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LATE JURASSIC TO EARLY CRETACEOUS DINOSAUR AND BIRD FOOTPRINTS FROM THE TETORI GROUP IN FUKUI CITY, FUKUI PREFECTURE, CENTRAL JAPAN

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ABSTRACT

Dinosaur and bird footprints from the Late Jurassic to Early Cretaceous Kowashimizu Formation of the Tetori Group have been newly discovered in the Asuwa River area of eastern Fukui City, Fukui Prefecture in the central part of Japan. The dinosaur footprints are those of a theropod and an ornithopod, and one footprint is considered to possibly be that of a sauropod. These footprints, discovered in the westernmost margin of the Tetori Group, indicate non-marine sedimentary conditions and further indicate that various dinosaurs thrived widely.

Key words: bird footprint, dinosaur footprint, Kowashimizu Formation, Tetori Group

島田正樹・野田芳和・林　重雄・東　洋一・矢部　淳・寺田和雄（2010）福井県福井市に分布する手取層群からのジュラ紀後期～白亜紀前期恐竜及び鳥類の足印化石．福井県立恐竜博物館紀要 9：47 – 54.

福井県福井市東部，足羽川地域に分布する手取層群小和清水層（ジュラ紀後期～白亜紀前期）から恐竜および鳥類の足印化石を新たに発見した．恐竜の足印化石は獣脚類および鳥脚類恐竜のものであり，また竜脚類である可能性のものが含まれる．手取層群分布域の最西端にあたる地域からのこうした恐竜足印化石は，陸上の堆積環境を示すとともに，多様な恐竜が広く繁栄していたことを示している．

INTRODUCTION

The paleontology and geology of the Middle Jurassic to Lower Cretaceous Tetori Group have provided considerable data for the Mesozoic paleobiogeography in East Asia. There are some reports on footprints (including dinosaurs, birds and pterosaurs) and eggshells (e.g., Azuma, 1991, 2003; Azuma and Takeyama, 1991; Azuma et al., 1991, 1992; Gifu-ken Dinosaur Fossil Excavation Party, 1999; Goto, 1993; Lee et al., 2010; Matsuoka et al., 2001; Matsukawa et al., 1997, 2002; Shikano et al., 2001; Toyama Dinosaur Research Group, 2002) as well as body fossils of vertebrate animals, and thereby faunal variation and sedimentary environments have also been discussed.

The Tetori Group is widely distributed as several sedimentary basins in the Hokuriku District (Toyama, Ishikawa, Fukui and Gifu Prefectures) but the sedimentary basins are rather small and isolated. The Tetori Group is subdivided into the Kuzuryu, Itoshiro and Akaiwa subgroups in ascending order, but correlation of strata between basins has long been debated (e.g., Maeda, 1961; Yamada, 1988; Fujita, 2003).

The Asuwa River area of the eastern part of Fukui City is a small, isolated basin, located in the westernmost margin of the Tetori Group (Fig. 1). The Tetori Group in this area is divided into the Higashiamada, Sakaidera and Kowashimizu formations in ascending order, and is included in the Kuzuryu Subgroup (Bathonian to Oxfordian), based on a poorly preserved ammonoid fossil from a float rock possibly derived from the Kowashimizu Formation (Maeda, 1961). From the uppermost part of the Sakaidera Formation, a reptile fossil *Tedorosaurus*

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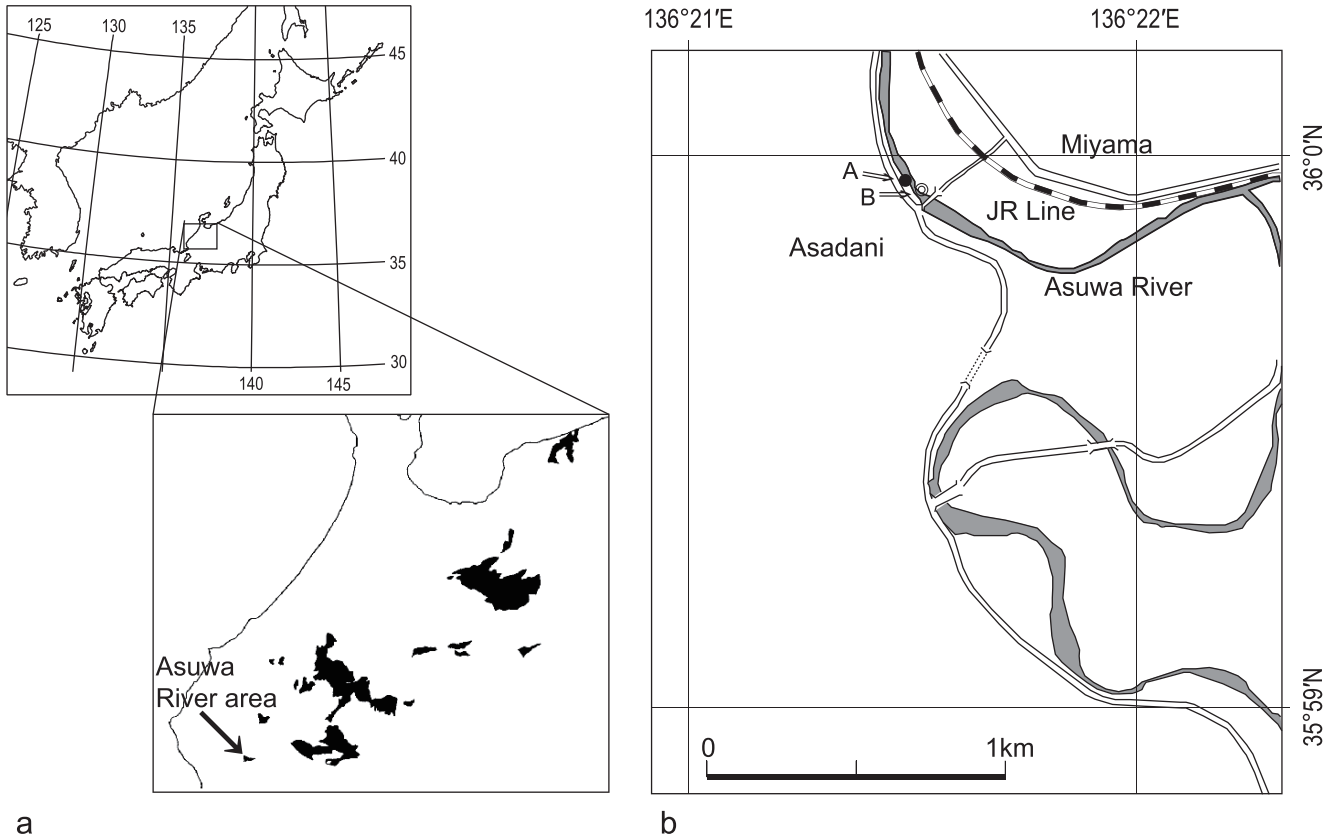

FIGURE 1. Maps showing the study area. **a**, map of Japan and an enlarged map indicating distribution of the Tetori Group after Fujita (2003) with an arrow indicating the Asuwa River area; **b**, Asuwa River area. A (●) indicates the locality of the outcrops shown on Fig. 2 and B (◎) indicates the locality of the slabs examined were collected.

asuwaensis was reported (Shikama, 1969). Recently, Yamada et al. (2008) revised the stratigraphy of the area. They placed the Higashiamada Formation in the basal conglomerate member and redefined the Kowashimizu Formation as the overlying beds of the Higashiamada Formation. The newly defined Kowashimizu Formation consists of the Sakaidera and Kowashimizu formations of Maeda (1961). Yamada et al. (2008) further assingned all the strata to the Itoshiro Subgroup (Tithonian to Hauterivian), based on chemical compositions of sand grains in addition to the total absence of marine strata in the area.

Dinosaur and bird footprints from the Asuwa River area were reported by Yasuno (2008, 2009). He mentioned that footprint fossils are distributed in many horizons of the Kowashimizu Formation of Yamada et al. (2008)

In this study, the authors describe in detail newly discovered footprints, in use of the 3D scanning machine.

MATERIALS AND METHODS

The footprints in this study are preserved on slabs collected on April 26 of 2007 by Shimada, one of the authors, as float rocks on the eastern riverbank of the Asuwa River (Fig. 1). No strata are exposed in the immediate area and the slabs were derived from outcrops of the riverbed and/or bank of the Asuwa River being dug up due to river-shore protection work to construct revetment along the river as anti-flood measures. According to Yamada et al. (2008), the middle part of the Kowashimizu Formation is exposed there.

Four slabs were collected. Three of them are of thin-laminated mudstone intercalated by fine-grained sandstone, and one is of sandstone. Laminations of the slabs were deformed by footprints. The authors examined outcrops exposed by river-shore protection work on the opposite side of the collection locality to clarify the lithologic character of the slabs, and found that other footprints were preserved on the outcrops (Figs. 1, 2) (N35°59' 58", E136°21' 28": WGS84 geodetic datum).

The strata of the outcrops consist of alternating beds of light gray, fine- to very coarse-grained sandstone and light- or dark-gray, mudstone (Figs. 2, 3). They strike N75°E and dip 20° north to 30°. The sandstone generally displays an erosional base and it gradually fines upward into mudstone, with occasional root traces. Possible dinosaur footprints were observed in three horizons at the top of each fining-upward sequence, but they were not complete enough to identify. The mudstone is frequently thin-

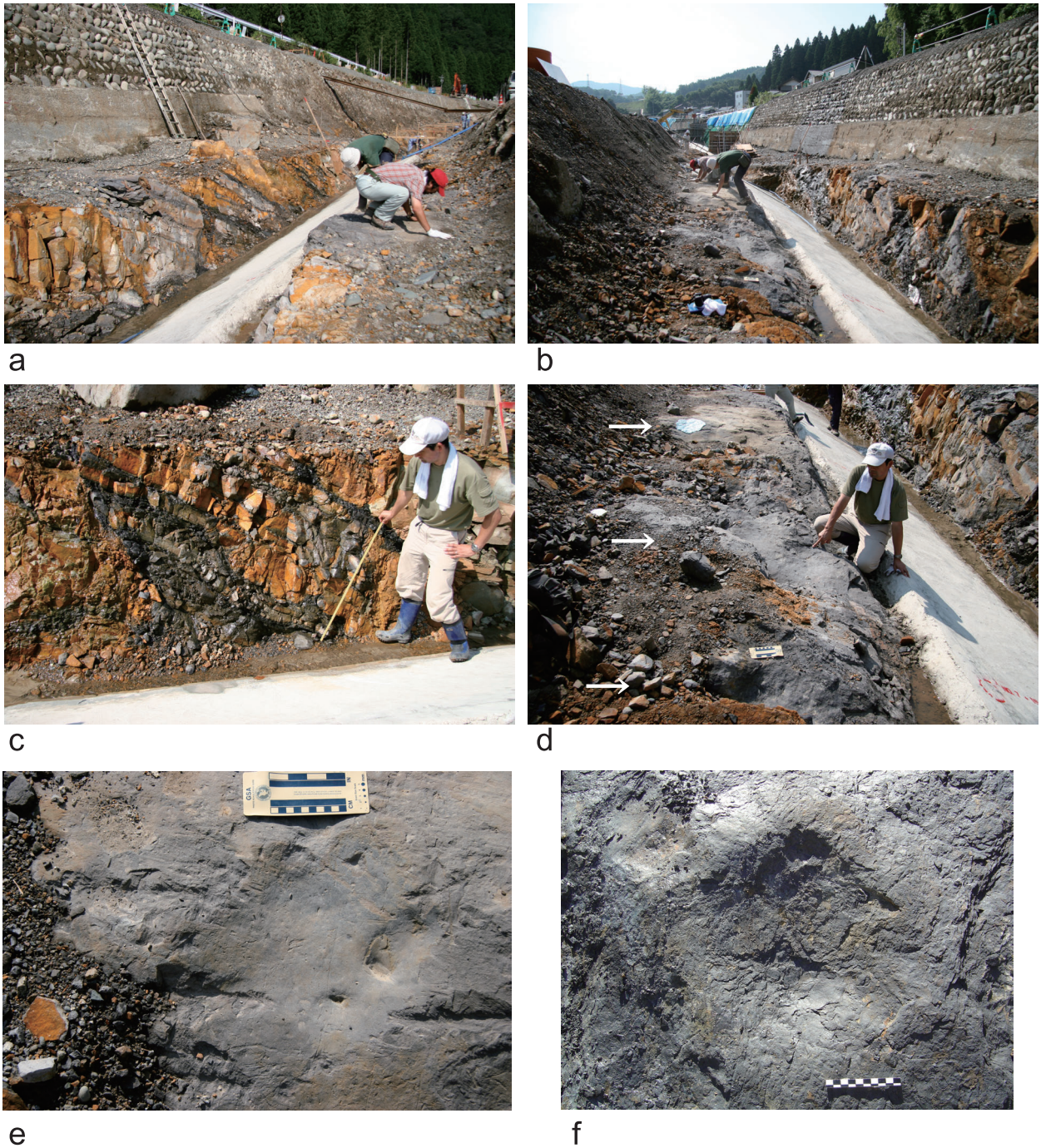

FIGURE 2. Photographs of the outcrops of the western bank of the Asuwa River shown as ● on Fig. 1. **a**, northwestern view; **b**, southeastern view; **c**, western side; **d**, eastern side. Arrows indicate the horizons of footprints; **e**, footprint on the lowermost horizon; **f**, footprint on the middle horizon.

laminated, and corresponds to the lithofacies of the mudstone slabs containing the footprints in focus in this study.

The footprints in the study were scanned by a non-contact three-dimensional digitizer, the ZScanner™ 700 (Z Corporation), to gather three-dimensional image data in STL format. 3D image data required some treatment (filtering, decimation, smoothing, filling holes and alignment) by using the software "leios 2008" and "leios 2009", and were analyzed and processed into topographic images by using the software "3D-Rugle 6 for Windows".

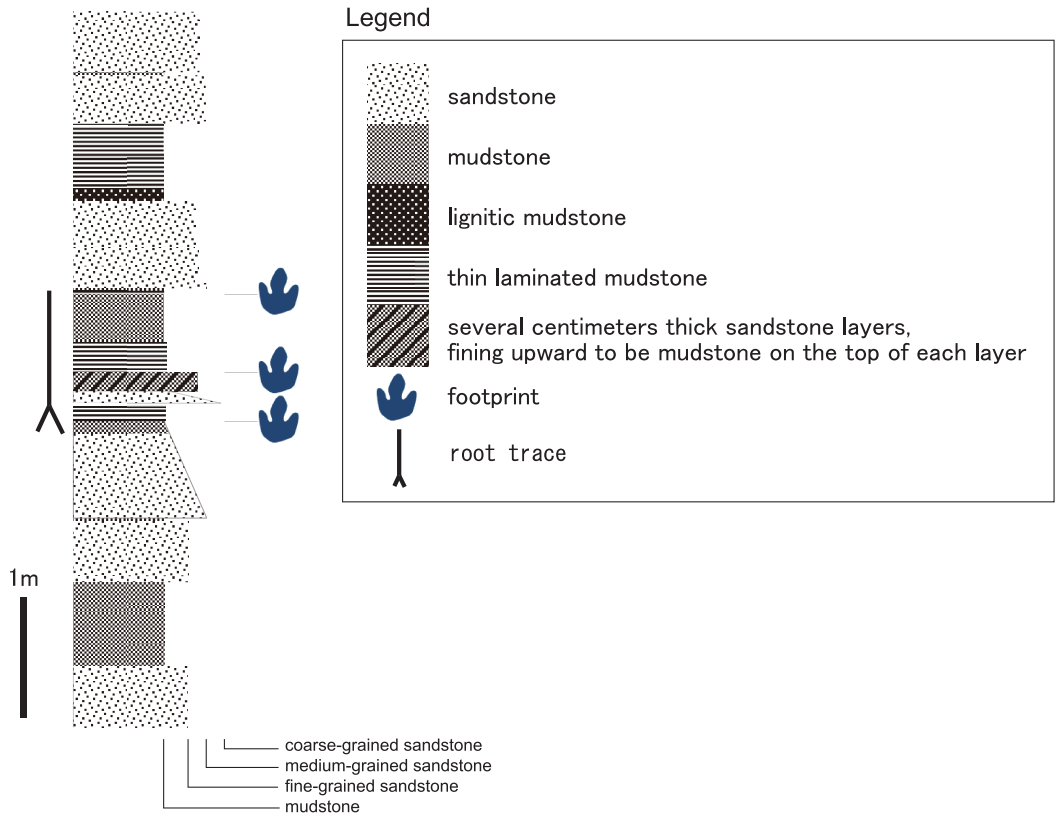

FIGURE 3. Measured columnar section of the outcrops of the western bank of the Asuwa River shown as ● on Fig. 1.

DESCRIPTION

One theropod footprint is found as a natural mold (Fig. 4a) and its natural cast (Fig. 4b). Two digits (digit III and IV) can be observed on the surface of the natural mold (Fig. 4c, d). Digit II is preserved on the upper surface of the cast. It can be confirmed on the polished surface (Fig. 4e). Therefore, this footprint is tridactyl and is a right pes print. The footprint length and width are uncertain. The digit lengths of digit III and IV are 69 mm and 32 mm, respectively. The divarication between digits II and III is 46° and the divarication between digits III and IV is 23°. The claw print is preserved on the ends of all digits.

One ornithopod footprint is discovered on an isolated sandstone slab and is a single natural cast. It was made by a right pes (Fig. 5a, b). The footprint is characterized as being tridactyl having digit II subparallel to digit IV and having a large metatarsal–phalangeal pad impression (Fig. 5). The footprint is 199 mm long and 151 mm wide (Fig. 5c). The digit lengths of digit II, III and IV are approximately 56 mm, 97 mm and 112 mm, respectively. The ends of all digits are pointed and there are distinct large digital pads beneath each digit. This ornithopod footprint is similar to Shiramine footprint (*Shiraminesauropus reini* Azuma and Takeyama, 1991) and Izumi footprint (*Shiraminesauropus hayashidaniensis* Azuma and Takeyama, 1991) in its shape.

One bird footprint is preserved as a natural mold and its cast on black mudstone slabs (Fig. 6a, b). The footprint is tridactyl and small in size, and each digit is slender with digital pad impressions. This footprint is a left pes print. The footprint length and width are 38 mm and 53 mm, respectively. The length-width ratio is 0.72 (Fig. 6c). The digit lengths of digits II, III and IV are 29 mm, 27 mm and 23 mm, respectively. The divarication between digit II and digit IV is 86°. The divarication between digits II and III is 35° and between digits III and IV it is 51°. Digit III curves outward anteromedially, but digit II curves inward laterally. Small triangular claw impressions are preserved on the ends of all digits. Three digits are disconnected proximally to each other, and a distinct ”heel” impression, hallux and webbing are not present. There are three distinct digital pads beneath each of digits III and IV, and at least two on the bottom of the second toe.

One bird ichnotaxon, *Aquatilavipes izumiensis* has been discovered from the Tetori Group in Ohno City, Fukui Prefecture (Azuma et al., 2002). The average footprint length and width of *A. izumiensis* are 37.7 mm and 44.5 mm, respectively. The length-width ratio is 0.85. The average divarication between digits II and IV is 120°. A newly discovered bird footprint from the Asuwa River area is nearly same size, but the divarication

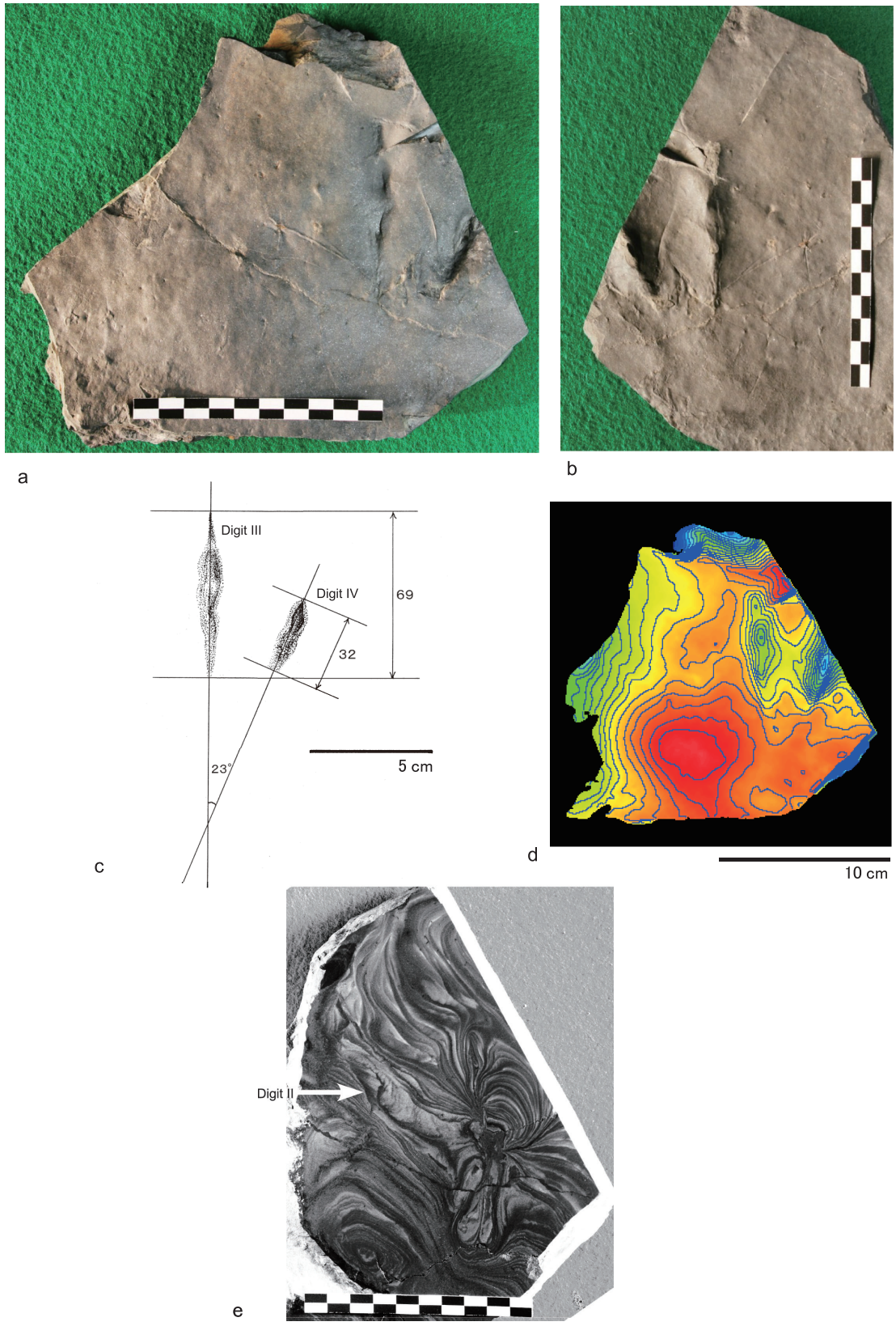

FIGURE 4. Theropod footprint. **a**, natural mold; **b**, cast; **c**, drawing and measurements of the footprint of the natural mold; **d**, topographic image of the natural mold. Contour intervals equal 0.7 mm; **e**, polished upper surface of the cast.

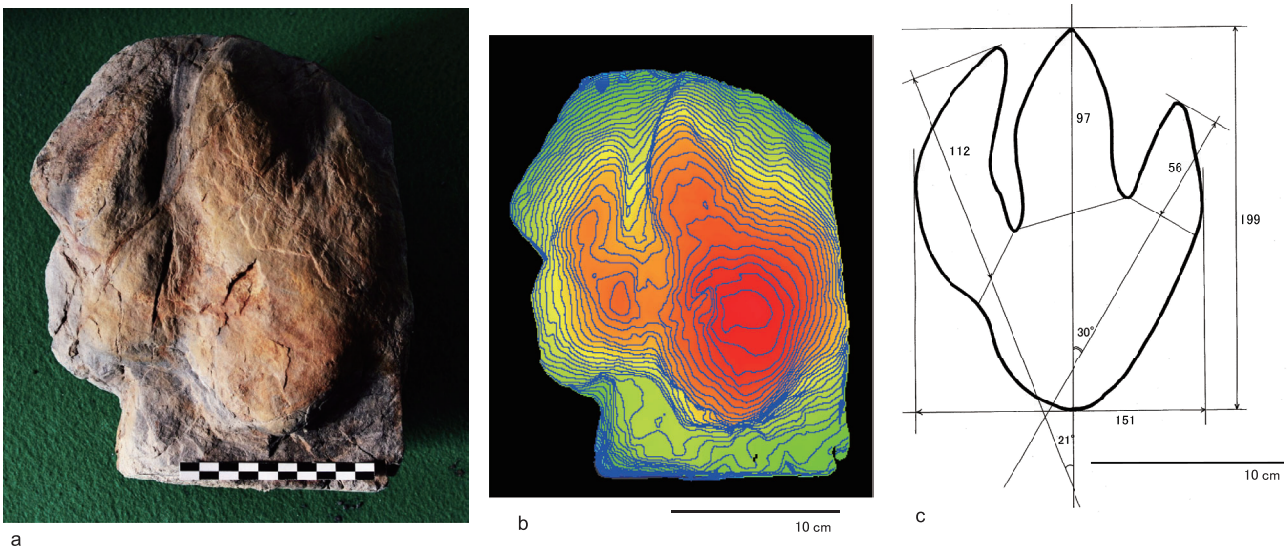

FIGURE 5. Ornithopod footprint. **a**, natural cast; **b**, topographic image of the cast. Contour intervals equal 2.0 mm; **c**, drawing and measurements of the footprint of the natural cast.

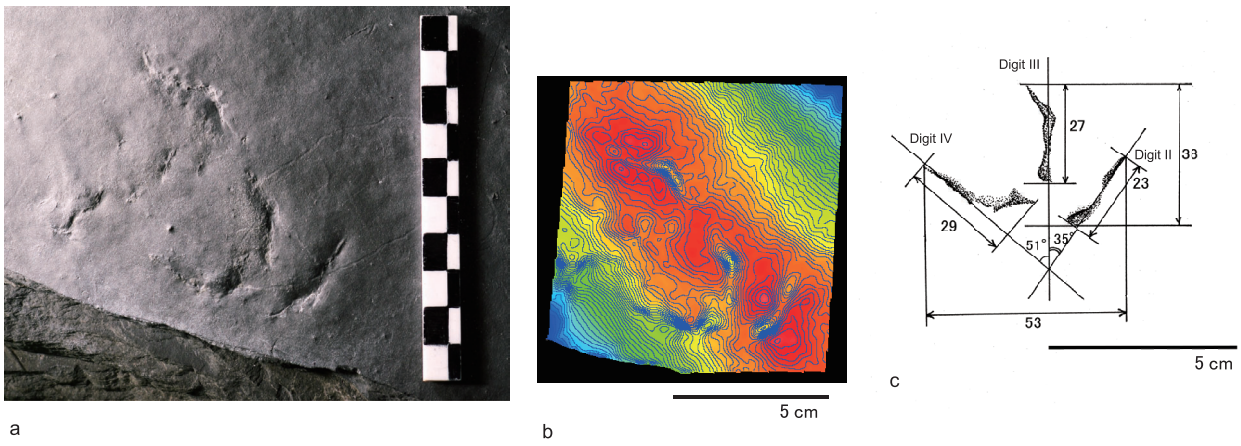

FIGURE 6. Bird footprint. **a**, natural mold; **b**, topographic image of the mold. Contour intervals equal 0.1 mm; **c**, drawing and measurements of the footprint of the natural mold.

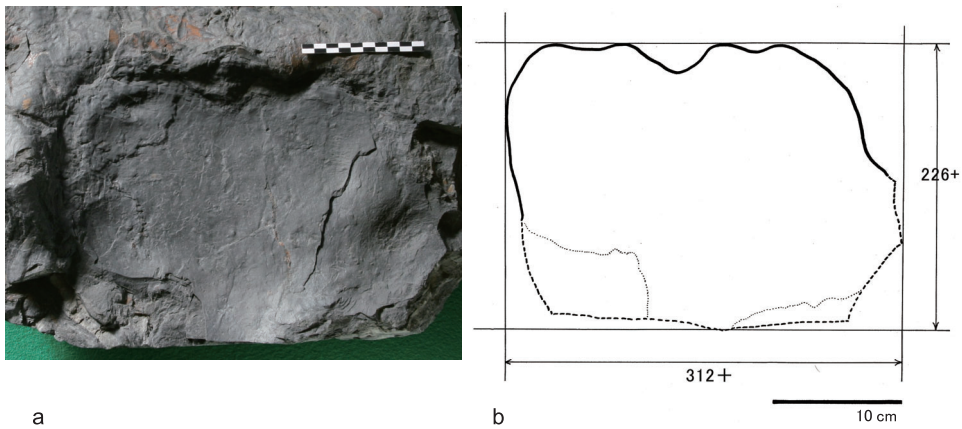

FIGURE 7. Footprint (natural mold) of a sauropod (?). **a**, natural mold; **b**, drawing and measurements of the footprint.

between digits II and IV is narrower than that of *A. izumiensis*. The footprint is clearly distinguishable from *A. izumiensis* by its total divarication and morphological characteristics.

Another possible dinosaur footprint is preserved as a natural mold on a black mudstone block. It is incomplete, but it suggests an assignment to a pes of a sauropod by its size and morphology (Fig. 7).

COMMENTS

The fossil footprints in this study are on slabs of float rocks. But they are assumed to have been derived from the middle part of the Kowashimizu Formation on the basis of lithologic characteristics of the slabs. In fact, *in situ* footprints were observed in the examined outcrops nearby having similar lithology

Yamada et al. (2008) concluded that the Higashiamada and Kowashimizu formations are composed of non-marine deposits. Non-marine sedimentary conditions of the middle part of the Kowashimizu Formation are also indicated by the newly discovered footprints as well as the presence of root traces. And the conditions do not contradict the presence of freshwater to brackish water molluscan remains and fossil upright tree trunks in the Kowashimizu Formation (Sakaidera Formation: Yasuno, 2005).

The identified fossil footprints are of a theropod, an ornithopod and a bird. And there is a dinosaur footprint which is possibly that of a sauropod. This discovery indicates that various dinosaurs thrived around the Asuwa River area.

The authors are unable to add new data for correlation and for the geologic age of the Kowashimizu Formation, but fossil footprints and fossil root traces indicating non-marine sedimentary conditions suggest that the Kowashimizu Formation can presumably be correlated to the Itoshiro Subgroup as suggested by Yamada et al. (2008).

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* : in Japanese with English abstract

** : in Japanese

＜ 地名・地層名 ＞

Akaiwa Subgroup …… 赤岩亜層群
Asadani …… 朝谷
Asuwa River …… 足羽川
Higashiamada Formation … 東天田層
Itoshiro Subgroup …… 石徹白亜層群
Izumi …… 和泉
Kowashimizu Formation … 小和清水層
Kuzuryu Subgroup … 九頭竜亜層群
Miyama …… 美山
Sakaidera Formation …… 境寺層
Shiramine …… 白峰
Tetori Group …… 手取層群