DOI: https://doi.org/10.2517/prpsj.250042
Paleontological Research, vol. 30, p. 122–134, 2026
https://www.jstage.jst.go.jp/browse/prpsj
Article

An iguanodontian sternal plate from the Upper Cretaceous Ashizawa Formation (Futaba Group) of Fukushima Prefecture, Japan

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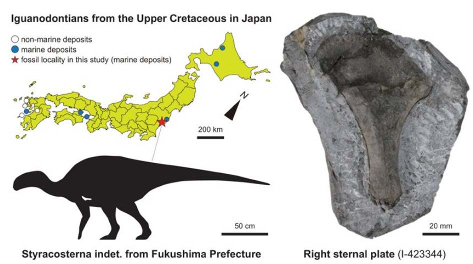
[Received August 30, 2025; Revised manuscript accepted March 15, 2026; Published online July 6, 2026]

ABSTRACT

Iguanodontia is a diverse clade of ornithopod dinosaurs known from Upper Jurassic to Upper Cretaceous deposits worldwide, including Japan. In 1999, an isolated sternal element tentatively attributed to a hadrosauroid was collected from the marine Ashizawa Formation of the Upper Cretaceous Futaba Group in Fukushima, northeastern Japan. Our description of this specimen reveals that it is a hatchet-shaped (unfused) sternal plate with an undeveloped caudomedial process, a concave lateral margin, and a relatively short (unflattened) caudolateral process. This element is assignable to an indeterminate styracosternan (Iguanodontia), likely a hadrosauroid. The size of the sternal plate suggests that it is from an individual with a body length of about 3 m. Given that all iguanodontian specimens previously recovered from Upper Cretaceous marine strata in Japan appear to belong to larger (over 3 m in body length) animals, our findings suggest that smaller individuals also inhabited coastal settings in the region.



Keywords: Ashizawa Formation, Fukushima Prefecture, Futaba Group, Iguanodontia, sternal plate, Upper Cretaceous

Introduction

Iguanodontia is a major group of small- to large-bodied ornithopod dinosaurs (approximately 2 m to greater than 10 m in length) that existed from the Late Jurassic through the latest Cretaceous (Hu *et al.*, 2001; Escaso *et al.*, 2014; Poole, 2022). Iguanodontians attained a worldwide distribution during this time, and their fossils are known from every continent. Asia was an important region for their diversification across Laurasia, as dispersals occurred both between Asia and North America and between Asia and Europe (Poole, 2022). A high diversity of iguanodontian species has been recovered from the Cretaceous of eastern and central Asia, including China (e.g. Wang and Xu, 2001; Norman, 2002; You *et al.*, 2005), Japan (e.g. Kobayashi and Azuma, 2003; Shibata and Azuma, 2015; Kobayashi *et al.*, 2019), Kazakhstan (e.g. Godefroit *et al.*, 2004a, 2012a; Bell and Brink, 2013), Mongolia (e.g. Norman, 1998; Tsogtbaatar *et al.*, 2014, 2019), and the Russia Far East (e.g. Godefroit *et al.*, 2003, 2004b; Bolotsky and Godefroit, 2004).

The increased number of reports of iguanodontian fossils from Japan over the past two decades is significant (e.g. Kubota, 2023), as this region represents an easternmost margin of Cretaceous Laurasia (Ando and Takahashi, 2017). Isolated teeth and bones as well as partial to nearly complete skeletons of these dinosaurs have been recovered from both terrestrial and marine strata (Figure 1A; Table 1). Their remains are relatively common from

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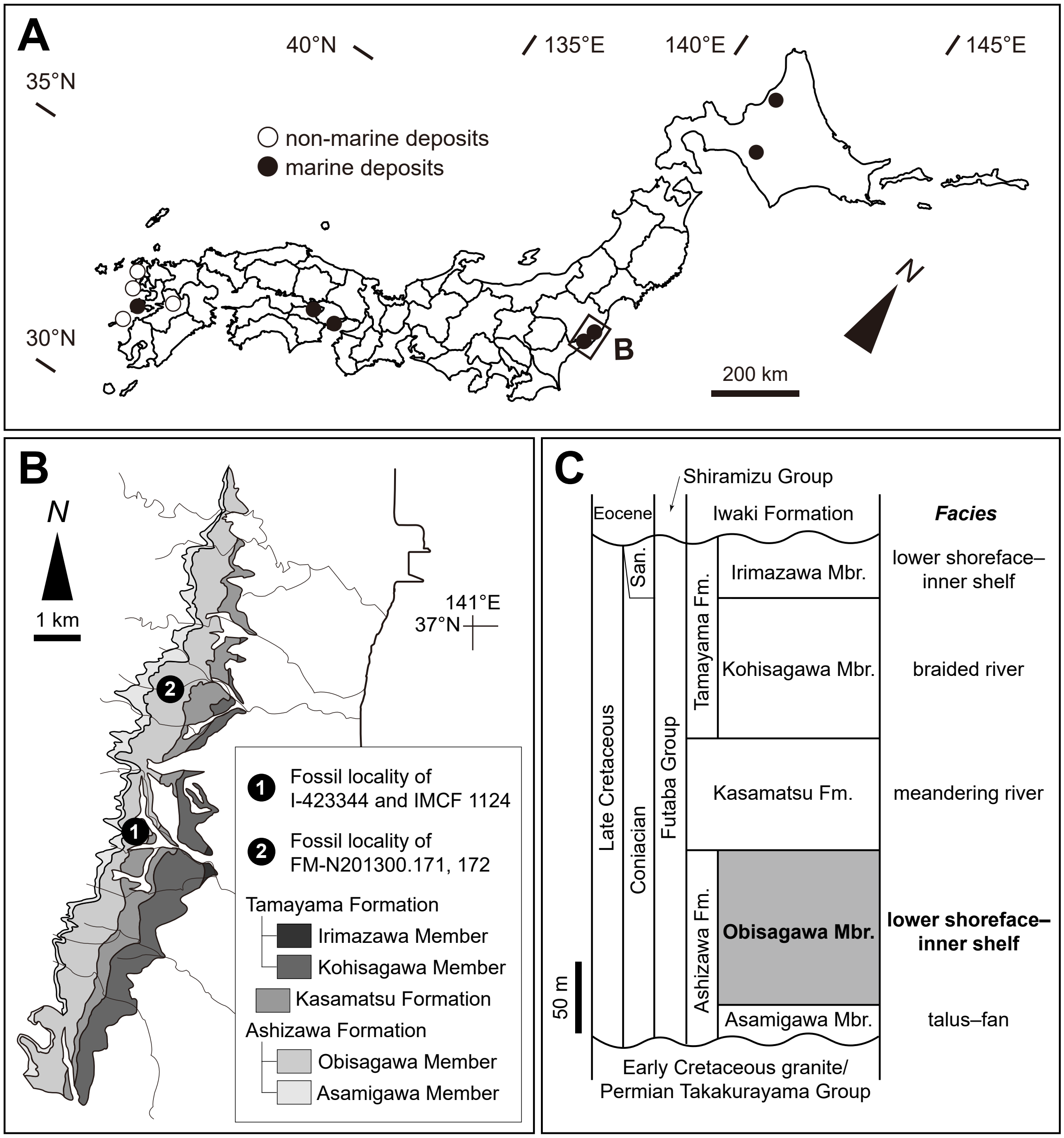

Figure 1. Locality map of the isolated right sternal plate, I-423344. **A,** localities of Upper Cretaceous iguanodontian (including hadrosauroid) remains in Japan (modified from Kubota, 2023); **B,** geological map of the Futaba Group in Fukushima (based on Ando *et al.*, 1995; Kubo *et al.*, 2002); **C,** the stratigraphic position of the Obisagawa Member (gray band) within the Ashizawa Formation (based on Ando *et al.*, 1995; Kubo *et al.*, 2002). The specimen numbers in B represent iguanodontian remains: I-423344, a sternal plate (this study); IMCF 1124, a dorsal vertebra (Manabe *et al.*, 2003); FM-N201300171, a cervical vertebra; and FM-N201300172, an isolated tooth (Ohashi *et al.*, 2015). Abbreviations: Fm., Formation; Mbr., Member.

Upper Cretaceous marine-influenced deposits throughout the country, with localities in Hokkaido (Hayakawa *et al.*, 2005; Kobayashi *et al.*, 2019), Fukushima (Manabe *et al.*, 2003; Ohashi *et al.*, 2015), Hyogo (Kobayashi *et al.*, 2021), Kagawa (Hayashi *et al.*, 2024) and Kumamoto (Kurosu *et al.*, 2022) (Figure 1A; Table 1). Fukushima Prefecture in northeastern Japan has yielded multiple iguanodontian elements from marine deposits of the Upper Cretaceous Ashizawa Formation (Futaba Group), which crop out in the southeastern region (Figure 1A, B). Isolated teeth, a cervical vertebra, a dorsal vertebra and an unidentified bone from this unit have been referred to hadrosauroids (Table 1). The latter specimen (I-423344: Kubo *et al.*, 2002) was excavated in 1999 by two local

Table 1. A list of iguanodontian (including hadrosauroid) skeletal remains from the Upper Cretaceous of Japan (modified from Kubota, 2023). Approximate total body length was estimated here or based on Kubota (2023) and references therein. Body size categories follow Norman (2015): 'small' is ≤ 3 m, 'medium' is > 3 m to < 8 m, and 'large' is ≥ 8 m. A question mark indicates indeterminate body size due to skeletal incompleteness. References for depositional environments: 1, Kobayashi *et al.*, 2019; 2, Tanabe *et al.*, 1977; 3, Takashima *et al.*, 2004; 4, Ando *et al.*, 1995; 5, Kobayashi *et al.*, 2021; 6, Yoshikawa *et al.*, 2011; 7, Ikegami, 2010; 8, Otsuka, 2011; 9, Inoue *et al.*, 1982; 10, Kurosu *et al.*, 2022; 11, Ishikawa *et al.*, 2025; 12, Miyata *et al.*, 2023; 13, Miyata *et al.*, 2022.

Geological unit	Age	Depositional environment [reference]	Locality	Taxon	Element	Body size category
Hakobuchi Formation, Yezo Group	early Maastrichtian	outer shelf [1]	Mukawa, Hokkaido	*Kamuysaurus japonicus*	a nearly complete skeleton with the skull and mandible	large
Yezo Group	Late Cretaceous	inner shelf–continental slope [2, 3]	Obira, Hokkaido	Hadrosauridae indet.	pelvic girdle, femur	medium–large
Ashizawa Formation, Futaba Group	Coniacian	lower shoreface–inner shelf [4]	Iwaki, Fukushima	Hadrosauridae indet.	dorsal vertebra	medium
			Iwaki, Fukushima	Hadrosauridae indet.	tooth	?
			Iwaki, Fukushima	Styracosterna indet. (this study)	sternal plate	small
			Hirono, Fukushima	Hadrosauridae indet.	tooth	?
			Hirono, Fukushima	Hadrosauroidea indet.	tooth, cervical vertebra	medium
Kita-ama Formation, Izumi Group	early Maastrichtian	continental slope [5]	Sumoto, Hyogo	*Yamatosaurus izanagii*	dentary, surangular, teeth, cervical vertebrae, caudal vertebra, cervical ribs, coracoid	large
Hiketa Formation, Izumi Group	Campanian	outer shelf [6]	Sanuki, Kagawa	Hadrosauroidea indet.	dorsal vertebra	large
'upper formation', Mifune Group	late Cenomanian–early Turonian	river [7]	Mifune, Kumamoto	Hadrosauroidea indet.	partial skull, teeth	?
			Mifune, Kumamoto	Iguanodontia indet.	teeth	?
Shimotsufukae Formation, Himenoura Group	Maastrichtian	tidal flat [8]	Amakusa, Kumamoto	Hadrosauroidea indet.	teeth	?
Himenoura Group	Maastrichtian	river [9–11]	Satsumasendai, Kagoshima	Hadrosauroidea indet.	femur	large
Mitsuse Formation	middle Campanian	river [12]	Nagasaki, Nagasaki	Hadrosauroidea indet.	teeth, scapula, partial femurs	medium–large
Yobukonose Formation	late Maastrichtian	river–fan [13]	Saikai, Nagasaki	Hadrosauroidea indet.	teeth	?

residents from the middle unit of the Obisagawa Member (Ashizawa Formation), within the premises of the Iwaki City Ammonite Center. This specimen was tentatively interpreted as the right sternal plate of a hadrosauroid but has remained unstudied. Here, we provide the first identification and detailed description of this sternal element and discuss its implications for body size diversity of iguanodontians in the marine-influenced Ashizawa Formation.

Institutional abbreviations.—AEHM, Amur Natural History Museum of the Far Eastern Institute of Mineral Resources, Far Eastern Branch of the Russian Academy

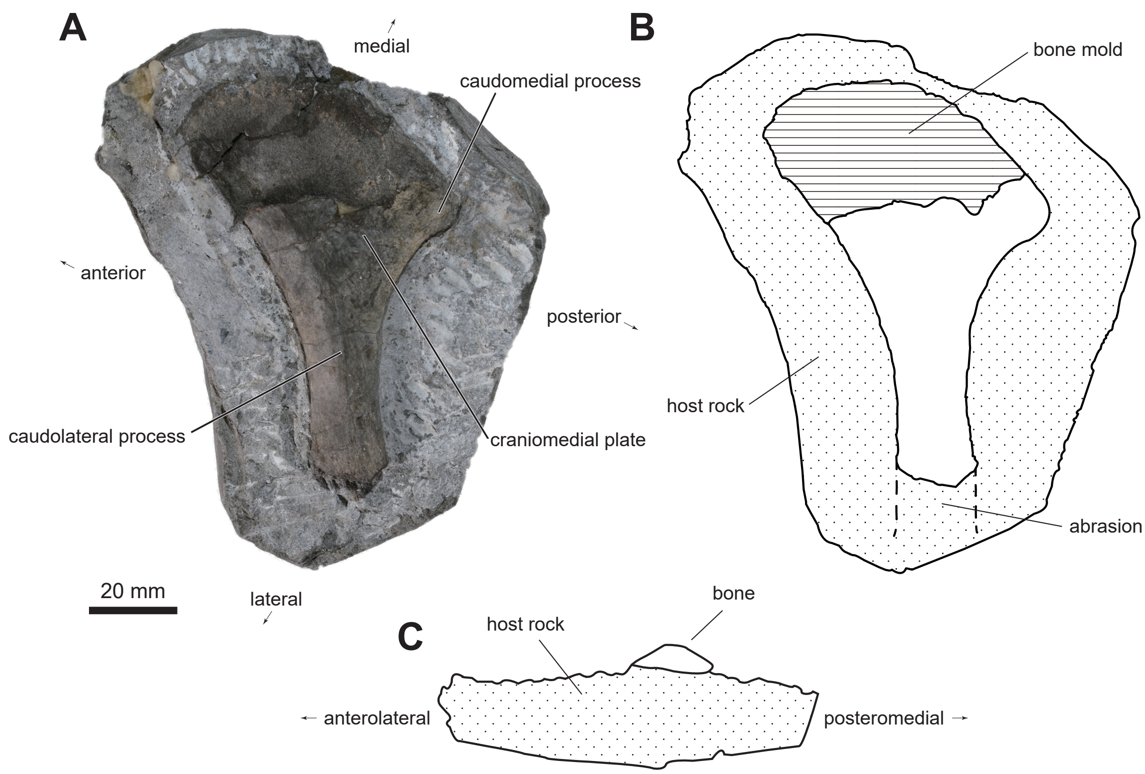

Figure 2. Isolated right sternal plate, I-423344. **A,** ventral view; **B,** line drawing of A; **C,** line drawing of the cross section of the caudolateral process.

of Sciences, Blagoveschensk, Russia; AUMP, Auburn University Museum of Paleontology, Auburn, Alabama, USA; FM, Fukushima Museum, Aizuwakamatsu, Fukushima, Japan; FPDM, Fukui Prefectural Dinosaur Museum, Katsuyama, Fukui, Japan; GMV, National Geological Museum of China, Beijing, China; GSLTZP, Fossil Research and Development Center of the Third Geology and Mineral Resources Exploration Academy of Gansu Province, Lanzhou, Gansu, China; HMG, Hobetsu Museum, Mukawa, Hokkaido, Japan; I, Iwaki City Board of Education, Iwaki, Fukushima, Japan; IMCF, Iwaki Museum of Coal and Fossil, Iwaki, Fukushima, Japan; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; MCD, Museu de la Conca Dellà, Isona, Lleida, Spain; MNHN, Museum National d'Histoire Naturelle, Paris, France; MPC, Mongolian Paleontological Center, Ulaanbaatar, Mongolia; NHMUK, Natural History Museum, London, UK; PIN, Paleontological Institute of the Russian Academy of Sciences, Moscow, Russia; SBDE, Sino-Belgian Dinosaur Expedition (specimens are property of the Inner Mongolian Museum in Hohhot, China; casts and some of the original specimens are temporarily housed at the Institut Royal des Sciences Naturelles de Belgique, Brussels, Belgium).

Geological setting

The Upper Cretaceous Ashizawa Formation is the lowermost formation of the Futaba Group (lower Coniacian–lower Santonian) and is exposed throughout southeastern Fukushima. It is successively overlain by the Kasamatsu and Tamayama formations (Figure 1A, B; Ando *et al.*, 1995). The Ashizawa Formation consists mainly of sandstone, with alternating layers of mudstone and conglomerate, interpreted to represent fluvial to marine deposits (Ando *et al.*, 1995). The Ashizawa Formation is divided into the lower Asamigawa Member and upper Obisagawa Member (Figure 1C). The Asamigawa Member consists mainly of coarse-grained sandstone deposited in delta fan to braided rivers/talus, whereas the Obisagawa Member is primarily composed of muddy fine-grained sandstone and sandy mudstone deposited in lower shoreface to inner shelf environments (Ando *et al.*, 1995; Kubo *et al.*, 2002).

The sternal element (I-423344) described in this study was collected from a layer of grey, very fine sandstone in the middle part of the Obisagawa Member. The Obisagawa Member has produced abundant marine verte-

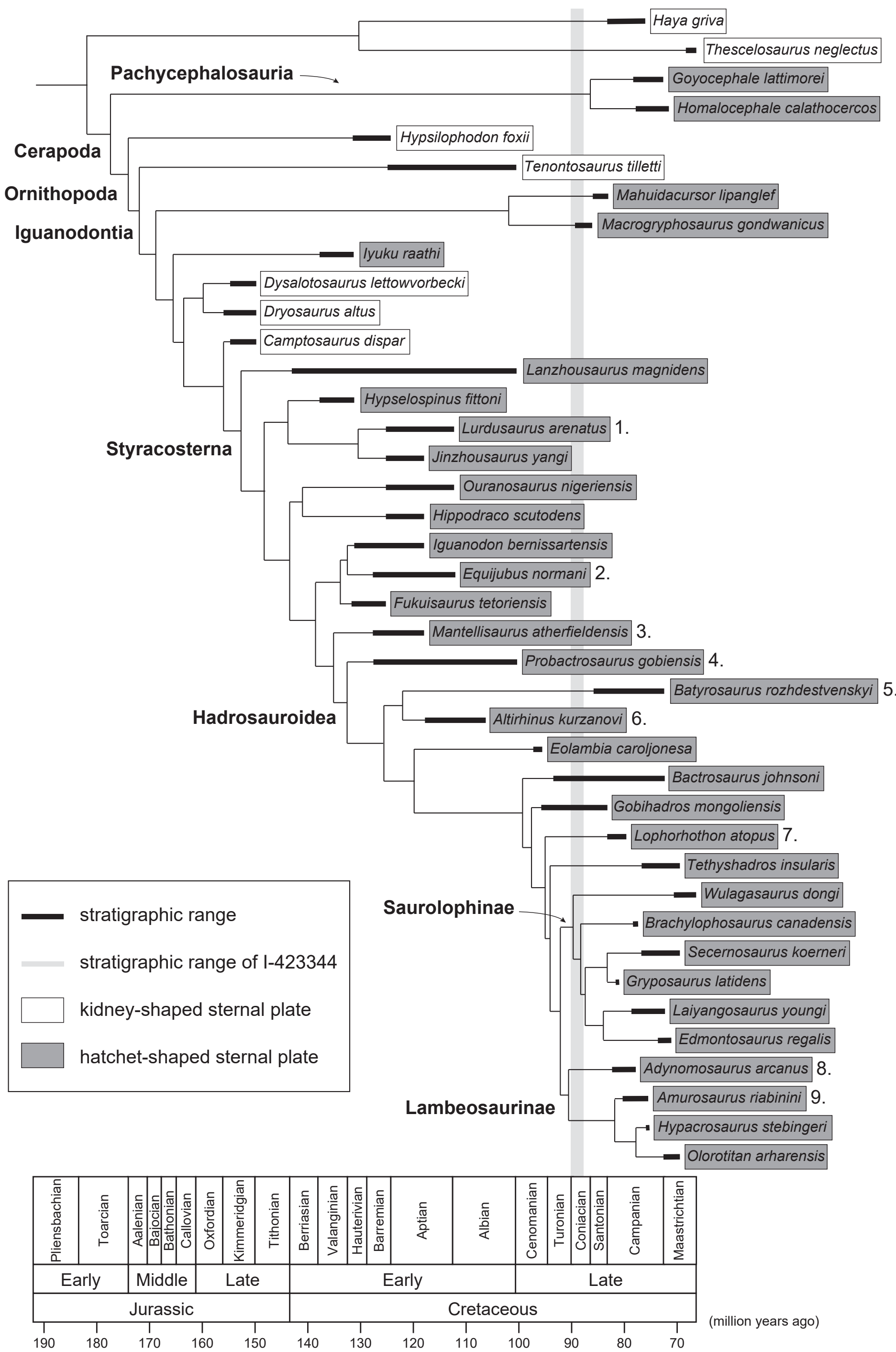

Figure 3. The phylogeny of ornithischian dinosaurs with morphological changes of the sternal plate. The phylogenetic tree is based on Poole (2022), Ramírez-Velasco (2022) and Fonseca *et al.* (2024). References for the sternal plates are as follows: 1, Taquet and Russell, 1999; 2, McDonald *et al.*, 2014; 3, Bonsor *et al.*, 2023; 4, Norman, 2002; 5, Godefroit *et al.*, 2012a; 6, Noman, 1998; 7, Gates and Lamb, 2021; 8, Prieto-Márquez *et al.*, 2019; 9, Godefroit *et al.*, 2004b.

brates (e.g. chondrichthyans, plesiosaurs and mosasaurs: Sato *et al.*, 2012; Takakuwa *et al.*, 2018) and invertebrates (e.g. ammonoids, bivalves, gastropods and brachiopods: Matsumoto *et al.*, 1990; Ando *et al.*, 1995; Kubo *et al.*, 2002), but terrestrial vertebrates are rare (Hasegawa *et al.*, 1987; Manabe *et al.*, 2003; Ohashi *et al.*, 2015). Inocera-

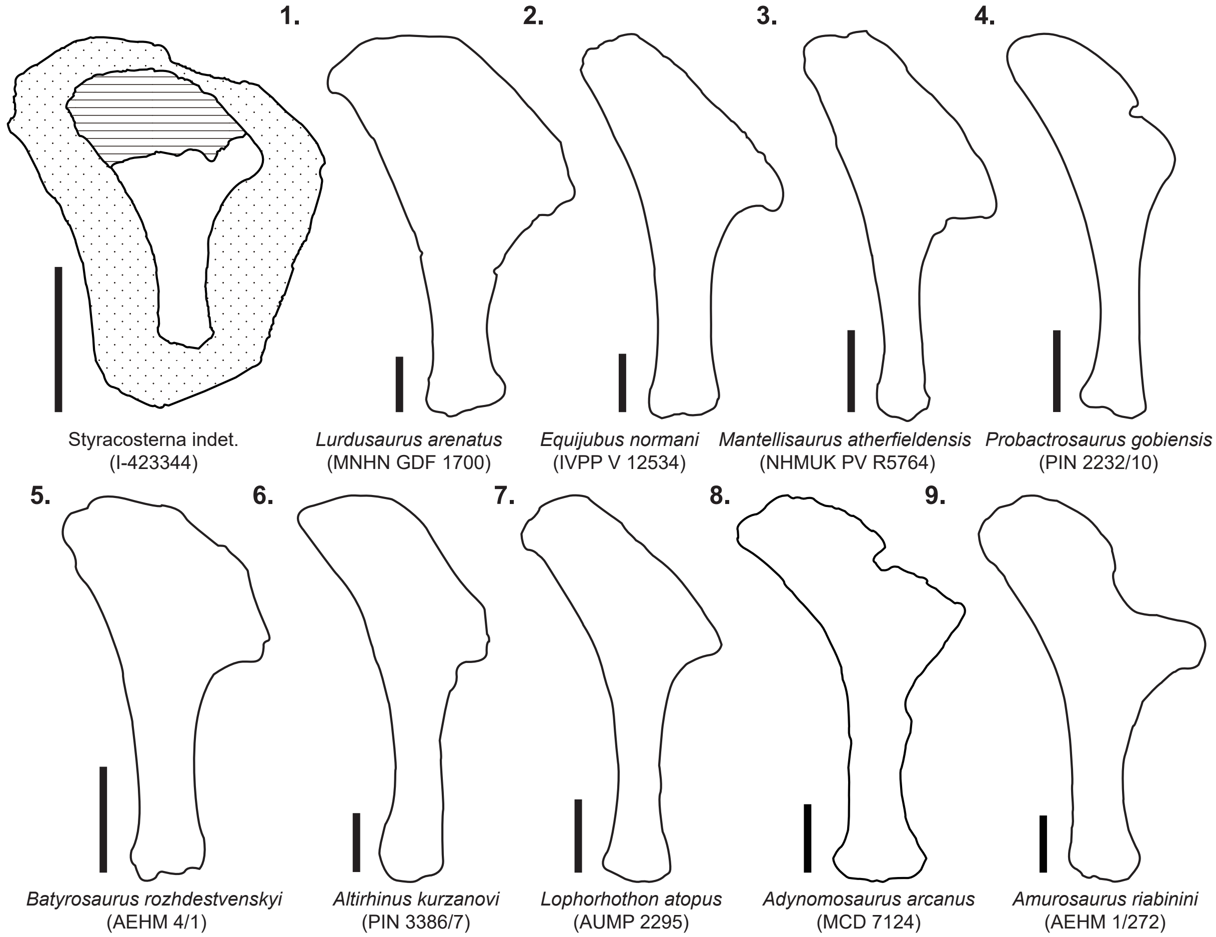

Figure 4. Morphological comparisons of the sternal plates among styracosternans (only the taxa that possess the sternal plates with a relatively short caudolateral process). Numbers correspond to those in Figure 3. All scale bars are 50 mm.

mids (e.g. *Inoceramus uwajimensis*) and ammonites (e.g. *Forresteria alluaudi* and *Yabeiceras orientale*) indicate an early (?) to middle Coniacian age for the Obisagawa Member (Toshimitsu *et al.*, 1995; Kubo *et al.*, 2002), but recent studies reveal inoceramid and ammonoid specimens indicate a late Turonian age for the lower to middle part of the member (Inose *et al.*, 2024; Inose, 2025).

Systematic paleontology

Dinosauria Owen, 1842
Ornithischia Seeley, 1888
Ornithopoda Marsh, 1881
Iguanodontia Baur, 1891
Styracosterna Sereno, 1986
Styracosterna indet.

Figure 2

Referred specimen.—I-423344, an isolated right sternal plate.

Locality.—I-423344 was collected from the premises in the Iwaki City Ammonite Center in Ohisa-machi Tsurubo, Iwaki, Fukushima, Japan.

Horizon.—I-423344 was found in a grey, very fine sandstone layer of the middle Obisagawa Member, Ashizawa Formation, Futaba Group ([?late Turonian to] middle Coniacian).

Description.—The ventral side of a right sternal plate is exposed in I-423344, with the dorsal side embedded in matrix (Figure 2A). Although the anterior half of the craniomedial plate was lost during excavation, a darkly stained impression preserved in the matrix represents an accurate mold of the missing piece of bone. The caudolateral process is also missing the posterior end due to breakage (Figure 2B). There is no evidence of a fused left sternal plate in the specimen.

The right sternal plate is relatively flat and hatchet-shaped, consisting of a blade-like craniomedial plate and

Table 2. Character scores of I-423344 based on the character lists of McDonald (2012) and Poole (2022).

	Morphological characters of the sternal plate	Character number	I-423344 coding
McDonald (2012)	Sternal, shape of main body in dorsal or ventral view, excluding caudolateral process if present: convex medially and concave laterally (0); convex medially and straight laterally (1).	98	0
Poole (2022)	Sternal plates, rod-like caudolateral process: absent (0); present (1).	189	1
	Sternals, caudolateral process, shape of cross-section: round (0); flattened (1).	190	0
	Sternal, caudolateral process, length relative to that of the craniomedial plate: caudolateral process slightly shorter or as long as the craniomedial plate (0); caudolateral process longer than the craniomedial plate (1).	191	0
	Sternal, pronounced caudomedial process projects from plate of sternal in addition to caudolateral process: absent (0); present (1).	192	0
	Sternals, midline fusion: absent (0); present (1).	193	0

a handle-like caudolateral process. The preserved length of the element is 108.40 mm, including the impression of the craniomedial plate. The anteroposterior length of the craniomedial plate alone (bone and impression) is 76.99 mm. Based on the shape of the impression, the anterior margin of the craniomedial plate is gently convex. Along the medial margin, the caudomedial process of the element is triangular, indicating that it is poorly developed. In ventral view, the lateral margin of the craniomedial plate is gently concave moving toward the caudolateral process. The caudolateral process extends almost straight posterolaterally from the craniomedial plate. Since the posterior end is broken, the original length of the caudolateral process would have been slightly longer than the preserved length of 64.14 mm. The caudolateral process is 19.70 mm in width and becomes slightly wider distally to articulate with the distal rib cartilage of the anterior dorsal vertebrae. The cross-sectional outline of the caudolateral process is flat dorsally but convex ventrally (Figure 2C).

General comparisons.—A hatchet-shaped sternal plate, as described for I-423344, is present in both iguanodontians and pachycephalosaurians (Figures 3, 4; Cruzado-Caballero *et al.*, 2019; Poole, 2022). However, I-423344 lacks the hook-like process extending from the medial margin of the craniomedial plate (*Homalocephale*: Maryańska and Osmólska, 1974) and the posterolaterally curved caudolateral process (*Goyocephale*: Perle *et al.*, 1982) found in pachycephalosaurs. I-423344 is thus more similar to the sternal plates of iguanodontians, particularly more derived members (i.e., non-hadrosauroid styracosternans and hadrosauroids: Tables 2, 3). These derived members generally have sternal plates with unfused midline margins of the craniomedial plates, an undeveloped caudomedial process, a concave lateral margin, and a relatively short and (ventrally) rounded caudolateral process, features also present in I-423344 (Figure 4; Table 3). Although the sternal plates of basal iguanodontians are also hatchet-shaped, they differ from I-423344 and more derived iguanodontian members in possessing fused anterior midline margins of the craniomedial plates (*Macrogryphosaurus*: Calvo *et al.*, 2007; *Mahuidacursor*: Cruzado-Caballero *et al.*, 2019), a developed caudomedial process (*Macrogryphosaurus*: Calvo *et al.*, 2007; *Mahuidacursor*: Cruzado-Caballero *et al.*, 2019), a straight lateral margin (*Iyuku*: Forster *et al.*, 2022), and a flat caudolateral process (*Iyuku*: Forster *et al.*, 2022; *Macrogryphosaurus*: Calvo *et al.*, 2007).

Discussion

Description of I-423344 and comparisons suggest that the isolated sternal element belongs to a styracosternan iguanodontian. Although a more detailed taxonomic identification is difficult to ascertain using morphology, the relative length of the caudolateral process has been used as a taxonomic indicator for styracosternans (e.g. Norman, 2015; Poole, 2022; Ramírez-Velasco, 2022). A caudolateral process shorter than or as long as the craniomedial plate is found in non-hadrosauroid styracosternans (e.g. *Lurdusaurus*: Taquet and Russell, 1999; *Lanzhousaurus*: You *et al.*, 2005; *Hypselospinus*: Norman, 2015) as well as in several hadrosauroids (e.g. *Batyrosaurus*: Godefroit *et al.*, 2012a; *Eolambia*: McDonald *et al.*, 2012; *Lophorhothon*: Gates and Lamb, 2021), including some lambeosaurines (*Tsintaosaurus*: Young, 1958; *Amurosaurus*: Godefroit *et al.*, 2004b; *Adynomosaurus*: Prieto-Márquez *et al.*, 2019). The alternate condition of a caudolateral process longer than the craniomedial plate is observed in other hadrosauroids (*Bactrosaurus*: Godefroit *et al.*,

Table 3. Comparison of character scores of I-423344 and other iguanodontians, including hadrosauroids. The classification of iguanodontian taxa follows Dieudonné *et al.* (2020), Poole (2022), and Ramírez-Velasco (2022). Gray bands indicate that the codings are the same as in I-423344.

Taxon		McDonald (2012)	Poole (2022)					References
		98	189	190	191	192	193	
	I-423344 coding	0	1	0	0	0	0	This study
Basal Iguanodontia	*Mahuidacursor lipanglef*	0	1	0	0	1	1	Cruzado-Caballero *et al.* (2019)
	Macrogryphosaurus gondwanicus	0	1	1	0	1	1	Calvo *et al.* (2007); Rozadilla *et al.* (2020)
	Iyuku raathi	1	1	0/1	0	0	0	Forster *et al.* (2022); Poole (2022)
Styracosterna	*Lanzhousaurus magnidens*	0	1	1	0	0	0	You *et al.* (2005)
	Hypselospinus fittoni	0	1	0	0	1	1	Norman (2015)
	Lurdusaurus arenatus	0	1	0	0	0	0	Taquet and Russell (1999); Poole (2022)
	Jinzhousaurus yangi	0	1	?	0	1	0	Wang *et al.* (2010)
	Ouranosaurus nigeriensis	0	1	0	0	1	0	Bertozzo *et al.* (2017)
	Hippodraco scutodens	0	1	1	0	0	0	McDonald *et al.* (2010)
	Iguanodon bernissartensis	1	1	0	0	0	0	Norman (1980)
	Equijubus normani	0	1	0	0	1	0	McDonald *et al.* (2014)
	Fukuisaurus tetoriensis	1	1	1	0	0	0	Kobayashi and Azuma (2003)
	Mantellisaurus atherfieldensis	0	1	0	0	0	0	Norman (1986); Bonsor *et al.* (2023)
Hadrosauroidea	*Probactrosaurus gobiensis*	0	1	0	0	0	0	Norman (2002)
	Batyrosaurus rozhdestvenskyi	0	1	0	0	0	0	Godefroit *et al.* (2012a)
	Altirhinus kurzanovi	0	1	0	0	0	0	Norman (1998)
	Eolambia caroljonesa	1	1	1	0	0	0	McDonald *et al.* (2012)
	Bactrosaurus johnsoni	0	1	1	1	1	0	Godefroit *et al.* (1998)
	Gobihadros mongoliensis	0	1	?	1	0	0	Tsogtbaatar *et al.* (2019)
	Lophorhothon atopus	0	1	?	0	1	0	Gates and Lamb (2021)
	Tethyshadros insularis	?	1	?	1	0	0	Dalla Vecchia (2009)
	Wulagasaurus dongi	0	1	0	1	1	0	Godefroit *et al.* (2008); Xing *et al.* (2012)
	Brachylophosaurus canadensis	0	1	0	1	0	0	Prieto-Márquez (2007)
	Secernosaurus koerneri	0	1	0	1	1	0	Prieto-Márquez and Salinas (2010)
	Gryposaurus latidens	0	1	1	1	?	0	Prieto-Márquez (2012)
	Laiyangosaurus youngi	0	1	0	1	1	0	Zhang *et al.* (2023)
	Edmontosaurus regalis	0	1	1	1	1	0	Campione (2014)
	Adynomosaurus arcanus	0	1	0	0	?	0	Prieto-Márquez *et al.* (2019)
	Amurosaurus riabinini	0	1	0	0	?	0	Godefroit *et al.* (2004b)
	Hypacrosaurus stebingeri	0	1	1	1	0	0	Horner and Currie (1994); Poole (2022)
	Olorotitan arharensis	0	1	0	1	0	1	Godefroit *et al.* (2012b)

1998; *Tethyshadros*: Dalla Vecchia, 2009; *Gobihadros*: Tsogtbaatar *et al.*, 2019), including both lambeosaurines (e.g. *Hypacrosaurus*: Horner and Currie, 1994; *Olorotitan*: Godefroit *et al.*, 2012b; *Corythosaurus*: Takasaki *et al.*, 2022) and saurolophines (e.g. *Wulagasaurus*: Godefroit *et al.*, 2008; *Secernosaurus*: Prieto-Márquez and Salinas,

Table 4. Sternal plate measurements and body length estimates for derived iguanodontians from Asia. The classification follows Poole (2022) and Ramírez-Velasco (2022). An asterisk denotes the preserved length of incomplete specimens.

	Taxon	Sternal specimen	Sternal whole length (cm)	Craniomedial plate length (cm)	Body length (cm)	References
	Styracosterna indet.	I-423344	10.84*	7.699	–	This study
Styracosterna	*Fukuisaurus tetoriensis*	FPDM-V-40-16	19.81	–	400	Kobayashi and Azuma (2003); Norman (2015)
	Jinzhousaurus yangi	IVPP V12691	24.00	17.50	500–550	Wang *et al.* (2010)
	Lanzhousaurus magnidens	GSLTZP 01-001	45.00	–	1,000	You *et al.* (2005)
Hadrosauroidea	*Bactrosaurus johnsoni*	SBDE 95E5/23	–	11.00	600–700	Norman (2015); Prieto-Márquez *et al.* (2019)
	Gobihadros mongoliensis	MPC-D100/746	11.26	6.941	300	Matsumoto and Hashimoto (2011); Tsogtbaatar *et al.* (2019)
	Kamuysaurus japonicus	HMG-1219	40.00*	–	800	Kobayashi *et al.* (2019)
	Olorotitan arharensis	AEHM 2/845	42.00	20.50	800	Godefroit *et al.* (2012b)
	Probactrosaurus gobiensis	PIN 2232/10	–	12.50	400–600	Norman (2002); Prieto-Márquez *et al.* (2019)
	Shantungosaurus giganteus	GMV 1780	72.40	29.00	1,470	Hu *et al.* (2001); Prieto-Márquez *et al.* (2019)
	Shantungosaurus giganteus	Zhao *et al.* (2007), p. 122	70.00	27.10	1,660	Zhao *et al.* (2007); Prieto-Márquez *et al.* (2019)

2010; *Laiyangosaurus*: Zhang *et al.*, 2023). Therefore, although the caudolateral process is relatively short in I-423344, the relative size of this feature appears to vary among hadrosauroid taxa (Figure 4), precluding further classification of I-423344 within Styracosterna using this feature. However, based on its stratigraphic position and other Asian fossil occurrences, a hadrosauroid styracosternan affinity for the sternal plate (I-423344) is most likely because among the iguanodontians, only hadrosauroid remains have been reported from the Upper Cretaceous Ashizawa Formation (Manabe *et al.*, 2003; Ohashi *et al.*, 2015; Kubota, 2023). This identification is consistent with other fossil occurrences in eastern Asia, revealing that hadrosauroids (including derived Hadrosauridae) became an important and taxonomically diverse component of dinosaur faunas during the Late Cretaceous (Prieto-Márquez, 2010; Kobayashi *et al.*, 2021).

Among hadrosauroids, ontogenetic changes in sternal plate morphology are known for relatively few species. In some species (e.g. *Maiasaura* and *Prosaurolophus*), the length of the caudolateral process relative to the width is known to have increased during ontogeny (Brett-Surman and Wagner, 2007; Drysdale *et al.*, 2018; Prieto-Márquez and Guenther, 2018), whereas in other species (e.g. *Equijubus*, *Jinzhousaurus* and *Lurdusaurus*), a relatively short caudolateral processes is retained into adulthood (Taquet and Russell, 1999; Wang *et al.*, 2010; McDonald *et al.*, 2014). Also, the midline margins of the craniomedial plates are fused in mature styracosternans (Godefroit *et al.*, 2012b; Norman, 2015), although fused plates are also found in juveniles of some taxa (e.g. *Edmontosaurus*: Prieto-Márquez, 2014). Due to effects of ontogeny and morphological variation among species, it is difficult to assess the growth stage of I-423344. However, I-423344 appears to represent a relatively small individual. It is comparable in size to the sternal element of an articulated subadult *Gobihadros* skeleton from Mongolia (MPC-D 100/746: Tsogtbaatar *et al.*, 2019), an individual measuring three meters in body length (Table 4).

The Obisagawa Member is unique in Japan for yielding a small styracosternan dinosaur from Upper Cretaceous marine strata (lower shoreface to inner shelf: Ando *et al.*, 1995). Although the currently available materials are limited (Table 1), the co-occurrence of relatively small to large styracosternan individuals suggests that the terrestrial coastal environments contemporaneous with the Obisagawa Member supported individuals across a range of body sizes. Similar patterns are found in Upper Cretaceous deposits of North America and North Africa, where hadrosauroid remains of both small (i.e., juveniles or small-sized adults) and large (i.e., adults) individuals have been reported from marine sediments (Horner, 1979; Drysdale *et al.*, 2018; Longrich *et al.*, 2024).

Acknowledgements

This paper is based on part of a bachelor's thesis by M.K. In addition, this study was supported by the Natural Sciences and Engineering Research Council of Canada Discovery Grant (RGPIN-04697) to D.K.Z. We thank the Cultural Promotion Division of the Iwaki City Office for allowing us to borrow the specimen. We also thank Tomoyuki Ohashi (Kitakyushu Museum of Natural History and Human History) for his useful comments regarding the morphological characters and ontogenetic changes of the iguanodontian sternal elements and Chisako Sakata (National Museum of Nature and Science) for her technical support. We would like to express our gratitude to Editor in Chief Shin-ichi Fujiwara (Nagoya University Museum) for handling our manuscript, and Filippo Bertozzo (Royal Belgian Institute of Natural Sciences) and an anonymous reviewer for their detailed reviews that improved the manuscript.

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Author contributions

M.K. designed this research and wrote the original manuscript draft; all authors contributed to revising subsequent manuscript drafts. K.T. supervised this study and contributed to scientific aspects of the manuscript. F.U. provided the specimen for study. J.Y. contributed to discussions. D.K.Z. revised the English phrasing and overall structure and contributed to scientific aspects of the manuscript.