FOSSIL DOWN FEATHER FROM THE LOWER CRETACEOUS OF BRAZIL

by A. W. A. KELLNER, J. G. MAISEY *and* D. A. CAMPOS

ABSTRACT. An Early Cretaceous (Aptian) fossil feather has been discovered in the Araripe Basin, northeast Brazil. Its features, including an overall fluffy aspect, indicate that it is a definitive down feather. This new material provides empirical evidence that birds had already developed an effective thermoregulatory insulation cover, with down feathers, by the Early Cretaceous. Furthermore, in the absence of skeletal remains, the fossil feathers are the only reliable evidence of Mesozoic birds in Brazil.

THE Lower Cretaceous Santana Formation of the Araripe Basin, northeast Brazil (Text-fig. 1), is very well known for the large quantity and exquisite preservation of its fossils (see Maisey 1991 for a review). The basal unit of the Santana Formation is the Crato Member, which includes laminated light gray micritic limestones alternating with dark-coloured, calcareous silty shales (Mabesoone and Tinoco 1973). According to recent palynological data the age of the Crato Member is Late Aptian (Pons *et al.* 1990). Fossils are abundant in these sediments, especially small pisces: teleostean fishes (Blum 1991) and a rich and diversified assemblage of insects (Grimaldi 1990; Martins Neto 1991). Other fossils such as pterosaurs (Kellner in preparation) and turtles are more rare. The depositional environment is generally regarded as lacustrine (Beurlen 1971), which is supported by the presence of freshwater insect larvae as well as halophobic vertebrates such as anurans (Kellner and Campos 1986). The presence of volant birds was demonstrated recently by the discovery of a flight feather (Martins Neto and Kellner 1988). Another feather having a profoundly different morphology is described here. It is housed in the palaeontological collection of the Departamento Nacional da Produção Mineral, Rio de Janeiro, Brazil, as specimen DNPM MCT 1493-R.

DESCRIPTION

The feather is comparatively small, with a preserved length of approximately 7·5 mm, measured from the preserved part of the calamus to the largest barb (Text-fig. 2). Its color is dark-brown, contrasting with the greyish color of the limestone slab in which it is preserved. There is almost no difference in relief between feather and matrix, possibly due to diagenetic process. SEM pictures of the uncoated specimen did not reveal any ultrastructure or featherprint. Many identifiable structures are, however, preserved. All measurements were taken by a digital optical micrometer (Shopscope Tm and Microcode II Tm).

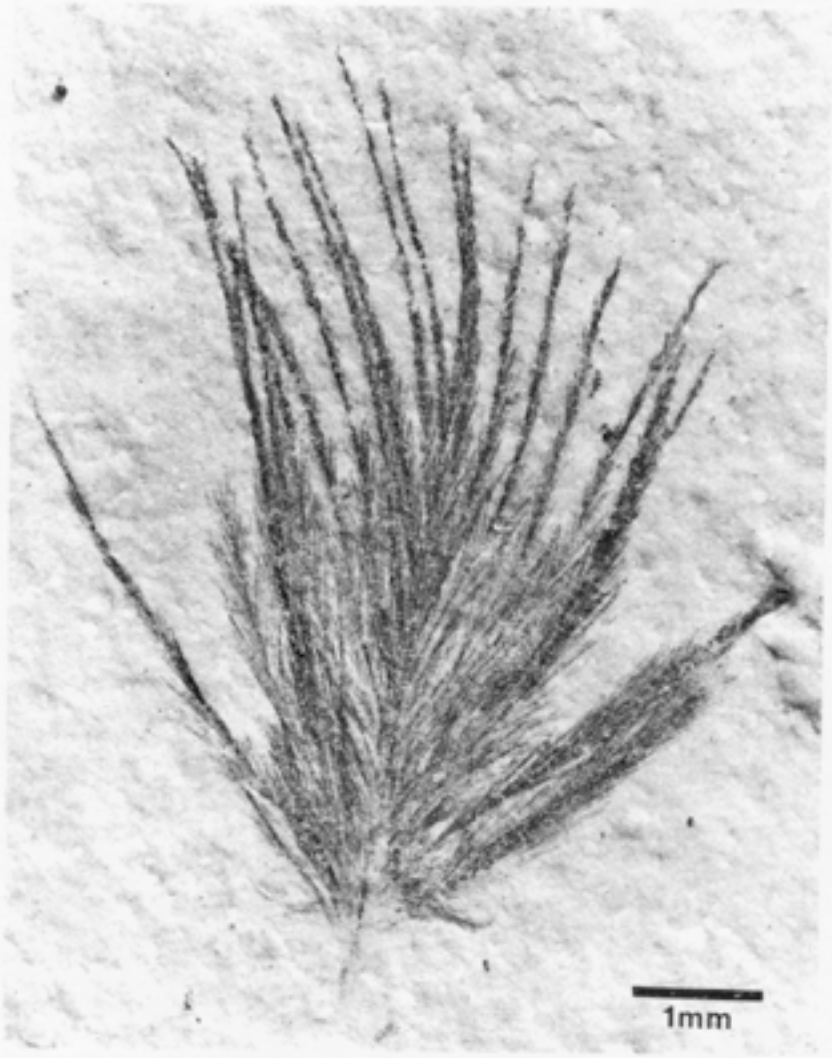
The shaft includes both the calamus and rachis. The calamus is weakly preserved and is represented only by a faint shadow. The rachis is very thin and is about 3·4 mm long, corresponding to approximately 46 per cent of the feather's total preserved length. Compared to the largest barbs, the rachis is smaller, which is one of the main characteristics used to distinguish down feathers from other types of feather (Lucas and Stettenheim 1972). No evidence of an afterfeather or hyporachis is observed.

The vanes are very clearly preserved. Some of the barbs are almost as thick as the rachis. The size of individual barbs decreases towards the distal portion of the shaft. The last and smallest barb on the terminal portion of the shaft is approximately 2·9 mm long, while the largest barb near the base of the shaft has a length of approximately 5·3 mm. There are approximately three to four barbs per mm of rachis. Barbules are longer on the proximal parts of the barbs. This increases the down density of the feather towards the rachis.

On the left upper portion in the matrix above the feather, a comparatively very long barb-like structure is present, at least 25 mm long, straight distally and curved proximally. Although poorly preserved, it is possible

[Palaeontology, Vol. 37, Part 3, 1994, pp. 489–492]

TEXT-FIG. 1. Map of South America, showing the position of the Araripe Basin.



TEXT-FIG. 2. Fossil down feather (MCT 1493-R) housed in the palaeontological collection of the Departamento Nacional da Produção Mineral (DNPM, Rio de Janeiro).

that the structure may have been connected originally with the largest basal barb. No barbules were observed on this structure, however, and it is entirely possible that it is not part of the feather.

All the above features, notably the proportional size of the rachis and the barbs, and the overall fluffy aspect of this feather, indicate that it is a definitive down feather, i.e. a feather developed only with the full body plumage (Lucas and Stettenheim 1972).

DISCUSSION

Fossil feathers are very rare in the palaeontological record, due to the fragility of their structure, and their preservation requires special fossilization conditions. Those conditions are found normally in calm waters of lacustrine (e.g. Waldman 1970; Kurochkin 1985; Martins Neto and Kellner 1988) or lagoonal environments (e.g. Meyer 1861). The best preserved feather (as well as other fossils in general) are found in amber, such as the specimen described by Schlee (1973), Schlee and Glöckner (1978), and the semiplume recently found in Lower Cretaceous deposits of New Jersey (D. Grimaldi pers. comm.).

In the Mesozoic, very few fossil feathers are known (Martins Neto and Kellner 1988; Kellner *et al.* 1991 and literature cited therein), limiting the information about primitive avian plumage. Most skeletal remains of early birds lack traces of an external body covering (e.g. Sanz *et al.* 1988; Sereno and Chenggang 1992). The reported Mesozoic feathers are contours, remiges, rectrices, or semiplumes (Martins Neto and Kellner 1988; Lacasa 1988). The only other supposed down feather reported so far comes from the Lower Cretaceous of Mongolia and was merely figured but not described (Kurochkin 1985). If it is a genuine down feather, it differs from the specimen described here in lacking a rachis (or having it greatly reduced), and by the apparent absence of barbules on the barbs.

Depending on their function, feathers have different shapes and structures. Down feathers are commonly regarded as best adapted to provide thermal insulation (e.g. Lucas and Stettenheim 1972; Gill 1990). The presence of down feathers in the Lower Cretaceous therefore suggests that bird plumage was already highly differentiated, with a wide range of functions including flight and an effective system of thermal insulation.

Although no skeletal material of birds have yet been reported from the Brazilian Mesozoic, the presence of feathers increases the expectation of finding early bird remains in this country, particularly in the Crato Member.

Acknowledgements. We thank José Betimar M. Filgueiras (Centro de Pesquisas Paleontológicas da Chapada do Araripe [CPCA-DNPM], Crato, Ceará, Brazil) for loaning the specimen to us, Chester Tarka (AMNH, New York) for preparing the negative of the feather, and Ivy S. Rutzky (AMNH, New York) for preparing the locality map. We profited from discussions and comments from Pamela Rasmussen (Smithsonian Institution, Washington D.C.), J. Allan Feduccia (University of North Carolina), Peter Wellnhofer (Bayerische Staatssammlung, Munich), Max Hecht (CUNY, New York), Walter Bock (Columbia University, New York), and David A. Grimaldi (AMNH, New York). Field work in Brazil was funded by the Department of Vertebrate Paleontology, American Museum of Natural History (Axelrod Fund and Frick Lab Endowment Fund) and the Department of Geological Sciences, Lamont-Doherty Geological Observatory, Columbia University (Summer Field Grant to A.W.A.K.).

REFERENCES

BEURLEN, K. 1971. As condições ecológicas e faciológicas da formação Santana no chapada do Araripe (Nordeste do Brasil). *Anais da Academia Brasileira de Ciências*, **43** (suppl.), 411–425.

BLUM, S. 1991. *Dastilbe* Jordan, 1910. 274–283. *In* MAISEY, J. G. (ed.). *Santana fossils, an illustrated atlas*. T.F.H. Publications, Neptune City, New Jersey, 459 pp.

GILL, F. B. 1990. *Ornithology*. Freeman and Company, New York, 598 pp.

GRIMALDI, D. A. (ed.) 1990. Insects from the Santana Formation, Lower Cretaceous, of Brazil. *Bulletin of the American Museum of Natural History*, **195**, 1–191.

KELLNER, A. W. A., MARTINS NETO, R. G. and MAISEY, J. G. 1991. Undetermined feather. 376–377. *In* MAISEY, J. G. (ed.). *Santana fossils, an illustrated atlas*. T.F.H. Publications, Neptune City, New Jersey, 459 pp.

KELLNER, A. W. A. and CAMPOS, D. A. 1986. Primeiro registro de amphibia (Anura) no Cretáceo Inferior da bacia do Araripe, nordeste do Brasil. *Anais da Academia Brasileira de Ciências*, **58**, 610.

KUROCHKIN, E. N. 1985. A true carinate bird from Lower Cretaceous deposits in Mongolia and other evidence of Early Cretaceous birds in Asia. *Cretaceous Research*, **6**, 271–278.

LACASA, A. 1988. An Early Cretaceous fossil bird from Montsec Mountain (Lleida, Spain). *Terra Research*, **1**, 45–46.

LUCAS, A. M. and STETTENHEIM, P. R. 1972. Avian anatomy integument, (part 1 and 2). *Agriculture Handbook*, **362**, 1–750.

MABESOONE, J. M. and TINOCO, I. M. 1973. Paleoecology of the Aptian Santana Formation (Northeastern Brazil). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **14**, 97–118.

MAISEY, J. G. (ed.) 1991. *Santana fossils, an illustrated atlas*. T.F.H. Publications, Neptune City, New Jersey, 459 pp.

MARTINS NETO, R. G. 1991. Sistemática dos Ensifera (Insecta, Orthopteroida) da Formação Santana, Cretáceo Inferior do Nordeste do Brasil. *Acta Geologica Leopoldensia*, **32**, 3–162.

—— and KELLNER, A. W. A. 1988. Primeiro registro de pena na Formação Santana (Cretáceo Inferior), Bacia do Araripe, Nordeste do Brasil. *Anais da Academia Brasileira de Ciências*, **60**, 61–68.

MEYER, H. von. 1861. *Archaeopteryx lithographica* (Vogel-Feder) und *Pterodactylus* von Solnhofen. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, 678–679.

PONS, D., BERTHOU, P. Y. and CAMPOS, D. A. 1990. Quelques observations sur la palynologie de l'Aptien Supérieur et de l'Albien du Bassin d'Araripe (N. E. du Brésil). 241–251. *In* CAMPOS, D. A., VIANA, M. S. S., BRITO, P. M. and BEURLEN, G. (eds.). *Atas do 1 Simpósio sôbre a Bacia do Araripe e Bacias Interiores do Nordeste*, Crato, Ceará, 406 pp.

SANZ, J. L., BONAPARTE, J. F. and LACASA, A. 1988. Unusual Early Cretaceous birds from Spain. *Nature*, **331**, 433–435.

SCHLEE, D. 1973. Harzkonservierte fossile Vogelfedern aus der untersten Kreide. *Journal für Ornithologie*, **114**, 207–219.

—— and GLÖCKNER, W. 1978. Bernstein. *Stuttgarter Beiträge zur Naturkunde (C)*, **8**, 1–72.

SERENO, P. C. and CHENGGANG, R. 1992. Early evolution of avian flight and perching: new evidence from the Lower Cretaceous of China. *Science*, **255**, 845–848.

WALDMAN, M. 1970. A third specimen of a Lower Cretaceous feather from Victoria, Australia. *The Condor*, **72**(1), 377.

A. W. A. KELLNER

J. G. MAISEY

Department of Vertebrate Paleontology
American Museum of Natural History
Central Park West at 79th Street
New York 10024-5192, USA

D. A. CAMPOS

Setor de Paleontologia do Departamento Nacional
de Produção Mineral
av. Pasteur 404, Rio de Janeiro
Brazil

Typescript received 9 February 1994
Revised typescript received 21 June 1994