

## EARLY CRETACEOUS VERTEBRATE REMAINS FROM KATSUYAMA CITY, FUKUI PREFECTURE, JAPAN

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### INTRODUCTION

Since the first discovery of a theropod tooth in 1985, the Mesozoic land vertebrate remains have been found at a number of sites in the Tetori Group, which is distributed in the Hokuriku Province, Central Japan (Fig. 1). The Tetori Group, which ranges from the Middle Jurassic to Early Cretaceous in age, is subdivided into three subgroups, the Kuzuryu, Itoshiro, and Akaiwa subgroups in ascending order (Maeda, 1961). In 1982, a Mesozoic crocodylian skeleton was recovered at the cliff on the left bank of the Sugiyama River in Katsuyama City, Fukui Prefecture. A number of vertebrate fossils including dinosaurs, crocodiles, turtles, and fish scales have been recovered from the site (Azuma and Tomida, 1995), called the Kitadani Dinosaur Quarry (Fig. 2). The Akaiwa Subgroup, the uppermost part of the Tetori Group, is exposed in and around the quarry. The Akaiwa Subgroup has been considered to represent Hauterivian to Barremian age on the basis of molluscan fauna and FT dating (Fujita, in this issue).

The Akaiwa Subgroup in this region is subdivided into two formations on the basis of its lithology: the Akaiwa Formation and the overlying Kitadani Formation (Maeda, 1958). The Akaiwa Formation consists of coarse-grained arkose sandstone, including orthoquartzite pebbles, interbedded with thin shale layers. The lower part of this formation yields *Myrene* sp. and plant fossils. The Kitadani Formation consists mainly of alternating beds of thick sandstone and shale interbedded with “tuff” layers. This formation contains abundant fresh water bivalves and gastropods: *Plicatounio*, *Nippononaia*, *Trigonioides*, *Pseudohyria*, *Nagdongia*, and *Viviparus* (Maeda, 1961; Tamura, 1990).

The Kitadani Formation consists of terrestrial sediments, which were deposited by ancient meandering rivers, and is rich in invertebrate fossils and terrestrial vertebrate footprints.

### DINOSAURS AND OTHER MATERIALS FROM THE KITADANI DINOSAUR QUARRY

#### Body fossils

**Pisces:** Abundant amiiform fish scales have been found from the site. Almost all fish scales are isolated, and are diamond or parallelogram in shape (Fig. 3a).

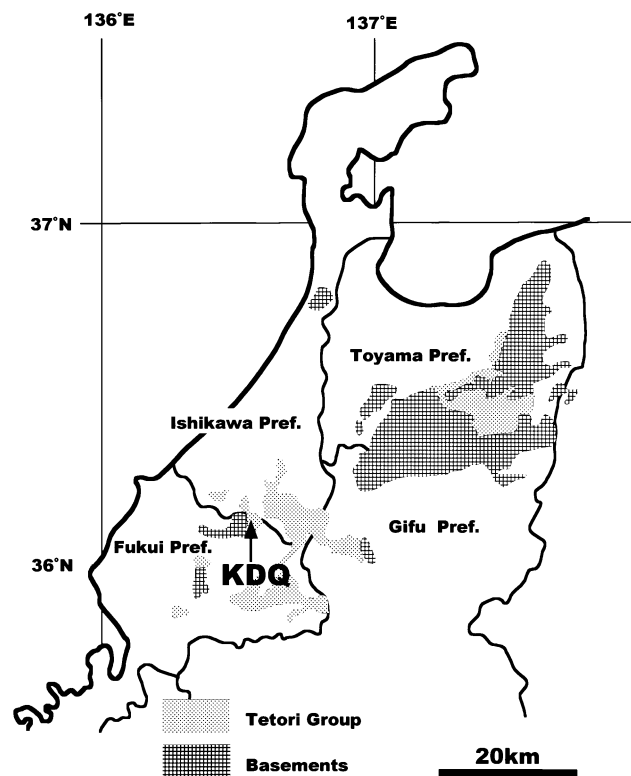


FIGURE 1. Map showing the distribution of the Tetori Group in the Hokuriku Province of Central Japan, and the Kitadani Dinosaur Quarry (KDQ).

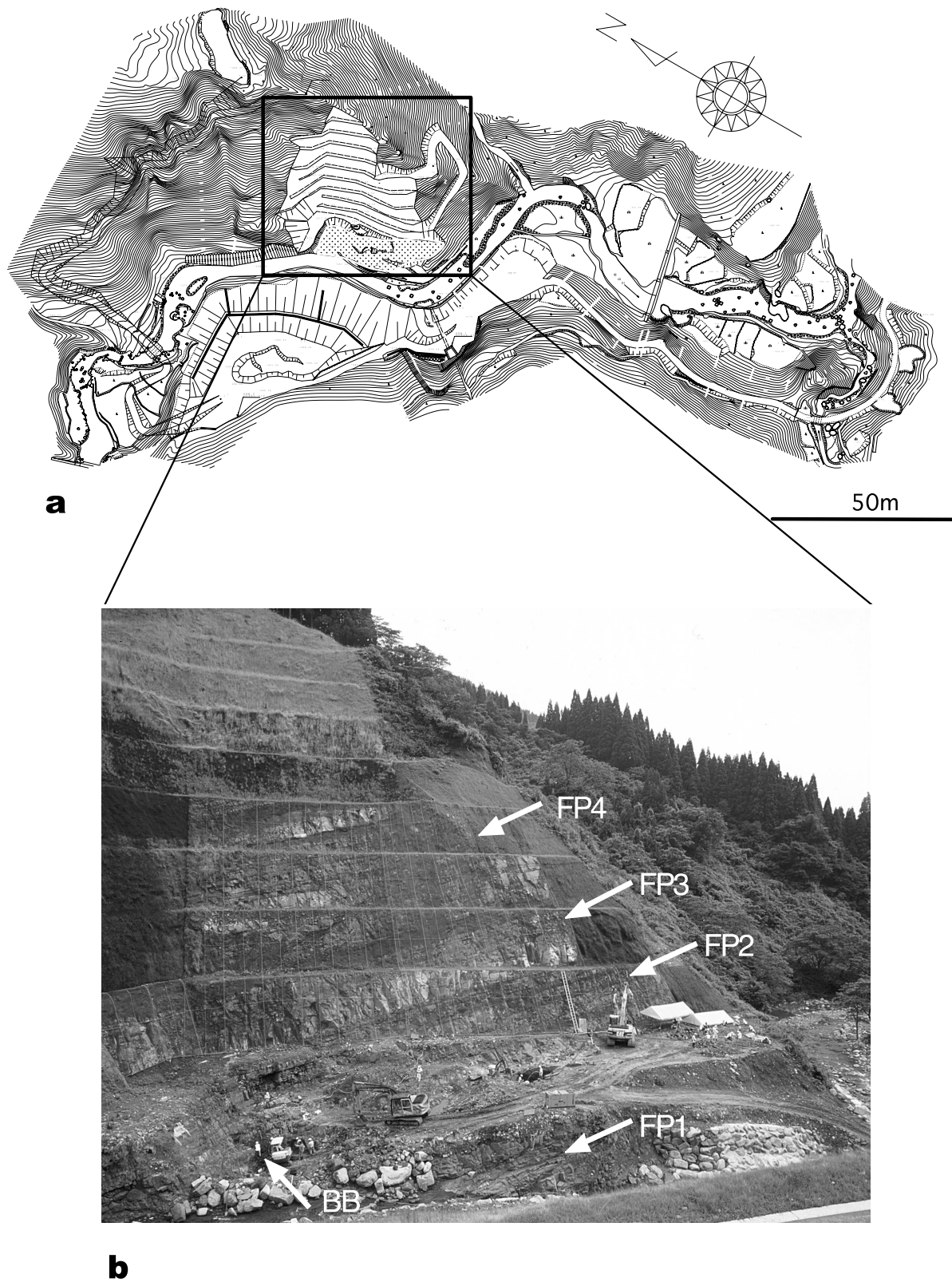


FIGURE 2. Kitadani Dinosaur Quarry. **a**. Topographic map showing the excavated area (hatched area); **b**. Photograph showing the bone bed and footprint horizons. **BB**: bone bed, **FP1–FP4**: footprint horizons

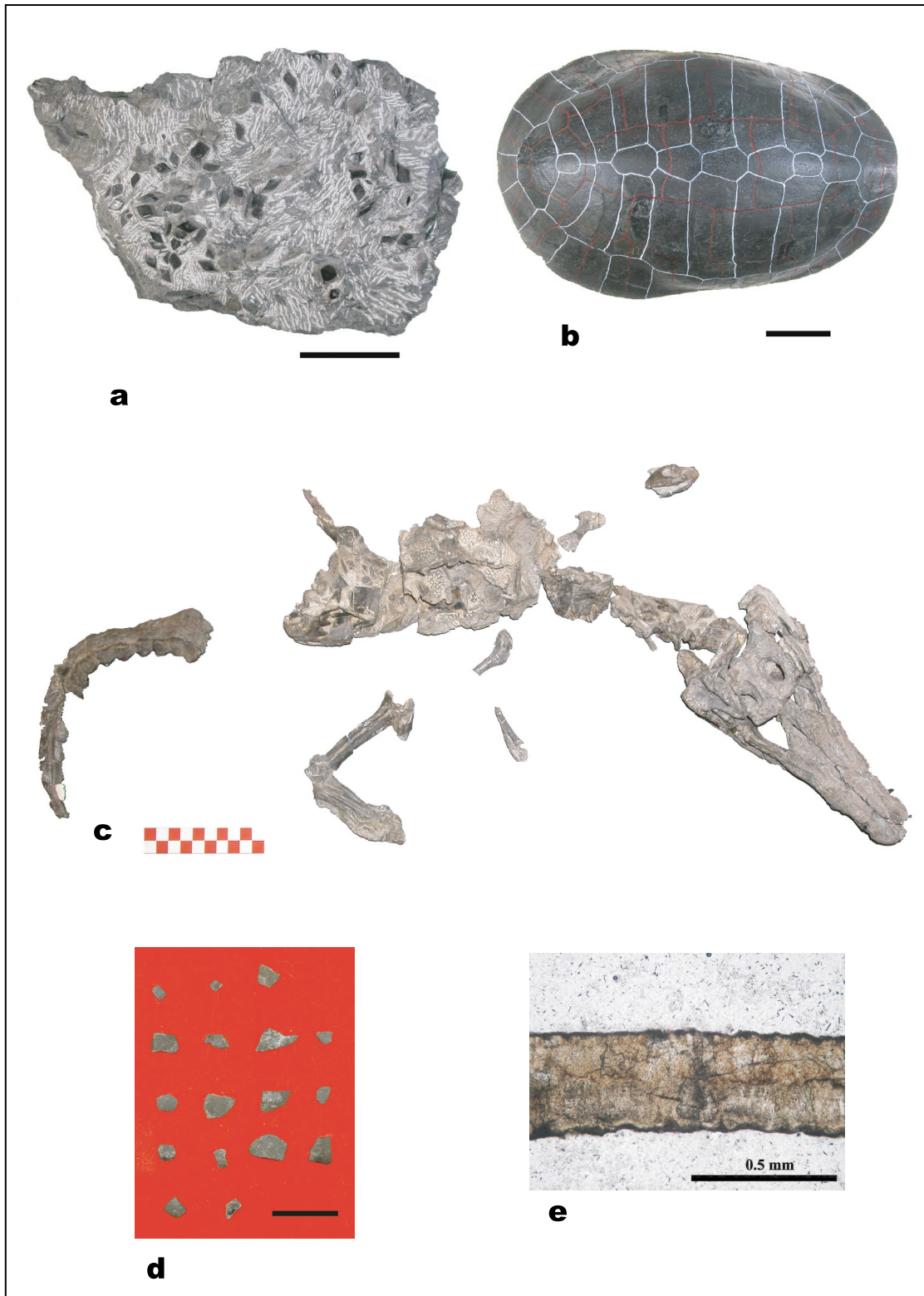


FIGURE 3. Vertebrate fossils from the Kitadani Dinosaur Quarry. **a**, amiiform fish scales; **b**, Reconstructed carapace of *Adocus* sp. (reconstructed by Dr. Hirayama of Teikyo Heisei University) ; **c**, skeleton of a goniopholidid crocodile ; **d**, eggshell fragments; **e**, ratite morphotype in radial section of eggshell. Scale bars: a–b, 5 cm; c, 10 cm; d, 1 cm; e, 0.5 mm.



FIGURE 4. Reconstructed skeleton of *Fukuiraptor kitadaniensis* Azuma and Currie, 2000. It reaches 4.2 m in total length.

**Chelonia:** Numerous fragmentary turtle carapace and plastron remains were collected (Fig. 3b). These turtle remains are classified into five taxa of eucryptodires: *Adocus* sp., *Basilemys* sp., Trionychidae, Sinemydidae?, and Testudinoidea (Hirayama, 2002).

**Crocodylia:** A nearly complete skeleton of Mesozoic crocodile was excavated in 1982. This crocodylian skeleton is the first vertebrate record from the Katsuyama Dinosaur Quarry (Fig. 3c). This specimen was referred to a goniopholidid (Kobayashi, 1998). A large number of crocodylian teeth were also recovered.

**Theropoda:** Since two theropod teeth were first found from the quarry in 1988, the Fukui Prefectural Museum continuously excavated dinosaur remains between 1989 and 1993 and from 1996 to 1998. An associated skeleton of theropod was collected and named as *Fukuiraptor kitadaniensis* (Azuma and Currie, 2000). Elements of *F. kitadaniensis* include the skull (fragments of the maxilla and the dentary and several isolated teeth), vertebral column (centra of dorsals and distal caudals), front limbs (humerus, ulna, manual phalanx, manual unguals), and hind limbs (femur, tibia, fibula, astragalus, metatarsals, and pedal phalanges). This theropod, approximately 4.2 m in length, is assigned to a carnosaur with some coelurosaurian characters (Fig. 4).

Additional *Fukuiraptor* materials of humeri and femora recently recovered from the Kitadani Quarry (Goto et al., 2002) are smaller than the holotype, probably representing a growth series.

**Sauropoda:** Sauropod teeth were first discovered in 1989, and over ten sauropod teeth have been collected so far. These sauropod teeth can be tentatively referred to brachiosaurids based on the tooth crown characters.

**Ornithopoda:** Iguanodontian materials were also found and described as *Fukuisaurus tetoriensis*, which includes the disarticulated skull elements (premaxilla, maxilla, jugal, quadrate, preantorbital, dentary, surangular, and isolated maxillary and dentary teeth) and a sternal plate (Kobayashi and Azuma, 2003). The described *F. tetoriensis* was considered to be a sub-adult to adult individual. Some other ornithopod materials such as tooth and tibia were collected.

#### Ichnofossils

**Footprints:** Abundant footprints of theropods, sauropod?, ornithopods, and birds have been found so far from the several horizons above and below the bone bed in the quarry (Fig. 2b). The rocks exposed at the quarry consist of fine- to coarse-grained grayish to pale yellow sandstones, black shales, and “greenish tuff”, and show three cycles of fining-upward sequence. A fining-upward sequence is composed of coarse- to medium-grained sandstones, alternating beds of medium- to fine-grained grayish sandstones and black shales, and black shales in ascending order. The dinosaur footprints have been found from middle parts of each cycle.

**Eggshell:** Eggshell fragments are found in the lower part of the bone bed in the quarry (Fig. 3d). To date, nearly fifty eggshell fragments have been collected, ranging from 0.3 to 1.2 mm in thickness. In most cases, the microstructure of the eggshells is difficult to examine, because the eggshell was recrystallized to some extent. In several thin sections, individual shell units are visible (Fig. 3e). At least one morphotype of egg (Ratite) has been identified.

## SUMMARY

The Kitadani Dinosaur Quarry is the typical site of the Dinosaur Fauna from the Tetori Group, which consists of amiiform fish, chelonians (*Adocus* sp., *Basilemys* sp., Trionychidae, Sinemydidae?, and Testudinoidea), a goniopholidid crocodile, a theropod (*Fukuiraptor kitadaniensis*), a sauropod (brachiosaurid?), and ornithopods (*Fukuisaurus tetoriensis* and others), dinosaur footprints (theropods, sauropod?, and ornithopods), avian footprints, and possible dinosaur eggshells. As the studies progress, the dinosaur fauna in the Kitadani Dinosaur Quarry is considered to be of great value to elucidate the ecosystem at that time and the mode of ontogenetic development of dinosaurs.

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\* : in Japanese with English abstract