Preliminary report of Carboniferous conodont fossils from the "Tsuchikurazawa Limestone", Kotaki, Itoigawa City, Niigata Prefecture, central Japan

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Abstract

Adetognathus unicornis (Rexroad and Burton) is the first representative of conodont fossils from the Carboniferous "Tsuchikurazawa Limestone" in the Itoigawa area, Niigata Prefecture, central Japan. The occurrence of this species indicates that the age of the limestone correlates with the late Serpukhovian (= late Chesterian) of the early Carboniferous, which is consistent with previous reports.

Key words: Conodont, Carboniferous, Kotaki Fomation, "Tsuchikurazawa Limestone," Hida Gaien Belt.

Introduction

Conodonts are minute fossils of extinct marine animals resembling spines, combs, or teeth (Briggs et al., 1983). Since the discovery of conodont-bearing animal fossils, they have been regarded as the earliest jawless fish (Purnell, 1995; Donoghue et al., 2000). Conodonts constitute the feeding apparatus of these animals and, in most cases, are the only parts of these animals preserved as fossils. Due to wide variation in their morphology, conodonts have been used in the biostratigraphy of Paleozoic and Triassic rocks in Japan (Igo and Koike, 1965; Koike, 1967).

The Kotaki Formation of the Hida Gaien Belt is distributed in and around the Tsuchikurazawa Valley, Kotaki, Itoigawa City, Niigata Prefecture in Japan (Nagamori et al.,

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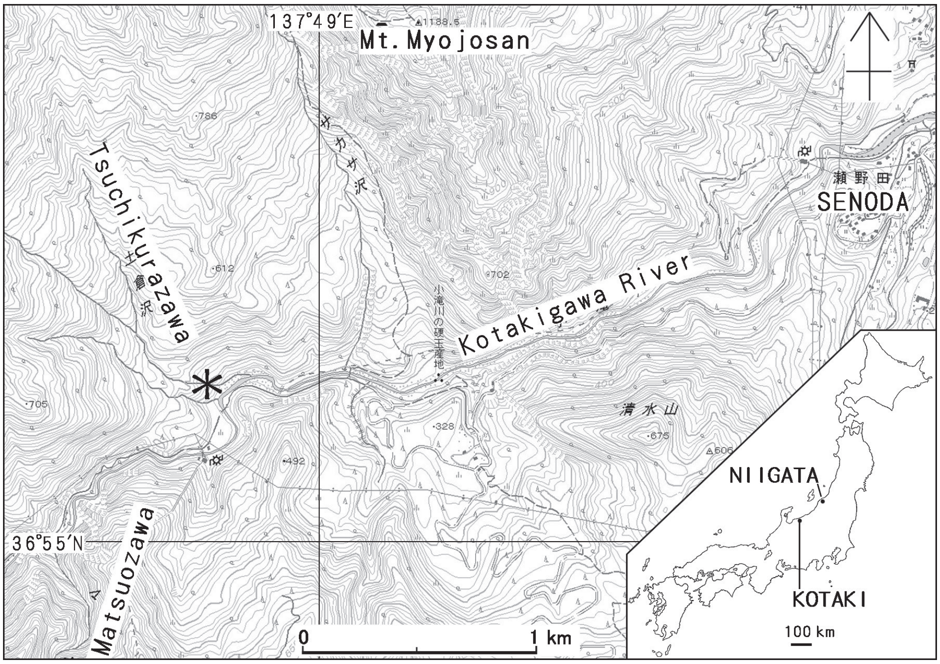

Fig. 1. This map represents the limestone block locality of the "Tsuchikurazawa Limestone" (asterisk). Topographic maps of Kotaki and Echigohiraiwa (scale 1:25,000), published by the Geospatial Information Authority of Japan, are used as a base map.

2010). This formation comprises pyroclastic rocks, sandstone, and mudstone, including mélange and chert (Nagamori et al., 2010). Because of large shear deformations, this formation was previously known as the Kotaki Complex (Kawai and Takeuchi, 2001); however, its name was changed to the Kotaki Formation based on similarities of its rock types with those of the adjacent Shiroumatake Formation (Nagamori et al., 2010). Radiolarian fossils from mudstone, siliceous shale, and chert date the formation to the Middle Permian (Tazawa et al., 1984; Kawai and Takeuchi, 2001). The mélange of this formation contains dark gray–black allochthonous limestone blocks—the "Tsuchikurazawa Limestone" (Nakazawa et al., 1998; Takenouchi, 2005). Over time, this limestone has yielded diverse Carboniferous fossils, including teeth of *Petalodus* and Cochliodontidae, which are considered the oldest shark remains found in Japan (Goto et al., 2011), and *Cyclus tazawai* Niko and Ibaraki, which is only the second-recorded cyclid crustacean in East Asia (Niko and Ibaraki, 2011). The occurrence of multiple taxa, such as foraminifers (Kamiya and Niko, 1996; Nakazawa et al., 1998), corals (Kamiya and Niko, 1996; Niko and Yamagiwa, 1998), brachiopods (Tazawa, 2004; Ibaraki et al., 2008, 2010; Ibaraki and Sato, 2013), and calcareous algae (Konishi, 1956), in this limestone dates it to the Early Carboniferous (Visean–Serpukhovian). Herein, we report the first conodont fossils found in the "Tsuchikurazawa Limestone".

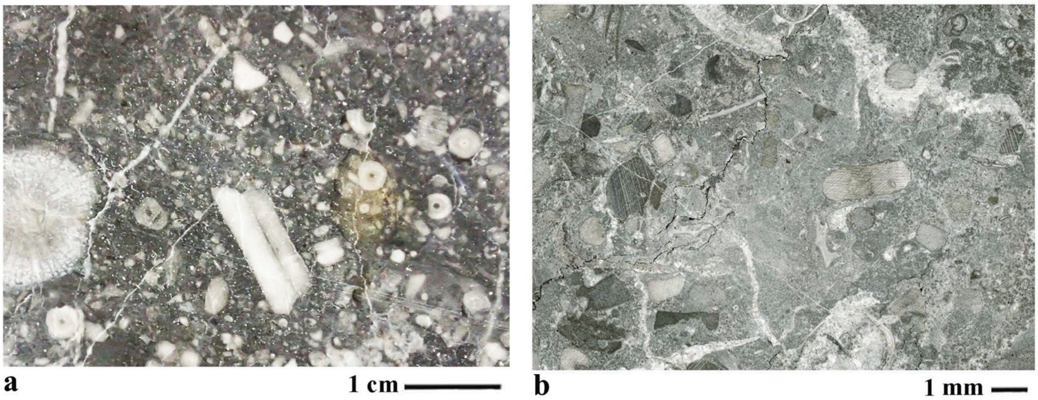

Fig. 2. Microlithology of the studied limestone blocks of the "Tsuchikurazawa Limestone." This limestone is composed of bioclasts, such as rugose corals and dominant small fragments of crinoids in the lime mud matrix, and limestone is determined to be bioclastic wackestone. **a**, Polished surface; **b**, thin section.

Materials and methods

Black limestone blocks originally collected from the Tsuchikurazawa Valley were deposited in the Fossa Magna Museum, and Y. I. handed over the limestone samples to Y. T., the first author of the present paper (Fig. 1 for details of the locality of the limestone). The limestone was examined by taking thin sections and polishing their surfaces (Fig. 2). Limestone comprising bioclasts (some millimeters or centimeters in size), such as rugose corals and dominant small fragments of crinoids in the black lime mud matrix, was determined to be bioclastic wackestone.

More than 5 kg limestone samples were treated with 5–10% acetic acid to recover conodont fossils. Limestone residues were sieved using a metal sieve with 105 μm mesh opening. The residues were dried and examined under a stereoscopic microscope (Nikon SMZ645). Under the microscope, conodonts were picked up using a thin brush, placed on slides, and photographed with a digital microscope (Keyence VH-Z100R).

Systematic paleontology

Family Cavusgnathidae Harris and Hallingsworth, 1933

Genus *Adetognathus* (Lane, 1967)

Type species.—*Cavusgnathus lautus* Gunnell, 1933

Remarks.—The P_1 element of this genus has a fairly deep median trough between two parapets, which continues to the posterior tip of the platform. These parapets are ornamented by nodes or ridges occupying the entire length of the lanceolate and slightly incurved platform. The short blade, which may or may not be slightly fixed, joins the outer parapet. *Adetognathus* is similar to an ancestral form of *Cavusgnathus*. The latter has a discrete fixed part on its blade, which in the case of *Adetognathus* is shorter or absent.

Adetognathus unicornis (Rexroad and Burton, 1961)

Fig. 3.1

Taphrognathus varians Cooper, 1947, p. 92, pl. 20, figs. 14–16.

Streptognathodus unicornis Rexroad and Burton, 1961, p. 1142, pl. 138, figs. 1–9; Collison et al., 1962, p. 27, charts 1, 4; Dunn, 1965, p. 1149, pl. 140, figs. 5, 6, 13, 14; Webster, 1969, p. 49, pl. 4, fig. 13.

Adetognathus unicornis (Rexroad and Burton); Lane, 1967, p. 930, pl. 119, figs. 16–25; Dunn, 1970, p. 316, pl. 61, figs. 20–22; Lane and Straka, 1974, figs. 33. 14–18; Kozitskaya et al., 1978, pl. 15, fig. 1, 2; Tynan, 1980, p. 1296, pl. 2, fig. 14; Nemirovskaya, 1983, p. 60, pl. 1, fig. 20; Grayson et al., 1985, p. 176, pl. 1, fig. 11; p. 178, pl. 2, fig. 10; Rexroad and Merrill, 1985, p. 56, pl. 1, figs. 1, 2, 8, 10, 17–19, p. 58, pl. 2, figs. 1–4, 40–54; Mapes and Rexroad, 1986, pl. 1, figs. 1–6; Grayson et al., 1990, pl. 2, figs. 25, 26; Morrow and Webster, 1992, pl. 1, figs. 10, 11; Weibel and Norby, 1992, p. 50, pl. 1, figs. 1–16; Nemyrovska, 1999, p. 95, pl. 11, fig. 11; Abplanalp et al., 2009, p. 95, fig. 7. 24–28.

? *Adetognathus unicornis* (Rexroad and Burton); Varker and Austin, 1975, p. 404, pl. 6, figs. 1, 2, 16–18.

Material.—A P_1 element and a probable M element. These specimens are deposited in the Earth Evolutionary Science, University of Tsukuba, Tsukuba, Ibaraki, Japan.

Revised diagnosis by Nemyrovska (1999).—Elongated narrow elements lacking a fixed blade. The largest denticle is present at the posterior end of the free blade and closest to the right (outer) parapet. The junction of the parapets forms the posterior tip.

Description.—The lanceolate platform of the dextral P_1 element occupies two-third of the entire length of the element. The entire length and height of the platform are 1.49 and 0.29 mm, respectively. The long, deep, median trough is the deepest at the anterior part. The parapets are ornamented by faint ridges. Each ridge is short and gentle. The free short blade continues to the outer parapet of the platform. The outer parapet is longer than the inner one. From a lateral view, the element is not arched and the basal and upper parts of the platform are thinly flanged. The blade is not fixed and bears six denticles. The prominent posterior huge cusp located in front of the platform is broken, while the other denticles are small and almost equal in size.

The probable M element comprises a huge broken cusp and posterior process with small denticles.

Remarks.—*Adetognathus unicornis* has been identified in the lower Carboniferous (upper Serpukhovian) strata of Eastern Europe and the Upper Mississippian (upper Chesterian)

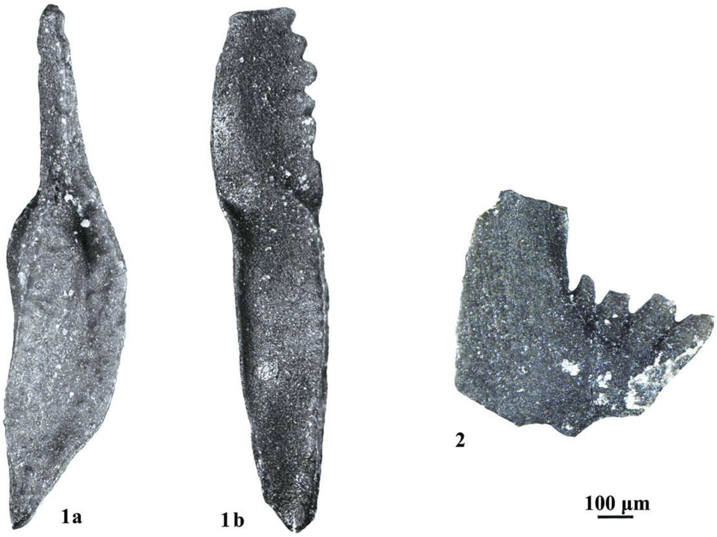

Fig. 3. *Adetognathus unicornis* (Rexroad and Burton) from the limestone blocks of the "Tsuchikurazawa Limestone." **1**, P_1 element. **a**, oral view; **b**, lateral view. **2**, probable M element.

strata of North America. This species was once identified as *Taphrognathus varians* by Cooper (1947), but Rexroad and Burton (1961) evaluated morphological commonalities between *Cavusgnathus unicornis* and *Streptognathodus primus* and renamed the species as *Streptognathodus unicornis*. The generic reassignment to *Adetognathus* was recognized by Lane (1967) based on the following features: the fixed blade is short or completely absent; the blade junction is not always located in the median position on the platform; and the blade is continuous with the outer margin.

The P_1 element of *Adetognathus unicornis* is different from that of *A. gigantus* and *A. lautus* due to the lack of a fixed blade and the presence of a huge, discrete denticle on the posterior end of the blade. *Adetognathus lautus* morphotype A, defined by Weibel and Norby (1992), is quite similar to *A. unicornis*, except for the location of the huge cusp, which is clearly inclined toward the outer parapet in the latter. The specimen reported in the present study is slightly different from *A. unicornis* specimens reported in other studies. The notch between the platform and blade is not deep because the ridges on both parapets of this specimen are lower and are less pronounced. However, because it shares almost all characteristics with *A. unicornis*, we identified it as *A. unicornis*.

Rexroad and Merrill (1985) have represented ramiform elements of the genus *Adetognathus*. An associated broken element (Fig. 3.2) is probably a part of the M element of *Adetognathus* due to its morphological similarities, but it remains uncertain whether the probable M element belongs to *Adetognathus unicornis*.

Biostratigraphic indications

Adetognathus unicornis (Rexroad and Burton) was recorded in Unit D of the Kinkaid Formation, the name of which was changed to the Grove Church Shale by Swann (1963), in the Mississippi Valley, Illinois (Rexroad and Burton, 1961). This is the uppermost part of both the Chester Series and the Mississippian System of Illinois, and the occurrence of this species is of stratigraphical importance. Collinson et al. (1962) used this species and established the *Streptognathodus unicornis* assemblage zone for the uppermost Mississippian. The zone was defined by the range of *A. unicornis*, but full range of the species in the Illinois Basin had not been determined because of the Mississippian–Pennsylvanian unconformity at the top of the Grove Church Shale. In southern Nevada, a more complete sequence was recognized across the Mississippian–Pennsylvanian boundary, where *A. unicornis* occurred in the Indian Springs and lower part of the Bird Spring Formations (Webster, 1969; Dunn, 1970). The species is associated with *Rhachistognathus muricatus* (Dunn) in the upper part of the Indian Springs Formation. Lane and Straka (1974) considered this association with *R. muricatus* to represent a new fauna (establishing *Adetognathus unicornis* and *Rhachistognathus muricatus* zones), which was absent in the Illinois Basin due to unconformity at the top of the Mississippian. This zonal scheme in North America has also been confirmed by other researchers (Grayson et al., 1985; Abplanalp et al., 2009). Nemyrovska (1999) established the *Gnathodus bilineatus bollandensis*–*Adetognathus unicornis* zone based on the occurrence of these species in the Donets Basin, Ukraine, Eastern Europe. Both species were associated with typical late Early Carboniferous (late Serpukhovian) conodonts, such as *Gn. bilineatus* (Roundy) and *Lochriea* spp., and the zone is easy to compare with other regions. According to Nemyrovska (1999), this zone corresponds to the *Adetognathus unicornis* and *Rhachistognathus muricatus* zones of North America, the upper part of the *Gn. bilineatus*–*Lochriea nodosus* zone of the Atetsu Limestone of Koike (1967), and the *Gn. bilineatus* zone of the Hina Limestone of Mizuno (1997). The latter two zones are the highest conodont zones of the Mississippian in the Akiyoshi Terrane. Together, these facts suggest that the occurrence of *A. unicornis* in blocks of the "Tsuchikurazawa Limestone" dates the limestone to the late Chesterian or late Serpukhovian of the early Carboniferous.

Our finding is consistent with those of previous paleontological works on the "Tsuchikurazawa Limestone". For instance, Abplanalp et al. (2009) suggested that the range of *A. unicornis* overlaps with the majority of zone 19 of the Mamet foraminiferal biozone framework. This biozone is characterized by the occurrence of *Eosigmoilina, Quasiarchaediscus, Biseriella,* and *Asteroarchaediscus* species, dating it to the late Chesterian (Mamet, 1975). *Asteroarchaediscus* was recorded in the "Tsuchikurazawa Limestone" by Niko and Yamagiwa (1998) and Nakazawa et al. (1998).

This is a preliminary report of the Carboniferous conodonts from the "Tsuchikurazawa Limestone". It is expected to find the early Carboniferous conodont fauna in the future research.

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