An unusual dinosaur from the Late Cretaceous of Romania and the island rule

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Island faunas are natural laboratories of evolutionary change and have long fascinated biologists. The peculiar ecological conditions on islands have frequently led to the evolution of endemic taxa that differ dramatically in body size and/or morphology from their mainland relatives. Many large animals tend to become smaller on islands, and small ones generally become larger—a phenomenon known as the island rule (1, 2). Perhaps the best-known examples from the fossil record are the pony-sized elephants and pig-sized hippopotami that populated Crete and various other Mediterranean islands during the Pleistocene and Holocene (3). Other examples include the Miocene hedgehog *Deinogalerix* from Italy, which attained a body length of about 70 cm (4), and the prehistoric rat *Coryphomys* from East Timor, which may have tipped the scales at 6 kg (5). Insular gigantism has also been found in certain groups of birds such as owls (6).

In the early decades of the last century, Franz Baron Nopcsa reported a distinctive Late Cretaceous (Maastrichtian) vertebrate assemblage from the Haţeg Basin of Transylvania (now part of Romania). This assemblage was dominated by several endemic taxa of dinosaurs that attained significantly smaller body size than related forms elsewhere. Impressed by this dwarfing, Nopcsa argued that the Haţeg fauna represented an island biota (7). However, his work and conclusions were largely ignored until there was a resurgence of interest in the Late Cretaceous vertebrates from Transylvania in the late 1970s (8). Since then, studies of the bone histology in the hadrosauroid dinosaur *Telmatosaurus* (9) and the titanosaurian sauropod *Magyarosaurus* (10) from the Haţeg Basin have supported Nopcsa's hypothesis that both taxa have undergone an evolutionary decrease in body size (nanism). Discoveries of additional vertebrate fossils from the Late Cretaceous of the Haţeg Basin have further underscored the distinctive nature of the Haţeg biota. In PNAS, Csiki et al. (11) report on one of the most remarkable finds to date—an unusual theropod dinosaur.

During the Late Cretaceous, a shallow epicontinental sea dotted with variously sized islands covered most of what is now Europe (Fig. 1). This topography reflected complex tectonic activities along the northern margin of the western Tethys related to counterclockwise rotation and northward motion of the African continental plate. Subduction resulted in volcanic activity, which, in turn, led to the formation of islands. The largest of these Cretaceous islands covered much of the present day Iberian Peninsula and France and extended well into central Europe. The Haţeg Basin was located on a smaller island in an archipelago that extended from the region now occupied by the European Alps eastward to present day southwest Asia.

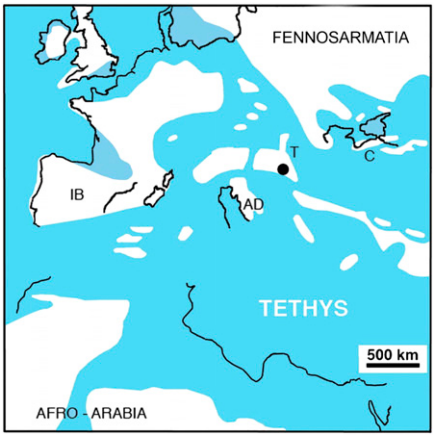

Fig. 1. Reconstructed paleogeography of the European archipelago in the western Tethys and adjacent regions during the Maastrichtian, with selected present day coastlines superimposed to facilitate orientation. Simplified from refs. 10 and 14. White areas denote land. Black circle indicates position of Haţeg region. AD, Adriatic-Dinaric Platform; C, Crimea; IB, Iberia; T, Tisia-Dacia Block.

In recent years, fieldwork in various parts of Europe has resulted in many discoveries of dinosaurs and other terrestrial vertebrates, which are finally beginning to shed light on the diversity of Late Cretaceous island ecosystems in this region. One of the most exciting discoveries, reported by Csiki et al. (11) in PNAS, is a previously unknown taxon of theropod dinosaur, *Baldaur bondoc*. *Baldaur* (named using an ancient Romanian word for dragon) is referable to the Dromaeosauridae (the "raptors" of *Jurassic Park* fame), which are the closest relatives of birds. The holotype of *Baldaur bondoc* is an articulated partial postcranial skeleton. It represents the most complete dromaeosaurid fossil from Europe to date, but its real scientific importance lies elsewhere.

First, the postcranial skeleton of *Baldaur* differs from that of other known dromaeosaurids in numerous features. The hand of *Baldaur* shows extensive fusion of the carpals and metacarpals, and there are only two functional digits, unlike the three-fingered grasping hand in other dromaeosaurids. The foot retains a large, functional first digit, unlike the much reduced digit in most derived theropod dinosaurs. This digit is very similar in size and shape to the second pedal digit, which, as in other dromaeosaurids, carries a greatly enlarged, strongly curved claw that had a considerable arc of motion. Thus, each foot of *Baldaur* sported a double set of these large claws, which were likely used for seizing and disemboweling prey. The robust hind limb shows extensive fusion of bones in its proportionately short distal portion, with formation of a tibiotarsus and a tarsometatarsus. These unusual features suggest that *Baldaur* was capable of delivering powerful strikes with its feet. Based on what is known about insular faunas past and present, Csiki et al. (11) hypothesize that the peculiar body plan of this predatory dinosaur is probably caused by the island effect. The body size of *Baldaur* is comparable with that of most other known dromaeosaurids.

Csiki et al. (11) conduct a thorough phylogenetic analysis of dromaeosaurid theropods and find that *Baldaur* is most closely related to *Velociraptor* from the Upper Cretaceous of Mongolia and China. One of the unresolved issues concerning the Late Cretaceous Haţeg biota had been its origin: was the Haţeg region a refugium for survivors of ancient lineages that had been in place for millions of years or did some of the taxa indicate faunal connections with neighboring continents late into the Cretaceous? The phylogenetic relationships of the small hadrosauroids *Telmatosaurus* and *Tethyshadros* (from the Maastrichtian Adriatic-Dinaric Island) suggest faunal connections to Asia (12–14), and the discovery of *Baldaur* now lends further support to this hypothesis. The recently described basal ceratopsian dinosaur

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Ajkaceratops from the early Late Cretaceous (Santonian) of Hungary (15) seems to represent yet another paleobiogeographic link between Europe and Asia. Presumably, the ancestors of these dinosaurs (and possibly other vertebrates) arrived from the Asiamerican landmass by island hopping, especially during times of lower sea levels (14).

1. Foster JB (1964) Evolution of mammals on islands. *Nature* 202:234–235.
2. Lomolino MV, et al. (2006) The island rule and a research agenda for studying ecogeographical patterns. *J Biogeogr* 33:1503–1510.
3. Sondaar PY (1994) Paleoecology and evolutionary patterns in horses and island mammals. *Hist Biol* 8:1–13.
4. Butler PM (1980) The giant erinaceoid insectivore, *Deinogalerix* Freudenthal, from the Upper Miocene of Italy. *Scripta Geol* 57:1–72.
5. Aplin K, Helgen KM (2010) Quaternary murid rodents of Timor. Part I: New material of *Coryphomys buehleri* Schaub, 1937, and description of a second species of the genus. *Bull Am Mus Nat Hist* 341:1–80.
6. Arredondo O (1976) The great predatory birds of the Pleistocene of Cuba. *Smithsonian Contr Paleobiol* 27:169–187.
7. Nopcsa F (1914) Die Lebensbedingungen der obercretacischen Dinosaurier Siebenbürgens. *Centralbl Mineral Geol Paläontol* 1914:564–574.
8. Weishampel DB, Grigorescu D, Norman DB (1991) Thedinosaurs of Transylvania. *Natl Geogr Res* 7:196–215.
9. Benton MJ, et al. (2010) Dinosaurs and the island rule: The dwarfed dinosaurs from Haţeg Island. *Palaeogeogr Palaeoclimatol Palaeoecol* 293:438–454.
10. Stein K, et al. (2010) Small body size and extreme cortical bone remodeling indicate phyletic dwarfism in *Magyarosaurus dacus* (Sauropoda: Titanosauria). *Proc Natl Acad Sci USA* 107:9258–9263.
11. Csiki Z, Vremir M, Brusatte SL, Norell MA (2010) An aberrant island-dwelling theropod dinosaur from the Late Cretaceous of Romania. *Proc Natl Acad Sci USA* 107:15357–15361.
12. Weishampel DB, Norman DB, Grigorescu D (1993) *Telmatosaurus transsylvanicus* from the Late Cretaceous of Romania: The most basal hadrosaurid dinosaur. *Palaeontology* 36:361–385.
13. Sues H-D, Averianov A (2009) A new basal hadrosauroid dinosaur from the Late Cretaceous of Uzbekistan and the early radiation of duck-billed dinosaurs. *Proc Biol Sci* 276:2549–2555.
14. Dalla Vecchia FM (2009) *Tethyshadros insularis*, a new hadrosauroid dinosaur (Ornithischia) from the Upper Cretaceous of Italy. *J Vertebr Paleontol* 29:1100–1116.
15. Ösi A, Butler RJ, Weishampel DB (2010) A Late Cretaceous ceratopsian dinosaur from Europe with Asian affinities. *Nature* 465:466–468.