On the Pliensbachian/Toarcian boundary in the Lower Jurassic Toyora Group in southwest Japan

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ABSTRACT: The Toyora Group, consisting of continental shelf sediments, is exposed in southwest Japan. It is divided into three formations, the Higashinagano, the Nishinakayama, and the Utano formations in ascending order. The Nm Member, the lower part of the Nishinakayama Formation, has yielded abundant ammonites, indicating successive ages of Early Toarcian. The ammonite zonation was established on these materials, but the Pliensbachian/Toarcian (P/T) boundary was not defined clearly in previous studies. A total of 99 ammonite specimens including 11 genera and 16 species were collected along the Sakuraguchi-dani Valley. The first occurrence of *Dactylioceras helianthoides* is the most suitable candidate for drawing the P/T boundary in the Toyora Group, the boundary being drawn at least 35.5 m lower than the previously indicated.

INTRODUCTION

The Toyora Group, consisting of Lower to Middle Jurassic continental shelf sediments, crops out in the westernmost part of Honshu Island, southwest Japan (Fig. 1). The group has been studied lithostratigraphically by Kobayashi (1926), Matsumoto and Ono (1947), and Hirano (1971), and is divided into three formations (Matsumoto and Ono 1947; Hirano 1971). The Toyora Group is known as one of the major sources of Early Jurassic ammonites in Japan and many species have been described especially from the Nishinakayama Formation, the middle part of the Group (Yokoyama 1904; Matsumoto and Ono 1947; Arkell 1956; Sato 1956, 1960, 1962; Hirano 1971, 1973a, b). Besides ammonites, bivalves, gastropods (*e.g.* Hayami 1959) and corals (Yabe and Eguchi 1933) have been found in this group.

The global Early Toarcian (Early Jurassic) Ocean Anoxic Event (OAE) has been studied worldwide (*e.g.* Jenkyns 1988). It has been pointed out that the black shales in the Nishinakayama Formation were deposited under anaerobic, oxygen-depleted bottom conditions representing the global Early Toarcian OAE (Tanabe 1991).

The Pliensbachian/Toarcian (P/T) boundary has not been defined clearly in previous studies. The purpose of this article is to discuss the P/T boundary in the Toyora Group, and to attempt to correlate the Toyora succession to internationally important successions such as GSSP candidate sections.

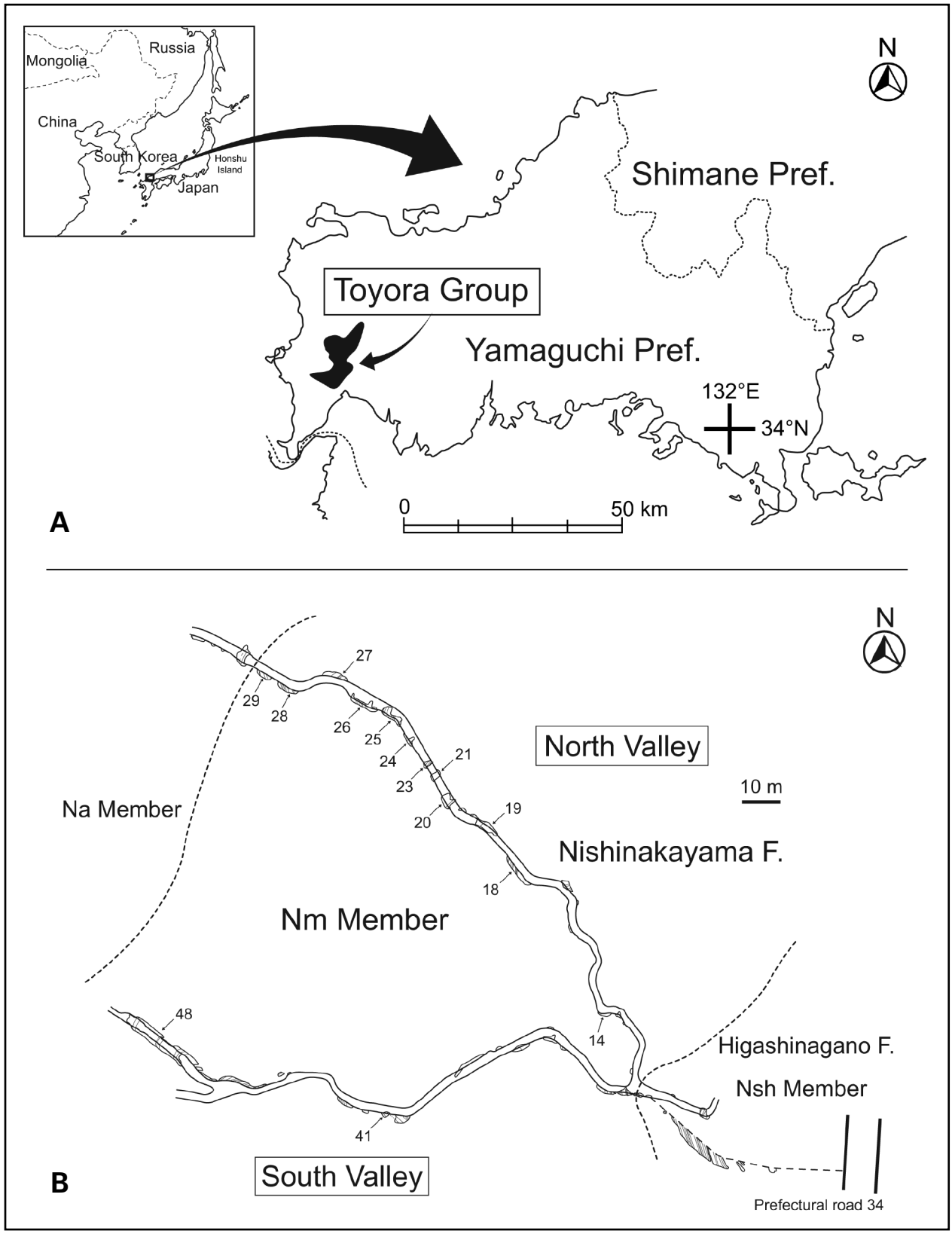


Fig. 1. Location maps: A – location map of the Toyora Group; B – map showing the outcrop localities in the Sakuraguchi-dani Valley; broken line – boundary of the members.

LITHOSTRATIGRAPHY

The Toyora Group is exposed in an area extending about 12 km northeast to southwest and about 9 km northwest to southeast, in the western part of Yamaguchi Prefecture, southwest Japan (Fig. 1A).

The lithostratigraphy of the group in this study follows Hirano's (1971) classification. The Toyora Group is mainly composed of sandstones and mudstones associated with conglomerates. It is divided into three formations: the Higashinagano Formation, the Nishinakayama Formation, and the Utano Formation in ascending order. The Higashinagano Formation is subdivided into four members (Nbc, Ncs, Nss, and Nsh in ascending order), the Nishinakayama Formation is subdivided into two members (Nm and Na in ascending order), and the Utano Formation is subdivided into four members (Up, Ub, Uh, and Ut in ascending order) (see Figs 1B, 2).

The Nm Member of the Nishinakayama Formation, the object of this study, is well exposed along the Sakuraguchi-dani Valley and is mainly composed of black mudstones. This member is characterized by the abundant occurrence of ammonites.

AMMONITE ASSEMBLAGE AND BIOSTRATIGRAPHY

Most of the ammonites have been obtained from the Nm Member along the Sakuraguchi-dani Valley. A total of 99 specimens were collected. The 11 genera and 16 species identified are as follows: *Dactylioceras helianthoides* (Yokoyama) (Pl. 1: 1a-b), *Fontanelliceras fontanellense* (Gemmellaro) (Pl. 1: 11), *Paltarpites toyoranus* (Matsumoto) (Pl. 1: 8), *Paltarpites paltus* (Buckman) (Pl. 1: 9), *Lioceratoides yokoyamai* (Matsumoto) (Pl. 1: 5), *Lioceratoides matsumotoi* Hirano (Pl. 1: 4), *Fuciniceras nakayamense* (Matsumoto) (Pl. 1: 10), *Protogrammoceras nipponicum* (Matsumoto) (Pl. 1: 6, 7), *Protogrammoceras yabei* Hirano, *Protogrammoceras onoi* Hirano, *Polyplectus okadai* (Yokoyama), *Cleviceras chrysanthemum* (Yokoyama) (Pl. 1: 3), *Cleviceras* cf. *exaratum* (Young et Bird), *Harpoceras inouyei* (Yokoyama), *Peronoceras subfibulatum* (Yokoyama) (Pl. 1: 2), and *Calliphylloceras* sp. Almost all the ammonite specimens examined are classified into the Hildoceratacеae and Eoderoceratacеae, and the fauna is characterized by the abundance of *D. helianthoides*, *P. nipponicum*, and *C. chrysanthemum*. Hirano (1973b) suggested that specimens occurring here indicate successive ages from Late Pliensbachian to Early Toarcian.

This biostratigraphic study was done in the Sakuraguchi-dani Valley because of the good outcrop condition and abundance of ammonites.

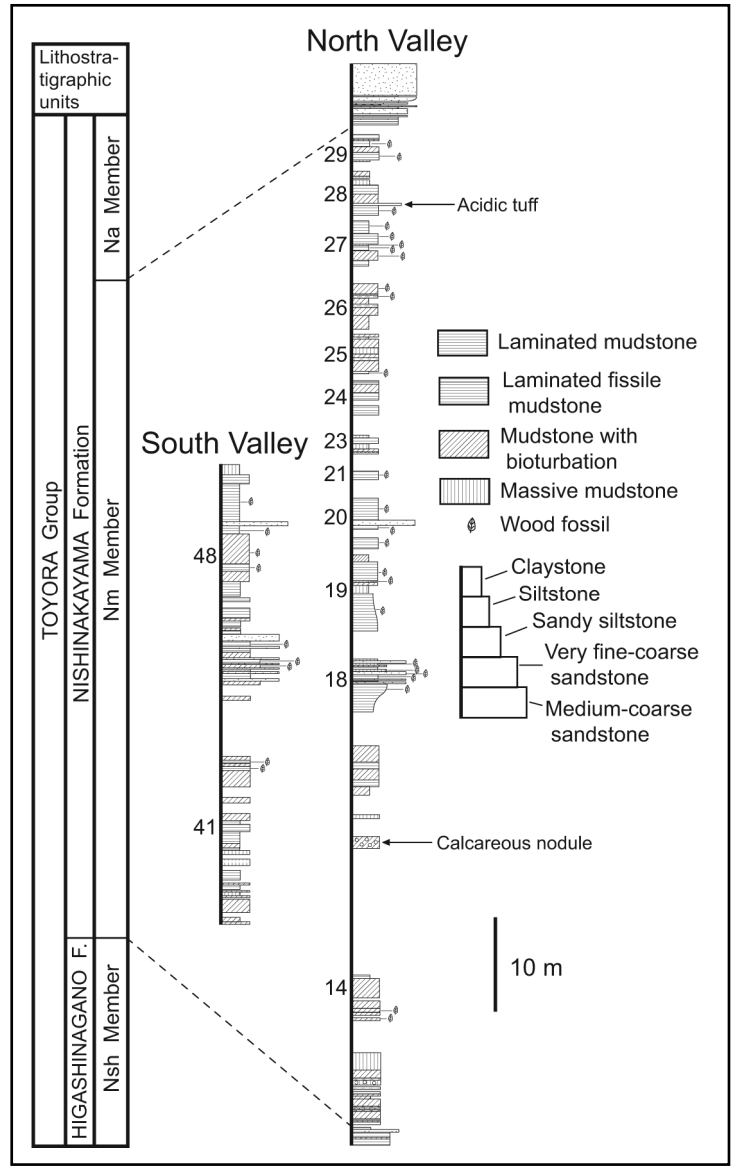
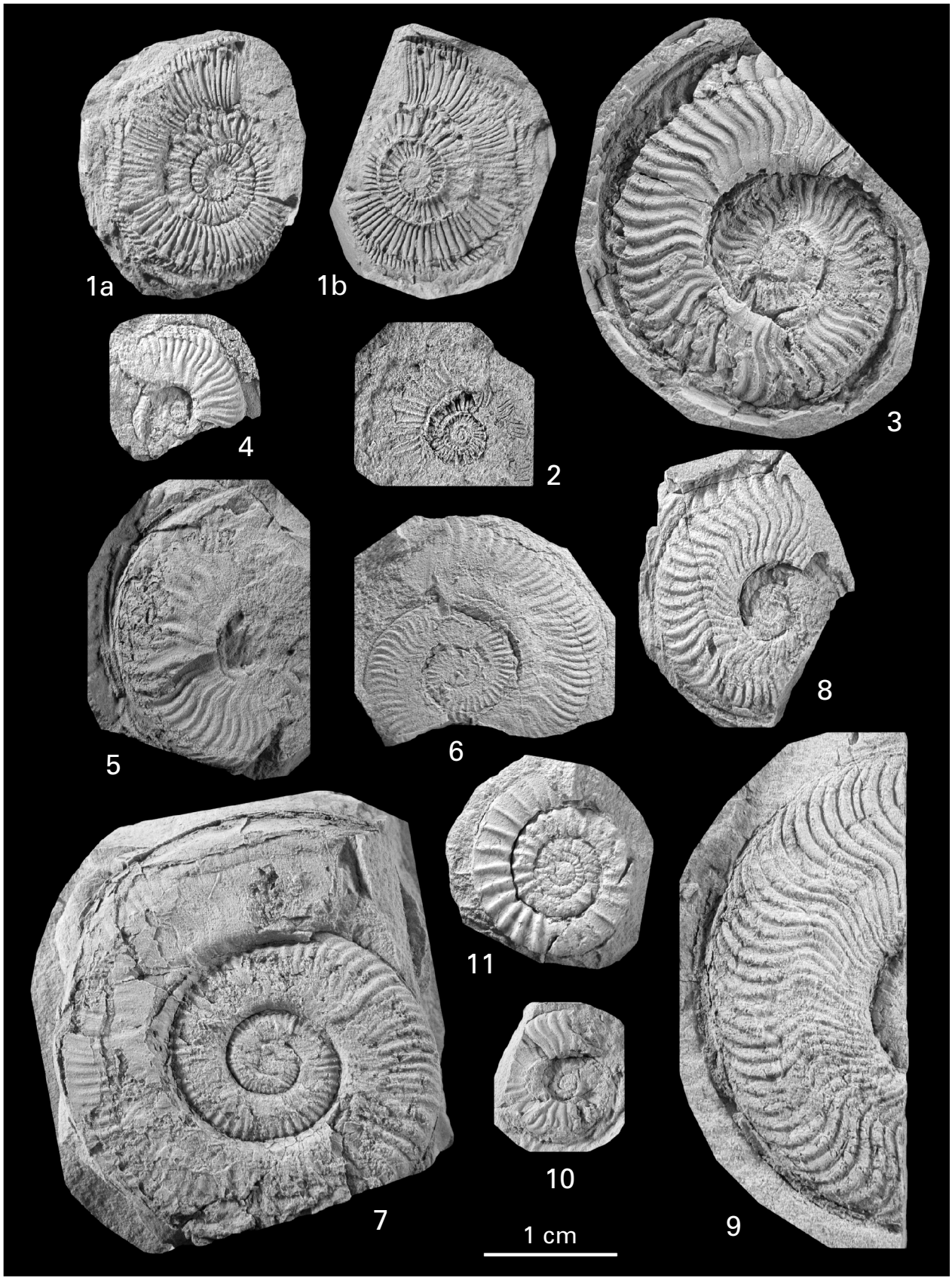


Fig. 2. Columnar sections of Nm Member in the Sakuraguchi-dani Valley. The number beside the columnar section corresponds to the number of outcrops in Fig. 1B.


1a
1b
3
4
2
8
5
6
11
10
7
9
1 cm

The valley branches into the North Valley and the South Valley. A route map is shown in Fig. 1, and corresponding lithological columnar sections of the valley are shown in Fig. 2. A composite columnar section from these two valleys with ammonite occurrences is presented in Fig. 3.

Hirano (1973b) established three ammonite zones in the Nm Member: the *Fontanelliceras fontanellense* Zone, *Protogrammoceras nipponicum* Zone and *Dactylioceras helianthoides* Zone in ascending order. The base of the *F. fontanellense* Zone was marked by the appearance of *Amaltheus*, *Arieticeras*, *Canavaria* and/or *Dactylioceras* (Hirano 1973b). The base of the *P. nipponicum* Zone was drawn immediately below the first occurrence of the genus *Protogrammoceras* in Hirano (1973b). Hirano (1973b) defined the base of the *D. helianthoides* Zone immediately above the last occurrence of *Protogrammoceras* and *Fuciniceras*. Tanabe (1991) redefined the base of this zone as the level immediately above the last occurrence of the genus *Protogrammoceras*. Ammonite zonation for the Nm Member along the Sakuraguchi-dani Valley based on the definition of Hirano (1973b) and Tanabe (1991) is also shown in Fig. 3.

PLIENSBACHIAN/TOARCIAN BOUNDARY

The Pliensbachian/Toarcian boundary in Europe

In Europe, the horizon where the appearance in abundance of the genus *Dactylioceras* is observed in association with the disappearance of the genera *Pleuroceras* and *Amaltheus* has been well known since the 19th century. Oppel (1856-1858) defined the base of the Toarcian as a horizon immediately above the highest *Pleuroceras* and below the first appearance of *Dactylioceras* in abundance. Since then, the P/T boundary has been defined by the first occurrence of the genus *Dactylioceras* because of the panglobal character of the genus (*e.g.* Dean *et al.* 1961). However, rare specimens of *Dactylioceras* have been found together with *Pleuroceras* in some places such as Baden-Württemberg in Germany (Schlatter 1985) and Klettgau in Switzerland (Schlatter 1982).

Several opinions for the placing of the P/T boundary have been proposed in different places. The P/T boundary in NW Europe is defined by the first occurrence of *Protogrammoceras paltum* (Buckman) (Howarth 1973). Around the Mediterranean area, it is defined by the first occurrence of the subgenus *Eodactylites* (genus *Dactylioceras*) (Guex 1973; Wiedenmayer 1980). In France, it is defined by the occurrence of *Paltarpites paltus* (Buckman) in addition to the genus *Dactylioceras* (Gabilly 1976; Elmi *et al.* 1997).

Pliensbachian/Toarcian boundary in the Toyora Group

Hirano (1973b) drew the P/T boundary within the *P. nipponicum* Zone in the Toyora Group. The criterion which was used to define the boundary was not mentioned in that paper. Judging from the range chart (Hirano 1973b: table 1), it seems to be defined as a level immediately below the first occurrence of *P. onoi*.

We attempt to define the P/T boundary in the Toyora Group by adopting the European index fossils. As mentioned above, definitions of the boundary vary from place to place. Firstly, we discuss which definition can be utilized for the Toyora Group. In the genus *Protogrammoceras*, three species, *P. nipponicum*, *P. yabei*, and *P. onoi*, were described in the Toyora Group (Hirano 1973b), but *P. paltum* has not been found so far. In the genus *Dactylioceras*, species belonging to the subgenus *Dactylioceras* such as *D. helianthoides* are common but the subgenus *Eodactylites* has not been discovered yet. Therefore, definitions based on the occurrence of *P. paltum* or *Eodactylites* are not applicable for the Toyora Group.

Both the ammonites of the genus *Dactylioceras* represented by *D. helianthoides,* and *Paltarpites*

Plate 1

Ammonites from Nm Member in Sakuraguchi-dani Valley. 1a-b – *Dactylioceras helianthoides* (Yokoyama), SA14-1, a: rubber cast, b: external mould. 2 – *Peronoceras subfibulatum* (Yokoyama), SA26-5. 3 – *Cleviceras chrysanthemum* (Yokoyama), SA20-3b. 4 – *Lioceratoides matsumotoi* Hirano, SA19-5b. 5 – *Lioceratoides yokoyamai* (Matsumoto), SA48-8a. 6 – *Protogrammoceras nipponicum* (Matsumoto), SA18-1c. 7 – *Protogrammoceras nipponicum* (Matsumoto), SA19-1c. 8 – *Paltarpites toyoranus* (Matsumoto), SA41-1. 9 – *Paltarpites paltus* (Buckman), SA41-1. 10 – *Fuciniceras nakayamense* (Matsumoto), SA48-9. 11 – *Fontanelliceras fontanellense* (Gemmellaro), SA18-1b. Every specimen has a fossil locality number composed of the code of the section (SA = Sakuraguchi-dani Valley), the number of outcrop, and the bed number into the outcrop. The numbers of outcrop correspond to that of Fig. 1B and Fig. 2. They are stored in the Department of Geology, Faculty of Science, Niigata University.

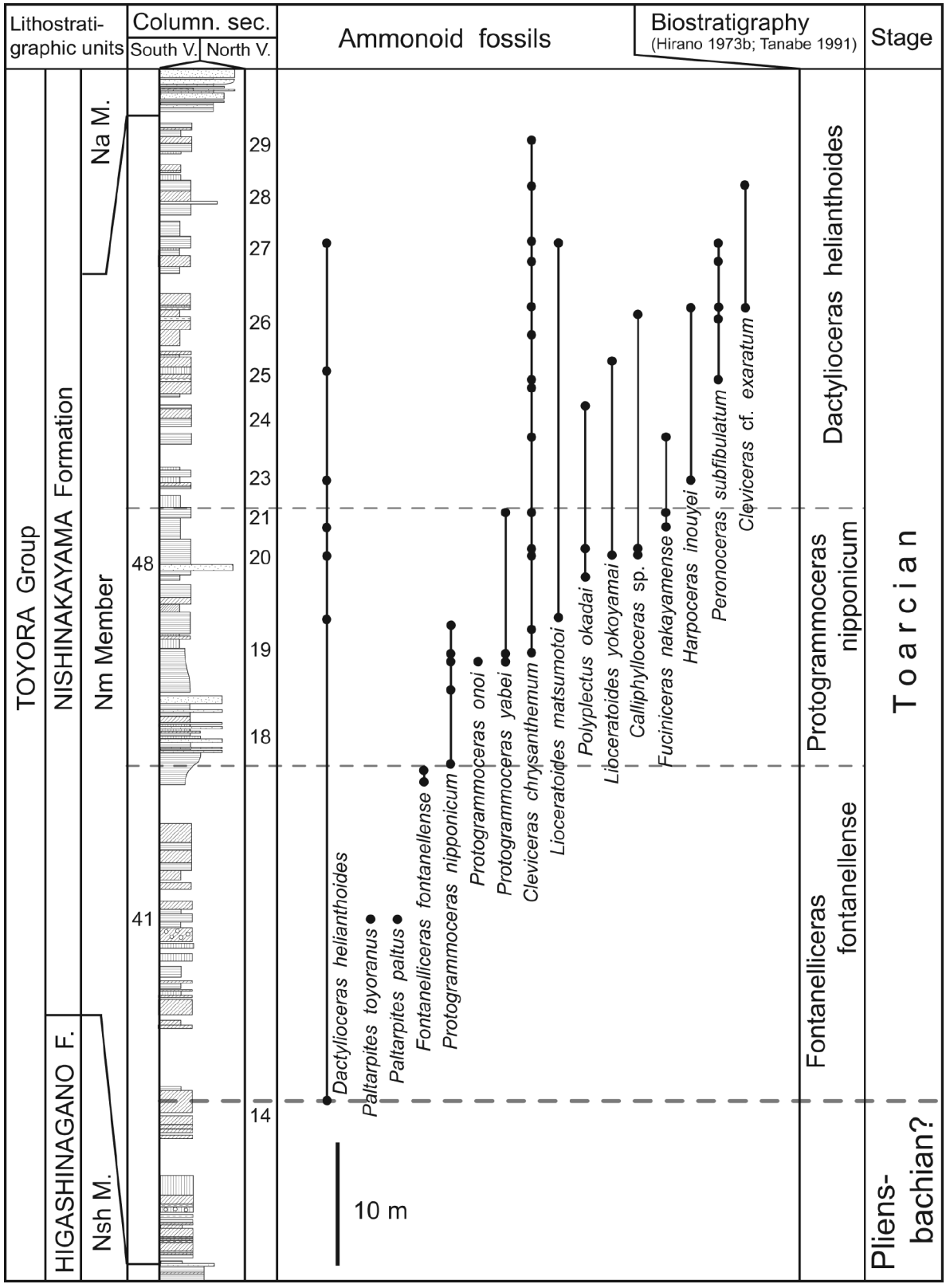


Fig. 3. Composite geologic columnar section and biostratigraphic succession of ammonoids in the Sakuraguchi-dani Valley. The numbers beside the columnar section corresponds to the number of outcrops in Fig. 1B. Broken line: boundary of the Zones. Dash line: boundary between Pliensbachian and Toarcian. Ammonite zonation follows Hirano (1973b) and Tanabe (1991). Lithology as in Fig. 2.

paltus were obtained from the group (Pl. 1: 1, 9). This means that the definition in France mentioned above (Gabilly 1976; Elmi *et al.* 1997) is applicable for the Toyora Group. However, no ammonite fossils were found in the layer below the first occurrence of the genus *Dactylioceras* in the Sakuraguchi-dani Valley. In consequence, the P/T boundary should be drawn below the first occurrence of the genus *Dactylioceras*, which is located at outcrop number 14 in Figs 2, 3. Accordingly, the P/T boundary is located at least 35.5 m lower than the previously indicated by Hirano (1973b).

ENDING REMARKS

No Pliensbachian indicative ammonite species have been found in the course of the present study. Hirano (1971) reported a specimen of *Amaltheus* sp. cf. *A. stokesi* (Sowerby) in the Higashinagano or Nishinakayama Formation of the Toyora Group. This genus is known as an index of the Upper Pliensbachian. More detailed discussions about the P/T boundary in the Toyora Group could be made when additional ammonite specimens are available. In any case, the Sakuraguchi-dani Valley section is an important section encompassing the P/T boundary in East Asia.

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