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Takeshi Tanaka

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Cover picture: *Carcharodon carcharias* (Linnaeus, 1758) from the Lower Pleistocene Dainichi Formation of the Kakegawa Group, collected by the senior author from Koichi, Kakegawa City, Shizuoka Prefecture, central Japan.

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Paleozoic, Mesozoic and Cenozoic Chondrichthyes from the Japanese Islands

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Abstract Fossil specimens of chondrichthyans collected by the senior author and colleagues from around the Japanese islands are reported geochronologically from older (Cisuralian-Guadalupain of Early-Middle Permian) to younger (Late Pleistocene), and geographically from north (Ashibetsu, Hokkaido) to south (Uruma, Okinawa). The total number of about 8,000 cheek teeth from localities that counts 76 with detailed descriptions and 19 with occurrence records. Although most of such localities belong to the Cenozoic, the collections also include specimens from the Paleozoic and the Mesozoic. The taxonomic diversity reaches two orders, four families and at least four genera from the Paleozoic; eight orders, 21 families and at least 30 genera from the Mesozoic; seven orders, 15 families and at least 28 genera from the Paleogene of the Cenozoic; 11 orders, 27 families and at least 43 genera from the Neogene of the Cenozoic; 12 orders, 19 families and at least 33 genera from the Quaternary of the Cenozoic; and thus 17 orders, 45 families and at least 84 genera as a whole.

Key words : Chondrichthyan, Elasmobranchii, tooth, Japan

INTRODUCTION

For about 40 years, the senior author has been interested in shark tooth fossils, especially their classifications, and has been collecting specimens since then. The senior author collected specimens from various localities in Japan and decided to donate them to the National Museum of Nature and Science to open to science as well as to public. In conjunction with the donation, this monograph is published with an overview of the collections mainly by the senior author, but some have been donated by many acquaintances. We hope that future researchers will refer and use these specimens to study the native chondrichthyans fossils. Some of the contributors for collecting specimens are now deceased, and it is with great regret that we are unable to report on them before their death. The names of the contributors are listed at the end of this report.

The chondrichthyan fossils from Japan have been studied for many years since Ishihara (1898) reported 10 shark teeth fossils from the

Neogene of Shimoda in Shizuoka Prefecture. However, the studies following Ishihara (1898) were limited to the reports of individual materials and/or localities, and there have been no studies taking a holistic view until Goto (1972) summarized the chondrichthyan fossils from the Japanese islands. In that report, he emphasized the importance to recognize the perspective of researches on fossil chondrichthyan fossils in Japan. Afterward, quite a few studies on chondrichthyan fossils by geological periods, such as the Paleozoic (Goto, 2009), Paleozoic- Mesozoic (Goto and Kuga, 1982, Goto, 1994), Mesozoic (Goto *et al.*, 1996), Mesozoic-Cenozoic (e.g., Yabumoto and Uyeno, 1994), Cenozoic (Kuga, 1985) were reported, and most recently Takakuwa (2021) reviewed such studies comprehensively. In addition, new specimens from the Paleozoic Ichinotani Formation (Goto and Okura, 2004) and the Akasaka Limestone (Goto *et al.*, 1988, Yamagishi and Fujimoto, 2011), and from various parts of Japan (Research group for Mesozoic fossil shark, 1977) including the

Mesozoic Sanchu Formation (Takakuwa *et al.*, 2008), Himenoura Formation (Kitamura, 2019) were reported. In the Cenozoic, there are reports summarizing the chondrichthyan faunas and/or assemblages from the Hokuriku region (Karasawa, 1989), the Eocene Namigata Formation (Tanaka *et al.*, 2006), the Oligocene Ashiya Group (Uyeno *et al.*, 1984), the Lower Miocene Ichishi Group (Tanaka, 2013), the Lower to Middle Miocene Mizunami Group (Itoigawa *et al.*, 1985), the Lower Miocene Tomikusa Group (Hasegawa and Uyeno, 1967), the Middle Miocene Nanao Formation (Nomura, 2002), the Upper Miocene Senhata Formation (Yabe and Hirayama, 1998), and the Lower Pleistocene Dainichi Formation (Yokoyama *et al.*, 2000). Deep-sea sharks were also reported from the Middle Miocene Yokoo Formation (Suzuki, 2012) and the Upper Miocene Tomioka Formation (Takakuwa, 2007). Among them, Itoigawa (1985) that summarized in detail the elasmobranch fossils from the Mizunami Group comprehensively, and it became a monumental one in the studies of Cenozoic elasmobranch fossils in Japan. Tanaka *et al.* (2006) was also recognized as a diminitive paper to demonstrate the *Otodus* fossils with species-level identification to be useful to reveal the geologic age of the Eocene Namigata Formation in Okayama Prefecture, which had previously been considered to be Oligocene and/or Early Miocene in age. During those periods, some other reports on

individual shark fossils have been published such as studies on associated tooth sets of *Carcharodon hastalis* (Uyeno *et al.*, 1990) and *Otodus megalodon* (Uyeno *et al.*, 1989, Koda *et al.*, 2007) continuously. However, the studies have been still limited to individual fossils, and a holistic overview for the chondrichthyan fossils in the Japanese islands through time has long been anticipated.

This monograph describes and illustrates the panoply of chondrichthyan fossils collected in a comprehensive manner from geographic and stratigraphic points of view, thus helping to clarify the entire panoply of chondrichthyan faunas from the seas around Japan. In this report, we present almost 8000 fossil specimens of chondrichthyans (mostly Elasmobranchii teeth) from Japan, and representative specimens are described and illustrated by locality, including an overview of the fossil specimens. The localities are listed in order of their northern localities, beginning with the earliest period.

Classification follows Cappetta (2012) and Goto *et al.* (2024) for tooth identification. The taxonomic system and species arrangement follows Cappetta (2012). The terminology for teeth follows Yabe and Goto (1999), see also Figure 1.

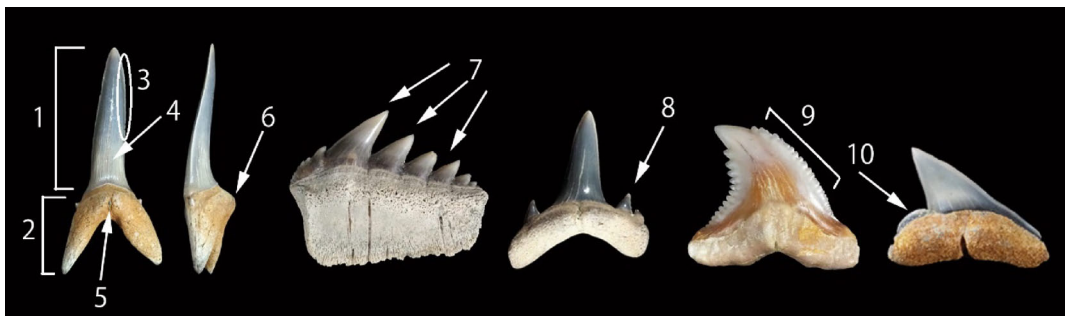


Figure 1. Tooth terminology of sharks; 1, crown; 2, root; 3, cutting edge; 4, striation; 5, nutritive groove; 6, lingual protuberance; 7, cusp; 8, cusplet; 9, serration; 10, shoulder.

SYSTEMATICS

I. PALEOZOIC ERA

Paleozoic chondrichthyan fossils are presented by Formation (Figure 2). Geological chronology of each Formation. Map number in parentheses ().

1. Funabuseyama Formation

Locality: Neohajikadani, Motosu City, Gifu Prefecture

Formation and Age: Funabuseyama Formation, Cisuralian-Guadalupain. According to Sano and Yamagata (2020), the age of the Funabuseyama Formation is considered to be Cisuralian-Guadalupain of Early-Middle Permian based on the radiolaria.

Class Chondrichthyes Huxley, 1880
Subclass Elasmobranchii Bonaparte, 1838
Order Ctenacanthiformes Glikman, 1964
Family Ctenacanthidae Dean, 1909
Ctenacanthidae gen. et sp. indet
Figure 3-1, 2

Description: The crown is thin, erect and conical with multiple secondary cusps in addition to the main cusp. The root is flat and semicircular.

Remarks: Ginter *et al.* (2005) classified Elasmobranchii with *Cladodus*-type teeth and placed most of them in the order

Ctenacanthiformes. This section follows their classification. These teeth can be determined to belong to the family Ctenacanthidae, but it is not possible to make a generic and specific identification.

Order Hybodontiformes Patterson, 1966
Family Acrodontidae Casier, 1959
Genus *Acrodus* Agassiz, 1838
Acrodus sp.
Figure 3-3,4

Description: The tooth is elongated, oval and of the grinding type. Viewed from the labial-lingual direction, the center is high and mountainous. The crown surfaces have the numerous wrinkles.

Family Lonchidiidae Herman, 1977
Genus *Lissodus* Brough, 1935
Lissodus sp.
Figure 3-5

Description: The tooth is elongated, oval and of the grinding type. The central portion of the crown is highly raised, and there are no wrinkles on the surface of the crown.

Remarks: This species is similar to *Acrodus* spp., but can be distinguished by the lack of wrinkles on the crown surface, and was identified according to Yamagishi and Fujimoto (2011).

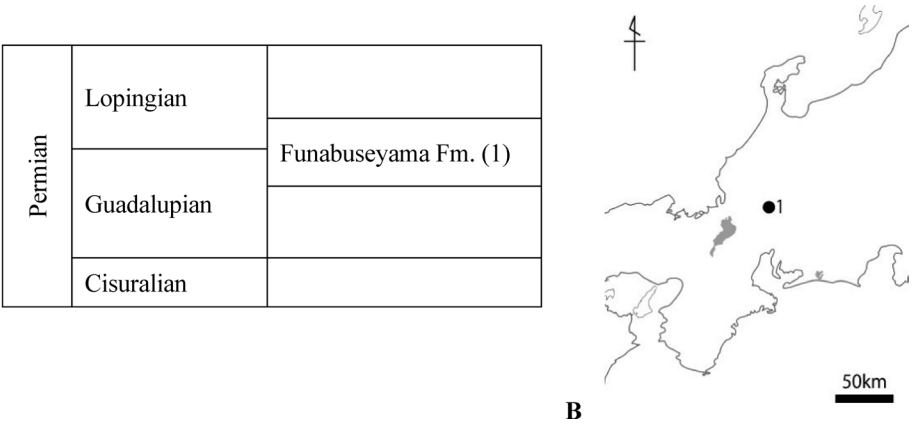


Figure 2. Geographical and geological context of the locality area. A, locality map. B, Stratigraphic diagram modified from Sano and Yamagata (2020).

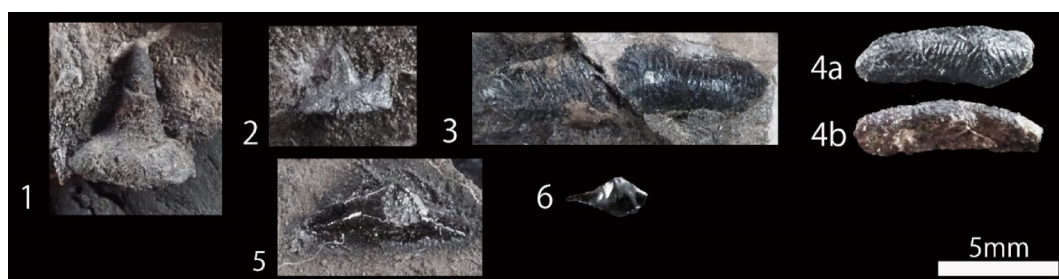


Figure 3. 1, *Ctenacanthidae* gen. et sp. indet., NMNS-PV 26743; 2, *Ctenacanthidae* gen. et sp. indet., NMNS-PV 26745; 3, *Acrodus* sp., NMNS-PV 26748; 4, *Acrodus* sp., NMNS-PV 26760, occlusal (a) and lingual (b) views; 5, *Lissodus* sp., NMNS-PV 26758; 6, *Polyacrodus* sp., NMNS-PV 26763. Scale bar equals 5 mm.

Family Polyacrodontidae Gluckman, 1964

Genus *Polyacrodus* Jaekel, 1889

Polyacrodus sp.

Figure 3-6

Description: The tooth is elongated, oval and of the grinding type, but much smaller than the genus *Acrodus*. The surface of the crown has no numerous wrinkles.

II. MESOZOIC ERA

Mesozoic chondrichthyan fossils are also presented by Formation, beginning with the earliest (Figures 4 and 5). Geological chronology of each Formation. Map number in parentheses ().

2. Waruishi Formation, Yakuno Group

Locality: Waruishi, Yakunocho, Fukuchiyama City, Kyoto Prefecture

Formation and Age: Waruishi Formation, Anisian. According to Nakazawa *et al.* (1957), the age of the Waruishi Formation of the Yakuno Group is considered to be Anisian of Middle Triassic, based on the large fossils such as ammonites.

Order Hybodontiformes Patterson, 1966

Family Hybodontidae Owen, 1846

Genus *Hybodus* Agassiz, 1837

Hybodus sp.

Figure 6-1,2

Description: The crown is thin, erect and

Cretaceous	Upper	Maastrichtian	Azenotani Fm. (13) Kokawa Fm. (12)
		Campanian	
		Santonian	Hinoshima Fm. (11)
		Conician	Asizawa Fm. (10) Haborogawa Fm. (9)
		Turonian	
		Cenomanian	Kashiwaguri Fm. (8)
	Lower	Albian	
		Aptian	
		Barremian	Hanenoura Fm. (7) Sebayashi Fm. (6)
		Hauterivian	Ishido Fm. (5)
		Valaanginian	
		Berriasian	
	Jurassic	Upper	—
		Middle	—
		Lower	—
		Toarcian	
		Pliensbachian	Yoshinazawa Fm. (4)
		Sinemurian	
Triassic	Upper	Hettangian	
		Rhaetian	
		Norain	
	Middle	Carnian	Izuriha Fm. (3)
		Ladinian	
		Anisian	Waruishi Fm. (2)
	Lower	—	

Figure 4. Geographical and geological context of the locality area, stratigraphic diagram modified from references cited below.

conical. There are usually several low lateral cusps on either side of the main cusp, but in some types they are absent. The basal part of the crown is finely wrinkled. The lingual face of the

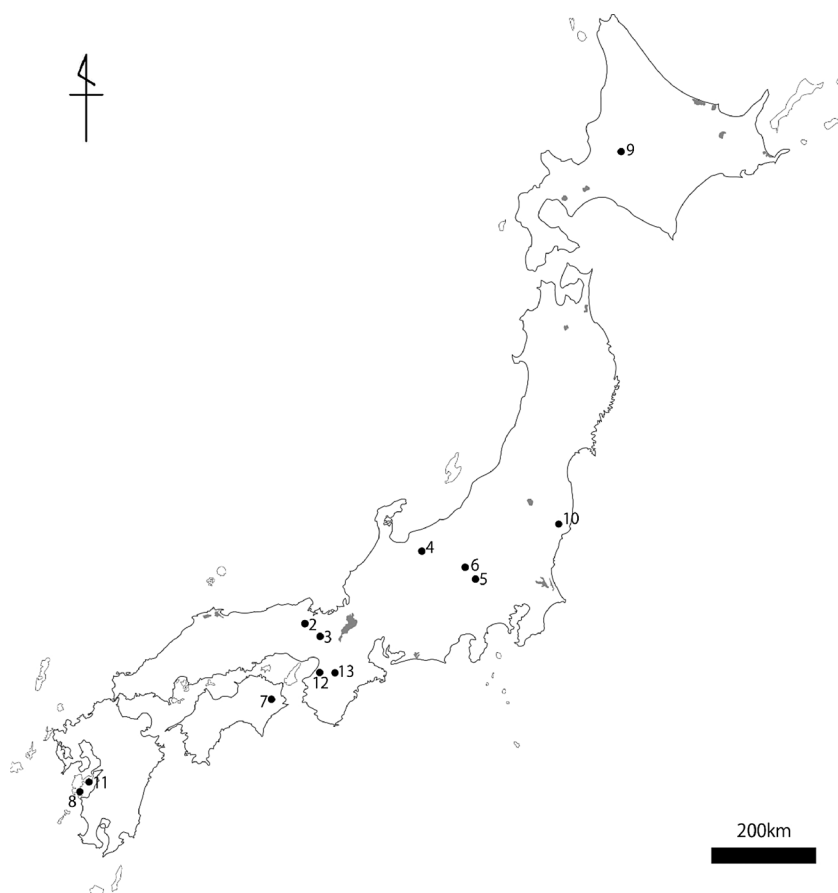


Figure 5. Geographical and geological context of the locality area, locality map.



Figure 6. 1, *Hybodus* sp., NMNS-PV 26101; 2, *Hybodus* sp., NMNS-PV 26103. Scale bar equals 5 mm.

crown is convex and the labial face is also slightly convex. The root is not bifurcated and the lingual face is strongly raised.

3. Izuriha Formation

Locality: Sugitani, Oharanoishizukuricho, Nishikyo Ward, Kyoto City, Kyoto Prefecture

Formation and Age: Izuriha Formation, Carnian. According to Shimizu (1967), the age of the Izuriha Formation is considered to be Permian, but Li and Ichida (2009) assigned it to Carnian of Upper Triassic based on conodont fossils. In this paper, Upper Triassic period is used.

Cohort Euselachii, Hay, 1902
 Superfamily Protacrodontoidea, Zangerl, 1981
 Genus *Protacrodus* Jaekel, 1925
Protacrodus sp.
 Figure 7-1

Description: The crown is low, broad and multicuspoid. The central cusp is the largest and its sides are successively lower. There are faint striations on the labial face of the crown.

Remarks: According to PBDB (<https://paleobiodb.org/#/>), most of the fossils of this taxon are known from the Devonian to Carboniferous, and only the Triassic record is known only from Poland. Accordingly, this is the second record of this taxon from the Triassic period.

Order Ctenacanthiformes Glikman, 1964
 Family Ctenacanthidae Dean, 1909
 Ctenacanthidae gen. et sp. indet.
 Figure 7-2

Description: The crown is thin, erect, conical and in addition to the main cusp, one secondary cusp is visible. It is likely that there was more than one, as it is missing. The root is flat and semicircular.

Remarks: Ginter *et al.* (2005) classified Elasmobranchii with Cladodus-type teeth and placed most of them in the order Ctenacanthiformes and this section follows this classification. These teeth can be assigned to the family Ctenacanthidae, but it is not possible to make a generic and specific identification.

Order Hybodontiformes Patterson, 1966
 Family Acrodontidae Casier, 1959
 Genus *Acrodus* Agassiz, 1838
Acrodus sp.
 Figure 7-3,4

Description: The tooth is elongated, oval and of the grinding type. Viewed from the labial-lingual direction, the center is high and mountainous. The surface of the crown has numerous wrinkles.

4. Yoshinazawa Formation, Kuruma Group

Locality: Kuruma, Kotani Village, Kitaazumi-Gun, Nagano Prefecture

Formation and Age: Yoshinazawa Formation, Pliensbachian. According to Kobayashi *et al.* (1957) and Shiraishi (1992), the age of the Yoshinazawa Formation of the Kuruma Group is considered to be Pliensbachian of Early Jurassic based on the radiolarian.

Order Hybodontiformes Patterson, 1966
 Family Acrodontidae Casier, 1959
 Genus *Acrodus* Agassiz, 1838
Acrodus sp.
 Figure 8-1,2

Description: The crown is small and triangular. The surface of the crown is strongly striated. Fig. 8-2 has a pair of lateral cusps.

Genus *Asteracanthus* Agassiz, 1837
Asteracanthus sp.
 Figure 8-3,4,5

Description: The crown is elongated and oval or nearly circular in shape. The tooth is of the



Figure 7. 1, *Protacrodus* sp., NMNS-PV 26765; 2, Ctenacanthidae gen. et sp. indet., NMNS-PV 26772; 3, *Acrodus* sp., NMNS-PV 26771; 4, *Acrodus* sp., NMNS-PV 26775. Scale bar equals 2 mm.

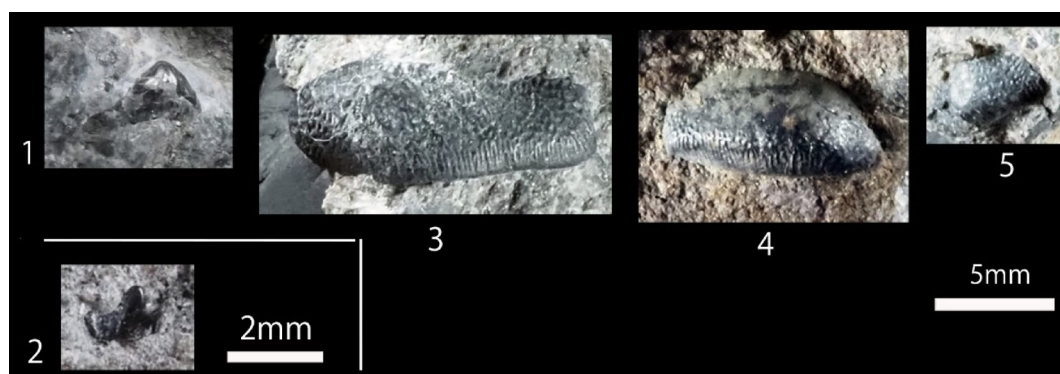


Figure 8. 1, *Acrodus* sp., NMNS-PV 26106; 2, *Acrodus* sp., NMNS-PV 26107; 3, *Asteracanthus* sp., NMNS-PV 26108; 4, *Asteracanthus* sp., NMNS-PV 26109; 5, *Asteracanthus* sp., NMNS-PV 26110. Scale bar equals 5 mm.

grinding type with numerous small holes on the occlusal surface.

5. Ishido Formation, Sanchu Group

Locality: Ryokamisusuki, Ogano Town, Chichibu-Gun, Saitama Prefecture

Formation and Age: Ishido Formation, Hauterivian-Barremian. According to Matsukawa and Tomishima (2009), the age of the Ishido Formation of the Sanchu Group is considered to be Hauterivian-Barremian of Early Cretaceous based on the large fossils such as ammonites.

Order Lamniformes Berg, 1958
Family Mitsukurinidae Jordan, 1898
Mitsukurinidae gen. et sp. indet.

Figure 9-1

Description: The crown is narrow, straight and long of consistent width. The cutting edge of the crown has no serrations.

Remarks: This specimen is similar to the teeth of species within the family Odontaspidae, but it is straighter and longer than those of the Odontaspidae.

Family Cretoxyrhinidae Glikman, 1958
Genus *Acrolamna* Zhelezko, 1990
Acrolamna sp.

Figure 9-2

Description: The crown is rather broad, thick and

stout. The cutting edge of the crown has no serrations. The lingual face of the crown is convex.

Family Odontaspidae Müller and Henle, 1839
Odontaspidae gen. et sp. indet.

Figure 9-3

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations.

Remarks: The tooth is thought to belong to the genus *Odontaspis* or *Carcharias* of the family Odontaspidae, but it is assigned to an unidentified genus and species due to its fragmentary condition.

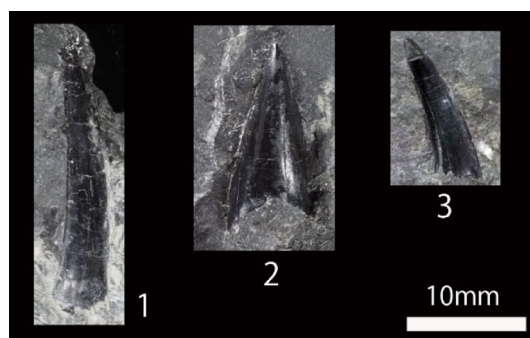


Figure 9. 1, *Mitsukurinidae* gen. et sp. indet., NMNS-PV 26157; 2, *Acrolamna* sp., NMNS-PV 26158; 3, *Odontaspidae* gen. et sp. indet., NMNS-PV 26168. Scale bar equals 10 mm.

Additional records: In addition to the species reported here, there are reports of *Scapanorhynchus* sp., *Carcharias* sp., *Protolamna* sp., Lamniformes gen. et sp. indet. from the same formation, according to Takakuwa *et al.* (2008).

6. Sebayashi Formation, Sanchu Group

Locality: Kagahara, Kanna Town, Tano-Gun, Gunma Prefecture

Formation and Age: Sebayashi Formation, Barremian-Aptian. According to Matsukawa and Tomishima (2009), the age of the Sebayashi Formation of the Sanchu Group is considered to be Barremian-Aptian of Early Cretaceous based on the large fossils such as ammonites.

Order Hybodontiformes Patterson, 1966

Family incertae sedis

Genus *Heteroptychodus* Yabe and Obata, 1930

Heteroptychodus steinmanni Yabe and Obata, 1930

Figure 10-1,2

Description: They are molar teeth. The occlusal surface of the crown has multiple ridges of striae, not raised as in *Ptycodus*, but almost flat and the striae on the occlusal surface are thin and numerous covering the entire crown.

Remarks: The family name of this genus is Ptychodontidae according to Cappetta (2012), but Böttcher (2024) was assigned Hybodontidae based on the root morphology. Here, according to Tumpeesuwan *et al.* (2024), it is designated Family incertae sedis. This species was described as a new

genus and species by Yabe and Obata (1930) on the basis of a specimen from Kamikatsu-cho, Katsuura-gun, Tokushima Prefecture. This species was also described as *Heteroptychodus* aff. *steinmanni* by Cappetta *et al.* (2006) on the basis of specimens from Thailand. The occurrence of this genus is restricted to Early Cretaceous.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Odontaspidae gen. et sp. indet.

Figure 10-3,4,5,6,7,8,9

Description: The crown is elongated and slightly curved distally or erect. There are one or two pairs of the lateral cusplets. The cutting edge of the crown has no serrations. The root is distinctly bifid.

Remarks: The tooth is thought to belong to the family Odontaspidae, but it is assigned to an unidentified genus and species due to its fragmentary condition and lack of separation from the host rock, so the entire specimen cannot be identified.

Additional records: In addition to the species reported here, there are reports of *Scapanorhynchus* sp. according to Takakuwa (1999), *Notorynchus* aff. *aptiensis* according to Takakuwa *et al.* (2001), *Acrodus* sp. according to Takakuwa (2022).

7. Hanenoura Formation, Mononobe Group

Locality: Nakagoya, Katsuura Town, Katsuura-Gun, Tokushima Prefecture



Figure 10. 1, *Heteroptychodus steinmanni*, NMNS-PV 26143; 2, *Heteroptychodus steinmanni*, NMNS-PV 26144; 3, Odontaspidae gen. et sp. indet., NMNS-PV 26145; 4, Odontaspidae gen. et sp. indet., NMNS-PV 26146; 5, Odontaspidae gen. et sp. indet., NMNS-PV 26148; 6, Odontaspidae gen. et sp. indet., NMNS-PV 26150; 7, Odontaspidae gen. et sp. indet., NMNS-PV 26149; 8, Odontaspidae gen. et sp. indet., NMNS-PV 26151. Scale bar equals 10 mm.

Formation and Age: Hanenoura Formation, Barremian. According to Ishida *et al.* (1992), the age of the Hanenoura Formation of the Mononobe Group is considered to be Barremian of Early Cretaceous based on the radiolarian.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Odontaspidae gen. et sp. indet.

Figure 11-1

Description: The crown of the tooth is elongated and slightly curved distally. The cutting edge of the crown has no serrations.

Remarks: The tooth is thought to belong to the family Odontaspidae, but it is assigned to an unidentified genus and species due to its fragmentary condition.

8. Kashiwaguri Formation, Goshoura Group

Locality: Shishijima Island, Nagashima Town, Izumi-Gun, Kagoshima Prefecture

Formation and Age: Kashiwaguri Formation, Cenomanian. According to Komatsu *et al.* (2006), the age of the Kashiwaguri Formation of the Goshoura Group is considered to be Cenomanian of Late Cretaceous, based on the large fossils such as ammonites.

Order Lamniformes Berg, 1958

Family Otodontidae Glikman, 1964

Genus *Cretalamna* Glikman, 1958

Cretalamna catoxodon Siversson *et al.*, 2015

Figure 12-1,2

Description: The crown is triangular and broad with the main cusp erect. The lateral cusplets are broad and triangular. The cutting edge of the crown has no serrations. The root is distinctly bifid.

Remarks: In Siversson *et al.* (2015), the genus *Cretalamna* in the Cenomanian species are shown 3 groups, *C. appendiculata* group: *C. appendiculata*, *C. borealis* group: *C. gertericorum*, *C. hattini* group: *C. deschutteri*, *C. catoxodon* and *Kenolamna gunsoni*, which do not belong to these groups. Among these, *C.*

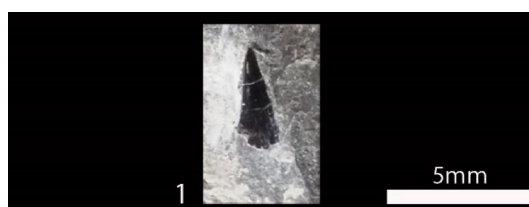


Figure 11. 1, Odontaspidae gen. et sp. indet., NMNS-PV 26466. Scale bar equals 5 mm.

catoxodon is characterised by a slightly rounded tip of the lateral cusplets in the lateral teeth.

9. Haborogawa Formation, Yezo Group

Locality: Kimun River, Ashibetu, Ashibetsu City, Hokkaido Prefecture

Formation and Age: Haborogawa Formation, Coniacian. According to Toshimitsu *et al.* (1995), the age of the Haborogawa Formation of the Yezo Group is considered to be Coniacian of Late Cretaceous based on the large fossils such as inoceramus.

Order Hybodontiformes Patterson, 1966

Family Ptychodontidae Jaekel, 1898

Genus *Ptychodus* Agassiz, 1835

Ptychodus latissimus Agassiz, 1843

Figure 13-1

Description: The crown is dome-shaped and of the grinding type. There is a thick ridge on the

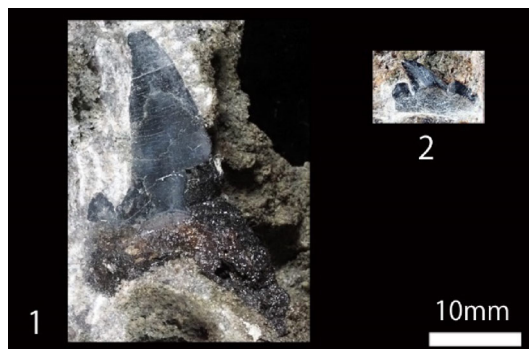


Figure 12. 1, *Cretalamna catoxodon*, NMNS-PV 26462; 2, *Cretalamna catoxodon*, NMNS-PV 26463. Scale bar equals 10 mm.

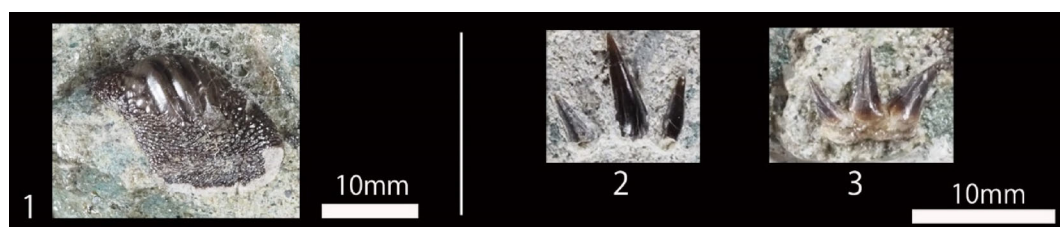


Figure 13. 1, *Ptychodus latissimus*, NMNS-PV 26207; 2, *Rolfodon* sp., NMNS-PV 26209; 3, *Rolfodon* sp., NMNS-PV 26210. Scale bar equals 10 mm.

occlusal surface of the crown. It also has many wrinkles on its periphery.

Remarks: Recently Vullo *et al.* (2024) described completely articulated specimens with preserved body outline of *Ptychodus* and included the genus in the Lamniformes based on some cranial characters. Here we prefer to reserve judgment on the ordinal assignment for the family, and we temporarily follow Capetta (2012).

Order Hexanchiformes Buen, 1926

Family Chlamydoselachidae Garman, 1884

Genus *Rolfodon* Capetta *et al.*, 2019

Rolfodon sp.

Figure 13-2,3

Description: It has three cusps like the teeth of *Chlamydoselachus*, but each cusp is thicker and the teeth are larger than those of this genus.

Family Hexanchidae Gray, 1851

Genus *Hexanchus* Rafinesque, 1810

Hexanchus sp.

Figure 14-1,2

Description: The tooth is multituberculate with the height of the cusps decreasing distally from the first cusp. Fine serrations at the proximal base of the first cusp, becoming finer distally. The root is not bifid, rectangular and flat.

Genus *Notorynchus* Ayres, 1855

Notorynchus sp.

Figure 14-4,5

Description: The tooth is multituberculate

becoming successively smaller from the first cusp to the distal cusp. The lower part of the mesial cutting edge of the first cusp has a distinct serration that increases towards the cusp apex. The serrations at the proximal base of the first cusp, become rougher towards the distal. The root is not bifid, rectangular and flat.

Hexanchidae gen.et sp. indet.

Figure 14-3

Description: The root is missing and only the crown is present in the specimen. The tooth is multituberculate with four visible cusps. The crown is shaped like an open fan, and the cusps of the crown are two at a time, each curved mesially-distally.

Remarks: This is thought to be a symphyseal tooth from the median lower jaw of the family Hexanchidae, but it is difficult to determine whether it belongs to the genus *Hexanchus* or to the genus *Notorynchus*.

Genus *Xampylodon* Capetta *et al.*, 2019

Xampylodon dentatus (Woodward, 1886)

Figure 14-6

Description: The tooth is multituberculate. There are multiple successively smaller cusps on each side, centered on the largest cusp. The root is not bifid, rectangular and flat.

Remarks: This species was previously belonged in the genus *Notidanodon*, but Capetta *et al.* (2019) newly established the genus *Xampylodon* for this and some other species with the exclusion of *N. pectinatus*.



Figure 14. 1, *Hexanchus* sp., NMNS-PV 26211; 2, *Hexanchus* sp., NMNS-PV 26217; 3, *Hexanchidae* gen.et sp. indet., NMNS-PV 26212; 4, *Notorynchus* sp., NMNS-PV 26214; 5, *Notorynchus* sp., NMNS-PV 26215; 6, *Xampylodon dentatus*, NMNS-PV 26218. Scale bar equals 10 mm.

Family Orthacodontidae Glikman, 1957

Genus *Sphenodus* Agassiz, 1843

Sphenodus sp.

Figure 15-1

Description: The crown is elongated, straight and erect. The crown is not curved mesially or distally. The cutting edge of the crown has no serrations. There is no striation on the labial face of the crown.

Family Paraorthacodontidae Glikman, 1958

Genus *Paraorthacodus* Glikman, 1957

Paraorthacodus sp.

Figure 15-3,4

Description: The main cusp is located in the center of the crown. It is thin and slightly curved distally. There are multiple pairs of secondary cusps on either side of the main cusp. The secondary cusps are on the root, side by side with the main cusp. The root is flat, does not overhang the crown, and protrudes lingually without bifurcation.

Order Echinorhiniformes de Buen, 1926

Family Echinorhinidae Gill, 1862

Genus *Echinorhinus* Blainville, 1816

Echinorhinus sp.

Figure 15-2

Description: The crown is single cuspid, triangular and curved distally. The cutting edge of the crown has no serrations. There is more of a

mountain shoulder on the distal margin of the main cusp.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Squalus* Linnaeus, 1758

Squalus sp.

Figure 15-5

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serrations. The labial face of the crown extends so that its central part hangs down to the root.

Remarks: Since 34 species have been identified in this genus, it is difficult to distinguish the species-specific characters on the basis of teeth, and it is appropriate to assign the genus to an undetermined species.

Family Centrophoridae Bleeker, 1859

Genus *Centrophorus* Müller and Henle, 1837

Centrophorus sp.

Figure 15-6

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serration. The labial face of the crown is extended. The central part hangs down to the root.

Remarks: This tooth is similar to the teeth of the genus *Squalus*, but the width of the crown is narrower than that of the genus *Squalus*.

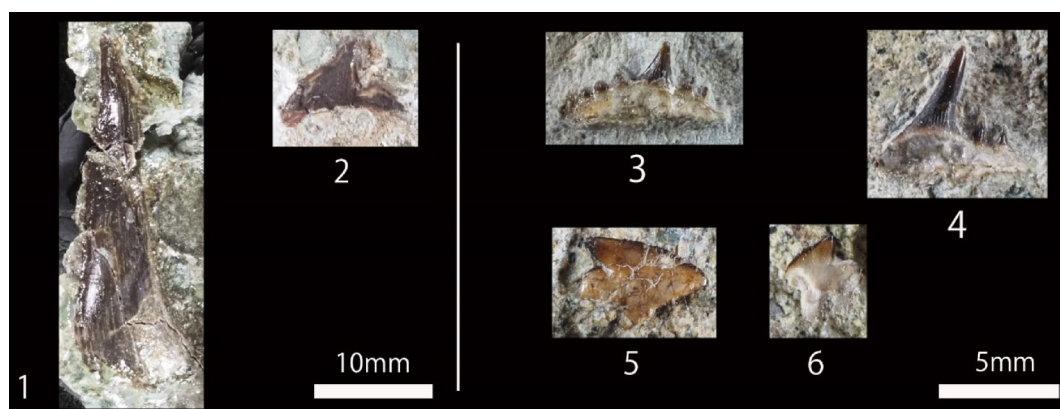


Figure 15. 1, *Sphenodus* sp., NMNS-PV 26220; 2, *Echinorhinus* sp., NMNS-PV 26223; 3, *Paraorthacodus* sp., NMNS-PV 26221; 4, *Paraorthacodus* sp., NMNS-PV 26222; 5, *Squalus* sp., NMNS-PV 26225; 6, *Centrophorus* sp., NMNS-PV 26226. Scale bar equals 10 mm (1,2) and 5 mm (3,4,5,6).

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Carcharias* Rafinesque, 1810
Carcharias sp.
 Figure 16-1,2

Description: The crown is elongated and erect. The cutting edge of the crown has no serrations. There are striations on the labial face of the crown and some have a secondary cusp.

Family Otodontidae Glikman, 1964
 Genus *Cretalamna* Glikman, 1958
Cretalamna sp.
 Figure 16-3,4

Description: The crown is triangular and broad with the main cusp erect and strongly curved distally. There is a broad, triangular lateral cusplets. The cutting edge of the crown has no serrations. There is no striation on the labial face of the crown.

Remarks: As for the specific identification, the genus was previously composed of a single species, *C. appendiculata* (e.g., Uyeno and Suzuki, 1995), but recently Siversson *et al.* (2015) subdivided this species into many species based on curving of the main cusp and root morphology. However, the species identification by Siversson *et al.* (2015) cannot be made exactly for the isolated tooth, such as the height of the lingual

protuberance of the root from the basal view, it is considered here as an unidentified species.

Family Cretoxyrhinidae Glikman, 1958
 Genus *Cretoxyrhina* Glikman, 1958
Cretoxyrhina mantelli (Agassiz, 1838)
 Figure 16-5

Description: The crown is thin, long and slightly curved distally. There are no lateral cusplets. There is no striation on the labial face of the crown. The cutting edge of the crown has no serrations. The root is distinctly bifid.

Family Anacoracidae Casier, 1947
 Genus *Squalicorax* Whitley, 1939
Squalicorax sp.
 Figure 17-1

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has finely serrations.

Order Synechodontiformes Duffin and Ward, 1993
 Family Palaeospinacidae Regan, 1906
 Genus *Synechodus* Woodward, 1881
Synechodus sp.
 Figure 17-2,3

Description: This is similar to teeth of the genus

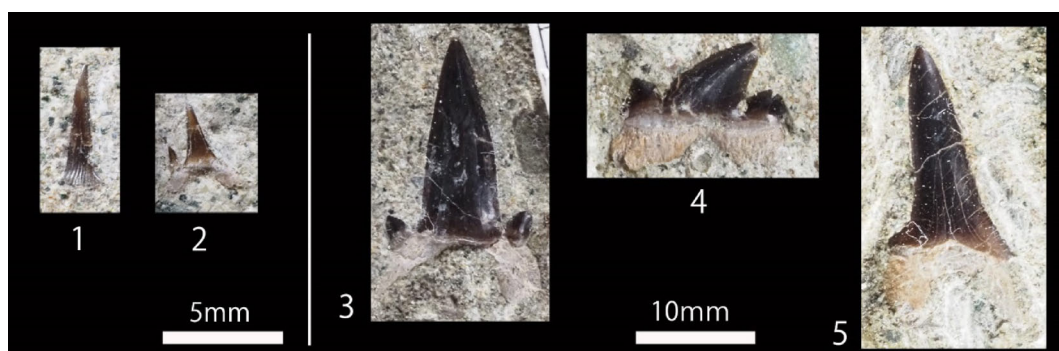


Figure 16. 1, *Carcharias* sp., NMNS-PV 26232; 2, *Carcharias* sp., NMNS-PV 26227; 3, *Cretalamna* sp., NMNS-PV 26238; 4, *Cretalamna* sp., NMNS-PV 26233; 5, *Cretoxyrhina mantelli*, NMNS-PV 26239. Scale bar equals 5 mm (1,2) and 10 mm (3,4,5).

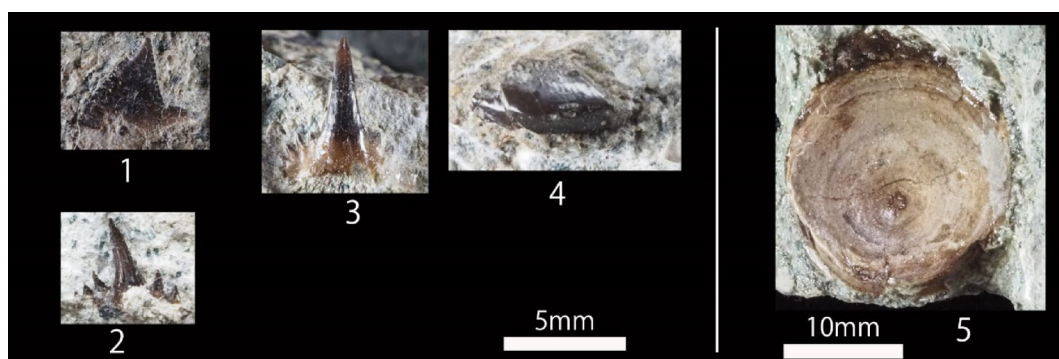


Figure 17. 1, *Squalicorax* sp., NMNS-PV 26244; 2, *Synechodus* sp., NMNS-PV 26245; 3, *Synechodus* sp., NMNS-PV 26246; 4, *Ptychotrygonoides* sp., NMNS-PV 25248; 5, vertebra, NMNS-PV 26270. Scale bar equals 5 mm (1,2,3,4) and 10 mm (5).

Paraorthacodus. The main cusp is located in the center of the crown and is thin and erect or slightly curved distally. There are multiple pairs of lateral cusplets on each side of the crown, but unlike *Paraorthacodus*, they are located below the main cusp.

Order Rajiformes Berg, 1937

Family Ptychotrygonidae Kriwent *et al.*, 2009

Genus *Ptychotrygonoides* Landemaine, 1991

Ptychotrygonoides sp.

Figure 17-4

Description: It is a circular, dome-shaped form of tooth.

Vertebra

Figure 17-5

Description: This has a mill-shape with a concave center.

Remarks: This is the shark vertebra, but family, genus, etc. are unknown.

10. Asizawa Formation, Futaba Group

Locality: Ohisa, Ohisamachi, Iwaki City, Fukushima Prefecture

Formation and Age: Asizawa Formation, Coniacian. According to Kubo *et al.* (2002), the age of the Asizawa Formation of the Futaba Group is considered to be Coniacian of Late Cretaceous based on the large fossils such as ammonites.

Order Hexanchiformes Buen, 1926
 Family Hexanchidae Gray, 1851
 Hexanchidae gen. et sp. indet.
 Figure 18-1

Description: The specimen retains only the cusp and part of the root. The crown is thin and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is slightly convex.

Remarks: We think this is the upper first or second tooth of *Hexanchus* or *Notorynchus* of the family Hexanchidae. However, it is so similar and difficult to distinguish, that it has been assigned to an unidentified genus and species in the family Hexanchidae.

Genus *Notorynchus* Ayres, 1855
Notorynchus aptiensis (Pictet, 1864)
 Figure 18-2

Description: The crown is multituberculate and becomes successively smaller from the first cusp to the distal cusp. The lower part of the mesial cutting edge of the first cusp has distinct serrations, which increase in size towards the cusp apex. The number of cusps is six, less than in *Hexanchus*. The root is not bifid, rectangular and flat.

Remarks: In the Ladwig (2011), *Gladioserratus* was valid for the genus name of this species, but here it is *Notorynchus* according to the Cappetta (2012).

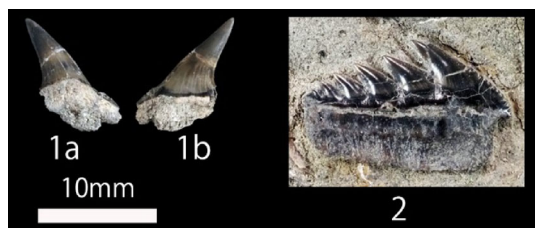


Figure 18. 1, Hexanchidae gen. et sp. indet., NMNS-PV 26329, lingual (a) and labial (b) views; 2, *Notorynchus aptiensis*, NMNS-PV 26330. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958
 Family Mitsukurinidae Jordan, 1898
 Genus *Scapanorhynchus* Woodward, 1889
Scapanorhynchus texanus (Roemer, 1849)
 Figure 19-1

Description: The crown is almost straight and elongated. There are distinct striations on the lingual face of the crown, a pair of small lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flattened. The root is distinctly bifid.

Family Otodontidae Glikman, 1964
 Genus *Cretalamna* Glikman, 1958
Cretalamna appendiculata (Agassiz, 1835)
 Figure 19-2

Description: The crown of this species is triangular and slightly curved distally or erect. In addition to the main cusp, there is a pair of triangular lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The basal view of the root is raised high near the center. The root is distinctly bifid.

Cretalamna borealis (Priem, 1897)
 Figure 19-3

Description: The crown is triangular and slightly curved distally or erect. The cutting edge of the crown has no serrations. In addition to the main cusp, there is a pair of triangular lateral cusplets. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Remarks: Compared with *C. appendiculata*, the lingual protuberance of the root is slightly lower and the thickness of the mesial and distal sides of the root is symmetrical with equal thickness on both sides. We think that most of the specimens of the genus *Cretalamna* from the Asizawa Formation, Coniacian from Iwaki City are *C. borealis*.

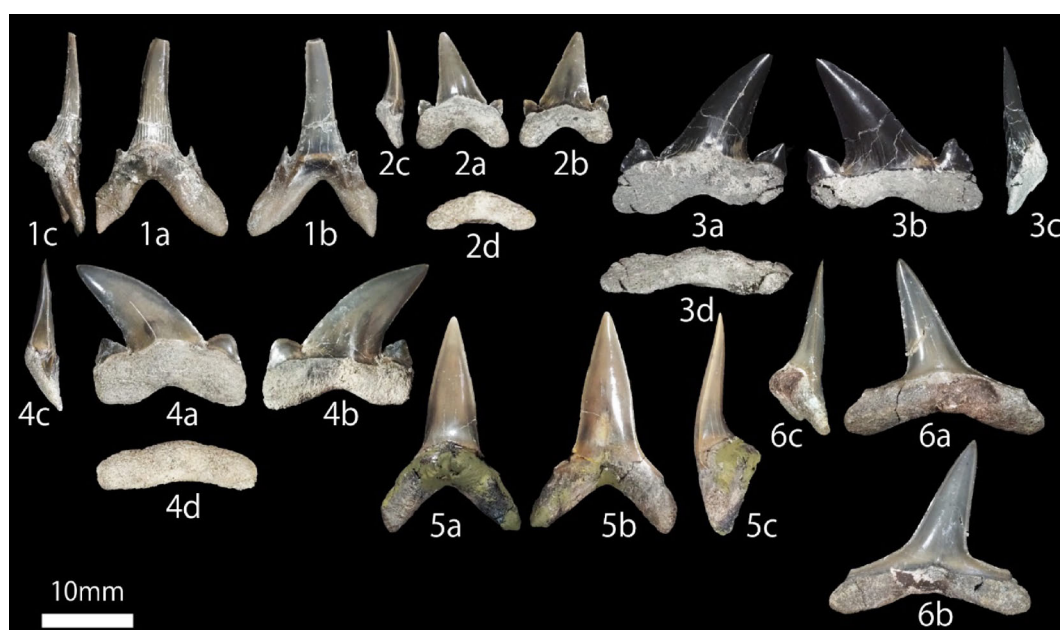


Figure 19. 1, *Scapanorhynchus texanus*, NMNS-PV 26331, lingual (a), labial (b) and profile (c) views; 2, *Cretalamna appendiculata*, NMNS-PV 26335, lingual (a) labial (b), profile (c) and basal (d) views; 3, *Cretalamna borealis*, NMNS-PV 26336, lingual (a) labial (b), profile (c) and basal (d) views; 4, *Cretalamna gertericorum*, NMNS-PV 26345, lingual (a) labial (b), c:profile (c) and basal (d) views; 5, *Cretoxyrhina mantelli*, NMNS-PV 26369, lingual (a), labial (b) and profile (c) views; 6, *Paranomotodon angustidens*, NMNS-PV 26370, lingual (a), labial (b), and profile (c) views. Scale bar equals 10 mm.

Cretalamna gertericorum Siverson *et al.*, 2015

Figure 19-4

Description: The crown is triangular and strongly curved distally. In addition to the main cusp, there is a pair of triangular lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Cretoxyrinidae Glikman, 1958

Genus *Cretoxyrhina* Glikman, 1958

Cretoxyrhina mantelli (Agassiz, 1838)

Figure 19-5

Description: The crown is thin, long and slightly curved distally. There are no lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family indet.

Genus *Paranomotodon* Herman

in Cappetta and Case, 1975

Paranomotodon angustidens (Reuss, 1845)

Figure 19-6

Description: The crown is thin, triangular and slightly curved distally. The cutting edge is straight with no serrations. The crown extends almost horizontally to cover the root on both sides. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Odontaspidae Müller and Henle, 1839

Genus *Cenocarcharias* Cappetta and Case, 1999

Cenocarcharias tenuiplicatus

(Cappetta and Case, 1975)

Figure 20-1

Description: The crown is thin and slightly



Figure 20. 1, *Cenocarcharias tenuiplicatus*, NMNS-PV 26333, lingual (a), labial (b) and profile (c) views; 2, *Protolamna sokolovi*, NMNS-PV 26376, lingual (a), labial (b) and profile (c) views; 3, *Squalicorax falcatus*, NMNS-PV 26371, lingual (a) and labial (b) views; 4, *Paratriakis* sp., NMNS-PV 26377; 5, Batoidea, Fam. gen. et sp. indet., NMNS-PV 26378, lingual (a), occlusal (b) and profile (c) views. Scale bar equals 5 mm.

curved distally. There is no striation on the lingual face of the crown. A pair of triangular lateral cusplets are present. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Pseudoscapanorhynchidae Herman, 1979
Genus *Protolamna* Cappetta, 1980
Protolamna sokolovi Cappetta, 1980

Figure 20-2

Description: The crown is triangular and short. The cusp is erect with slightly broader lateral cusplets. The lingual protuberance of the root is very high and narrow. The cutting edge of the crown has no serrations. The lingual face of the crown is very convex and the labial face is flat.

Family Anacoracidae Casier, 1947
Genus *Squalicorax* Whitley, 1939
Squalicorax falcatus (Agassiz, 1843)

Figure 20-3

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Triakidae Gray, 1851

Genus *Paratriakis* Herman, 1977

Paratriakis sp.

Figure 20-4

Description: The crown is nearly equilateral and strongly curved distally. The mesial cutting edge of the crown has multiple rough serrations.

Batoidea

Fam. gen. et sp. indet.

Figure 20-5

Description: The tooth is small. The crown is rectangular from the occlusal view, and the occlusal surface is flat. The root emerges from the underside of the crown.

Remarks: This tooth has characteristics of batoid ray sharks, but all of the characters seen in this tooth are not diagnostic to determine the genus or family in Batoidea. Therefore, we can only assume that this tooth belongs to Batoidea.

Additional records: In addition to the species reported here, there are reports of *Hexanchus microdon*, *Odontaspis* sp., *Squatina* sp. according to Uyeno and Suzuki (1985), *Polyacrodus* sp. according to Tanaka and Usui (2002) *Cretodus crassidens* according to Takakuwa *et al.* (2018).

11. Hinoshima Formation, Himenoura Group

Locality: Takado, Ryugadake-machi, Kamiyamakusa City, Kumamoto Prefecture

Formation and Age: Hinoshima Formation, Santonian. According to Kojo *et al.* (2011), the age of the Hinoshima Formation of the Himenoura Group is considered to be Santonian of Late Cretaceous based on foraminiferal and radiolarian fossils.

Order Hybodontiformes Patterson, 1966

Family Ptychodontidae Jaekel, 1898

Genus *Ptychodus* Agassiz, 1835

Ptychodus anonymus Williston, 1900

Figure 21-1

Description: The crown is dome-shaped with a high central projection. There is a thick ridge on the occlusal face of the crown.

Remarks: As was mentioned above, completely articulated specimens with preserved body outline of *Ptychodus* was described by Vullo *et al.* (2024) and they included the genus in the Lamniformes based on some cranial characters. However, we prefer to reserve judgment on the ordinal assignment for the family, and here we temporarily follow Cappetta (2012).

Order Hexanchiformes Buen, 1926

Family Chlamydoselachidae Garman, 1884

Genus *Chlamydoselachus* Garman, 1884

Chlamydoselachus sp.

Figure 21-2

Description: The crown has three cusps and is elongated and conical. The base of the crown is spherical.

Family Hexanchidae Gray, 1851

Genus *Hexanchus* Rafinesque, 1810

Hexanchus microdon (Agassiz, 1835)

Figure 21-3,4

Description: The tooth is multituberculate with the height of the cusps decreasing distally from the first cusp. There are serrations on the mesial cutting edge of the first cusp, which become smaller towards the apex.

Genus *Xampylodon* Cappetta *et al.*, 2019

Xampylodon dentatus (Woodward, 1886)

Figure 21-5

Description: The tooth is multituberculate and the first cusp is not elevated as in the genus *Hexanchus*.

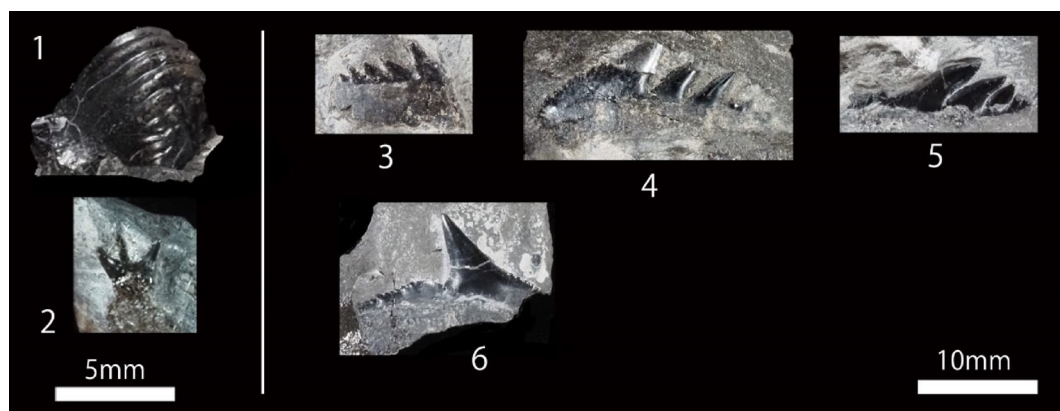


Figure 21. 1, *Ptychodus anonymus*, NMNS-PV 26389; 2, *Chlamydoselachus* sp., NMNS-PV 26390; 3, *Hexanchus microdon*, NMNS-PV 26394; 4, *Hexanchus microdon*, NMNS-PV 26396; 5, *Xampylodon dentatus*, NMNS-PV 26397; 6, *Echinorhinus* sp., NMNS-PV 26398. Scale bar equals 5 mm (1,2) and 10 mm (3,4,5,6).

Order Echinorhiniformes de Buen, 1926

Family Echinorhinidae Gill, 1862

Genus *Echinorhinus* Blainville, 1816

Echinorhinus sp.

Figure 21-6

Description: The crown is triangular and slightly curved distally. A shoulder develops at the distal base of the crown with rough serrations. There are weak serrations at the base of the mesial crown and no serrations on the upper part of the crown.

Remarks: Kitamura (2013) described a new species of this genus, *Echinorhinus wadanohanaensis*. We consider this specimen to be distinct from *E. wadanohanaensis*, because of the rough serrations on the distal base of the crown plate compared to *E. wadanohanaensis*.

Order Lamniformes Berg, 1958

Family Otodontidae Glikman, 1964

Genus *Cretalamna* Glikman, 1958

Cretalamna sp.

Figure 22-2,3

Description: The crown is triangular, broad and erect. There are broad and triangular lateral cusplets. The cutting edge of the crown has no serrations. The root is distinctly bifid without a nutritive groove.

Family Cretoxyrhinidae Glikman, 1958

Genus *Cretoxyrhina* Glikman, 1958

Cretoxyrhina mantelli (Agassiz, 1838)

Figure 22-1

Description: The crown is thin, long and almost erect. The cutting edge of the crown has no serrations. There are no lateral cusplets. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Cardabiodontidae Siverson, 1999

Genus *Dwardius* Siverson, 1999

Dwardius sp.

Figure 22-4

Description: The crown is almost straight, elongated and almost uniform in crown width. The cutting edge of the crown has no serrations. The lingual face of the crown is very convex and the labial face is flat.

Remarks: This tooth is also similar to species of *Sphenodus*, but its crown is not as long as those of *Sphenodus* spp.

Additional records: In addition to the species reported here, there are reports of *Notorynchus* sp., *Echinorhinus wadanohanaensis*, *Centrophoroides* cf. *latidens*, *Cretascymnus* sp., *Squalicorax falcatus*, *Squalicorax* sp., *Paranomotodon* sp., *Protolamna skolovi*,

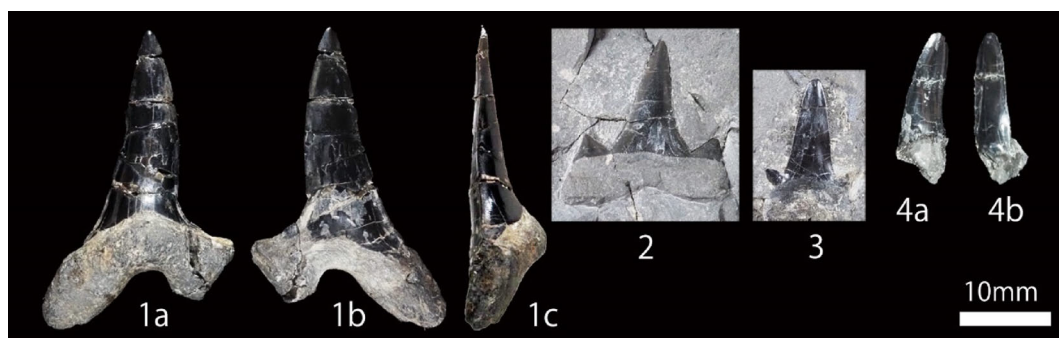


Figure 22. 1, *Cretoxyrhina mantelli*, NMNS-PV 26433, lingual (a), labial (b) and profile (c) views; 2, *Cretalamna* sp., MNS-PV 26401; 3, *Cretalamna* sp., NMNS-PV 26403; 4, *Dwardius* sp., NMNS-PV 26434, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Protolamna sp., Mitukurinidae gen. et sp. indet., *Sphenodus* sp., *Synechodus* sp., according to Kitamura (2019).

12. Azenotani Formation, Izumi Group

Locality 1: Sobura, Kaizuka City, Osaka Prefecture

Locality 2: Kaminogotakinoike, Izumisano City, Osaka Prefecture

Locality 3: Kuwabata, Hannan City, Osaka Prefecture

Formation and Age (Localities 1,2,3): Azenotani Formation, Maastrichtian. According to Itihara *et al.* (1986), the age of the Azenotani Formation of the Izumi Group is considered to be Maastrichtian of Late Cretaceous based on the large fossils such as ammonites.

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Genus *Hexanchus* Rafinesque, 1810

Hexanchus sp.

Figure 23-1

Description: The tooth is multituberculate. The crown is visible from the first cusp to the fourth

cusp. The other cusps are absent. The height of the cusps decreases distally from the first cusp. There are serrations on the mesial cutting edge of the first cusp, which become almost uniform and do not increase towards the apex.

Genus *Xampylodon* Cappetta *et al.*, 2019

Xampylodon dentatus (Woodward, 1886)

Figure 23-2

Description: The crown of the tooth has multiple cusps. There are multiple successively smaller cusps on each side, centered on the largest cusps. The root is flat and rectangular.

Order Lamniformes Berg, 1958

Family Mitsukurinidae Jordan, 1898

Genus *Scapanorhynchus* Woodward, 1889

Scapanorhynchus sp.

Figure 23-3

Description: The crown is almost straight and elongated. The cutting edge of the crown has no serrations. There are distinct striations on the lingual face of the crown.

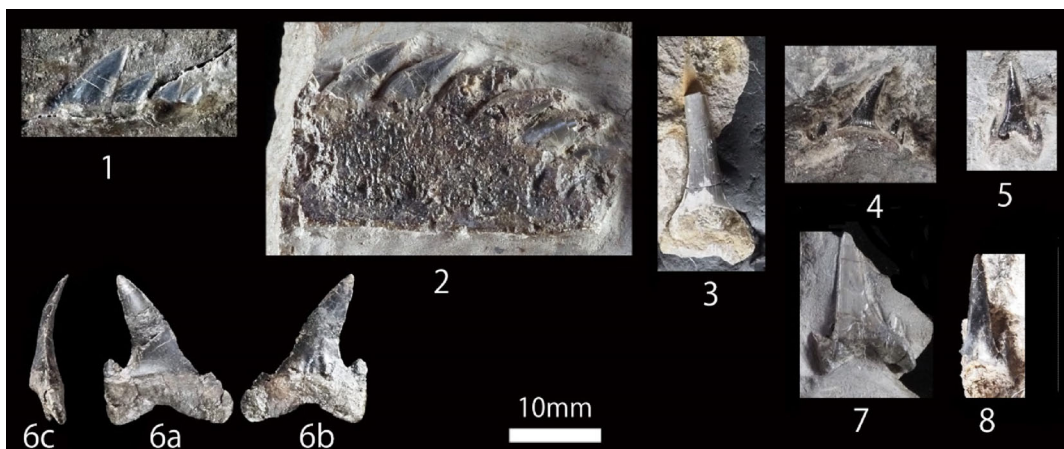


Figure 23. 1, *Hexanchus* sp., NMNS-PV 26439, Locality 1; 2, *Xampylodon dentatus*, NMNS-PV 26440, Locality 1; 3, *Scapanorhynchus* sp., NMNS-PV 26443, Locality 1; 4, *Carcharias* sp., NMNS-PV 26451, Locality 2; 5, *Carcharias* sp., NMNS-PV 26449, Locality 2; 6, *Cretalmna* sp., NMNS-PV 26458, Locality 1, lingual (a), labial (b) and profile (c) views; 7, *Cretalmna* sp., NMNS-PV 26459, Locality 1; 8, *Cretodus semiplicatus*, NMNS-PV 26460, Locality 3. Scale bar equals 10 mm.

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias sp.

Figure 23-4,5

Description: The crown is elongated and erect. There are striations on the lingual face of the crown. There is the secondary cusp. The cutting edge of the crown has no serrations. The root is distinctly bifid.

Family Otodontidae Glikman, 1964

Genus *Cretalamna* Glikman, 1958

Cretalamna sp.

Figure 23-6,7

Description: The crown is triangular and broad. The main cusp of Fig.23-6 is strongly curved distally. The crown of Fig.23-7 is erect. There is a broad and triangular lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family indet.

Genus *Cretodus* Sokolov, 1965

Cretodus semiplicatus (Münster in Agassiz, 1843)

Figure 23-8

Description: The crown is elongated, straight and erect. There is a long and thin lateral cusplets. The cutting edge of the crown has no serrations. The root is distinctly bifid.

Additional records: In addition to the species reported here, there are reports of *Odontaspis* (?) sp., *Scapanorhynchus texanus*, *Plicatolamna* sp., *Pristiophorus* sp. according to Nishimoto and Morozumi (1979), *Rolfodon* sp. (Reported as *Thrinax* sp. in Tanimoto and Tani, 1998) according to Tanimoto and Tani (1998), *Scyliorhinus* sp. according to Tanimoto *et al.* (2001a), *Squalicorax* cf. *kaupi*, *S.* cf. *pristodontus* according to Tanimoto *et al.* (2001b), *Chlamydoselachus* sp. according to Tanimoto *et al.* (2002a), *Squatina* sp. to Tanimoto *et al.* (2002b).

13. Kokawa Formation, Izumi Group

Locality: Futondani, Hashiramoto, Hashimoto City, Wakayama Prefecture

Formation and Age: Kokawa Formation, Maastrichtian. According to Kurimoto *et al.* (1998), the age of the Kokawa Formation of the Izumi Group is considered to be Maastrichtian of Late Cretaceous based on the large fossils such as ammonites.

Order Hexanchiformes Buen, 1926

Family Chlamydoselachidae Garman, 1884

Rolfodon Cappetta *et al.*, 2019

Rolfodon sp.

Figure 24-1

Description: The crown is thin, conical and fig-like with a thicker lower part. The teeth can be assumed to be those of Chlamydoselachidae, but only one cusp remains in this specimen.

Remarks: This specimen is similar to *Chlamydoselachus* spp., but due to the crown is the thick and quite large compared to *Chlamydoselachus* spp. according to Cappetta *et al.*, 2019.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Protosqualus* Cappetta, 1977

Protosqualus sp.

Figure 24-2

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown have no serration. The central part of the crown on the labial face hangs apron-like on the root side. The apron tip of the crown is not rounded, but triangular.

Family Centrophoridae Bleeker, 1859

Genus *Centrophorus* Müller and Henle, 1837

Centrophorus sp.

Figure 24-3

Description: The crown is triangular and curved distally. The cutting edge of the crown have no



Figure 24. 1, *Rolfodon* sp., NMNS-PV 26435; 2, *Protosqualus* sp., NMNS-PV 26436; 3, *Centrophorus* sp., NMNS-PV 26437. Scale bar equals 5 mm.

serrations. The central part of the crown on the labial face hangs apron-like on the root side. The

Remarks: This specimen is similar to *Squalus* spp., but due to the crown is width of the crown is narrower than *Squalus* spp.

Additional records: In addition to the species reported here, there are reports of *Chlamydoselachus* sp. according to Tanimoto and Takata (2002).

III. CENOZOIC ERA (Paleogene Period)

Paleogene chondrichthyan fossils are presented by Formation, beginning with the earliest (Figures 25 and 26). Geological chronology of each Formation. Map number in parentheses ().

14. Shiratakei Formation, Miroku Group

Locality: Shishijima Island, Nagashima Town, Izumi-Gun, Kagoshima Prefecture

Formation and Age: Shiratakei Formation, Middle Eocene. According to Tashiro *et al.* (1980), the age of the Shiratakei Formation of the Miroku Group is considered to be Middle Eocene (50 Ma) based on the calcareous nanno-fossils.

Order Lamniformes Berg, 1958
Family Otodontidae Glikman, 1964
Genus *Cretalamna* Glikman, 1958
Cretalamna sp.
Figure 27-1

Description: The crown is triangular and broad.

The main cusp curved distally. There is a triangular lateral cusplets. The cutting edge of the crown has no serrations. The root is distinctly bifid.

Remarks: This specimen was reported as *C. appendiculata* by Tanaka and Utsunomiya (2007). However, Siversson *et al.* (2015) subdivided the species into Cretaceous species, and it is unclear what the Eocene species corresponds to, so it is considered an unidentified species.

15. Namigata Formation

Locality: Odayamanoue, Yakage Town, Oda-Gun, Okayama Prefecture

Formation and Age: Namigata Formation, Middle- Late Eocene. According to Tanaka *et al.* (2006) the Elasmobranchii fossils of the Namigata Formation were examined and the age of this Formation was determined to Middle-Late Eocene, mainly based on the presence of *Otodus auriculatus*. Matsubara (2013) also suggested Late Eocene age based on the shell fossils produced.

Order Hexanchiformes Buen, 1926
Family Hexanchidae Gray, 1851
Genus *Hexanchus* Rafinesque, 1810
Hexanchus agassizi Cappetta, 1976
Figure 28-1,2

Description: The number of cusps in Fig.28-1 is 4. The first cusp is high and the 2-4 cusps are very low. Fig.28-2 is multituberculate with the height of the cusps decreasing distally from the first cusp.

Order Squatiniformes Buen, 1926
Family Squatinidae Bonaparte, 1838
Genus *Squatina* Dumeril, 1806
Squatina sp.
Figure 28-3

Description: The crown is thin and triangular. The basal center of the crown deeply overhangs towards the root.

Paleogene	Oligocene	Chattian	
		Rupelian	Sari sandstone Fm. (20) Jinnobaru Fm. (19) Yamaga Fm. (18) Iwaki Fm. (17)
	Eocene	Priaboniain	Yotsuyama Fm. (16)
		Bartonian	Namigata Fm. (15)
		Lutetian	Shiratakei Fm. (14)
		Ypresian	
	Paleocene	—	

Figure 25. Geographical and geological context of the locality area, stratigraphic diagram modified from references cited below.

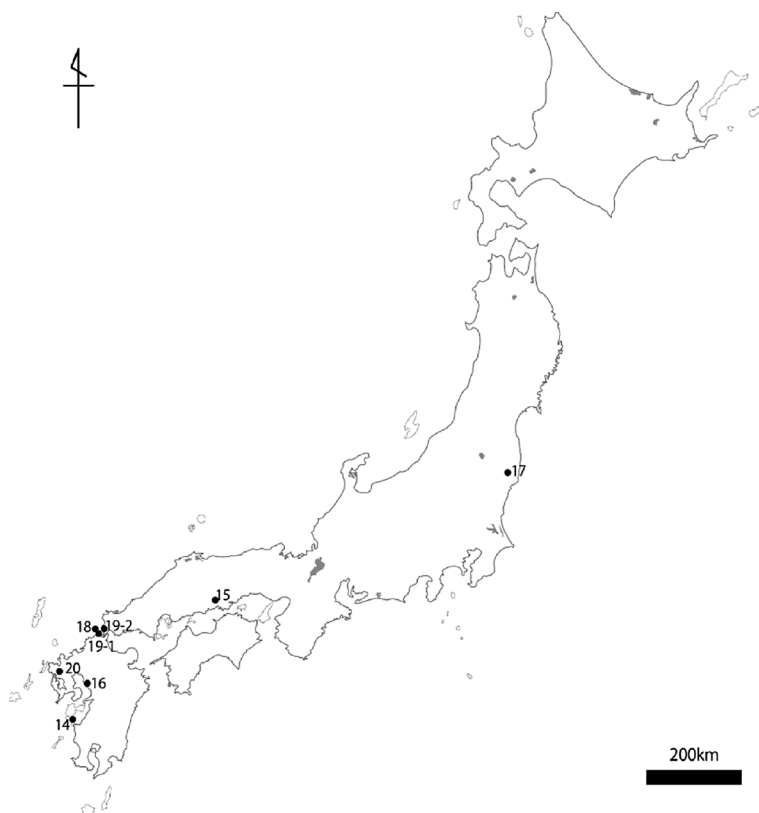


Figure 26. Geographic and geological context of the locality area, locality map.



Figure 27. 1, *Cretalamna* sp., NMNS-PV 26461.
Scale bar equals 10 mm.

Order Heterodontiformes Berg, 1937

Family Heterodontidae Gray, 1851

Genus *Heterodontus* Blainville, 1816

Heterodontus cf. *H. vincenti* (Leriche, 1905)

Figure 28-4

Description: This tooth is of the cobblestone grinding type, elongated, parallelogram. The crown surface has numerous wrinkles.

Remarks: This is very similar to *Heterodontus vincenti*, but as *H. vincenti* is a European species, it is used here as a comparative species.

Order Lamniformes Berg, 1958

Family Mitsukurinidae Jordan, 1898

Genus *Striatolamia* Glickman, 1964

Striatolamia macrota (Agassiz, 1838)

Figure 29-1

Description: The crown is almost straight and elongated. There are distinct striations on the lingual face of the crown. The cutting edge of the crown has no serrations. This species is larger than the genus *Carcharias*.

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias contortidens (Agassiz, 1843)

Figure 29-2,3,4,5,6

Description: The crown is thin and almost erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and there are lateral cusplets. There is a striation on the lingual face of the crown. The lingual face of



Figure 28. 1, *Hexanchus agassizi*, NMNS-PV 26468; 2, *Hexanchus agassizi*, NMNS-PV 26470; 3, *Squatina* sp., NMNS-PV 26474; 4, *Heterodontus* cf. *H. vincenti*, NMNS-PV 26473, occlusal (a) and lingual (b) views.
Scale bar equals 5 mm.

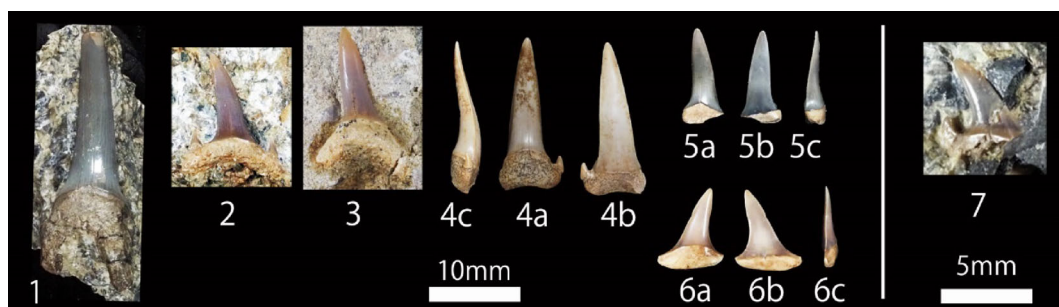


Figure 29. 1, *Striatolamna macrota*, NMNS-PV 26477; 2, *Carcharias contortidens*, NMNS-PV 26478; 3, *Carcharias contortidens*, NMNS-PV 26479; 4, *Carcharias contortidens*, NMNS-PV 26485, lingual (a), labial (b) and profile (c) views; 5, *Carcharias contortidens*, NMNS-PV 26490, lingual (a), labial (b) and profile (c) views; 6, *Carcharias contortidens*, NMNS-PV 26491, lingual (a), labial (b) and profile (c) views; 7, *Brachycarcharias lerichei*, NMNS-PV 26555. Scale bar equals 10 mm (1,2,3,4,5,6) and 5 mm (7).

the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Genus *Brachycarcharias* Cappetta and Nolf, 2005
Brachycarcharias lerichei (Casier, 1946)

Figure 29-7

Description: The crown is broad and triangular. There is no striation on the lingual face. The cutting edge of the crown has no serrations. The lateral cusplets are paired and have a rather broad triangular shape.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus auriculatus (Blainville, 1818)

Figure 30-1,2

Description: The tooth is very large. The crown is broadly triangular and slightly curved distally. The cutting edge of the crown has serrations. There is also usually a pair of large triangular lateral cuspltes. The lingual face of the crown is convex and the labial face is flattened. The root is bifid.

Order Carcharhiniformes Compagno, 1973

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassiz, 1843

Hemipristis curvatus Dames, 1883

Figure 31-1

Description: The crown is triangular and curved distally. The cutting edge of the crown has rough serrations, but the serrations do not extend to the apical part of the cusp. The central root of the lingual face of the crown is raised so that it enters the crown.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Negaprion* Whitley, 1940

Negaprion cf. *N. eurybathrodon* (Brake, 1862)

Figure 31-2

Description: The crown is thin, triangular and almost erect or slightly curved distally. The cutting edge of the crown has no serrations. The root is bifid.

Additional records: In addition to the species reported here, there are reports of *Physogaleus secundus* from the same formation, according to Tanaka *et al.* (2006).



Figure 30. 1, *Otodus auriculatus*, NMNS-PV 26476; 2, *Otodus auriculatus*, NMNS-PV 26475, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

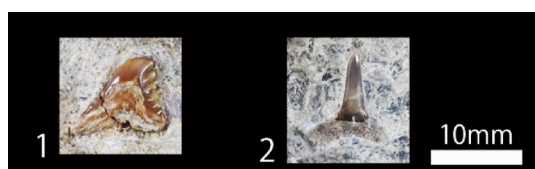


Figure 31. 1, *Hemipristis curvatus*, NMNS-PV 26556; 2, *Negaprion* cf. *N. eurybathrodon*, NMNS-PV 26557. Scale bar equals 10 mm.

16. Yotsuyama Formation, Manda Group

Locality: Yotsuyama, Omuta City, Fukuoka Prefecture

Formation and Age: Yotsuyama Formation, Late Eocene. According to Okada (1992), the age of the Yotsuyama Formation of the Manda Group is considered to be Late Eocene based on the planktonic microfossils.

Order Lamniformes Berg, 1958
Family Otodontidae Glickman, 1964
Genus *Otodus* Agassiz, 1838
Otodus auriculatus (Blainville, 1818)
Figure 32-1

Description: The cutting edge of the crown has rough serration. The lingual face of the crown is convex and the labial face is flat.

17. Iwaki Formation, Shiramizu Group

Locality: Tairaakaihira, Iwaki City, Fukushima Prefecture

Formation and Age: Iwaki Formation, Early Oligocene. According to Sudo *et al.* (2005), the age of the Iwaki Formation of the Shiramizu Group is considered to be Early Oligocene based on the large fossils.

Order Hexanchiformes Buen, 1926
Family Hexanchidae Gray, 1851
Genus *Hexanchus* Rafinesque, 1810
Hexanchus agassizi Cappetta, 1976
Figure 33-1,2

Description: The number of cusps in Fig.33-1 is 5. The first cusp is high and the 2-5 cusps are very low. Fig.33-2 is multituberculate with the



Figure 32. 1, *Otodus auriculatus*, NMNS-PV 26467. Scale bar equals 10 mm.

height of the cusps decreasing distally from the first cusp. The root is flat and rectangular.

Remarks: This species may be included in the modern species *H. nakamurai*, but a detailed comparative study is needed. Here this species is used in accordance with Cappetta (2012).

Order Heterodontiformes Berg, 1937
Family Heterodontidae Gray, 1851
Genus *Heterodontus* Blainville, 1816
Heterodontus sp.
Figure 33-3

Description: This tooth is of the cobblestone grinding type, elongated, parallelogram. The crown surface is partially defective, but has numerous wrinkles.

Order Lamniformes Berg, 1958
Family Odontaspidae Müller and Henle, 1839
Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
Figure 33-4

Description: The crown is thin and erect. The cross section of the crown is rounded. There is a striation on the lingual face of the crown. The cutting edge of the crown has no serrations. There are traces of the lateral cusplets that were originally present and it appears to be missing. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

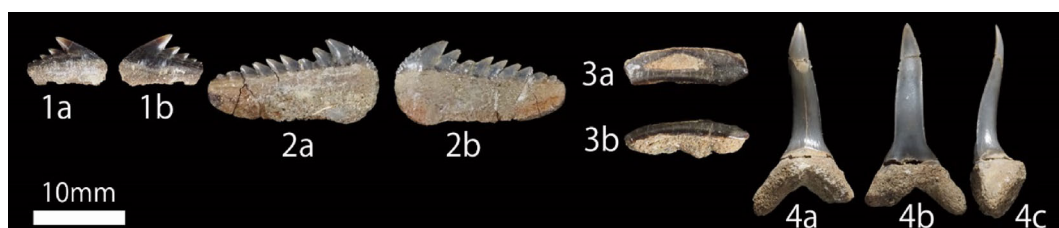


Figure 33. 1, *Hexanchus agassizi*, NMNS-PV 26564, lingual (a) and labial (b) views; 2, *Hexanchus agassizi*, NMNS-PV 32550, lingual (a) and labial (b) views; 3, *Heterodontus* sp., NMNS-PV 26565, occlusal (a) and lingual (b) views; 4, *Carcharias contortidens*, NMNS-PV 26568, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

18. Yamaga Formation, Ashiya Group

Locality: Ainoshima Island, Kokurakita Ward, Kitakyushu City, Fukuoka Prefecture

Formation and Age: Yamaga Formation, Early Oligocene. According to Ozaki and Hamazaki (1991), the age of the Yamaga Formation of the Asiya Group is considered to be Early Oligocene based on the fission-track age.

Order Hexanchiformes Buen, 1926
 Family Hexanchidae Gray, 1851
 Genus *Hexanchus* Rafinesque, 1810
Hexanchus agassizi Cappetta, 1976
 Figure 34-1

Description: The tooth is multituberculate with the height of the cusps decreasing distally from the first cusp. This specimen is assigned to this species because it is smaller than the species described below. The root is flat and rectangular.

Hexanchus sp.
 Figure 34-2,3

Description: The number of cusps in Fig.34-2 is

3. The first cusp is high and the 2nd and 3rd cusps are very low. Fig.34-3 is multituberculate with the height of the cusps decreasing distally from the first cusp. The root is flat and rectangular.

Order Squaliformes Goodrich, 1909
 Family Squalidae Bonaparte, 1834
 Genus *Squalus* Linnaeus, 1758
Squalus sp.
 Figure 35-1

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serration. The central part of the crown on the labial face hangs apron-like on the root side.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 35-2

Description: The crown is thin and triangular.



Figure 34. 1, *Hexanchus agassizi*, NMNS-PV 26577; 2, *Hexanchus* sp., NMNS-PV 26579; 3, *Hexanchus* sp., NMNS-PV 26593. Scale bar equals 10 mm.

The basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serration. The root is flat and triangular.

Order Heterodontiformes Berg, 1937

Family Heterodontidae Gray, 1851

Genus *Heterodontus* Blainville, 1816

Heterodontus sp.

Figure 35-3

Description: This tooth is of the cobblestone grinding type, elongated, parallelogram. The surface of the crown is partially defective, but has numerous wrinkles.

Order Lamniformes Berg, 1958

Family Mitsukurinidae Jordan, 1898

Genus *Striatolamia* Glikman, 1964

Striatolamia macrotia (Agassiz, 1838)

Figure 36-1

Description: The crown is almost straight and elongated. There is a distinct striation on the lingual face of the crown. The cutting edge of the crown have no serrations. There is a pair of very small lateral cusplets. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias contortidens (Agassiz, 1843)

Figure 36-2,3

Description: The crown is thin. The crown of Fig.36-2 is elongated. The crown of Fig.36-3 is rather broad. The cutting edge of the crown has no serrations. The cross section of the crown is

rounded and there are lateral cusps. There is a striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Genus *Araloselachus* Glikman, 1964

Araloselachus cuspidatus (Agassiz, 1843)

Figure 36-4

Description: The crown is thin and long. The cross section of the crown is rounded and there are lateral cusps. There is no striation on the lingual face of the crown. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Genus *Odontaspis* Agassiz, 1838

Odontaspis molassica (Probst, 1879)

Figure 36-5

Description: The crown is thin and long. There is no striation on the lingual face of the crown. The cutting edge of the crown has no serrations. The multiple lateral cusplets are present. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Family Lamnidae Müller and Henle, 1838

Genus *Isurus* Rafinesque, 1810

Isurus praecursor (Leriche, 1905)

Figure 36-6

Description: The crown is elongated and long. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Remarks: Some place this species in the genus



Figure 35. 1, *Squalus* sp., NMNS-PV 26595; 2, *Squatina* sp., NMNS-PV 26597, lingual (a) and labial (b) views; 3, *Heterodontus* sp., NMNS-PV 26603 occlusal (a) and lingual (b) views. Scale bar equals 10 mm

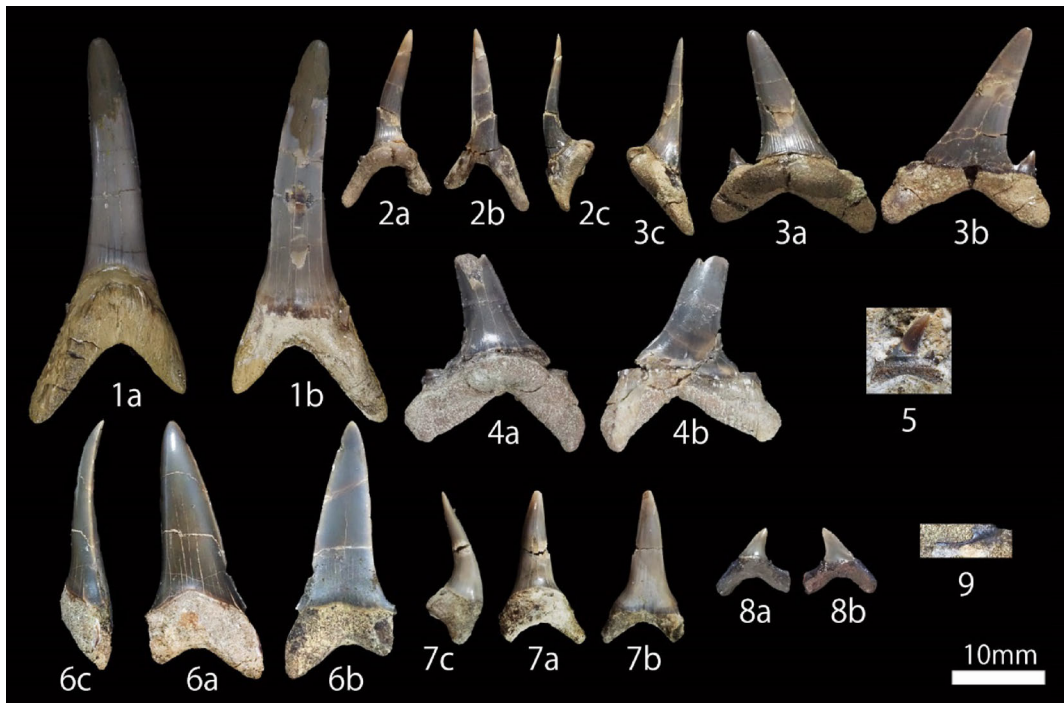


Figure 36. 1, *Striatolamia macrota*, NMNS-PV 26627, lingual (a) and labial (b) views; 2, *Carcharias contortidens*, NMNS-PV 26618, lingual (a), labial (b) and profile (c) views; 3, *Carcharias contortedens*, NMNS-PV 26617, lingual (a), labial (b) and profile (c) views; 4, *Araloselachus cuspidatus*, NMNS-PV 26625, lingual (a) and labial (b) views; 5, *Odontaspis molassica*, NMNS-PV 26626; 6, *Isurus praecursor*, NMNS-PV 26629, lingual (a), labial (b) and profile (c) views; 7, *Alopias latidens*, NMNS-PV 26634, lingual (a), labial (b) and profile (c) views; 8, *Alopias exigua*, NMNS-PV 26635, lingual (a) and labial (b) views; 9, *Cetorhinus* sp., NMNS-PV 26638. Scale bar equals 10 mm.

Macrorhizodus instead of the genus *Isurus*. However, we use the genus *Isurus*.

Family Alopiidae Bonaparte, 1838

Genus *Alopias* Rafinesque, 1810

Alopias latidens Leriche, 1909

Figure 36-7

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid and rather long.

Alopias exigua (Probst, 1879)

Figure 36-8

Description: The crown is narrowly triangular,

long and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid and rather long.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus angustidens (Agassiz, 1835)

Figure 37-1

Description: The crown is broadly triangular and erect. There is evidence of a lateral cusplet at the base of the crown. The cutting edge of the crown has irregular serrations. The lingual face of the crown is convex and the labial face is flat.

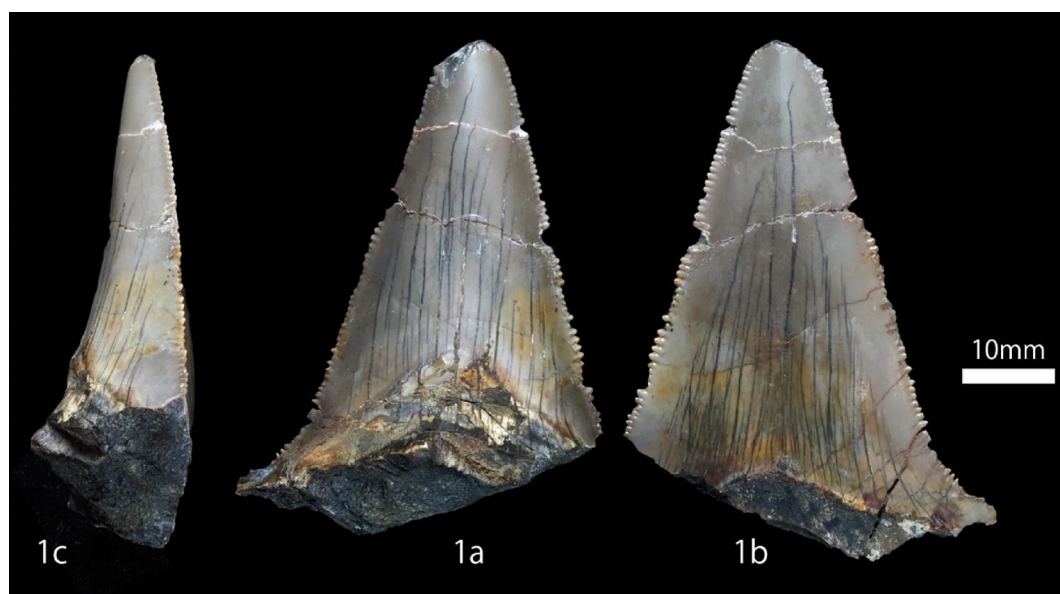


Figure 37. 1, *Otodus angustidens*, NMNS-PV 26637, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Family Cetorhinidae Gill, 1862
Genus *Cetorhinus* Blainville, 1816
Cetorhinus sp.
Figure 36-9

strongly curved distally. The lower part of the mesial cutting edge of the crown has weaker serrations. The distal cutting edge of the crown has strongly serrations. The root is distinctly bifid.

Description: This is hook-shaped, flat and elongated.

Remarks: This is the gill of the basking shark.

Family Hemigaleidae Hasse, 1879
Genus *Chaenogaleus* Gill, 1826
Chaenogaleus affinis (Probst, 1879)
Figure 38-1

Description: The crown is triangular and strongly curved distally. The distal cutting edge of the crown has rough serrations and the mesial cutting edge of the crown has no serrations. The base of the crown is shaped to cover the root. The root is distinctly bifid.

Genus *Hemigaleus* Bleeker, 1852
Hemigaleus cf. *H. microstoma* Bleeker, 1852
Figure 38-2

Description: The crown is triangular and

Genus *Hemipristis* Agassi, 1843
Hemipristis tanakai Tomita *et al.*, 2024
Figure 38-3,4

Description: The crown of Fig.38-3 is triangular and curved distally. The cutting edge of the crown has rough serrations, unlike in the genus *Carcharhinus*, but the serrations do not extend to the apical part of the cusp. The central root of the lingual face of the crown is raised so that it enters the crown. The lingual face of the crown is convex and the labial face is flat. The crown of Fig.38-4 is almost straight and elongated. It is slightly serrated at the base of the cutting edge of the crown, but not above it. The lingual face of the crown is convex and the labial face is weakly convex.

Remarks: Tomida *et al.* (2024) described this species based on the specimen of Figure 38-3 as a holotype.

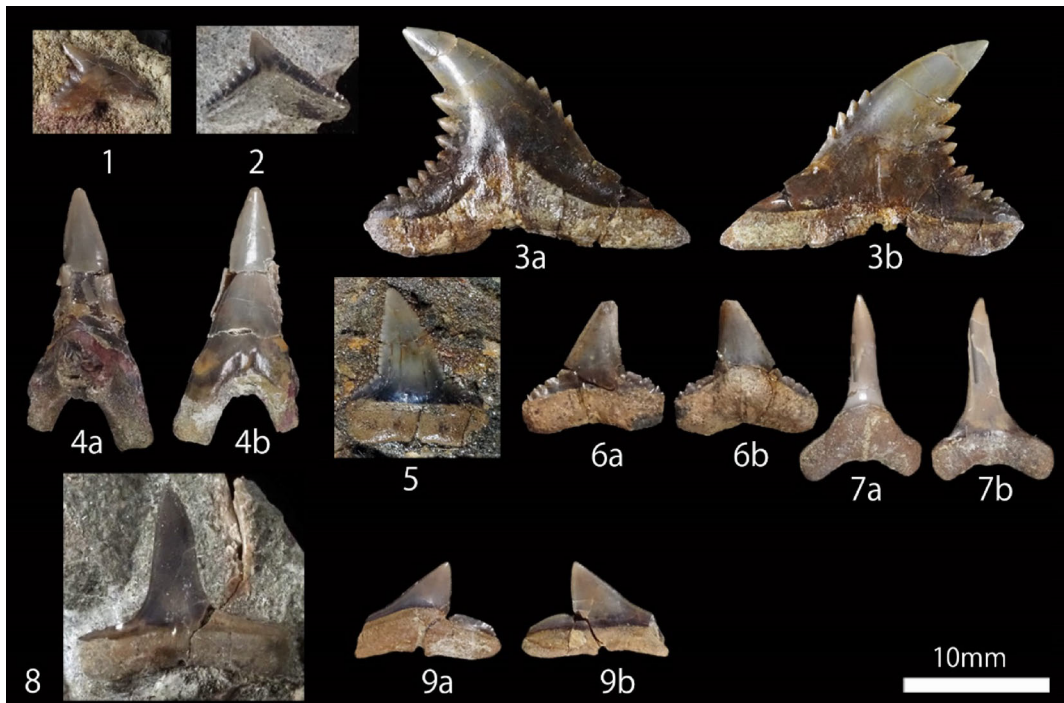


Figure 38. 1, *Chaenogaleus affinis*, NMNS-PV 26648; 2, *Hemigaleus* cf. *H. microstoma*, NMNS-PV 26650; 3, *Hemipristis tanakai*, NMNS-PV 25076, lingual (a) and labial (b) views; 4, *Hemipristis tanakai*, NMNS-PV 26652, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. albimarginatus*, NMNS-PV 32961; 6, *Carcharhinus* cf. *C. macloiti*, NMNS-PV 26656, lingual (a) and labial (b) views; 7, *Isogomphodon acuarius*, NMNS-PV 26657, lingual (a) and labial (b) views; 8, *Negaprion* sp., NMNS-PV 26660; 9, *Sphyrna* sp., NMNS-PV 26665, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. albimarginatus*
(Rüppell, 1837)

Figure 38-5

Description: The crown is nearly equilateral triangular and almost erect. The cutting edge is slightly curved inwards in the lower part. The cutting edge of the crown has fine serrations.

Carcharhinus cf. *C. macloiti*
(Müller and Henle, 1839)

Figure 38-6

Description: The crown is thin and erect. The cutting edge of the crown has no serrations, but there are rough serrations at the base of the crown. The lingual face of the crown is convex

and the labial face is flat.

Genus *Isogomphodon* Gill, 1861

Isogomphodon acuarius (Probst, 1879)

Figure 38-7

Description: The crown is thin and erect. The cutting edge is almost straight. The cutting edge of the crown has no serrations. The base of the crown does not extend towards the root. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Negaprion* Whitley, 1940

Negaprion sp.

Figure 38-8

Description: The crown is thin, triangular and

almost erect or slightly curved distally. The cutting edge of the crown has no serrations and there is a weakly serrate shoulder at the base of the crown.

Family Sphyrnidae Gill, 1872
Genus *Sphyrna* Rafinesque, 1810
Sphyrna sp.
Figure 38-9

Description: The crown is triangular and curved distally. The cutting edge of the crown has no serrations. A shoulder develops at the distal base of the crown. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973
Family Myliobatididae Bonaparte, 1838
Genus *Myliobatis* Cuvier, 1816
Myliobatis sp.
Figure 39-1

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Vertebra
Figure 39-2

Description: This has a mill-shape with a concave center. There is a round and almost square hole on the side, but no slits.

Remarks: This is the vertebra of the family Carcharhinidae.

Additional records: In addition to the species reported here, there are reports of *Galeorhinus* sp. according to Tomita and Oji (2010), *Parotodus benedeni* according to Kushimoto and Tanaka (2014).

19. Jinnobaru Formation, Ashiya Group

Locality 1: Umashima island, Kokurakita Ward, Kitakyushu City, Fukuoka Prefecture

Locality 2: Hikojima, Shimonoseki City, Yamaguchi Prefecture

Formation and Age (localities 1,2): Jinnobaru Formation, Early Oligocene. According to Sakai *et al.* (2014), the age of the Jinnobaru Formation of the Ashiya Group is considered to be Early Oligocene based on the uranium-lead radiometric age.

Order Hexanchiformes Buen, 1926
Family Hexanchidae Gray, 1851
Genus *Notorynchus* Ayres, 1855

Notorynchus primigenius (Agassiz, 1835)
Figure 40-1

Description: The number of cusps is 5. The first cusp is high and the 2-5 cusps are very lower. The lower part of the mesial cutting edge of the first cusp has distinct serrations, that increase in size towards the apex. The root is rectangular but slightly raised in the center.



Figure 39. 1, *Myliobatis* sp., NMNS-PV 26732, occlusal (a), basal (b) and lingual (c) views; 2, vertebra, NMNS-PV 26725, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.



Figure 40. 1, *Notorynchus primigenius*, NMNS-PV 26575, Locality 1. Scale bar equals 10 mm.

Order Squaliformes Goodrich, 1909
 Family Squalidae Bonaparte, 1834
 Genus *Squalus* Linnaeus, 1758
Squalus sp.
 Figure 41-1

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serration. The central part of the crown on the labial face hangs apron-like on the root side.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 41-2

Description: The crown is thin and triangular. The basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serrations. The root is flat and triangular.

Order Heterodontiformes Berg, 1937
 Family Heterodontidae Gray, 1851
 Genus *Heterodontus* Blainville, 1816
Heterodontus sp.
 Figure 41-3,4

Description: Figure 41-3 is of the

cobblestone-like grinding type, elongated, parallelogram. The crown surface is partially defective but has numerous wrinkles. Fig.41-4 is very small, protruding tooth. The crown is conical, shaded and pointed. It is located as an anterior part of the jaw.

Remarks: This tooth is extremely elongated transversely compared to the teeth of known species of *Heterodontus* and therefore may belong to an unknown species.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
 Figure 42-1

Description: The crown is thin and elongated. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and there are lateral cusplets. There is a striation on the lingual face of the crown. The cutting edge of the crown have no serrations. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Family Lamnidae Müller and Henle, 1838
 Genus *Isoiolamna* Cappetta, 1976
Isoiolamna affinis (Casier, 1946)
 Figure 42-2

Description: The crown is thin, isosceles triangular and erect. There is a pair of broad triangular lateral cusplets. The bases of the main and lateral cusplets are straight and not inclined. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial

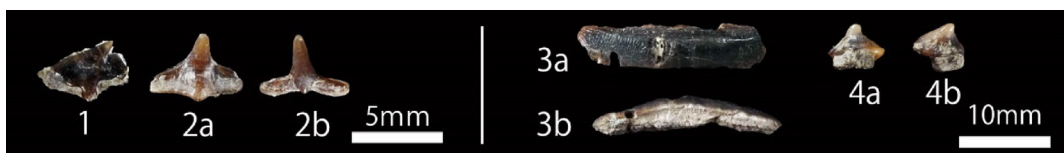


Figure 41. 1, *Squalus* sp., NMNS-PV 26596, Locality 1; 2, *Squatina* sp., NMNS-PV 26601, Locality 1, lingual (a) and labial (b) views; 3, *Heterodontus* sp., NMNS-PV 26602 Locality 1, occlusal (a) and lingual (b) views; 4, *Heterodontus* sp., NMNS-PV 26613, Locality 1, lingual (a) and profile (c) views. Scale bar equals 5 mm (1,2) and 10 mm (3,4).



Figure 42. 1, *Carcharias contortidens*, NMNS-PV 26616, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Isurolamna affinis*, NMNS-PV 26633, Locality 1, lingual (a), labial (b) and profile (c) views; 3, *Cetorhinus* sp., NMNS-PV 26643, Locality 1. Scale bar equals 10 mm.

face is flat. The root is distinctly bifid.

Family Cetorhinidae Gill, 1862
Genus *Cetorhinus* Blainville, 1816
Cetorhinus sp.
Figure 42-3

Description: This is hook-shaped, flat and elongated.

Remarks: This is the gill of the basking shark.

Order Carcharhiniformes Compagno, 1973
Family Scyliorhinidae Gill, 1862
Genus *Megascyliorhinus* Cappetta and Ward, 1977
Megascyliorhinus miocaenicus
(Antunes and Jonet, 1970)
Figure 43-1

Description: Very small teeth. The crown is elongated and conical. The cutting edge of the crown has no serrations. There is no lateral cusplets. The cusp is strongly recurved lingually. The lingual face of the crown is convex and the

labial face is convex. The root is distinctly bifid.

Genus *Pachyscyllium* Reinecke *et al.*, 2005
Pachyscyllium albigensis Reinecke *et al.*, 2005
Figure 43-2

Description: Very small teeth. The crown is narrowly triangular. The cutting edge of the crown has no serrations. There is a pair of broad triangular lateral cusplets. The lingual face of the crown is strongly convex and the labial face is slightly convex. The root is distinctly bifid.

Genus *Casieria* Noubhani and Cappetta, 1997
Casieria maghrebiana Noubhani and Cappetta, 1997
Figure 43-3

Description: Very small teeth. The main cusp is elongated and conical. The cutting edge of the crown has no serrations. There are numerous striae at the base of the lateral surface of the labrum. The lateral cusplets are elongated and conical like the main cusp.

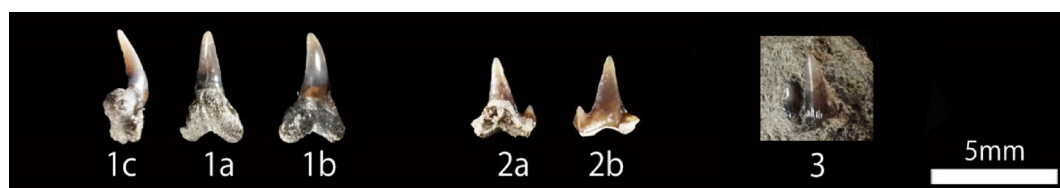


Figure 43. 1, *Megascyliorhinus miocaenicus*, NMNS-PV 26645, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Pachyscyllium albigensis*, NMNS-PV 26646, Locality 1, lingual (a) and labial (b) views; 3, *Casieria maghrebiana*, NMNS-PV 26647, Locality 2. Scale bar equals 5 mm.

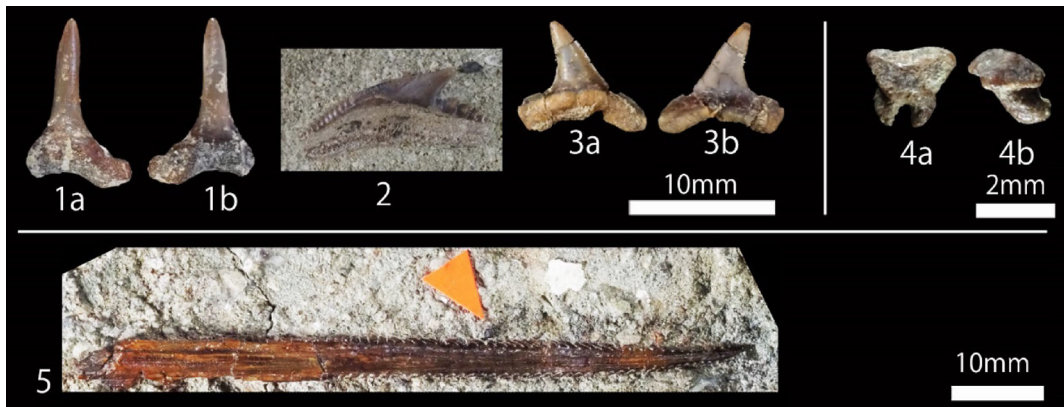


Figure 44. 1, *Isogomphodon acuarius*, NMNS-PV 26659, Locality 1, lingual (a) and labial (b) views; 2, *Galeocerdo eaglesomei*, NMNS-PV 26654, Locality 1; 3, *Negaprion* sp., NMNS-PV 26664, Locality 1, lingual (a) and labial (b) views; 4, *Dasyatidae* gen. et sp. indet., NMNS-PV 26723, Locality 1, lingual (a) and profile (b) views; 5, *Dasyatidae* gen. et sp. indet., NMNS-PV 26724, Locality 1. Scale bar equals 10 mm (1,2,3,5) and 2 mm (4).

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Isogomphodon* Gill, 1861

Isogomphodon acuarius (Probst, 1879)

Figure 44-1

Description: The crown is thin and erect. The cutting edge is straight. The cutting edge of the crown has no serrations. The base of the crown is not extended towards the root. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo eaglesomei White, 1955

Figure 44-2

Description: The crown is multicuspidal with the mesial first cusp being large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Negaprion* Whitley, 1940

Negaprion sp.

Figure 44-3

Description: The crown is thin, triangular and

almost erect or slightly curved distally. The cutting edge of the crown has no serrations and there is a weakly serrated shoulder at the base of the crown. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Dasyatidae Jordan, 1888

Dasyatidae gen. et sp. indet.

Figure 44-4,5

Description: Fig.44-4 is a small tooth with a rhombic crown, the occlusal surface of the crown slightly raised towards the center and has a shadow-like shape. The root hangs down from the lower part of the crown of the tooth. Fig.43-5 is elongated and has a spear-like tip. There are fine spines on both sides. We think that this is the caudal spine of Myliobatiformes, but the presence of teeth of *Dasyatidae* at the arrow points suggests that this is the spine of this genus.

Remarks: Last (2016) reviewed the family *Dasyatidae* and classified it into 7 genera, *Bathytoshia*, *Dasyatis*, *Fontitrygon*, *Hemitrygon*, *Hypanus*, *Megatrygon* and *Telatrygon*. Conventionally, the genus would have been *Dasyatis*, but as it is difficult to distinguish it from the other genera in the family *Dasyatidae*, it

is referred to as *Dasyatidae* gen. et sp. indet..

Additional records: In addition to the species reported here, there are reports of *Parotodus benedeni* according to Fukata *et al.* (2014).

20. Sari Sandstone Formation, Kishima Group

Locality: Sari, Ochicho, Karatsu City, Saga Prefecture

Formation and Age: Sari Sandstone Formation, Early Oligocene. According to Miyachi and Sakai (1991), the age of the Sari Sandstone Formation of the Kishima Group is considered to be Early Oligocene based on the fission-track age.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 45-1,2

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Vertebra

Figure 45-3

Description: This has a mill-shape with a concave center.

Remarks: This is the shark vertebra, but family, genus, etc. are unknown.

IV. CENOZOIC ERA (Neogene Period)

Mesozoic chondrichthyan fossils are presented by the Formation, beginning with the earliest (Figures 46 and 47). Geological chronology of each Formation. Map number in parentheses ().

21. Shimosato Formation, Kumano Group

Locality: Nassa, Taichi Town, Higashimuro-Gun, Wakayama Prefecture

Formation and Age: Shimosato Formation, Early-Middle Miocene. According to the Kishu Shimanto Research Group (2008), the age of the Shimosato Formation of the Kumano Group is considered to be Early-Middle Miocene (20.5–15.7 Ma) based on the radiolarian fossil.

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Hexanchidae gen. et sp. indet.

Figure 48-1

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is slightly convex.

Remarks: This is the upper first or second tooth of *Hexanchus* or *Notorynchus* of the family Hexanchidae. However, these teeth are similar and difficult to distinguish, so it has been assigned to an unidentified genus and species in the family Hexanchidae.



Figure 45. 1, *Isurus desori*, NMNS-PV 34002, lingual (a) and labial (b) views; 2, *Isurus desori*, NMNS-PV 34003, lingual (a) and labial (b) views; 3, vertebra, NMNS-PV 34006. Scale bar equals 10 mm.

Pleistocene			Annai Fm. (68)
Pliocene	Placenzian	Naarai Fm. (67) Zugawa Fm. (66)	Dainenji Fm. (65)
	Zanclean	Shigarami Fm. (62) Hasse Fm. (61) Tatsunokuchi Fm. (60) Harada Fm. (59)	Nobori Fm. (64) Shimajiri G. or Chinen Fm (63)
Miocene	Messinian	Nashimoto Fm. (56) Oiso Fm. (55) Furuya Fm. (54) Misaki Fm. (53)	Senhata Fm. (58) Zushi Fm. (57)
	Tortonian	Nanakita Fm. (52) Otogawa Fm. (51) Aoso Fm. (50) Shimoshiroiwa Fm. (49) Tamari Fm. (48) Yamairi Fm. (47) Onagawa Fm. (46)	
	Serravallian	Oya Fm. (42) Wajimazaki Fm. (41) Sekinohana Fm. (40) Nanao Fm. (39)	Haratajino Fm. (45) Taga G. (44) Hannoura Fm. (43)
	Langhian	Moniwa Fm. (38) Godo Fm. (37) Sakurada Fm. (36) Oidawara Fm. (35) Oido Fm. (34) Chichibumachi Fm. (33)	
		Korematsu Fm. (32) Shikiya Fm. (31) Itabashi Fm. (30) Kurosedani Fm. (29)	
	Burdigalian	Kokozura Fm. (28) Syukunohora Fm. (27) Ohi Fm. (26) Yoshino Fm. (25) Oshimo Fm. (24) Yuyadani Fm. (23) Akeyo Fm. (22) Shimosato Fm. (21)	
	Aquitanian		

Figure 46. Geographical and geological context of locality area, stratigraphic diagram modified from references cited below.

Order Lamniformes Berg, 1958
 Family Mitsukurinidae Jordan, 1898
 Genus *Mitsukurina* Jordan, 1898
Mitsukurina lineata (Probst, 1879)
 Figure 49-1

Description: The crown is narrow, straight and long of consistent width. The specimen is embedded in the rock and the only visible features are the sides of the labial face, which are

slightly convex. The cutting edge of the crown has no serrations.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 49-2

Description: The crown is broad, isosceles triangular and slightly curved distally. The cutting edge

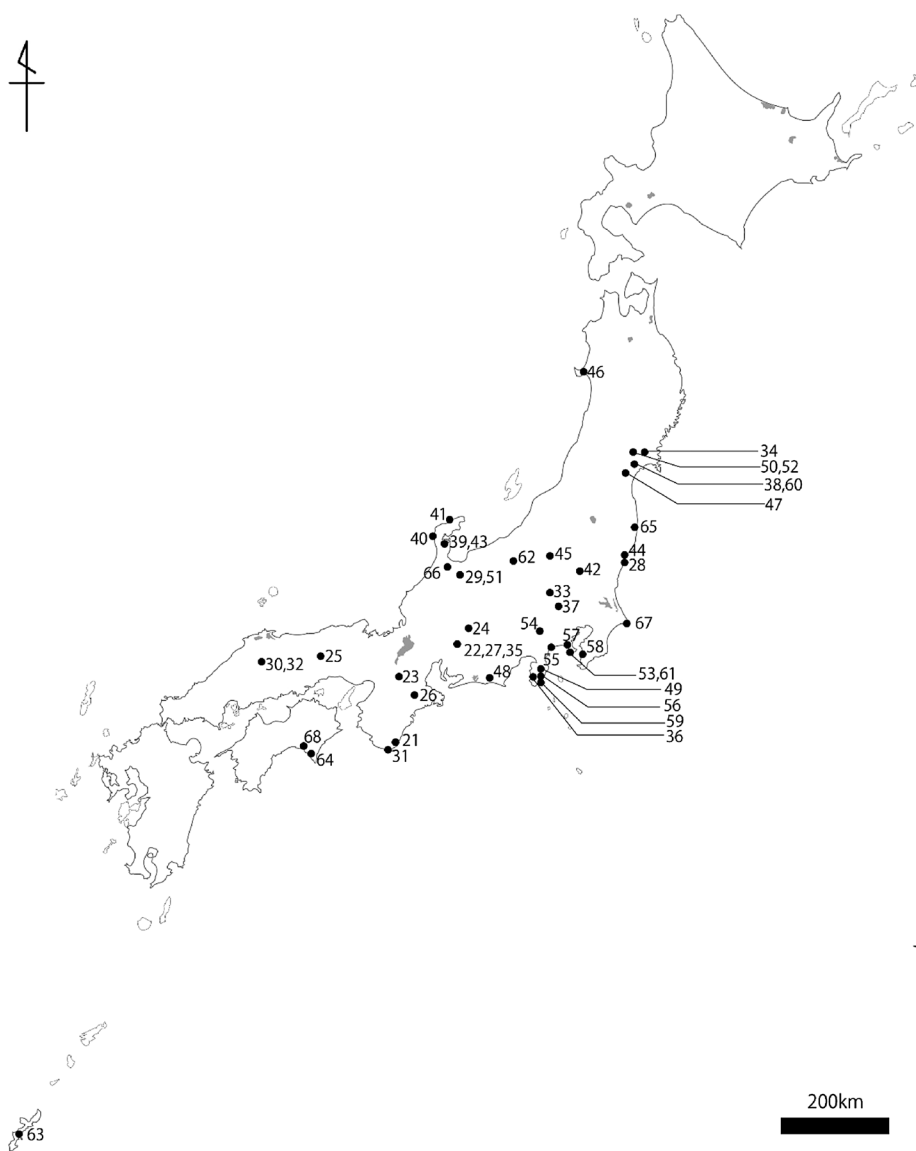


Figure 47. Geographical and geological context of locality area, locality map.

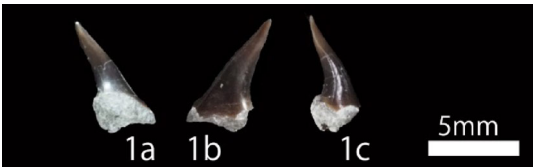


Figure 48. 1, Hexanchidae gen.et sp. indet., NMNS-PV 28226, lingual (a), labial (b) and profile (c) views. Scale bar equals 5 mm.

of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
Figure 49-3

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown

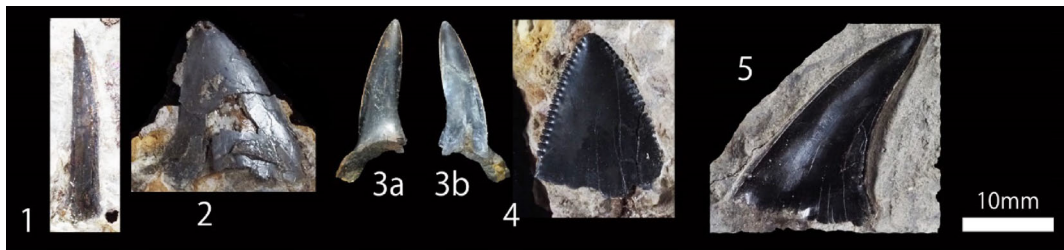


Figure 49. 1, *Mitsukurina lineata*, NMNS-PV 28117; 2, *Carcharodon hastalis*, NMNS-PV 28180; 3, *Isurus desori*, NMNS-PV 28186, lingual (a) and labial (b) views; 4, *Otodus* sp., NMNS-PV 28209, 5, *Parotodus benedeni*, NMNS-PV 28211. Scale bar equals 10 mm.

is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus sp.

Figure 49-4

Description: This specimen is missing most of the crown, although the crown apex is still present. The crown is broadly triangular and erect. The cutting edge of the crown has the regular fine serrations.

Remarks: The presence or absence of the cusplets at the base of the crown could not be confirmed, so the species was marked as unidentified.

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 49-5

Description: The crown is strongly curved distally. The cutting edge of the crown has no serrations. This specimen is embedded in host rock, the thickness of the crown could not be confirmed. However, the unique curvature of the crown allows identification of the specimen as this species.

Order Carcharhiniiformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 50-1

Description: The crown is triangular and slightly

curved distally. The cutting edge of the crown has fine serrations.

Genus *Negaprion* Whitley, 1940

Negaprion eurybathrodon (Brake, 1862)

Figure 50-2

Description: The crown is thin, triangular and almost erect or slightly curved distally. The cutting edge of the crown has no serrations.

22. Akeyo Formation, Mizunami Group

Locality: Matsugasecho, Mizunami City, Gifu Prefecture

Formation and Age: Akeyo Formation, Early Miocene. According to Yanagisawa and Akiba (1998), and Hiroki and Matsumoto (1999), the age of the Akeyo Formation of the Mizunami Group is considered to be Early Miocene (18–17 Ma) based on the diatom fossils and the magnetostratigraphic correlation.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Megasqualus* Herman, 1982

Megasqualus occidentalis (Agassiz, 1856)

Figure 51-1

Description: The crown is triangular with a strong distal slope. The cutting edge of the crown has finely serrations. The labial face of the crown is extended so that its central part protrudes over the root. The lingual face of the crown is inflated and the labial face is flat.

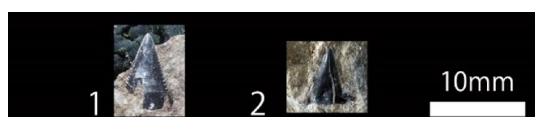


Figure 50. 1, *Carcharhinus* sp., NMNS-PV 28212; 2, *Negaprion eurybathrodon*, NMNS-PV 28225. Scale bar equals 10 mm.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 51-2

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The basal part of the crown widens in the mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serrations. The root is not bifurcated and is triangular and flattened when viewed from the apex.

Order Lamniformes Berg, 1958
 Family Lamnidae Müller and Henle, 1838
 Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
 Figure 52-1,2

Description: The crown of Fig.52-1 is elongated and curved distally. The crown of Fig.52-2 is small equilateral triangles, not high and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 52-3

Description: The crown is broadly triangular and erect. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Cetorhinidae Gill, 1862
 Genus *Cetorhinus* Blainville, 1816
Cetorhinus sp.
 Figure 52-4

Description: This is hook-shaped, flat, very long and elongated.

Remarks: This is the gill of the basking shark.

Order Carcharhiniformes Compagno, 1973
 Family Hemigaleidae Hasse, 1879
 Genus *Hemipristis* Agassiz, 1843
Hemipristis serra Agassiz, 1843
 Figure 53-1

Description: The crown is triangular and curved distally. The cutting edge of the crown has rough serrations, unlike in the genus *Carcharhinus*, but the serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo aduncus (Agassiz, 1835)
 Figure 53-2

Description: The crown is multicuspid with the



Figure 51. 1, *Megasqualus occidentalis*, NMNS-PV 27581, lingual (a) and labial (b) views; 2, *Squatina* sp., NMNS-PV 27582, lingual (a) and labial (b) views. Scale bar equals 5 mm.

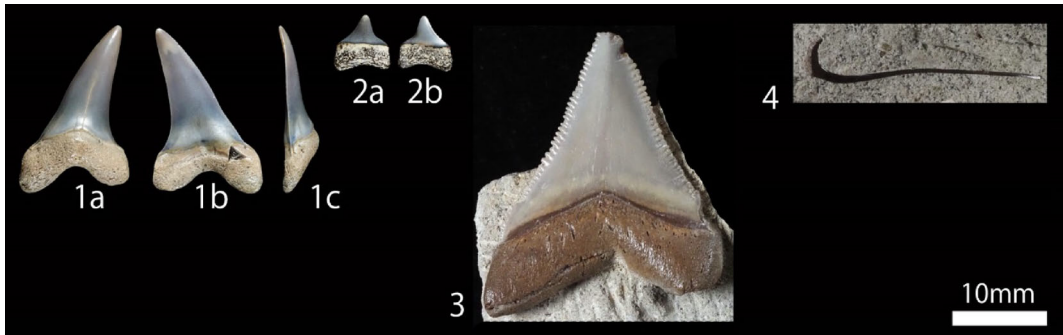


Figure 52. 1, *Isurus desori*, NMNS-PV 27583, lingual (a), labial (b) and profile (c) views; 2, *Isurus desori*, NMNS-PV 27584, lingual (a) and labial (b) views; 3, *Otodus megalodon*, NMNS-PV 2785; 4, *Cetrohinus* sp., NMNS-PV 27586. Scale bar equals 10 mm.

mesial first cusp large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus cf. *C. altimus* (Springer, 1950)
 Figure 53-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the

crown is convex and the labial face is flat.

Carcharhinus cf. *C. brachyurus* (Günther, 1870)
 Figure 53-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)
 Figure 53-5

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting



Figure 53. 1, *Hemipristis serra*, NMNS-PV 27587, lingual (a) and labial (b) views; 2, *Galeocerdo aduncus*, NMNS-PV 27588, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. altimus*, NMNS-PV 27589, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27593, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 27594, lingual (a) and labial (b) views; 6, *Rhinoptera* sp., NMNS-PV 27614, occlusal (a), basal (b) and lingual (c) views. Scale bar equals 10 mm.

edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973
Family Rhinopteridae Jordan and Evermann, 1896
Genus *Rhinoptera* Hasselt, 1824
Rhinoptera sp.
Figure 53-6

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The tooth thickness becomes slightly thinner towards one end. The root is comb-shaped with numerous slits.

Additional records: In addition to the species reported here, there are reports of *Isurus* cf. *I. paucus*, *Raja* sp., *Dasyatis* gen. et sp. indet. (Reported as “*Dasyatis*” *nipponensis*, *Dasyatis* sp. in Itoigawa *et al.*, 1985) according to Itoigawa *et al.* (1985).

23. Yuyadani Formation, Tsuzuki Group

Locality: Kayamura, Ujodawara Town, Tsuzuki-Gun, Kyoto Prefecture.

Formation and Age: Yuyadani Formation, Early Miocene. According to Irizuki *et al.* (2021), the age of the Yuyadani Formation of the Tsuzuki Group is considered to be Early Miocene (18.2–16.9 Ma) based on the diatom fossils.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
Figure 54-1,2

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus sp.
Figure 54-3,4

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has fine serrations.

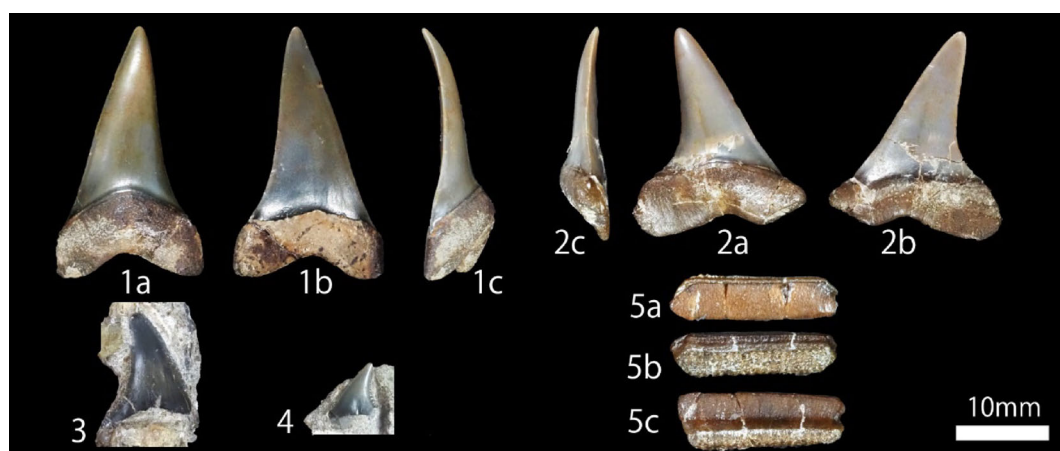


Figure 54. 1, *Isurus desori*, NMNS-PV 32969, lingual (a), labial (b) and profile (c) views; 2, *Isurus desori*, NMNS-PV 32970, lingual (a), labial (b) and profile (c) views; 3, *Carcharhinus* sp., NMNS-PV 32971; 4, *Carcharhinus* sp., NMNS-PV 32972; 5, *Rhinoptera* sp., NMNS-PV 32981, occlusal (a), basal (b) and lingual (c) views. Scale bar equals 10 mm.

Order Myliobatiformes Compagno, 1973
 Family Rhinopteridae Jordan and Evermann, 1896
 Genus *Rhinoptera* Hasselt, 1824
Rhinoptera sp.
 Figure 54-5

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The tooth thickness becomes slightly thinner towards one end. The root is comb-shaped with numerous slits.

24. Oshimojo Formation, Tomikusa Group

Locality: Onsawa, Anan Town, Shimoina-Gun, Nagano Prefecture

Formation and Age: Oshimojo Formation, Early Miocene. According to Sako and Hoshi (2014), the age of the Oshimojo Formation of the Tomikusa Group is considered to be Early Miocene (18.1–17.5 Ma) based on the paleomagnetic direction.

Order Squaliformes Goodrich, 1909
 Family Squalidae Bonaparte, 1834
 Genus *Megasqualus* Herman, 1982
Megasqualus occidentalis (Agassiz, 1856)
 Figure 55-1

Description: Similar to the teeth of the modern *Squalus*, but more than twice as large as those of the modern species. The crown is triangular with a strong distal slope. The cutting edge of the crown has finely serrations. The lingual face of the crown is inflated and the labial face is flat. The labial face of the crown is extended so that its central part overhangs the root.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 55-2

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The basal portion of the crown widens in the mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serrations. The root is not bifurcated and is triangular and flattened when viewed from the apex.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo aduncus (Agassiz, 1835)
 Figure 56-1,2

Description: The crown of these teeth is multicuspoid. The mesial first cusp of Fig.56-1 is large and curved distally. The distal cusps following the first cusp are smaller. On the other hand, the central cusp of Fig.56-2 is large and erect. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: Fig.56-2 is a parasymphysis tooth of the upper jaw.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus cf. *C. brachyurus* (Günther, 1870)
 Figure 56-3

Description: The crown is thin and curved



Figure 55. 1, *Megasqualus occidentalis*, NMNS-PV 27547, lingual (a) and labial (b) views; 2, *Squatina* sp., NMNS-PV 27549, lingual (a) and labial (b) views. Scale bar equals 5 mm.

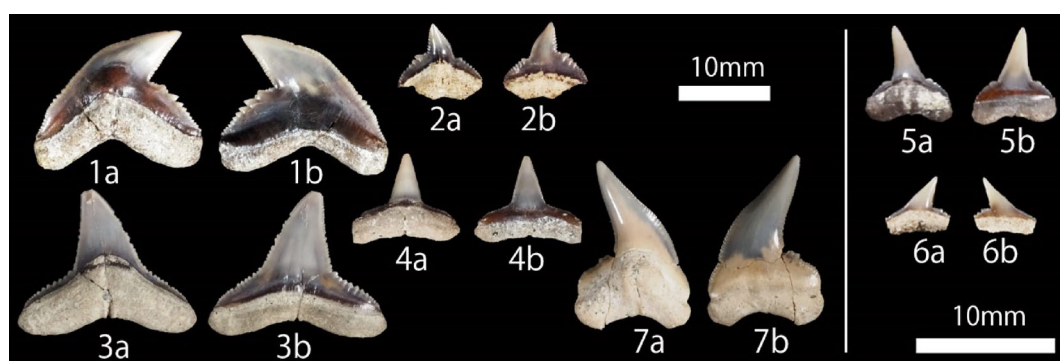


Figure 56. 1, *Galeocerdo aduncus*, NMNS-PV 27551, lingual (a) and labial (b) views; 2, *Galeocerdo aduncus*, NMNS-PV 27552, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27556, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. limbatus*, NMNS-PV 32994, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. macloti*, NMNS-PV 27575, lingual (a) and labial (b) views; 6, *Carcharhinus* cf. *C. tjtjt*, NMNS-PV 33011, lingual (a) and labial (b) views; 7, *Physogaleus contortus*, NMNS-PV 27576, lingual (a) and labial (b) views. Scale bar equals 10 mm.

distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. limbatus* (Valenciennes, 1839)
Figure 56-4

Description: The crown is thin and almost erect. The cutting edge of the crown has very fine serrations, with slightly rougher serrations at the base. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. macloti*
(Müller and Henle, 1839)
Figure 56-5

Description: The crown is thin and erect. The cutting edge of the crown has no serrations, but there are rough serrations at the base of the crown. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. tjtjt* (Bleeker, 1852)
Figure 56-6

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial

cutting edge has very rough serrations. The distal cutting edge is straight. The lingual face of the crown is convex and the labial face is flat.

Genus *Physogaleus* Cappetta, 1980
Physogaleus contortus (Gibbes, 1849)
Figure 56-7

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: The crown morphology is similar to the genus *Galeocerdo*, but the crown is monocuspid and differs from the multicuspid genus *Galeocerdo*. The cutting edge of the crown is serrate rather than cusped. Ward and Bonavia (2001) placed it in the genus *Physogaleus*, which also includes *G. aduncus*. However, *G. aduncus* should remain in the genus *Galeocerdo*.

Order Myliobatiformes Compagno, 1973
Family Myliobatidae Bonaparte, 1838
Genus *Myliobatis* Cuvier, 1816
Myliobatis sp.
Figure 57-1

Description: This tooth is hexagonal in shape. The thickness of the crown is constant and the



Figure 57. 1, *Myliobatis* sp., NMNS-PV 33016, occlusal (a), basal (b) and lingual (c) views; 2, dermal denticle, NMNS-PV 33017, dorsal (a) and profile (b) views; 3, vertebra, NMNS-PV 33018, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.

occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Remarks: This tooth is located on both sides of the jaw.

Dermal denticle

Figure 57-2

Description: It has an elongated oval shape and is slightly mountainous when viewed in profile. The upper part is elongated with enamel remaining.

Remarks: This is the dermal denticle of the ray.

Vertebra

Figure 57-3

Description: This has a mill-shape with a concave center. There are no slits on the sides.

Remarks: This is the vertebra of the family Carcharhinidae.

Additional records: In addition to the species reported here, there are reports of *Isurus* sp. *Lamna* sp., *Megalolamna serotinus* (Reported as *Otodus* sp. in Hasegawa and Uyeno, 1967),

Otodus chubutensis (Reported as *Carcharodon* sp. in Hasegawa and Uyeno, 1967), *Otodus megalodon* (Reported as *Carcharodon megalodon* in Hasegawa and Uyeno, 1967) according to Hasegawa and Uyeno (1967).

25. Yoshino Formation, Katsuta Group

Locality: Kaki, Nagi Town, Katsuta-Gun, Okayama Prefecture.

Formation and Age: Yoshino Formation, Early Miocene. According to Suzuki *et al.* (2003), the age of the Yoshino Formation of the Katsuta Group is considered to be Early Miocene based on the fission-track age.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias contortidens (Agassiz, 1843)

Figure 58-1

Description: The crown is thin, elongated and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and there are lateral cusplets. There is a striation

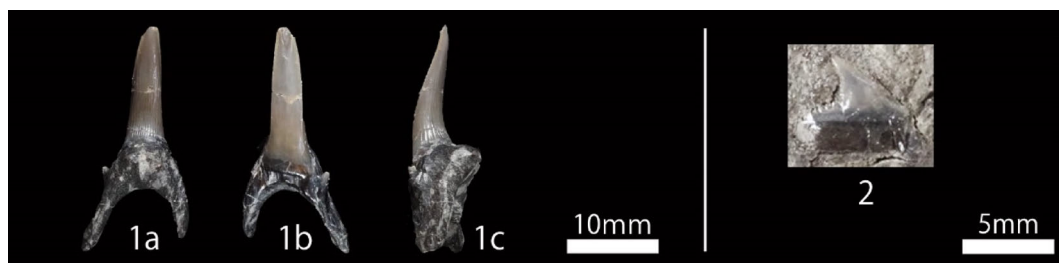


Figure 58. 1, *Carcharias contortidens*, NMNS-PV-33998, lingual (a), labial (b) and profile (c) views; 2, *Carcharhinus* sp., NMNS-PV-33999. Scale bar equals 10 mm (1) and 5 mm (2).

on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus sp.
 Figure 58-2

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has serrations.

26. Ohi Formation, Ichishi Group

Locality 1: Yanidani, Misatocho, Tsu City, Mie Prefecture

Locality 2: Bungo, Misatocho, Tsu City, Mie Prefecture

Locality 3: Iedoko1, Misatocho, Tsu City, Mie Prefecture

Locality 4: Iedoko2, Misatocho, Tsu City, Mie Prefecture

Locality 5: Kitanagano, Misatocho, Tsu City, Mie Prefecture

Locality 6: Minaminagano, Misatocho, Tsu City, Mie Prefecture

Locality 7: Ashizaka, Misatocho, Tsu City, Mie Prefecture

Formation and Age (Locality 1-7): Ohi Formation, Early Miocene. According to Oshida (2018), Hoshi *et al.* (2019), the age of the Ohi Formation of the Ichishi Group is considered to be Early Miocene (17 Ma) based on the planktonic foraminifera etc.

Order Hexanchiformes Buen, 1926
 Family Hexanchidae Gray, 1851
 Genus *Hexanchus* Rafinesque, 1810
Hexanchus sp.
 Figure 59-1,2

Description: The crown of Fig.59-1 is multituberculate with the height of the cusps decreasing in the distally from the first cusp. The proximal base of the first cusp has finely serrations. The root is



Figure 59. 1, *Hexanchus* sp., NMNS-PV 32563, Locality 3; 2, *Hexanchus* sp., NMNS-PV 27763, Locality 1. Scale bar equals 10 mm.

flat and rectangular. The crown of Fig.59-2 has 4 cusps. The first cusp is high and the others are very low. The root is flat and rectangular.

Order Squaliformes Goodrich, 1909
 Family Squalidae Bonaparte, 1834
 Genus *Megasqualus* Herman, 1982
Megasqualus occidentalis (Agassiz, 1856)
 Figure 60-1

Description: The crown is triangular with a strong distal slope. The cutting edge of the crown has finely serrations. The labial face of the crown is extended so that its central part overhangs the root. The lingual face of the crown is inflated and the labial face is flat.

Genus *Squalus* Linnaeus, 1758
Squalus sp.
 Figure 60-2

Description: This specimen is similar to the above mentioned *Megasqualus*, but with very small teeth. It is more similar to the modern species. The crown is triangular and strongly curved distally. The cutting edge of the crown has no serration. The central part of the crown on the labial face hangs apron-like on the root side.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 60-3

Description: The crown is thin and triangular.



Figure 60. 1, *Megasqualus occidentalis*, NMNS-PV 28023, Locality 5; 2, *Squalus* sp., NMNS-PV 27765, Locality 1; 3, *Squatina* sp., NMNS-PV 32572, Locality 1. Scale bar equals 5 mm.

The basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serration. The root is flat and triangular.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Araloselachus* Glikman, 1964

Araloselachus cuspidatus (Agassiz, 1843)

Figure 61-1,2

Description: The crown is thin and long. The cross section of the crown is rounded and there are lateral cusplets. The cutting edge of the crown has no serration. No striation on the lingual face of the crown. The lingual face of the crown is strongly convex and the labial face is slightly convex. The root is distinctly bifid.

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon hastalis (Agassiz, 1838)

Figure 61-3,4,5,6

Description: The crowns of Fig. 61-3,4 are elongated and erect. The crown of Fig. 61-5,6 is broad, triangular and slightly curved distally. The cutting edge of the crown have no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Carcharodon planus (Agassiz, 1856)

Figure 61-7

Description: The crown is broad and

characteristically strongly curved distally. The cutting edge have no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Remarks: This species is found only in Japan, the west coast of the USA, and other areas of the Pacific Rim, and not in Europe or the east coast of the USA. The genus *Isurus* has long been used for this species, but in recent years some researchers have used the genus *Cosmopolitodus*, and since Ehret *et al.* (2012) *Cosmopolitodus* has become a synonym for *Carcharodon*, so this genus is used here.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 62-1,2,3,4,5,6

Description: The crowns of Fig.62-1,2,3 are elongated and curved distally. The crowns of Fig.62-4,5,6 are elongated and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Isurus retroflexus (Agassiz, 1838)

Figure 62-7

Description: The labial face of the crown is convex, but not as much as in *I. desori*. The crown is broad, triangular, slightly curved distally and thinner than *I. desori*. The cutting edge of the crown has no serrations.

Family Alopiidae Bonaparte, 1838

Genus *Alopias* Rafinesque, 1810

Alopias sp.

Figure 62-8

Description: The crown is narrowly triangular and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex. The root is distinctly bifid and quite long.

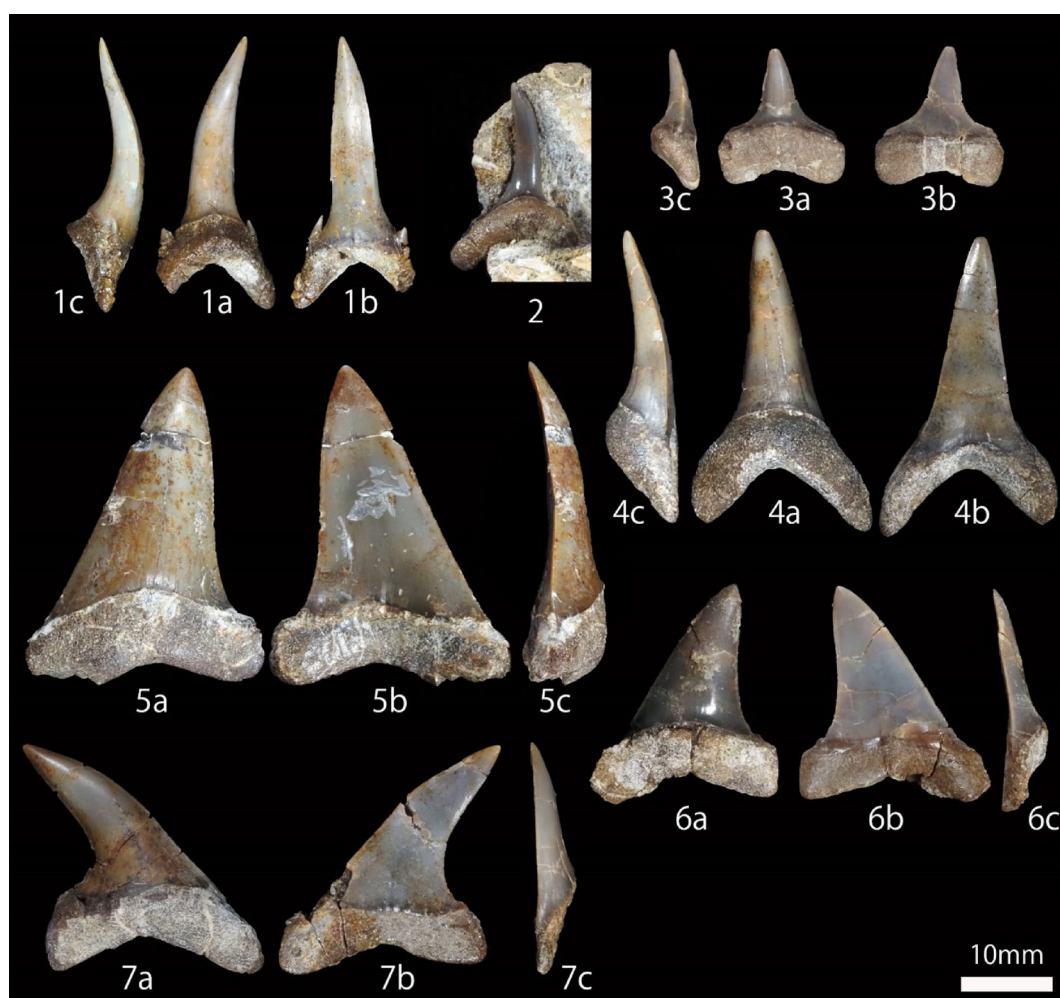


Figure 61. 1, *Araloselachus cuspidatus*, NMNS-PV 27776, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Araloselachus cuspidatus*, NMNS-PV 32556, Locality 3; 3, *Carcharodon hastalis*, NMNS-PV 27804, Locality 1, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 27802, Locality 1, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon hastalis*, NMNS-PV 27806, Locality 1, lingual (a), labial (b) and profile (c) views; 6, *Carcharodon hastalis*, NMNS-PV 27807, Locality 1, lingual (a), labial (b) and profile (c) views; 7, *Carcharodon planus*, NMNS-PV 27820, Locality 1, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Family Cetorhinidae Gill, 1862
Genus *Cetorhinus* Blainville, 1816
Cetorhinus sp.
Figure 62-9

Description: The tooth is very small with a single cusp. The crown is conical and the cusp is pointed. The cutting edge of the crown has no serrations.

Family Otodontidae Glickman, 1964
Genus *Otodus* Agassiz, 1838
Otodus chubutensis (Ameghino, 1901)
Figure 63-1,2,3,4

Description: The tooth is broadly triangular. The crown of Fig.63-1,2 is curved distally. The crowns of Fig.63-3,4 are erect. The cutting edge of the crown has the regular, fine serrations. In



Figure 62. 1, *Isurus desori*, NMNS-PV 27777, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Isurus desori*, NMNS-PV 28007, Locality 2, lingual (a), labial (b) and profile (c) views; 3, *Isurus desori*, NMNS-PV 32555, Locality 6, lingual (a), labial (b) and profile (c) views; 4, *Isurus desori*, NMNS-PV 27788, Locality 1, lingual (a), labial (b) and profile (c) views; 5, *Isurus desori*, NMNS-PV 28050, Locality 1, lingual (a), labial (b) and profile (c) views; 6, *Isurus desori*, NMNS-PV 32559, Locality 1, lingual (a), labial (b) and profile (c) views; 7, *Isurus retroflexus*, NMNS-PV 32564, Locality 1; 8, *Alopias* sp., NMNS-PV 32599, Locality 1; 9, *Cetorhinus* sp., NMNS-PV 32579, Locality 1. Scale bar equals 10 mm (1,2,3,4,5,6,7,8) and 2 mm (9).

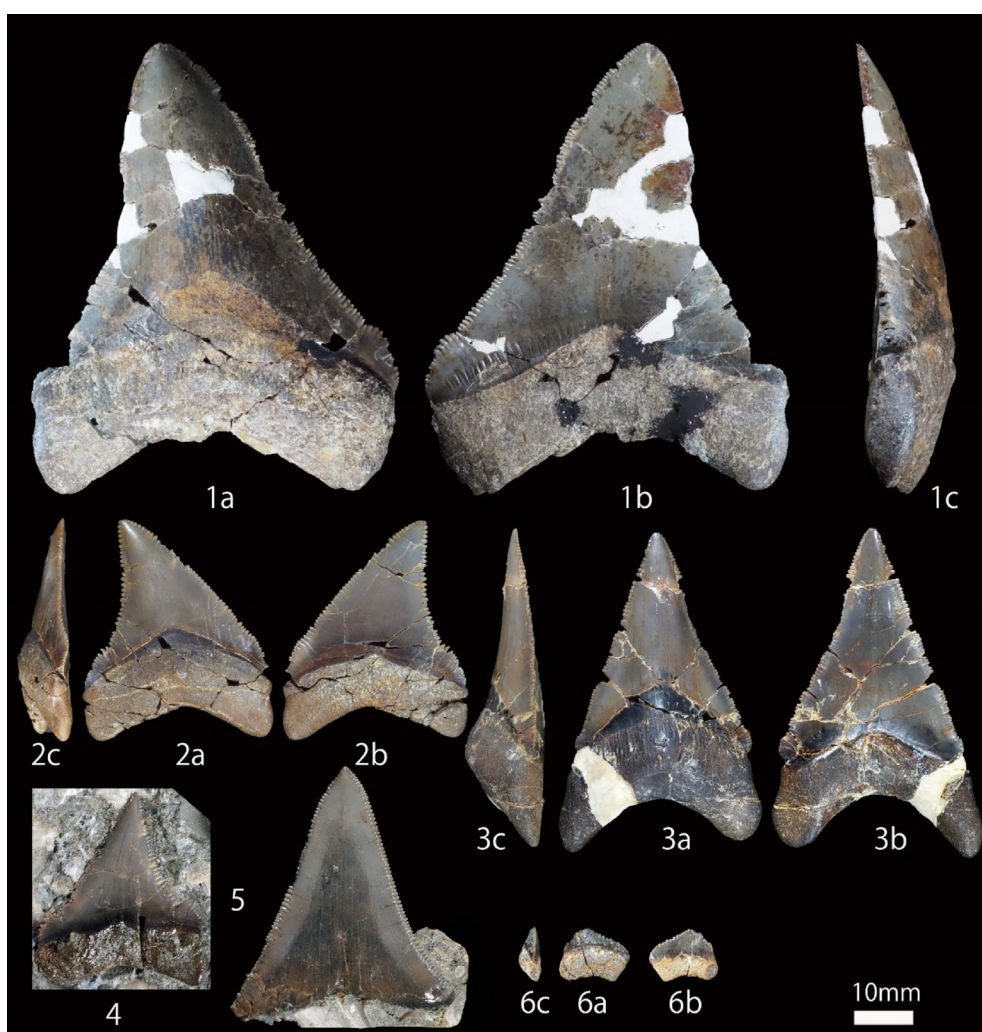


Figure 63. 1, *Otodus chubutensis*, NMNS-PV 28146, Locality 6, lingual (a), labial (b) and profile (c) views; 2, *Otodus chubutensis*, NMNS-PV 28123, Locality 3, lingual (a), labial (b) and profile (c) views; 3, *Otodus chubutensis*, NMNS-PV 32562, Locality 3, lingual (a), labial (b) and profile (c) views; 4, *Otodus chubutensis*, NMNS-PV 27829, Locality 4; 5, *Otodus megalodon*, NMNS-PV 32591, Locality 1; 6, *Otodus megalodon*, NMNS-PV 32594, Locality 3, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

addition to the main cusp, the crown has a weak lateral cusplets. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Otodus megalodon (Agassiz, 1843)

Figure 63-5,6

Description: The crown of Fig.63-5 is broadly

triangular and erect. The cutting edge of the crown has the regular, fine serrations. Fig.63-6 is small and curved distally. The cutting edge of the crown has the regular, fine serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: Fig.63-6 is the posterior tooth.

Family indet.

Genus *Trigonotodus* Kozolov in
Zhelezko and Kolozov, 1999
Trigonotodus grandis (Leriche, 1942)

Figure 64-1

Description: The crown is broad and strongly

curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid and curved in the middle.

Remarks: This genus is treated like the giant thresher shark and some consider it to be in the genus *Alopias*. In fact, the tooth morphology is

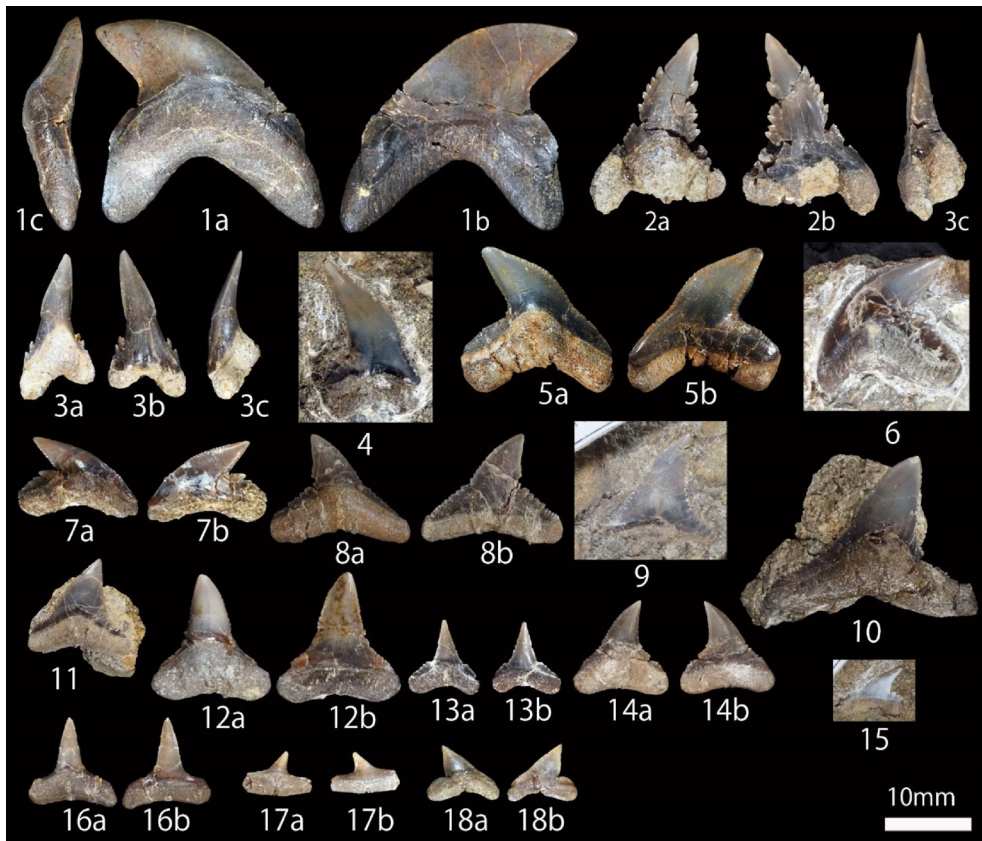


Figure 64. 1, *Trigonotodus grandis*, NMNS-PV 27834, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Hemipristis serra*, NMNS-PV 28068, Locality 1, lingual (a), labial (b) and profile (c) views; 3, *Hemipristis serra*, NMNS-PV 28124, Locality 1, lingual (a), labial (b) and profile (c) views; 4, *Physogaleus contortus*, NMNS-PV 27984, Locality 1; 5, *Physogaleus contortus*, NMNS-PV 32573, Locality 1, lingual (a) and labial (b) views; 6, *Galeocерdo aduncus*, NMNS-PV 27840, Locality 1; 7, *Galeocерdo aduncus*, NMNS-PV 28006, Locality 1, lingual (a) and labial (b) views; 8, *Carcharhinus* cf. *C. albimarginatus*, NMNS-PV 32614, Locality 1, lingual (a) and labial (b) views; 9, *Carcharhinus* cf. *C. altimus*, NMNS-PV 27084, Locality 1; 10, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27851, Locality 1; 11, *Carcharhinus* cf. *C. leucas*, NMNS-PV 32600, Locality 1; 12, *Carcharhinus* cf. *C. leucas*, NMNS-PV 27852, Locality 1, lingual (a) and labial (b) views; 13, *Carcharhinus* cf. *C. macloiti*, NMNS-PV 28104, Locality 1, lingual (a) and labial (b) views; 14, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 32601, Locality 1, lingual (a) and labial (b) views; 15, *Carcharhinus* cf. *C. tjutjot*, NMNS-PV 27853, Locality 7; 16, *Carcharhinus* sp., NMNS-PV 32604, Locality 1, lingual (a) and labial (b) views; 17, *Rhizoprionodon* sp., NMNS-PV 27985, Locality 2, lingual (a) and labial (b) views; 18, *Sphyrna* sp., NMNS-PV 28014, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.

similar to a larger version of *Alopias*. However, the teeth are too large to be placed in the genus *Alopias*, so we have ventured to place it in the genus *Trigonotodus*.

Order Carcharhiniformes Compagno, 1973

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassiz, 1843

Hemipristis serra Agassiz, 1843

Figure 64-2,3

Description: The crown of Fig.64-2 is triangular and curved distally. The cutting edge of the crown has rough serrations and these serrations do not extend to the apical part of the cusp. The crown of Fig.64-3 is elongated and slightly curved distally. The cutting edge of the crown has few serrations. The two pairs of cusplets are present on the lower part of the crown. The lingual face of the crown is convex and the labial face is flat.

Genus *Physogaleus* Cappetta, 1980

Physogaleus contortus (Gibbes, 1849)

Figure 64-4,5

Description: The crown is thin, triangular and curved distally. The cutting edge of the crown is curved at about midpoint. The crown morphology is similar to the genus *Galeocerdo*, but the crown is monocuspid and differs from the multicupid genus *Galeocerdo*. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo aduncus (Agassiz, 1835)

Figure 64-6,7

Description: The crown is multicupid with the mesial first cusp large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. albimarginatus* (Rüppell, 1837)

Figure 64-8

Description: The crown is narrowly triangular and almost erect. The upper part of the cutting edge of the crown has fine serrations, while the lower part near the base is rougher. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. altimus* (Springer, 1950)

Figure 64-9

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations.

Carcharhinus cf. *C. brachyurus* (Günther, 1870)

Figure 64-10

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations.

Carcharhinus cf. *C. leucas* (Müller and Henle, 1839)

Figure 64-11,12

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. macloiti*

(Müller and Henle, 1839)

Figure 64-13

Description: The crown is thin and erect. The cutting edge of the crown has no serrations, but there are rough serrations at the base of the crown. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)

Figure 64-14

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. tujot* (Bleeker, 1852)

Figure 64-15

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial cutting edge has very rough serrations. The distal cutting edge is straight.

Carcharhinus sp.

Figure 64-16

Description: The crown is thin and erect. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Rhizoprionodon* Whitley, 1929

Rhizoprionodon sp.

Figure 64-17

Description: The crown is thin and curved distally. The cutting edge of the crown has no serrations and there is a distal shoulder at the base of the crown. The cusp is slightly recurved mesially. The lingual face of the crown is convex and the labial face is flat.

Family Sphyrnidae Gill, 1872

Genus *Sphyrna* Rafinesque, 1810

Sphyrna sp.

Figure 64-18

Description: The crown is triangular and concave near the apex. The cutting edge of the crown has no serrations. The mesial cutting edge

of the crown is curved outwards. A shoulder develops at the distal base of the crown. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Myliobatidae Bonaparte, 1838

Genus *Aetobatus* Blainville, 1816

Aetobatus sp.

Figure 65-1

Description: Tooth morphology is similar to that of the genus *Myliobatis*, but differs in that the tooth is slightly tapered towards the edges in the occlusal view.

Genus *Myliobatis* Cuvier, 1816

Myliobatis sp.

Figure 65-2

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Family Dasyatidae Jordan, 1888

Dasyatidae gen. et sp. indet.

Figure 65-3

Description: This is a small tooth. The crown is conical and pointed. The apex of crown is tilted posteriorly. The root hangs down from the lower part of the crown of the tooth.

Fin spine

Figure 65-4

Description: This is very elongated, lanceolate and a long, right-angled triangle form the profile view. It has wrinkles that resemble growth lines, and its cross section forms a rounded triangle.

Remarks: This is the fin spine of a member of the shark family. Based on the teeth produced, it is most likely the fin spine of the family Squalidae.



Figure 65. 1, *Aetobatis* sp., NMNS-PV 28143, Locality 3, occlusal (a), basal (b) and lingual (c) views; 2, *Myliobatis* sp., NMNS-PV 32598, Locality 1, occlusal (a), basal (b) and lingual (c) views; 3, *Dasyatidae* gen. et sp. indet., NMNS-PV 27993, Locality 1; 4, fin spine, NMNS-PV 27770, Locality 1, articular (a), profile (b) views; 5, caudal spine, NMNS-PV 28000, Locality 1, dorsal (a), ventral (b) and profile (c) views; 6, vertebra, NMNS-PV 28001, Locality 1, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm (1,2,4,5,6) and 2 mm (3).

Caudal spine Figure 65-5

Description: This is elongated and pointed at the tip like a spear. Both sides have fine spiny projections.

Remarks: This is the caudal spine of *Myliobatiformes*.

Vertebra Figure 65-6

Description: This has a mill-shape with a concave center.

Remarks: This is the shark vertebra, but family, genus, etc. are unknown.

reported here, there are reports of *Megalolamna serotinus* (Reported as *Megalolamna paradoxodon* in Shimada *et al.*, 2017) according to Pollerspöck and Shimada (2024).

27. Shukunohora Formation, Mizunami Group

Locality 1: Oginoshima, Kamdo-cho, Mizunami City, Gifu Prefecture

Locality 2: Suganuma, Hiyoshi-cho, Mizunami City, Gifu Prefecture

Formation and Age (Locality 1,2): Syukunohora Formation, Middle Miocene. According to Ibaraki (1981), the age of the Syukunohora Formation of the Mizunami Group is considered to be Middle Miocene (16.4 Ma) based on the planktonic foraminifera.

Additional records: In addition to the species

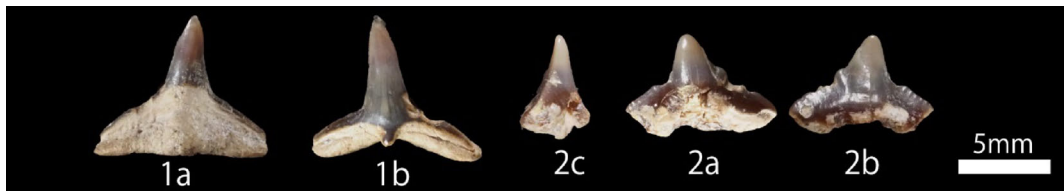


Figure 66. 1, *Squatina* sp., NMNS-PV 27615, Locality 1, lingual (a) and labial (b) views; 2, *Nebrius* sp., NMNS-PV 27616, Locality 2, lingual (a), labial (b) and profile (c) views. Scale bar equals 5 mm.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 66-1

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The cutting edge of the crown has no serrations. The basal part of the crown widens in the mesially-distally and the basal center of the crown deeply overhangs the root. The root is not bifurcated and is triangular and flattened when viewed from the apex.

Order Orectolobiformes Applegate, 1972
 Family Ginglymostomatidae Gill, 1862
 Genus *Nebrius* Rüppell, 1837
Nebrius sp.
 Figure 66-2

Description: The labial face of the crown slightly overhangs from the center of the root. The labial face of the crown is raised and protrudes from the center of the root. There are fine secondary cusps or serrations on either side of

the main cusp in the center of the crown.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
 Figure 67-1

Description: The crown is thin, elongated and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and there are lateral cusplets on only one side. There is the striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 67-2

Description: The crown is thin, erect and not very high. The cutting edge of the crown have very finely serrations. The lingual face of the crown is convex and the labial face is slightly



Figure 67. 1, *Carcharias contortidens*, NMNS-PV 27618, Locality 2, lingual (a), labial (b) and profile (c) views; 2, *Otodus megalodon*, NMNS-PV 27620, Locality 2, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

convex. The root is very thick.

Remarks: This is the abnormal tooth of the posterior tooth.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo aduncus (Agassiz, 1835)

Figure 68-1

Description: The crown is multicuspid with the mesial first cusp being large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. albimarginatus* (Rüppell, 1837)

Figure 68-2

Description: The crown is narrowly triangular and almost erect. The upper part of the cutting edge of the crown has finely serrations, while the lower part near the base is rougher. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. altimus* (Springer, 1950)

Figure 68-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the

apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)

Figure 68-4

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Caudal spine

Figure 68-5

Description: This is elongated and pointed at the tip like a spear. Both sides have fine spiny projections.

Remarks: This is the caudal spine of *Myliobatiformes*.

Additional records: In addition to the species reported here, there are reports of *Hexanchus* sp., *Odontaspis* cf. *C. volax*, *Carcharodon hastalis* (Reported as *Isurus hastalis* in Itoigawa *et al.*, 1985), *Otodus megalodon* (Reported as *Carcharodon megalodon* in Itoigawa *et al.*, 1985), *Rhynchobatus* sp., *Dasyatidae* gen. et sp. indet. (Reported as “*Dasyatis*” *nipponensis*,

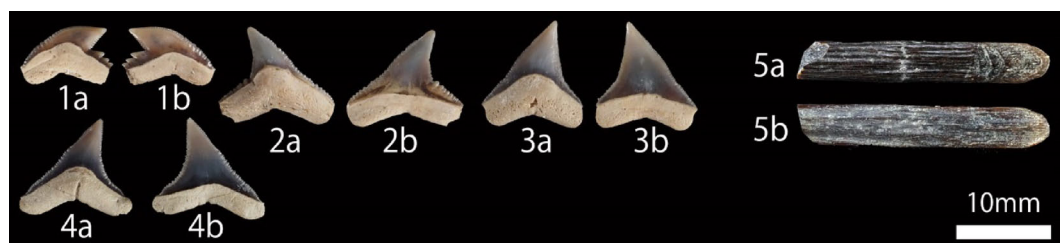


Figure 68. 1, *Galeocerdo aduncus*, NMNS-PV 27622, Locality 2, lingual (a) and labial (b) views; 2, *Carcharhinus* cf. *C. albimarginatus*, NMNS-PV 27623, Locality 2, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. altimus*, NMNS-PV 27625, Locality 2, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 27628, Locality 1, lingual (a) and labial (b) views; 5, caudal spine, NMNS-PV 27640, Locality 1, dorsal (a) and ventral (b) views. Scale bar equals 10 mm.

Dasyatis sp. in Itoigawa *et al.*, 1985), *Rhinoptera* sp. according to Itoigawa *et al.* (1985).

28. Kokozura Formation, Takaku Group

Locality: Izura, Ohchu-cho, Kitaibaraki City, Ibaraki Prefecture

Formation and Age: Kokozura Formation, Early Miocene. The Kokozura Formation is sometimes included in the Taga Group, but is distinguished here. According to Ando *et al.* (2011), the age of the Kokozura Formation of the Takaku Group is considered to be Early Miocene (16.7 Ma) based on the diatom fossils.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus cf. *C. brachyurus* (Günther, 1870)
Figure 69-1

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Otodus megalodon* (Reported as *Carcharodon megalodon* in Koda *et al.*, 2007) according to Koda *et al.* (2007).

29. Kurosedani Formation, Yatsuo Group

Locality: Hukatani, Yatsuo City, Toyama Prefecture

Formation and Age: Kurosedani Formation, Middle Miocene. According to Hayakawa and Takemura (1987), the age of the Kurosedani Formation of the Yatsuo Group is considered to be Middle Miocene (16 Ma) based on the fission-track age.

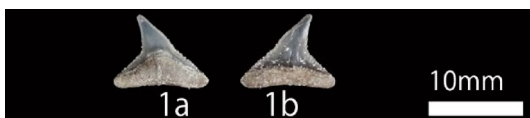


Figure 69. 1, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 26897, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958
Family Otodontidae Glickman, 1964
Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
Figure 70-1

Description: The specimen is almost complete. The tooth is very large. The crown is broadly triangular and slightly curved in the distal direction. The lingual face of the crown is convex and the labial face is flattened. The cutting edge has the regular, fine serration. The mesial and distal cutting edges curve gently S-shaped. A distinct cervical band remains. The root is distinctly bifurcated and medially curved.

Additional records: In addition to the species reported here, there are reports of *Carcharhinus* sp. according to Kaneko and Goto (1992).

30. Itabashi Formation, Bihoku Group

Locality: Shinjyocho, Shyobara City, Hiroshima Prefecture

Formation and Age: Itabashi Formation, Middle Miocene. According to Yamamoto (1999), the age of the Itabashi Formation of the Bihoku Group is considered to be Middle Miocene (16.1–15.6 Ma) based on the calcareous fossil and the planktonic foraminifera.

Order Hexanchiformes Buen, 1926
Family Hexanchidae Gray, 1851
Genus *Hexanchus* Rafinesque, 1810
Hexanchus sp.
Figure 71-1

Description: This is a polycuspid with the height of the cusps decreasing distally from the first cusp.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon planus (Agassiz, 1856)
Figure 72-1

Description: The crown is broad and



Figure 70. 1, *Otodus megalodon*, NMNS-PV 27252. Scale bar equals 10 mm.

characteristically strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
 Figure 72-2,3

Description: The crown of Fig.72-2 is slightly broad and curved distally. The cutting edge has no serrations. The crown of Fig.72-3 is elongated, almost erect and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 72-4

Description: The crown is broadly lower, triangular and curved distally. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: This is the posterior tooth.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo aduncus (Agassiz, 1835)
 Figure 73-1



Figure 71. 1, *Hexanchus* sp., NMNS-PV 28277. Scale bar equals 10 mm.

Description: The crown is multicuspid with the mesial first cusp being large and curved distally. The distal cusps following the first cusp are small. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.



Figure 72. 1, *Carcharodon planus*, NMNS-PV 28282, lingual (a), labial (b) and profile (c) views; 2, *Isurus desori*, NMNS-PV 28284, lingual (a), labial (b) and profile (c) views; 3, *Isurus desori*, NMNS-PV 28297, lingual (a), labial (b) and profile (c) views; 4, *Otodus megalodon*, NMNS-PV 28281, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. albimarginatus* (Rüppell, 1837)

Figure 73-2

Description: The crown is narrowly triangular and almost erect. The upper part of the cutting edge of the crown has finely serrations, while the lower part near the base is rougher. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. macloti*

(Müller and Henle, 1839)

Figure 73-3

Description: The crown is thin and erect. The cutting edge of the crown has no serrations, but there are rough serrations at the base of the crown. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. sorrah*

(Müller and Henle, 1839)

Figure 73-4

Description: The crown is triangular and

strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial cutting edge has very rough serrations. The distal cutting edge is straight. The lingual face of the crown is convex and the labial face is flat.

Additional records: According to Yamaoka (1987) and Nakano (1999), there are reports of Chondrichthyes fossils from the Bihoku Group, but individual specimens have not been differentiated between Itabashi Fm. and Korematsu Fm.. Hence, the report here is omitted.

31. Shikiya Formation, Kumano Group

Locality: Suganohama, Kushimoto Town, Higashimuro-Gun, Wakayama Prefecture

Formation and Age: Shikiya Formation, Middle Miocene. According to Ikebe *et al.* (1975), the age of the Shikiya Formation of the Kumano Group is considered to be Middle Miocene (16 Ma) based on the planktonic foraminifera.

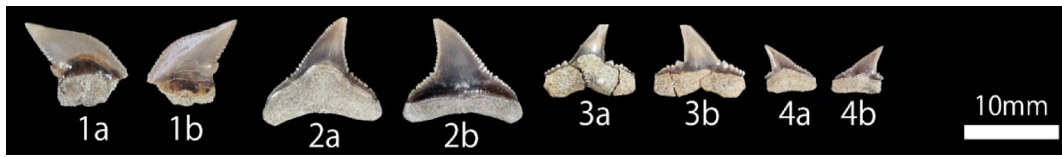


Figure 73. 1, *Galeocерdo aduncus*, NMNS-PV 28299, lingual (a) and labial (b) views; 2, *Carcharhinus* cf. *C. albimarginatus*, NMNS-PV 28300, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. macloiti*, NMNS-PV 28301, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. sorrah*, NMNS-PV 28302, lingual (a) and labial (b) views. Scale bar equals 10 mm.



Figure 74. 1, Hexanchidae gen.et sp.indet., NMNS-PV 28226, lingual (a), labial (b) and profile (c) views. Scale bar equals 5 mm.

Order Hexanchiformes Buen, 1926
Family Hexanchidae Gray, 1851
Hexanchidae gen.et sp.indet.
Figure 74-1

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is slightly convex.

Order Lamniformes Berg, 1958
Family Odontaspidae Müller and Henle, 1839
Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
Figure 75-1

Description: The crown is thin and erect. The cross section of the crown is rounded. The cutting edge of the crown has no serrations. There is the striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
Figure 75-2

Description: The crown is broad, isosceles triangular and slightly curved distally. The cutting edge has no serrations.



Figure 75. 1, *Carcharias contortidens*, NMNS-PV 28242, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon hastalis*, NMNS-PV 28227; 3, *Isurus desori*, NMNS-PV 28231, lingual (a), labial (b) and profile (c) views; 4, *Parotodus benedeni*, NMNS-PV 28244, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 75-3

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 75-4

Description: The crown is strongly curved distally. The cutting edge of the crown has no serrations. This specimen is embedded in host rock, the thickness of the crown could not be confirmed. However, the unique curvature of the crown allows identification of the specimen as this species. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassiz, 1843

Hemipristis serra Agassiz, 1843

Figure 76-1

Description: The crown is triangular and curved distally. The cutting edge of the crown has rough serrations, unlike in the genus *Carcharhinus*, but the serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocерdo* Müller and Henle, 1837

Galeocерdo aduncus (Agassiz, 1835)

Figure 76-2

Description: The crown is multicuspid with the mesial first cusp being large and curved distally. The distal cusps following the first cusp are small. The cutting edge of each cusp has fine serrations.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 76-3,4

Description: The crown of Fig.76-3 is triangular and slightly curved distally. The cutting edge of the crown has fine serrations. The crown of Fig.76-4 is thin and erect. The cutting edge of the crown has fine serrations.

Genus *Negaprion* Whitley, 1940

Negaprion eurybathrodon (Brake, 1862)

Figure 76-5

Description: The crown is thin, triangular and almost erect or slightly curved distally. The cutting edge of the crown has no serrations.

Family Sphyrnidae Gill, 1872

Genus *Sphyrna* Rafinesque, 1810

Sphyrna sp.

Figure 76-6

Description: The crown is triangular and curved



Figure 76. 1, *Hemipristis serra*, NMNS-PV 28246, lingual (a) and labial (b) views; 2, *Galeocерdo aduncus*, NMNS-PV 28248; 3, *Carcharhinus* sp., NMNS-PV 28252; 4, *Carcharhinus* sp., NMNS-PV 28254; 5, *Negaprion eurybathrodon*, NMNS-PV 28275; 6, *Sphyrna* sp., NMNS-PV 28276. Scale bar equals 10 mm.

distally. The cutting edge of the crown has no serrations. A shoulder develops at the distal base of the crown.

Additional records: In addition to the species reported here, there are reports of *Otodus megalodon* (Reported as *Carcharocles megalodon* in Sako *et al.*, 2015) according to Sako *et al.* (2015).

32. Korematsu Formation, Bihoku Group

Locality 1: Higashihonmachi, Shyobara City, Hiroshima Prefecture

Locality 2: Shinjyocho, Shyobara City, Hiroshima Prefecture

Locality 3: Nishihonmachi, Shyobara City, Hiroshima Prefecture

Locality 4: Osa, Saijyochou, Shyobara City, Hiroshima Prefecture

Formation and Age (Locality 1,2,3,4): Korematsu Formation, Middle Miocene. According to Yamamoto (1999), the age of the Korematsu Formation of the Bihoku Group is considered to be Middle Miocene (16.1–15.6 Ma) based on the calcareous fossil and the planktonic foraminifera.

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Genus *Hexanchus* Rafinesque, 1810

Hexanchus nakamurai (Teng, 1962)

Figure 77-1

Description: This is a polycuspid. The height of the cusps decreases distally from the first cusp.

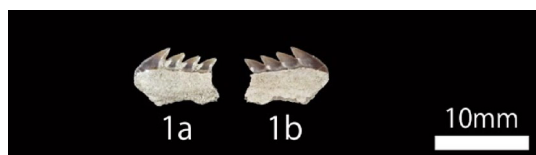


Figure 77. 1, *Hexanchus nakamurai*, NMNS-PV 28278, Locality 2, lingual (a) and labial (b) views. Scale bar equals 10 mm.



Figure 78. 1, *Carcharias contortidens*, NMNS-PV 28279, Locality 3, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias contortidens (Agassiz, 1843)

Figure 78-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is a striation on the lingual face of the crown. The lingual face of the crown is strongly convex and the labial face is flat. There are traces of the lateral cusplets that were originally present and they appear to be missing.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo aduncus (Agassiz, 1835)

Figure 79-1

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.



Figure 79. 1, *Galeocерdo aduncus*, NMNS-PV 28298, Locality 1, lingual (a) and labial (b) views; 2, *Carcharhinus* sp., NMNS-PV 28306, Locality 3, lingual (a) and labial (b) views; 3, *Rhinoptera* sp., NMNS-PV 28313, Locality 4, occlusal (a), basal (b) and lingual (c) views. Scale bar equals 10 mm.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 79-2

Description: The crown is narrowly triangular and almost erect. The upper part of the cutting edge of the crown has finely serrations, while the lower part near the base is rougher. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Rhinopteridae Jordan and Evermann, 1896

Genus *Rhinoptera* Hasselt, 1824

Rhinoptera sp.

Figure 79-3

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The tooth thickness becomes slightly thinner towards one end. The root is comb-shaped with numerous slits.

Additional records: According to Yamaoka (1987) and Nakano (1999), there are reports of Chondrichthyes fossils from the Bihoku Group, but individual specimens have not been differentiated between Itabashi Fm. and Korematsu Fm.. Hence, the report here is omitted.

33. Chichibumachi Formation, Akahira Group

Locality 1: Tadenuma, Onohara, Chichibu City, Saitama Prefecture

Locality 2: Nakaterao, Onohara, Chichibu City, Saitama Prefecture

Formation and Age (Locality 1,2):

Chichibumachi Formation, Middle Miocene. According to Matsumaru *et al.* (1982), the age of the Chichibumachi Formation of the Akahira Group is considered to be Middle Miocene (N.8-N.10) based on the planktonic foraminifera.

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Genus *Hexanchus* Rafinesque, 1810

Hexanchus nakamurai (Teng, 1962)

Figure 80-1,2,3

Description: Fig.80-1 has a single cusp. The crown is elongated and strongly curved distally. Fig.80-2 has three cusps, the first of which is very high and the others very small. Fig.80-3 is multituberculate with the height of the cusps decreasing distally from the first cusp. The crown is thin and rectangular. There are serrations on the mesial cutting edge of the first cusp, which become smaller towards the apex. The root is flat and rectangular.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Squalus* Linnaeus, 1758

Squalus sp.

Figure 80-4

Description: Very small tooth. The crown is triangular and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The labial face of the crown is extended, so that its central part overhangs the root.

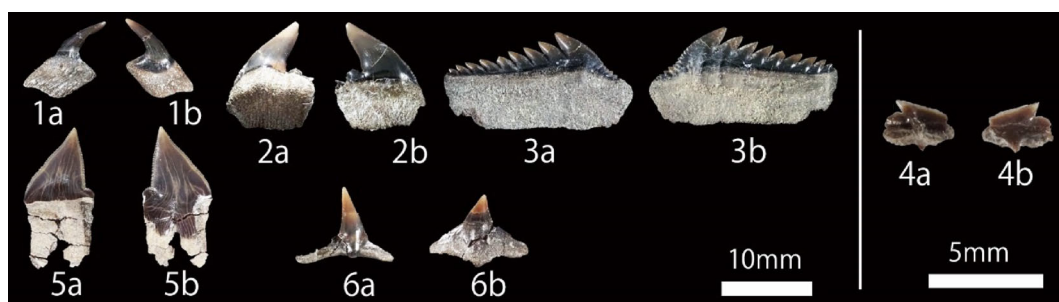


Figure 80. 1, *Hexanchus nakamurai*, NMNS-PV 26916, Locality 1, lingual (a) and labial (b) views; 2, *Hexanchus nakamurai*, NMNS-PV 26917, Locality 1, lingual (a) and labial (b) views; 3, *Hexanchus nakamurai*, NMNS-PV 26919, Locality 1, lingual (a) and labial (b) views; 4, *Squalus* sp., NMNS-PV 26927, Locality 1, lingual (a) and labial (b) views; 5, *Dalatias licha*, NMNS-PV 26928, Locality 2, lingual (a) and labial (b) views; 6, *Squatina* sp., NMNS-PV 26930, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm (1,2,3,5,6), 5 mm (4).

Family Dalatiidae Gray, 1851
Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
Figure 80-5

Description: The crown is almost equilateral triangular in shape and erect or slightly curved distally. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Squatiniformes Buen, 1926
Family Squatinidae Bonaparte, 1838
Genus *Squatina* Dumeril, 1806
Squatina sp.
Figure 80-6

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The cutting edge of the crown has no serrations. The basal part of the crown widens in the mesially-distally, and the basal center of the crown deeply overhangs the root. The root is not bifurcated and is triangular and flat when viewed from the cusp apex.

Order Lamniformes Berg, 1958
Family Odontaspidae Müller and Henle, 1839
Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
Figure 81-1,2,3

Description: The crown is thin and erect. The crown of Fig.81-1 is elongated and Fig.81-2,3 are rather broad. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and the presence of lateral cusplets. There is a striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Remarks: 81-3 is very small, so this is the posterior tooth.

Family Alopiidae Bonaparte, 1838
Genus *Alopias* Rafinesque, 1810
Alopias cf. *A. superciliosus* (Lowe, 1841)
Figure 81-4

Description: The crown is narrowly triangular, long and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid and quite long.

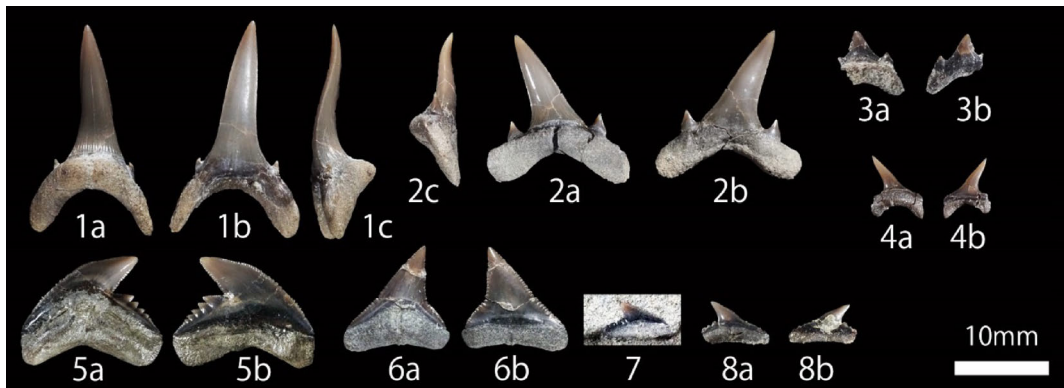


Figure 81. 1, *Carcharias contortidens*, NMNS-PV 26933, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Carcharias contortidens*, NMNS-PV 26934, Locality 1, lingual (a), labial (b) and profile (c) views; 3, *Carcharias contortidens*, NMNS-PV 26939, Locality 1, lingual (a) and labial (b) views; 4, *Alopias* cf. *A. superciliosus*, NMNS-PV 26940, Locality 1, lingual (a) and labial (b) views; 5, *Galeocerdo aduncus*, NMNS-PV 26942, Locality 1, lingual (a) and labial (b) views; 6, *Carcharhinus* cf. *C. altimus*, NMNS-PV 26943, Locality 1, lingual (a) and labial (b) views; 7, *Carcharhinus* cf. *C. sorrah*, NMNS-PV 26946, Locality 1; 8, *Carcharhinus* cf. *C. tjutjot*, NMNS-PV 26947, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo aduncus (Agassiz, 1835)

Figure 81-5

Description: The crown is multicuspid with the mesial first cusp being large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. altimus* (Springer, 1950)

Figure 81-6

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. sorrah*

(Müller and Henle, 1839)

Figure 81-7

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial cutting edge has very rough serrations. The distal cutting edge is straight.

Carcharhinus cf. *C. tjutjot* (Bleeker, 1852)

Figure 81-8

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial cutting edge has very rough serrations. The distal cutting edge is straight. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Dasyatidae Jordan, 1888

Dasyatidae gen. et sp. indet.

Figure 82-1

Description: This is a small tooth. The crown is conical and pointed. The apex of the crown is



Figure 82. 1, *Dasyatidae* gen. et sp. indet., NMNS-PV 26956, Locality 1, lingual (a) and profile (b) views; 2, caudal spine, NMNS-PV 26945 Locality 1. Scale bar equals 10 mm.

tilted posteriorly. The root hangs down from the lower part of the crown of the tooth.

Caudal spine
Figure 82-2

Description: This is elongated and pointed at the tip like a spear. Both sides have fine spiny projections.

Remarks: This is the caudal spine of *Myliobatiformes*.

Additional records: In addition to the species reported here, there are reports of *Carcharodon hastalis* (Reported as *Isurus hastalis* in Uyeno *et al.*, 1983), *Isurus desori*, *Otodus megalodon* (Reported as *Carcharodon megalodon* in Uyeno *et al.*, 1983), *Negaprion* sp. according to Uyeno *et al.* (1983), *Carcharhinus* cf. *C. brachyurus*, *Carcharhinus* cf. *C. leucas*, *Carcharhinus* cf.

C. macloiti, *Carcharhinus* cf. *C. dussumieri*, *Carcharhinus* cf. *C. plumbeus* according to Furukuma (2017).

34. Oido Formation

Locality: Wakuya Town, Toda-Gun, Miyagi Prefecture.

Formation and Age: Oido Formation, Middle Miocene. According to Ishii and Yanagisawa (1984), the age of the Oido Formation is considered to be Middle Miocene based on the planktonic foraminifera and K-Ar age.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
Figure 83-1

Description: The crown is broad and isosceles

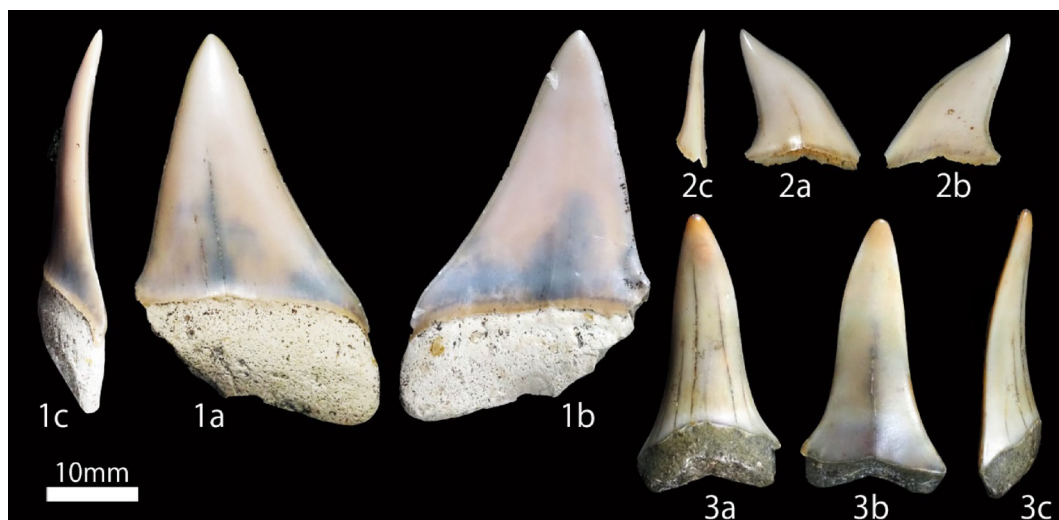


Figure 83. 1, *Carcharodon hastalis*, NMNS-PV 26826, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon planus*, NMNS-PV 26838, lingual (a), labial (b) and profile (c) views; 3, *Isurus desori*, NMNS-PV 26843, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)

Figure 83-2

Description: The crown is broad and characteristically strongly curved distally. The cutting edge has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 83-3

Description: The crown is elongated and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

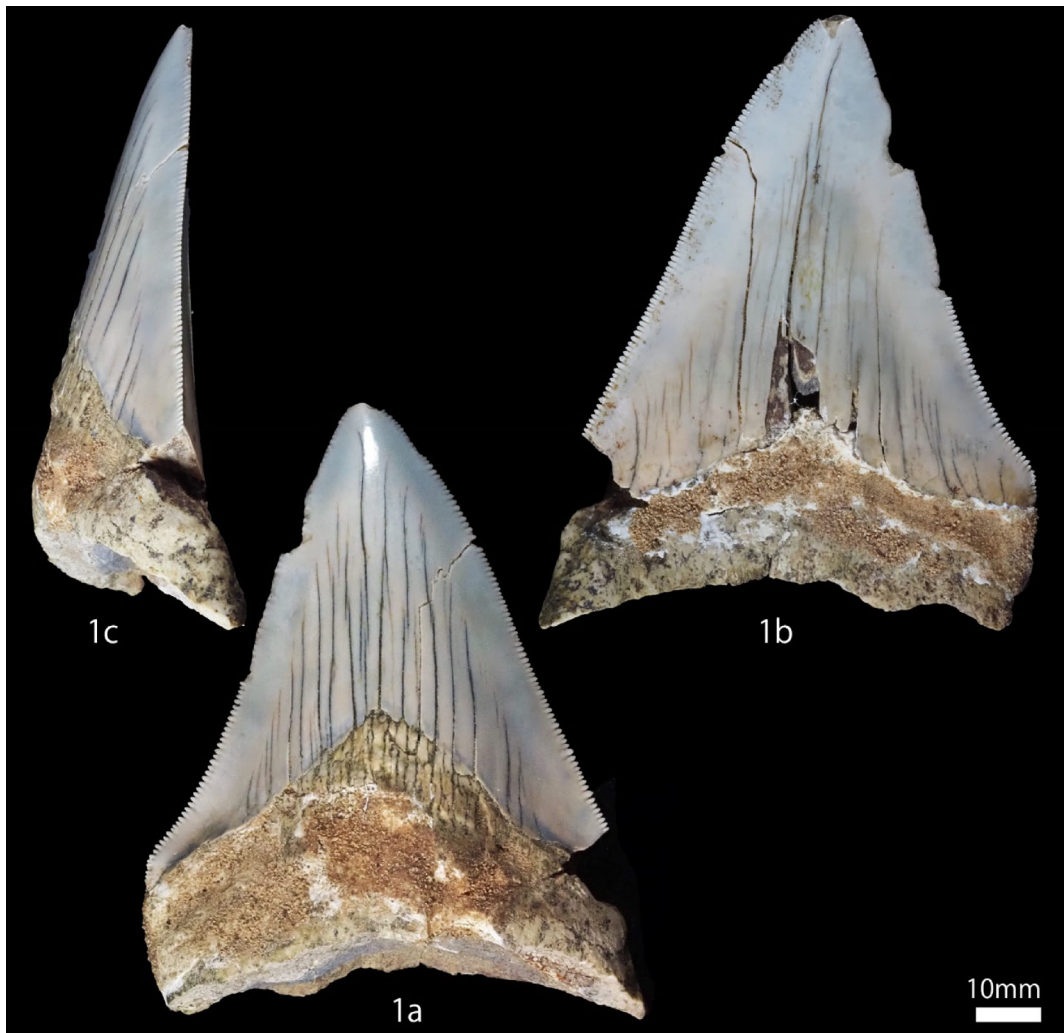


Figure 84. 1, *Otodus megalodon*, NMNS-PV 26844, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.



Figure 85. 1, *Dalatias licha*, NMNS-PV 27647, Locality 2, lingual (a) and labial (b) views; 2, *Squatina* sp., NMNS-PV 27648, Locality 1, lingual (a) and labial (b) views; 3, *Nebrius* sp., NMNS-PV 27649, Locality 1, lingual (a), labial (b) and profile (c) views. Scale bar equals 5 mm.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 84-1

Description: The tooth is very large. The crown is broadly triangular and erect. The cutting edge of the crown has regular, fine serrations. The lingual face of the crown is convex and the labial face is flat.

35. Oidawara Formation, Mizunami Group

Locality 1: Okuna, Toki-cho, Mizunami City, Gifu Prefecture

Locality 2: Sakuradonishi, Toki-cho, Mizunami City, Gifu Prefecture

Locality 3: Nataki, Toki-cho, Mizunami City, Gifu Prefecture

Formation and Age (Locality 1,2,3): Oidawara Formation, Middle Miocene. According to Yanagisawa and Akiba (1998), the age of the Oidawara Formation of the Mizunami Group is considered to be Middle Miocene (16.4 Ma) based on the diatom fossils.

Order Squaliformes Goodrich, 1909

Family Dalatiidae Gray, 1851

Genus *Dalatias* Rafinesque, 1810

Dalatias licha (Bonnaterre, 1788)

Figure 85-1

Description: The crown is nearly equilateral triangular. The cutting edge of the crown has fine serrations, but they are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Squatiniformes Buen, 1926

Family Squatinidae Bonaparte, 1838

Genus *Squatina* Dumeril, 1806

Squatina sp.

Figure 85-2

Description: The crown is thin, conical and erect. The basal part of the crown widens in the mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serrations. The root is not bifurcated and is triangular and flat when viewed from the cusp apex.

Order Orectolobiformes Applegate, 1972

Family Ginglymostomatidae Gill, 1862

Genus *Nebrius* Rüppell, 1837

Nebrius sp.

Figure 85-3

Description: The crown is equilateral triangular with a slightly protruding apex. The cutting edge of the crown has fine serrations. The labial face of the crown slightly overhangs from the center of the root. The labial face of the crown is raised and protrudes from the center of the root.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias contortidens (Agassiz, 1843)

Figure 86-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and the presence of lateral cusplets on the only one side.

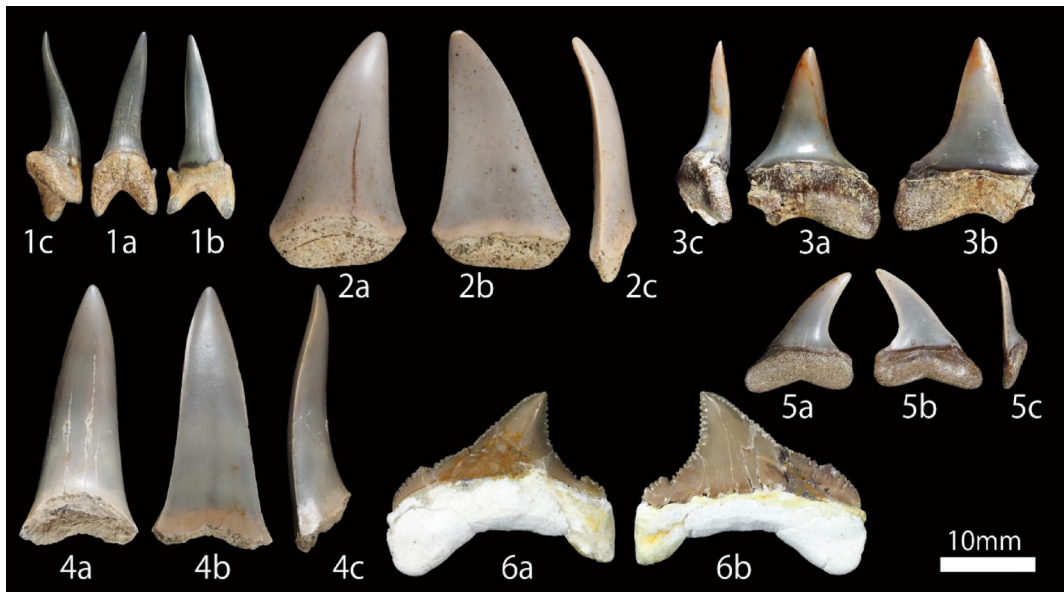


Figure 86. 1, *Carcharias contortidens*, NMNS-PV 27650, Locality 2, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon hastalis*, NMNS-PV 27656, Locality 2, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon hastalis*, NMNS-PV 27657, Locality 2, lingual (a), labial (b) and profile (c) views; 4, *Isurus desori*, NMNS-PV 27659, Locality 2, lingual (a), labial (b) and profile (c) views; 5, *Isurus desori*, NMNS-PV 27660, Locality 2, lingual (a), labial (b) and profile (c) views; 6, *Otodus chubutensis*, NMNS-PV 27664, Locality 2, lingual (a) and labial (b) views. Scale bar equals 10 mm.

There is a striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)

Figure 86-2,3

Description: The crown is broad and isosceles triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
Figure 86-4,5

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown

is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964
Genus *Otodus* Agassiz, 1838
Otodus chubutensis (Ameghino, 1901)
Figure 86-6

Description: The crown is broadly triangular and curved distally. The cutting edge of the crown regular, fine serrations. In addition to the main cusp, the crown has a weak lateral cusplets. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniiformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo aduncus (Agassiz, 1835)
Figure 87-1

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The

distal cusps are almost lost, but the small one cusp remains. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. albimarginatus*
(Rüppell, 1837)

Figure 87-2

Description: The crown is narrowly triangular and almost erect. The upper part of the cutting edge of the crown has finely serrations, while the lower part near the base is rougher. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. altimus* (Springer, 1950)

Figure 87-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. brachyurus* (Günther, 1870)

Figure 87-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. limbatus* (Valenciennes, 1839)

Figure 87-5

Description: The crown is thin and almost erect. The cutting edge of the crown has very fine serrations with slightly rougher serrations at the base. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. macloiti*

(Müller and Henle, 1839)

Figure 87-6

Description: The crown is thin and erect. The cutting edge of the crown has no serrations, but there are rough serrations at the base of the crown. The lingual face of the crown is convex and the labial face is flat.



Figure 87. 1, *Galeocerdo aduncus*, NMNS-PV 27667, Locality 1, lingual (a) and labial (b) views; 2, *Carcharhinus* cf. *C. albimarginatus*, NMNS-PV 27668, Locality 1, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. altimus*, NMNS-PV 27670, Locality 3, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27671, Locality 1, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. limbatus*, NMNS-PV 27672, Locality 1, lingual (a) and labial (b) views; 6, *Carcharhinus* cf. *C. macloiti*, NMNS-PV 27675, Locality 1, lingual (a) and labial (b) views; 7, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 27676, Locality 1, lingual (a) and labial (b) views; 8, *Sphyrna* sp., NMNS-PV 27752, Locality 1, lingual (a) and labial (b) views; 9, *Dasyatidae* gen. et sp. indet., NMNS-PV 27755, Locality 1. Scale bar equals 10 mm (1-8) and 2 mm (9).

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)

Figure 87-7

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Family Sphyrnidae Gill, 1872

Genus *Sphyrna* Rafinesque, 1810

Sphyrna sp.

Figure 87-8

Description: The crown is triangular and concave near the apex. The cutting edge of the crown has no serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Dasyatidae Jordan, 1888

Dasyatidae gen. et sp. indet.

Figure 87-9

Description: This is a small tooth with a rhombic crown, the occlusal surface of the crown is slightly raised towards the center and has a shadow-like shape. The root hangs down from the lower part of the crown of the tooth.

Additional records: In addition to the species reported here, there are reports of *Chlamydoselachus* sp., *Hexanchus* sp., *Heptranchias* ? sp., *Squalus* sp., *Galeus* ? sp., *Odontaspis* cf. *C. volax*, *Araloselachus cuspidatus* (Reported as *Odontaspis cuspidata* in Itoigawa *et al.*, 1985), *Alopias* cf. *exigua*, *Cetorhinus* sp., *Otodus megalodon* (Reported as *Carcharodon megalodon* in Itoigawa *et al.*,

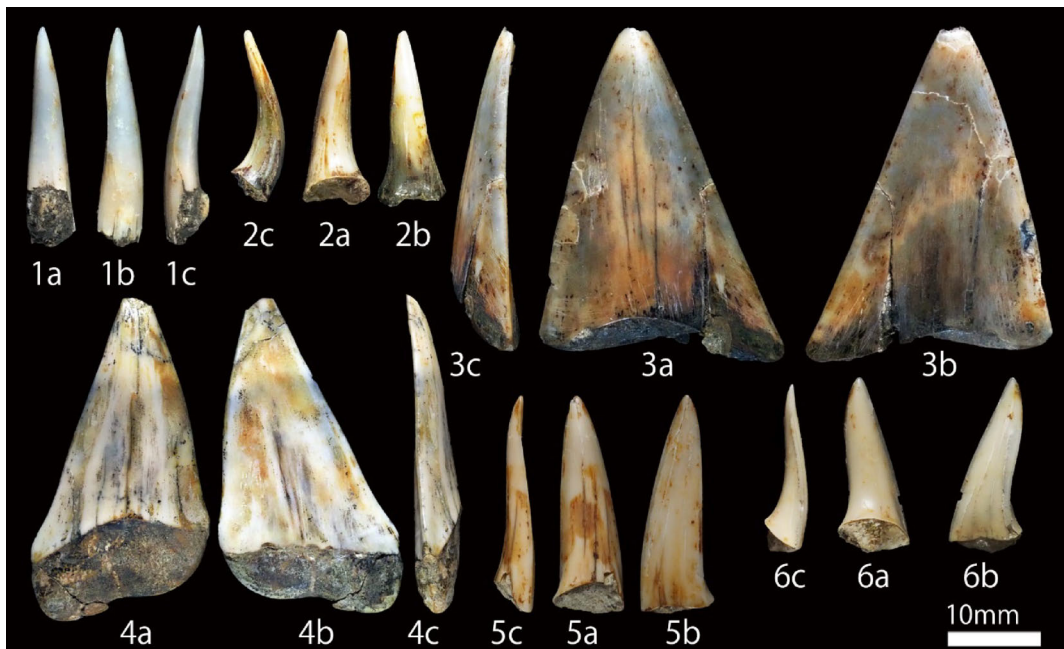


Figure 88. 1, *Odontaspidae* gen. et sp. indet., NMNS-PV 29211, lingual (a), labial (b) and profile (c) views; 2, *Odontaspidae* gen. et sp. indet., NMNS-PV 29214, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon hastalis*, NMNS-PV 29221, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 29222, lingual (a), labial (b) and profile (c) views; 5, *Isurus desori*, NMNS-PV 29229, lingual (a), labial (b) and profile (c) views; 6, *Isurus desori*, NMNS-PV 29230, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

1985), *Hemipristis serra*, Dasyatidae gen. et sp. indet. (Reported as “*Dasyatis*” *nipponensis*, *Dasyatis* sp. in Itoigawa *et al.*, 1985), *Rhinoptera* sp., *Mobula* ? sp., *Aetobatis* sp. according to Itoigawa *et al.* (1985).

36. Sakurada Formation, Yugashima Group

Locality: Ikeshiro, Matsuzaki Town, Kamo-Gun, Shizuoka Prefecture

Formation and Age: Sakurada Formation, Middle Miocene. According to Okada (1987) and Ibaraki (1981), the age of the Sakurada Formation of the Yugashima Group is considered to be Middle Miocene based on the calcareous nannofossil and the planktonic foraminifera.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Odontaspidae gen. et sp. indet.

Figure 88-1,2

Description: The crown is elongated and long. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is weakly convex.

Remarks: The crown is worn, most of the root is missing and the presence or absence of striations on the lingual face of the crown and the presence or absence of secondary cusps are unknown. Therefore, genus and species of this specimen within the Odontaspidae is uncertain and undeterminable.

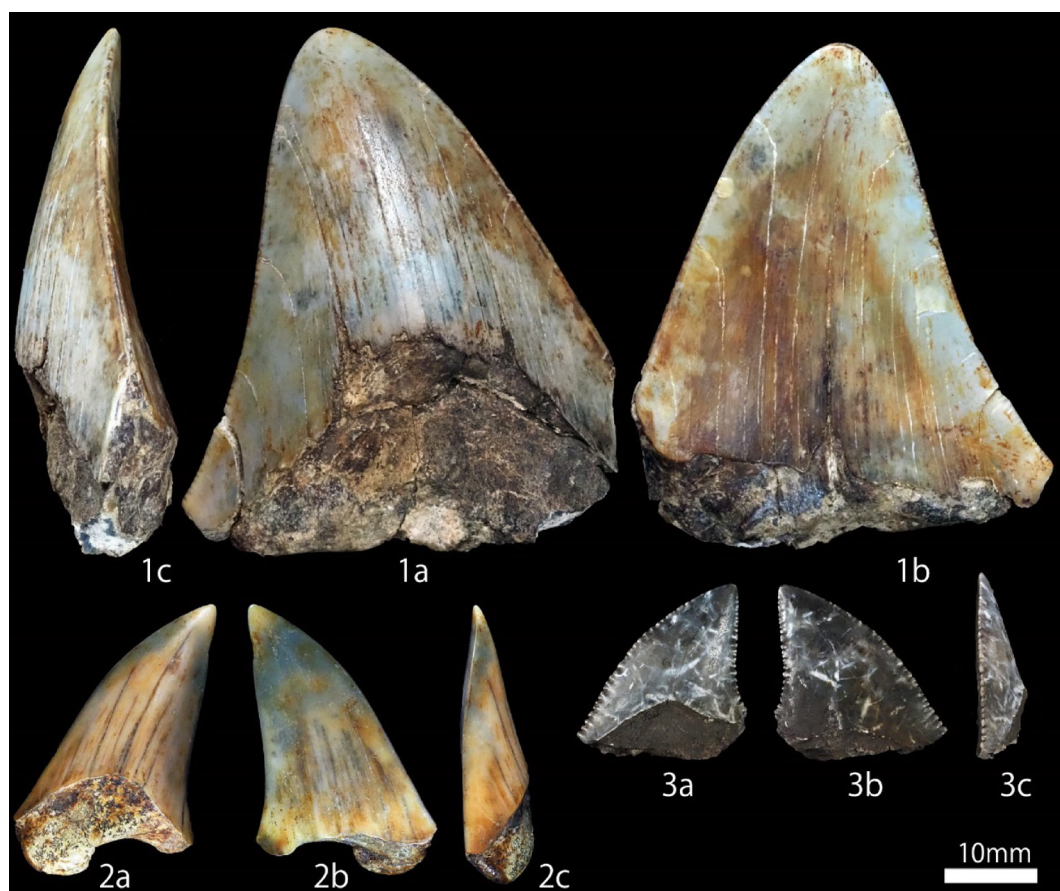


Figure 89. 1, *Otodus megalodon*, NMNS-PV 32543, lingual (a), labial (b) and profile (c) views; 2, *Parotodus benedeni*, NMNS-PV 29268, lingual (a), labial (b) and profile (c) views; 3, *Trigonotodus palatasi*, NMNS-PV 29269, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 88-3,4

Description: The crown is broad and isosceles triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
 Figure 88-5,6

Description: The crown is elongate and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 89-1

Description: The crown is broadly triangular and erect. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Parotodus* Cappetta, 1980
Parotodus benedeni (Le Hon, 1871)
 Figure 89-2

Description: The crown is very thick and curved strongly distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Family indet.
 Genus *Trigonotodus* Kozlov in
 Zheiezko and Kozolov, 1999
Trigonotodus palatasi (Kent and Ward, 2018)
 Figure 89-3

Description: The crown is broadly triangular and strongly curved distally. The cutting edge of

the crown has no serrations. The serrations are rougher than in *Otodus megalodon*. The lingual face of the crown is convex and the labial face is flat.

Remarks: Kent and Ward (2018) reported it as a new mmm species *Alopias palatasi* in the genus *Alopias*.

In fact, the tooth morphology is similar to a larger version of *Alopias*. However, the teeth are too large to be placed in the genus *Alopias*, so we have adopted the genus *Trigonotodus*.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus cf. *C. falciformis*
 (Bibron in Müller and Henle, 1839)
 Figure 90-1

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has a deep median notch, finely serrated above and roughened below.

Carcharhinus cf. *C. obscurus* (Lesueur, 1818)
 Figure 90-2

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and curves gently outwards. The lingual face of the crown is convex and the labial face is flat.



Figure 90. 1, *Carcharhinus* cf. *C. falciformis*, NMNS-PV 29270; 2, *Carcharhinus* cf. *C. obscurus*, NMNS-PV 29271, lingual (a) and labial (b) views. Scale bar equals 10 mm.

37. Godo Formation, Tokigawa Group

Locality: Kuzubukuro, Higashimatsuyama City, Saitama Prefecture

Formation and Age: Godo Formation, Middle Miocene. According to Kurihara *et al.* (2003), the age of the Godo Formation of the Tokigawa Group is considered to be Middle Miocene (15.4–15.1 Ma) based on the planktonic foraminifera.

Order Squaliformes Goodrich, 1909
Family Centrophoridae Bleeker, 1859
Genus *Deania* Jordan and Snyder, 1902
Deania sp.
Figure 91-1

Description: The crown is strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is slightly convex and the labial face is flat. The root is round.

Family Dalatiidae Gray, 1851
Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
Figure 91-2

Description: The crown is almost equilateral triangular in shape. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.



Figure 91. 1, *Deania* sp., NMNS-PV 26969, lingual (a) and labial (b) views; 2, *Dalatias licha*, NMNS-PV 26970, lingual (a) and labial (b) views; 3, *Pristiophorus* cf. *P. japonicus*, NMNS-PV 26972, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 5 mm.

Order Pristiophoriformes Berg, 1958
Family Pristiophoridae Bleeker, 1859
Genus *Pristiophorus* Müller and Henle, 1837
Pristiophorus cf. *P. japonicus* Günther, 1870
Figure 91-3

Description: The crown is knife-shaped, long and thin.

Remarks: This is the rostral tooth of the rostrum.

Order Lamniformes Berg, 1958
Family Mitsukurinidae Jordan, 1898
Genus *Mitsukurina* Jordan, 1898
Mitsukurina lineata (Probst, 1879)
Figure 92-1

Description: The crown is narrow, straight and long of consistent width. The crown is worn but there is a distinct striation on the lingual face of the crown. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is weakly convex.

Family Odontaspidae Müller and Henle, 1839
Odontaspidae gen. et sp. indet.
Figure 92-2,3,4

Description: The crown is elongated and long. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is weakly convex.

Remarks: The crown is worn, most of the root is missing and the presence or absence of striations on the lingual face of the crown and the presence or absence of secondary cusps are unknown. Therefore, genus and species of this specimen is undeterminable.

Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
Figure 92-5,6

Description: The crown is broad and isosceles triangular. The cutting edge of the crown have no

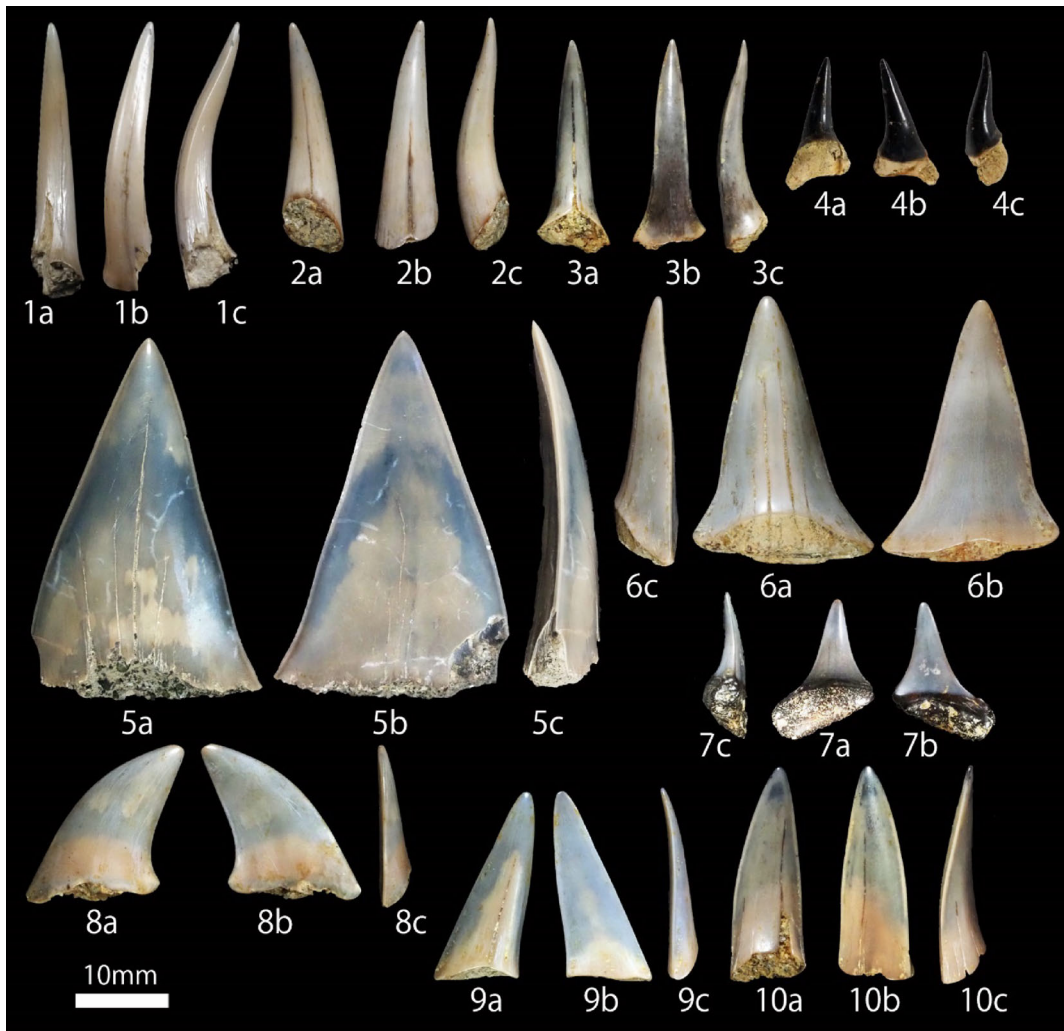


Figure 92. 1, *Mitsukurina lineata*, NMNS-PV 26974, lingual (a), labial (b) and profile (c) views; 2, *Odontaspidae* gen. et sp. indet., NMNS-PV 26975, lingual (a), labial (b) and profile (c) views; 3, *Odontaspidae* gen. et sp. indet., NMNS-PV 26976, lingual (a), labial (b) and profile (c) views; 4, *Odontaspidae* gen. et sp. indet., NMNS-PV 26977, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon hastalis*, NMNS-PV 27129, lingual (a), labial (b) and profile (c) views; 6, *Carcharodon hastalis*, NMNS-PV 27132, lingual (a), labial (b) and profile (c) views; 7, *Carcharodon planus*, NMNS-PV 27161, lingual (a), labial (b) and profile (c) views; 8, *Carcharodon planus*, NMNS-PV 27155, lingual (a), labial (b) and profile (c) views; 9, *Isurus desori*, NMNS-PV 27162, lingual (a), labial (b) and profile (c) views; 10, *Isurus desori*, NMNS-PV 27163, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)

Figure 92-7,8

thin and elect, but thickens at the base. The crown of Fig.92-8 is broad and characteristically curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Description: The crown of Fig.92-7 is slightly

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 92-9,10

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 93-1,2

Description: Fig.93-1 is very large. The crown is broadly triangular and erect. The crown of Fig.93-2 is broadly triangular and curved distally. The cutting edge of the crown has regular fine

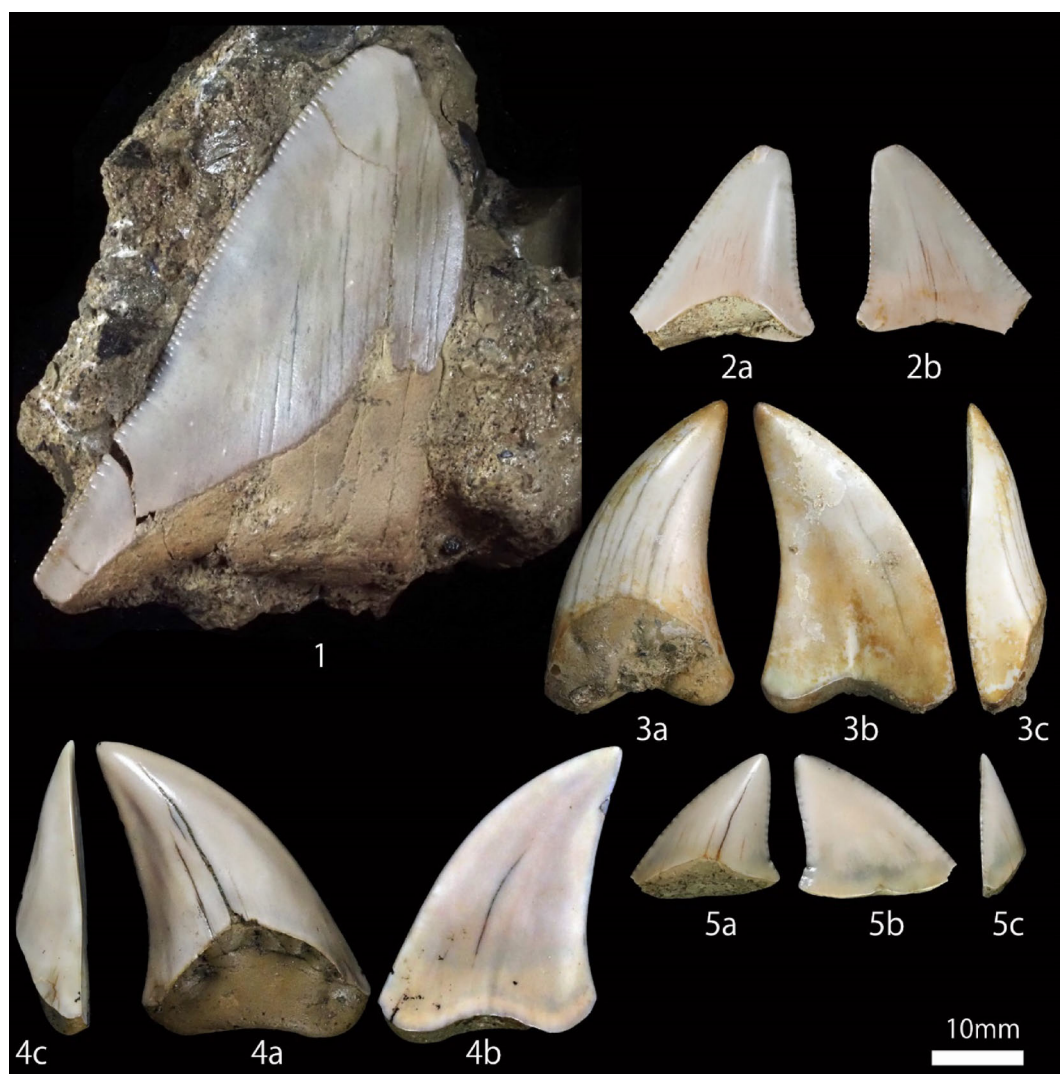


Figure 93. 1, *Otodus megalodon*, NMNS-PV 27200; 2, *Otodus megalodon*, NMNS-PV 27203, lingual (a) and labial (b) views; 3, *Parotodus benedeni*, NMNS-PV 32539, lingual (a), labial (b) and profile (c) views; 4, *Parotodus benedeni*, NMNS-PV 27205, lingual (a), labial (b) and profile (c) views; 5, *Trigonotodus palatasi*, NMNS-PV 27213, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

serrations. The lingual face of the crown is convex and the labial face is flattened.

Remarks: Fig.93-2 is rather small and considered to be a juvenile or lateral tooth.

Genus *Parotodus* Cappetta, 1980
Parotodus benedeni (Le Hon, 1871)
 Figure 93-3,4

Description: The crown is very thick and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Family indet.
 Genus *Trigonotodus* Kozlov in Zheiezko and Kozolov, 1999
Trigonotodus palatasi (Kent and Ward, 2018)
 Figure 93-5

Description: The crown is broadly triangular and strongly curved distally. The cutting edge of the crown has serrations. The serrations are rougher than in *Otodus megalodon*. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus sp.
 Figure 94-1

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Vertebra
 Figure 94-2

Description: This has a mill-shape with a concave center.

Remarks: This is the shark vertebra, but family, genus, etc. are unknown.

Additional records: In addition to the species

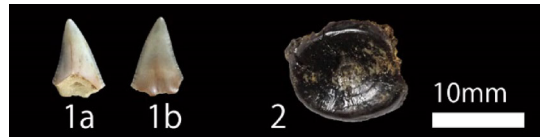


Figure 94. 1, *Carcharhinus* sp., NMNS-PV 27214, lingual (a) and labial (b) views; 2, vertebra, NMNS-PV 27230. Scale bar equals 10 mm.

reported here, there are reports of *Chlamydoselachus* sp., *Centrophorus* sp., *Squalus* sp. according to Harada (2015).

38. Moniwa Formation, Natori Group

Locality 1: Moniwa, Taihakuku, Sendai City, Miyagi Prefecture

Locality 2: Goishi, Kawasakicho, Shibata-Gun, Miyagi Prefecture

Locality 3: Kanagase, Okawaracho, Shibata-Gun, Miyagi Prefecture

Locality 4: Kumanosu, Natori City and Shibata-Gun, Miyagi Prefecture

Formation and Age (Locality 1,2,3,4): Moniwa Formation, Early-Middle Miocene. According to Fujiwara *et al.* (2013), the age of the Moniwa Formation of the Natori Group is considered to be Early-Middle Miocene based on the planktonic foraminifera.

Order Lamniformes Berg, 1958
 Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 95-1

Description: The crown is broad and equilateral triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)
 Figure 95-2

Description: The crown is not very high, slender, erect and almost an isosceles triangle. The

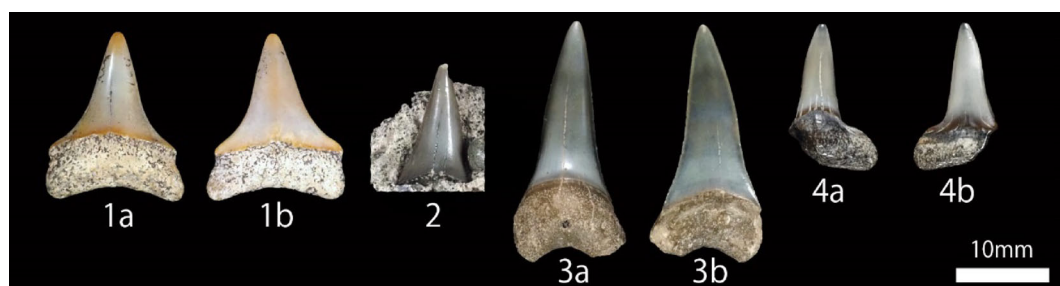


Figure 95. 1, *Carcharodon hastalis*, NMNS-PV 26846, Locality 2, lingual (a) and labial (b) views; 2, *Carcharodon planus*, NMNS-PV 26847, Locality 1; 3, *Isurus desori*, NMNS-PV 26848, Locality 4, lingual (a) and labial (b) views; 4, *Carchrhinus* sp., NMNS-PV 26849, Locality 3, lingual (a) and labial (b) views. Scale bar equals 10 mm.

base of the crown is thick and the crown is slightly thin. The crown is almost thin overall, but thickens at the base. The cutting edge of the crown has no serrations.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 95-3

Description: The crown is elongated and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 95-4

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Araloselachus cuspidatus* or *Carcharias contortidens* (Reported as *Carcharias obliqua* in Hatai *et al.*, 1974), *Carcharodon carcharias*, *Otodus megalodon* (Reported as *Carcharodon megalodon* in Hatai *et al.*, 1974), *Parotodus benedeni* (Reported as

Isurus moniwaensis in Hatai *et al.*, 1974) according to Hatai *et al.* (1974).

39. Nanao Formation

Locality 1: Osugizaki, Nanao City, Ishikawa Prefecture

Locality 2: Iwaya, Nanao City, Ishikawa Prefecture

Formation and Age (Locality 1,2): Nanao Formation, Middle Miocene. According to Kami *et al.* (1981), the age of the Nanao Formation is considered to be Middle Miocene based on calcareous nannofossil.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Megasqualus* Herman, 1982

Megasqualus occidentalis (Agassiz, 1856)

Figure 96-1

Description: Similar to the tooth of the modern *Squalus*, but more than twice the size of the modern species. The crown is triangular with a strong distal slope. The cutting edge of the crown has finely serrations. The lingual face of the crown is inflated and the labial face is flat. The labial face of the crown is extended so that its central part overhangs the root.



Figure 96. 1, *Megasqualus occidentalis*, NMNS-PV 27293, Locality 1, lingual (a) and labial (b) views; 2, *Squatina* sp., NMNS-PV 27295, Locality 1, lingual (a) and labial (b) views. Scale bar equals 5 mm.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 96-2

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The lingual face of the crown is strongly convex, as is the labial face. The basal part of the crown widens in the mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serrations. The root is not bifurcated and is triangular and flat when viewed from the cusp apex.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
 Figure 97-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is a striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Genus *Araloselachus* Glikman, 1964
Araloselachus cuspidatus (Agassiz, 1843)
 Figure 97-2,3

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The

lingual face of the crown is convex and the labial face is slightly convex. Fig.97-3 shows one side of the lateral cusplet, which is elongated and needle-shaped.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 97-4,5

Description: The crown is broad and equilaterally triangular. The crown of Fig.97-4 is erect, another of Fig.97-5 is slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)
 Figure 97-6,7,8

Description: The crowns of Fig.97-6,7 are broad and characteristically curved distally. The crown curve of Fig.97-7 is a very strong. The crown of Fig.97-8 is thin, straight and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
 Figure 97-9

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

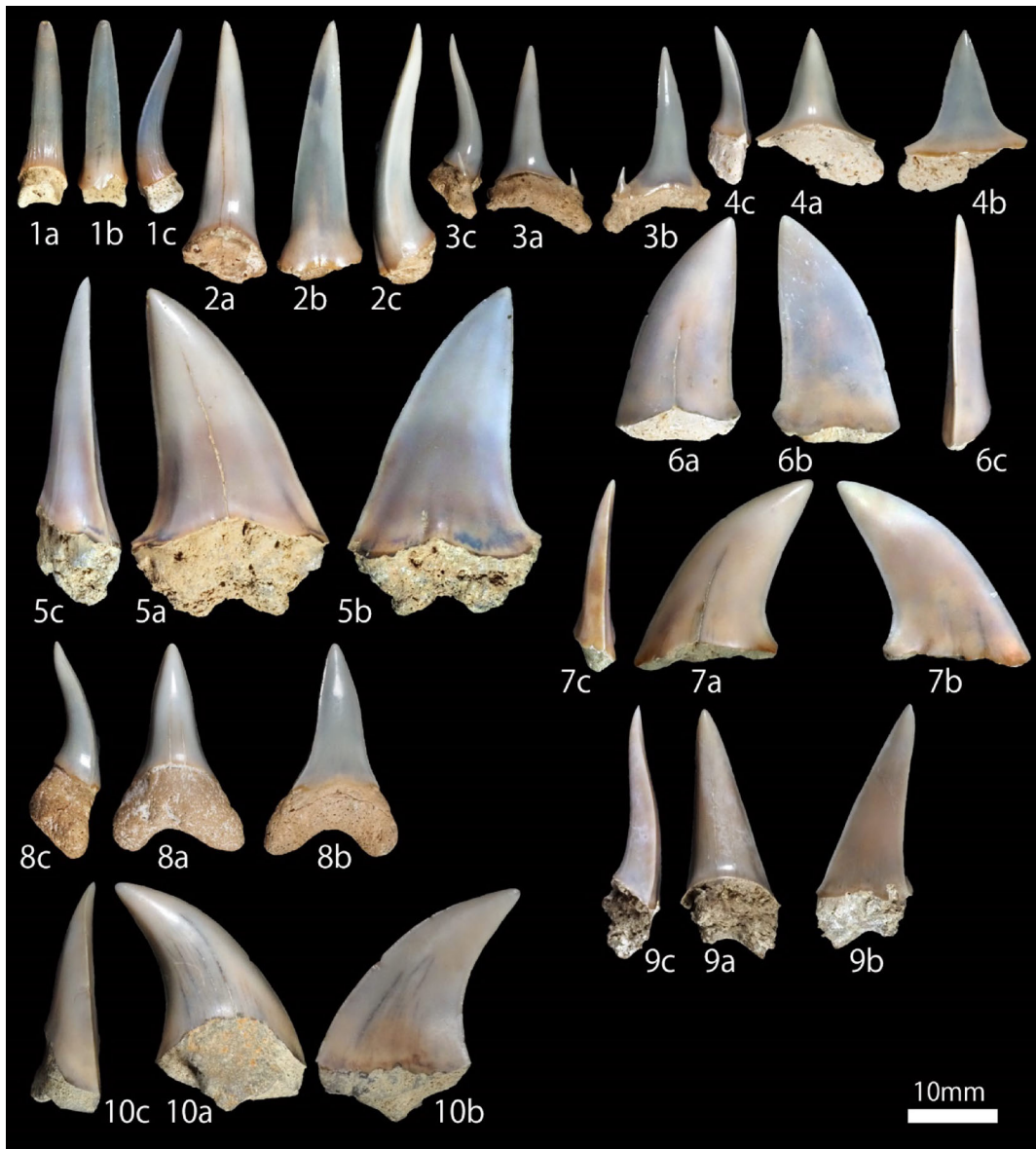


Figure 97. 1, *Carcharias contortidens*, NMNS-PV 27296, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Araloselachus cuspidatus*, NMNS-PV 27299, Locality 1, lingual (a), labial (b) and profile (c) views; 3, *Araloselachus cuspidatus*, NMNS-PV 27300, Locality 1, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 27306, Locality 1, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon hastalis*, NMNS-PV 27315, Locality 1, lingual (a), labial (b) and profile (c) views; 6, *Carcharodon planus*, NMNS-PV 27321, Locality 1, lingual (a), labial (b) and profile (c) views; 7, *Carcharodon planus*, NMNS-PV 27322, Locality 1, lingual (a), labial (b) and profile (c) views; 8, *Carcharodon planus*, NMNS-PV 27376, Locality 1, lingual (a), labial (b) and profile (c) views; 9, *Isurus desori*, NMNS-PV 27386, Locality 1, lingual (a), labial (b) and profile (c) views; 10, *Parotodus benedeni*, NMNS-PV 27399, Locality 1, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Family Otodontidae Glickman, 1964

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 97-10

Description: The crown is very thick and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniiformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo aduncus (Agassiz, 1835)

Figure 98-1

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. amboinensis*

(Müller and Henle, 1839)

Figure 98-2

Description: The crown is nearly equilateral triangular with little distal curvature. The cutting edge of the crown has rough serrations, the upper part of the crown being finely serrated and the lower part becoming slightly rougher than the middle. The central part of the distal cutting edge

is slightly convex. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. brachyurus* (Günther, 1870)

Figure 98-3

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. falciformis*

(Bibron in Müller and Henle, 1839)

Figure 98-4

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has a deep central notch, which is finely serrated above and roughened below. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)

Figure 98-5

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown curves outwards. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Chimaera* sp. according to Nomura (2000). *Hexanchus gigas*, *Dalatias licha*, *Carcharodon carcharias*, *Carcharhinus* cf. *C. macroti* (Reported as

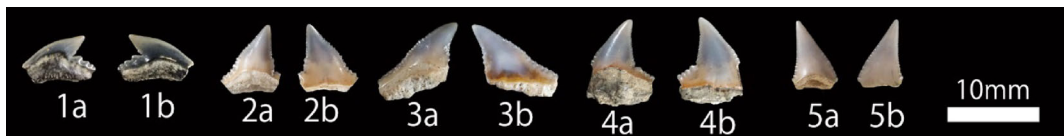


Figure 98. 1, *Galeocerdo aduncus*, NMNS-PV 27400, Locality 1, lingual (a) and labial (b) views; 2, *Carcharhinus* cf. *C. amboinensis*, NMNS-PV 27401, Locality 1, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27403, Locality 1, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. falciformis*, NMNS-PV 27404, Locality 1, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 27439, Locality 2, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Negaprion sp. in Nomura, 2002), Dasyatidae gen. et sp. indet. (Reported as *Dasyatis* sp. in Nomura, 2002) according to Nomura (2002). *Myliobatis* sp., *Rhinoptera* sp. according to Nomura (2005). *Sphyrna* sp. according to Nomura and Tazaki (2007). *Heptanchias* sp. according to Sano (2022).

40. Sekinohana Formation

Locality: Sekinohana, Shiga Town, Hakui-Gun, Ishikawa Prefecture

Formation and Age: Sekinohana Formation, Middle Miocene. According to Kami *et al.* (1981), the age of the Sekinohana Formation is considered to be Middle Miocene based on calcareous nannofossil.

Order Hexanchiformes Buen, 1926
Family Hexanchidae Gray, 1851
Genus *Hexanchus* Rafinesque, 1810
Hexanchus sp.
Figure 99-1

Description: The number of cusps is 3. The first cusp is high and the 2,3 cusps are very low. The lingual face of the crown is slightly convex and the labial face is flat. The root is flat and rectangular.

Order Squaliformes Goodrich, 1909
Family Dalatiidae Gray, 1851
Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
Figure 99-2

Description: The crown is nearly equilateral

triangular. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Squatiniformes Buen, 1926
Family Squatinidae Bonaparte, 1838
Genus *Squatina* Dumeril, 1806
Squatina sp.
Figure 99-3

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The basal part of the crown widens in the mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serrations. The root is not bifurcated and is triangular and flat when viewed from the cusp apex.

Order Lamniformes Berg, 1958
Family Odontaspidae Müller and Henle, 1839
Genus *Carcharias* Rafinesque, 1810
Carcharias contortidens (Agassiz, 1843)
Figure 100-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is a striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.



Figure 99. 1, *Hexanchus* sp., NMNS-PV 27443, lingual (a) and labial (b) views; 2, *Dalatias licha*, NMNS-PV 27444, lingual (a) and labial (b) views; 3, *Squatina* sp., NMNS-PV 27445, lingual (a) and labial (b) views. Scale bar equals 5 mm.

Genus *Araloselachus* Glikman, 1964
Araloselachus cuspidatus (Agassiz, 1843)

Figure 100-2,3

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. Fig.100-2 is a retention

of one side of the lateral cusplet.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)

Figure 100-4

Description: The crown is broad, equilateral triangular and slightly curved distally. The cutting edge of the crown has no serrations. The lingual

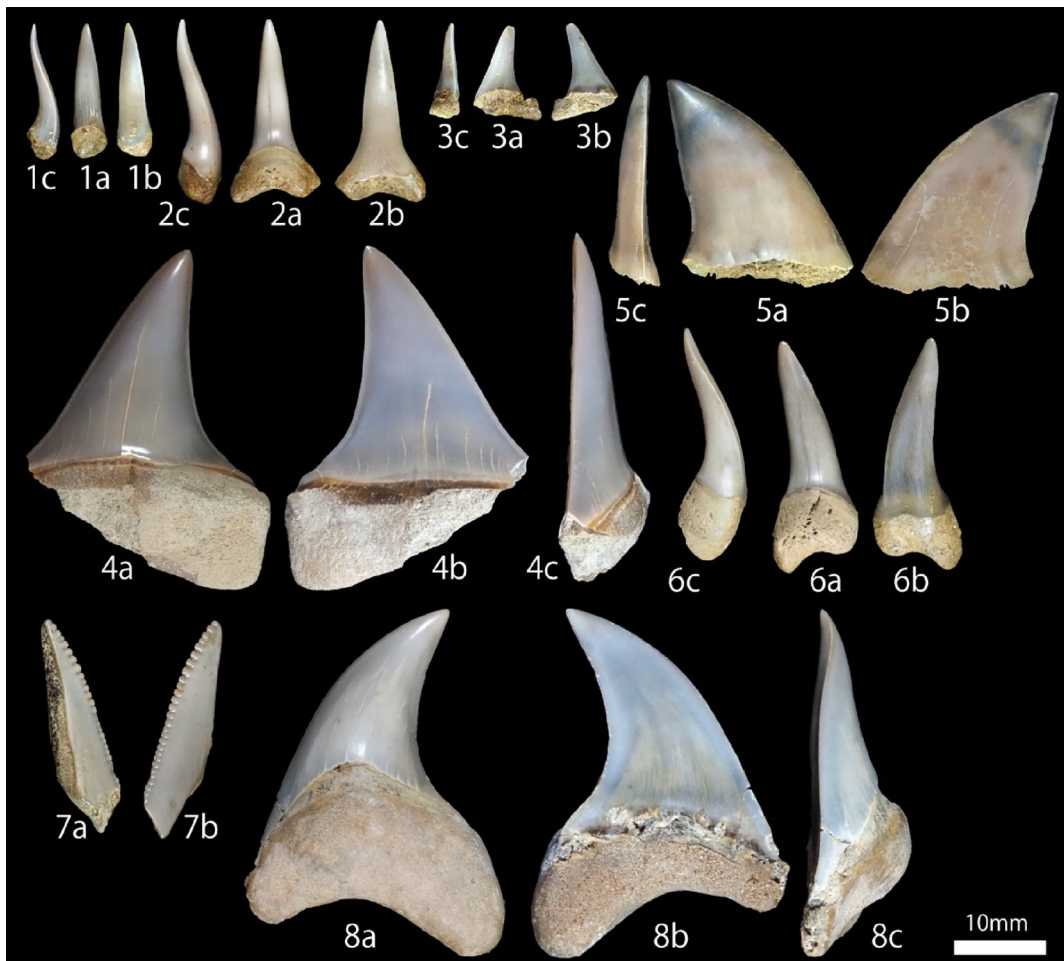


Figure 100. 1, *Carcharias contortidens*, NMNS-PV 27446, lingual (a), labial (b) and profile (c) views; 2, *Araloselachus cuspidatus*, NMNS-PV 27452, lingual (a), labial (b) and profile (c) views; 3, *Araloselachus cuspidatus*, NMNS-PV 27453, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 27461, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon planus*, NMNS-PV 27471, lingual (a), labial (b) and profile (c) views; 6, *Isurus desori*, NMNS-PV 27477, lingual (a), labial (b) and profile (c) views; 7, *Otodus megalodon*, NMNS-PV 27486, lingual (a) and labial (b) views; 8, *Parotodus benedeni*, NMNS-PV 27488, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)

Figure 100-5

Description: The crown is broad and characteristically curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 100-6

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Genus *Lamna* Cuvier, 1816

Lamna sp.

Figure 101-2

Description: The crown is triangular and almost erect. The cutting edge of the crown has no serrations. In addition to the main cusp, there is a pair of triangular lateral cusplets. The lingual face of the crown is convex and the labial face is flat.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 100-7

Description: Although only a part of the crown remains in the specimen, it is identifiable as this

species by the characteristic regular and fine serrations on the cutting edge of the crown.

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 100-8

Description: The crown is very thick and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Family Alopiidae Bonaparte, 1838

Genus *Alopias* Rafinesque, 1810

Alopias cf. *A. superciliosus* (Lowe, 1841)

Figure 101-1

Description: The crown is narrowly triangular, long and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassiz, 1843

Hemipristis serra Agassiz, 1843

Figure 102-1

Description: The crown is triangular and curved distally. The cutting edge of the crown has rough serrations, unlike in the genus *Carcharhinus*, but the serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

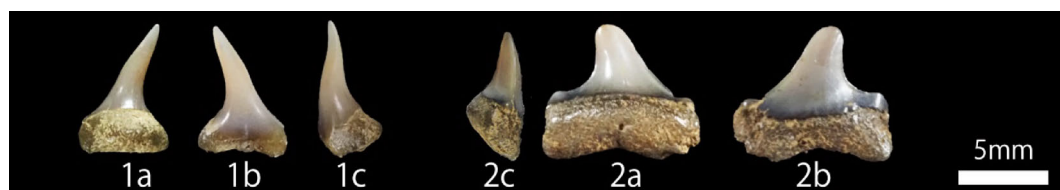


Figure 101. 1, *Alopias* cf. *A. superciliosus*, NMNS-PV 27490, lingual (a), labial (b) and profile (c) views; 2, *Lamna* sp., NMNS-PV 27485, lingual (a), labial (b) and profile (c) views. Scale bar equals 5 mm.

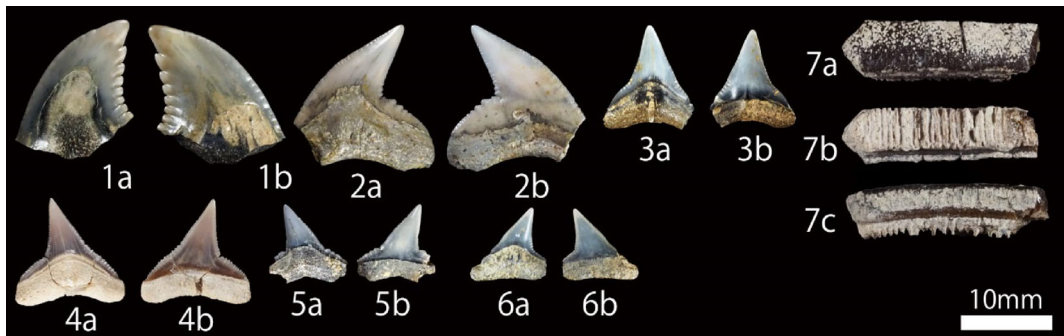


Figure 102. 1, *Hemipristis serra*, NMNS-PV 27491, lingual (a) and labial (b) views; 2, *Galeocerdo aduncus*, NMNS-PV 27492, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. altimus*, NMNS-PV 27493, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27494, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. macloiti*, NMNS-PV 27496, lingual (a) and labial (b) views; 6, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 27497, lingual (a) and labial (b) views; 7, *Myliobatis* sp., NMNS-PV 27530, occlusal (a), basal (b) and lingual (c) views. Scale bar equals 10 mm.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo aduncus (Agassiz, 1835)

Figure 102-2

Description: The crown is multicuspoid with the mesial first cusp large and curved distally. The distal cusps following the first cusp are smaller. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. altimus* (Springer, 1950)

Figure 102-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. brachyurus* (Günther, 1870)

Figure 102-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine

serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. macloiti*

(Müller and Henle, 1839)

Figure 102-5

Description: The crown is thin and erect. The cutting edge of the crown has no serrations, but there are rough serrations at the base of the crown. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)

Figure 102-6

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown curves outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Myliobatidae Bonaparte, 1838

Genus *Myliobatis* Cuvier, 1816

Myliobatis sp.

Figure 102-7

Description: This tooth has an elongated

hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Additional records: In addition to the species reported here, there are reports of *Pristiophorus* sp., *Odontaspis volax*, *Rhinoptera* sp. according to Karasawa (1989).

41. Wajimazaki Formation

Locality: Wajimasakicho, Wajima City, Ishikawa Prefecture

Formation and Age: Wajimazaki Formation, Middle Miocene. According to Kami *et al.* (1981), the age of the Wajimazaki Formation is considered to be Middle Miocene based on calcareous nannofossil.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)

Figure 103-1

Description: The crown is broad, equilateral triangular and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)

Figure 103-2

Description: The crown is broad and characteristically curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

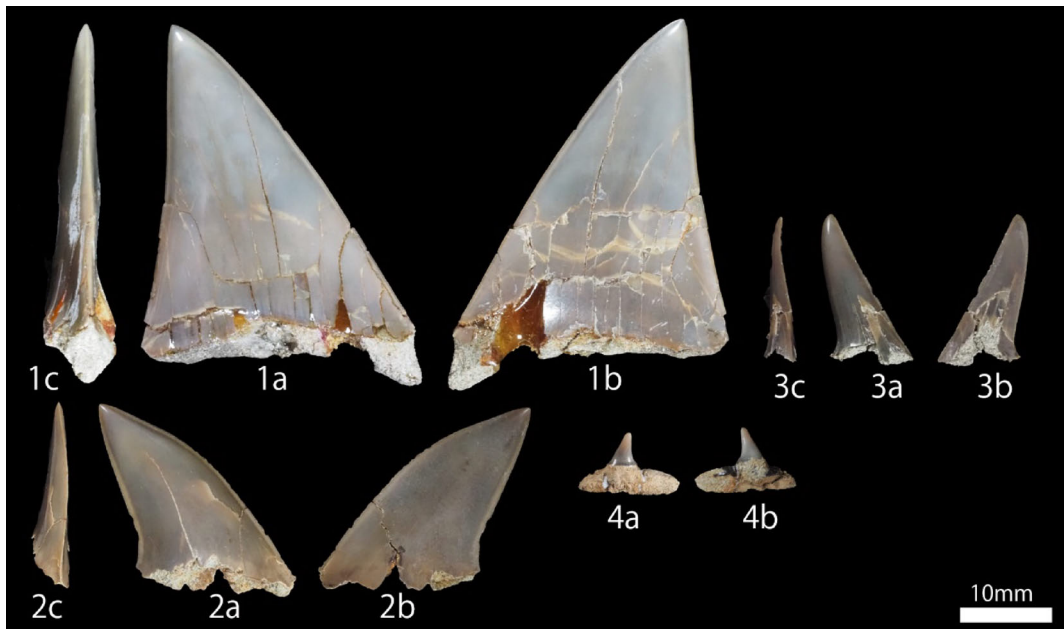


Figure 103. 1, *Carcharodon hastalis*, NMNS-PV 27538, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon planus*, NMNS-PV 27541, lingual (a), labial (b) and profile (c) views; 3, *Isurus desori*, NMNS-PV 27544, lingual (a), labial (b) and profile (c) views; 4, *Carcharhinus* sp., NMNS-PV 27546, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 103-3

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniiformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 103-4

Description: The crown is thin and erect. The cutting edge of the crown has fine serrations, although these are too worn to be visible. The lingual face of the crown is strongly convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Parotodus benedeni*, Rajidae gen. et sp. indet. according to Karasawa (1989).

42. Oya Formation, Utsunomiya Group

Locality: Shimodawaracho, Utsunomiya City, Tochigi Prefecture.

Formation and Age: Oya Formation, Middle Miocene. According to Hayashi *et al.* (2004), the age of the Oya Formation of the Utsunomiya Group is considered to be Middle Miocene (13 Ma) based on the planktonic foraminifera.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Odontaspis* Agassiz, 1838

Odontaspis sp.

Figure 104-1

Description: The crown is elongated and erect with no striation on the lingual face. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 104-2

Description: The crown is slightly broad and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniiformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 104-3

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has no serrations.

43. Hannoura Formation

Locality: Hannoura, Notojima island, Nanao City, Ishikawa Prefecture

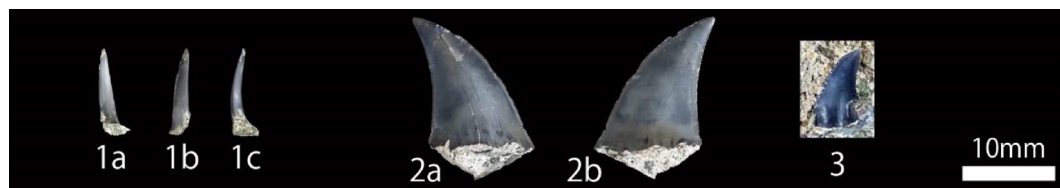


Figure 104. 1, *Odontaspis* sp., NMNS-PV 26898, lingual (a), labial (b) and profile (c) views; 2, *Isurus desori*, NMNS-PV 26899, lingual (a) and labial (b) views; 3, *Carcharhinus* sp., NMNS-PV 26901. Scale bar equals 10 mm.

Formation and Age: Hannoura Formation, Middle Miocene. According to Nomura and Tazaki (2007), the age of the Hannoura Formation is considered to be equivalent to the Nanao Formation and is considered to be Middle Miocene in the age based on *Desmostylus* production (Takai, 1944).

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Carcharias* Rafinesque, 1810

Carcharias contortidens (Agassiz, 1843)

Figure 105-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is a striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Genus *Araloselachus* Glikman, 1964

Araloselachus cuspidatus (Agassiz, 1843)

Figure 105-2

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon hastalis (Agassiz, 1838)

Figure 105-3,4

Description: The crown is broad and equilaterally triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

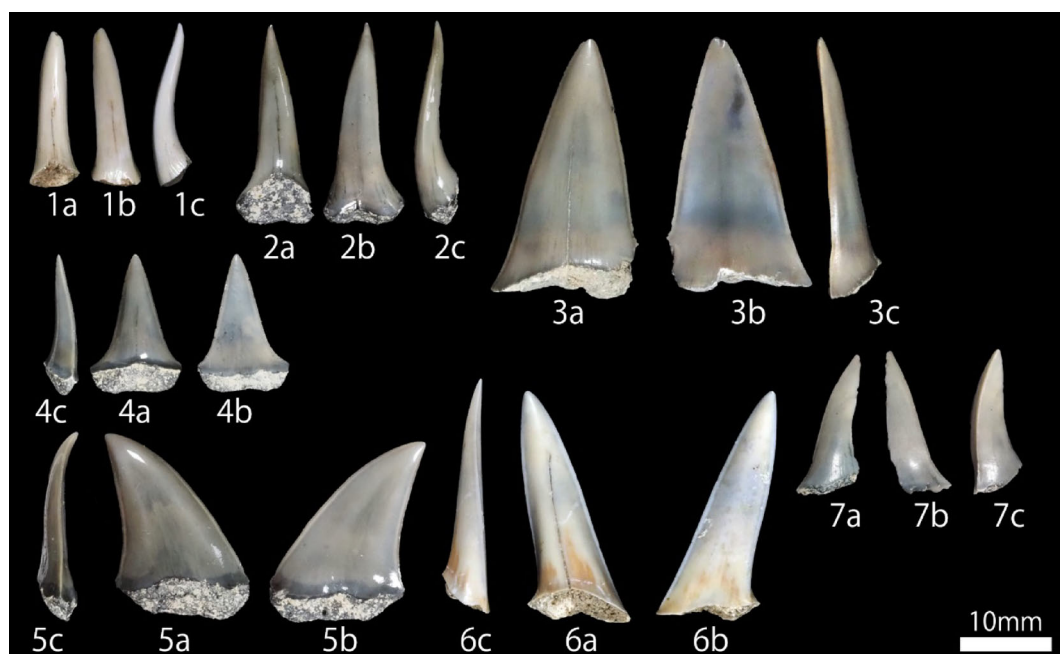


Figure 105. 1, *Carcharias contortidens*, NMNS-PV 27254, lingual (a), labial (b) and profile (c) views; 2, *Araloselachus cuspidatus*, NMNS-PV 33874, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon hastalis*, NMNS-PV 27256, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 33888, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon planus*, NMNS-PV 33889, lingual (a), labial (b) and profile (c) views; 6, *Isurus desori*, NMNS-PV 27264, lingual (a), labial (b) and profile (c) views; 7, *Parotodus benedeni*, NMNS-PV 33886, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Carcharodon planus (Agassiz, 1856)
Figure 105-5

Description: The crown is broad and characteristically strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
Figure 105-6

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

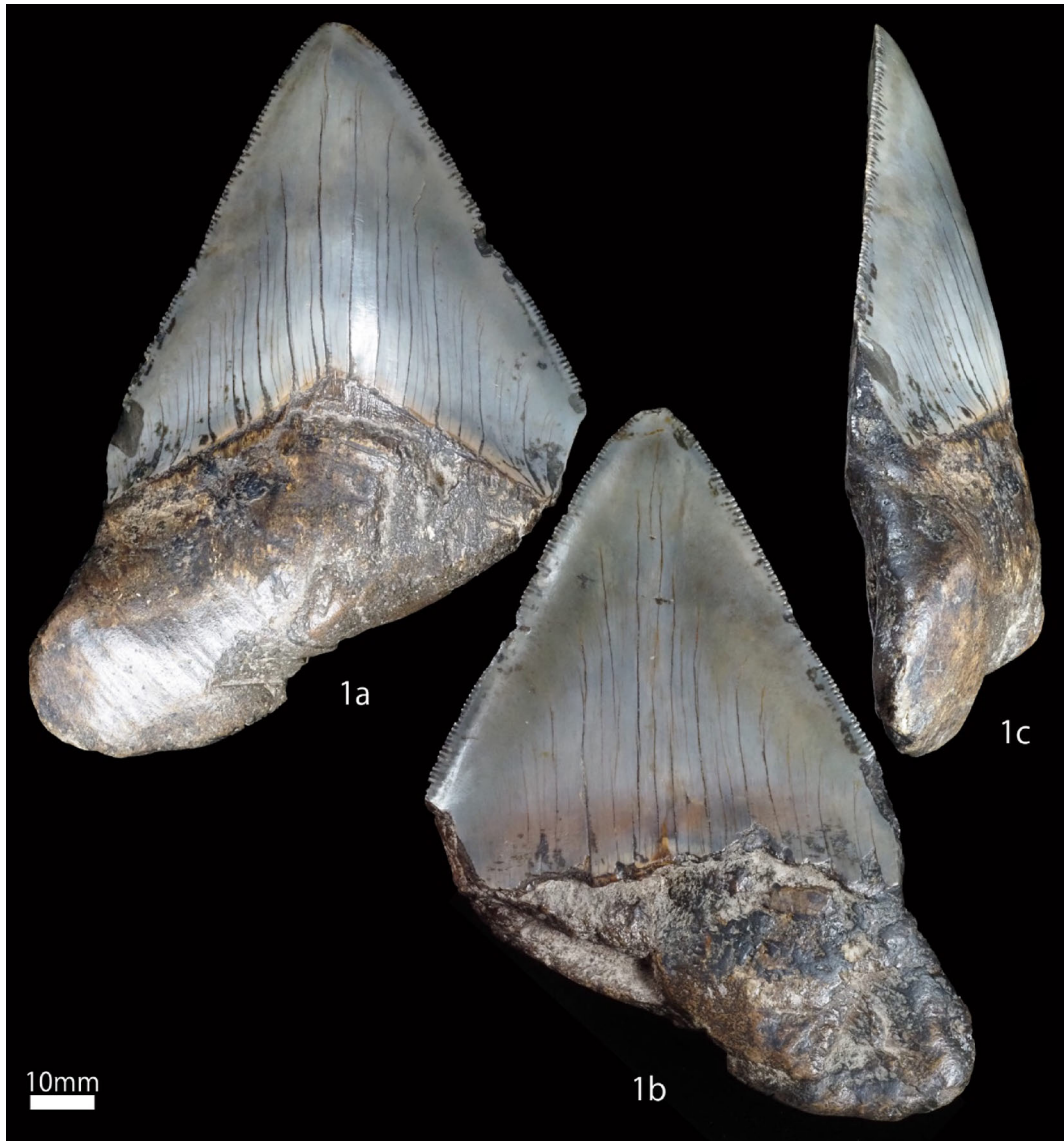


Figure 106. 1, *Otodus megalodon*, NMNS-PV 27265, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Family Otodontidae Glickman, 1964

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 105-7

Description: The crown is very thick and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 106-1

Description: The tooth is very large. The crown is broadly triangular and erect. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Scyliorhinidae Gill, 1862

Genus *Scyliorhinus* Blainville, 1816

Scyliorhinus kasenoii Karasawa, 1989

Figure 107-1,2

Description: Very small teeth. The cutting edge of the crown has no serrations. The central part of the lingual face of the root is raised and high. There is one pair of the lateral cusplets. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. altimus* (Springer, 1950)

Figure 107-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. brachyurus* (Günther, 1870)

Figure 107-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. brevipinna*

(Müller and Henle, 1839)

Figure 107-5

Description: The crown is slender and curved distally. The cutting edge of the crown has finely serrations on the lower portion. The lingual face of the crown is convex and the labial face is flat.

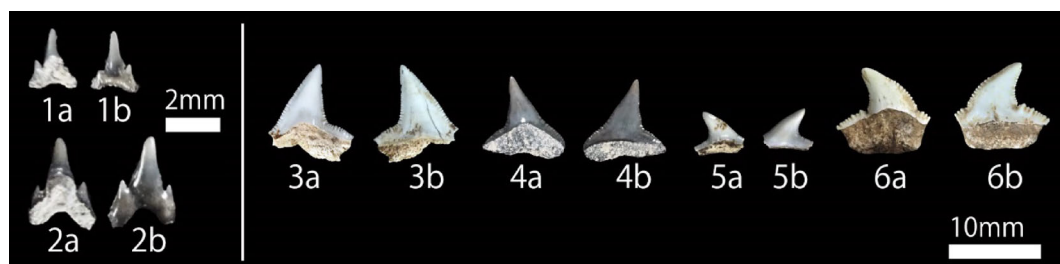


Figure 107. 1, *Scyliorhinus kasenoii*, NMNS-PV 33887, lingual (a) and labial (b) views; 2, *Scyliorhinus kasenoii*, NMNS-PV 27269, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. altimus*, NMNS-PV 27270, lingual (a) and labial (b) views; 4, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 33884, lingual (a) and labial (b) views; 5, *Carcharhinus* cf. *C. brevipinna*, NMNS-PV 27273, lingual (a) and labial (b) views; 6, *Carcharhinus* cf. *C. falciformis*, NMNS-PV 27274, lingual (a) and labial (b) views. Scale bar equals 2 mm (1,2) and 10 mm (3,4,5,6).

Carcharhinus cf. *C. falciformis*
(Bibron in Müller and Henle, 1839)
Figure 107-6

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has a deep median notch, finely serrated on top and roughened on the underside. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Hexanchus gigas*, *Squatina* sp. according to Karasawa (1989).

44. Taga Group

Locality: Nagahama, Hiragatacho, Kitaibaraki City, Ibaraki Prefecture.

Formation and Age: Taga Group, Middle Miocene. According to Yanagisawa *et al.* (2016), the age of the Taga Group is considered to be Middle Miocene (13.1–12.7 Ma) based on the diatom fossils.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
Figure 108-1,2

Description: The crown is broad and isosceles triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. In particular Fig.108-1 is a very large tooth.

Carcharodon planus (Agassiz, 1856)
Figure 108-3

Description: The crown is broad and characteristically curved distally. The cutting edge of the crown has no serrations. In this specimen the distal cutting edge is curved outwards in a bulging manner. This is one of the most common characters in this species. The lingual face of the crown is convex and the labial face is flat.

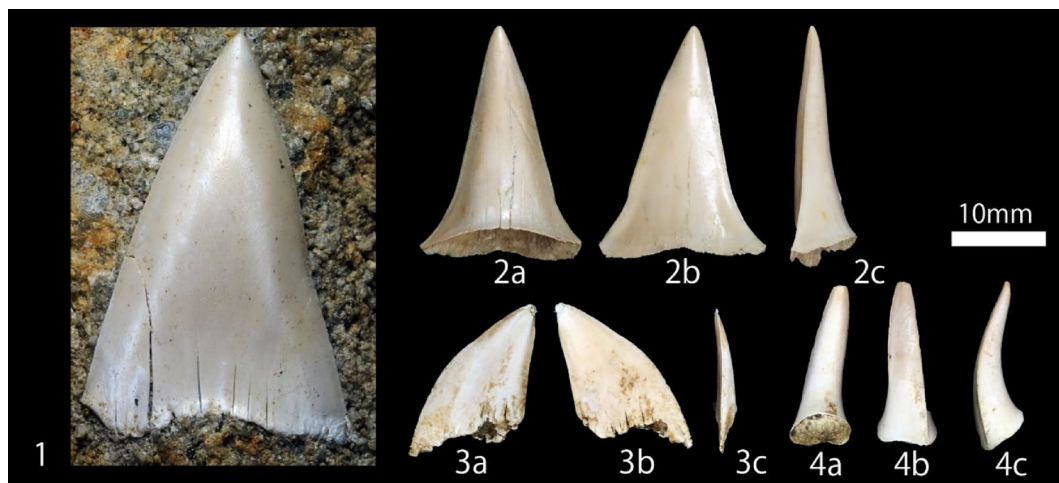


Figure 108. 1, *Carcharodon hastalis*, NMNS-PV 26886; 2, *Carcharodon hastalis*, NMNS-PV 26891, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon planus*, NMNS-PV 26892, lingual (a), labial (b) and profile (c) views; 4, *Isurus desori*, NMNS-PV 26893, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 108-4

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

45. Haratajino Formation, Tomioka Group

Locality: Gohara, Annaka City, Gunma Prefecture

Formation and Age: Haratajino Formation, Middle Miocene. According to Takahashi and Hayashi (2004), the age of the Haratajino Formation of the Tomioka Group is considered to be Middle Miocene based on the planktonic foraminifera.

Order Hexanchiformes Buen, 1926

Family Chlamydoselachidae Garman, 1884

Genus *Chlamydoselachus* Garman, 1884

Chlamydoselachus sp.

Figure 109-1

Description: The crown is very elongated and conical. The base of the crown is spherical and fig-like. The cutting edge of the crown has no serrations. Originally, the teeth of this genus had three cusps, but this specimen has one cusp.

Order Squaliformes Goodrich, 1909

Family Centrophoridae Bleeker, 1859

Genus *Centrophorus* Müller and Henle, 1837

Centrophorus sp.

Figure 109-2

Description: The tooth is very thin. The crown is an isosceles triangle, erect and the cusp is not curved mesially or distally. The cutting edge of the crown has no serrations. On the lingual face, the central part of the crown hangs down towards the root on the labial face. The lingual face of the crown is slightly convex and the labial face is flat. The root is square and flat.

Family Centrophoridae Bleeker, 1859

Genus *Deania* Jordan and Snyder, 1902

Deania sp.

Figure 109-3

Description: The crown is strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is slightly convex and the labial face is flat. The root is rounded.

Family Etmopteridae Fowler, 1934

Genus *Etmopterus* Rafinesque, 1810

Etmopterus sp.

Figure 109-4

Description: Very small tooth. The crown is narrow and deeply curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is slightly convex and the labial face is flat. The root is flat and rectangular.

Family Somniosidae Jordan, 1888

Genus *Centroscymnus* Bocage and Capello, 1864

Centroscymnus sp.

Figure 109-5

Description: The crown is thin and strongly curved distally. The cutting edge of the crown has no serrations and there is a shoulder at the base of the distal cutting edge. On the labial face, the center of the crown is long and pendant. The lingual face of the crown is slightly convex and the labial face is flat. The root is flat, long and rectangular.

Genus *Centroselachus* Garman, 1913

Centroselachus sp.

Figure 109-6

Description: The crown is thin and slightly inclined distally with an upwardly recurved apex. The cutting edge of the crown has no serrations and has a shoulder at the base of the distal cutting edge. The center of the labial face of the crown is deeply overhanging. The lingual face of the crown is slightly convex and the labial face is flat.



Figure 109. 1, *Chlamydoselachus* sp., NMNS-PV 26908, lingual (a), labial (b) and profile (c) views; 2, *Centrophorus* sp., NMNS-PV 26909, lingual (a) and labial (b) views; 3, *Deania* sp., NMNS-PV 26910, lingual (a) and labial (b) views; 4, *Etmopterus* sp., NMNS-PV 26912, lingual (a) and labial (b) views; 5, *Centroscyrnus* sp., NMNS-PV 26913, lingual (a) and labial (b) views; 6, *Centroselachus* sp., NMNS-PV 26914, lingual (a) and labial (b) views; 7, *Somniosus* sp., NMNS-PV 26915, lingual (a) and labial (b) views. Scale bar equals 2 mm.

Genus *Somniosus* Lesueur, 1818

Somniosus sp.

Figure 109-7

Description: The crown is very elongated, conical and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Chlamydoselachus bracheri*, *Hexanchus* sp., *Dalatias licha*, *Squaliolus* sp., *Pseudocarcharias* sp., *Mitsukurina* sp. according Takakuwa (2007).

46. Onagawa Formation, Funagawa Group

Locality: Funagawaminato, Ojika City, Akita Prefecture

Formation and Age: Onagawa Formation, Middle-Late Miocene. According to Kato and Yanagisawa (2021), the age of the Onagawa Formation of the Funagawa Group is considered to be Middle-Late Miocene (12.3–9.6 Ma) based on the diatom fossils.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Isurus* Rafinesque, 1810

Isurus desori (Agassiz, 1843)

Figure 110-1

Description: The crown is elongated and curved

distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

47. Yamairi Formation

Locality: Watari Town, Watari-Gun, Miyagi Prefecture

Formation and Age: Yamairi Formation, Middle Miocene. According to Yanagisawa and Kurihara (2002), the age of the Yamairi Formation is considered to be Middle Miocene based on the diatom age.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon hastalis (Agassiz, 1838)

Figure 111-1

Description: The crown is broad, triangular and



Figure 110. 1, *Isurus desori*, NMNS-PV 34007, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.



Figure 111. 1, *Carcharodon hastalis*, NMNS-PV 26850, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon planus*, NMNS-PV 26857, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon planus*, NMNS-PV 26858, lingual (a), labial (b) and profile (c) views; 4, *Isurus desori*, NMNS-PV 26867, lingual (a), labial (b) and profile (c) views; 5, *Hemipristis serra*, NMNS-PV 26885, lingual (a) and labial (b) views. Scale bar equals 10 mm.

slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon planus (Agassiz, 1856)
Figure 111-2,3

Description: The crown of Fig.111-2 is broad and characteristically strongly curved distally. The crown of Fig.111-3 is slightly thin and erect,

but thickens at the base. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)
Figure 111-4

Description: The crown is elongated and erect. The cutting edge of the crown has no serrations.

The lingual face of the crown is convex and the labial face is flat.

Family Otodontidae Glickman, 1964
Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
Figure 112-1

Description: The tooth is very large. The crown is broadly triangular and slightly curved distally. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
Family Hemigaleidae Hasse, 1879
Genus *Hemipristis* Agassiz, 1843
Hemipristis serra Agassiz, 1843
Figure 111-5

Description: The serrations on the cutting edge of the remaining crown base are very rough. The central root of the lingual face of the crown is raised so that it enters the crown.

48. Tamari Formation

Locality: Chokaiji, Kikukawa City, Shizuoka Prefecture

Formation and Age: Tamari Formation, Late Miocene. According to Kameo *et al.* (1998), the age of the Tamari Formation is considered to be Late Miocene (10.7 Ma) based on the calcareous nannofossil.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
Figure 113-1

Description: The crown is broad and isosceles triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus cf. *C. brachyurus* (Günther, 1870)
Figure 113-2

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. limbatus* (Valenciennes, 1839)
Figure 113-3

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has very fine serrations with slightly rougher serrations at the base.

Additional records: In addition to the species reported here, there are reports of *Otodus megalodon* (Reported as *Carcharocles megalodon* in Ohe *et al.*, 2011) according to Ohe *et al.* (2011).

49. Shimoshiroiwa Formation, Yugashima Group

Locality: Shimoshiroiwa, Izu City, Shizuoka Prefecture

Formation and Age: Shimoshiroiwa Formation, Late Miocene. According to Matsumaru (2017), the age of the Shimoshiroiwa Formation of the Yugashima Group is considered to be Late Miocene (11–6 Ma) based on the calcareous nannofossil (CN6) and the planktonic foraminifera (N17).

Order Squaliformes Goodrich, 1909
Family Dalatiidae Gray, 1851
Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
Figure 114-1

Description: The crown is nearly equilateral triangular. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

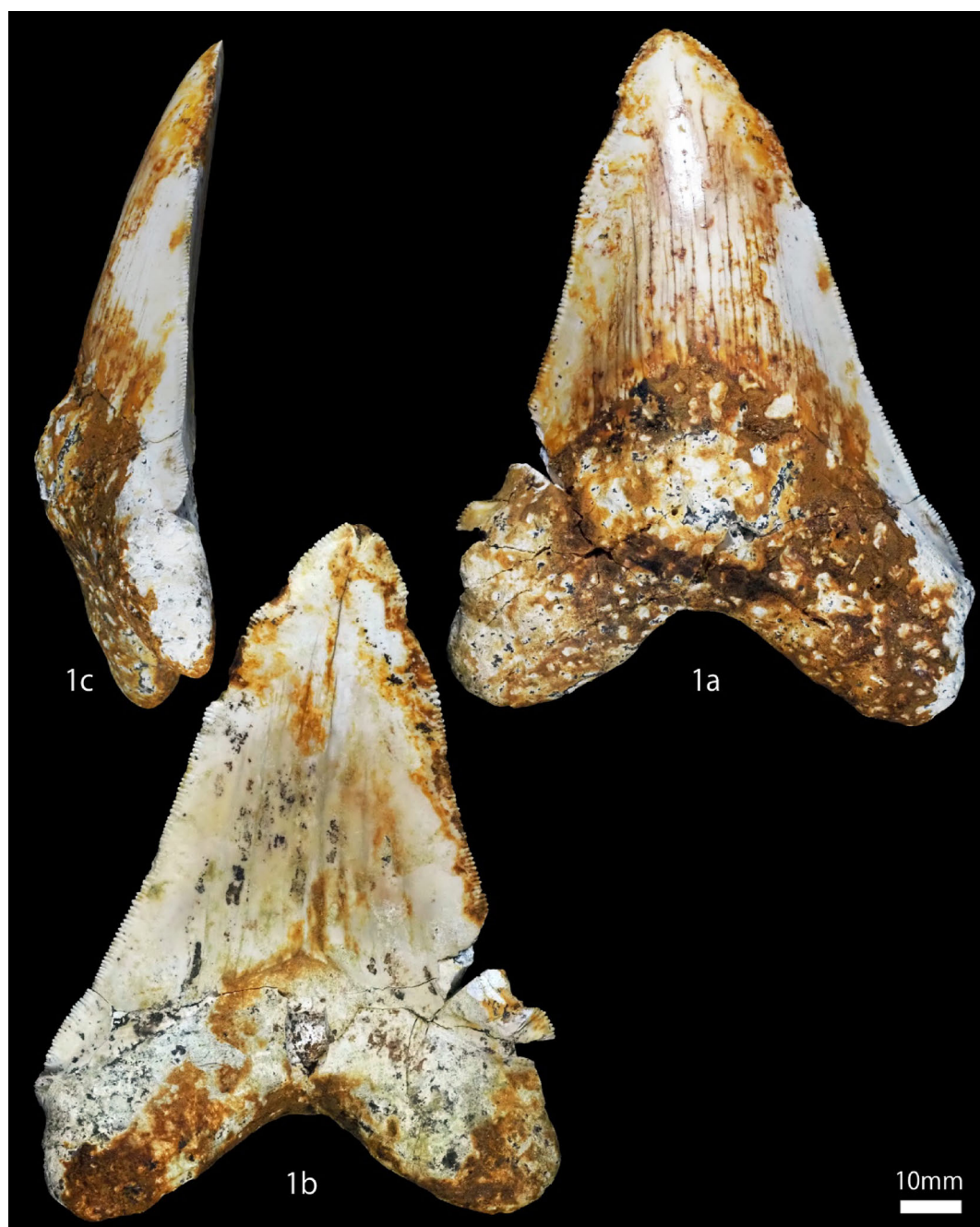


Figure 112. 1, *Otodus megalodon*, NMNS-PV 26872 lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.



Figure 113. 1, *Carcharodon hastalis*, NMNS-PV 29324, lingual (a) and labial (b) views; 2, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 29326, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. limbatus*, NMNS-PV 29327. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958
Family Odontaspidae Müller and Henle, 1839
Odontaspidae gen. et sp. indet.

Figure 115-1,2

Description: The crown is elongated and long. The cutting edge of the crown has no serrations. The crown has a strongly convex labial face and a weakly convex lingual face of the crown.

Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)

Figure 115-3,4

Description: The crown is broad and isosceles triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus desori (Agassiz, 1843)

Figure 115-5,6

Description: The crown is elongated and slightly



Figure 114. 1, *Dalatias licha*, NMNS-PV 29288, lingual (a), labial (b) and profile (c) views. Scale bar equals 5 mm.

curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniiformes Compagno, 1973

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassiz, 1843

Hemipristis serra Agassiz, 1843

Figure 116-1

Description: The crown is triangular and curved distally. The cutting edge of the crown has rough serrations, but the serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus sp.

Figure 116-2

Description: The crown is triangular and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

50. Aoso Formation, Shida Group

Locality: Tsurusu, Taiwa Town, Kurokawa-Gun, Miyagi Prefecture

Formation and Age: Aoso Formation, Late Miocene. According to Suzuki *et al.* (2019), the age of the Aoso Formation of the Shida Group is considered to be Late Miocene (10.5–8.4 Ma) based on the planktonic foraminifera.

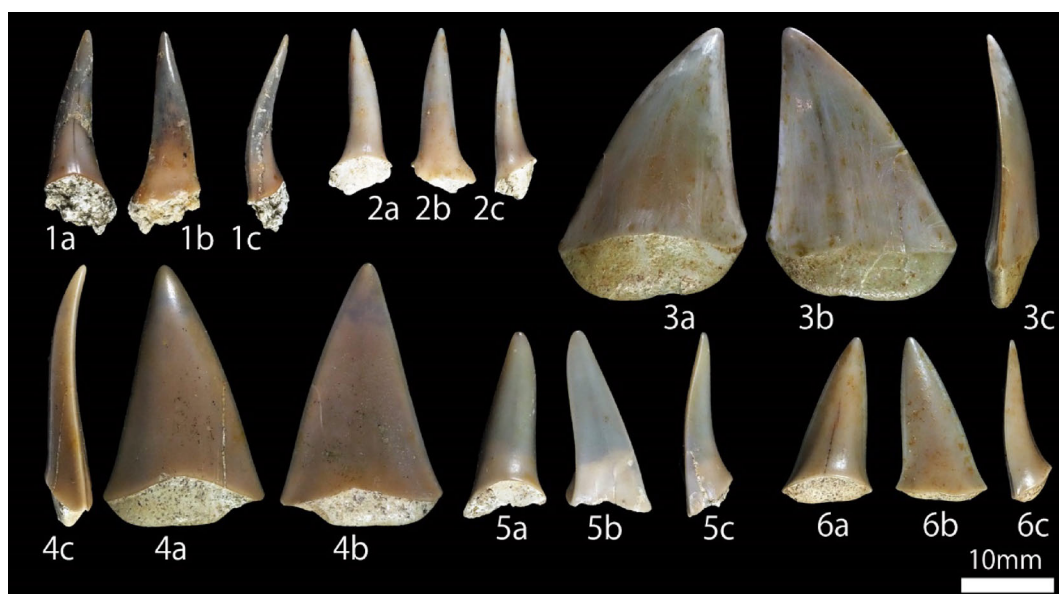


Figure 115. 1, *Odontaspidae* gen. et sp. indet., NMNS-PV 29289, lingual (a), labial (b) and profile (c) views; 2, *Odontaspidae* gen. et sp. indet., NMNS-PV 29294, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon hastalis*, NMNS-PV 29295, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 29296, lingual (a), labial (b) and profile (c) views; 5, *Isurus desori*, NMNS-PV 29305, lingual (a), labial (b) and profile (c) views; 6, *Isurus desori*, NMNS-PV 29306, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958
 Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 117-1,2,3

Description: The crown is broad, isosceles triangular and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.



Figure 116. 1, *Hemipristis serra*, NMNS-PV 29309, lingual (a), labial (b) and profile (c) views; 2, *Carcharhinus* sp., NMNS-PV 29310, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810
 Figure 117-4,5

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 118-1,2,3

Description: The crowns of Fig.118-1,2 are broadly triangular and erect. Fig.118-3 is small and the crown height is very low. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: Fig.118-3 is the posterior tooth.

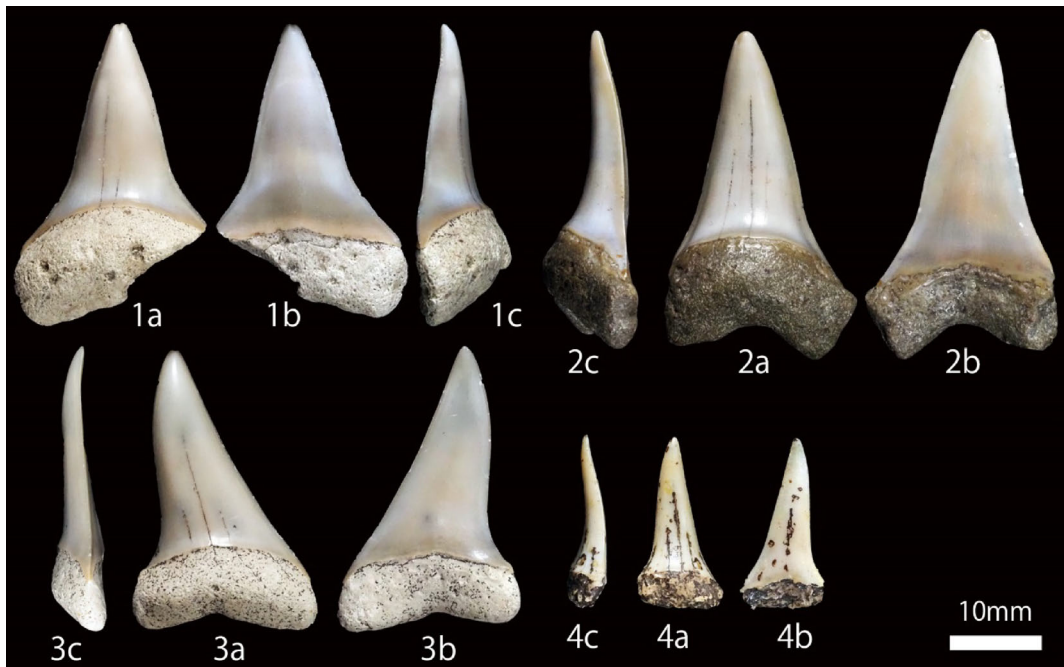


Figure 117. 1, *Carcharodon hastalis*, NMNS-PV 28317, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon hastalis*, NMNS-PV 28316, lingual (a), labial (b) and profile (c) views; 3, *Isurus oxyrinchus*, NMNS-PV 28328, lingual (a), labial (b) and profile (c) views; 4, *Isurus oxyrinchus*, NMNS-PV 28329, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus altimus (Springer, 1950)
 Figure 119-1

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus brachyurus (Günther, 1870)
 Figure 119-2

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)
 Figure 119-3

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is curved gently outwards. The lingual face of the crown is convex and the labial face is flat.

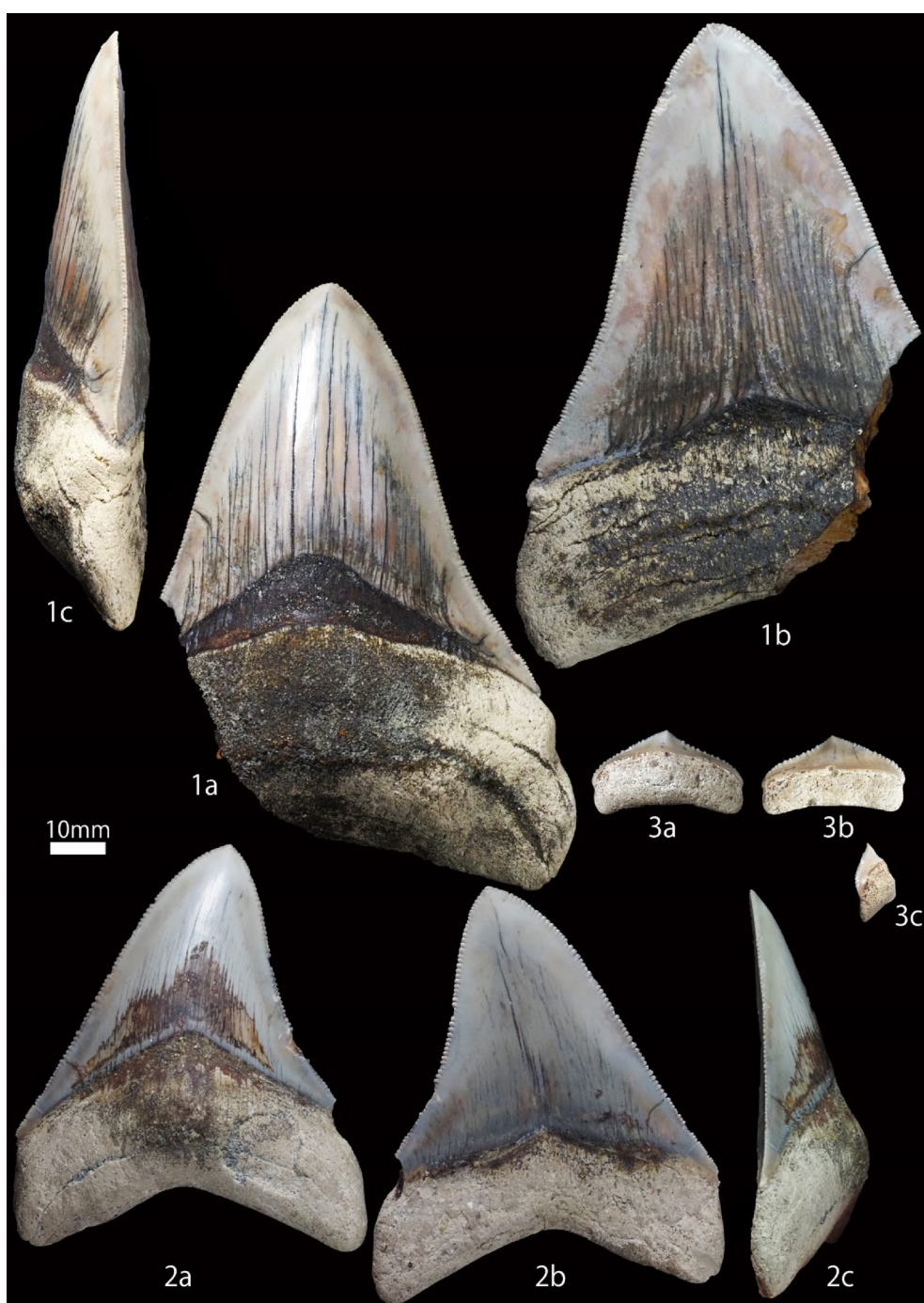


Figure 118. 1, *Otodus megalodon*, NMNS-PV 28330, lingual (a), labial (b) and profile (c) views; 2, *Otodus megalodon*, NMNS-PV 28331, lingual (a), labial (b) and profile (c) views; 3, *Otodus megalodon*, NMNS-PV 28335, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Vertebra
Figure 120-1

Description: This has a mill-shape with a concave center. There are no vertical slits on this side.

Remarks: This is the vertebra of a shark of the genus *Carcharhinus*.

51. Otogawa Formation, Tonami Group

Locality: Fukatani, Yatsuo City, Toyama Prefecture

Formation and Age: Otogawa Formation, Late Miocene. According to Hayakawa and Takemura

(1987), the age of the Otogawa Formation of the Tonami Group is considered to be Late Miocene (9.2–7.3 Ma) based on the diatom fossils.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Megasqualus* Herman, 1982

Megasqualus occidentalis (Agassiz, 1856)

Figure 121-1

Description: The size of the tooth is more than twice as large as that of the modern genus *Squalus*. The crown is triangular with a strong



Figure 119. 1, *Carcharhinus altimus*, NMNS-PV 28336, lingual (a) and labial (b) views; 2, *Carcharhinus brachyurus*, NMNS-PV 28337, lingual (a) and labial (b) views; 3, *Carcharhinus obscurus*, NMNS-PV 28338, lingual (a) and labial (b) views. Scale bar equals 10 mm.



Figure 120. 1, vertebra, NMNS-PV 28343, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.



Figure 121. 1, *Megasqualus occidentalis*, NMNS-PV 27231, lingual (a) and labial (b) views; 2, *Alopias* cf. *A. superciliosus*, NMNS-PV 27234, lingual (a) and labial (b) views. Scale bar equals 5 mm.

distal slope. The cutting edge of the crown has fine serrations. The lingual face of the crown is inflated and the labial face is flat. The labial face of the crown is extended so that its central part overhangs the root.

Order Lamniformes Berg, 1958

Family Alopiidae Bonaparte, 1838

Genus *Alopias* Rafinesque, 1810

Alopias cf. *A. superciliosus* (Lowe, 1841)

Figure 121-2

Description: The crown is narrowly triangular, long and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid and quite long.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus cf. *C. brachyurus* (Günther, 1870)

Figure 122-1

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. galapagensis*

(Snodgrass and Heller, 1905)

Figure 122-2

Description: The crown is isosceles triangular

and erect. The cutting edge of the crown has regular serrations. The mesial cutting edge of the crown is slightly concave in the center and the distal cutting edge is gently curved. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus cf. *C. plumbeus* (Nardo, 1827)

Figure 122-3

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Isurus desori*, *Isurus hastalis*, Scyliorhinidae gen. et sp. indet., *Sphyrna* sp., Dasyatidae gen. et sp. indet. (Reported as *Dasyatis* sp. in Furumi *et al.*, 2014a) according to Furumi *et al.* (2014a).

52. Nanakita Formation, Shida Group

Locality: Akashi, Tomiya City, Miyagi Prefecture

Formation and Age: Nanakita Formation, Late Miocene. According to Suzuki *et al.* (2019), the age of the Nanakita Formation of the Shida Group is considered to be Late Miocene (9.3–8.7 Ma) based on the diatom fossils.



Figure 122. 1, *Carcharhinus* cf. *C. galapagensis*, NMNS-PV 27235, lingual (a) and labial (b) views; 2, *Carcharhinus* cf. *C. brachyurus*, NMNS-PV 27236, lingual (a) and labial (b) views; 3, *Carcharhinus* cf. *C. plumbeus*, NMNS-PV 27237, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958
 Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)

Figure 123-1

Description: The crown is broad, isosceles triangular and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810

Figure 123-2

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown

is strongly convex and the labial face is flat.

53. Misaki Formation, Miura Group

Locality 1: Sajima, Yokosuka City, Kanagawa Prefecture

Locality 2: Misakimachijogashima, Miura City, Kanagawa Prefecture

Locality 3: Harumicho, Miura City, Kanagawa Prefecture

Formation and Age (Locality 1,2,3): Misaki Formation, Middle Miocene-Early Pliocene. According to Kanie *et al.* (1991) and Suzuki and Kanie (2012), the age of the Misaki Formation of the Miura Group is considered to be Middle Miocene-Early Pliocene based on the calcareous nannofossil.



Figure 123. 1, *Carcharodon hastalis*, NMNS-PV 28379, lingual (a), labial (b) and profile (c) views; 2, *Isurus oxyrinchus*, NMNS-PV 28380, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Order Pristiophoriformes Berg, 1958
 Family Pristiophoridae Bleeker, 1859
 Genus *Pristiophorus* Müller and Henle, 1837
Pristiophorus japonicus Günther, 1870
 Figure 124-1

Description: The crown is knife-shaped and thin. The cutting edge of the crown has no serrations.

Remarks: This is the rostral tooth of the rostrum.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Odontaspis* Agassiz, 1838
Odontaspis ferox (Risso, 1810)
 Figure 124-2

Description: The crown is thin. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There are no striations on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 124-3

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810
 Figure 124-4

Description: The crown is broad, triangular and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964
 Genus *Parotodus* Cappetta, 1980
Parotodus benedeni (Le Hon, 1871)
 Figure 124-5

Description: The crown is very thick, erect and

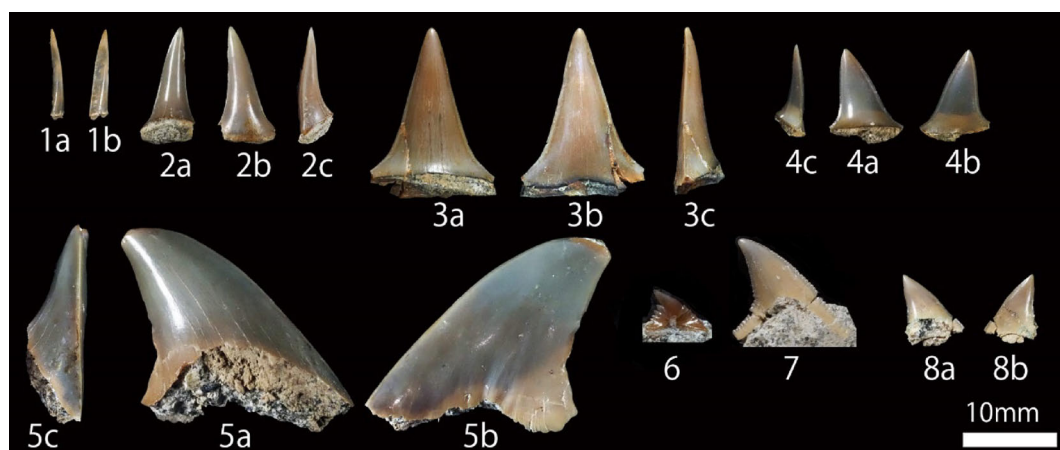


Figure 124. 1, *Pristiophorus japonicus*, NMNS-PV 29052, Locality 1, articular or axial (a) and dorsal or ventral (b) views.; 2, *Odontaspis ferox*, NMNS-PV 29053, Locality 1, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon hastalis*, NMNS-PV 29057, Locality 1, lingual (a), labial (b) and profile (c) views; 4, *Isurus oxyrinchus*, NMNS-PV 29059, Locality 1, lingual (a), labial (b) and profile (c) views; 5, *Parotodus benedeni*, NMNS-PV 29065, Locality 2, lingual (a), labial (b) and profile (c) views; 6, *Hypogaleus hyugaensis*, NMNS-PV 29068, Locality 3; 7, *Carcharhinus altimus*, NMNS-PV 29069, Locality 3; 8, *Sphyrna lewini*, NMNS-PV 29076, Locality 3, lingual (a) and labial (b) views. Scale bar equals 10 mm.

strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
 Family Triakidae Gray, 1851
 Genus *Hypogaleus* Smith, 1957
Hypogaleus hyugaensis (Miyosi, 1939)
 Figure 124-6

Description: The crown is nearly equilateral with the cusp curved distally. The mesial cutting edge of the crown has multiple rough serrations that is extended close to the cusp. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus altimus (Springer, 1950)
 Figure 124-7

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations.

Family Sphyrnidae Gill, 1872
 Genus *Sphyrna* Rafinesque, 1810
Sphyrna lewini (Griffith and Smith, 1834)
 Figure 124-8

Description: The crown is triangular and concave near the apex. The cutting edge of the crown has no serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Otodus megalodon* (Reported as *Carcharocles megalodon* in Tanaka, 2001) according to Tanaka (2001).

54. Furuya Formation, Nishikatura Group

Locality 1: Tonoirisawa, Kamikurechi, Fujiyoshida City, Yamanashi Prefecture

Locality 2: Mizunoki, Shimokurechi, Nishikatura Town, Minamitsuru-Gun, Yamanashi Prefecture

Formation and Age (Locality 1,2): Furuya Formation, Late Miocene. According to Aochi (1999), the age of the Furuya Formation of the Nishikatura Group is considered to be Late Miocene based on the nannofossil.

Order Lamniformes Berg, 1958
 Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon hastalis (Agassiz, 1838)
 Figure 125-1,2

Description: The crown is broad and equilaterally triangular. The crown of Fig.125-1 is slightly curved distally, another of Fig.125-2 is erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 125-3

Description: The crown is broadly triangular. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus leucas (Müller and Henle, 1839)
 Figure 126-1

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.



Figure 125. 1, *Carcharodon hastalis*, NMNS-PV 29080, Localities 1, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon hastalis*, NMNS-PV 32545, Localities 1, lingual (a), labial (b) and profile (c) views; 3, *Otodus megalodon*, NMNS-PV 29084, Localities 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Carcharhinus limbatus (Valenciennes, 1839)

Figure 126-2

Description: The crown is thin and almost erect. The cutting edge of the crown has very fine serrations with slightly rougher serrations at the base. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)

Figure 126-3

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards.

Carcharhinus plumbeus (Nardo, 1827)

Figure 126-4

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Myliobatidae Bonaparte, 1838

Genus *Myliobatis* Cuvier, 1816

Myliobatis sp.

Figure 126-5

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Additional records: In addition to the species reported here, there are reports of *Squatina* sp., *Carcharodon hubbelli* (Reported as *Carcharodon* sp. in Uyeno and Ono, 1982), *Hemipristis serra*, *Negaprion* sp. according to Uyeno and Ono (1982).

55. Oiso Formation

Locality: Nishikoiso, Oiso Town, Naka-Gun, Kanagawa Prefecture

Formation and Age: Oiso Formation, Late Miocene. According to Ito (1986), the age of the Oiso Formation is considered to be Late Miocene based on the calcareous nannofossil.

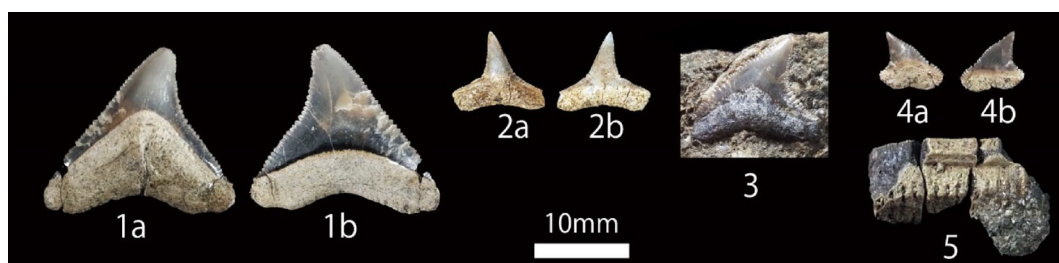


Figure 126. 1, *Carcharhinus leucas*, NMNS-PV 29135, Locality 2, lingual (a) and labial (b) views; 2, *Carcharhinus limbatus*, NMNS-PV 29138, Locality 2, lingual (a) and labial (b) views; 3, *Carcharhinus obscurus*, NMNS-PV 29086, Locality 1; 4, *Carcharhinus plumbeus*, NMNS-PV 29139, Locality 2, lingual (a) and labial (b) views; 5, *Myliobatis* sp., NMNS-PV 29133, Locality 1. Scale bar equals 10 mm.

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Hexanchidae gen. et sp. indet.

Figure 127-1

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is slightly convex.

Remarks: This is the upper first or second tooth of *Hexanchus* or *Notorynchus* of the family Hexanchidae. However, it is so similar and difficult to distinguish that it has been assigned to unidentified genus and species in the family Hexanchidae.

Order Squaliformes Goodrich, 1909

Family Dalatiidae Gray, 1851

Genus *Dalatias* Rafinesque, 1810

Dalatias licha (Bonnaterre, 1788)

Figure 128-1

Description: The crown is nearly equilateral



Figure 127. 1, Hexanchidae gen. et sp. indet., NMNS-PV 32142, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

triangular and erect or slightly curved distally. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Pristiophoriformes Berg, 1958

Family Pristiophoridae Bleeker, 1859

Genus *Pristiophorus* Müller and Henle, 1837

Pristiophorus japonicus Günther, 1870

Figure 128-2

Description: The crown is knife-shaped and thin. The cutting edge of the crown has no serrations.

Remarks: This is the rostral tooth of the rostrum.

Order Squatiniformes Buen, 1926

Family Squatinidae Bonaparte, 1838

Genus *Squatina* Dumeril, 1806

Squatina sp.

Figure 128-3

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex, as is the labial face. The basal part of the crown widens mesially-distally and the basal center of the crown deeply overhangs the root.



Figure 128. 1, *Dalatias licha*, NMNS-PV 32155, lingual (a) and labial (b) views; 2, *Pristiophorus japonicus*, NMNS-PV 32251, articular or axial (a) and dorsal or ventral (b) views.; 3, *Squatina* sp., NMNS-PV 32076, lingual (a) and labial (b) views; 4, *Heterodontus* sp., NMNS-PV 32077, occlusal (a) and lingual (b) views. Scale bar equals 5 mm.

Order Heterodontiformes Berg, 1937
 Family Heterodontidae Gray, 1851
 Genus *Heterodontus* Blainville, 1816
Heterodontus sp.
 Figure 128-4

Description: This tooth is of the cobblestone grinding type, elongated, parallelogram. The surface of the crown has numerous wrinkles.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Odontaspis* Agassiz, 1838
Odontaspis ferox (Risso, 1810)
 Figure 129-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. This is retained on one side of the two lateral cusplet. The presence of multiple cusplet on one side is a characteristic of this species. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon carcharias (Linnaeus, 1758)
 Figure 129-2

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown

has regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon hastalis (Agassiz, 1838)
 Figure 129-3

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon hubbelli Ehret *et al.*, 2012
 Figure 129-4,5

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown has weekly serrations. The lingual face of the crown is convex and the labial face is flat. Fig.129-5 has the one pair of the cusplets.

Remarks: Fig.129-5 is the juvenile tooth for the one pair of the cusplets.

Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810
 Figure 129-6

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

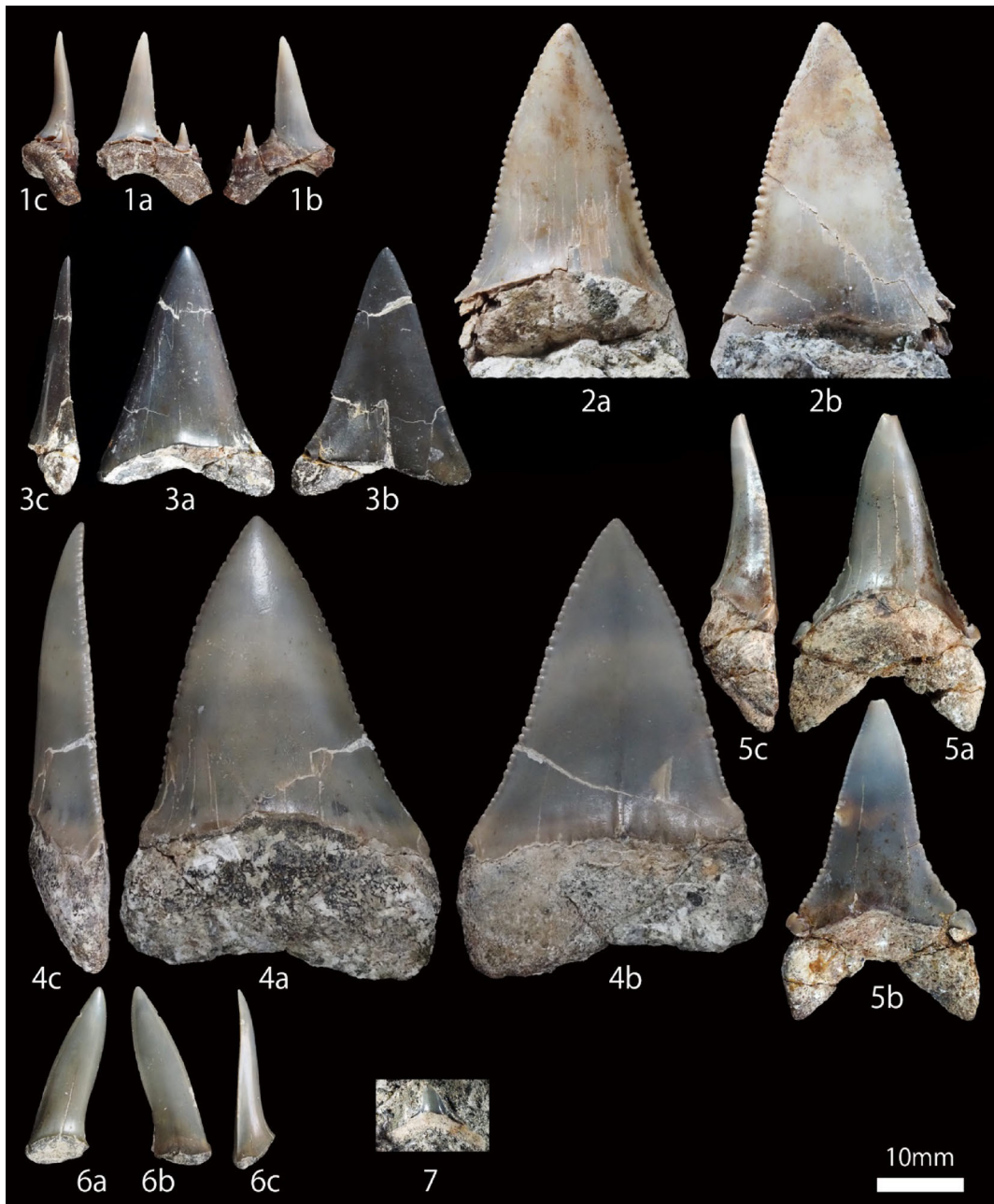


Figure 129. 1, *Odontaspis ferox*, NMNS-PV 32105, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 32252, lingual (a) and labial (b) views; 3, *Carcharodon hastalis*, NMNS-PV 32521, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hubbelli*, NMNS-PV 32119, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon hubbelli*, NMNS-PV 32518, lingual (a), labial (b) and profile (c) views; 6, *Isurus oxyrinchus*, NMNS-PV 32524, lingual (a), labial (b) and profile (c) views; 7, *Alopias superciliosus*, NMNS-PV 32210. Scale bar equals 10 mm.

Family Alopiidae Bonaparte, 1838
Genus *Alopias* Rafinesque, 1810
Alopias superciliosus (Lowe, 1841)
Figure 129-7

Description: The crown is narrowly triangular and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex. The root is distinctly bifid and quite long.

Family Otodontidae Glickman, 1964
Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
Figure 130-1

Description: This tooth is large. The crown is broadly triangular and erect. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo cuvier (Péron and Lesueur, 1822)
Figure 131-1

Description: The crown is multicuspid with the mesial first cusp being large and curved distally. The cutting edge of each cusp has fine serrations.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus albimarginatus (Rüppell, 1837)
Figure 131-2

Description: The crown is narrowly triangular and almost erect. The upper part of the cutting edge of the crown has fine serrations, while the lower part near the base is rougher. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus altimus (Springer, 1950)
Figure 131-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is

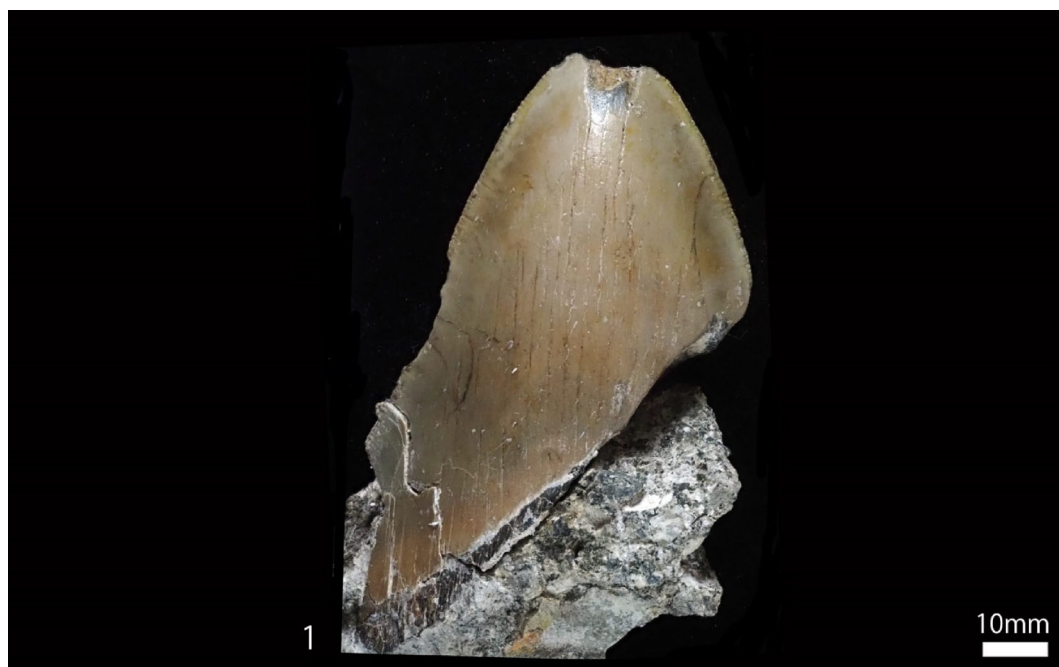


Figure 130. 1, *Otodus megalodon*, NMNS-PV 32156. Scale bar equals 10 mm.

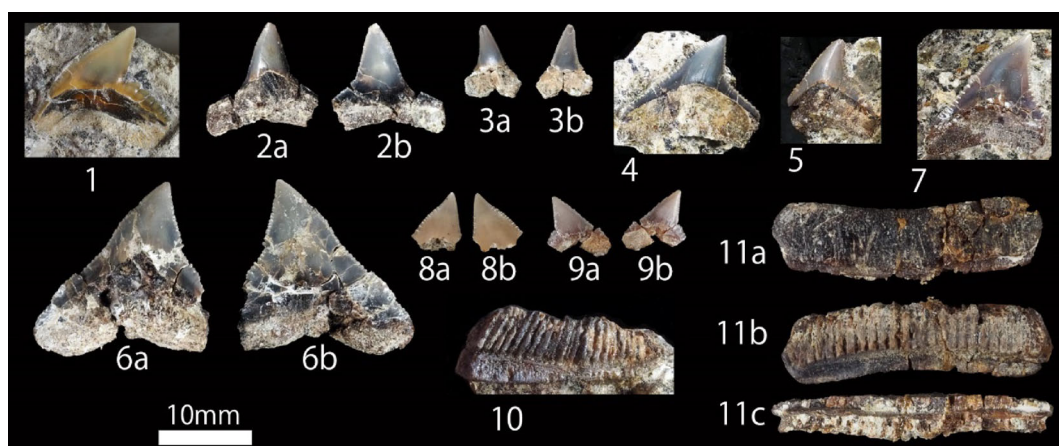


Figure 131. 1, *Galeocerdo cuvier*, NMNS-PV 32255; 2, *Carcharhinus albimarginatus*, NMNS-PV 32208, lingual (a) and labial (b) views; 3, *Carcharhinus altimus*, NMNS-PV 32082, lingual (a) and labial (b) views; 4, *Carcharhinus brachyurus*, NMNS-PV 32117; 5, *Carcharhinus galapagensis*, NMNS-PV 32192; 6, *Carcharhinus leucas*, NMNS-PV 32137, lingual (a) and labial (b) views; 7, *Carcharhinus obscurus*, NMNS-PV 32148; 8, *Carcharhinus plumbeus*, NMNS-PV 32086, lingual (a) and labial (b) views; 9, *Carcharhinus sorrah*, NMNS-PV 32296, lingual (a) and labial (b) views; 10, *Aetobatus* sp., NMNS-PV 32313; 11, *Myliobatis* sp., NMNS-PV 32533, occlusal (a), basal (b) and lingual (c) views. Scale bar equals 10 mm.

curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus brachyurus (Günther, 1870)

Figure 131-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations.

Carcharhinus galapagensis
(Snodgrass and Heller, 1905)

Figure 131-5

Description: The crown is isosceles triangular and erect. The cutting edge of the crown has regular serrations. The mesial cutting edge of the crown is slightly concave in the center and the distal cutting edge is gently curved.

Carcharhinus leucas (Müller and Henle, 1839)

Figure 131-6

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)

Figure 131-7

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards.

Carcharhinus plumbeus (Nardo, 1827)

Figure 131-8

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The

lingual face of the crown is convex and the labial face is flat.

Carcharhinus sorrah (Müller and Henle, 1839)
Figure 131-9

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial cutting edge has very rough serrations. The distal cutting edge is straight. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973
Family Myliobatididae Bonaparte, 1838
Genus *Aetobatus* Blainville, 1816
Aetobatus sp.
Figure 131-10

Description: Tooth morphology is similar to that of the genus *Myliobatis*, but differs in that the teeth are slightly tapered towards the edges in the occlusal view.

Genus *Myliobatis* Cuvier, 1816
Myliobatis sp.
Figure 131-11

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

56. Nashimoto Formation, Yugashima Group

Locality: Nashimoto, Kawazu Town, Kamo-Gun, Shizuoka Prefecture

Formation and Age: Nashimoto Formation, Late Miocene. According to Ibaraki (1981), the age of the Nashimoto Formation of the Yugashima Group is considered to be Late Miocene (6 Ma) based on the planktonic foraminifera.

Order Squaliformes Goodrich, 1909
Family Dalatiidae Gray, 1851
Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
Figure 132-1,2

Description: The crown is nearly equilateral triangular. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus sp.
Figure 132-3

Description: The crown is triangular and curved distally. The cutting edge of the crown has fine serrations.

57. Zushi Formation, Miura Group

Locality 1: Sakurayama, Zushi City, Kanagawa Prefecture

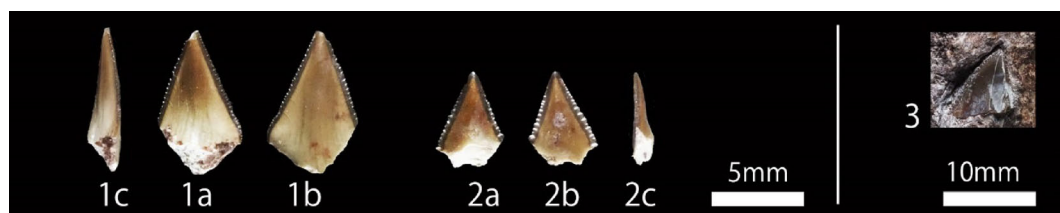


Figure 132. 1, *Dalatias licha*, NMNS-PV 29313, lingual (a), labial (b) and profile (c) views; 2, *Dalatias licha*, NMNS-PV 29314, lingual (a), labial (b) and profile (c) views; 3, *Carcharhinus* sp., NMNS-PV 29323. Scale bar equals 5 mm (1,2) and 10 mm (3).

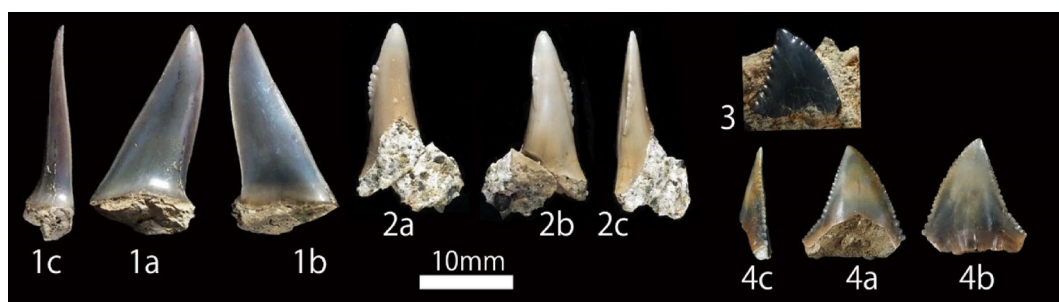


Figure 133. 1, *Isurus oxyrinchus*, NMNS-PV 29036, Locality 2, lingual (a), labial (b) and profile (c) views; 2, *Hemipristis serra*, NMNS-PV 29037, Locality 2, lingual (a), labial (b) and profile (c) views; 3, *Hemipristis serra*, NMNS-PV 29038, Locality 2; 4, *Carcharhinus obscurus*, NMNS-PV 29039, Locality 1, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Locality 2: Isshiki, Hayama Town, Miura-Gun, Kanagawa Prefecture

Formation and Age (Locality 1,2): Zushi Formation, Late Miocene-Early Pliocene. According to Kanie *et al.* (1991) and Suzuki and Kanie (2012), the age of the Zushi Formation of the Miura Group is considered to be Late Miocene-Early Pliocene based on the calcareous nannofossil.

Order Lamniformes Berg, 1958
 Family Lamnidae Müller and Henle, 1838
 Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810
 Figure 133-1

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
 Family Hemigaleidae Hasse, 1879
 Genus *Hemipristis* Agassi, 1843
Hemipristis serra Agassiz, 1843
 Figure 133-2,3

Description: The crown of Fig.133-2 is elongated and slightly curved distally. The crown of Fig.133-3 is triangular and curved distally. The cutting edge of the crown has rough serrations and these serrations do not extend to the apical

part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus obscurus (Lesueur, 1818)
 Figure 133-4

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Dalatias licha*, *Carcharodon carcharias*, *Carcharodon hastalis* (Reported as *Isurus hastalis* in Tanaka, 2001), *Carcharodon hubbelli* (Reported as ? *Carcharodon carcharias* in Tanaka, 2001), *Otodus megalodon* (Reported as *Carcharocles megalodon* in Tanaka, 2001) according to Tanaka (2001).

58. Senhata Formation, Miura Group

Locality: Motona, Kyonan Town, Awa-Gun, Chiba Prefecture

Formation and Age: Senhata Formation, Late Miocene-Early Pliocene. According to Ishikawa *et al.* (1982), the age of the Senhata Formation of the Miura Group is considered to be Late Miocene-Early Pliocene based on the foraminifera.



Figure 134. 1, *Chimaera* sp., NMNS-PV 28382; 2, *Hexanchus gigas*, NMNS-PV 28385, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Subclasses Holocephali Bonaparte, 1832
 Order Chimaeriformes Obruchev, 1953
 Family Chimaeridae Bonaparte, 1831
 Genus *Chimaera* Linnaeus, 1758
Chimaera sp.
 Figure 134-1

Description: The characteristic pleromine is identified and assumed to be a tooth plate of the order Chimaeriformes.

Remarks: This is similar to the lower plate of *Chimaera phantasma*. However, as no comparison with other species has been made, it is considered to be an unidentified species.

Subclasses Elasmobranchii Bonaparte, 1838
 Order Hexanchiformes Buen, 1926
 Family Hexanchidae Gray, 1851
 Genus *Hexanchus* Rafinesque, 1810
Hexanchus gigas (Sismonda, 1861)
 Figure 134-2

Description: The tooth is multituberculate with the height of the cusps decreasing distally from the first cusp. The root is flat and rectangular.

Remarks: Compared to the modern species *H. griseus*, this tooth is particularly characterized by the fact that each cusp is broad and thick.

Order Squaliformes Goodrich, 1909
 Family Dalatiidae Gray, 1851
 Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
 Figure 135-1

Description: The crown is nearly equilateral triangular. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Pristiophoriformes Berg, 1958
 Family Pristiophoridae Bleeker, 1859
 Genus *Pristiophorus* Müller and Henle, 1837
Pristiophorus japonicus Günther, 1870
 Figure 135-2,3

Description: The crown is knife-shaped and thin. The root is apron-shaped (see Fig.135-2).

Remarks: This is the rostral tooth of the rostrum.

Order Squatiniformes Buen, 1926
 Family Squatinidae Bonaparte, 1838
 Genus *Squatina* Dumeril, 1806
Squatina sp.
 Figure 135-4

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly



Figure 135. 1, *Dalatias licha*, NMNS-PV 28386, lingual (a) and labial (b) views; 2, *Pristiophorus japonicus*, NMNS-PV 28389, articular or axial (a) and dorsal or ventral (b) views; 3, *Pristiophorus japonicus*, NMNS-PV 28391, articular or axial (a) and dorsal or ventral (b) views; 4, *Squatina* sp., NMNS-PV 28424, lingual (a) and labial (b) views. Scale bar equals 5 mm.

inclined distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex, as is the labial face. The basal center of the crown deeply overhangs the root.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Odontaspis* Agassiz, 1838

Odontaspis ferox (Risso, 1810)

Figure 136-1,2

Description: The crown is thin and erect. Fig.136-2 shows one side of the lateral cusplet, which is elongated and needle-shaped. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon hastalis (Agassiz, 1838)

Figure 136-3,4,5

Description: The crown is broad and equilaterally triangular. The crown of Fig.136-3 is slightly curved distally. The crowns of Fig.136-4,5 are erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex

and the labial face is flattened. The root is distinctly bifid.

Carcharodon hubbelli Ehret *et al.*, 2012

Figure 137-1,2

Description: The crown is broad and equilaterally triangular. The crown of Fig.137-1 is slightly curved distally. The crown of Fig.137-2 is erect. The cutting edge has weak serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharodon plicatilis (Agassiz, 1843)

Figure 137-3

Description: The crown is very broad and equilaterally triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: This specimen has a much wider crown than *C. hastalis*.

Genus *Isurus* Rafinesque, 1810

Isurus oxyrinchus Rafinesque, 1810

Figure 137-4,5,6

Description: The crowns of Fig.137-4,5 are elongated and slightly curved distally. The crown of Fig.137-6 is broad and strongly curved distally. The

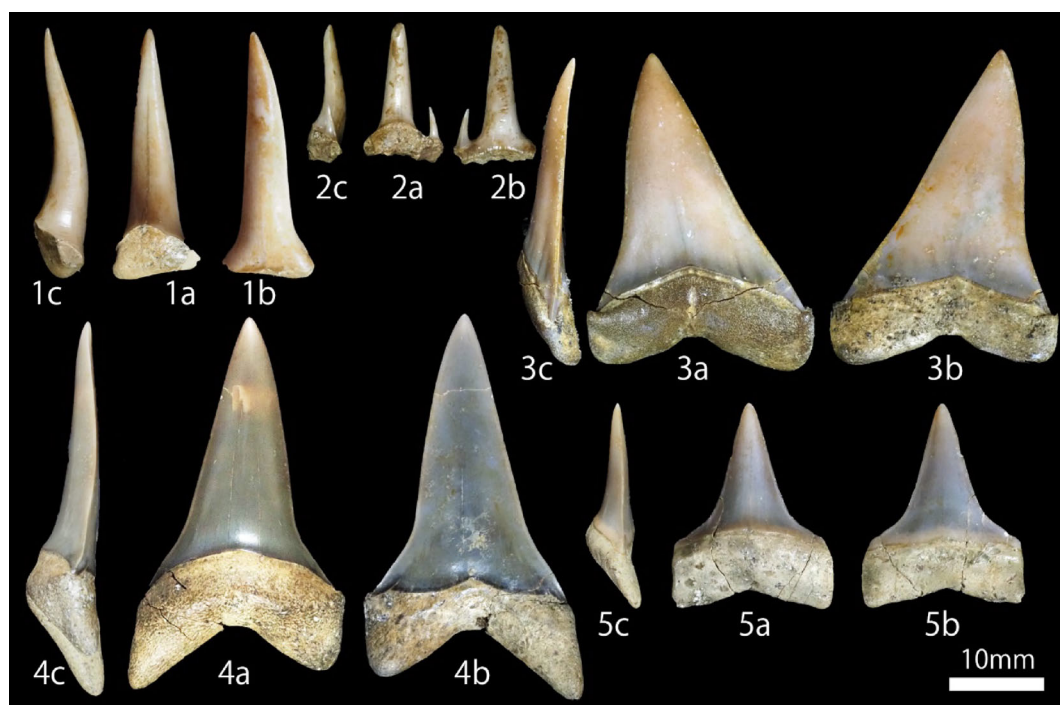


Figure 136. 1, *Odontaspis ferox*, NMNS-PV 28425, lingual (a), labial (b) and profile (c) views; 2, *Odontaspis ferox*, NMNS-PV 32512, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon hastalis*, NMNS-PV 28444, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon hastalis*, NMNS-PV 32408, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon hastalis*, NMNS-PV 28437, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Isurus paucus Guitart Manday, 1966

Figure 137-7

Description: The tooth of this specimen is thinner with the lingual face of the crown convex, but not as much as in *I. oxyrinchus*. The crown is elongated and slightly curved distally. The cutting edge of the crown has no serrations. The labial face is flat. The root is distinctly bifid.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 138-1,2

Description: The teeth are very large. The crown

is broadly triangular and slightly curved distally. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat. The root is bifid.

Remarks: Fig.138-2 is the juvenile tooth.

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 139-1,2

Description: The crown of Fig.139-1 is very thick, erect and slightly curved distally. The crown of Fig.139-2 is very thick and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.



Figure 137. 1, *Carcharodon hubbelli*, NMNS-PV 28592, lingual (a) and labial (b) views; 2, *Carcharodon hubbelli*, NMNS-PV 28599, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon plicatilis*, NMNS-PV 32398, lingual (a), labial (b) and profile (c) views; 4, *Isurus oxyrinchus*, NMNS-PV 28600, lingual (a), labial (b) and profile (c) views; 5, *Isurus oxyrinchus*, NMNS-PV 28605, lingual (a), labial (b) and profile (c) views; 6, *Isurus oxyrinchus*, NMNS-PV 28604, lingual (a), labial (b) and profile (c) views; 7, *Isurus paucus*, NMNS-PV 28707, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.



Figure 138. 1, *Otodus megalodon*, NMNS-PV 32321, lingual (a), labial (b) and profile (c) views; 2, *Otodus megalodon*, NMNS-PV 32322, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

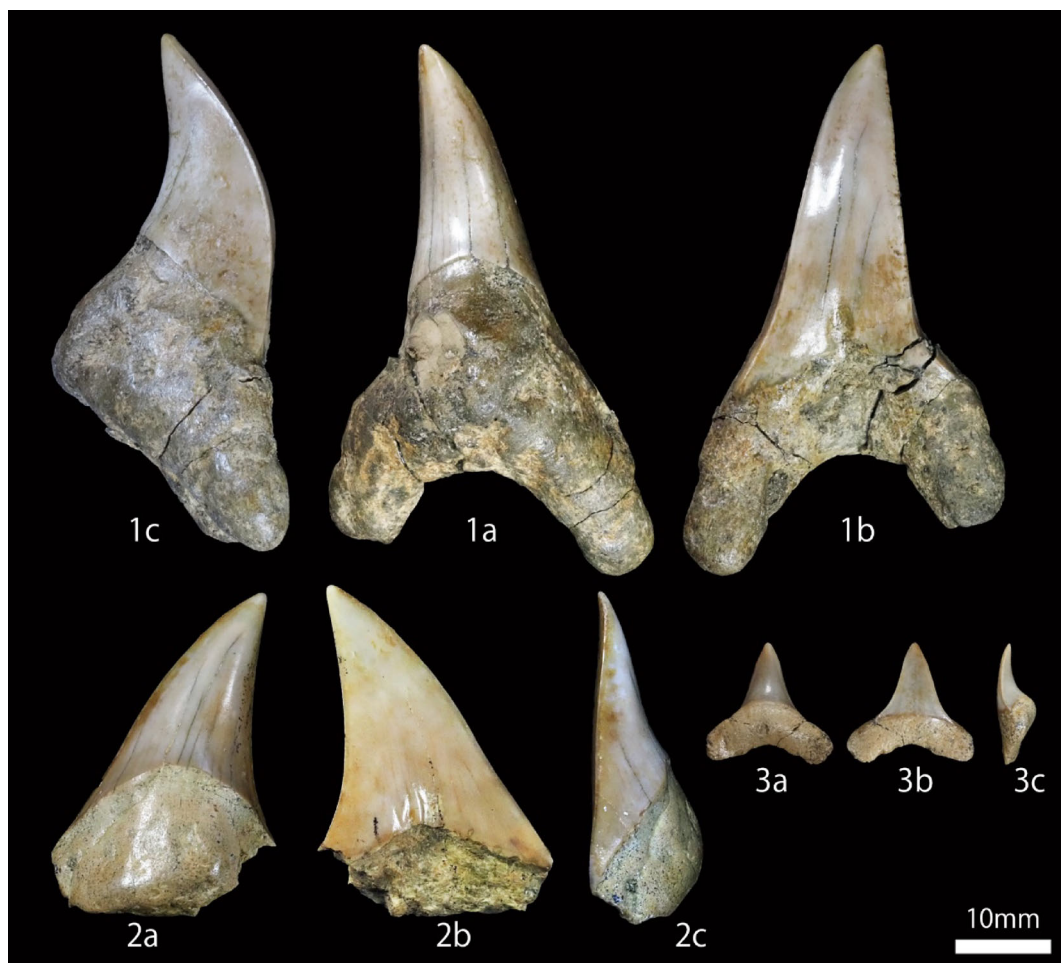


Figure 139. 1, *Parotodus benedeni*, NMNS-PV 32323, lingual (a), labial (b) and profile (c) views; 2, *Parotodus benedeni*, NMNS-PV 28722, lingual (a), labial (b) and profile (c) views; 3, *Alopias* sp., NMNS-PV 28434, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Family Alopiidae Bonaparte, 1838

Genus *Alopias* Rafinesque, 1810

Alopias sp.

Figure 139-3

Description: The crown is narrowly triangular and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid and quite long.

Order Carcharhiniformes Compagno, 1973

Family Triakidae Gray, 1851

Genus *Galeorhinus* Blainville, 1816

Galeorhinus sp.

Figure 140-1

Description: The crown is nearly equilaterally



Figure 140. 1, *Galeorhinus* sp., NMNS-PV 28734, Scale bar equals 5 mm.

triangular and curved distally. The mesial cutting edge of the crown has multiple rough serrations, but the distal cutting edge has no serrations.

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassi, 1843

Hemipristis serra Agassiz, 1843

Figure 141-1,2

Description: The crown of Fig.141-1 is triangular and curved distally. The crown of Fig.141-2 is elongated and slightly curved distally. The cutting edge of the crown has rough serrations and these serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus amboinensis

(Müller and Henle, 1839)

Figure 141-3

Description: The crown is nearly equilaterally triangular and hardly curved distally. The cutting edge of the crown has rough serrations, the upper part of the crown being finely serrated and the lower part becoming slightly rougher than the middle. The central part of the distal cutting edge is slightly convex. The lingual face of the crown is convex and the labial face is flat.

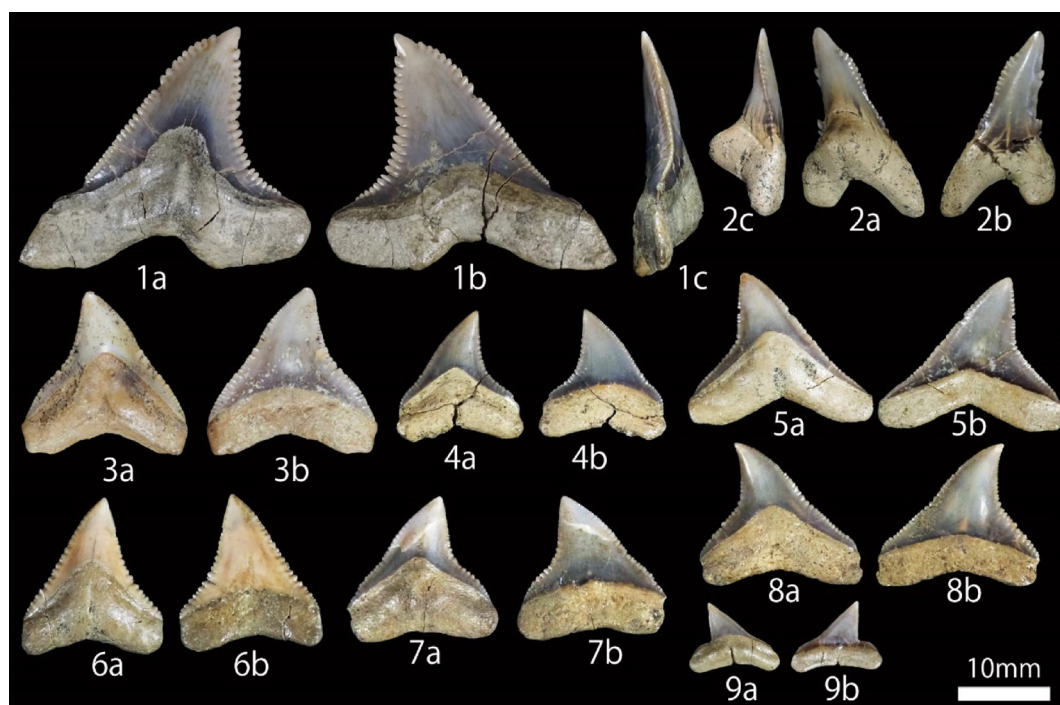


Figure 141. 1, *Hemipristis serra*, NMNS-PV 28736, lingual (a), labial (b) and profile (c) views; 2, *Hemipristis serra*, NMNS-PV 28737, lingual (a), labial (b) and profile (c) views; 3, *Carcharhinus amboinensis*, NMNS-PV 32417, lingual (a) and labial (b) views; 4, *Carcharhinus altimus*, NMNS-PV 28748, lingual (a) and labial (b) views; 5, *Carcharhinus brachyurus*, NMNS-PV 28749, lingual (a) and labial (b) views; 6, *Carcharhinus leucas*, NMNS-PV 28751, lingual (a) and labial (b) views; 7, *Carcharhinus obscurus*, NMNS-PV 28753, lingual (a) and labial (b) views; 8, *Carcharhinus plumbeus*, NMNS-PV 28755, lingual (a) and labial (b) views; 9, *Sphyrna lewini*, NMNS-PV 28974, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Carcharhinus altimus (Springer, 1950)

Figure 141-4

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus brachyurus (Günther, 1870)

Figure 141-5

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus leucas (Müller and Henle, 1839)

Figure 141-6

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)

Figure 141-7

Description: The crown is broad, triangular and

curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus plumbeus (Nardo, 1827)

Figure 141-8

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Family Sphyrnidae Gill, 1872

Genus *Sphyrna* Rafinesque, 1810*Sphyrna lewini* (Griffith and Smith, 1834)

Figure 141-9

Description: The crown is triangular and concave near the apex. The cutting edge of the crown has no serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Caudal spine

Figure 142-1

Description: This is elongated and pointed at the tip like a spear. Both sides have fine spiny projections.



Figure 142. 1, caudal spine, NMNS-PV 28997, dorsal (a) and profile (c) viwes; 2, vertebra, NMNS-PV 28998, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.

Remarks: This is the caudal spine of *Myliobatiformes*.

Vertebra
Figure 142-2

Description: This has a mill-shape with a concave center. There is a round and almost square hole on the side, but no slits.

Remarks: This is vertebra of the family *Carcharhinidae*.

Additional records: In addition to the species reported here, there are reports of *Isistius* sp., *Sphyrna zygaena* according to Yabe and Hirayama (1998).

59. Harada Formation, Shirahama Group

Locality: Shirahama, Shimoda City, Shizuoka Prefecture

Formation and Age: Harada Formation, Early Pliocene. According to Ibaraki (1976), the age of the Harada Formation of the Shirahama Group is considered to be Early Pliocene (5 Ma) based on the planktonic foraminifera.

Order Squaliformes Goodrich, 1909
Family Dalatiidae Gray, 1851
Genus *Dalatias* Rafinesque, 1810
Dalatias licha (Bonnaterre, 1788)
Figure 143-1

Description: The crown is nearly equilateral triangular and erect or slightly curved distally. The cutting edge of the crown has fine serrations, but

these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Pristiophoriformes Berg, 1958
Family Pristiophoridae Bleeker, 1859
Genus *Pristiophorus* Müller and Henle, 1837
Pristiophorus japonicus Günther, 1870
Figure 143-2

Description: The crown is knife-shaped and thin.

Remarks: This is the rostral tooth of the rostrum.

Order Heterodontiformes Berg, 1937
Family Heterodontidae Gray, 1851
Genus *Heterodontus* Blainville, 1816
Heterodontus sp.
Figure 143-3

Description: This tooth is of the cobblestone grinding type, elongated, parallelogram. The crown surface has numerous wrinkles.

Order Lamniformes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon carcharias (Linnaeus, 1758)
Figure 144-1,2,3

Description: The crown is broad, equilaterally triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.



Figure 143. 1, *Dalatias licha*, NMNS-PV 29955, lingual (a), labial (b) and profile (c) views; 2, *Pristiophorus japonicus*, NMNS-PV 29956, articular or axial (a) and dorsal or ventral (b) views; 3, *Heterodontus* sp., NMNS-PV 29959, occlusal (a) and lingual (b) views. Scale bar equals 5 mm (1,2) and 10 mm (3).

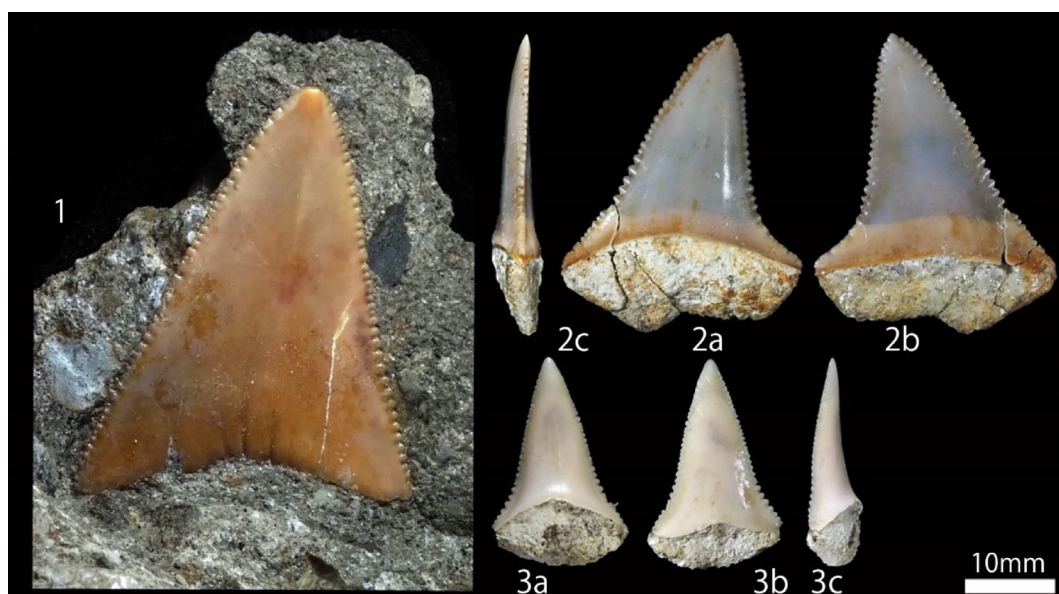


Figure 144. 1, *Carcharodon carcharias*, NMNS-PV 29979; 2, *Carcharodon carcharias*, NMNS-PV 29972, lingual (a), labial (b) and profile (c) views. 3, *Carcharodon carcharias*, NMNS-PV 29984, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo cuvier (Péron and Lesueur, 1822)
 Figure 145-1

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus altimus (Springer, 1950)
 Figure 145-2

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations.

Carcharhinus brachyurus (Günther, 1870)
 Figure 145-3

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)
 Figure 145-4

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus plumbeus (Nardo, 1827)
 Figure 145-5

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The



Figure 145. 1, *Galeocerdo cuvier*, NMNS-PV 29992; 2, *Carcharhinus altimus*, NMNS-PV 29993. 3, *Carcharhinus brachyurus*, NMNS-PV 29994, lingual (a) and labial (b) views; 4, *Carcharhinus obscurus*, NMNS-PV 29995, lingual (a) and labial (b) views; 5, *Carcharhinus plumbeus*, NMNS-PV 29996, lingual (a) and labial (b) views. Scale bar equals 10 mm.

lingual face of the crown is convex and the labial face is flat.

60. Tatsunokuchi Formation, Sendai Group

Locality: Kawauchi, Aoba Ward, Sendai City, Miyagi Prefecture

Formation and Age: Tatsunokuchi Formation, Early Pliocene. According to Yanagisawa (1990), the age of the Tatsunokuchi Formation of the Sendai Group is considered to be Early Pliocene (5.4 Ma) based on the diatom fossils.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Squalus* Linnaeus, 1758

Squalus sp.

Figure 146-1

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The labial face of the crown is extended so that its central part overhangs the root.



Figure 146. 1, *Squalus* sp., NMNS-PV 29345, lingual (a) and labial (b) views. Scale bar equals 5 mm.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 147-1,2

Description: The crown is broad, equilaterally triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat. Fig.147-1 has the cusplets. Fig.147-2 has small and the low crown.

Remarks: Fig.147-1 is close for the juvenile tooth. Fig.147-2 is the lateral-posterior tooth.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus altimus (Springer, 1950)

Figure 147-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus falciformis

(Bibron in Müller and Henle, 1839)

Figure 147-4

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown

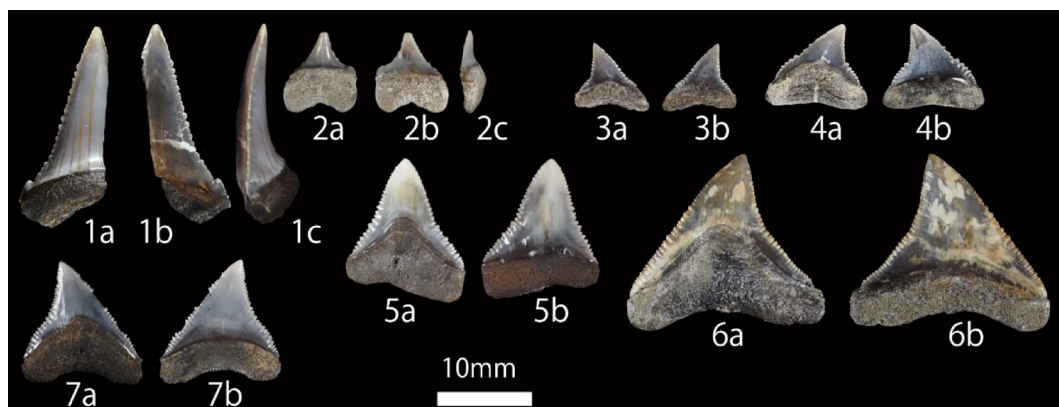


Figure 147. 1, *Carcharodon carcharias*, NMNS-PV 29346, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 29347, lingual (a), labial (b) and profile (c) views; 3, *Carcharhinus altimus*, NMNS-PV 29348, lingual (a) and labial (b) views; 4, *Carcharhinus falciformis*, NMNS-PV 29349, lingual (a) and labial (b) views; 5, *Carcharhinus galapagensis*, NMNS-PV 29352, lingual (a) and labial (b) views; 6, *Carcharhinus leucas*, NMNS-PV 29353, lingual (a) and labial (b) views; 7, *Carcharhinus obscurus*, NMNS-PV 29354, lingual (a) and labial (b) views. Scale bar equals 10 mm.

has a deep central notch, which is finely serrated above and roughened below. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus galapagensis
(Snodgrass and Heller, 1905)

Figure 147-5

Description: The crown is isosceles triangular and erect. The cutting edge of the crown has regular serrations. The mesial cutting edge of the crown is slightly concave in the center and the distal cutting edge is gently curved. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus leucas (Müller and Henle, 1839)

Figure 147-6

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)

Figure 147-7

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Rajiformes Berg, 1940
Family Rajidae Blainville, 1816
Genus *Raja* Linnaeus, 1758
Raja pulchra Liu, 1932
Figure 148-1

Description: The crown is very long and pointed. The crown is conical with a brim like a hat at the base of the crown. The root hangs down from the lower part of the crown of the tooth.

Order Myliobatiformes Compagno, 1973
Family Dasyatidae Jordan, 1888
Dasyatidae gen. et sp. indet.
Figure 148-2

Description: This is a small tooth. The crown is

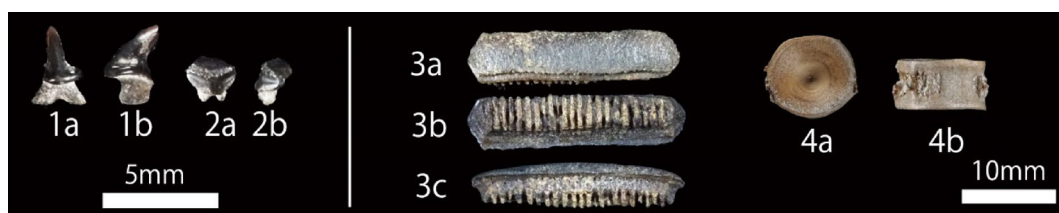


Figure 148. 1, *Raja pulchra*, NMNS-PV 29368, lingual (a) labial and profile (b) views; 2, *Dasyatidae* gen. et sp. indet., NMNS-PV 29370, lingual (a) and profile (b) views; 3, *Myliobatis sendaicus*, NMNS-PV 29371, occlusal (a), basal (b) and lingual (c) views; 4, vertebra, NMNS-PV 29379, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 5 mm (1,2) and 10 mm (3,4).

conical and pointed. The apex of the crown is tilted posteriorly. The root hangs down from the lower part of the crown of the tooth.

Family Myliobatididae Bonaparte, 1838

Genus *Myliobatis* Cuvier, 1816

Myliobatis sendaicus Hatai *et al.*, 1965

Figure 148-3

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Vertebra

Figure 148-4

Description: This has a mill-shape with a concave center. There is a round and almost square hole on the side, but no slits.

Remarks: This is the vertebra of the family Carcharhinidae.

Additional records: In addition to the species reported here, there are reports of *Otodus megalodon* (Reported as *Carcharodon megalodon* in Hatai *et al.*, 1974) according to Hatai *et al.* (1974), *Squatina* sp., *Cetorhinus* sp., *Carcharhinus* cf. *C. longimanus*, *Sphyrna zygaena*, *Dasyatis akajei*, caudal spine of *Myliobatis* sp. according to Nakai (2020).

61. Hasse Formation, Miura Group

Locality: Sajima, Yokosuka City, Kanagawa

Prefecture

Formation and Age: Hasse Formation, Early Pliocene. According to Kanie *et al.* (1991), the age of the Hasse Formation of the Miura Group is considered to be Early Pliocene based on the calcareous nannofossil.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Odontaspis* Agassiz, 1838

Odontaspis ferox (Risso, 1810)

Figure 149-1,2

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 149-3

Description: The cutting edge of the crown has regular and fine serrations.

62. Shigarami Formation

Locality: Togagushi, Nagano City, Nagano Prefecture

Formation and Age: Shigarami Formation, Late Pliocene. According to Tsuchi and Ibaraki (1988), the age of the Shigarami Formation is



Figure 149. 1, *Odontaspis ferox*, NMNS-PV 29054, lingual (a), labial (b) and profile (c) views; 2, *Odontaspis ferox*, NMNS-PV 29055, lingual (a), labial (b) and profile (c) views; 3, *Otodus megalodon*, NMNS-PV 29056. Scale bar equals 10 mm.

considered to be Late Pliocene (4–3 Ma) based on the planktonic foraminifera.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 150-1

Description: The crown is broad, equilaterally triangular and erect. The labial face is flat. The cutting edge of the crown has regular serrations.

Additional records: In addition to the species reported here, there are reports of *Carcharodon hubbelli* (Reported as *Isurus escheri* in Goto *et al.*, 1993) according to Goto *et al.* (1993).

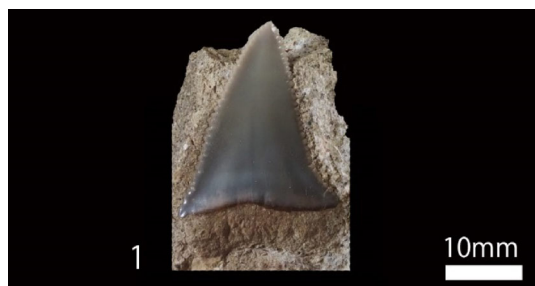


Figure 150. 1, *Carcharodon carcharias*, NMNS-PV 34020. Scale bar equals 10 mm.

63. Shimajiri Group or Chinen Formation

Locality: Teruma Coast, Uruma City, Okinawa Prefecture

Formation and Age: Shimajiri Group or Chinen Formation, Pliocene. According to Tanaka and Ujiie (1984) and Imai *et al.* (2013), the age of the formation is Late Miocene to Early Pleistocene. However, the stratigraphic position of the fossil is not known because most of the specimens are collected as floats along the Teruma Coast. The identification of the specimen in the present study based on the serrations (those of *Carcharodon carcharias* are not weakly serrated like those of *C. hubbelli*, but are closer to those of the extant species) makes it unlikely that the specimen comes from the Late Miocene age formation. The occurrence of *Otodus megalodon* suggests that the *C. carcharias* is not newer than the Pleistocene and is probably from Pliocene of the Shimajiri Group or the Chinen Formation.

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Genus *Notorynchus* Ayres, 1855

Notorynchus cepedianus (Péron, 1807)

Figure 151-1

Description: The crown is multituberculate becoming progressively smaller from the first cusp towards the distal cusp. The lower part of the mesial cutting edge of the first cusp has distinct serrations that increase in size towards the cusp apex.

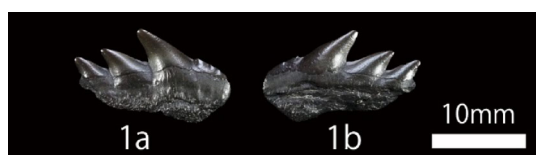


Figure 151. 1, *Notorynchus cepedianus*, NMNS-PV 33937, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 152-1,2

Description: The crown is broad, equilaterally triangular and erect. The lingual face of the crown is convex and the labial face is flat. The cutting edge of the crown has regular serrations.

Genus *Isurus* Rafinesque, 1810

Isurus oxyrinchus Rafinesque, 1810

Figure 152-3

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 153-1

Description: The tooth is large. The crown is broadly triangular and erect. The cutting edge has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Genus *Parotodus* Cappetta, 1980

Parotodus benedeni (Le Hon, 1871)

Figure 154-1

Description: The crown is very thick, erect and

strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Hemigaleidae Hasse, 1879

Genus *Hemipristis* Agassiz, 1843

Hemipristis serra Agassiz, 1843

Figure 155-1

Description: The crown is elongated and slightly curved distally. The cutting edge of the crown has rough serrations and these serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocерdo* Müller and Henle, 1837

Galeocерdo cuvier (Péron and Lesueur, 1822)

Figure 155-2

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Carcharhinus* Blainville, 1816

Carcharhinus altimus (Springer, 1950)

Figure 155-3

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.



Figure 152. 1, *Carcharodon carcharias*, NMNS-PV 30057, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 30058, lingual (a), labial (b) and profile (c) views; 3, *Isurus oxyrinchus*, NMNS-PV 30072, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

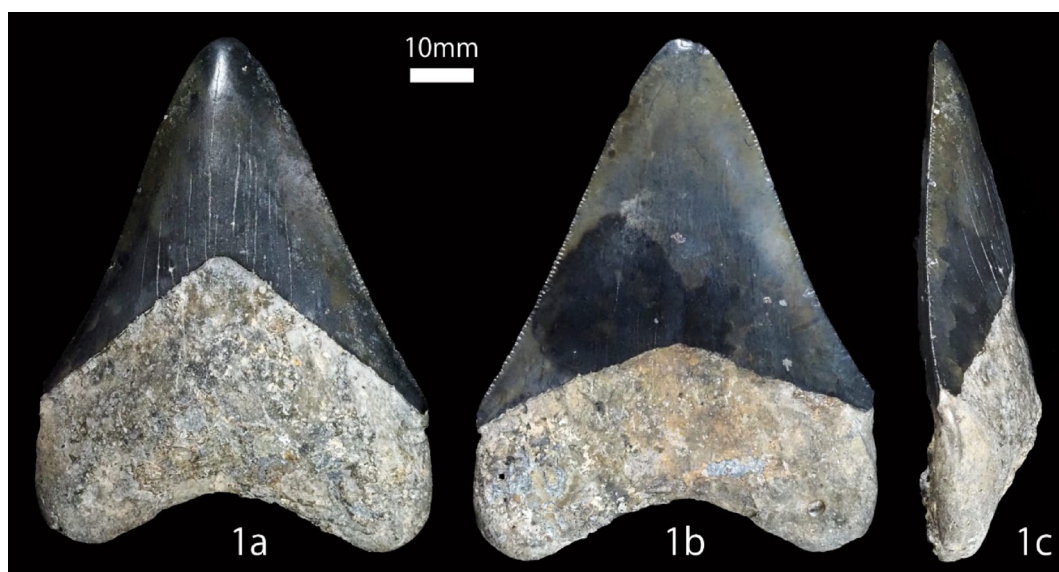


Figure 153. 1, *Otodus megalodon*, NMNS-PV 30072, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.



Figure 154. 1, *Parotodus benedeni*, NMNS-PV 30074, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Carcharhinus leucas (Müller and Henle, 1839)
Figure 155-4

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus limbatus (Valenciennes, 1839)
Figure 155-5

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has very fine serrations with slightly rougher serrations at the base. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species

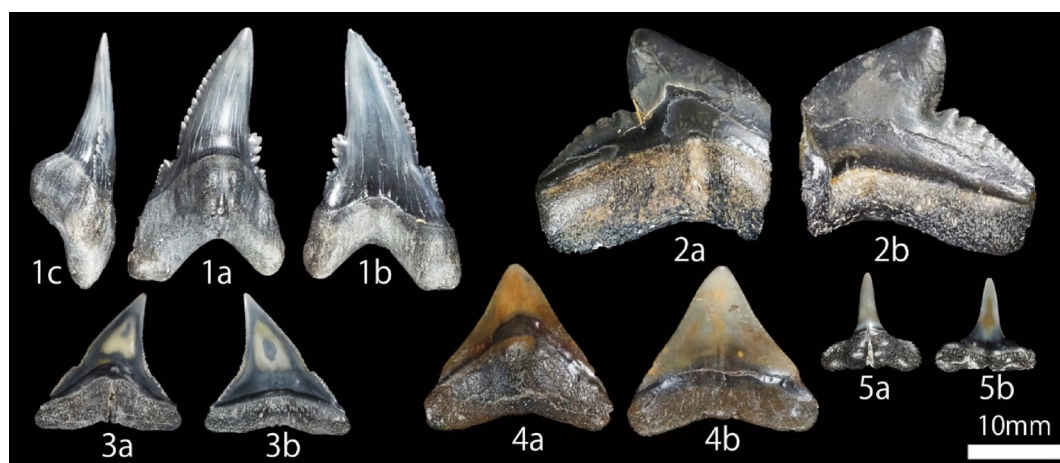


Figure 155. 1, *Hemipristis serra*, NMNS-PV 30076, lingual (a), labial (b) and profile (c) views; 2, *Galeocerdo cuvier*, NMNS-PV 30078, lingual (a) and labial (b) views; 3, *Carcharhinus altimus*, NMNS-PV 30081, lingual (a) and labial (b) views; 4, *Carcharhinus leucas*, NMNS-PV 30080, lingual (a) and labial (b) views; 5, *Carcharhinus limbatus*, NMNS-PV 30083, lingual (a) and labial (b) views. Scale bar equals 10 mm.

reported here, there are reports of *Megachasma* cf. *M. pelagios* according to Tomita and Yokoyama (2015).

64. Nobori Formation, Tonohama Group

Locality: Hanecho, Muroto City, Kochi Prefecture

Formation and Age: Nobori Formation, Pliocene. According to Matsubara (2004), the age of the Nobori Formation of the Tonohama Group is considered to be Pliocene (4.2–3.2 Ma) based on the microfossil data.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus sp.
Figure 156-1

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Mitsukurina owstoni*, *Lamna ditropis*, according to Uyeno *et al.* (1996), *Isurus oxyrinchus* according to Tanaka and Mimoto (1991), Uyeno *et al.* (1996), *Carcharodon carcharias* according to Uyeno *et al.* (1975), Tanaka and Mimoto (1991), Uyeno *et al.* (1996), vertebra, according to Tanaka and Mimoto (1991).

65. Dainenji Formation, Sendai Group

Locality: Futatsunuma, Hirono Town, Futaba-Gun, Fukushima Prefecture.

Formation and Age: Dainenji Formation, Pliocene. According to Yanagisawa *et al.* (2003), the age of the Dainenji Formation of the Sendai Group is considered to be Pliocene (2.4–4.0 Ma) based on the various microfossils.



Figure 156. 1, *Carcharhinus* sp., NMNS-PV 30056, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Odontaspis* Agassiz, 1838
Odontaspis ferox (Risso, 1810)
 Figure 157-1

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. There are several pairs of thin, rather long lateral cusplets are present on each side of the main cusp. The lingual face of the crown is convex and the labial face is slightly convex. The root is distinctly bifid.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon carcharias (Linnaeus, 1758)
 Figure 157-2

Description: The crown is broad, equilaterally triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus brachyurus (Günther, 1870)
 Figure 157-3

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)
 Figure 157-4

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Dalatias* sp., *Odontaspis cuspidatus*, *Isurus oxyrinchus* (Reported as *Isurus hastalis* in Hashimoto and Koda, 1979), *Otodus megalodon* (Reported as

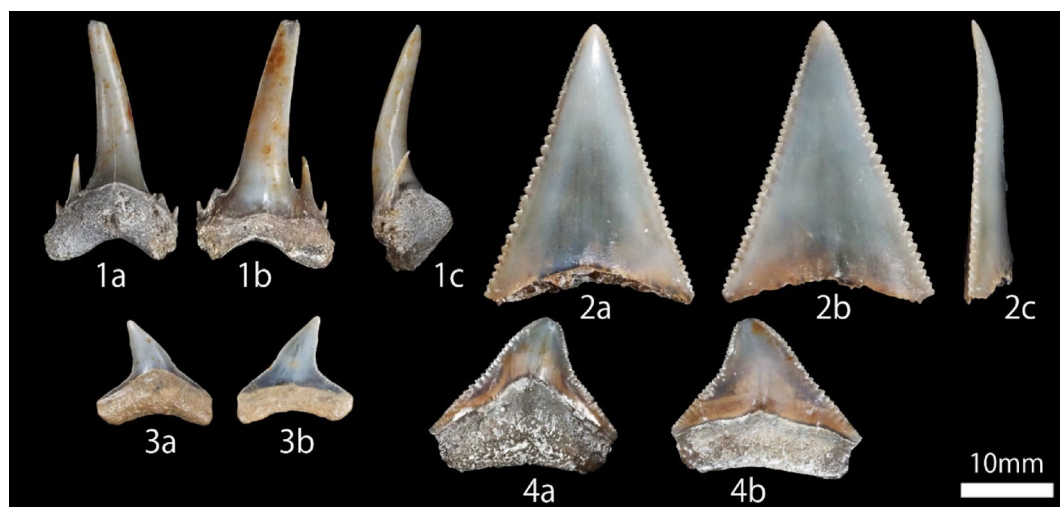


Figure 157. 1, *Odontaspis ferox*, NMNS-PV 29384, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 29385, lingual (a), labial (b) and profile (c) views; 3, *Carcharhinus brachyurus*, NMNS-PV 29386, lingual (a) and labial (b) views; 4, *Carcharhinus obscurus*, NMNS-PV 29387, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Carcharodon megalodon in Hashimoto and Koda, 1979), *Parotodus benedeni* (Reported as *Isurus* cf. *hastalis* in Hashimoto and Koda, 1979), *Myliobatis* sp. according to Hashimoto and Koda (1979).

66. Zugawa Formation, Hokuriku Group

Locality: Zugawa, Takaoka City, Toyama Prefecture

Formation and Age: Zugawa Formation, Late Pliocene. According to Amano *et al.* (2012), the age of the Zugawa Formation of the Hokuriku Group is considered to be Late Pliocene based on the calcareous nannofossil.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 158-1

Description: The crown is broad, equilaterally triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.

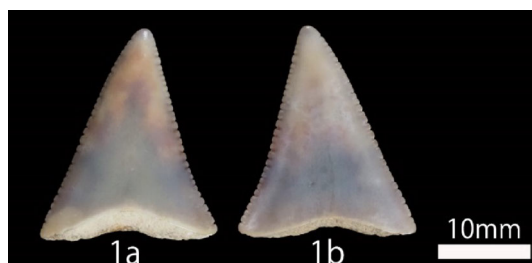


Figure 158. 1, *Carcharodon carcharias*, NMNS-PV 30048, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Family Otodontidae Glickman, 1964

Genus *Otodus* Agassiz, 1838

Otodus megalodon (Agassiz, 1843)

Figure 159-1

Description: The tooth is very large. The crown is broadly triangular and erect. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Odontaspis*



Figure 159. 1, *Otodus megalodon*, NMNS-PV 30049, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

ferox, *Isurus oxyrinchus*, *Carcharhinus* sp. according to Furumi *et al.* (2014b), *Isurus hastalis*, *Isurus* sp. according to Matsumoto *et al.* (2018).

67. Naarai Formation, Inubo Group

Locality: Togawa, Choshi City, Chiba Prefecture.

Formation and Age: Naarai Formation, Late Pliocene. According to Ishikawa and Hatta (1984) and Nakamitsu *et al.* (2008), the age of the Naarai Formation of the Inubo Group is considered to be Late Pliocene (3 Ma) based on the planktonic foraminifera.

Order Squaliformes Goodrich, 1909

Family Dalatiidae Gray, 1851

Genus *Dalatias* Rafinesque, 1810

Dalatias licha (Bonnaterre, 1788)

Figure 160-1

Description: The crown is nearly equilateral triangular and erect or slightly curved distally. The cutting edge of the crown has fine serrations, but these are directed upwards. The lingual face of the crown is slightly convex and the labial face is flat.

Order Pristiophoriformes Berg, 1958

Family Pristiophoridae Bleeker, 1859

Genus *Pristiophorus* Müller and Henle, 1837

Pristiophorus japonicus Günther, 1870

Figure 160-2

Description: The crown is knife-shaped and thin.

Remarks: This is the rostral tooth of the ro-

trum.

Order Heterodontiformes Berg, 1937

Family Heterodontidae Gray, 1851

Genus *Heterodontus* Blainville, 1816

Heterodontus sp.

Figure 160-3

Description: This tooth is of the cobblestone grinding type, elongated, parallelogram. The crown surface has numerous wrinkles.

Order Lamniformes Berg, 1958

Family Odontaspidae Müller and Henle, 1839

Genus *Odontaspis* Agassiz, 1838

Odontaspis ferox (Risso, 1810)

Figure 161-1

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The trace of a cusplet can be seen on one side. The lingual face of the crown is convex and the labial face is slightly convex.

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 161-2,3,4,5

Description: The crown is broad, equilaterally triangular and erect. The cutting edge of the



Figure 160. 1, *Dalatias licha*, NMNS-PV 29391, lingual (a), labial (b) and profile (c) views; 2, *Pristiophorus japonicus*, NMNS-PV 29398, articular or axial (a) and dorsal or ventral (b) views; 3, *Heterodontus* sp., NMNS-PV 32534, occlusal (a) and lingual (b) views. Scale bar equals 5 mm (1,2) and 10 mm (3).

crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: Fig.161-5 is small and the crown is very thin, indicating that it is closed for the juvenile tooth.

Carcharodon hastalis (Agassiz, 1838)

Figure 161-6

Description: The crown is broad, equilaterally triangular and erect. The cutting edge of the crown has no serrations. The lingual face of the

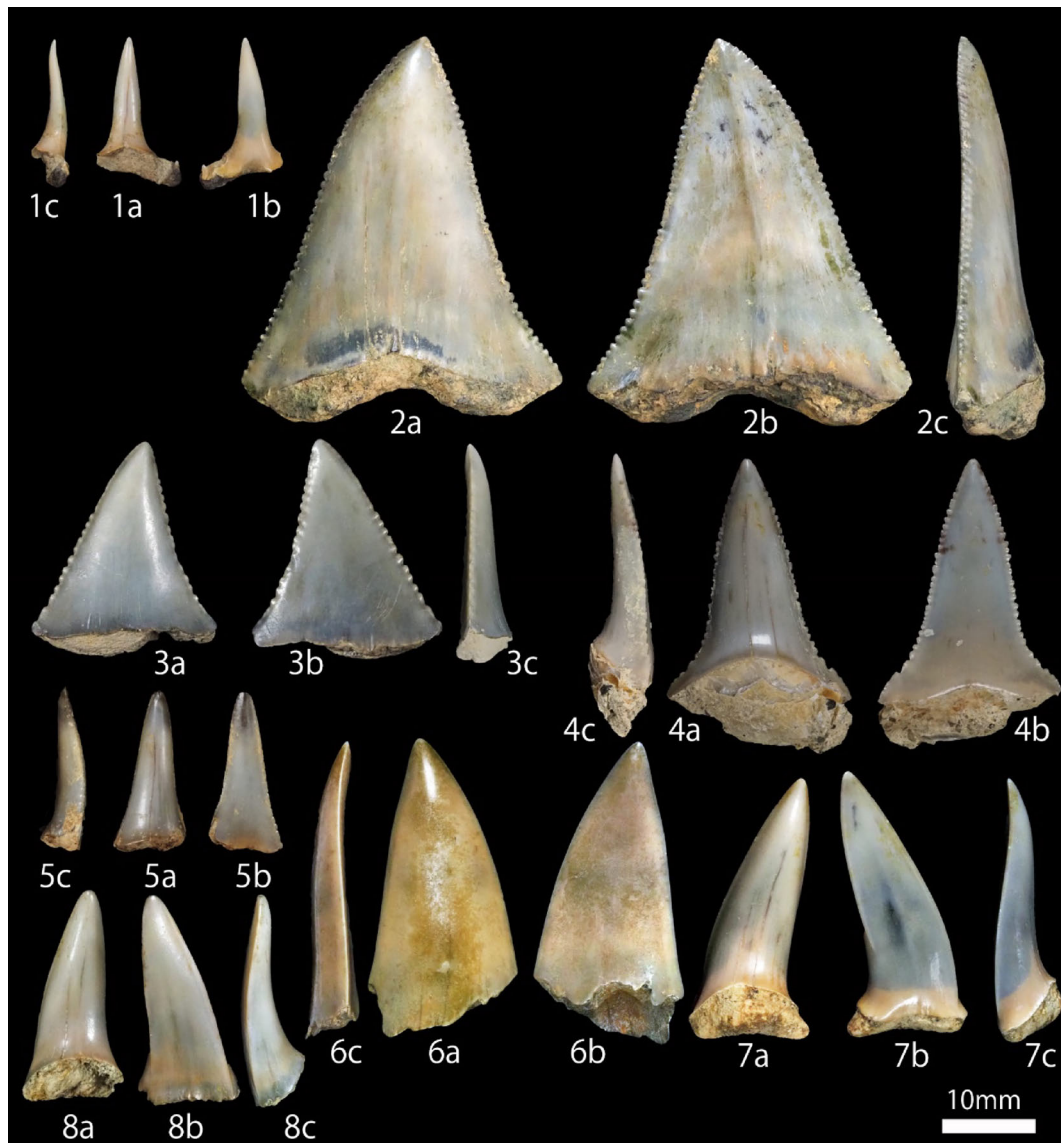


Figure 161. 1, *Odontaspis ferox*, NMNS-PV 29408, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 32537, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon carcharias*, NMNS-PV 29420, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon carcharias*, NMNS-PV 29421, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon carcharias*, NMNS-PV 29569, lingual (a), labial (b) and profile (c) views; 6, *Carcharodon hastalis*, NMNS-PV 29612, lingual (a), labial (b) and profile (c) views; 7, *Isurus oxyrinchus*, NMNS-PV 29628, lingual (a), labial (b) and profile (c) views; 8, *Isurus oxyrinchus*, NMNS-PV 29629, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

crown is convex and the labial face is flat.

Remarks: Some fossil specimens from the Naarai Formation are heavily worn. This specimen may also have lost its serrations due to wear.

Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810
 Figure 161-7,8

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is

strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964
 Genus *Otodus* Agassiz, 1838
Otodus megalodon (Agassiz, 1843)
 Figure 162-1,163-1,2

Description: The teeth of Fig.162-1 and 163-1 are very large. The crown is broadly triangular and erect. The crown of Fig.163-2 is low. The cutting edge of the crown has the regular fine serrations. The lingual face of the crown is con-



Figure 162. 1, *Otodus megalodon*, NMNS-PV 29614, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

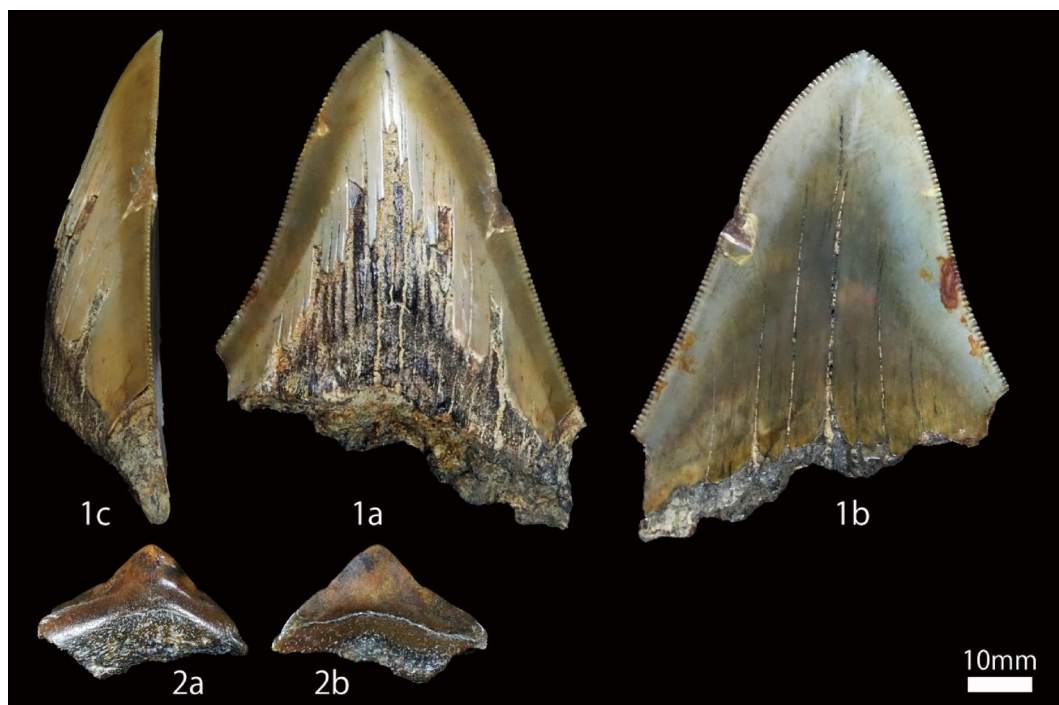


Figure 163. 1, *Otodus megalodon*, NMNS-PV 29615, lingual (a), labial (b) and profile (c) views; 2, *Otodus megalodon*, NMNS-PV 29620, lingual (a) and labial (b) views. Scale bar equals 10 mm.

vex and the labial face is flat.

Remarks: Fig.163-2 is the lateral-posterior tooth.

Genus *Parotodus* Cappetta, 1980
Parotodus benedeni (Le Hon, 1871)
 Figure 164-1,2

Description: The crown of Fig.164-1 is very thick and strongly curved distally. The crown of Fig.164-2 is erect. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniiformes Compagno, 1973
 Family Hemigaleidae Hasse, 1879
 Genus *Hemipristis* Agassi, 1843
Hemipristis serra Agassiz, 1843
 Figure 164-3

Description: The crown is triangular and curved distally. The cutting edge of the crown has rough

serrations and these serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat.

Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus brachyurus (Günther, 1870)
 Figure 164-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus falciformis
 (Bibron in Müller and Henle, 1839)
 Figure 164-5

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has a deep median notch, which is finely serrated above, and roughened below. The lingual face of

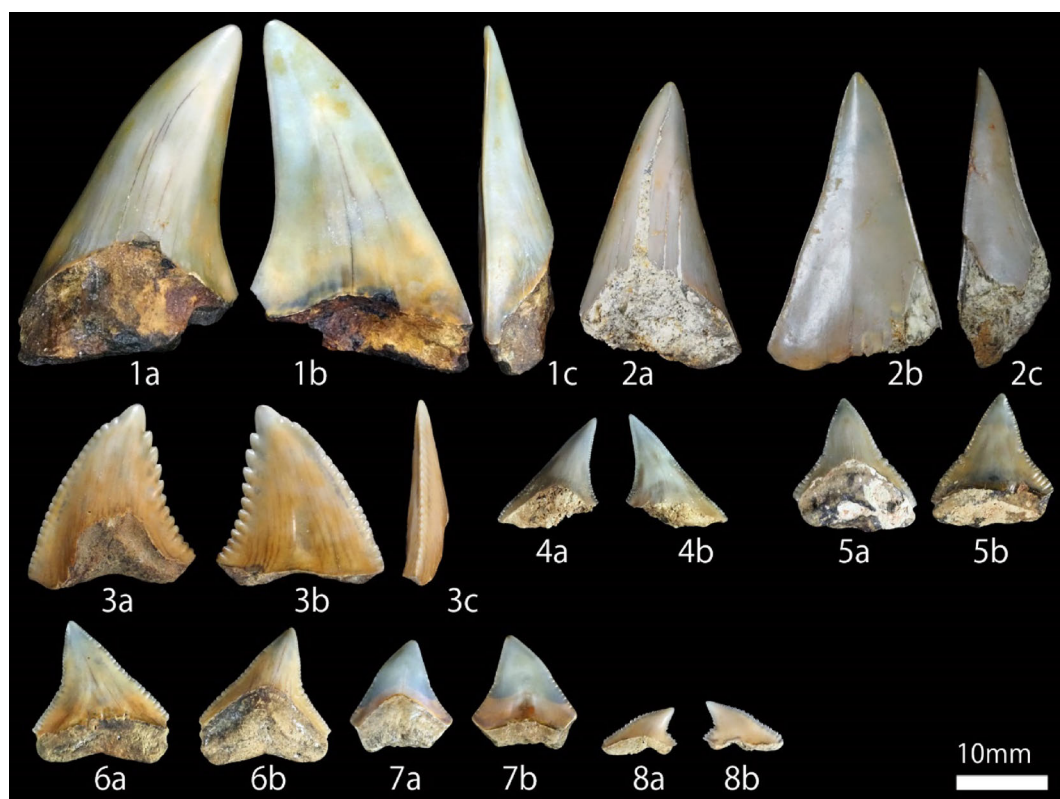


Figure 164. 1, *Parotodus benedeni*, NMNS-PV 32538, lingual (a), labial (b) and profile (c) views; 2, *Parotodus benedeni*, NMNS-PV 29626, lingual (a), labial (b) and profile (c) views; 3, *Hemipristis serra*, NMNS-PV 32536, lingual (a), labial (b) and profile (c) views; 4, *Carcharhinus brachyurus*, NMNS-PV 29666, lingual (a) and labial (b) views; 5, *Carcharhinus falciformis*, NMNS-PV 29667, lingual (a) and labial (b) views; 6, *Carcharhinus leucas*, NMNS-PV 29668, lingual (a) and labial (b) views; 7, *Carcharhinus obscurus*, NMNS-PV 29669, lingual (a) and labial (b) views; 8, *Carcharhinus sorrah*, NMNS-PV 29670, lingual (a) and labial (b) views. Scale bar equals 10 mm.

the crown is convex and the labial face is flat.

Carcharhinus leucas (Müller and Henle, 1839)

Figure 164-6

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)

Figure 164-7

Description: The crown is broad, triangular and

curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus sorrah (Müller and Henle, 1839)

Figure 164-8

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has fine serrations and the basal part of the mesial cutting edge has very rough serrations. The distal cutting edge is straight. The lingual face of the crown is convex and the labial face is flat.

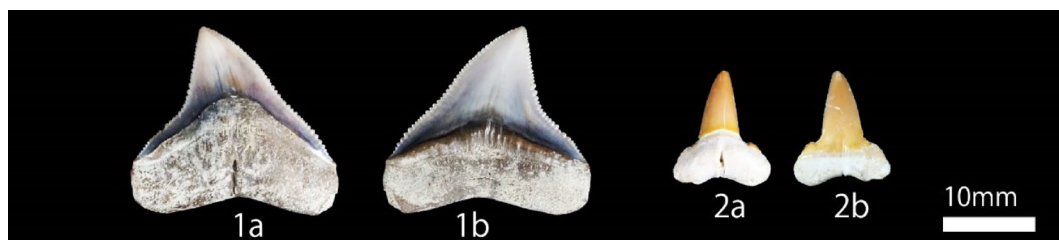


Figure 165. 1, *Carcharhinus obscurus*, NMNS-PV 30050, lingual (a) and labial (b) views; 2, *Negaprion acutidens*, NMNS-PV 30055, lingual (a) and labial (b) views. Scale bar equals 10 mm.

68. Ananai Formation, Tonohama Group

Locality: Tonohama, Yasuda Town, Aki-Gun Kochi Prefecture

Formation and Age: Ananai Formation, Late Pliocene-Early Pleistocene. According to Matsubara (2004), the age of the Ananai Formation of the Tonohama Group is considered to be Late Pliocene-Early Pleistocene (2.78–1.98 Ma) based on the microfossil data.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus obscurus (Lesueur, 1818)
Figure 165-1

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Genus *Negaprion* Whitley, 1940
Negaprion acutidens (Rüppell, 1837)
Figure 165-2

Description: The crown is thin, triangular and nearly erect. The cutting edge of the crown has no serrations. There is a weakly serrated shoulder at the base of the crown. The lingual face of the crown is convex and the labial face is flat.

Additional records: In addition to the species reported here, there are reports of *Parotodus benedenii* according to Mimoto and Sato *et al.* (1996), *Carcharodon carcharias* according to Tanaka and Mimoto (1991), Takakuwa *et al.*

(1996), *Squatina* sp., *Sphyrna* ? sp., dermal denticle according to Tanaka and Mimoto (1991).

V. CENOZOIC ERA (Quaternary Period)

Quaternary chondrichthyan fossils are presented by Formation, beginning with the earliest (Figures 166 and 167). Geological chronology of each Formation. Map number in parentheses ().

69. Dainichi Formation, Kakegawa Group

Locality 1: Hongo, Kakegawa City, Shizuoka Prefecture

Locality 2: Yuge, Kakegawa City, Shizuoka Prefecture

Locality 3: Koichi, Kakegawa City, Shizuoka Prefecture

Locality 4: Kamisaigo, Kakegawa City, Shizuoka Prefecture

Locality 5: Koyo, Kakegawa City, Shizuoka Prefecture

Formation and Age: Dainichi Formation, Early Pleistocene. According to Shiba *et al.* (2000), the age of the Dainichi Formation of the Kakegawa Group is considered to be Early Pleistocene (2.0 Ma) based on the fission-track age.

Subclasses Holocephali Bonaparte, 1832
Order Chimaeriformes Obruchev, 1953
Family Chimaeridae Bonaparte, 1831
Genus *Chimaera* Linnaeus, 1758

Chimaera sp.
Figure 168-1

Description: The characteristic pleromine is identified and assumed to be a tooth plate of the

Quaternary	Holocene	—	Nanyo Fm.(76) Umeda Fm.(75)
	Pleistocene	Upper	Kioroshi Fm.(74)
		Chibanian	Ichijyuku Fm.(73) Miyata Fm.(72) Takatsukayama Fm.(71)
		Calabrian	Onma Fm.(70)
		Gelasian	Dainichi Fm.(69)

Figure 166. Geographical and geological context of locality area, stratigraphic diagram modified from references cited below.



Figure 167. Geographical and geological context of locality area, locality map.



Figure 168. 1, *Chimaera* sp., NMNS-PV 33867, Locality 3; 2, *Pristiophorus japonicus*, NMNS-PV 33660, Locality 1, articular or axial (a) and dorsal or ventral (b) views; 3, *Pristiophorus japonicus*, NMNS-PV 30788, Locality 1, articular or axial (a) and dorsal or ventral (b) views; 4, *Squalus* sp., NMNS-PV 30790, Locality 1, lingual (a) and labial (b) views; 5, *Squatina* sp., NMNS-PV 30804, Locality 2, lingual (a) and labial (b) views; 6, *Squatina* sp., NMNS-PV 30865, Locality 3, lingual (a) and labial (b) views; 7, *Orectolobus japonicus*, NMNS-PV 30877, Locality 3, lingual (a) and labial (b) views. Scale bar equals 5 mm.

order Chimaeriformes.

Order Pristiophoriformes Berg, 1958

Family Pristiophoridae Bleeker, 1859

Genus *Pristiophorus* Müller and Henle, 1837

Pristiophorus japonicus Günther, 1870

Figure 168-2,3

Description: The crown is knife-shaped and thin. The root is apron-shaped (see Fig.168-2).

Remarks: This is the rostral tooth of the rostrum.

Order Squaliformes Goodrich, 1909

Family Squalidae Bonaparte, 1834

Genus *Squalus* Linnaeus, 1758

Squalus sp.

Figure 168-4

Description: This specimen is very small teeth. The crown is triangular and strongly curved distally. The cutting edge of the crown has no serration. The central part of the crown on the labial face hangs apron-like on the root side.

Order Squatiniformes Buen, 1926

Family Squatinidae Bonaparte, 1838

Genus *Squatina* Dumeril, 1806

Squatina sp.

Figure 168-5,6

Description: The crown is thin, conical erect and slightly recurved lingually. The cusp is slightly

inclined distally. The basal part of the crown widens mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serration. The root is not bifurcated and is triangular and flat when viewed from the cusp apex.

Order Orectolobiformes Applegate, 1972

Family Orectolobidae Gill, 1862

Genus *Orectolobus* Bonaparte, 1834

Orectolobus japonicus Regan, 1906

Figure 168-7

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The basal part of the crown widens mesially-distally and the basal center of the crown deeply overhangs the root. The cutting edge of the crown has no serration. The root is not bifurcated and is triangular and flat when viewed from the cusp apex. This is similar to the genus *Squatina*, but the crown near the lateral teeth is slightly raised on both sides resembling lateral cusplets.

Order Heterodontiformes Berg, 1937

Family Heterodontidae Gray, 1851

Genus *Heterodontus* Blainville, 1816

Heterodontus sp.

Figure 169-1,2,3,4

Description: The crown of Figure 169-1 is

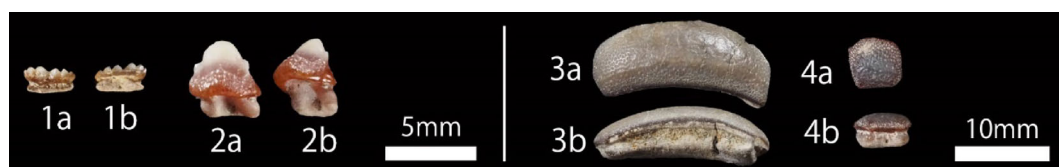


Figure 169. 1, *Heterodontus* sp., NMNS-PV 33456, Locality 2, lingual (a) and labial (b) views; 2, *Heterodontus* sp., NMNS-PV 30892, Locality 2, lingual (a) and profile (b) views; 3, *Heterodontus* sp., NMNS-PV 31044, Locality 3, occlusal (a) and lingual (b) views; 4, *Heterodontus* sp., NMNS-PV 30926, Locality 3, occlusal (a) and lingual (b) views. Scale bar equals 5 mm (1,2) and 10 mm (3,4).

small, low and polycuspid. The crown of Figure 169-2 is conical with lateral cusplets on each side. The teeth of Figure 169-3,4 are of the cobblestone grinding type, elongated, parallelogram. The surface of the crown has numerous wrinkles.

Remarks: Figure 169-1 is the anterior tooth of the juvenile.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 170-1,2, 171-1,2,3,4,5

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Isurus* Rafinesque, 1810

Isurus oxyrinchus Rafinesque, 1810

Figure 172-1,2

Description: The crown is elongated and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat. The root is distinctly bifid.

Genus *Isurus* Rafinesque, 1810

Isurus paucus Guitart Manday, 1966

Figure 172-3

Description: The crown is elongated and curved distally. The cutting edge of the crown have no serrations. The lingual face of the crown is weak

convex and the labial face is flat. The convexity of the lingual face is thinner than in *Isurus oxyrinchus*.

Remarks: This difference in crown thickness clearly distinguishes the two species. The cutting edge is slightly S-shaped in *I. oxyrinchus*, whereas in *I. paucus* it is almost straight with a slightly outwardly curved distal cutting edge.

Family Alopiidae Bonaparte, 1838

Genus *Alopias* Rafinesque, 1810

Alopias superciliosus (Lowe, 1841)

Figure 172-4

Description: The crown is narrowly triangular and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid and quite long.

Genus *Alopias* Rafinesque, 1810

Alopias vulpinus (Bonnaterre, 1788)

Figure 172-5

Description: The crown is narrowly triangular and erect. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The root is distinctly bifid.

Family Cetorhinidae Gill, 1862

Genus *Cetorhinus* Blainville, 1816

Cetorhinus maximus (Gunnerus, 1765)

Figure 173-1,2

Description: The teeth are very small with a



Figure 170. 1, *Carcharodon carcharias*, NMNS-PV 31074, Locality 3 lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 32837, Locality 2 lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

single cusp. The crown is conical and the cusp is pointed. The cutting edge of the crown has no serrations.

Order Carcharhiniiformes Compagno, 1973

Family Scyliorhinidae Gill, 1862

Genus *Galeus* Rafinesque, 1810

Galeus sp.

Figure 174-1

Description: Very small teeth. There is a pair of

lateral cusplets which are also large. The cutting edge of the crown has no serrations.

Family Triakidae Gray, 1851

Genus *Galeorhinus* Blainville, 1816

Galeorhinus galeus (Linnaeus, 1758)

Figure 174-2

Description: The crown is nearly equilateral triangular and curved distally. The mesial cutting edge of the crown has multiple rough serrations

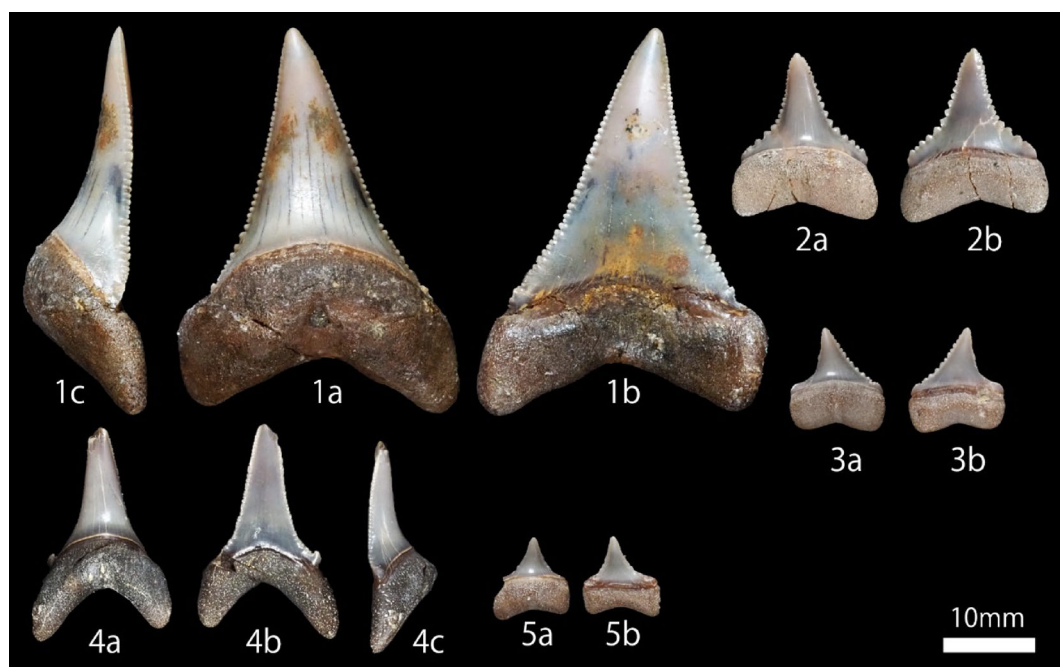


Figure 171. 1, *Carcharodon carcharias*, NMNS-PV 31065, Locality 2, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 31076, Locality 2, lingual (a) and labial (b) views; 3, *Carcharodon carcharias*, NMNS-PV 31068, Locality 2, lingual (a) and labial (b) views; 4, *Carcharodon carcharias*, NMNS-PV 31079, Locality 3, lingual (a), labial (b) and profile (c) views; 5, *Carcharodon carcharias*, NMNS-PV 31069, Locality 2, lingual (a) and labial (b) views. Scale bar equals 10 mm.

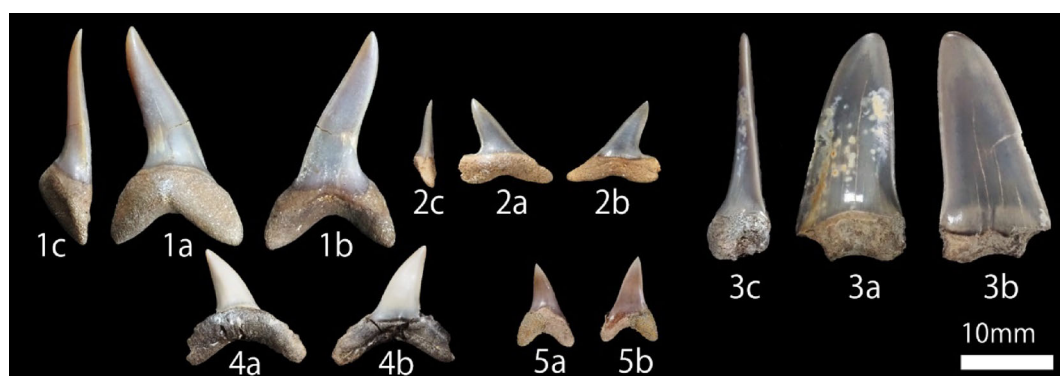


Figure 172. 1, *Isurus oxyrinchus*, NMNS-PV 31082, Locality 1, lingual (a), labial (b) and profile (c) views; 2, *Isurus oxyrinchus*, NMNS-PV 31083, Locality 3, lingual (a), labial (b) and profile (c) views; 3, *Isurus paucus*, NMNS-PV 31085, Locality 5, lingual (a), labial (b) and profile (c) views; 4, *Alopias superciliosus*, NMNS-PV 31086, Locality 3, lingual (a) and labial (b) views; 5, *Alopias vulpinus*, NMNS-PV 33675, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.



Figure 173. 1, *Cetorhinus maximus*, NMNS-PV 31088, Locality 2, lingual (a), labial (b) and profile (c) views; 2, *Cetorhinus maximus*, NMNS-PV 33764, Locality 1, lingual (a) and profile (b) views. Scale bar equals 5 mm.

extending close to the cusp. The lingual face of the crown is convex and the labial face is flat. The base of the labial face of the crown slightly overhangs the root. The lingual face of the root is mountainous.

Genus *Hypogaleus* Smith, 1957
Hypogaleus hyugaensis (Miyosi, 1939)
 Figure 174-3

Description: The crown is almost equilateral and curved distally. The crown is narrower than that of the genus *Galeorhinus*. The mesial cutting edge of the crown has multiple rough serrations extending close to the cusp. The lingual face of the crown is convex and the labial face is flat.

Genus *Mustelus* Linck, 1790
Mustelus sp.
 Figure 174-4

Description: This is a very small, oval and flat tooth. The occlusal surface is flat. The center of the labial face of the crown slightly overhangs the root.

Genus *Triakis* Blainville Müller and Henle, 1838
Triakis scyllium Müller and Henle, 1839
 Figure 174-5

Description: This is a small tooth. The crown is thin and triangular with small lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. The lingual protuberance of the root is high and rises towards the crown. The base of the labial crown overhangs the root.

Family Hemigaleidae Hasse, 1879
 Genus *Chaenogaleus* Gill, 1826
Chaenogaleus macrostoma (Bleeker, 1852)
 Figure 174-6,7

Description: The crown of Fig.174-6 is thin and erect. The cutting edge of the crown has no serrations. There is a rounded lateral cusplets-like

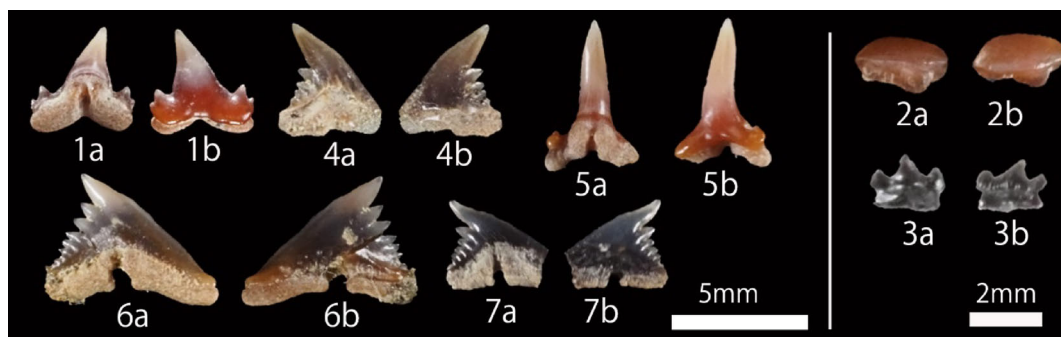


Figure 174. 1, *Galeus* sp., NMNS-PV 31090, Locality 2, lingual (a) and labial (b) views; 2, *Galeorhinus galeus*, NMNS-PV 33571, Locality 3, lingual (a) and labial (b) views; 3, *Hypogaleus hyugaensis*, NMNS-PV 31098, Locality 3, lingual (a) and labial (b) views; 4, *Mustelus* sp., NMNS-PV 31096, Locality 1, lingual (a) and labial (b) views; 5, *Triakis scyllium*, NMNS-PV 31094, Locality 1, lingual (a) and labial (b) views; 6, *Chaenogaleus macrostoma*, NMNS-PV 33572, Locality 3, lingual (a) and labial (b) views; 7, *Chaenogaleus macrostoma*, NMNS-PV 32843, Locality 1, lingual (a) and labial (b) views. Scale bar equals 5 mm (1,2,5,6,7) and 2 mm (3,4).

projection is present at the central base of the crown. The lingual protuberance of the root is high and rises towards the crown. The base of the labial crown overhangs the root. The crown of Fig.174-7 is triangular and strongly curved distally. The distal cutting edge of the crown has rough serrations and there are no serrations on the mesial cutting edge. The base of the crown is shaped to cover the root, in contrast to the genus *Galeorhinus*. In addition, the serrations on the cutting edge of the crown do not extend to the vicinity of the cuspid apex, but are located less than halfway along the cutting edge.

Genus *Hemipristis* Agassi, 1843

Hemipristis serra Agassiz, 1843

Figure 175-1,2

Description: The crown of Fig.175-1 is triangular and curved distally. The cutting edge of the crown has rough serrations and these serrations do not extend to the apical part of the cusp. The lingual face of the crown is convex and the labial face is flat. The crown of Fig.175-2 is elongated

and slightly curved distally. There are 2-3 pairs of lateral cusplets. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is weakly convex. The lingual protuberance of the root is high.

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocерdo* Müller and Henle, 1837

Galeocерdo cuvier (Péron and Lesueur, 1822)

Figure 175-3,4,5

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus altimus (Springer, 1950)

Figure 176-1

Description: The crown is triangular and slightly curved distally. The crown tapers towards the apex. The mesial cutting edge of the crown is

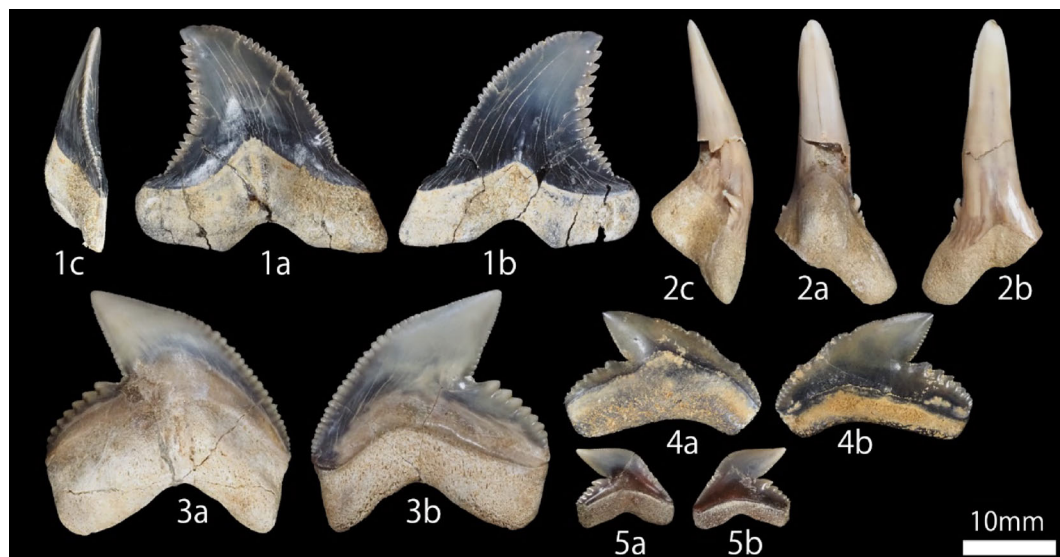


Figure 175. 1, *Hemipristis serra*, NMNS-PV 31154, Locality 4, lingual (a), labial (b) and profile (c) views; 2, *Hemipristis serra*, NMNS-PV 31153, Locality 3, lingual (a), labial (b) and profile (c) views; 3, *Galeocерdo cuvier*, NMNS-PV 31159, Locality 3, lingual (a) and labial (b) views; 4, *Galeocерdo cuvier*, NMNS-PV 33871, Locality 4, lingual (a) and labial (b) views; 5, *Galeocерdo cuvier*, NMNS-PV 33762, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.

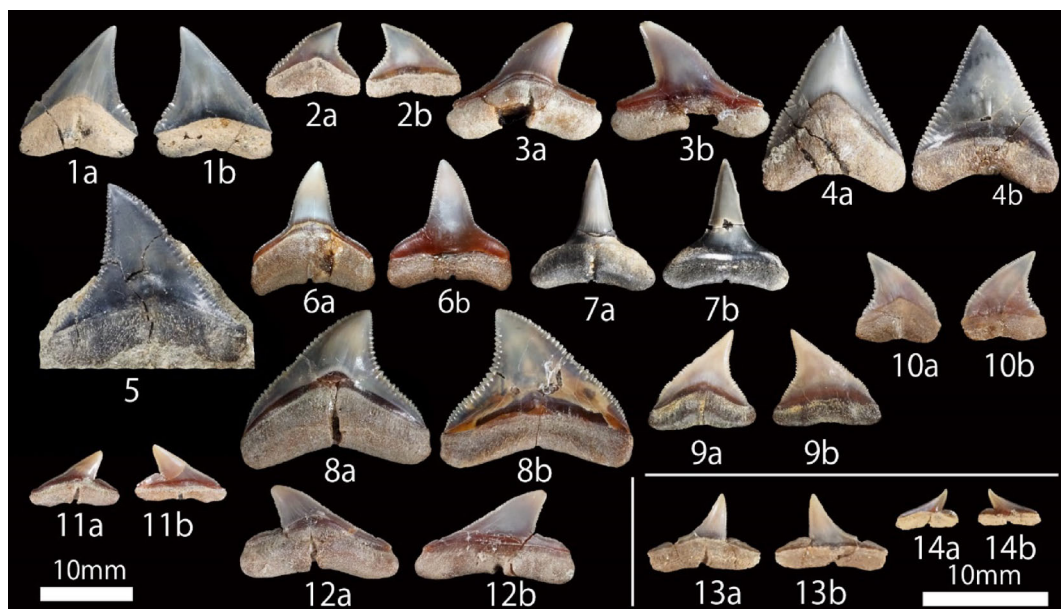


Figure 176. 1, *Carcharhinus altimus*, NMNS-PV 32622, Locality 2, lingual (a) and labial (b) views; 2, *Carcharhinus amboinensis*, NMNS-PV 31162, Locality 2, lingual (a) and labial (b) views; 3, *Carcharhinus brachyurus*, NMNS-PV 31163, Locality 2, lingual (a) and labial (b) views; 4, *Carcharhinus galapagensis*, NMNS-PV 31165, Locality 3, lingual (a) and labial (b) views; 5, *Carcharhinus leucas*, NMNS-PV 31168, Locality 4; 6, *Carcharhinus leucas*, NMNS-PV 31167, Locality 2, lingual (a) and labial (b) views; 7, *Carcharhinus limbatus*, NMNS-PV 31171, Locality 3, lingual (a) and labial (b) views; 8, *Carcharhinus obscurus*, NMNS-PV 32621, Locality 2, lingual (a) and labial (b) views; 9, *Carcharhinus plumbeus*, NMNS-PV 31174, Locality 2, lingual (a) and labial (b) views; 10, *Prionace glauca*, NMNS-PV 31328, Locality 4, lingual (a) and labial (b) views; 11, *Sphyrna lewini*, NMNS-PV 33789, Locality 1, lingual (a) and labial (b) views; 12, *Sphyrna zygaena*, NMNS-PV 32835, Locality 2, lingual (a) and labial (b) views; 13, *Rhizoprionodon acutus*, NMNS-PV 33785, Locality 1, lingual (a) and labial (b) views; 14, *Rhizoprionodon oligolinx*, NMNS-PV 33786, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.

curved in the middle, while the distal cutting edge is almost straight. The cutting edge of the crown has regular fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus amboinensis
(Müller and Henle, 1839)
Figure 176-2

Description: The crown is nearly equilateral triangular with little distal curvature. The cutting edge of the crown has rough serrations, the upper part of the crown being finely serrated and the lower part becoming slightly rougher than the middle. The central part of the distal cutting edge is slightly convex. The lingual face of the crown

is convex and the labial face is flat.

Carcharhinus brachyurus (Günther, 1870)
Figure 176-3

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus galapagensis
(Snodgrass and Heller, 1905)
Figure 176-4

Description: The crown is isosceles triangular and erect. The cutting edge of the crown has regular serrations. The mesial cutting edge of the crown is

slightly concave in the middle and the distal cutting edge is gently curved. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus leucas (Müller and Henle, 1839)
Figure 176-5,6

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus limbatus (Valenciennes, 1839)
Figure 176-7

Description: The crown is thin and slightly curved distally. The cutting edge of the crown has very fine serrations with slightly rougher serrations at the base. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)
Figure 176-8

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus plumbeus (Nardo, 1827)
Figure 176-9

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Genus *Prionace* Cantor, 1849
Prionace glauca (Linnaeus, 1758)
Figure 176-10

Description: This is similar to the teeth of *Carcharhinus*, but the crown is triangular and the cusp is strongly curved distally. The mesial cutting

edge of the crown is curved outwards and the distal cutting edge is curved inwards. The cutting edge of the crown has serrations. The lingual face of the crown is convex and the labial face is flat.

Family Sphyrnidae Gill, 1872
Genus *Sphyrna* Rafinesque, 1810
Sphyrna lewini (Griffith and Smith, 1834)
Figure 176-11

Description: The crown is triangular and concave near the apex. The cutting edge of the crown has no serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Sphyrna zygaena (Linnaeus, 1758)
Figure 176-12

Description: The crown is triangular and concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Genus *Rhizoprionodon* Whitley, 1929
Rhizoprionodon acutus (Rüppell, 1837)
Figure 176-13

Description: The crown is thin and curved distally. The cutting edge of the crown has no serrations and there is a distal shoulder at the base of the crown. The cusp is slightly recurved mesially. The lingual face of the crown is convex and the labial face is flat.

Remarks: The present *Rhizoprionodon oligolinx* is not of large size, so it is probably *R. acutus*.

Rhizoprionodon oligolinx Springer, 1964
Figure 176-14

Description: The crown is thin and curved distally. The cutting edge of the crown has no serrations and there is a distal shoulder at the base of the crown. The cusp is slightly recurved mesially. The lingual face of the crown is convex and the

labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Myliobatididae Bonaparte, 1838

Genus *Aetobatus* Blainville, 1816

Aetobatus sp.

Figure 177-1

Description: Tooth morphology is similar to that of the genus *Myliobatis*, but differs in that the teeth are slightly tapered towards the edges in the occlusal view.

Genus *Myliobatis* Cuvier, 1816

Myliobatis sp.

Figure 177-2,3,4

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat.

The root is comb-shaped with numerous slits.

Family Dasyatidae Jordan, 1888

Dasyatidae gen. et sp. indet.

Figure 177-5,6

Description: This is a small tooth. The crown of the tooth is square, almost rhomboid and may be flat or pointed. The apex of the pointed crown is inclined posteriorly. The tooth with the pointed crown is male (see Fig.177-5). The root hangs down from the lower part of the crown of the tooth.

Dermal denticle

Figure 177-7,8,9

Description: The crown is elongated, needle-like, some almost erect and others strongly curved distally. The root is hakama-like, spread-

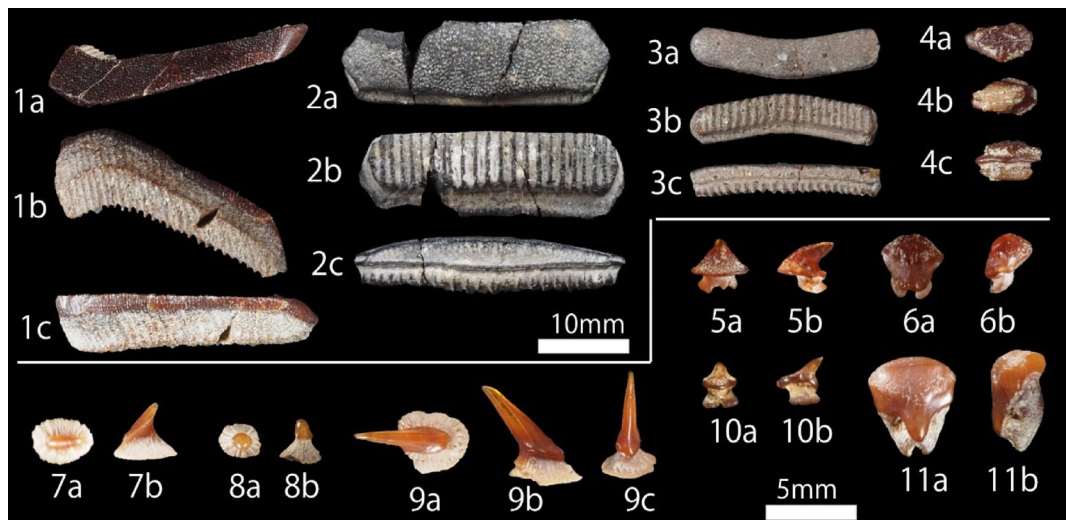


Figure 177. 1, *Aetobatus* sp., NMNS-PV 31453, Locality 2, occlusal (a), basal (b) and lingual (c) views; 2, *Myliobatis* sp., NMNS-PV 31416, Locality 3, occlusal (a), basal (b) and lingual (c) views; 3, *Myliobatis* sp., NMNS-PV 31336, Locality 2, occlusal (a), basal (b) and lingual (c) views; 4, *Myliobatis* sp., NMNS-PV 31337, Locality 2, occlusal (a), basal (b) and lingual (c) views; 5, Dasyatidae gen. et sp. indet., NMNS-PV 31493, Locality 1, lingual (a) and profile (b) views; 6, Dasyatidae gen. et sp. indet., NMNS-PV 31562, Locality 2, lingual (a) and labial (b) views; 7, dermal denticle, NMNS-PV 31649, Locality 2, dorsal (a) and profile (b) views; 8, dermal denticle, NMNS-PV 31650, Locality 2, dorsal (a) and profile (b) views; 9, dermal denticle, NMNS-PV 32940, Locality 1, dorsal (a), profile (b) and frontal (c) views; 10, *Raja pulchra*, NMNS-PV 33023, Locality 1, lingual (a) and profile (b) views; 11, *Rhynchobatus* sp., NMNS-PV 33039, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm (1,2,3,4) and 5 mm (5,6,7,8,9,10,11).

ing and rounded.

Remarks: The dermal denticle is located on the skin of the family Dasyatidae.

Order Rajiformes Berg, 1940
Family Rajidae Blainville, 1816
Genus *Raja* Linnaeus, 1758
Raja pulchra Liu, 1932
Figure 177-10

Description: This is a small tooth. The crown is conical, thin and pointed. The crown is shaped like a mountain hat with a brim-like margin at the base of the crown. The root is comb-shaped with numerous slits.

Order Rhinopristiformes Naylor *et al.*, 2012
Family Rhinidae Müller and Henle, 1841
Genus *Rhynchobatus* Müller and Henle, 1837
Rhynchobatus sp.
Figure 177-11

Description: This is a small tooth. The morphology of the tooth is similar to that of the Dasyatidae, the lingual face is flat to weakly concave on each side separated by a moderate medial uvula. The root is comb-like with numerous slits.

Caudal spine
Figure 178-1,2

Description: This is in near perfect condition. It is elongated and pointed at the tip like a spear. Both sides have fine spiny projections.

Remarks: This is the caudal spine of Myliobatiformes.

Fin spine
Figure 178-3

Description: It has the shape of an elongated, triangular, pyramid. Slightly inclined posteriorly. The articular view is pointed and slightly curved anteriorly in the axial view. There is striation on the face.

Remarks: This is a spine attached to the first and second dorsal fins of sharks of the genera *Squalus* or *Heterodontus*. It seems difficult to identify species only by spines alone.

Vertebra
Figure 178-4,5

Description: They are a mill-shaped with a concave center. There are no slits on their sides. Fig.178-5 is oval in shape

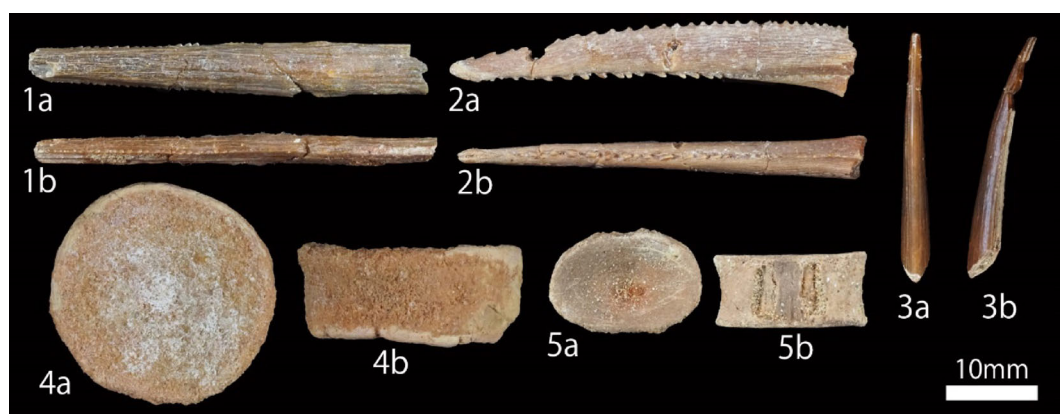


Figure 178. 1, caudal spine, NMNS-PV 31691, Locality 1, dorsal (a) and profile (b) views; 2, caudal spine, NMNS-PV 32831, Locality 2, dorsal (a) and profile (b) views; 3, fin spine, NMNS-PV 33765, Locality 1, articular (a) and profile (b) views; 4, vertebra, NMNS-PV 31732, Locality 1, articular or axial (a) and dorsal or ventral (b) views; 5, vertebra, NMNS-PV 33038, Locality 1, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.

Remarks: Fig.178-4 is a vertebra of the family Carcharhinidae. Fig.178-5 is a vertebra of the genus *Squatina*.

Additional records: In addition to the species reported here, there are reports of *Parotodus* sp., *Carcharhinus longimanus* according to Yokoyama *et al.* (2000), *Parotodus benedenii* according to Yokoyama *et al.* (2003), *Hexanchus* sp. according to Kitamura and Fujita (2006).

70. Onma Formation, Hokuriku Group

Locality: Ookuwa-cho, Kanazawa City, Ishikawa Prefecture

Formation and Age: Onma Formation, Middle Pleistocene. According to Tamura and Yamazaki (2004), the age of the Onma Formation of the Hokuriku Group is considered to be Middle Pleistocene (2.3–0.8 Ma) based on the tephra stratigraphy.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 179-1,2

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973

Family Carcharhinidae Jordan and Evermann, 1896

Genus *Galeocerdo* Müller and Henle, 1837

Galeocerdo cuvier (Péron and Lesueur, 1822)

Figure 180-1

Description: The crown is multicuspoid with the mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816

Carcharhinus falciformis

(Bibron in Müller and Henle, 1839)

Figure 180-2

Description: The crown is triangular and slightly curved distally. The cutting edge of the crown has a deep central notch, which is finely serrated above and roughened below. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus galapagensis

(Snodgrass and Heller, 1905)

Figure 180-3

Description: The crown is isosceles triangular and erect. The cutting edge of the crown has regular serrations. The mesial cutting edge of the crown is slightly concave in the center and the distal cutting edge is gently curved. The lingual face of the crown is convex and the labial face is flat.

71. Takatsukayama Formation, Osaka Group

Locality: Tamoncho, Tarumi Ward, Kobe City, Hyogo Prefecture

Formation and Age: Takatsukayama Formation, Middle Pleistocene. According to Fujita and Maeda (1985), the age of the Takatsukayama Formation of the Osaka Group is considered to be Middle Pleistocene (0.49 Ma) based on the fission-track age.

Order Lamniformes Berg, 1958

Family Lamnidae Müller and Henle, 1838

Genus *Carcharodon* Müller and Henle, 1838

Carcharodon carcharias (Linnaeus, 1758)

Figure 181-1

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown has regular serrations. The lingual face of the crown is convex and the labial face is flat.

72. Miyata Formation, Sagami Group

Locality: Tsukui, Yokosuka City, Kanagawa Prefecture



Figure 179. 1, *Carcharodon carcharias*, NMNS-PV 30759, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 30757, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

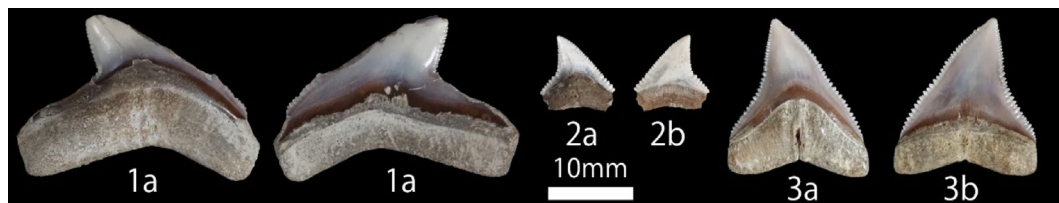


Figure 180. 1, *Galeocerdo cuvier*, NMNS-PV 30763, lingual (a) and labial (b) views; 2, *Carcharhinus falciformis*, NMNS-PV 30764, lingual (a) and labial (b) views; 3, *Carcharhinus galapagensis*, NMNS-PV 30765, lingual (a) and labial (b) views. Scale bar equals 10 mm.



Figure 181. 1, *Carcharodon carcharias*, NMNS-PV 32069, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

Formation and Age: Miyata Formation, Middle Pleistocene. According to Yamaguchi *et al.* (1983), the age of the Miyata Formation of the Sagami Group is considered to be Middle Pleistocene based on the calcareous nannofossil.

Order Lamniformes Berg, 1958
Family Odontaspidae Müller and Henle, 1839
Genus *Odontaspis* Agassiz, 1838
Odontaspis ferox (Risso, 1810)
Figure 182-1

Description: The crown is thin and almost erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is flat.

Family Lamnidae Müller and Henle, 1838
Genus *Carcharodon* Müller and Henle, 1838
Carcharodon plicatilis ? (Agassiz, 1843)
Figure 182-2

Description: The crown is very broad and equilateral triangular. The cutting edge of the crown has no serrations. The lingual face of the crown is convex and the labial face is flat. This specimen has a much wider crown than *C. hastalis*.

Remarks: This species is known from the Miocene- Pliocene of Chile according to Chávez-Hoffmeister *et al.* (2023). In this regard, the occurrence of this species from the Middle Pleistocene Miyata Formation is somewhat skeptic. The identification here is based exclusively the morphological similarity.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Carcharhinus* Blainville, 1816
Carcharhinus obscurus (Lesueur, 1818)
Figure 182-3

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.



Figure 182. 1, *Odontaspis ferox*, NMNS-PV 30754, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon plicatilis* ?, NMNS-PV 30755, lingual (a), labial (b) and profile (c) views; 3, *Carcharhinus obscurus*, NMNS-PV 30756, lingual (a) and labial (b) views. Scale bar equals 10 mm.

73. Ichijyuku Formation, Kazusa Group

Locality: Ichijyuku, Kimitsu City, Chiba Prefecture

Formation and Age: Ichijyuku Formation, Middle Pleistocene. According to Niitsuma (1976), the age of the Ichijyuku Formation of the Kazusa Group is considered to be Middle Pleistocene (0.6–0.8 Ma) based on the magnetic stratigraphy.

Subclasses Holocephali Bonaparte, 1832

Order Chimaeriformes Obruchev, 1953

Family Chimaeridae Bonaparte, 1831

Genus *Chimaera* Linnaeus, 1758

Chimaera sp.

Figure 183-1

Description: This tooth is flat trapezoidal plate. There is a round bulge (pleromine) in the center of the lingual face. There are several small pleromines on the upper right side of the lingual face. The labial face is flat and smooth.

Remarks: This is similar to the lower plate of *Chimaera phantasma*. However, we have not identified all the species of the genus *Chimaera*, so we will refer to them here as undetermined species.

Subclasses Elasmobranchii Bonaparte, 1838

Order Hexanchiformes Buen, 1926

Family Hexanchidae Gray, 1851

Genus *Hexanchus* Rafinesque, 1810

Hexanchus griseus (Bonnaterre, 1788)

Figure 183-2

Description: This crown is polycuspid with the height of the cusps decreasing distally from the first cusp. The number of cusps is larger than in the genus *Notorynchus*.

Genus *Notorynchus* Ayres, 1855

Notorynchus cepedianus (Péron, 1807)

Figure 183-3

Description: The teeth are multituberculate and become successively smaller from the first cusp to the distal cusp. The lower part of the mesial cutting edge of the first cusp has a distinct serration, which increases in size towards the apex.

Hexanchidae gen. et sp. indet.

Figure 183-3

Description: The crown is multituberculate with four visible cusps. The crown is shaped like an open fan and the cusps of the crown are two at a time, each curved mesially-distally.

Remarks: This is thought to be a symphyseal tooth in the median lower jaw of the family

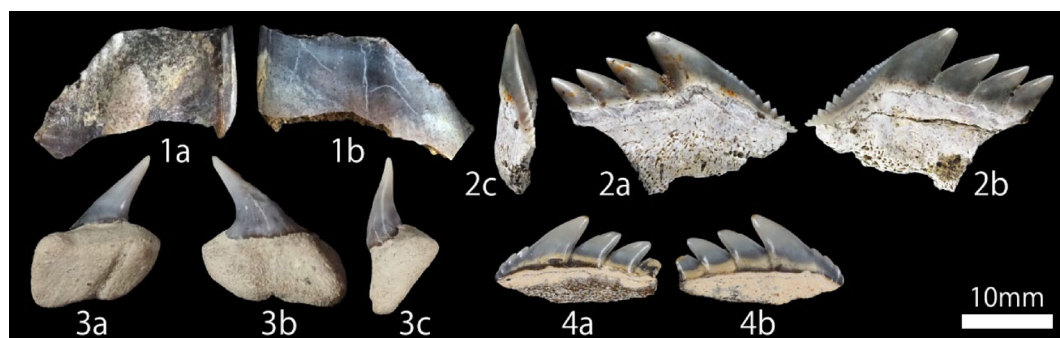


Figure 183. 1, *Chimaera* sp., NMNS-PV 30094, lingual (a) and labial (b) views; 2, *Hexanchus griseus*, NMNS-PV 30095, lingual (a), labial (b) and profile (c) views; 3, Hexanchidae gen. et. sp. indet., NMNS-PV 30096, lingual (a), labial (b) and profile (c) views; 4, *Notorynchus cepedianus*, NMNS-PV 32547, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Hexanchidae, but it is difficult to determine whether it belongs to the genus *Hexanchus* or the genus *Notorynchus*.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Odontaspis* Agassiz, 1838
Odontaspis ferox (Risso, 1810)
 Figure 184-1,2

Description: The crown is thin and erect. The cutting edge of the crown has no serrations. The cross section of the crown is rounded. There is no striation on the lingual face of the crown. The lingual face of the crown is convex and the labial face is slightly convex. Fig.184-2 shows one side of the lateral cusplet, which is elongated and needle-shaped.

Family Lamnidae Müller and Henle, 1838
 Genus *Carcharodon* Müller and Henle, 1838
Carcharodon carcharias (Linnaeus, 1758)
 Figure 185-1,2,3,4,5, 186-1,2,3

Description: The crown is broad, equilateral triangular and erect. The cutting edge of the crown have regular serrations. The lingual face of the crown is convex and the labial face is flat.

Remarks: Fig.185-5 is the abnormal tooth.

Genus *Isurus* Rafinesque, 1810
Isurus oxyrinchus Rafinesque, 1810
 Figure 187-1,2,3,4,5,6

Description: The crown is elongate and curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Genus *Lamna* Cuvier, 1816
Lamna ditropis Hubbs and Follett, 1947
 Figure 188-1

Description: The crown is thick and erect. There are the lateral cusplets on either side of the main cusp. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Family Otodontidae Glickman, 1964
 Genus *Parotodus* Cappetta, 1980
Parotodus benedeni (Le Hon, 1871)
 Figure 188-2

Description: The crown is very thick, erect and strongly curved distally. The cutting edge of the crown has no serrations. The lingual face of the crown is strongly convex and the labial face is flat.

Remarks: This specimen may have been derived from the underlying Miura Group (Miocene), because the species is common in the Miocene but is quite rare in the Pleistocene.



Figure 184. 1, *Odontaspis ferox*, NMNS-PV 30097, lingual (a), labial (b) and profile (c) views; 2, *Odontaspis ferox*, NMNS-PV 30098, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

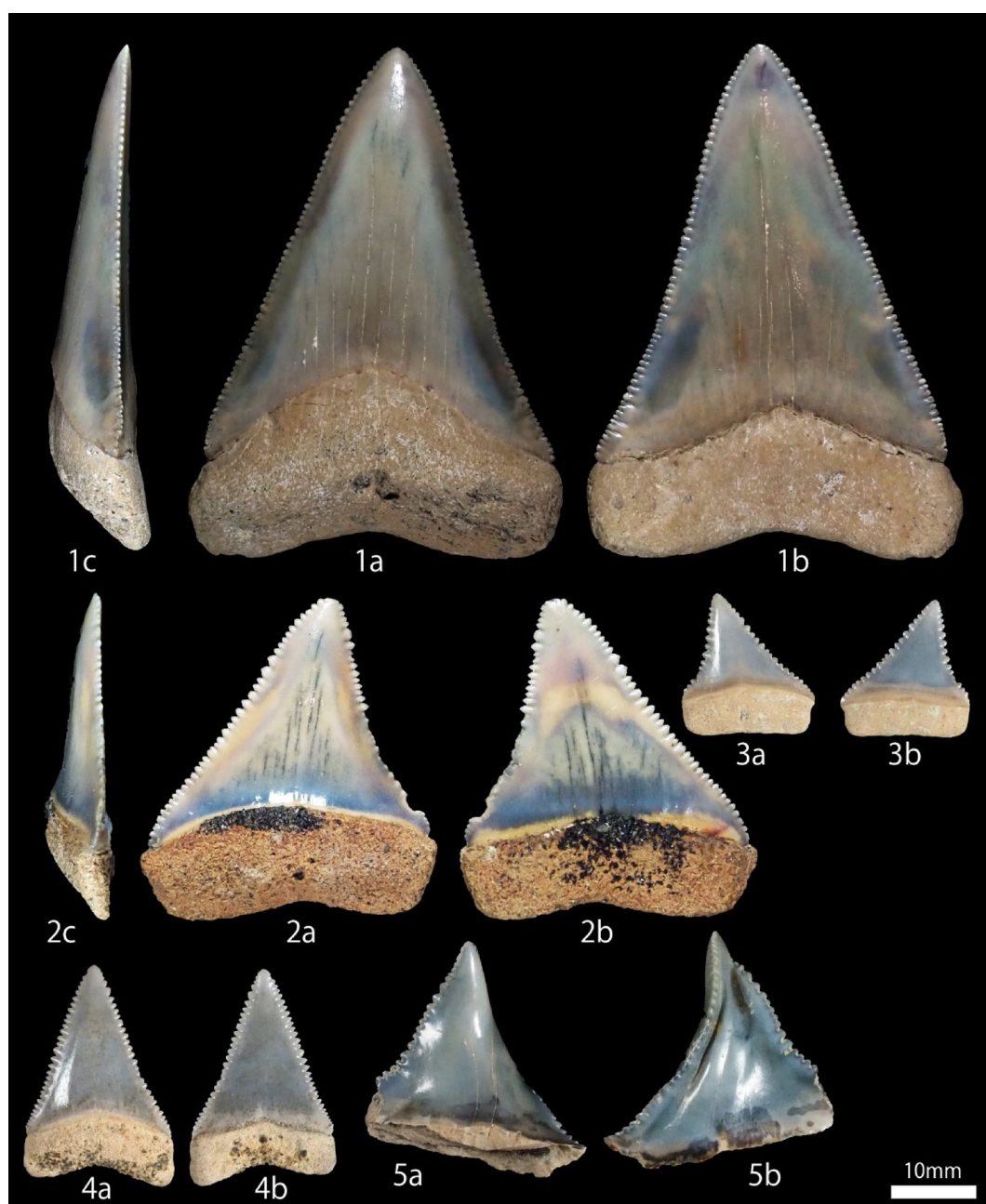


Figure 185. 1, *Carcharodon carcharias*, NMNS-PV 30101, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 30105, lingual (a), labial (b) and profile (c) views; 3, *Carcharodon carcharias*, NMNS-PV 30118, lingual (a) and labial (b) views; 4, *Carcharodon carcharias*, NMNS-PV 30117, lingual (a) and labial (b) views; 5, *Carcharodon carcharias*, NMNS-PV 30104, lingual (a) and labial (b) views. Scale bar equals 10 mm.

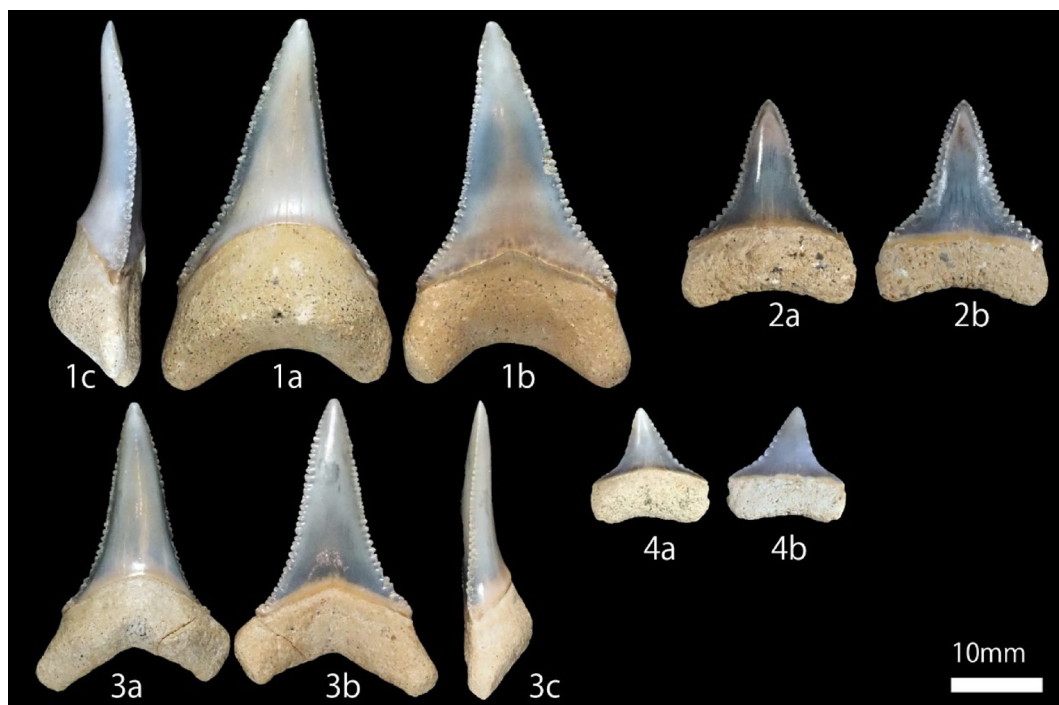


Figure 186. 1, *Carcharodon carcharias*, NMNS-PV 30119, lingual (a), labial (b) and profile (c) views; 2, *Carcharodon carcharias*, NMNS-PV 30120, lingual (a) and labial (b) views; 3, *Carcharodon carcharias*, NMNS-PV 30121, lingual (a), labial (b) and profile (c) views; 4, *Carcharodon carcharias*, NMNS-PV 30122, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Order Carcharhiniiformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo cuvier (Péron and Lesueur, 1822)
 Figure 189-1,2,3

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus leucas (Müller and Henle, 1839)
 Figure 189-4,5

Description: The crown is broad and nearly equilateral. The cutting edge of the crown is almost straight with regular serrations. The

lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)
 Figure 189-6

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Caudal spine
 Figure 190-1

Description: This is elongated and pointed at the tip like a spear. Both sides have fine spiny projections.

Remarks: This is the caudal spine of *Myliobatiformes*.



Figure 187. 1, *Isurus oxyrinchus*, NMNS-PV 30315, lingual (a), labial (b) and profile (c) views; 2, *Isurus oxyrinchus*, NMNS-PV 30317, lingual (a), labial (b) and profile (c) views; 3, *Isurus oxyrinchus*, NMNS-PV 30316, lingual (a), labial (b) and profile (c) views; 4, *Isurus oxyrinchus*, NMNS-PV 30318, lingual (a), labial (b) and profile (c) views; 5, *Isurus oxyrinchus*, NMNS-PV 30319, lingual (a), labial (b) and profile (c) views; 6, *Isurus oxyrinchus*, NMNS-PV 30314, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.



Figure 188. 1, *Lamna ditropis*, NMNS-PV 30492, lingual (a), labial (b) and profile (c) views; 2, *Parotodus benedeni*, NMNS-PV 30495, lingual (a), labial (b) and profile (c) views. Scale bar equals 10 mm.

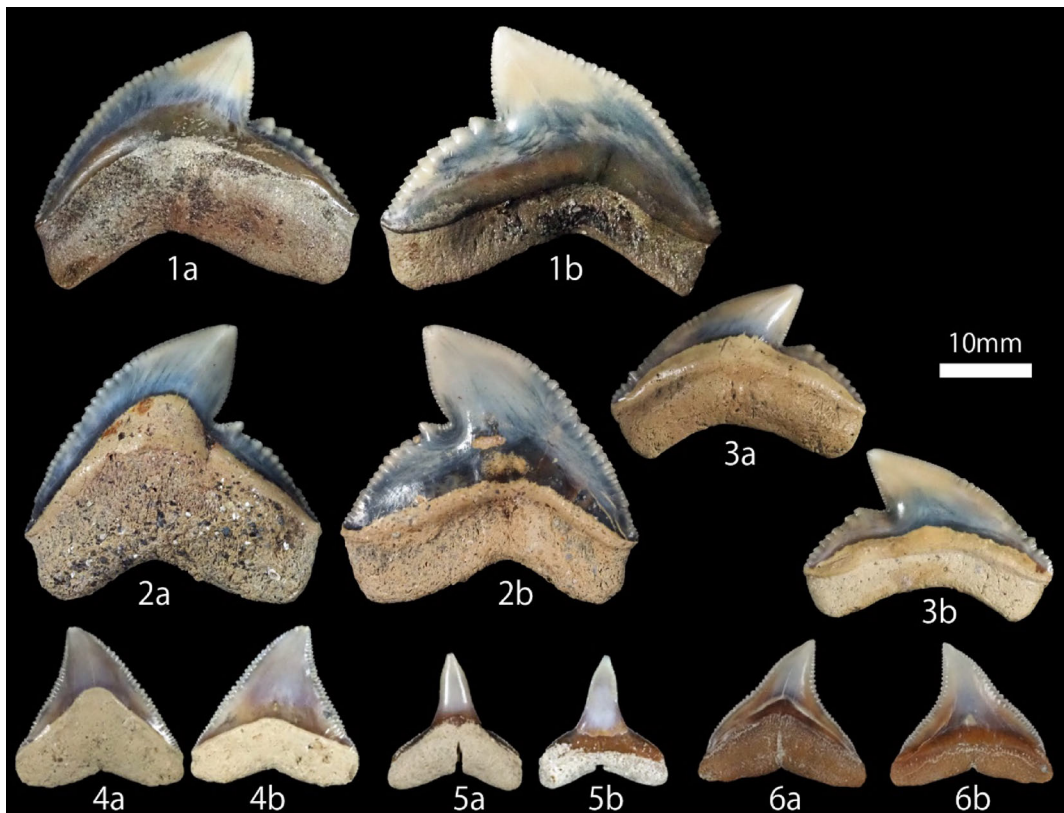


Figure 189. 1, *Galeocerdo cuvier*, NMNS-PV 30496, lingual (a) and labial (b) views; 2, *Galeocerdo cuvier*, NMNS-PV 32548, lingual (a) and labial (b) views; 3, *Galeocerdo cuvier*, NMNS-PV 30497, lingual (a) and labial (b) views; 4, *Carcharhinus leucas*, NMNS-PV 30540, lingual (a) and labial (b) views; 5, *Carcharhinus leucas*, NMNS-PV 30622, lingual (a) and labial (b) views; 6, *Carcharhinus obscurus*, NMNS-PV 30541, lingual (a) and labial (b) views. Scale bar equals 10 mm.

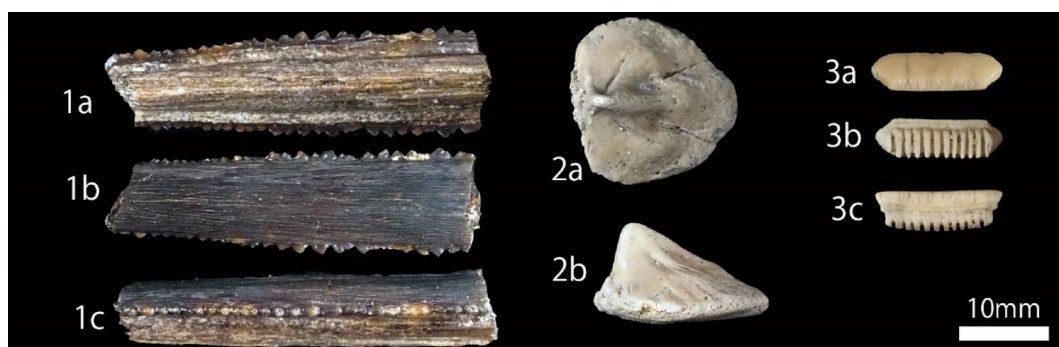


Figure 190. 1, caudal spine, NMNS-PV 30705, dorsal (a), ventral (b) and profile (c) views; 2, dermal denticle, NMNS-PV 30702, dorsal (a) and profile (b) views; 3, *Myliobatis* sp., NMNS-PV 30704, occlusal (a), basal (b) and lingual (c) views. Scale bar equals 10 mm.

Dermal denticle
Figure 190-2

Description: The crown is low and mountain-like cones with pointed tips. The root is hakama-like, spreading and rounded.

Remarks: The dermal denticle is located on the skin of the family Dasyatidae.

Order Myliobatiformes Compagno, 1973

Family Myliobatidae Bonaparte, 1838

Genus *Myliobatis* Cuvier, 1816

Myliobatis sp.

Figure 190-3

constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Rostral node
Figure 191-1

Description: Conical in shape, but the apical portion is rounded rather than pointed. Three circular holes.

Remarks: The rostral node is located at the tip of the head. Among modern sharks, only *Lamna* have fossils in this calcified state.

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is

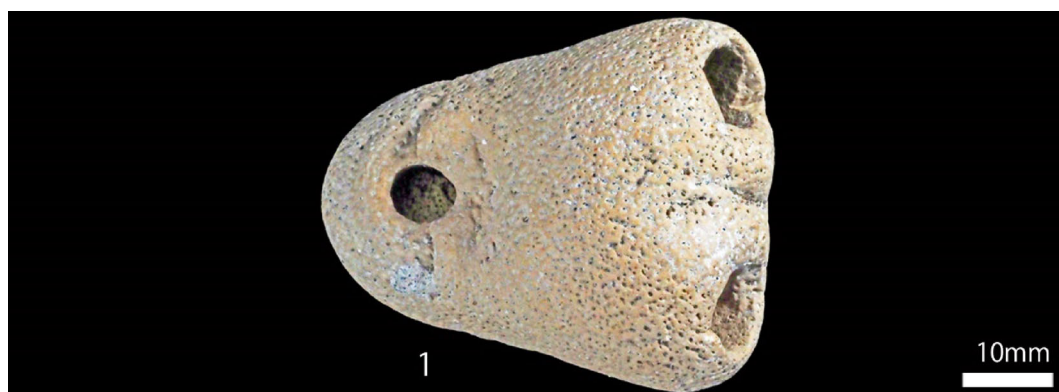


Figure 191. 1, rostral node, NMNS-PV 30494. Scale bar equals 10 mm.

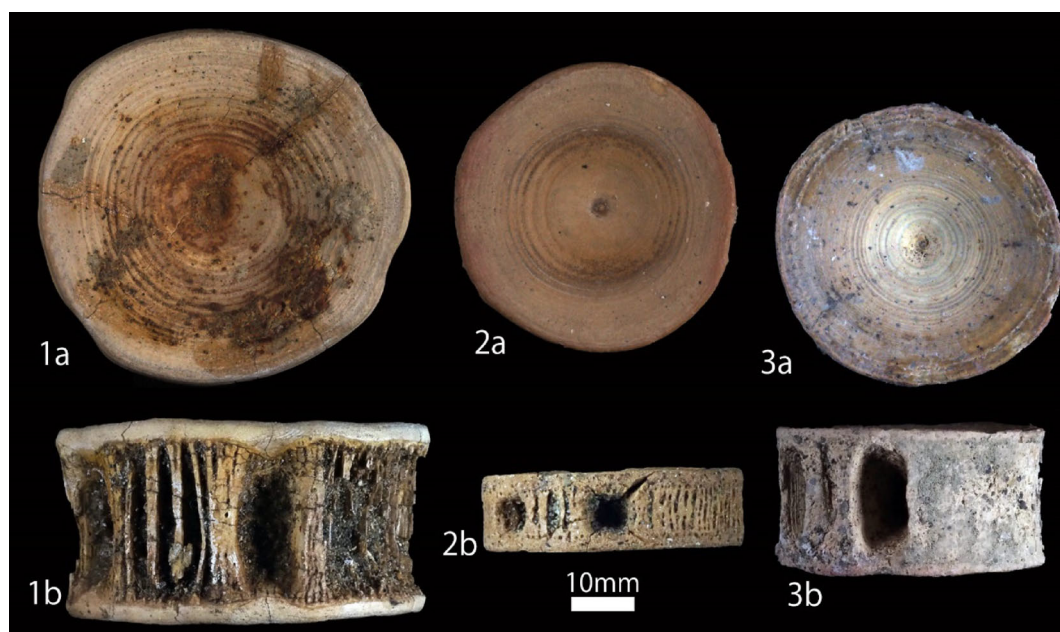


Figure 192. 1, vertebra, NMNS-PV 30707, articular or axial (a) and dorsal or ventral (b) views; 2, vertebra, NMNS-PV 30708, articular or axial (a) and dorsal or ventral (b) views; 3, vertebra, NMNS-PV 30709, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.

Vertebra
Figure 192-1,2,3

Description: This has a mill-shape with a concave center. There are numerous slits on the sides of Figure 192-1,2. There are no slits on the sides of Figure 192-3.

Remarks: Fig.192-1,2 are vertebrae of the family Lamnidae. Fig.192-3 is vertebrae of the family Carcharhinidae.

74. Kioroshi Formation, Shimosa Group

Locality 1: Shimazu, Ami Town, Inashiki-Gun, Ibaraki Prefecture

Locality 2: Funato, Inzai City, Chiba Prefecture

Formation and Age (Locality 1,2): Kioroshi Formation, Late Pleistocene. According to Nakazato and Sato (2001), the age of the Kioroshi Formation of the Shimosa Group is considered to be Late Pleistocene (0.125 Ma) based on the correlation of dated marker tephra.

Order Squaliformes Goodrich, 1909
Family Squalidae Bonaparte, 1834
Genus *Squalus* Linnaeus, 1758

Squalus sp.

Figure 193-1

Description: The crown is triangular and strongly curved distally. The cutting edge of the crown has no serration. The lingual face of the crown is convex and the labial face is flat. The labial face of the crown is prolonged so that its central part overhangs the root.

Order Squatiniformes Buen, 1926
Family Squatinidae Bonaparte, 1838
Genus *Squatina* Dumeril, 1806

Squatina sp.

Figure 193-2

Description: The crown is thin, conical, erect and slightly recurved lingually. The cusp is slightly inclined distally. The basal part of the crown widens mesially-distally and the basal



Figure 193. 1, *Squalus* sp., NMNS-PV 30085, Locality 1, lingual (a) and labial (b) views; 2, *Squatina* sp., NMNS-PV 30086, Locality 1, lingual (a) and labial (b) views. Scale bar equals 5 mm.

center of the crown deeply overhangs the root. The cutting edge of the crown has no serration. The root is not bifurcated and is triangular and flat when viewed from the cusp apex.

Order Carcharhiniformes Compagno, 1973
Family Carcharhinidae Jordan and Evermann, 1896
Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo cuvier (Péron and Lesueur, 1822)

Figure 194-1

Description: The crown is multicuspid with the mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus brevipinna (Müller and Henle, 1839)

Figure 194-2

Description: The crown is slender and almost erect or slightly curved distally. The cutting edge of the crown is finely serrated on the lower portion. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)

Figure 194-3

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Dasyatidae Jordan, 1888

Dasyatidae gen. et sp. indet.

Figure 195-1,2

Description: This is a small tooth. The crown is conical and pointed. The apex of the crown is tilted posteriorly. The root hangs down from the lower part of the crown of the tooth.

Additional records: In addition to the species reported here, there are reports of *Pristiophorus japonicus*, *Heterodontus japonicus*, *Carcharias taurus*, *Carcharodon carcharias*, *Isurus oxyrinchus*, *Alopias vulpinus*, *Mustelus* sp., *Triakis scyllium*, *Hypogaleus hyugaensis*, *Carcharhinus longimanus*, *Carcharhinus plumbeus*, *Sphyrna*

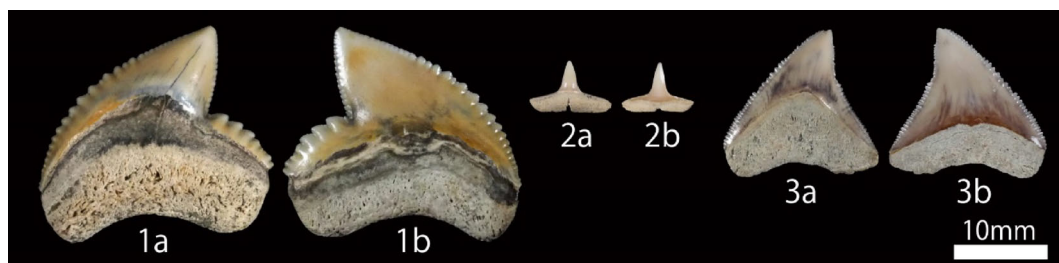


Figure 194. 1, *Galeocerdo cuvier*, NMNS-PV 30087, Locality 2, lingual (a) and labial (b) views; 2, *Carcharhinus brevipinna*, NMNS-PV 30089, Locality 1, lingual (a) and labial (b) views; 3, *Carcharhinus obscurus*, NMNS-PV 30088, Locality 1, lingual (a) and labial (b) views. Scale bar equals 10 mm.

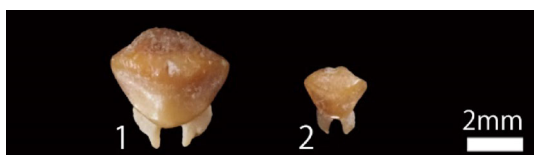


Figure 195. 1, *Dasyatidae* gen. et sp. indet., NMNS-PV 30090, Locality 1; 2, *Dasyatidae* gen. et sp. indet., NMNS-PV 30093, Locality 1. Scale bar equals 5 mm.

lewini, *Rhynchobatus djiddensis*, *Myliobatis tobi-jei*, *Aetobatus narinari* according to Kuzubukuro Earth Science Society (2010).

75. Umeda Formation, Osaka Group

Locality: Umeda, Osaka City, Osaka Prefecture
Formation and Age: Umeda Formation, Holocene. According to Fujita and Maeda (1985), the age of the Umeda Formation of the Osaka Group is considered to be Holocene based on the C14 age.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Carcharhinus* Blainville, 1816
Carcharhinus obscurus (Lesueur, 1818)

Figure 196-1

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973
 Family Myliobatidae Bonaparte, 1838
 Genus *Aetobatus* Blainville, 1816

Aetobatus sp.

Figure 197-1

Description: Tooth morphology is similar to that of the genus *Myliobatis*, but differs in that the teeth are slightly tapered towards the edges in the occlusal view.



Figure 196. 1, *Carcharhinus obscurus*, NMNS-PV 32067, lingual (a) and labial (b) views. Scale bar equals 10 mm.

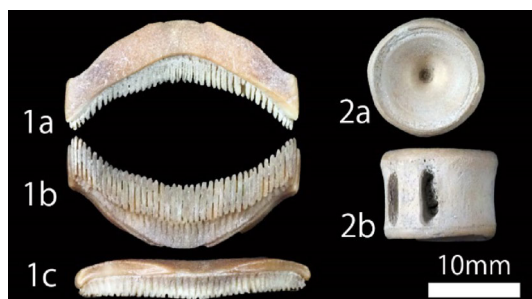


Figure 197. 1, *Aetobatus* sp., NMNS-PV 32987, occlusal (a), basal (b) and lingual (c) views; 2, vertebra, NMNS-PV 32068, articular or axial (a) and dorsal or ventral (b) views. Scale bar equals 10 mm.

Vertebra
 Figure 197-2

Description: This has a mill-shape with a concave center. There is a round almost square hole on the side, but no slits.

Remarks: This is the vertebra of the family Carcharhinidae.

76. Nanyo Formation

Locality: Nagoya Port, Minato Ward, Nagoya City, Aichi Prefecture

Formation and Age: Nanyo Formation, Holocene. According to Minami *et al.* (2022), the age of the Nanyo Formation is considered to be Holocene based on the C14 age.

Order Lamniformes Berg, 1958
 Family Odontaspidae Müller and Henle, 1839
 Genus *Carcharias* Rafinesque, 1810
Carcharias taurus Rafinesque, 1810
 Figure 198-1,2

Description: The crown of Fig.198-1 is elongated and erect, Fig.198-2 is rather broad and curved distally. The cutting edge of the crown has no serrations. The cross section of the crown is rounded and there are lateral cusplets. There is a striation on the lingual face of the crown. The lingual face of the crown is strongly convex and the labial face is flat.

Order Carcharhiniformes Compagno, 1973
 Family Carcharhinidae Jordan and Evermann, 1896
 Genus *Galeocerdo* Müller and Henle, 1837
Galeocerdo cuvier (Péron and Lesueur, 1822)
 Figure 198-3

Description: The crown is multicuspid with the

mesial first cusp large and curved distally. The cutting edge of each cusp has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Genus *Carcharhinus* Blainville, 1816
Carcharhinus brachyurus (Günther, 1870)
 Figure 198-4

Description: The crown is thin and curved distally. The cutting edge of the crown has fine serrations. The lingual face of the crown is convex and the labial face is flat.

Carcharhinus obscurus (Lesueur, 1818)
 Figure 198-5

Description: The crown is broad, triangular and curved distally. The cutting edge of the crown has serrations and is gently curved outwards. The lingual face of the crown is convex and the labial face is flat.

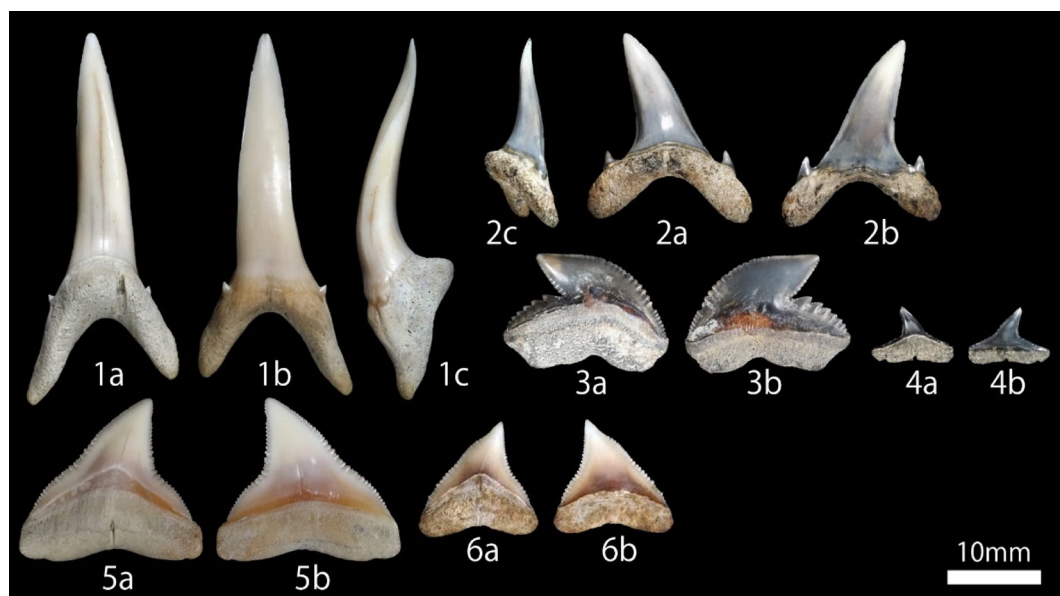


Figure 198. 1, *Carcharias taurus*, NMNS-PV 32023, lingual (a), labial (b) and profile (c) views; 2, *Carcharias taurus*, NMNS-PV 33038, lingual (a), labial (b) and profile (c) views; 3, *Galeocerdo cuvier*, NMNS-PV 32026, lingual (a) and labial (b) views; 4, *Carcharhinus brachyurus*, NMNS-PV 32027, lingual (a) and labial (b) views; 5, *Carcharhinus obscurus*, NMNS-PV 32028, lingual (a) and labial (b) views; 6, *Carcharhinus plumbeus*, NMNS-PV 32029, lingual (a) and labial (b) views. Scale bar equals 10 mm.

Carcharhinus plumbeus (Nardo, 1827)

Figure 198-6

Description: The crown is triangular and slightly concave near the apex. The cutting edge of the crown has fine serrations. The mesial cutting edge of the crown is curved outwards. The lingual face of the crown is convex and the labial face is flat.

Order Myliobatiformes Compagno, 1973

Family Myliobatidae Bonaparte, 1838

Genus *Aetobatus* Blainville, 1816*Aetobatus* sp.

Figure 199-1,2

Description: Tooth morphology is similar to that of the genus *Myliobatis*, but differs in that the teeth are slightly tapered towards the edges in the occlusal view.

Genus *Myliobatis* Cuvier, 1816*Myliobatis* sp.

Figure 199-3,4

Description: This tooth has an elongated hexagonal shape. The thickness of the crown is constant and the occlusal surface of the crown is flat. The root is comb-shaped with numerous slits.

Caudal spine

Figure 199-5

Description: This is in near perfect condition. It is elongated and pointed at the tip like a spear. Both sides have fine spiky projections.

Remarks: This is the caudal spine of Myliobatiformes.

Additional records: In addition to the species reported here, *Negaprion* sp., Dasyatidae gen. et sp. indet. (Reported as *Dasyatis* sp. in Ohe, 1977), vertebrae are reported from the same formation according to Ohe (1977).



Figure 199. 1, *Aetobatus* sp., NMNS-PV 32058, occlusal (a) and basal (b) views; 2, *Aetobatus* sp., NMNS-PV 32059, occlusal (a) and basal (b) views; 3, *Myliobatis* sp., NMNS-PV 32038, occlusal (a), basal (b) and lingual (c) views; 4, *Myliobatis* sp., NMNS-PV 32039, occlusal (a), basal (b) and lingual (c) views; 5, caudal spine, NMNS-PV 32063, dorsal (a) and ventral (b) views. Scale bar equals 10 mm.

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Because of the inadequacy of the fossil records of chondrichthyans in the Japanese Islands, in quality, quantity, and utility of specimens, and in their field data, we believe that the information of the temporal and spatial distributions of chondrichthyans around the Japanese Islands offered here, however tentative, collectively provide the most coherent working hypothesis explaining the evolutionary history of chondrichthyans around those islands, based on available fossil evidence, and with geologic age and paleogeography. In this regard, specimens are prerequisite to any possible progress. Accordingly, we wish to thank foremost the following donors and colleagues who made specimens available for the senior author (in alphabetical order, titles omitted, some are deceased): Tsuyahiko Fujimoto, Yoshitomo Fujita, Tomoyuki Hitomi, Yutaka Iwama, Iwao Ohe, Shoji Kashima, Masato Kadota, Hiroyo Kawanishi, Satoshi Morinobu, Masakatsu Saita, Yukio Sako, Kiyoshi Seida, Hideshi Suzuki, Masahiro Suzuki, Yoshitaka Takayama, Kazuyuki Usui, Satoshi Utsunomiya, Takanobu Yamaoka, Nichihei Yoshiwara, Yukio Watanabe. We are grateful to Henri Cappetta, Kenshu Shimada, and Teryya Uyeno; all of whom provided useful information and access to specimens. Masato Kadota, Naoyuki Kuga, Satoshi Morinobu, Masazumi Nomura, Iwao Ohe, Hajime Taru, Kazuyuki Usui, Yukio Watanabe, Takanobu Yamaoka, have been generous for many years in sharing their extensive knowledge of collecting localities and biostratigraphy. The illustrations and photographs were prepared by Takeshi Mizuhara and the senior author. Financial support for this monograph was provided in part by the special expenditures from the director of the National Museum of Nature and Science, Tokyo, Japan. Finally, the manuscript was greatly improved by careful attention to detail and extensive comments from Shinya Miyata, to which we greatly appreciate it. However, any deficiencies, inadequacies,

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APPENDIX I:

List of the specimens produced by Formations

1. Funabuseyama Formation, Gifu

Ctenacanthidae gen. et sp. indet. (NMNS-PV 26738–26747), *Acrodus* sp. (NMNS-PV 26748–26758, 26760–26762, 33938–33980, 34043), Acrodontidae gen. et sp. indet. (NMNS-PV 26759), *Polyacrodus* sp. (NMNS-PV 26763, 26764)

2. Waruishi Formation, Yakuno Group, Kyoto

Hybodus sp. (NMNS-PV 26101–26104)

3. Izuriha Formation, Kyoto

Protacrodus sp. (NMNS-PV 26765–26771), Ctenacanthidae gen. et sp. indet. (NMNS-PV 26772–26774), *Acrodus* sp. (NMNS-PV 26775–26784)

4. Yoshinazawa Formation, Kuruma Group, Nagano

Acrodus sp. (NMNS-PV 26106, 26107), *Asteracanthus* sp. (NMNS-PV 26108–26142)

5. Ishido Formation, Sanchu Group, Saitama

Mitsukurinidae gen. et sp. indet.. (NMNS-PV 26157), *Acrolamna* sp. (NMNS-PV 26158), Odontaspidae gen. et sp. indet. (NMNS-PV 26159–26206)

6. Sebayashi Formation, Sanchu Group, Gunma

Heteroptychodus steinmanni (NMNS-PV 26143, 26144), *Striatolamia* sp. (NMNS-PV 26145), Odontaspidae gen. et sp. indet. (NMNS-PV 26146–26155), Fam., gen. et sp. indet. (NMNS-PV 26156)

7. Hanenoura Formation, Mononobe Group, Tokushima

Odontaspidae gen. et sp. indet. (NMNS-PV 26466)

8. Kashiwaguri Formation, Goshoura Group, Kagoshima

Cretalmna catoxodon (NMNS-PV 26462, 26463)

9. Haborogawa Formation, Yezo Group, Hokkaido

Ptychodus latissimus (NMNS-PV 26207, 26208), *Rolfodon* sp. (NMNS-PV 26209, 26210), *Hexanchus* sp. (NMNS-PV 26211, 26217), *Notorynchus* sp. (NMNS-PV 26213–26216), *Xampylodon dentatus* (NMNS-PV 26218), Hexanchidae gen. et sp. indet. (NMNS-PV 26212), *Sphenodus* sp. (NMNS-PV 26219, 26220), *Paraorthacodus* sp. (NMNS-PV 26221, 26222), *Echinorhinus* sp. (NMNS-PV 26223), *Squalus* sp. (NMNS-PV 26224, 26225), *Centrophorus* sp. (NMNS-PV 26226), *Carcharias* sp. (NMNS-PV 26227–26232), *Cretalamna* sp. (NMNS-PV 26233–26238), *Cretoxyrhina mantelli* (NMNS-PV 26239–26242), *Scapanorhynchus* sp. (NMNS-PV 26243), *Squalicorax* sp. (NMNS-PV 26244), *Synechodus* sp. (NMNS-PV 26245–26247), *Ptychotrygonoides* sp. (NMNS-PV 26248), Fam., gen. et sp. indet. (NMNS-PV 26249–26270)

10. Asizawa Formation, Futaba Group, Fukushima

Hexanchidae gen. et sp. indet. (NMNS-PV 26329), *Notorynchus aptiensis* (NMNS-PV 26330), *Scapanorhynchus texanus* (NMNS-PV 26331, 26332), *Cenocarcharias tenuiplicatus* (NMNS-PV 26333, 26334), *Cretalamna appendiculata* (NMNS-PV 26335), *Cretalamna borealis* (NMNS-PV 26336–26344, 26384–26388), *Cretalamna gertericorum* (NMNS-PV 26345), *Cretalamna* sp. (NMNS-PV 26346–26368), *Cretoxyrhina mantelli* (NMNS-PV 26369), *Paranomotodon angustidens* (NMNS-PV 26370), *Squalicorax falcatus* (NMNS-PV 26371–26373), *Carcharias* sp. ? (NMNS-PV 26374, 26375, 26464, 26465), *Protolamna sokolovi* (NMNS-PV 26376), *Paratriakis* sp. (NMNS-PV 26377), Fam., gen. et sp. indet. (NMNS-PV 26378)

11. Hinoshima Formation, Himenoura Group, Kumamoto

Ptychodus sp. (NMNS-PV 26389), *Chlamydoselachus* sp. (NMNS-PV 26390),

Hexanchus microdon (NMNS-PV 26391–26396), *Xampylodon dentatus* (NMNS-PV 26397), *Echinorhinus* sp. (NMNS-PV 26398), *Cretalamna* sp. (NMNS-PV 26399–26431), *Cretoxyrhina mantelli* (NMNS-PV 26432, 26433), *Dwardius* sp. (NMNS-PV 26434)

12. Azenotani Formation, Izumi Group, Osaka

Hexanchus sp. (NMNS-PV 26439), *Xampylodon dentatus* (NMNS-PV 26440), *Scapanorhynchus* sp. (NMNS-PV 26441–26443), *Carcharias* sp. (NMNS-PV 26444–26456), *Cretalamna* sp. (NMNS-PV 26457–26459), *Cretodus semiplicatus* (NMNS-PV 26460)

13. Kokawa Formation, Izumi Group, Wakayama

Rolfodon sp. (NMNS-PV 26435), *Protosqualus* sp., (NMNS-PV 26436), *Centrophorus* sp. (NMNS-PV 26437)

14. Shiratakei Formation, Miroku Group, Kagoshima

Cretalamna sp. (NMNS-PV 26461)

15. Namigata Formation, Okayama

Hexanchus agassizi (NMNS-PV 26468–26472), *Heterodontus* cf. *H. vincenti* (NMNS-PV 26473), *Squatina* sp. (NMNS-PV 26474), *Otodus auriculatus* (NMNS-PV 26475, 26476), *Striatolamia macrota* (NMNS-PV 26477), *Carcharias contortidens* (NMNS-PV 26478–26554), *Brachycarcharias lerichei* (NMNS-PV 26555), *Hemipristis curvatus* (NMNS-PV 26556, 26557), *Negaprion* cf. *N. eurybathrodon* (NMNS-PV 26558), Fam., gen. et sp. indet. (NMNS-PV 26559)

16. Yotsuyama Formation, Manda Group, Fukuoka

Otodus auriculatus (NMNS-PV 26467)

17. Iwaki Formation, Shiramizu Group, Fukushima

Hexanchus agassizi (NMNS-PV 26564, 32550), *Heterodontus* sp. (NMNS-PV 26565–26567), *Carcharias contortidens* (NMNS-PV 26568–26574)

18. Yamaga Formation, Ashiya Group, Fukuoka

Hexanchus agassizi (NMNS-PV 26576, 26577), *Hexanchus* sp. (NMNS-PV 26578–26593, 26670), *Squalus* sp. (NMNS-PV 26594, 26595, 32963), *Squatina* sp. (NMNS-PV 26598–26601, 32962), *Heterodontus* sp. (NMNS-PV 26602–26610, 26613, 32964), *Carcharias contortidens* (NMNS-PV 26617–26624, 32968), *Araloselachus cuspidatus* (NMNS-PV 26625), *Odontaspis molassica* (NMNS-PV 26626), *Striatolamia macrota* (NMNS-PV 26627), *Isurus praecursor* (NMNS-PV 26628–26632), *Alopias latidens* (NMNS-PV 26634), *Alopias exigua* (NMNS-PV 26635), *Otodus angustidens* (NMNS-PV 26636, 26637), *Cetorhinus* sp. (NMNS-PV 26638–26640), *Chaenogaleus affinis* (NMNS-PV 26648), *Chaenogaleus* sp. (NMNS-PV 26649), *Hemigaleus* cf. *H. microstoma* (NMNS-PV 26650), *Hemipristis tanakai* (NMNS-PV 26651–26653), *Isogomphodon acurarius* (NMNS-PV 26657, 26658, 32965–32967), *Negaprion* sp. (NMNS-PV 26660–26663), *Carcharhinus* cf. *C. albimarginatus* (NMNS-PV 32961), *Carcharhinus* cf. *C. macloiti* (NMNS-PV 26656), *Sphyrna* sp. (NMNS-PV 26665–26668), *Myliobatis* sp. (NMNS-PV 26721, 26732), Fam., gen. et sp. indet. (NMNS-PV 26671–26716, 26725, 26726)

19. Jinnobaru Formation, Ashiya Group, Fukuoka

Notorynchus primigenius (NMNS-PV 26575), *Squalus* sp. (NMNS-PV 26596), *Squatina* sp. (NMNS-PV 26597), *Heterodontus* sp. (NMNS-PV 26611, 26612, 26669), *Carcharias contortidens* (NMNS-PV 26614–26616), *Isurolamna affinis* (NMNS-PV 26633), *Cetorhinus* sp. (NMNS-PV 26641–26643), *Megascyliorhinus miocaenicus* (NMNS-PV 26644, 26645), *Pachyscyllium albigensis* (NMNS-PV 26646), *Casieria maghrebiana* (NMNS-PV 26647), *Galeocерdo eaglesomei* (NMNS-PV 26654, 26655), *Isogomphodon acurarius* (NMNS-PV 26659), *Negaprion* sp. (NMNS-PV 26664), *Dasyatidae* gen. et sp. indet.

(NMNS-PV 26722–26724), Fam., gen. et sp. indet. (NMNS-PV 26717–26720)

20. Sari sandstone Formation, Kishima Group, Saga

Isurus desori (NMNS-PV 34002–34005), Fam., gen. et sp. indet. (NMNS-PV 34006)

21. Shimosato Formation, Kumano Group, Wakayama

Mitsukurina lineata (NMNS-PV 28177), *Carcharias contortidens* (NMNS-PV 28178), *Carcharodon hastalis* (NMNS-PV 28179–28185), *Isurus desori* (NMNS-PV 28186–28201), *Isurus* sp. (NMNS-PV 28202–28208), *Otodus* sp. (NMNS-PV 28209, 28210), *Parotodus benedeni* (NMNS-PV 28211), *Carcharhinus* sp. (NMNS-PV 28212–28224), *Negaprion eurybathrodon* (NMNS-PV 28225)

22. Akeyo Formation, Mizunami Group, Gifu

Megasqualus occidentalis (NMNS-PV 27581), *Squatina* sp. (NMNS-PV 27582), *Isurus desori* (NMNS-PV 27583, 27584), *Otodus megalodon* (NMNS-PV 27585), *Cetorhinus* sp. (NMNS-PV 27586), *Hemipristis serra* (NMNS-PV 27587), *Galeocerdo aduncus* (NMNS-PV 27588), *Carcharhinus* cf. *C. altimus* (NMNS-PV 27589–27591), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27592, 27593), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27594), *Carcharhinus* sp. (NMNS-PV 27595–27610), *Rhinoptera* sp. (NMNS-PV 27611–27614)

23. Yuyadani Formation, Tsuzuki Group, Kyoto

Isurus desori (NMNS-PV 32969, 32970, 34036), *Carcharhinus* sp. (NMNS-PV 32971–32980, 34035, 34037, 34038), *Rhinoptera* sp. (NMNS-PV 32981–32985), Fam., gen. et sp. indet. (NMNS-PV 32986)

24. Oshimojo Formation, Tomikusa Group, Nagano

Megasqualus occidentalis (NMNS-PV 27547, 27548, 33015), *Squatina* sp. (NMNS-PV 27549,

27550), *Galeocerdo aduncus* (NMNS-PV 27551–27555), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27556), *Carcharhinus* cf. *C. limbatus* (NMNS-PV 32994), *Carcharhinus* cf. *C. maclovi* (NMNS-PV 27575), *Carcharhinus* cf. *C. tyutjot* (NMNS-PV 33011), *Carcharhinus* sp. (NMNS-PV 27557–27574, 32990, 32991, 32993, 32995–33010, 33012–33014), *Physogaleus contortus* (NMNS-PV 27576), *Sphyrna* sp. (NMNS-PV 27577), *Myliobatis* sp. (NMNS-PV 27578, 27579, 33016), *Dasyatidae* gen. et sp. indet. (NMNS-PV 27580), Fam., gen. et sp. indet. (NMNS-PV 33017, 33018)

25. Yoshino Formation, Katsuta Group, Okayama

Carcharias contortidens (NMNS-PV 33998), *Carcharhinus* sp. (NMNS-PV 33999)

26. Ohi Formation, Ichishi Group, Mie

Hexanchus sp. (NMNS-PV 27762–27764, 28125, 28126, 32563), *Megasqualus occidentalis* (NMNS-PV 28022, 28023, 28049, 28173, 32595, 33911), *Squalus* sp. (NMNS-PV 27765–27770, 32568, 32609, 32610, 33908), *Squatina* sp. (NMNS-PV 27771–27775, 28019, 28020, 28024, 32572, 32578, 32608), *Araloselachus cuspidatus* (NMNS-PV 27776, 32615), *Carcharias* sp. (NMNS-PV 28073, 28160, 32556, 32596), *Isurus desori* (NMNS-PV 27777–27801, 28007–28012, 28025–28027, 28050–28059, 28102, 28103, 28148, 32555, 32560, 32561, 32587, 32588, 32590, 32597, 32603), *Isurus retroflexus* (NMNS-PV 32564, 32565), *Carcharodon hastalis* (NMNS-PV 27802–27818, 28017, 28018, 28060–28066, 28151, 28152, 28156, 28159, 32554, 32559, 32567, 32574, 32582, 32586, 33909), *Carcharodon planus* (NMNS-PV 27819–27821, 28013, 32557), *Isurus* sp. (NMNS-PV 27822, 27823), *Alopias* sp. (NMNS-PV 27824, 32599), *Otodus chubutensis* (NMNS-PV 27825–27829, 28123, 28146), *Otodus megalodon* (NMNS-PV 27830–27833, 28067, 32551, 32552, 32562, 32585, 32589, 32591–32594), *Trigonotodus grandis* (NMNS-PV 27834, 27835), *Cetorhinus* sp. (NMNS-PV 32579), *Hemipristis serra*

(NMNS-PV 27836–27839, 28068–28072, 28124, 32553), *Galeocerdo aduncus* (NMNS-PV 27840–27849, 28006, 28120–28122, 28147, 32570, 32611, 33903–33905), *Carcharhinus* cf. *C. albimarginatus* (NMNS-PV 32614), *Carcharhinus* cf. *C. altimus* (NMNS-PV 27850, 28074), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27851), *Carcharhinus* cf. *C. leucas* (NMNS-PV 27852), *Carcharhinus* cf. *C. tjutjot* (NMNS-PV 27853, 27862), *Carcharhinus* cf. *C. limbatus* (NMNS-PV 27856), *Carcharhinus* cf. *C. macloiti* (NMNS-PV 27854, 27857–27859, 28104), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27860, 27861), *Carcharhinus* sp. (NMNS-PV 27855, 27863–27983, 28021, 28028–28046, 28075–28101, 28105–28113, 28127–28140, 28144, 28149, 28150, 28153–28155, 28157, 28161–28172, 32566, 32569, 32571, 32575, 32577, 32600–32602, 32604–32607, 32612–32613, 33906, 33907, 33910), *Physogaleus contortus* (NMNS-PV 27984, 28118, 28119, 32573), *Rhizoprionodon* sp. (NMNS-PV 27985), *Sphyrna* sp. (NMNS-PV 27986–27992, 28014–28016, 28047, 28114, 28176), *Dasyatidae* gen. et sp. indet. (NMNS-PV 27993–27999, 28115–28117, 28141, 28142, 28145, 32583, 32584), *Aetobatus* sp. (NMNS-PV 28143), *Myliobatis* sp. (NMNS-PV 32558, 32598), Fam., gen. et sp. indet. (NMNS-PV 28000, 28001–28005, 28048, 28158, 32576, 32580, 32581)

27. Shukunohora Formation, Mizunami Group, Gifu

Squatina sp. (NMNS-PV 27615), *Nebrius* sp. (NMNS-PV 27616, 27617), *Carcharias contortidens* (NMNS-PV 27618, 27619), *Otodus megalodon* (NMNS-PV 27620), *Isurus desori* (NMNS-PV 27621), *Galeocerdo aduncus* (NMNS-PV 27622), *Carcharhinus* cf. *C. albimarginatus* (NMNS-PV 27623, 27624), *Carcharhinus* cf. *C. altimus* (NMNS-PV 27625–27627), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27628, 27629), *Carcharhinus* sp. (NMNS-PV 27630–27639), Fam., gen. et sp. indet. (NMNS-PV 27640)

28. Kokozura Formation, Takaku Group, Ibaraki

Carcharhinus cf. *C. brachyurus* (NMNS-PV 26897)

29. Kurosedani Formation, Yatsuo Group, Toyama

Otodus megalodon (NMNS-PV 27252)

30. Itabashi Formation, Bihoku Group, Hiroshima

Hexanchus sp. (NMNS-PV 28277), *Otodus megalodon* (NMNS-PV 28281), *Carcharodon planus* (NMNS-PV 28282, 28283), *Isurus desori* (NMNS-PV 28284–28293, 29296, 28297), *Galeocerdo aduncus* (NMNS-PV 28299), *Carcharhinus* cf. *C. albimarginatus* (NMNS-PV 28300), *Carcharhinus* cf. *C. macloiti* (NMNS-PV 28301), *Carcharhinus* cf. *C. sorrah* (NMNS-PV 28302), *Carcharhinus* sp. (NMNS-PV 28303–28307)

31. Shikiya Formation, Kumano Group, Wakayama

Hexanchidae gen. et sp. indet. (NMNS-PV 28226), *Carcharodon hastalis* (NMNS-PV 28227–28230), *Isurus desori* (NMNS-PV 28231–28240), *Carcharias contortidens* (NMNS-PV 28241–28243), *Parotodus benedeni* (NMNS-PV 28244, 28245), *Hemipristis serra* (NMNS-PV 28246), *Galeocerdo aduncus* (NMNS-PV 28247–28251, 32988, 32989), *Carcharhinus* sp. (NMNS-PV 28252–28274), *Negaprion eurybathrodon* (NMNS-PV 28275), *Sphyrna* sp. (NMNS-PV 28276)

32. Korematsu Formation, Bihoku Group, Hiroshima

Hexanchus nakamurai (NMNS-PV 28278), *Carcharias contortidens* (NMNS-PV 28279, 28280), *Isurus desori* (NMNS-PV 28294, 28295), *Galeocerdo aduncus* (NMNS-PV 28298), *Carcharhinus* sp. (NMNS-PV 28308–28312), *Rhinoptera* sp. (NMNS-PV 28313, 28314)

33. Chichibumachi Formation, Akahira Group, Saitama

Hexanchus nakamurai (NMNS-PV 26916–26924), *Squalus* sp. (NMNS-PV 26925, 26926), *Dalatias licha* (NMNS-PV 26928, 26929), *Squatina* sp. (NMNS-PV 26930, 26931), *Carcharias contortidens* (NMNS-PV 26932–26939), *Alopias* cf. *A. superciliosus* (NMNS-PV 26940), *Galeocerdo aduncus* (NMNS-PV 26942), *Carcharhinus* cf. *C. altimus* (NMNS-PV 26943–26945), *Carcharhinus* cf. *C. sorrah* (NMNS-PV 26946), *Carcharhinus* cf. *C. tjutjot* (NMNS-PV 26947), *Carcharhinus* sp. (NMNS-PV 26948–26955), *Dasyatidae* gen. et sp. indet. (NMNS-PV 26956–26964), Fam., gen. et sp. indet. (NMNS-PV 26965)

34. Oido Formation, Miyagi

Carcharodon hastalis (NMNS-PV 26826–26836), *Carcharodon planus* (NMNS-PV 26837, 26838), *Isurus desori* (NMNS-PV 26839–26843), *Otodus megalodon* (NMNS-PV 26844, 26845)

35. Oidawara Formation, Mizunami Group, Gifu

Dalatias licha (NMNS-PV 27647), *Squatina* sp. (NMNS-PV 27648), *Nebrius* sp. (NMNS-PV 27649), *Carcharias contortidens* (NMNS-PV 27650–27655, 32992), *Carcharodon hastalis* (NMNS-PV 27656–27658), *Isurus desori* (NMNS-PV 27659–27663), *Otodus chubutensis* (NMNS-PV 27664–27666), *Galeocerdo aduncus* (NMNS-PV 27667), *Carcharhinus* cf. *C. albi-marginatus* (NMNS-PV 27668, 27669), *Carcharhinus* cf. *C. altimus* (NMNS-PV 27670), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27671), *Carcharhinus* cf. *C. limbatus* (NMNS-PV 27672), *Carcharhinus* cf. *C. maclovi* (NMNS-PV 27673–27675), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27676), *Carcharhinus* sp. (NMNS-PV 27677–27751, 32990, 32991), *Sphyrna* sp. (NMNS-PV 27752), *Rhinoptera* sp. (NMNS-PV 27753, 27754), *Dasyatidae* gen. et sp. indet. (NMNS-PV 27755–27758)

36. Sakurada Formation, Yugashima Group, Shizuoka

Odontaspidae gen. et sp. indet. (NMNS-PV 29211–29216), *Carcharodon hastalis* (NMNS-PV 29217–29228), *Isurus desori* (NMNS-PV 29229–29265), *Isurus* sp. (NMNS-PV 29266, 29267), *Otodus megalodon* (NMNS-PV 32543), *Parotodus benedeni* (NMNS-PV 29268, 32541, 32542), *Trigonotodus palatasi* (NMNS-PV 29269), *Carcharhinus* cf. *C. falciformis* (NMNS-PV 29270), *Carcharhinus* cf. *C. obscurus* (NMNS-PV 29271), *Carcharhinus* sp. (NMNS-PV 292672–29276), Fam., gen. et sp. indet. (NMNS-PV 29277–29286)

37. Godo Formation, Tokigawa Group, Saitama

Deania sp. (NMNS-PV 26969), *Dalatias licha* (NMNS-PV 26970, 26971), *Pristiophorus* cf. *P. japonicus* (NMNS-PV 26972, 26973), *Mitsukurina lineata* (NMNS-PV 26974), *Odontaspidae* gen. et sp. indet. (NMNS-PV 26975–27128), *Carcharodon hastalis* (NMNS-PV 27129–27154), *Carcharodon planus* (NMNS-PV 27155–27161), *Isurus desori* (NMNS-PV 27162–27199), *Otodus megalodon* (NMNS-PV 27200–27204), *Parotodus benedeni* (NMNS-PV 27205–27212, 32539, 32540), *Trigonotodus palatasi* (NMNS-PV 27213), *Carcharhinus* sp. (NMNS-PV 27214–27228), Fam., gen. et sp. indet. (NMNS-PV 27229, 29230)

38. Moniwa Formation, Natori Group, Miyagi

Carcharodon hastalis (NMNS-PV 26846), *Carcharodon planus* (NMNS-PV 26847), *Isurus desori* (NMNS-PV 26848), *Carcharhinus* sp. (NMNS-PV 26849)

39. Nanao Formation, Ishikawa

Megasqualus occidentalis (NMNS-PV 27293, 27294), *Squatina* sp. (NMNS-PV 27295), *Carcharias contortidens* (NMNS-PV 27296–27298), *Araloselachus cuspidatus* (NMNS-PV 27299–27305), *Carcharodon hastalis* (NMNS-PV 27306–27320), *Carcharodon planus*

(NMNS-PV 27321–27385, 27414–27432, 33891), *Isurus desori* (NMNS-PV 27386–27397), *Otodus megalodon* (NMNS-PV 27398), *Parotodus benedeni* (NMNS-PV 27399), *Galeocерdo aduncus* (NMNS-PV 27400), *Carcharhinus* cf. *C. amboinensis* (NMNS-PV 27401, 27402), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27403), *Carcharhinus* cf. *C. falciformis* (NMNS-PV 27404), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27439), *Carcharhinus* sp. (NMNS-PV 27405–27411, 27433–27438, 33890), Fam., gen. et sp. indet. (NMNS-PV 27412, 27413)

40. Sekinohana Formation, Ishikawa

Hexanchus sp. (NMNS-PV 27443), *Dalatis licha* (NMNS-PV 27444), *Squatina* sp. (NMNS-PV 27445), *Carcharias contortidens* (NMNS-PV 27446–27451), *Araloselachus cuspidatus* (NMNS-PV 27452–27460), *Carcharodon hastalis* (NMNS-PV 27461–27470), *Carcharodon planus* (NMNS-PV 27471–27476), *Isurus desori* (NMNS-PV 27477–27484), *Lamna* sp. (NMNS-PV 27485), *Otodus megalodon* (NMNS-PV 27486), *Parotodus benedeni* (NMNS-PV 27487–27489), *Alopias* cf. *A. superciliosus* (NMNS-PV 27490), *Hemipristis serra* (NMNS-PV 27491), *Galeocерdo aduncus* (NMNS-PV 27492), *Carcharhinus* cf. *C. altimus* (NMNS-PV 27493), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27494, 27495), *Carcharhinus* cf. *C. macloiti* (NMNS-PV 27496), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27497, 27498), *Carcharhinus* sp. (NMNS-PV 27499–27529), *Myliobatis* sp. (NMNS-PV 27530–27533)

41. Wajimazaki Formation, Ishikawa

Carcharodon hastalis (NMNS-PV 27538–27540), *Carcharodon planus* (NMNS-PV 27541–27543), *Isurus desori* (NMNS-PV 27544, 27545), *Carcharhinus* sp. (NMNS-PV 27546)

42. Oya Formation, Utsunomiya Group, Tochigi

Odontaspis sp. (NMNS-PV 26898), *Isurus desori* (NMNS-PV 26899), *Carcharhinus* sp.

(NMNS-PV 26900–26905), Fam., gen. et sp. indet. (NMNS-PV 26906, 26907)

43. Hannoura Formation, Ishikawa

Carcharias contortidens (NMNS-PV 27253, 27254, 33874–33883), *Araloselachus cuspidatus* (NMNS-PV 27255), *Carcharodon hastalis* (NMNS-PV 27256, 27257, 33888), *Carcharodon planus* (NMNS-PV 27258–27263, 33889), *Isurus desori* (NMNS-PV 27264), *Otodus megalodon* (NMNS-PV 27265), *Parotodus benedeni* (NMNS-PV 33886), *Scyliorhinus kasenoi* (NMNS-PV 27266–27269, 33887), *Carcharhinus* cf. *C. altimus* (NMNS-PV 27270, 27271), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 27272), *Carcharhinus* cf. *C. brevipinna* (NMNS-PV 27273), *Carcharhinus* cf. *C. falciformis* (NMNS-PV 27274), *Carcharhinus* sp. (NMNS-PV 27275–27292, 33884, 33885)

44. Taga Group, Ibaraki

Carcharodon hastalis (NMNS-PV 26886–26891), *Carcharodon planus* (NMNS-PV 26892), *Isurus desori* (NMNS-PV 26893–26896)

45. Haratajino Formation, Tomioka Group, Gunma

Chlamydoselachus sp. (NMNS-PV 26908), *Centrophorus* sp. (NMNS-PV 26909), *Deania* sp. (NMNS-PV 26910, 26911), *Etmopterus* sp. (NMNS-PV 26912), *Centroscymnus* sp. (NMNS-PV 26913), *Centroselachus* sp. (NMNS-PV 26914), *Somniosus* sp. (NMNS-PV 26915)

46. Onagawa Formation, Funagawa Group, Akita

Isurus desori (NMNS-PV 34007)

47. Yamairi Formation, Miyagi

Carcharodon hastalis (NMNS-PV 26850–26856), *Carcharodon planus* (NMNS-PV 26857–26866), *Isurus desori* (NMNS-PV 26867–26871), *Otodus megalodon* (NMNS-PV 26872–26884), *Hemipristis serra* (NMNS-PV 26885)

48. Tamari Formation, Shizuoka

Carcharodon hastalis (NMNS-PV 29324), *Isurus desori* (NMNS-PV 29325), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 29326), *Carcharhinus* cf. *C. limbatus* (NMNS-PV 29327), *Carcharhinus* sp. (NMNS-PV 29328–29342)

49. Shimoshiroiwa Formation, Yugashima Group, Shizuoka

Dalatias licha (NMNS-PV 29288), Odontaspidae gen. et sp. indet. (NMNS-PV 29289–29294), *Carcharodon hastalis* (NMNS-PV 29295–29304), *Isurus desori* (NMNS-PV 29305–29308), *Hemipristis serra* (NMNS-PV 29309), *Carcharhinus* sp. (NMNS-PV 29310–29312)

50. Aoso Formation, Shida Group, Miyagi

Carcharodon hastalis (NMNS-PV 28315–28327), *Isurus oxyrinchus* (NMNS-PV 28328, 28329), *Otodus megalodon* (NMNS-PV 28330–28335), *Carcharhinus altimus* (NMNS-PV 28336), *Carcharhinus brachyurus* (NMNS-PV 28337), *Carcharhinus obscurus* (NMNS-PV 28338, 28339), *Carcharhinus* sp. (NMNS-PV 28340–28342), Fam., gen. et sp. indet. (NMNS-PV 28343–28378)

51. Otogawa Formation, Tonami Group, Toyama

Megasqualus occidentalis (NMNS-PV 27231–27233), *Alopias* cf. *A. superciliosus* (NMNS-PV 27234), *Carcharhinus* cf. *C. galapagensis* (NMNS-PV 27235), *Carcharhinus* cf. *C. brachyurus* (NMNS-PV 2736), *Carcharhinus* cf. *C. plumbeus* (NMNS-PV 27237–27239), *Carcharhinus* sp. (NMNS-PV 27240–27251)

52. Nanakita Formation, Shida Group, Miyagi

Carcharodon hastalis (NMNS-PV 28379), *Isurus oxyrinchus* (NMNS-PV 28380)

53. Misaki Formation, Miura Group, Kanagawa

Pristiophorus japonicus (NMNS-PV 29052, 29066, 29067), *Odontaspis ferox* (NMNS-PV

29053), *Carcharodon hastalis* (NMNS-PV 29057, 29058), *Isurus oxyrinchus* (NMNS-PV 29059), *Parotodus benedeni* (NMNS-PV 29065), *Hypogaleus hyugaensis* (NMNS-PV 29068), *Carcharhinus altimus* (NMNS-PV 29069), *Carcharhinus* sp. (NMNS-PV 29060–29063, 29070–29075), *Sphyrna lewini* (NMNS-PV 29076), Fam., gen. et sp. indet. (NMNS-PV 29077)

54. Furuya Formation, Nishikatura Group, Yamanashi

Carcharodon hastalis (NMNS-PV 29079–29083, 29134, 32544, 32545), *Otodus megalodon* (NMNS-PV 29084), *Carcharhinus leucas* (NMNS-PV 29085, 29135, 29136), *Carcharhinus limbatus* (NMNS-PV 29137, 29138), *Carcharhinus obscurus* (NMNS-PV 29086), *Carcharhinus plumbeus* (NMNS-PV 29139), *Carcharhinus* sp. (NMNS-PV 29087–29132, 29140–29206), *Myliobatis* sp. (NMNS-PV 29133)

55. Oiso Formation, Kanagawa

Hexanchidae gen. et sp. indet. (NMNS-PV 32142), *Pristiophorus japonicus* (NMNS-PV 32093, 32096, 32114, 32118, 32120, 32123, 32126, 32144, 32146, 32149, 32167, 32171, 32178, 32179, 32198, 32204, 32205, 32217–32219, 32229, 32251, 32254, 32256, 32257, 32259, 32262, 32266, 32272, 32274, 32280, 32316), *Dalatias licha* (NMNS-PV 32136, 32155, 32284), *Squatina* sp. (NMNS-PV 32076, 32230, 32301), *Heterodontus* sp. (NMNS-PV 32077, 32125), *Carcharias taurus* (NMNS-PV 32075), Odontaspidae gen. et sp. indet. (NMNS-PV 32276), *Odontaspis ferox* (NMNS-PV 32105, 32154), *Carcharodon carcharias* (NMNS-PV 32252), *Carcharodon hastalis* (NMNS-PV 32115, 32195, 32243, 32520–32523), *Carcharodon hubbelli* (NMNS-PV 32070, 32074, 32078, 32080, 32081, 32085, 32088–32090, 32092, 32095, 32097, 32102, 32104, 32106–32110, 32119, 32121, 32128, 32129, 32132–32135, 32139, 32147, 32161–32164, 32168, 32169, 32173, 32175, 32176,

32181, 32188, 32190, 32201–32203, 32207, 32211–32213, 32220, 32222, 32225, 32226, 32228, 32232, 32233, 32240, 32242, 32244–32249, 32253, 32260, 32264, 32273, 32275, 32277, 32278, 32283, 32285–32288, 32292–32294, 32298, 32302, 32303, 32305–32310, 32312, 32518, 32519), *Isurus oxyrinchus* (NMNS-PV 32087, 32127, 32138, 32140, 32186, 32282, 32285–32288, 32291, 32295, 32524–32530), *Otodus megalodon* (NMNS-PV 32071, 32079, 32103, 32156, 32290), *Alopias superciliosus* (NMNS-PV 32210), *Galeocерdo cuvier* (NMNS-PV 32255), *Carcharhinus albimarginatus* (NMNS-PV 32208), *Carcharhinus altimus* (NMNS-PV 32082), *Carcharhinus brachyurus* (NMNS-PV 32117, 32131), *Carcharhinus galapagensis* (NMNS-PV 32192), *Carcharhinus leucas* (NMNS-PV 32137), *Carcharhinus obscurus* (NMNS-PV 32148), *Carcharhinus plumbeus* (NMNS-PV 32086), *Carcharhinus sorrah* (NMNS-PV 32296), *Carcharhinus* sp. (NMNS-PV 32072, 32073, 32083, 32091, 32098–32101, 32111–32113, 32122, 32124, 32130, 32141, 32145, 32151, 32152, 32158–32160, 32165, 32166, 32170, 32172, 32174, 32177, 32182, 32183, 32185, 32187, 32189, 32191, 32193, 32194, 32197, 32199, 32209, 32214–32216, 32221, 32223, 32224, 32227, 32234, 32235, 32237–32239, 32241, 32250, 32261, 32263, 32265, 32267, 32269, 32271, 32279, 32281, 32297, 32299, 32304, 32311, 32315, 32318–32320, 32531, 32532), *Sphyrna* sp. (NMNS-PV 32116), *Aetobatus* sp. (NMNS-PV 32313), *Myliobatis* sp. (NMNS-PV 32143, 32150, 32180, 32184, 32196, 32236, 32258, 32268, 32270, 32300, 32314, 32317, 32533)

56. Nashimoto Formation, Yugashima Group, Shizuoka

Dalatias licha (NMNS-PV 29313–29322), *Carcharhinus* sp. (NMNS-PV 29323)

57. Zushi Formation, Miura Group, Kanagawa

Isurus oxyrinchus (NMNS-PV 29036), *Hemipristis serra* (NMNS-PV 29037, 29038),

Carcharhinus obscurus (NMNS-PV 29039), *Carcharhinus* sp. (NMNS-PV 29040–290044),

58. Senhata Formation, Miura Group, Chiba

Chimaera sp. (NMNS-PV 28382–28384), *Hexanchus gigas* (NMNS-PV 28385), *Pristiophorus japonicus* (NMNS-PV 28389–28423, 32325–32347), *Dalatias licha* (NMNS-PV 28386–28288), *Squatina* sp. (NMNS-PV 28424), *Odontaspis ferox* (NMNS-PV 28425–28433), *Carcharodon hastalis* (NMNS-PV 28437–28583, 32391–32416), *Carcharodon hubbelli* (NMNS-PV 28592–28599), *Carcharodon plicatilis* (NMNS-PV 28584–28591), *Otodus megalodon* (NMNS-PV 28708–28721, 32321, 32322), *Parotodus benedeni* (NMNS-PV 28722–28733, 32323, 32324), *Isurus oxyrinchus* (NMNS-PV 28600–28706), *Isurus paucus* (NMNS-PV 28707, 32517), *Isurus* sp. (NMNS-PV 32348–32360), *Alopias* sp. (NMNS-PV 28434–28436, 32515, 32516), *Hemipristis serra* (NMNS-PV 28736–28747, 32361), *Galeocерdo cuvier* ? (NMNS-PV 28977), *Galeorhinus* sp. (NMNS-PV 28734, 28735), *Carcharhinus altimus* (NMNS-PV 28748), *Carcharhinus brachyurus* (NMNS-PV 28749, 28750), *Carcharhinus leucas* (NMNS-PV 28751), *Carcharhinus obscurus* (NMNS-PV 28752–28754), *Carcharhinus plumbeus* (NMNS-PV 28755, 28756), *Carcharhinus* sp. (NMNS-PV 28757–28973, 32362–32382, 32417–32512), *Sphyrna lewini* (NMNS-PV 28974–28976), *Sphyrna* sp. (NMNS-PV 32513, 32514), Fam., gen. et sp. indet. (NMNS-PV 28978–29001)

59. Harada Formation, Shirahama Group, Shizuoka

Dalatias licha (NMNS-PV 29955), *Pristiophorus japonicus* (NMNS-PV 29956, 29957), *Heterodontus* sp. (NMNS-PV 29958–29967), *Carcharodon carcharias* (NMNS-PV 29968–29991), *Galeocерdo cuvier* (NMNS-PV 29992), *Carcharhinus altimus* (NMNS-PV 29993), *Carcharhinus brachyurus* (NMNS-PV 29994), *Carcharhinus obscurus* (NMNS-PV 29995), *Carcharhinus plumbeus* (NMNS-PV 29996), *Carcharhinus* sp. (NMNS-PV 29997–30013)

60. Tatsunokuchi Formation, Sendai Group, Miyagi

Squalus sp. (NMNS-PV 29344, 29345), *Carcharodon carcharias* (NMNS-PV 29346, 29347), *Carcharhinus altimus* (NMNS-PV 29348), *Carcharhinus falciformis* (NMNS-PV 29349–29351), *Carcharhinus galapagensis* (NMNS-PV 29352), *Carcharhinus leucas* (NMNS-PV 29353), *Carcharhinus obscurus* (NMNS-PV 29354), *Carcharhinus* sp. (NMNS-PV 29355–29367), *Raja pulchra* (NMNS-PV 29368), *Dasyatidae* gen. et sp. indet. (NMNS-PV 29369, 29370), *Myliobatis sendaicus* (NMNS-PV 29371–29378), Fam., gen. et sp. indet. (NMNS-PV 29379–29383)

61. Hasse Formation, Miura Group, Kanagawa

Odontaspis ferox (NMNS-PV 29054, 29055), *Otodus megalodon* (NMNS-PV 29056),

62. Shigarami Formation, Nagano

Carcharodon carcharias (NMNS-PV 34020)

63. Shimajiri Group or Chinen Formation, Okinawa

Notorynchus cepedianus (NMNS-PV 33937), *Carcharodon carcharias* (NMNS-PV 30057–30071), *Isurus oxyrinchus* (NMNS-PV 30072), *Otodus megalodon* (NMNS-PV 30073), *Parotodus benedeni* (NMNS-PV 30074, 30075), *Hemipristis serra* (NMNS-PV 30076, 30077), *Galeocerdo cuvier* (NMNS-PV 30078, 30079), *Carcharhinus altimus* (NMNS-PV 30081), *Carcharhinus leucas* (NMNS-PV 30080), *Carcharhinus limbatus* (NMNS-PV 30083), *Carcharhinus* sp. (NMNS-PV 30082, 30084)

64. Nobori Formation, Tonohama Group, Kochi

Carcharhinus sp. (NMNS-PV 30056)

65. Dainenji Formation, Sendai Group, Miyagi

Odontaspis ferox (NMNS-PV 29384), *Carcharodon carcharias* (NMNS-PV 29385), *Carcharhinus brachyurus* (NMNS-PV 29386),

Carcharhinus obscurus (NMNS-PV 29387), *Carcharhinus* sp. (NMNS-PV 29388–29390)

66. Zugawa Formation, Hokuriku Group, Toyama

Carcharodon carcharias (NMNS-PV 30047, 30048), *Otodus megalodon* (NMNS-PV 30049)

67. Naarai Formation, Inubo Group, Chiba

Dalatis licha (NMNS-PV 29391–29397), *Pristiophorus japonicus* (NMNS-PV 29398–29405), *Heterodontus* sp. (NMNS-PV 29406, 29407, 32534), *Odontaspis ferox* (NMNS-PV 29408–29415), *Odontaspidae* gen. et sp. indet. (NMNS-PV 29416), *Carcharodon carcharias* (NMNS-PV 29417–29611, 32537, 33892, 33893), *Carcharodon hastalis* (NMNS-PV 29612, 29613), *Otodus megalodon* (NMNS-PV 29614–29623, 33894, 33895), *Parotodus benedeni* (NMNS-PV 29624–29627, 32538), *Isurus oxyrinchus* (NMNS-PV 29628–29664, 33899, 33900), *Hemipristis serra* (NMNS-PV 29665, 32535, 32536), *Carcharhinus brachyurus* (NMNS-PV 29666), *Carcharhinus falciformis* (NMNS-PV 29667), *Carcharhinus leucas* (NMNS-PV 29668), *Carcharhinus obscurus* (NMNS-PV 29669), *Carcharhinus sorrah* (NMNS-PV 29670), *Carcharhinus* sp. (NMNS-PV 29671–29891, 33898)

68. Ananai Formation, Tonohama Group, Kochi

Carcharhinus obscurus (NMNS-PV 30050), *Carcharhinus* sp. (NMNS-PV 30051–30054), *Negaprion acutidens* (NMNS-PV 30055)

69. Dainichi Formation, Kakegawa Group, Shizuoka

Chimaera sp. (NMNS-PV 30787, 33805–33807, 33867–33869), *Pristiophorus japonicus* (NMNS-PV 30788, 30789, 33660–33674), *Squalus* sp. (NMNS-PV 30790–30795, 33718–33759), *Squatina* sp. (NMNS-PV 30796–30876, 32722–32759, 32952, 32953, 33406–33455), *Orectolobus japonicus* (NMNS-PV 30877), *Heterodontus* sp. (NMNS-PV 30788–31063,

31089, 32760–32764, 32829, 32830, 32954–32958, 33456–33570, 33820–33846), *Carcharodon carcharias* (NMNS-PV 31064–31081, 32836–32842, 33812–33816), *Isurus oxyrinchus* (NMNS-PV 31082–31084, 33676, 33817, 33818), *Isurus paucus* (NMNS-PV 31085), *Alopias superciliosus* (NMNS-PV 31086), *Alopias vulpinus* (NMNS-PV 33675), *Cetorhinus maximus* (NMNS-PV 31087, 31088, 33764), *Galeus* sp. (NMNS-PV 31090), *Galeorhinus galeus* (NMNS-PV 32939), *Triakis scyllium* (NMNS-PV 31091–31095, 32960, 33855), *Mustelus* sp. (NMNS-PV 31096, 31097, 33654–33659), *Hypogaleus hyugaensis* (NMNS-PV 31098), *Chaenogaleus macrostoma* (NMNS-PV 31099–31152, 3284–3328912, 38936–38938, 33571–33653), *Hemipristis serra* (NMNS-PV 31153, 31154, 33847), *Galeocerdo cuvier* (NMNS-PV 31155–31160, 32959, 33760–33763, 33808–33811, 33870–33873), *Carcharhinus altimus* (NMNS-PV 31161), *Carcharhinus amboinensis* (NMNS-PV 31162), *Carcharhinus brachyurus* (NMNS-PV 31163, 31164), *Carcharhinus galapagensis* (NMNS-PV 31165), *Carcharhinus leucas* (NMNS-PV 31166–31168), *Carcharhinus limbatus* (NMNS-PV 31169–31171), *Carcharhinus obscurus* (NMNS-PV 31172, 31173), *Carcharhinus plumbeus* (NMNS-PV 31174), *Carcharhinus* sp. (NMNS-PV 31175–31327, 32621–32721, 32913–32935, 33677–33717, 33792–33804, 33918, 33919, 33922–33927), *Prionace glauca* (NMNS-PV 31328), *Rhizoprionodon acutus* (NMNS-PV 33784, 33785), *Rhizoprionodon oliginx* (NMNS-PV 31329, 33786, 33787), *Sphyrna lewini* (NMNS-PV 31330–31332, 32834, 33788–33790), *Sphyrna zygaena* (NMNS-PV 31333, 32835, 33791), *Sphyrna* sp. (NMNS-PV 31334, 31335, 33920, 33921, 33928–33936), *Aetobatus* sp. (NMNS-PV 31453–31492), *Myliobatis* sp. (NMNS-PV 31336–31452, 32765–32774, 33856–33865), *Dasyatidae* gen. et sp. indet. (NMNS-PV 31493–31621, 32783–32811, 33099–33405), *Rhynchobatus* sp. (NMNS-PV 31622–31646, 32812–32828, 33039–33098), *Raja pulchra*

(NMNS-PV 33023–33027), Fam., gen. et sp. indet. (NMNS-PV 31647–31741, 32775–32781, 32831–32833, 32940–32951, 33028–33038, 33765, 33848–33854)

70. Onma Formation, Hokuriku Group, Ishikawa

Carcharodon carcharias (NMNS-PV 30757–30762), *Galeocerdo cuvier* (NMNS-PV 30763), *Carcharhinus falciformis* (NMNS-PV 30764), *Carcharhinus galapagensis* (NMNS-PV 30765), *Carcharhinus* sp. (NMNS-PV 30766–30786)

71. Takatsukayama Formation, Osaka Group, Osaka

Carcharodon carcharias (NMNS-PV 32069)

72. Miyata Formation, Sagami Group, Kanagawa

Odontaspis ferox (NMNS-PV 30753, 30754), *Carcharodon plicatilis* ? (NMNS-PV 30755), *Carcharhinus obscurus* (NMNS-PV 30756)

73. Ichijyuku Formation, Kazusa Group, Chiba

Chimaera sp. (NMNS-PV 30094), *Hexanchus griseus* (NMNS-PV 30095), *Hexanchidae* gen. et sp. indet. (NMNS-PV 30096), *Notorynchus cepedianus* (NMNS-PV 32547), *Odontaspis ferox* (NMNS-PV 30097–30100), *Carcharodon carcharias* (NMNS-PV 30101–30313, 32546, 33901), *Isurus oxyrinchus* (NMNS-PV 30314–30491), *Lamna ditropis* (NMNS-PV 30492, 30493), *Parotodus benedeni* (NMNS-PV 30495), *Galeocerdo cuvier* (NMNS-PV 30496–30539, 32548), *Carcharhinus leucas* (NMNS-PV 30540, 30622), *Carcharhinus obscurus* (NMNS-PV 30541), *Carcharhinus* sp. (NMNS-PV 30542–30621, 30623–30701), *Dasyatidae* gen. et sp. indet. (NMNS-PV 30702), *Myliobatis* sp. (NMNS-PV 30703, 30704, 32549), Fam., gen. et sp. indet. (NMNS-PV 30494, 30705–30726)

74. Kioroshi Formation, Shimosa Group, Ibaraki and Chiba

Squalus sp. (NMNS-PV 30085), *Squatina* sp.

(NMNS-PV 30086), *Galeocерdo cuvier* (NMNS-PV 30087), *Carcharhinus obscurus* (NMNS-PV 30088), *Carcharhinus brevipinna* (NMNS-PV 30089), *Dasyatidae* gen. et sp. indet. (NMNS-PV 30090–30093)

75. Umeda Formation, Osaka Group, Osaka

Carcharhinus obscurus (NMNS-PV 32067), *Aetobatus* sp. (NMNS-PV 32987), Fam., gen. et sp. indet. (NMNS-PV 32068)

76. Nanyo Formation, Aichi

Carcharias taurus (NMNS-PV 32016–32025, 33912, 33913), *Galeocерdo cuvier* (NMNS-PV 32026), *Carcharhinus brachyurus* (NMNS-PV 32027), *Carcharhinus obscurus* (NMNS-PV 32028), *Carcharhinus plumbeus* (NMNS-PV 32029–32031), *Carcharhinus* sp. (NMNS-PV 32032–32037), *Aetobatus* sp. (NMNS-PV 32058–32062), *Myliobatis* sp. (NMNS-PV 32038–32057, 33914–33917), Fam., gen. et sp. indet. (NMNS-PV 32063–32066)

APPENDIX II: Other records (not described)

1) Akasaka Limestone (Middle Permian), Ogaki City, Gifu

Petalodus sp. (NMNS-PV 34039–34041), *Sandalodus* sp. (NMNS-PV 34042)

2) Ezo Group (Upper Cretaceous), Hokkaido

Ptychodus latissimus (NMNS-PV 26282), *Ptychodus mantelli* (NMNS-PV 26281), *Ptychodus* sp. (NMNS-PV 26320–26328), *Hexanchus* sp. (NMNS-PV 26278, 26283, 26293, 26315), *Notorynchus* sp. (NMNS-PV 26285), *Xampylodon dentatus* (NMNS-PV 26274–26277, 26298, 26301, 26318, 26319), *Sphenodus* sp. (NMNS-PV 26273, 26291), *Echinorhinus* sp. (NMNS-PV 26292), *Protosqualus* sp. (NMNS-PV 26290), *Squalus* sp. (NMNS-PV 26290), *Centrophorus* sp. (NMNS-PV 26306), *Squaliformes* gen. et sp. indet. (NMNS-PV 26317), *Carcharias* sp. (NMNS-PV 26284, 26288, 26300, 26303, 26309), *Cretalamna appendiculata* (NMNS-PV 26287, 26308), *Cretalamna*

sp. (NMNS-PV 26279, 26294, 26302, 26304, 26305, 26311), *Cretoxyrhina mantelli* (NMNS-PV 26272, 26312, 26313), *Cretodus crassidens* (NMNS-PV 26316), *Scapanorhynchus texanus* (NMNS-PV 26295–26297), *Paranomotodon angustidens* (NMNS-PV 26280), *Squalicorax falcatus* (NMNS-PV 26310), *Squalicorax* sp. (NMNS-PV 26307), Fam., gen. et sp. indet. (NMNS-PV 26299, 26314)

3) Shimonada Formation, Izumi Group (Upper Cretaceous), Minamiawaji City, Hyogo

Carcharias sp. (NMNS-PV 33997)

4) Maeshima Formation (Middle-Upper Eocene), Setouchi City, Okayama

Carcharias contortidens (NMNS-PV 26560–26563)

5) Hioki Group (Lower Oligocene), Shimonoseki City, Yamaguchi

Fam., gen. et sp. indet. (NMNS-PV 26727)

6) Hontani Formation (Lower Miocene), Iwaki City, Fukushima

Carcharhinus sp. (NMNS-PV 34008)

7) Orito Formation (Lower Miocene), Sado City, Niigata

Carcharias contortidens (NMNS-PV 34016), *Isurus desori* (NMNS-PV 34017)

8) Kurami Group (Lower Miocene), Mori Town, Shizuoka

Parotodus benedeni (NMNS-PV 33996)

9) Yamami Formation, Morozaki Group (Lower Miocene), Minamichita Town, Aichi

Isurus desori (NMNS-PV 33983), *Carcharhinus* sp. (NMNS-PV 33902, 33982), *Sphyrna* sp. (NMNS-PV 33981)

10) Makino Formation, Awa Group (Lower Miocene), Iga City, Mie

Carcharhinus sp. (NMNS-PV 34034)

11) Nenokami Formation, Oganomachi Group (Middle Miocene), Chichibu City, Saitama

Squalus sp. (NMNS-PV 26927), *Hemipristis serra* (NMNS-PV 26941)

12) Hontanigawa Formation, Tanzawa Group (Middle Miocene), Yamakita Town, Kanagawa

Carcharhinus sp. (NMNS-PV 33984–33993)

13) Futamata Group (Middle Miocene), Iwata City, Shizuoka

Isurus desori (NMNS-PV 33995), *Carcharhinus* sp. (NMNS-PV 33994)

14) Sunagozaka Formation, Hokuriku Group (Middle Miocene), Kanazawa City, Ishikawa

Carcharodon hastalis (NMNS-PV 34021)

15) Shimo Formation, Uchiura Group (Middle Miocene), Takahama Town, Fukui

Carcharias contortidens (NMNS-PV 34032, 34033), *Isurus desori* (NMNS-PV 34031), *Carcharhinus* sp. (NMNS-PV 34023–34030)

16) Yokoo Formation (Middle Miocene), Ueda City, Nagano

Dalatias licha (NMNS-PV 34018, 34019)

17) Fujina Formation (Middle Miocene), Matsue City, Shimane

Carcharodon hastalis (NMNS-PV 34001), *Carcharhinus* cf. *altimus* (NMNS-PV 34000)

18) Kubota Formation (Upper Miocene), Hanawa Town, Fukushima

Squatina sp. (NMNS-PV 34009)

19) Haraihci Formation (Upper Miocene), Takasaki City, Gunma

Carcharodon hastalis (NMNS-PV 34015)

20) Hatsuzaki Formation, Hitachi Group (Lower Pliocene), Hitachi City, Ibaraki

Carcharodon carcharias (NMNS-PV 34012), *Otodus megalodon* (NMNS-PV 34013, 34014)

21) Ninomiya Group (Middle Pleistocene), Ninomiya Town, Kanagawa

Carcharias taurus (NMNS-PV 34022)

22) Tsukahara Formation (Middle-Upper Pleistocene), Minamisouma City, Fukushima

Carcharhinus sp. (NMNS-PV 34010, 34011)

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