the umbilical shoulder to the ventral shoulder.

The ventral lobe is partly preserved and its base is serrated. Three lateral saddles have rounded crest. The second is largest and the third is small. The first and second lateral lobes are denticulate at the base and the denticulations are up to the one-third of the sides in the specimen no. 112662. The auxiliary loves are irregular in shape and size.

Discussion.—The shell shape, surface ornamentation and outline of the suture line of the present specimens from the Fukkoshi Formation are identical with those of *Ussuriphyllites amurensis* (Kiparisova) reported from the Triassic strata of South Primorye, Far East Russia, although the umbilicus is rather small in the small specimen.

Occurrence.—Middle part of the Fukkoshi Formation (Fk-1a: no. 112662; Fk-1b: no. 112663) at the south of Ozashi, Jusanhama, Kitakami-cho, Ishinomaki City, Miyagi Prefecture.

Discussion

Ammonoid fauna of the Fukkoshi Formation and its geologic age

Fukkoshi ammonoid fauna comprises 13 families, 21 genera and about 40 species listed below:

Family Hemilecanitidae
- *Hemilecanites discus* (Arthaber)

Family Sageceratidae
- *Parasageceras* aff. *discoidale* Welter

Family Hedenstroemiidae
- *Pseudosageceras multilobatum* Noetling

Family Parapopanoceratidae
- *Parapopanoceras involutum* sp. nov.

Family Megaphyllitidae
- *Megaphyllites* sp.

Family Khvalynitidae
- *Metadagnoceras* spp.
- *Psilokhvalynites takaizumii* gen. and sp. nov.

Family Acrochordiceratidae
- *Paracrochordiceras* cf. *denseplicatum* Fantini Sestini
- *Paracrochordiceras watanabei* sp. nov.
- *Paracrochordiceras* spp.

Family Japonitidae
- *Aegeiceras*? sp.
- *Eogymnites* sp.
- *Japonites* cf. *meridianus* Welter
- *Japonites raphaelizoyae* (Tommasi)
- *Japonites* spp.

Family Gymnitidae
- *Buddhaites*? sp.

Family Danubitidae
- *Danubites* cf. *ambika* Diener
- *Danubites floriani* (Mojsisovics)
- *Danubites* cf. *tozeri* Korchinskaya
- *Paradanubites kansa* (Diener)
- *Paradanubites* cf. *kansa* (Diener)
- *Paradanubites ozashiense* sp. nov.
- *Paradanubites phyllus* He
- *Paradanubites* sp.

Family Longobarditidae

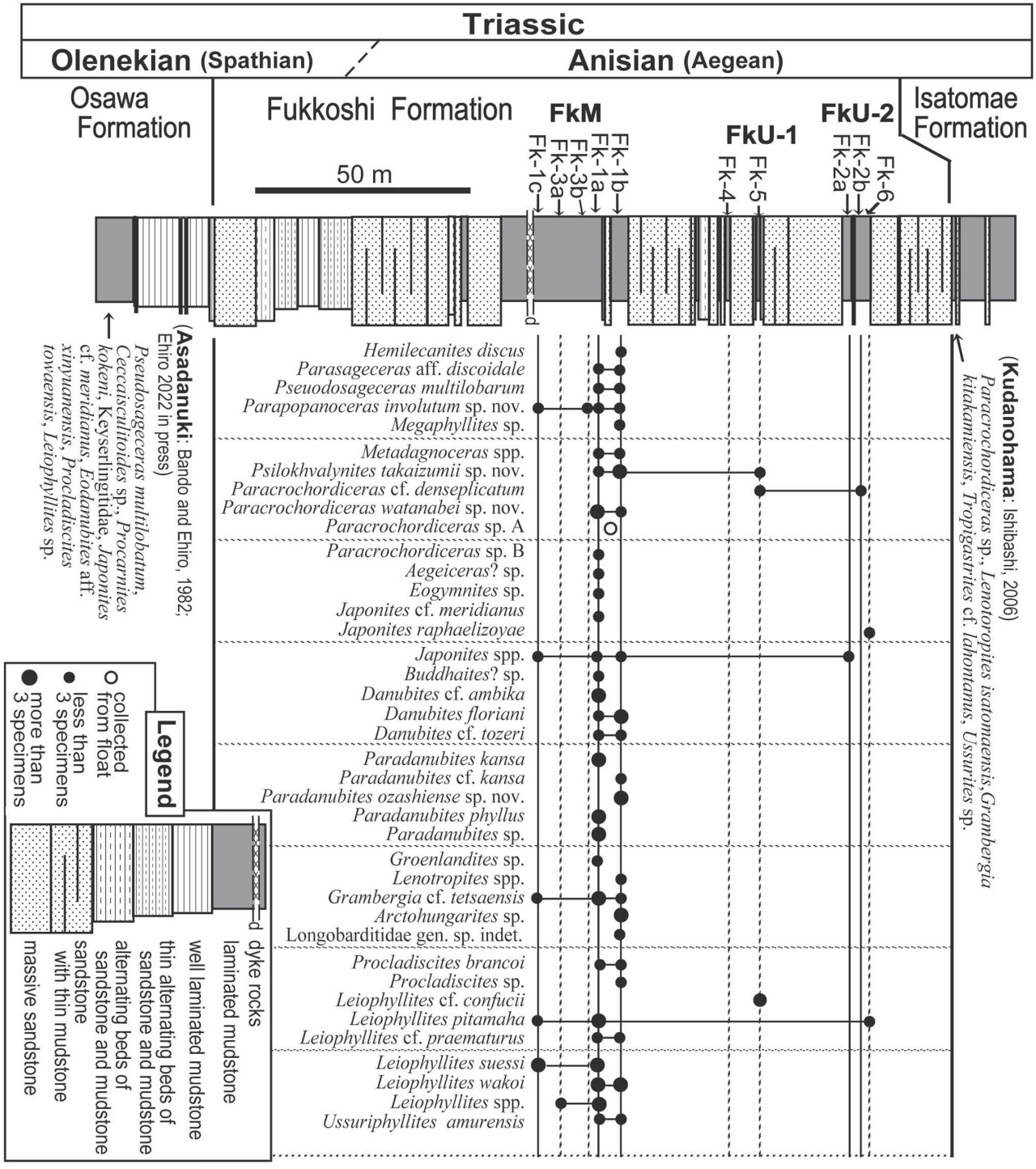

Figure 15. Stratigraphic distribution of ammonoid species from the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan. Ammonoids from the uppermost part of the Osawa Formation at the south of Asadanuki and from the lowermost part of the Isatomae Formation at Kudanohama are also shown.

Groenlandites sp.
Lenotropites spp.
Grambergia cf. *tetsaensis* McLearn
Arctohungarites sp.
Longobarditidae? gen. and sp. indet.
Family Cladiscitidae
Procladiscites brancoi Mojsisovics
Procladiscites sp.
Family Palaeophyllitidae
Leiophyllites cf. *confucii* (Diener)
Leiophyllites pitamaha (Diener)
Leiophyllites cf. *praematurus* Kiparisova
Leiophyllites suessi (Mojsisovics)
Leiophyllites wakoi Ehiro, Sasaki and Kano
Leiophyllites spp.
Ussuriphyllites amurensis (Kiparisova)

These ammonoids were collected from the nine localities (horizons) belonging to the middle to upper part of the Fukkoshi Formation (Figure 15), but these are largely classified into three horizons: the mudstone dominated middle part (FkM: including the horizons Fk-1c, Fk-3a, Fk-3b, Fk-1a and Fk-1b: about 30 m total stratigraphic interval), mudstone beds of the lower part of the upper part (FkU-1: horizon Fk-5) and upper mudstone dominated beds in the upper part (FkU-2: including the horizons Fk-2a, Fk2b and Fk-6: less than 10 m interval). FkM has rather wide stratigraphic range of ca. 30 m, but there is no remarkable difference between the generic compositions of Fk-1a and Fk-1b, and genera from the Fk-1c, Fk-3a and Fk-3b are also yield from Fk-1a and Fk-1b. The ammonoid specimens are few in number in both FkU-1 and FkU-2 and it makes precise comparison with FkM difficult, but their faunas are poor in number of specimens belong to the family Palaeophyllitidae and Danubitidae, which are predominated in the FkM.

Among the fauna of FkM, specimens belong to the genera *Leiophyllites* are most dominated and hold more than half of the collection, including those ill preserved and undescribed ones. Those belong to the genera *Paradanubites* is the next, and those of *Parapopanoceras*, *Psilokhvalynites*, *Paracrochordiceras* and *Danubites* are also common.

More than half of the genera (13 genera) among the fauna (20 genera: excluding the new genus *Psilokhvalynites*), are known from the Anisian strata (rarely from also Ladinian or late Triassic strata), and mostly restricted in the lower Anisian (Aegean): *Parasageceras*, *Parapopanoceras*, *Megaphyllites*, *Paracrochordiceras*, *Aegeiceras*, *Buddhaites*, *Danubites*, *Paradanubites*, *Groenlandites*, *Lenotropites*, *Grambergia*, *Arctohungarites* and *Ussuriphyllites*. The last genus has been only known from the lower Anisian *Ussuriphyllites amurensis* Zone of South Primorye (Zakharov, 1967, 1968; Zakharov et al., 2005a, 2005b). Shigeta and Kumagae (2016) stressed that the genus *Ussuriphyllites* is late Olenekian (late Spathian) in age, because it is associated with *Keyserlingites* sp. However, *U. amurensis* is accompanied with typical Anisian genera, such as *Parasageceras*, *Megaphyllites*, *Paracrochordiceras*, *Prohungarites*, *Arctohungarites*, *Tropigastrites* and *Ussurites* in the *U. amurensis* Zone of the Atlasov Cape section, South Primorye (Zakharov et al., 2005a, 2005b). Moreover, genus *Keyserlingites* is not restricted in the Olenekian. Many species of *Keyserlingites* (= *Durgaites*) have been reported from the lower Anisian strata in the Tethys region, such as Qinghai (e.g. Wang, 1985; He et al., 1986) and Spiti (Krystin et al., 2004). Therefore, the genus *Ussuriphyllites* is early Anisian in age.

Two genera, *Japonites* and *Procladiscites*, are also typical for the Anisian of Tethys province, although they already appeared in the latest Olenekian as reported from the uppermost part of the underlying Osawa Formation (Ehiro, 2022 in press). The genus *Leiophyllites* ranges from Olenekian to Anisian.

Few exceptions are the genera *Hemilecanites*, *Pseudosageceras*, *Metadagnoceras* and *Eogymnites*. They are typical Olenekian or Induan to Olenekian genera. However, the first three have been also described from the lower Anisian strata, although very few in number. Bucher (1989) described *Hemilecanites* cf. *paradiscus* Kummel, *Metadagnoceras youngi* Bucher and *Metadagnoceras* sp. from the Lower Anisian of Nevada. *Pseudosageceras*? sp. described from the Anisian strata of Primorye, Far East Russia (Kiparisova, 1961) is ill preserved, but it has involute conch with multi-lobed suture line and its generic assignment is highly probable. The present discovery of these three genera from the Fukkoshi Formation in association with many Anisian genera clarified that they range up to the lower Anisian, although these genera are generally thought to be restricted in pre-Anisian strata. The species of the genus *Eogymnites* have been reported from the upper Olenekian, but *Eogymnites* is closely related with *Japonites* and some authors consider that it is synonymous with the genus *Japonites*.

Among the Fukkoshi ammonoid fauna from FkM, two genera, *Parapopanoceras* and *Buddhaites*, are generally considered to be middle Anisian (to late Anisian) genera, but the majority of the genera of the fauna are stratigraphically restricted to or range down into the lower Anisian. Therefore, the ammonoid fauna from FkM is definitely early Anisian (Aegean) in age.

Fauna from FkU-1 and FkU-2 are not diverse, and comprise only *Psilokhvalynites* (gen. nov.), *Paracrochordiceras*, *Japonites* and *Leiophyllites*. They are also considered to be early Anisian in age, because of the occurrence of *Paracrochordiceras*. The early Anisian genera, such as *Grambergia*, *Lenotropites*, *Tropigastrites*

and *Ussurites*, are also known from the lowermost part of the overlying Isatomae Formation (Ishibashi, 2006).

Olenekian/Anisian boundary in the South Kitakami Belt, Northeast Japan

Although some candidate sections have been proposed as the global boundary stratotype section and point (GSSP) for the base of the Anisian, it is yet to be ratified. There are two dominant biostratigraphic markers for the base of the Anisian: ammonoid and conodont. When Grădinaru et al. (2007) proposed the base of ammonoid *Paracrochordiceras–Japonites* Beds in the Deşli Caira Hill, Dobrogea, Romania as the GSSP, this level was considered to coincide also with the FAD of conodont *Chiosella timorensis* (Orchard et al., 2007). Goudemand et al. (2012), however, clarified that this conodont FAD datum is actually in the underlying *Deslicairites* Beds, which characterized by Olenekian ammonoids.

Gaetani et al. (1992) had proposed that the base of the *Aegeiceras–Japonites* beds, that is correlated with the *Paracrochordiceras–Japonites* Beds of Dobrogea, at the Marathovouno section in Chios Island, Greece as the base of the Anisian. It coincides with the base of the Aegean Substage proposed by Assereto (1974). Also in Chios, the FAD of *C. timorensis* is slightly below the base of the *Aegeiceras–Japonites* beds and located in the late Spathian bed with *Procarnites* and *Hellenites* (Assereto et al., 1980; Gaetani et al., 1992). The same stratigraphic relationship between the ammonoids and conodonts are also known from Nevada, North America. The occurrence of *C. timorensis* from the upper part of the Olenekian *Neopopanoceras haugi* Zone was reported by Goudemand et al. (2012).

Based mainly on the FAD of *C. timorensis*, some OAB boundary sections in the Nanpanjiang Basin, Guangxi, South China have been introduced for the candidate GSSP for the base of the Anisian (e.g. Ovtcharova et al., 2006; Galfetti et al., 2007, 2008; Chen et al*.,* 2020). In these sections, unfortunately, the ammonoid fossils are very poor.

Recently, Golding (2021) proposed a new criterion of conodont-based definition for the base of the Anisian. He suggests that *Neogondolella curva* and associated species is suitable for the index of the base of the Anisian. The FADs of these species are slightly above that of *C. timorensis* and nearly the same as those of Anisian ammonoids, that characterize the *Paracrochordiceras–Japonites* Beds or its correlatives. Grădinaru (2022) investigated the biostratigraphy of some OAB boundary sections and the stratigraphic position of FAD of *C. timorensis* with problems on its taxonomy and definition, and stressed that *C. timorensis* is ineligible for the stratigraphic index for the OAB and the OAB boundary should be defined basically on ammonoids.

By adopting the ammonoid-based (traditional) criteria or Golding's (2021) proposal, the base of the Anisian in the South Kitakami Belt is considered to be located below the middle part of the Fukkoshi Formation, because it yields rich early Anisian (Aegean) ammonoids, which correlate with *Paracrochordiceras–Japonites* Beds and its correlatives. Since the uppermost part of the underlying Osawa Formation is characterized by the Olenekian ammonoids (Ehiro, 2022 in press), the Olenekian/Anisian boundary is considered to locate somewhere in the lower part of the Fukkoshi Formation.

Comparison with the early Anisian ammonoid faunas in the Tethys and Panthalassa regions

The ammonoid fauna of the Fukkoshi Formation is very diverse (consisting of 21 genera and 38 species) among the early Anisian (Aegean) ammonoid fauna, being equal to those of Qinghai, China (He et al., 1986) and Nevada, North America (Bucher, 1989). It is most dominated in the genera of the Family Palaeophyllitidae, mostly of *Leiophyllites*, and characterized common occurrences of the families Danubitidae (*Danubites* and *Paradanubites*), Acrochordiceratidae (*Paracrochordiceras*) and Longobarditidae (*Groenlandites*, *Lenotropites*, *Grambergia* and *Arctohungarites*). The fauna also includes quite a few specimens belong to the families Parapopanoceratidae (*Parapopanoceras*) and Khvalynitidae (*Metadagnoceras*, *Psilokhvalynites*). The Fukkoshi ammonoid fauna has some resemblance in the generic and species compositions to those known from southern Tethys (Himalayas: Diener, 1895b; Timor: Welter, 1915), western and central Tethys (Chios: Fantini Sestini, 1981 and Gaetani et al., 1992; Caucasus: Shevyrev, 1968, 1995; Qinghai, western China: He et al., 1986), western Panthalassa (South Primorye: Zakharov et al., 2005a, 2005b) and eastern Panthalassa provinces (Nevada: Bucher, 1989).

Qinghai, west China: The ammonoid fauna reported from Qinghai, west China (He et al., 1986) is one of the most diverse Aegean faunas, which comprises 47 species belonging to 18 genera of ammonoids. According to He et al. (1986), the majority of this fauna are specimens belonging to the genera *Groenlandites*, *Pearylandites*, *Lenotropites*, *Grambergia* and *Arctohungarites* (family Longobarditidae) and those of the genera *Keyserlingites*, *Japonites*, *Procladiscites*, *Leiophyllites*, *Ussurites*, *Paradanubites* and *Megaphyllites* are also common. Among the genera known from Qinghai, ten genera are also known in the Fukkoshi fauna, and dominant and common genera in the Qinghai fauna are also included in the Fukkoshi fauna, except for the genus *Ussurites*. The main difference between these two faunas is the absence of the genera of family Acrochordiceratidae in the Qinghai fauna.

Nevada, USA: Lower Anisian beds in the northern Humboldt Range, Nevada, USA are classified into the *Japonites welteri* beds, *Pseudokeyserlingites guexi* beds, *Mulleri* Zone and *Caurus* Zone, in ascending order (Bucher, 1989). The lower Anisian ammonoid fauna of Nevada is another diverse one and comprises 28 species of 17 genera. Ten genera are common in both Nevada and Fukkoshi faunas. It is worthy of attention that both faunas include two "relict" genera *Hemilecanites* and *Metadagnoceras*. However, there are some faunal differences between them: *Silberlingites* and *Caucasites*, both common elements in the Nevada fauna are absent in the Fukkoshi fauna and, on the other hand, the genera of the family Danubitidae and Palaeophyllitidae, dominated or common in the latter, are rare in the former.

Timor: From the Anisian limestone (2 m in thickness) in Nifoekoko, Timor, Welter (1915) described 12 genera (23 species) of ammonoids. Based on the re-examination of these genera by Shevyrev (1968, 1995), Spath (1954), Fantini Sestini (1981), etc., this fauna is considered to be composed of 13 genera (22 species). Among these, eight genera are common to the Fukkoshi fauna. Genera of the family Longobarditidae are missing and those of Acrochordiceratidae are rare in the Timor fauna.

Chitichun, Himalayas: The Chitichun limestone in Himalayas is classical Aegean ammonoid locality. Chitichun ammonoids originally described by Diener (1895b) have been reexamined by Diener (1915), Spath (1934), Shevyrev (1968), Wang and Chen (1979) and Fantini Sestini (1981, 1988), and are now classified into 13 species belonging to eight genera: *Paracrochordiceras pandya* (Diener), *Danubites ambika* Diener, *Paradanubites kansa* (Diener), *Aegeiceras ugra* (Diener), *Psilosturia mongolica* (Diener), *Procladiscites yasoda* Diener, *Leiophyllites confucii* (Diener), *L*.? *middlemissi* (Diener), *L*. *pitamaha* (Diener), *L*. *pradyumna* (Diener), *L*. *pseudopradyumna* (Welter), *Ussurites hara* (Diener) and *U*. *kingi* (Diener). Among these eight genera, six of them are common to the Fukkoshi fauna, and three species (*P*. *kansa*, *L*. *confucii*, *L*. *pitamaha*) from the Fukkoshi Formation are identified or compared to the Chitichun ones. According to Diener (1895b), specimens of *Leiophyllites* have, as with the Fukkoshi fauna, the largest number (35 specimens) among the fauna, followed by those of *Procladiscites* (10 specimens). On the other hand, the Chitichun fauna lacks the genera of the family Longobarditidae.

South Primorye: The Lower Anisian strata of the Atlasov Cape section, South Primorye, Far East Russia yield 15 species belonging to 12 genera of ammonoids (Zakharov et al., 2005a, 2005b). Among them seven genera are common to the Fukkoshi fauna. The fauna dominated in *Ussuriphyllites amurensis* (Kiparisova), which is endemic to South Primorye but now known from the Fukkoshi Formation. The Atlasov Cape fauna, however, differ from the Fukkoshi fauna in lacking the genera belonging to the families Japonitidae and Longobarditidae, and in small number of specimens of family Danubitidae and genus *Leiophyllites*.

Chios Island, Greece: The Marathovouno section in Chios Island, Greece includes the proposed candidate GSSP (the base of the *Aegeiceras–Japonites* beds: the base of the Aegean Substage proposed by Assereto, 1974) for the base of the Anisian (Gaetani et al., 1992). The Aegean ammonoid fauna was studied by Bender (1970), Assereto (1974), Fantini Sestini (1981) and Gaetani et al. (1992). This fauna comprises 17 species in 10 genera, of which seven genera are common to the Fukkoshi fauna. Former fauna differs from the latter in lacking the genera of the family Longobarditidae.

Caucasus: According to Shevyrev (1995), the lower Anisian Malotkhach Formation of Caucasus yields *Stenopopanoceras transiens* Tozer, *Megaphyllites compressus* Shevyrev, *Megaphyllites* sp., *Groenlandites*? *glaber* Shevyrev, *Longobardites caucasius* Shevyrev, *Laboceras gracile* Shevyrev, *Leiophyllites pitamaha* (Diener). Three genera of them are also known in the Fukkoshi fauna, but the Caucasus fauna lacks in the genera belonging to the families Danubitidae and Acrochordiceratidae, which are common in the Fukkoshi fauna.

Conclusions

1. Ammonoid fauna from the middle to upper part of the Fukkoshi Formation in the Kamiwarizaki area, South Kitakami Belt, Northeast Japan is diverse, consisting 21 genera. Among them, the genus *Leiophyllites* is most dominated and specimens belonging to the genera *Paradanubites*, *Parapopanoceras*, *Psilokhvalynites*, *Paracrochordiceras* and *Danubites* are also abundant. The majority of the genera are stratigraphically restricted to or range down into the lower Anisian, and therefore, the ammonoid fauna is considered definitely to be early Anisian (Aegean) in age.

2. Since the uppermost part of the underlying Osawa Formation yields late Olenekian ammonoids, the Olenekian/Anisian boundary in the South Kitakami Belt is located to be somewhere in the lower part of the Fukkoshi Formation.

3. The Fukkoshi ammonoid fauna exhibits some similarities in the generic composition with those of some localities exhibited in low-latitude regions in the Tethys and Panthalassa, especially with that of Qinghai, west China.

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