Scincomorphan Lizards from the Lower Cretaceous Sasayama Group, Hyogo, Japan

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Abstract

A terrestrial vertebrate fossil assemblage of dinosaurs, small mammals, anurans, and lizards was discovered in the Lower Cretaceous Sasayama Group, Hyogo Prefecture, Japan. Here, some fragmentary lizard fossils are described briefly, and taxonomic allocations are tentatively identified. The combination of some osteological characters on each fragmentary remain indicates that these fossil lizards are assigned to the infraorder Scincomorpha, and the general morphological differences between each fossil suggest that the lizard fauna of the Lower Cretaceous Sasayama Group contains at least four taxa of Scincomorphan lizards.

Key words: Lizard, Lower Cretaceous, Sasayama Group, Hyogo, Scincomorpha.

Introduction

Lizards belong to the Squamata, along with snakes and amphisbaenas. Lizards currently include more than 5600 species and are distributed extensively over every continent except Antarctica (Uetz, 2013). The origin, phylogenetic, relationships, and evolutionary processes of the Squamata are based on neontological (morphological and molecular), and paleontological studies have been discussed by many authors over the past several decades (e.g., Camp, 1923; Estes, 1983, 1988; Lee, 1998; Evans et al., 2005; Conrad, 2008; Vidal and Hedge, 2009; Gauthier et al., 2012). Fossil lizards, which substantiate the existence of each species at each geological time, play an important role in the discussion, and new discoveries of fossil lizards provide an increased understanding of the lizard’s evolutionary history.

The earliest fossil lizard, *Bharatagama rebbanensis*, was reported from the Early-Middle Jurassic Kota Formation of India (Evans et al., 2002), and the origin of the Squamata was estimated at around the Middle Triassic based on paleontological and molecular data (e.g., Evans, 2003; Vidal and Hedge, 2005). Early diversification in lizards as well as other reptiles has been hypothesized to originate during the Mesozoic era. However, the fossil record of the era to substantiate the evolutionary event is patchy and limited (e.g., Evans, 2003). Among the lizard fossils from the Mesozoic era, Early Cretaceous remains are significant for investigating the faunal transition from the archaic lizards of the Jurassic (e.g., paramacrololids and *Andeosauroidea*) to the modern lizards of the Late Cretaceous (e.g., varanoids and teiids) (Alifanov, 1993; Evans, 1993; Gao and Hou, 1995). Lizard fossils of the Early Cretaceous are relatively rare compared with those of the Late Cretaceous, but some fossil lizard assemblages of the Early Cretaceous are currently known from Europe;
North, Central, and South America; Africa; and Asia (e.g., Hoffstetter, 1967; Gao and Nussov, 1998; Nydam, 1999; Evans and Searle, 2002). More recently, new fossil representatives of the Early Cretaceous such as *Pachygenys* (Gao and Cheng, 1999), *Xianglong* (Li et al., 2007), *Kuwajimalla* (Evans and Manabe, 2008), and *Liushusaurus* (Evans and Wang, 2010) have been successively reported from China, Inner Mongolia, and Japan.

In addition to the fossil records mentioned above, the present study reports on the Early Cretaceous fossil lizard assemblage in a new locality. Moreover, taxonomic allocations of fragmentary lizard remains from the ‘Lower Formation’ of the Sasayama Group are described based on taxonomic accounts of lizards by previous authors (e.g., Estes, 1988).

**Institutional Abbreviations:** MNHAH, Museum of Nature and Human Activities, Hyogo, Japan

**Geological background**

The fragmental fossils of the lizards described here were found from the ‘Lower Formation’ of the Sasayama Group, in the eastern part of Hyogo Prefecture, Japan (Fig. 1). The group is divided into the ‘Lower Formation’ and the ‘Upper Formation’

![Map showing geographical location Tamba and Sasayama City, Hyogo, Japan. The gray area denotes the distributional area of the Sasayama Group. B, Geological Map of Tamba-Sasayama Area; modified after Yoshikawa (1993). Blue stars represents the fossil localities of the Sasayama Group. C, a view of “Kamitaki” fossil locality. D, a view of “Miyada” fossil locality.](image-url)
based on lithological characters (Yoshikawa, 1993; Kusuhashi et al., 2013). The ‘Lower Formation’ is composed mainly of conglomerate, sandstone, and mudstone intercalating several tuff beds, and the ‘Upper Formation’ is represented by hornblende andesite pyroclastic rocks, tuffaceous sandstone, and mudstone (Yoshikawa, 1993). In the past several years, abundant vertebrate remains of dinosaurs, small mammals, anurans, and lizards have been found from the ‘Lower Formation’ of the Sasayama Group in some localities, i.e., at Kamitaki in Tamba City and at Oyama, Miyada, and Nishikosa in Sasayama City (Fig. 1) (Saegeusa et al., 2008 a, b; Ikeda and Saegusa, 2009; Saegeusa et al., 2009; Ikeda et al., 2010; Saegusa et al., 2010 a, b; Saegusa and Tomida, 2011).

The geological age of the ‘Lower Formation’ of the Sasayama Group remains still controversial. A zircon fission track age of 138 ± 9 Ma was obtained from rhyolite tuff beds in the ‘Lower Formation’ of the group (Matsuura and Yoshikawa, 1992). Recently, Hayashi et al. (2010) reexamined ostracode and conchostracan biostratigraphies and zircon fission track dating of the Sasayama Group and estimated the geological age of the ‘Lower Formation’ of the group as Aptian-Cenomanian. Recently Kusuhashi et al. (2013) obtained a high-precision U-Pb age of zircons from a tuff bed in the lower part of the ‘Lower Formation’ using a sensitive high-resolution ion microscope (SHRIMP II), and estimated the date of the stratum, from which fossils of Sasayamamylos kawaii were excavated with the lizard mandibles examined here, to be 112.1 ± 0.4 Ma. In the present study, we adopt this last estimation as the date of our materials.

Material and Methods

Five fragmental dentaries of fossil lizards, described here, were collected from two localities. One of the five dentaries was found in red mudstone of the ‘Lower Formation of the Sasayama Group exposed on riverbank of the Sasayama River at Kamitaki in Tamba City together with a partial skeleton of a titanosauriform sauropod, shed teeth of theropods and ornithopods, and many anurans (e.g., Ikeda et al., 2010; Saegeusa et al., 2008 a, b) (Fig. 1). The other dentaries were reported from red mudstone in the Lower Formation of the Sasayama Group at Miyada in Sasayama City (Fig. 1). The fossil assemblages at Miyada are characterized by microvertebrate remains that contain many fragmentary cranial and postcranial elements of lizards, some mammalian lower jaws which were described as S. kawaii, and a few cranial remains of dinosaurs (e.g., Ikeda and Saegusa, 2009; Kusuhashi et al., 2013; Saegeusa et al., 2009).

In the present study, the terminology used for cranial osteological features mainly follows Gao and Fox (1996), and Evans (2008). The terminology used to describe tooth morphology follows Kosma (2004), who prescribed terms for tooth forms based on extant and extinct Scinciform lizards. Orientation terminology also follows Gao and Fox (1996). Researchers have discussed the taxonomic definitions and systematics of lizards since the end of the 19th century (see Historical Analysis of Conrad [2008]), and controversies continue. Here, the classification follows Estes et al. (1988), who defined the diagnosis of each higher taxon based on the osteological features of extant lizards in systematic paleontology because it is widely accepted by many authors and is used as a standard for investigating squamate relationships (e.g., Conrad, 2008).

Systematic paleontology

**SQUAMATA** Oppel, 1811

**SCINCOGNEKKONOMORPHA** Sukhanov, 1961

**SCLEROGLOSSA** Estes et al., 1988

**SCINCOMORPHA** Camp, 1923

Scincomorphi gen. et sp. indet.

Material: Three fragmental right dentaries (MNHAH D1-032077, D1-032152, and D1-032440), and two fragmental left dentaries (MNHAH D1-032154 and D1-032159).

Locality and horizon: Four specimens (D1-032077, D1-032152, D1-032154, and D1-032159) and one specimen (D1-032440) were discovered from the lower part of the ‘Lower Formation’ of the Sasayama Group at Miyada in Sasayama City (35°05’ 34” N, 135°10’ 40” E) and at Kamitaki in Tamba City (35°08’ 21”N, 135°10’ 53” E), respectively, in Hyogo Prefecture, Japan. The approximate geological age of the formation is considered as early Albion (Early
Cretaceous).

Indeterminate Type A

Description of D1-032077 (Fig. 2)

D1-032077 is an incomplete right dentary missing its anterior end and posterior portions, and preserves 16 tooth positions, two complete teeth (d, e), and eleven incomplete teeth (a, b, c, g, h, j, k, l, m, o, p). The total length of the specimen is 139 mm.

The lateral surface of D1-032077 is smooth and convex, and has six mental foramina (inferior alveolar foramina of Gao and Fox [1996]). The dorsal margin of the dentary is nearly straight, whereas the ventral margin is convex. The subdental shelf is tall and robust anteriorly (approximately one-third of the tooth height) but gradually narrows posteriorly. The subdental gutter is narrow and shallow. Posteriorly, the Meckelian canal is wide, opens medially, and narrows anteriorly. The articular facet for the splenial is preserved on the ventral surface of the subdental shelf and extends anteriorly to the (i) tooth position. The lateral border of the Meckelian canal also bears the facet on the medial side. Both articular facets of the specimen indicate that the splenial originally extended to the (h) tooth position.

The inferior alveolar canal is situated ventral to the (m) tooth position, on the roof of the Meckelian canal. The posterior projection of the intramandibular septum is not developed. The teeth are pleurodont and are attached to the medial wall of the dentary. Each tooth is narrowly spaced along the tooth row. The anterior teeth are posteriorly inclined, but the teeth in the middle and posterior positions are straight. The tooth shafts are cylindrical. The tooth crowns of the anterior teeth (d, e) are unicusp and moderately pointed, with weak mesial and distal ridges. Due to the poor preservation of the specimen, other features of the tooth crown such as striae and the cusps lingualis are not clearly observed in the anterior teeth (d, e) with a stereomicroscope. Because the tooth crowns of the middle and posterior teeth are not preserved, detailed structures of these tooth crowns cannot be evaluated. Small replacement pits are observed at the bases of some tooth positions (h, m, o, p).

Remarks for D1-032077

The combination of characters, such as pleurodont teeth, a developed subdental shelf, and no apparent posterior projection of the intramandibular septum

Fig. 2. Scincomorpha gen. et sp. indet. (D1-032077 : Type A) from the “Lower Formation” of the Sasayama Group at Miyada in Sasayama city (Hyogo Pref., Japan). A. a photograph in medial view. B. a photograph in lateral view. C. close up of “d, e” teeth in medial view. Abbreviations : den, dentary ; mc, Meckelian canal ; mf, mental foramen ; rp, replacement pit ; sbds, subdental shelf ; sd, sulcus dentalis.
indicates that the D1-032077 is assigned to the infraorder Scincemorpha (see Discussion). Moreover, some character states of the specimen (e.g., shapes of the dorsal and ventral margins of the dentary and slightly recurved anterior teeth) are shared with <i>Sakurasaurus shokawensis</i>, which was reported from the Early Cretaceous Okurodani Formation of Gifu Prefecture, Japan (Evans and Manabe, 1999, 2009). However, further investigations of other Mesozoic lizards such as the Chinese lizard <i>Yabeinosaurus</i> (Endo and Shikama, 1942), which is believed to be closely related to <i>Sakurasaurus</i> (Evans and Manabe, 2009), and additional remains are required to determine the taxonomic allocation of D1-032077 in detail.

Indeterminate Type B
Description of D1-032152 (Fig. 3)
D1-032152 is a partial right dentary with 14 tooth positions, two nearly complete teeth (b, l), and eight incomplete teeth (d, f, g, i, j, k, l, n). The specimen is missing the anterior part of the bone and the posteroventral and coronoid processes from the posterior end of the bone. The length of this specimen is 11.9 mm.

The lateral surface of D1-032152 is smooth and moderately convex and bears three mental foramina. The dorsal and ventral margins of the dentary are nearly straight. The subdental shelf is well developed and tall anteriorly (approximately one-half of the tooth height) but narrows posteriorly. The subdental gutter is narrow and shallow. The Meckelian canal is wide posteriorly and opens medially. The canal gradually narrows anteriorly. The vertebral surface of the subdental shelf bears a shallow groove for the articulation of the splenial that extends anteriorly to beneath the (d) tooth position. The facet for the splenial cannot be recognized on the medial side of the lateral border of the Meckelian canal due to the poor preservation of the specimen. The shallow groove for the articulation of the splenial, however, indicates the presence of the splenial reaching to at least beneath the (d) tooth position. The inferior alveolar canal is located ventral to the (d) tooth position, on the roof of the Meckelian canal. There is no apparent posterior projection of the intramandibular septum. The specimen has pleurodont teeth, which are attached to the medial wall of the dentary. Each tooth is narrowly spaced along the tooth row, and is straight. The tooth shafts

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Fig. 3. Scincemorpha gen. et sp. indet. (D1-032152 : Type B) from the ‘Lower Formation’ of the Sasayama Group at Miyada in Sasayama city (Hyogo Pref., Japan). A, a photograph in medial view. B, a photograph in lateral view. C, close up of “b” tooth in medial view. D, close up of “l” tooth in medial view. Additions: den, dentary; mc, Meckelian canal; mf, mental foramen; sbds, subdental shelf; sd, sulcus dentalis.
are cylindrical, whereas the medial surfaces of the
tooth crowns (b, l) are slightly curved lingually and
flattened. The tooth crowns (b, l) of the tooth are
almost blunt. The crista mesials of each tooth crown
(b, l) is longer than the crista distalis (approximately
twice as long). Other features of the tooth crowns
such as the striae, cuspis lingualis, and culmen
lateris cannot be identified because the specimen is
covered with Parafoil, an acrylic polymer used to
protect fossil specimens. The replacement pits at the
tooth base cannot be evaluated due to the poor
preservation of the specimen and the protective flux.

Description of D1-032154 (Fig. 4)

D1-032154 is a fragmental left mandible
preserving the middle and posterior portion of the
dentary, the anterior portions of the splenial and
surangular, and the anterior tip of the anteromedial
process of the coronoid. The dentary of the specimen
has at least 12 tooth positions, six complete teeth (f,
g, h, i, k, l) and five incomplete teeth (a, b, c, d, e).
The total length of the mandible is 12.4 mm.

The lateral surface of the dentary is slightly
convex and smooth. Three mental foramina open on
the lateral surface. In lateral view, the posterior
portion of the dentary has a single large notch
(surangular notch), and the posterodorsal and
posteroventral processes of the dentary are well
developed. The degree of development of these
processes, however, is not obvious due to the poor
state of preservation of the specimen. The dentary
presents relatively straight dorsal and ventral
margins. The subdental shelf is tall and robust
anteriorly (approximately one-half of the tooth
height) but narrows posteriorly. The subdental
gutter is narrow and shallow. The splenial covers
the Meckelian canal of the specimen medially and
preserves two well-developed foramina: the large
anterior inferior alveolar foramen opens close to the
splenodentary suture, and the small anterior
mylohyoid foramen is situated posteroventrally to
the former foramen, beneath the (j) tooth position.
Although most of the coronoid is broken off, the
anteromedial process of the coronoid extends
anteriorly and reaches under the (j) tooth position.
The dentary has straight teeth that are narrowly
spaced along the tooth row, and the mode of tooth
attachment is pleurodont. The shape of each tooth
shaft is cylindrical. The tooth crowns are blunt, and
the medial surfaces of these crowns are slightly

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Fig. 4. Scincomorpha gen. et sp. indet. (D1-032154 : Type B) from the "Lower Formation" of the
Sasayama Group at Miyada in Sasayama city (Hyogo Pref., Japan). A, a photograph in
medial view. B, a photograph in lateral view. C, close up of "i, h" teeth in medial view.
Addrivation : aiaf, anterior inferior alveolar foramen ; amf, anterior mylohyoid foramen ;
den, dentary ; mf, mental foramen ; sa, surangular ; sbds, subdental shelf ; sd, sulcus
dentalis ; sp, splenial.
curved lingually and flattened. The anterior tooth (a) and posterior teeth (k, l) are relatively robust compared to the middle teeth. The crista mesialis and the crista distalis are recognized on each tooth crown (f, g, h, i, k, l), and the crista mesialis is approximately twice as long as the crista distalis. The states of preservation of these tooth crowns are too poor to determine other crown features in detail. No tooth base bears an obvious replacement pit.

Remarks for D1-032152 and D1-032154

D1-032152 and D1-032154 are classified in the infraorder Scincomorpha based on the combination of characters, such as pleurodont teeth, a developed subdental shelf, and no apparent posterior projection of the intramandibular septum (see Discussion). Moreover, D1-032152 and D1-032154 are briefly assigned to indeterminate type B of the scincomorphan lizard, because these specimens exhibit same characters such as the shapes of the dentary and tooth crown, and number and position of the mental foramen. Furthermore, the tooth structure of these specimens resembles that of the Paramacellodidae, a widespread extinct group reported from the Middle Jurassic to the Lower Cretaceous in Europe, North America, Africa, and Asia (Evans, 2003). However, the significant characters for evaluating taxonomic position, such as the cusps lingualis and stria dominans, cannot be observed in these specimens due to the poor state of preservation. Further observations of the tooth crowns of D1-032152 and D1-032154 using an electron microscope, careful comparisons within the Mesozoic lizards, and more complete materials are required for more reliable taxonomic determinations of these specimens.

Indeterminate Type C

Description of D1-032159 (Fig. 5)

D1-032159 is a partial left mandible missing the posteriormost portion of the element. The mandible preserves the dentary, the anterior portion of splenial and surangular, and the anteromedial process of the coronoid. The dentary of the specimen has at least 22 tooth positions, three complete teeth (l, n, o), and 14 incomplete teeth (c, d, e, f, h, i, j, m, q, r, s, t, u, v). The total length of the mandible is 9.7 mm.

The specimen has a smooth lateral surface that is moderately convex. The dentary carries six mental foramina on the surface. A surangular notch

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![Diagram of scincomorpha gen. et sp. indet. (D1-032159 : Type C) from the “Lower Formation” of the Sasayama Group at Miyada in Sasayama city (Hyogo Pref., Japan). A, a photograph in medial view. B, a photograph in lateral view. C, close up of “l” tooth in medial view. Abbreviations: aiat, anterior inferior alveolar foramen; amf, anterior mylohyoid foramen; den, dentary; mc, Meckelian canal; mf, mental foramen; rp, replacement pit; sa, surangular; sbds, subdental shelf; sd, sulcus dentalis; sp, splenial; sy, symphysis.](image)
is well developed on the posterior portion of the dentary in lateral view, and the posterodorsal process of the dentary is relatively robust and extends posteriorly compared to the posteroverentral process based on the scar of the surangular notch. The dorsal and ventral margins of the dentary are straight in the lateral view. The subdental shelf is tall anteriorly (nearly one-third of the tooth height) and narrows posteriorly. The symphysis forms a flat surface ventrally, extending under the anteriormost three tooth positions (a, b, c). The subdental gutter is narrow and shallow. The Meckelian canal of the specimen is largely covered with the splenial and opens ventrally under the anterior tooth positions (c, d, e, f). A large inferior alveolar foramen of the mandible opens close to the spleniodentary suture on the splenial, and a small anterior mylohyoid foramen is positioned posteriormost to the former foramen, beneath the (p) tooth position. The anteromedial process of the coronoid extends anteriorly and reaches under the (t) tooth position. The teeth are pleurodont, with narrow, cylindrical tooth shafts, and are closely spaced along the tooth row. Tooth crowns are conical and unicusp (l, n, o). The medial surfaces of these crowns are slightly concave. The distinct cutting edges of the tooth crown are not clearly observed with a stereomicroscope. The replacement pits open at the bases of the (e, n, o) tooth positions and are slightly posterior to the centers of their teeth. The position of the replacement pits indicates lingual tooth replacement, and the replacement teeth are recognized on the (e, p) tooth positions.

Remarks for D1-032159

On the basis of the combination of characters such as pleurodont teeth, a developed subdental shelf, and base positions of tooth replacement pits, D1-032159 is assigned to the infraorder Scincomorpha (See Discussion). D1-032159 presents a slender dentary, and the morphology of the specimen is clearly distinct from any of the other lizards recovered from the lower formation of the Sasayama Group. Moreover, some characters of the specimen, such as the slender dentary and shapes of the tooth shaft and crown, are similar to these of Saurillus robustidens (Paramacellidae), which was reported from the Early Cretaceous Lulworth Formation in England (Hoffstetter, 1967; Evans and Searle, 2002). A more confident taxonomic identification of D1-032159 requires detailed observations of the tooth crown of the specimen with an electron microscope as well as careful comparisons within the Mesozoic lizards.

Indeterminate Type D

Description of D1-032440 (Fig. 6)

D1-032440 is an incomplete right dentary with 11 tooth positions, four complete teeth (c, e, f, g), and six incomplete teeth (a, b, d, i, j, k). The specimen is missing the anterior tip and posterior part of the bone, and the total length of the dentary is 3.9 mm.

The lateral surface of D1-032440 is smooth and convex. The mental foramen on the lateral

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Fig. 6. Scincomorpha gen. et sp. indet. (D1-532440: Type D) from the "Lower Formation" of the Sasayama Group at kamitaki in Tamba city (Hyogo Pref., Japan). A, a photograph in medial view. B, a photograph in lateral view. C, close up of "b, c" teeth in medial view. Abbreviations: den, dentary; mc, Meckelian canal; sbds, subdental shelf; sd, sulcus dentalis.
surface is not clearly visible. The dorsal margin of the specimen is weakly convex. The shape of the preserved ventral margin of the specimen indicates that the dentary originally had a convex ventral margin. The specimen shows a moderately developed subdental shelf that is thicker anteriorly, and the subdental gutter is narrow and shallow. The Meckelian canal is widely open medially in the posterior part of the specimen and narrows anteriorly. There are no obvious articulation facets for the splenial on the ventral margin of the subdental shelf and on the medial side of the lateral border of the Meckelian canal. The inferior alveolar canal and intramandibular septum are not recognized on the dentary. The teeth of the specimen, which are attached to the medial surface of the mandible, are pleurodont and quite robust. Each tooth is straight and closely spaced along the tooth row. The tooth shafts are cylindrical, and the shape of the tooth crowns is slightly pointed. Tooth crowns (c, e, f, g) are slightly concave medially and present the crista mesialis and the crista distalis. The former is approximately twice as long as the latter. Observation with a stereomicroscope reveals no other features of the tooth crown due to the protective flux and small size of the specimen. The replacement pits of the tooth base cannot be clearly identified.

Remarks for D1-032440

D1-032440 is assigned to the infraorder Scincomorpha based on the combination of characters such as pleurodont teeth, a developed subdental shelf, and no apparent posterior projection of the intramandibular septum (see Discussion). The size of the specimen is remarkably small compared with other described lizards from the Sasayama Group, and the incomplete right dentary is relatively tall in a dorsoventral direction. Here, the taxonomic allocation of the specimen is not identified in detail, but morphological differences between D1-032440 and the other specimens reported here suggest that the specimen belongs to a different taxon.

Discussion

Conrad (2008) and Gauthier et al. (2012) performed comprehensive cladistic analyses using numerous phenotypic characters of extant and extinct lizards and revised the definitions and diagnoses for each clade suggested in previous studies. The diagnostic features for each clade that were redefined in these studies were composed of a mixture of character states derived from several skeletal elements. However, not all of the clades had the diagnostic features that were derived from the fragmentary parts (e.g., dentary, maxilla, and vertebra) commonly found as fossils (Conrad, 2008).

The teeth of the fossil specimens described here are pleurodont, which is a general character in lizards except Agamidae and Chamaeleontidae, which have acrodont teeth (Estes et al., 1988; Conrad, 2008). Fossil specimens also present a well-developed subdental shelf, described as a synapomorphy of the Scleroglossa by Estes et al. (1988). Moreover, Estes et al. (1988) mentioned that a subdental shelf is absent in helodermatids, Lanthanotus, Varanus, some agamids, iguanids, chamaeleontids, and amphisbaenians. Conrad (2008) suggests an absence of the subdental shelf in Acrodonta, Amphisbaenia, and Serpentes. The replacement pits of the tooth row are not clearly observed in the fossil specimens except in D1-032077 and D1-032159, which have replacement pits at the tooth base or slightly posterior to the center of the tooth, respectively. The replacement mode of the fossil specimens, however, is assumed to be “iguanid replacement” or “intermediate condition” rather than “varanid replacement” based on closely spaced tooth row and well-developed subdental shelf of the fossils (Edmund, 1960, 1969). The tooth replacement type also implies that these fossil specimens have more affinity with the Scincomorpha than with the Anguimorpha (Estes, et al., 1988; Conrad, 2008). The well-developed intramandibular septum, which is common in Anguimorpha (Estes et al., 1988; Evans, 2008), is not observed in some fossil specimens. The closed Meckelian canal and fused dentary tube are described as synapomorphic characters of Gekkota by Estes et al. (1988), and these characters also occur in Xantusiidae and in some species of other families (Estes et al., 1988; Conrad, 2008; Evans, 2008). The Meckelian canal of fossil specimens is medially open and restricted anteriorly, which is quite different from the closed condition of these taxa. Considering the characters mentioned above, the fossil specimens examined here are selectively assigned to the infraorder Scincomorpha. Moreover, the morphological
differences within these specimens indicate that these fossils are divided into four indeterminate types of Scincomorpha lizards and that the lizard fauna of the Lower Cretaceous Sasayama Group consist of at least four different taxa. Other fragmental remains of lizards, such as vertebrae, maxillae, and braincases, were also discovered in the ‘Lower Formation’ of the Sasayama Group (Ikeda and Saegusa, 2009). Further investigations including these unexamined specimens and additional materials might increase the richness of the faunal composition.

Although fragmental fossil specimens of lizards occur frequently around the world, identification is often difficult even at the family level based on only a few characteristic features (e.g., Rieppel, 1994; Rees, 2000; Brizuela and Albino, 2011). Unambiguous diagnostic characters of fragmental remains such as dentaries have not been clearly determined at each taxonomic level: nevertheless, these remains have often been reported as a new species by previous authors (e.g., Seiffert, 1973; Allifanov, 1993; Gao and Fox, 1996; Kosma, 2004). In the present study, taxonomic allocations of fossil specimens were not determined in detail. We tentatively compared these fossils with some Mesozoic lizards found in Japan, China, and Europe. Results of the preliminary comparison showed that D1-032077 (a fragment right dentary) shares some characters, such as shape of the dentary and slightly recurved anterior tooth with weak crown ridges, with Sakurasaurus shokawensis, which occurred from the Early Cretaceous Okuradani Formation of Gifu Prefecture, Japan (Evans and Manabe, 1999, 2009). Moreover, other specimens (D1-032152, 032154, 032159, and 032440) exhibit a crista mesials and crista distals on each tooth crown; the tooth structures of these fossils are somewhat similar to those of paramacelolid lizards, which is a group ranging from the Middle Jurassic to the Early Cretaceous in Europe, North America, Africa and Asia (Evans, 2003; Kosma, 2004). Furthermore, D1-032159, which has a slender dentary and narrow, cylindrical tooth shafts, is roughly similar to Sauillus robustidens (Paramacelolidae) from the Early Cretaceous Lulworth Formation in England (Hafferstetter, 1967; Evans and Searle, 2002). However, the fossil specimens described here are too fragmented to perform a detailed comparison with other Mesozoic lizards, and further materials and advanced investigations, such as the use of an electron microscope and CT scanning, are needed to determine the accurate taxonomic allocations of these specimens. In particular, comprehensive studies of fragmental elements, such as the dentaries of extant and extinct lizards, are essential for accurate identifications of these fragmental fossil lizards and for resolving the taxonomic problem of Mesozoic lizards such as the Paramacelolidae (Nydam and Cifelli, 2002b).

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