

Dinosaur nests at the sea shore

SIR — Beach deposits of the Arenisca de Arén Formation¹ (southern Pyrenees, Maastrichtian, Upper Cretaceous) are rich in dinosaur eggs and bones, distributed over an area of about 15 km² along the northern flank of the Tremp syncline (Fig. 1). At one locality (Bastús, Lleida) we have estimated the presence of up to 300,000 eggs in a rock volume \approx 12,000 m³, suggesting some kind of 'site fidelity'.

Dinosaur remains have frequently been reported from marine sediments. Efremov²

ing well-preserved dinosaur nests (Fig. 1). Farther down, the red layer passes into shore face sandstones with well-preserved, wave-induced sedimentary structures, forming part of a near-shore environment passing landward into mudflat deposits, occasionally dissected by small channels⁵. As the beach-ridge plain was built up to seaward (progradation), the dinosaurs nested in the exposed sandy sediment.

A huge number of egg shell fragments are scattered along the outcrop (Fig. 2).

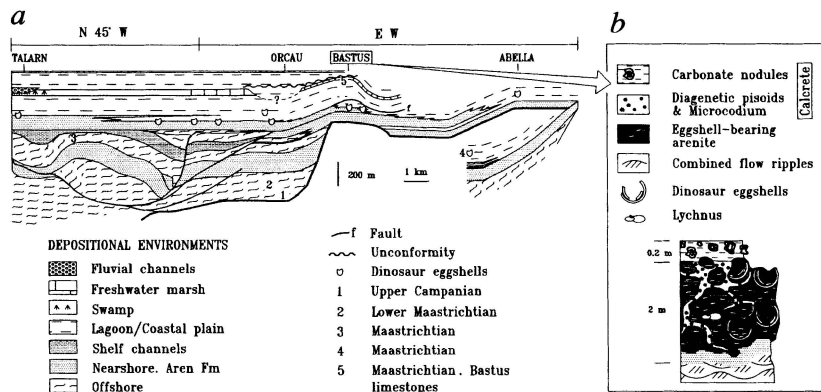


FIG. 1 a, Cross-section through the NW-prograding depositional sequence, Late Campanian and Maastrichtian in age, along the northern flank of the Tremp syncline (South Central Pyrenees, Spain). The succession formed under high terrigenous influx and relative sea-level rise. The sequence passes from coastal plain (Tremp Fm. p.p.) through strand-plain/barrier island (Arenisca de Arén Fm.) to offshore sediments. It overlies near-shore deposits of a similar sequence, which are affected by growth faults⁵. The dinosaur nests have been preserved mainly at the top of the Arenisca de Arén Formation. b, Log of the Bastús section. The matrix of the eggshell-bearing rock is a calcite-cemented, medium-to-coarse-grained arenite of mixed siliciclastic and carbonate grain composition. Carbonate grains comprise different types of worn skeletal fragments dominated by shallow-marine elements, intraclasts as well as dinosaur eggshell debris, and are generally affected by microbial micritization. This, along with the local preservation of relict dripstone and meniscus cement fabrics, suggests that lithification was initiated at the strand line (beach rock). Shoreline progradation then caused the incipiently cemented sand to become exposed to meteoric waters. Diagenesis in the freshwater phreatic environment involved selective leaching of initially aragonitic components and concomitant precipitation of new diagenetic calcite. Further diagenetic alteration before final burial of the sediment occurred in the meteoric vadose zone, as documented by the presence of a variety of petrographic features diagnostic of pedogenic calcrete development. c, Aspect of the outcrop.



suggested a marine habitat for some dinosaurs, although these were later interpreted as the remains of individuals that had been washed to the sea. Chanda³ proposed a shallow-water marine environment for the dinosaur egg-bearing Lameta Formation of India, however, Shani *et al.*⁴ conclusively argued for the continental (palustrine) origin of these sediments. Thus, the Arenisca de Arén egg sites represent the first unambiguous evidence of dinosaurs nesting at a sea shore.

The top of the Arén Formation at Bastús is 2-m-thick red sandstone contain-

Other fossils include large bone fragments; tiny smashed bones, probably belonging to young dinosaurs; a fairly complete skeleton of a small lizard and land snails (*Lychnus giganteus* Repelin). As the original disposition of some nests and bones are well preserved, post-depositional transport can be excluded as a primary cause of fragmentation. Rather, the eggs were destroyed by the animals' nesting and trampling activities and later by paedogenesis (Fig. 1). The nesting probably occurred in the unconsolidated sands of the beach ridge, in a short time interval between beach abandonment

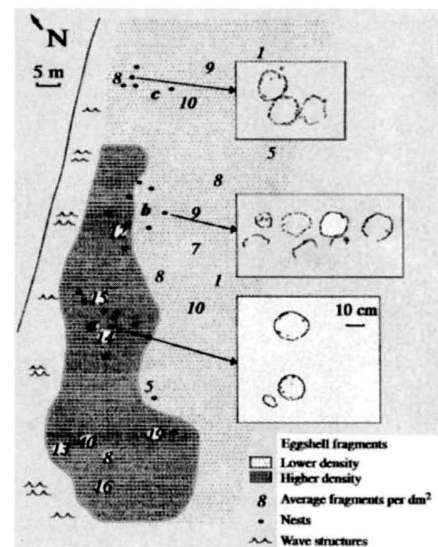


FIG. 2 Map illustrating nest distribution and eggshell density. The preserved nests, probably the last clutches, are in three main clusters. The distance between nests is 1–5 m (a), 4–6 m (b) and 3–8 m (c). The distance between some nests (1 m) is too short with respect to the presumed body size of the adult dinosaurs, suggesting that the nesting strategy is different from the colonial nesting behaviour described elsewhere⁶.

and early diagenesis (meteoric leaching, incipient lithification and paedogenesis).

The eggshell structure is tubospherulitic, and most of the preserved egg sections show subcircular contours. Some complete eggs from this locality, housed in the Freie Universität, Berlin, have a subspherical shape, with a diameter \approx 20 cm. The outcrop has yielded the remains of 24 nests arranged in three clusters on a surface \approx 6,000 m² (Fig. 2). Each nest contains 1–7 eggs, most of them having only two or three preserved eggs, representing portions of nests deposited in a hole dug in the sediment.

The Bastús nests are closely spaced but do not overlap (modal distance 2.5 m; Fig. 2). As the preservation state of the nests is generally good, some factor has precluded the destruction of previous clutches by newcomers. Some territorial behaviour may account for this feature. A high population density and/or scarcity of favourable substratum could explain the observed short distances between nests.

Using a 1-dm² grid in 20 randomly chosen areas (Fig. 2), we calculate that the eggshell material amounts to \approx 0.5% of the total rock volume. Given the volume of the sandstone body (12,000 m³) and assuming an average egg size of 20 cm diameter and 1.45 mm shell thickness, we estimate

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that the lithic body contains the remains of some 300,000 eggs. This suggests that the area was a nesting ground, and that the dinosaurs may have returned to this same area during several reproductive seasons.

The Bastús egg site is the result of the nesting behaviour of a dinosaur population living very near the sea shore and may represent a local example of a widespread phenomenon in the Upper Cretaceous of the south-central Pyrenees.

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