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A Fossil Feather from the Late Pleistocene Deposits in Jeju Island, Korea

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제주도 후기 플라이스토세 퇴적층에서 산출된 깃털 화석

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Abstract: A fossil feather found from the Late Pleistocene sediments of Jeju Island, Korea is described. The sediments deposited in a shallow marine environment yielded numerous footprints of diverse birds and mammals including hominids. A fossil feather well-preserved as a thin white film on the light gray mudstone is part of a vaned flight one. Although the specimen is relatively small in size (10.3 mm long and 9.0 mm wide), a rachis with two flat vanes and nearly parallel curved barbs with numerous proximal and distal barbules are well preserved. The specimen represents the first record of a fossil feather from Korea and is also the first record of feather from the Pleistocene deposits in the world.

Keywords: fossil feather, Late Pleistocene, Jeju Island, Korea

요 약: 제주도의 후기 플라이스토세 퇴적층에서 깃털 화석을 발견하여 기재하였다. 수심이 얕은 바닷가에서 퇴적된 이 퇴적층에서는 사람 발자국을 포함하여 다양한 새 발자국 화석과 포유류 발자국 화석이 풍부하게 산출되었다. 담회색 이암에 밝은 색의 얇은 막으로 잘 보존된 깃털 화석은 깃 판(vane)이 있는 깃털의 일부분이다. 비록 표본의 크기가 길이 10.3 mm, 폭 9.0 mm로 비교적 작지만, 깃대 양쪽에 두 개의 편평한 깃판(vane), 거의 나란하게 휘어진 깃 가지(barbs) 그리고 수많은 전면과 후면의 작은 깃 가지(barbules)들이 잘 보존되어 있다. 이 깃털 화석은 국내에서 최초로 발견되어 기재된 것이며 또한 전 세계의 플라이스토세 퇴적층에서도 처음으로 발견된 것이다.

주요어: 깃털 화석, 후기 플라이스토세, 제주도, 한국

Introduction

Feathers of theropod dinosaur from China have recently attracted great attention from paleontologists and general public especially in regarding the evolution of birds (Norell, 2005). The evolutionary origin of feathers has been a persistent question for more than 140 years (Feduccia, 1999; Maderson and Homberger, 2000). Birds are the only living or modern animal with feathers (Proctor and Lynch, 1998; Elbroch et al., 2001; Elphick et al., 2001). Feathers, toothless beaks, perching feet, and several characteristic bones are only part of the combination of skeletal features that no other living animals have in common with them (Padian and Chiappe, 1998).

The form of fossil feathers provides a particularly important evidence of the mode of life for extinct birds (Davis and Briggs, 1995). Apart from *Archaeopteryx* in Jurassic rocks, many examples have been reported from Jurassic to Cretaceous strata, fossil feathers were less commonly recorded from Tertiary rocks (Davis and Briggs, 1995; Martill and Davis, 2001). Davis and Briggs (1995)

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listed 27 records of fossil feathers from the Early Paleocene to the Late Pliocene deposits; however, fossil feathers from the Pleistocene deposits were not listed. Fossil feathers are very uncommon in the paleontological record, due to the fragility of structure. Hence, their preservation requires special fodilization conditions (Kellner et al., 1994). Fossil feathers are still relatively exceptional fossils representing special types of fossilization (Davis and Briggs, 1995).

The purpose of this study is to describe a fossil feather from the Late Pleistocene deposits in Jeju Island, Korea. The finding of this fossil represents the first report of a fossil feather from Korea and the second occurrence from the Cenozoic strata in Asia. It is also the first record of feather from the Pleistocene deposits.

Geologic Setting

The sedimentary deposits distributed along the coastline of Sagaeri, Jeju Island are recently well-known as a fossil locality of hominid footprints (Kim et al., 2004). It is composed of reworked tuffaceous sediments, about 2 m thick (Fig. 1). The sediments contain desiccation cracks and ripple marks as well as numerous and diverse footprints of birds, artiodactyla, probscideans, carnivores, and hominids, diverse invertebrate trace fossils, molluscas, crabs and fissils plants which suggest the low energy shallow shoreline environment.

Sohn et al. (2002) regarded that the age of the Hamori Formation is less than 4,000 yr B.P. by ^{14}C dating of the mollusks collected at the west coast of Mt. Songak and the Hamori Formation was formed during and after the eruption of the Songaksan Tuff (ST). Park et al. (2005) and Cho et al. (2005) regarded that ^{14}C data of humin fraction is the maximum age of the hominid Footprint-bearing Strata as 15,161 ± 70 yr B.P. and insisted that the age of the strata is from 6,800 ± 300 to 7,600 ± 300 yr B.P. by OSL. However, Pessenda et al. (2001) compared ^{14}C data of total soil organic matter, humin fraction, and

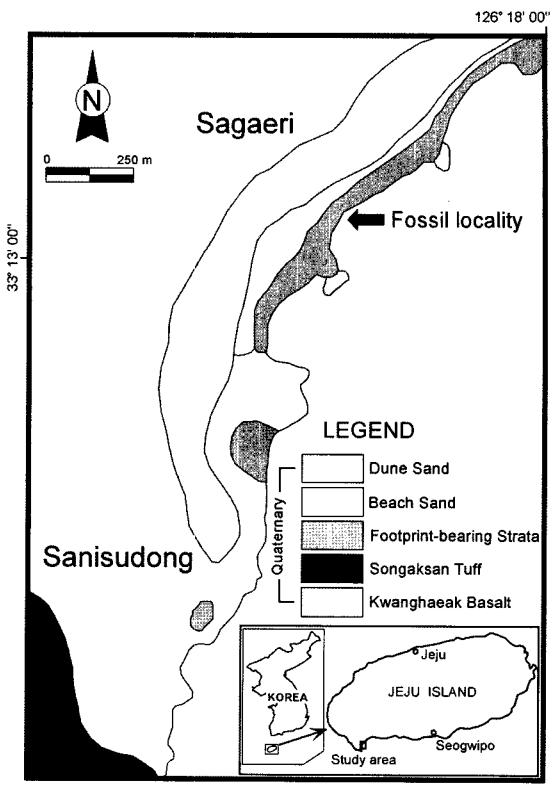

Fig. 1. Geologic map of study area (Cho et al., 2005). Arrow indicates the fossil feather preserved locality.

charcoal in several soil profiles under natural vegetation from different locations, and thought that the humin fraction ages could be assumed as the minimum ages for carbon in soils.

On the basis of field observation, the geologic sequence, in ascending order, in the study area consists of the Kwanghaeak Basalt, unnamed strata, ST, Hamori Formation, and Dune Sand, on the west coast of Mt. Songak. At the hominid footprint site, Sagaeri area in the northeast coast of Mt. Songak, the sequence is composed of the Kwanghaeak Basalt, Footprint-bearing Strata, Beach Sand, and Dune Sand in ascending order. According to the designation that the Hamori Formation overlies the ST (Sohn et al., 2002), age dating results (Park et al., 2005; see the review of Kim and Kim, 2006), and the geologic sequence observed in the field, the strata containing hominid footprints are not correlated with the Hamori Formation but the unnamed

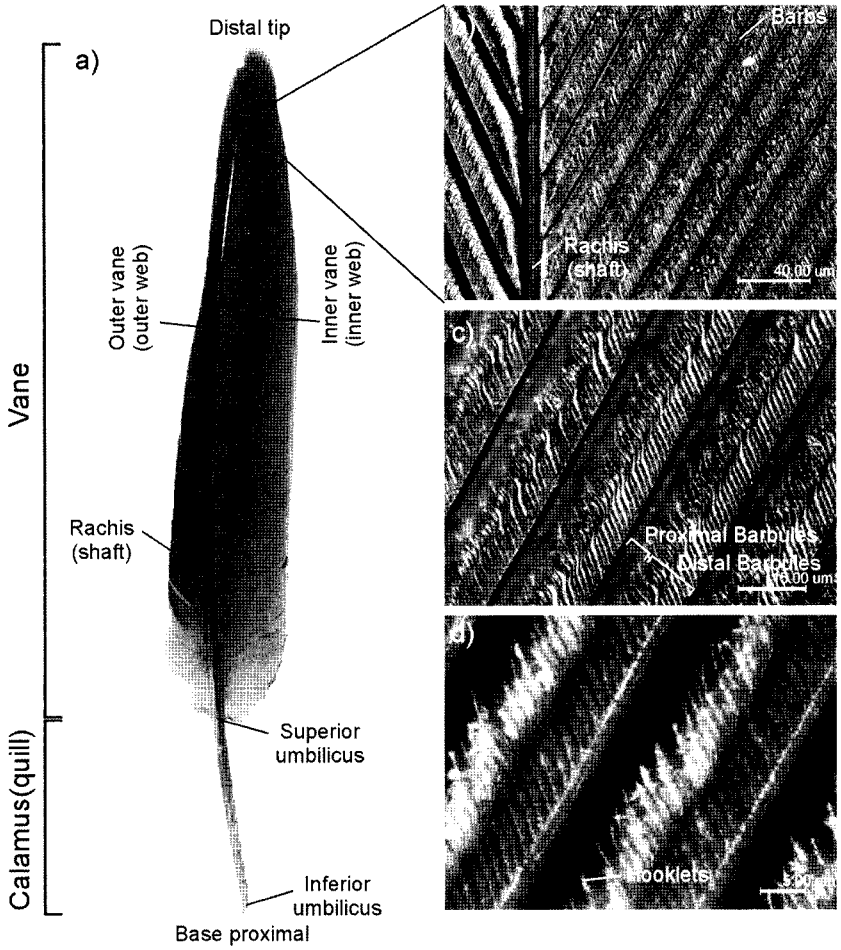

Fig. 2. Feather structure of modern rufous turtle dove, Streptopelia orientalis. a) Primary feather and basic feather structure, b) the rachis and barbs, c) barbs with proximal and distal barbules, and d) hooklets of the distal barbules.

strata at the west coast of Mt. Songak, though the strata are shown as the Hamori Formation on the geologic map (Park et al., 2000). It seems, therefore, to be more reasonable that the geologic age of the Footprint-bearing Strata is thought to be around ca. 15,161 ± 70 yr B.P. (Kim and Kim, 2006) according to the ^{14}C data of Park et al. (2005).

Feather Structure

The terms about feather structure used herein follow those of Elbroch et al. (2001), Brown et al. (2003), and Cornell Laboratory of Ornithology (2004) (Fig. 2).

Vane: the extended part from the central shaft to each side of the feather. It consists of a series of parallel branches called barbs.

Outer vane (outer web): the leading edge of the feather during flight.

Inner vane (outer web): the opposite vane, wider than the outer vane.

Calamus (quill): the part of the shaft closet to the bird's body or a hornlike shaft at the base of the feather. It is hollow and does not contain any vane.

Rachis (shaft): the distal end of the central shaft or the shaft between the barbs. It is solid and is defined as the area to which vanes are attached.

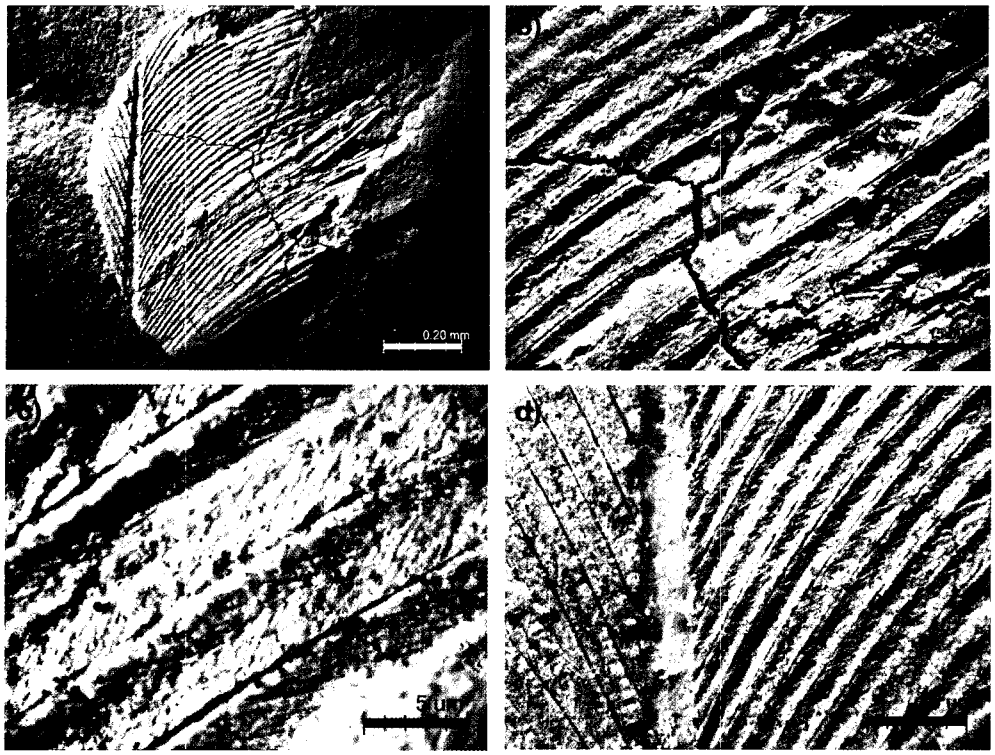

Fig. 3. Fossil feather from the Late Pleistocene deposits of Sagaeri in Jeju Island, Korea. a) a slab with a fossil feather, b) parallel curved barbs, c) barbs with proximal and distal barbules, and d) rachis, barbs, and barbules.

Inferior umbilicus: a tiny hole at calamus base.

Superior umbilicus: a second hole farther out where the wispy branches begin.

Barbs: a series of parallel first branches.

Barbules: a series of parallel short branchlets.

Hooklets (hamuli or barbicels): a hook-shaped parts of the distal barbules, hook the barbules together, like a zipper, forming a tight, smooth surface.

Systematic Paleontology

Class Aves

(Fig. 3)

Material and methods: KNUE 050601 (sample number), a feather preserved as an impression on a small rock block, housed in the paleontological collection of the Department of Earth Science, Korea National University of Education. All measurements were taken by a digital optical micrometer.

Description: The fossil feather (Fig. 3) is exceptionally well preserved as an impression on the one mm thick yellowish mud layer overlying the light gray siltstone. The specimen is composed of a rachis (shaft) and two vanes. Calamus (quill) is not preserved. The specimen measures 10.31 mm in length and 9.02 mm in width (Fig. 3a). The rachis is nearly straight and 6.78 mm long. The width of rachis gradually decreases from 0.320 mm at the proximal part to 0.137 mm at the distal part. This change of rachis width may partly be affected by depth of impression. Absence of the ventral ridges and grooves support that the feather seems to represent the dorsal aspect (Fig. 3b).

The right vane, probably inner vane, is relatively well preserved and the left vane, probably outer vane, is mostly brocken away. The barbs on the right vane reach their maximum length of 9.28 mm. The width of each barbs is 0.016 mm. The barbs diverge from the rachis at an angle of about 30° and 20° near the distal part of the right vane. The

barbs are slightly curved upward, convex toward distal part of vanes. The separations of two adjoining barbs are observed at the left vane and the proximal part of the right vane. In contrast to barb separation, barbs are overlapped at the proximal part of right vane margin. The barbs on the right and left vanes alternately branch from the rachis. There are approximately three barbs per one mm of rachis (Fig. 3c).

The proximal and distal barbules are well developed. They are branched from barbs at an angle of about 30°. The barbules are nearly straight and about 0.005 mm in width. The length of proximal barbules is longer, about 0.155 mm, than that of distal barbules which is about 0.140 mm. Therefore, barbules from each barb show slight asymmetry. The number of barbules on each side of the barbs is 2 to 3 in 0.1 mm. Hooklets are not clearly observed at the end of both the proximal and distal barbules (Fig. 3d).

Discussion

On the basis of presence of a nearly straight rachis and cohesive barbs, the fossil is thought to be a vaned flight feather among the types of feathers (Proctor and Lynch, 1998). The microstructure of feather has a taxonomic relationship (Chandler, 1916).

On some cases it is possible to classify a fossil feather to a family and rarely to a species level. However, the feather of Jeju Island cannot be exactly assigned to any particular group, due to lack of information on microstructure and incomplete specimen. In the fossil locality, at least 8 kinds of bird's footprints were recognized (Kim et al., 2004). The fossil feather may be a feather of bird probably belonged to a group of aquatic-or semi-aquatic-dweller who left footprints on the shoreline deposit.

The occurrence of this fossil feather from the Late Pleistocene sediments deposited in the low-energy shallow shoreline environment is noteworthy. The majority of fossil feathers have been recorded from the Late Jurassic to Late Pliocene rocks deposited in the lacustrine environment (Davis and Briggs, 1995). While a relatively large number of fossil feathers have been recorded from the Tertiary rocks, the Pleistocene feathers are rarely known yet. Hence, the discovery of feathers from the Late Pleistocene deposit of Jeju Island is the youngest geological record and represents the first record of the Class Aves on the Cenozoic strata of Korea.

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