

THE CRATO FOSSIL BEDS OF BRAZIL

Window into an Ancient World

This beautifully illustrated volume describes the entire flora and fauna of the famous Lower Cretaceous Crato Formation of Brazil – one of the world's most important fossil deposits, exhibiting exceptional preservation. For the first time, the entire fossil assemblage is brought together in a single volume.

Chapters on the fauna cover a range of invertebrates including arachnids, crustaceans and an immense number of insect groups, while vertebrates are treated in chapters on fishes, anurans, lizards, turtles, crocodiles, pterosaurs and birds. A diverse flora is described in chapters on macrophytes ranging from ferns to some of the earliest angiosperms, including eudicots. Palynomorphs are also considered. Virtually all species are illustrated, many for the first time and some in full colour, while numerous interpretative drawings add to the scientific value of this work. Many new species and higher taxa are described. The fossil descriptions are supported by detailed explanations of the geological history of the deposit and its tectonic setting. Each chapter also contains a comprehensive bibliography.

Drawing on expertise from around the world and specimens from the most important museum collections, this book forms an essential reference for all researchers and enthusiasts with an interest in Mesozoic fossils, and will provide a springboard for further research.

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Preface

In the late 1830s Scottish botanist, surgeon and explorer George Gardner (1810–1849) made his way on horseback from the picturesque spring-line village of Brejo Grande towards the now palaeontologically famous town of Santana do Cariri on the flanks of the Chapada do Araripe. In his published diaries (Gardner, 1846) it is noted that parts of the track were naturally paved in a slabby limestone. Some of these exposures still exist, although this picturesque country track has recently been resurfaced. What Gardner didn't record was that these limestones contain a wealth of fossils, some of which are spectacularly preserved and the *raison d'être* for this book. Although primarily a botanist, Gardner had a keen interest in fossils and, just a few weeks earlier, he had been exploring outcrops where carbonate nodules contained three-dimensionally preserved fishes: the so-called Santana Formation fish nodules, often seen for sale in fossil shops around the world.

Gardner shipped many of the fish-bearing nodules back to Scotland where they formed the basis of studies by the famous ichthyologist Louis Agassiz (1807–1873; Agassiz, 1841, 1833–1844a, 1844b), but the fossils in the slabby limestones seemed to pass him by. Perhaps it was because few quarries excavated the stone at this time, houses then being constructed mainly of mud and sticks or, for the wealthier, bricks made in the traditional style using locally dug alluvial clays.

Even 20 years ago fossils from the Crato Formation were still hardly known. Description of the fossil fish *Dastilbe*, the commonest macrofossil in the Crato Formation, didn't occur until 1947, over 100 years after Gardner's first mention of the rocks (Silva Santos, 1947). Shortly after the description of the fish the first fossil insects from the limestones were described (Costa Lima, 1950), but serious palaeontological research did not commence until the 1980s when Brito (1984, 1987), Campos (1986), Kellner and Campos (1986) and Martins-Neto and Kellner (1988) described elements of the fauna and Duarte (1985) described the first floral remains.

These announcements coincided with the commencement of a major increase in the commercial extraction of the Crato limestones or so-called *pedra de larje*. Today, specimens of *Dastilbe* can be purchased in fossil shops around the world or on the Internet, and the number of scientific papers describing Crato fossils is in the hundreds. From an initial faunal list of a single fish and an unnamed mayfly larva in the middle of the twentieth century, the faunal and floral list today includes over 100 insect species, nine species of fish and nearly a dozen arachnids. Turtles, lizards and even a bird are known, but among the vertebrates the formation is gaining prominence for the diversity and spectacular preservation of its pterosaurs.

The Crato Formation has the most diverse fossil assemblage for any non-marine Cretaceous locality in Gondwana, and perhaps Laurasia too. Museum collections around the world are full of new species of Crato insects, plants and even pterosaurs just waiting to be described. This book brings together the various components of the palaeobiota and attempts to describe the ancient environments represented by the formation. It is one of the clearest windows yet into the Mesozoic, and although its edges may still be misty, a picture of a Cretaceous low-latitude environment is becoming much, much clearer.

D. M. Martill, G. Bechly and R. F. Loveridge 2007

References

- Agassiz, L. 1841. On the fossil fishes found by Mr Gardner in the Province of Ceará, in the north of Brazil. *Edinburgh New Philosophical Journal* **30**: 82–84.
 — 1833–1844a. *Recherches sur les Poissons fossiles*, 5 vols. Neuchatel.
 — 1844b. Sur quelques poissons fossiles du Brésil. *Compte Rendus Hebdomadaires des Seances des l'Académie des Sciences, Paris* **18**: 1007–1015.
- Brito, I. M. 1984. Nota preliminar sobre os insetos de Formação Santana, Cretáceo inferior da Chapada do Araripe, *Anais XXXIII Congresso Brasileiro de Geologia, Rio de Janeiro*: 530–535.
 — 1987. Nota preliminar sobre uma nova efêmera do Cretáceo do Ceará (Insecta Ephemeroptera). *Anais do X Congresso Brasileiro Paleontologia, Rio de Janeiro* **2**: 593–597.
- Campos, D. R. B. 1986. Primeiro registro fossil de Scorpionidae na Chapada do Araripe (Cretáceo Inferior), Brasil. *Anais Academia brasileira, Ciencias* **58**: 135–137.
- Costa Lima, A. da 1950. Ninfa de efemerideo fossil do Ceará. *Anais Academia brasileira, Ciencias* **22**: 419–420.
- da Silva Santos, R. da 1947. Uma redescricao de *Dastilbe elongatus*, com algumas considerações sobre o genero *Dastilbe*. *D.G.M./D.N.P.M. Notas Preliminar, Estudos* **42**: 1–7.
- Duarte, L. 1985. Vegetais fósseis da Chapada do Araripe, Br. *Coletânea de Trabalhos Paleontológicos, Série Geologia, 27, Seção Paleontologia e Estratigrafia, 2, Brasilia*: 557–563.

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- Gardner, G. 1846. *Travels in the Interior of Brazil, Principally Through the Northern Provinces and the Gold and Diamond Districts During the Years 1836–1841*. London: Reeves Brothers.
- Kellner, A. W. A. and Campos, D. de A. 1986. Primeira registro de amphibia (Anura) no Cretaceo Inferior da Bacia do Araripe, nordeste do Brasil. *Anais Academia brasileiro, Ciencias, Rio de Janeiro* **58**: 610.
- Martins-Neto, R. G. and Kellner, A. W. A. 1988. Primeiro registro de pena na Formação Santana (Cretaceo Inferior), Bacia do Araripe, nordeste do Brasil. *Anais Academia brasileiro, Ciencias* **60**: 61–68.

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