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Possible fossil ostracod (Crustacea) eggs from the Cretaceous of Brazil

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ABSTRACT – Spherical objects recovered from the acetic acid preparation residues of vertebrate fossils from the Santana Formation (Lower Cretaceous) of northeast Brazil are postulated as the eggs of the ostracod *Pattersoncypris micropapillosa* Bate, 1972 (Ostracoda). These spheres are phosphatized and range from 85 to 110 μm in diameter, and are comparable in many respects to the eggs of several Recent ostracod species. *J. Micropalaeontol.* **18(1):** 81–87, June 1999.

INTRODUCTION

The Santana Formation in northeast Brazil (Fig. 1) is a world famous *Lagerstätte*, known for the excellent preservation of a diverse fauna that includes fish, pterosaurs and ostracods (Martill, 1993). Other uncommon invertebrates include shrimps (Maisey & De Carvalho, 1995) and rare parasitic copepods found on the gills of fish (Cressey & Boxshall, 1989). The formation is of Albian age (Lima, 1979) and consists of a series of silty clays, calcareous nodules and thin limestones. The best preserved vertebrate fossils occur in calcareous nodules in the Romualdo Member, near the top of the formation (Fig. 1). In some specimens the fish sometimes show excellent preservation, with muscle fibre and even single cells with nuclei still present (Martill, 1988, 1990). Such fish, in some cases, have ostracod associates, some of which have excellently preserved appendages (Bate, 1971; 1972; 1973; Smith, in press). In addition, hundreds of small spheres are found as a part of this association. The aim of this paper is to address the possibility that these spheres represent ostracod eggs.

The ostracod fauna of the Santana Formation is mostly monospecific, consisting of *Pattersoncypris micropapillosa* Bate, 1971, and a much rarer sympatric species of the genus *Reconcavona* Krömmelbein, 1962 (Smith, in press). The ostracods are preserved as whole calcitic carapaces or, more rarely, as apatitic carapaces and appendages. The apatitic specimens show excellent preservation, complete with setae and even setules as small as 1 μm in length. This excellent preservation is largely due to the rapid fossilization (Martill, 1989).

PREVIOUS WORK

The fossil fish from the Santana Formation were first studied by Agassiz (1841), since when 25 species of fish have been described (Martill, 1993). Ostracods with preserved appendages from the Santana Formation were first recorded by Bate (1971), who reported their association with the fish *Cladocyclus gardneri* Agassiz, 1841. Bate (1972; 1973) later described the ostracods and noted the presence of small, spherical objects which he suggested might be ostracod eggs, although he did not detail any supporting evidence. In the preparation of nodules from the Santana Formation, the present author has found many additional spheres, similar to those noted by Bate (1972). Herein these spheres are compared in detail with Recent ostracod eggs and other fossil spheres (eggs?).

The limited amount of work that has been carried out on the morphology of Recent ostracod eggs has mostly been on material of the genus *Heterocypris*. Roessler (1982b) conducted a detailed study of the eggs of *Heterocypris bogotensis* Roessler, 1982a, documenting the structure of the shell and identifying a prenauplius stage within the eggs. Additionally, experimental work on the eggs of *Heterocypris incongruens* (Ramdohr, 1808) has demonstrated their robust nature (Angel & Hancock, 1989; Kornicker & Sohn, 1971; Sohn & Kornicker, 1979). Eggs from *Cypridopsis vidua* (Müller, 1898) have been described, but not figured (Kesling, 1951).

MATERIALS AND METHODS

Collection of fossil material in the field mostly targeted concretions containing fish with a high amount of visible preserved soft tissue because such material is more likely to produce phosphatized arthropods (Martill, pers. comm.). The concretions were dissolved in 2–3% acetic acid and the residue was regularly washed and picked. The residue from five nodules contained over 800 phosphatic ostracods, many in an excellent state of preservation, and thousands of small, phosphatic, spherical objects. The spherical objects were mounted on stubs, coated in gold and viewed using an Hitachi S-520 scanning electron microscope. Stereo-photography was used extensively in this study.

Eggs from the ostracods *Cypridopsis vidua*, *Eucypris virens* (Jurine, 1820), *Herpetocypris chevreuxi* (Sars, 1896) and *Heterocypris incongruens* were obtained from live cultures in the laboratory by examining sediment, weed, wood and the sides of the tanks. This resulted in single eggs and clumps of eggs being located, which were dried and mounted on stubs. Eggs from *Darwinula stevensoni* (Brady & Robertson, 1870) were removed from the brooding area of a dead specimen which had been stored in 70% ethanol. After coating, the eggs were viewed using scanning electron microscopy.

All material is deposited in the Palaeontology Department, Natural History Museum, London, numbers OS 15588 to OS 15597.

MORPHOLOGY AND OCCURRENCE OF THE SPHERES FROM THE SANTANA FORMATION

A total of 40 spheres was recovered for study. Partially digested nodules reveal that the spheres occur singly, in specific areas. This reflects the occurrence of preservation of the phosphatic ostracods, which also occur in some areas of the nodules but not in others (Smith, in press). The spheres, although found in association with ostracods, are not generally found within the carapaces of ostracods. Only one example of an ostracod with a sphere within the carapace has been observed by this author,

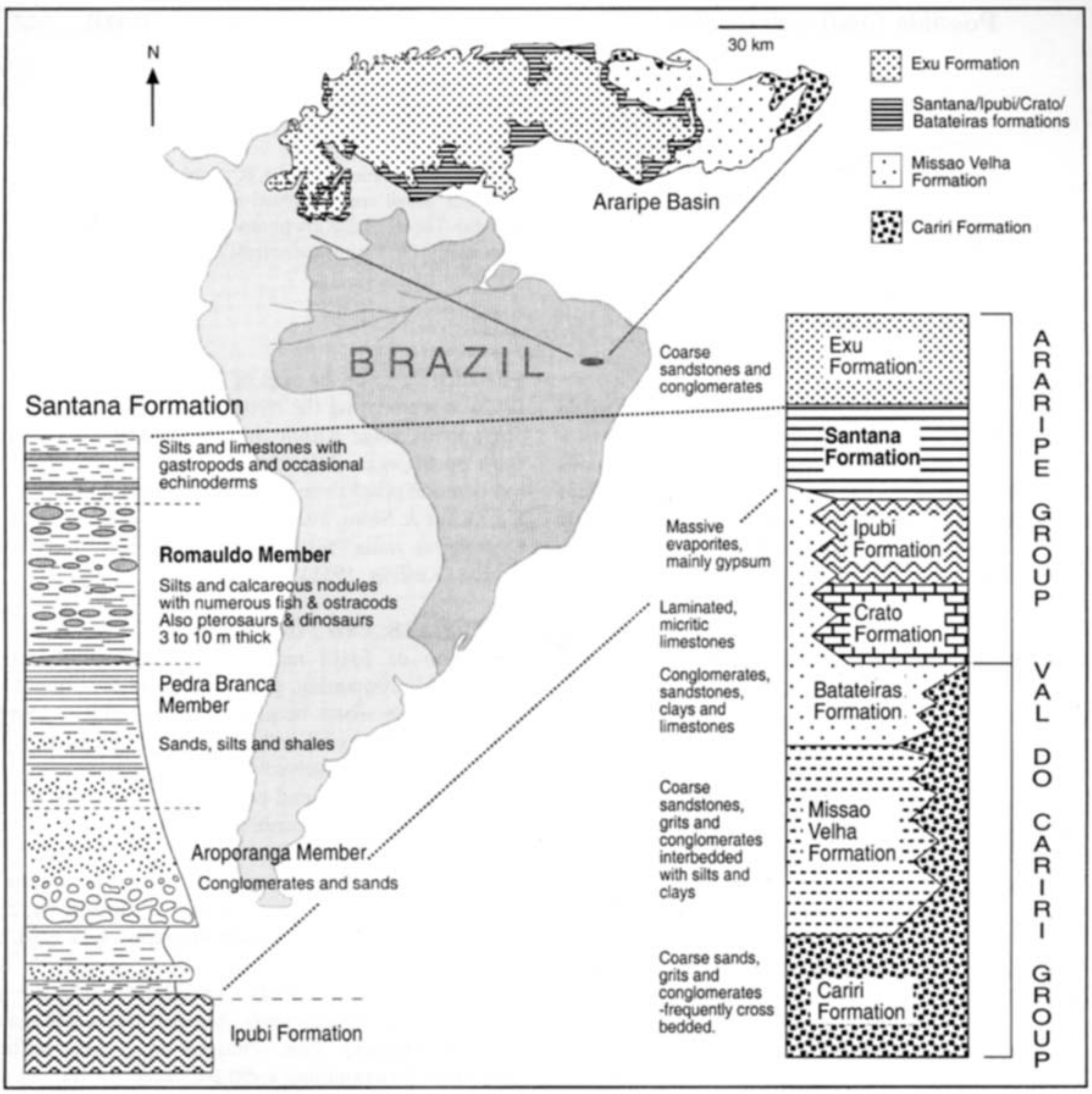


Fig. 1. Location map and sections of the Santana Formation.

and such a relationship is probably coincidental.

The spheres range between 85 and 110 μm in diameter and have a weakly textured surface (Plate 1, figs 1–3). They are phosphatized, which is similar to the apatitic ostracods found in association with them. The wall of the spheres is 4–5 μm thick, although in some cases this may reflect the thickness of the 'shell' plus a phosphatic coating. The spheres are mostly complete and their surface appears to be undamaged. However, some of the spheres are penetrated by one or two small holes (Plate 1, figs 2, 3) and some show wrinkled surfaces to varying degrees. It is not clear whether the phosphate represents a coating on the outside or inside of the sphere, or if the sphere surface is replaced with the phosphate.

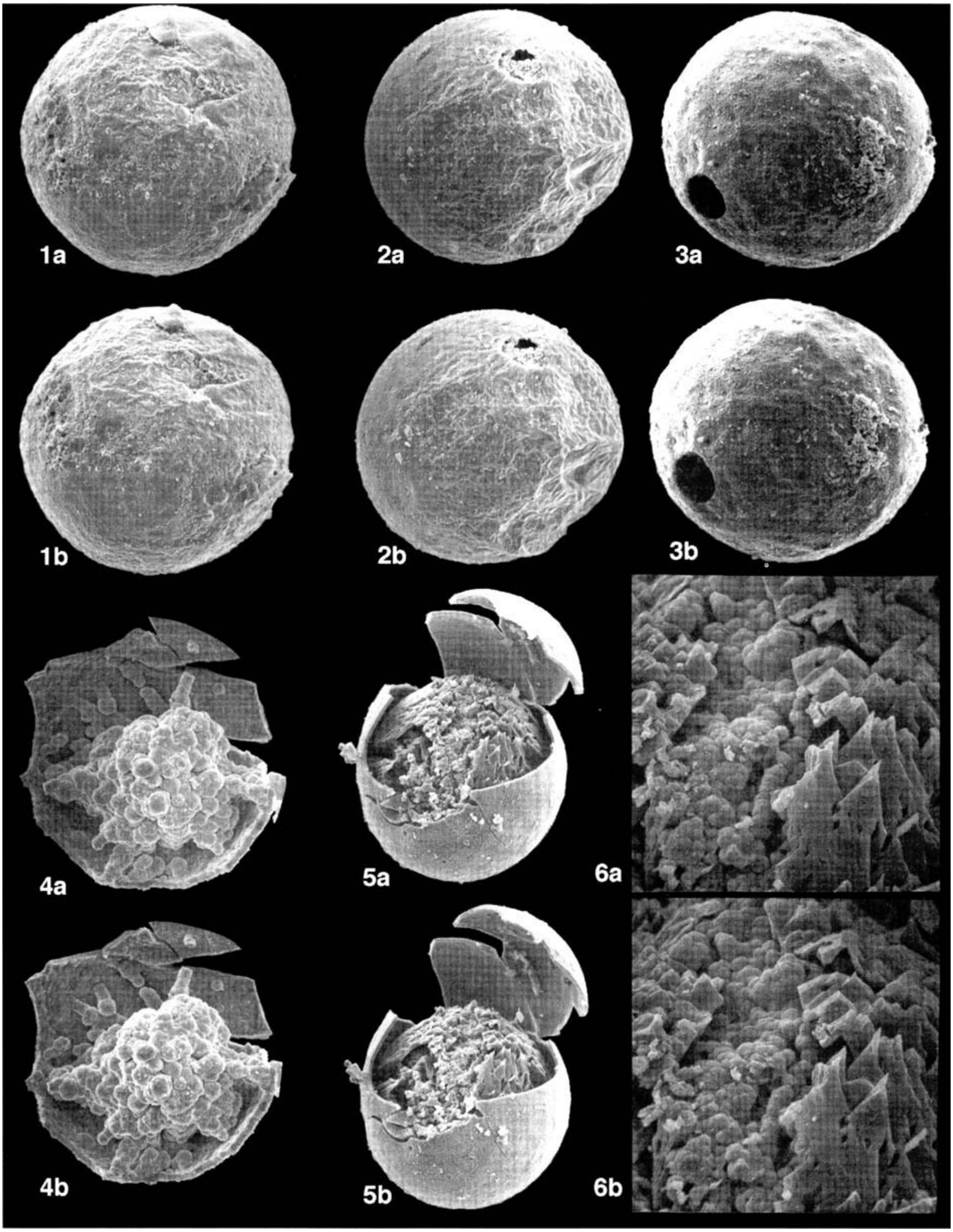
Dissection of the spheres reveals that most appear to have contained a sparry calcite (energy-dispersive X-ray analysis), some of which remains after partial acid digestion (Plate 1, figs 5, 6). A number of spheres also contain a phosphatic residue, consisting of a central mass with a vague radial pattern (Plate 1, fig 4). The phosphatic residue consists of a series of coalesced microspheres and is located towards one side of each sphere; in some cases it is associated with a hole through the nearby region of the sphere (Plate 1, fig. 3). The internal surface of the sphere consists of irregularly arranged phosphatic microspheres which are not seen on the outer surface of the sphere (Plate 1, fig. 4).

THE SANTANA SPHERES: OSTRACOD EGGS?

The size and nature of occurrence of the spheres found in the Santana Formation invoke close comparisons with Recent ostracod eggs and other spheres in the fossil record.

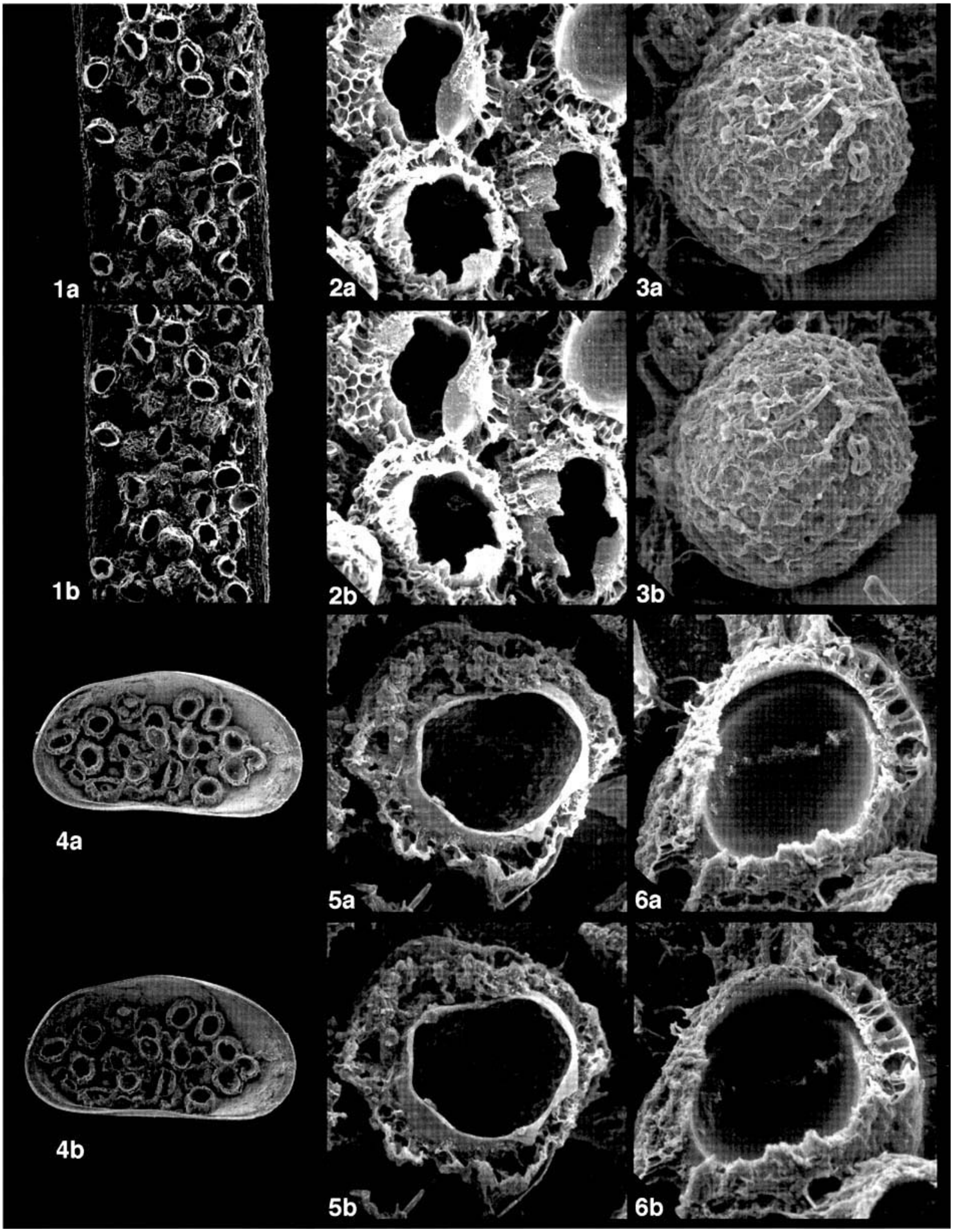
Occurrence

The Santana spheres occur within nodules as isolated objects.



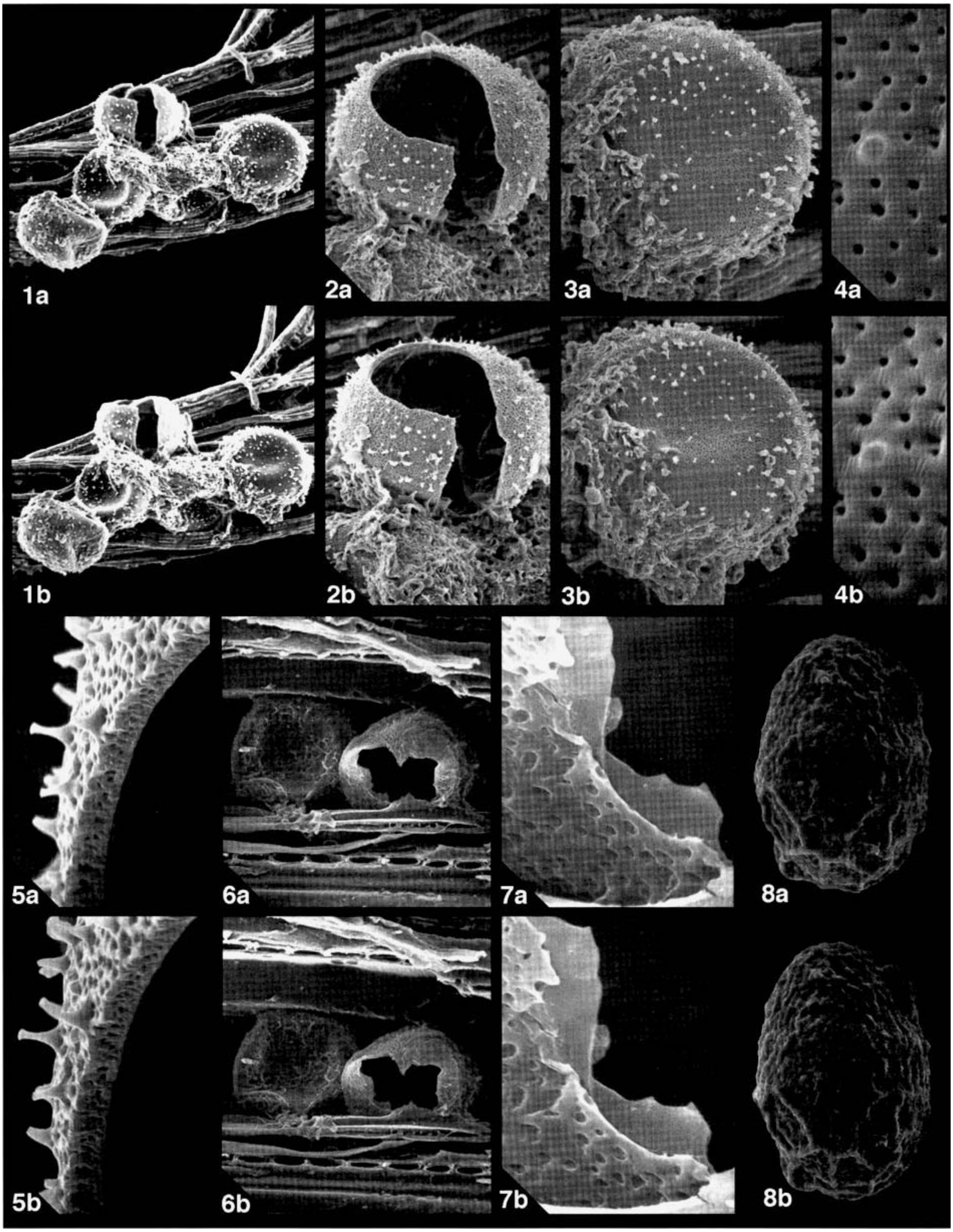
Explanation of Plate 1

figs 1–6. Phosphatic spheres from the Romualdo Member of the Santana Formation, northeast Brazil. **fig. 1.** Whole sphere (OS 15590) ×408. **fig. 2.** Whole sphere (OS 15530) ×408. **fig. 3.** Whole sphere (OS 15588) ×420. **fig. 4.** Internal view of dissected sphere (OS 15589) ×463. **figs 5, 6.** Dissected sphere (OS 15591). **5** ×350; **6** ×1172.



Explanation of Plate 2

figs 1–3. Eggs of the Recent ostracod *Heterocypris incongruens* Leicestershire, UK (OS 15593). **fig. 1.** Unhatched and hatched eggs on a stout piece of weed, ×40. **fig. 2.** Hatched eggs, ×201. **fig. 3.** Unhatched egg, ×346. **figs 4–6.** Eggs of the Recent ostracod *Herpetocypris chevreuxi*, Leicestershire, UK (OS 15594). **fig. 4.** Unhatched and hatched eggs in a discarded valve of *H. chevreuxi* ×35. **fig. 5.** Hatched egg, ×289. **fig. 6.** Unhatched egg, ×346.



Explanation of Plate 3

figs 1–5. Eggs of the Recent ostracod *Eucypris virens*, Lincolnshire, UK (OS 15595). **fig. 1.** Cluster of four unhatched and one hatched egg on weed, ×100. **fig. 2.** Hatched egg, ×235. **fig. 3.** Unhatched egg, ×394. **fig. 4.** Surface ornamentation of egg, ×2940. **fig. 5.** Wall of hatched egg, ×1470. **figs 6, 7.** Eggs of the Recent ostracod *Cypridopsis vidua*, Avon, UK (OS 15596). **fig. 6.** Hatched and unhatched egg deposited on a piece of wood, ×294. **fig. 7.** Edge of hatched egg, ×2051. **fig. 8.** Egg of the Recent ostracod *Darwinula stevensoni*, Finland (OS 15597) ×411.

This is consistent with the mode of occurrence of the eggs of the studied ostracod species. Recent ostracods either brood eggs within the carapace (e.g. Darwinulidae) or deposit eggs into the environment (e.g. Cyprididae). Eggs deposited in the environment are either laid in clusters or singly. The four species studied that deposit their eggs mostly stuck the eggs to a substrate. Stout, roughened substrates such as wood and the stems of weeds were preferred (Plate 2, fig. 1; Plate 3, figs 1, 6), although discarded valves (Plate 2, fig. 4) and the glass of the tank were also utilized.

Numbers

Clusters of ostracod eggs in this study range in number from two to about 30 (Plate 2, figs 1, 4; Plate 3, figs 1, 6). More rarely, all four species studied deposited their eggs loose into the sediment. No information exists about how many eggs in total an ostracod might lay in the *natural* environment, but as ostracods can reach very high densities (up to 700 000 individual adults per square metre of sediment; Heip, 1976), the density of eggs is potentially very high. The Santana spheres are very numerous, with thousands within the residues of prepared nodules; this is therefore consistent with a probable high density of occurrence of the species *Pattersoncypris micropapillosa.*

Size

The size range of the Santana spheres (85–110 μm in diameter) is similar to the size range of eggs from Recent ostracods such as *Heterocypris incongruens* (95–110 μm in diameter), *Herpetocypris chevreuxi* (97–133 μm in diameter), *Eucypris virens* (120–145 μm in diameter), *Cypridopsis vidua* (70–90 μm in diameter) and *Darwinula stevensoni* (116–129 μm in length and 72–82 μm in width).

Shape

The shape of the Santana spheres is consistent with the shape of the eggs of the Recent ostracod species. The eggs of *Heterocypris incongruens*, *Herpetocypris chevreuxi*, *Eucypris virens* and *Cypridopsis vidua* are all basically spherical, although they are often slightly flattened on one side as a result of being stuck to a substrate. With the exception of eggs from *Heterocypris incongruens* (Plate 2, fig. 3), eggs become dimpled when air-dried (Plate 2, fig. 6; Plate 3, figs 3, 6). Other ostracod eggs, such as those from *Darwinula stevensoni*, are oblate (Plate 3, fig. 8) and are therefore not similar in shape to the Santana spheres.

Surface ornamentation

The smooth outer surface of the Santana spheres is similar to that of some Recent ostracod eggs such as those belonging to *Herpetocypris chevreuxi*, *Heterocypris incongruens*, *Cypridopsis vidua* and *Darwinula stevensoni*. The eggs of *Heterocypris incongruens* have a thick, spongy outer coating which, when breached during hatching, reveals the smooth layer of the egg itself (Plate 2, figs 2, 3). Eggs from *Herpetocypris chevreuxi* also have a similar thick outer coating, but this coating does not totally cover the eggs (Plate 2, figs 5, 6) as it does in the eggs of *Heterocypris incongruens*. The eggs of *Cypridopsis vidua* have a much thinner coating covering the smooth surface (Plate 3, fig. 7). Eggs from *Darwinula stevensoni* do not have a coating and have a smooth texture, although the eggs show considerable wrinkling when air-dried (Plate 3, fig. 8). The eggs from *Eucypris virens* are dissimilar to the other eggs studied and the Santana spheres, having a thick, porous wall (Plate 3, figs 3, 5), which in places has striations between the pores (Plate 3, fig. 4). Additionally, the eggs of *Eucypris virens* have a large number of small processes projecting from the outer surface.

Comparisons of the Santana spheres with other fossil spheres

Unequivocal invertebrate eggs are rare in the fossil record. The best preserved occurrences are both from China: embryos of unknown animals from the late Precambrian (Xiao *et al.*, 1998) and embryos of worm-like animals from the Lower Cambrian (Bengtson & Zhao, 1997). Possible fossil arthropod eggs are limited to a few occurrences and include: unsubstantiated trilobite eggs (Barrande, 1852); possible bradoriid eggs from the Lower Cambrian of China (Zhang, 1987); Middle Cambrian arthropod embryos with blastomeres (Zhang & Pratt, 1994); organic, sculptured oblate spheroids, which are possible insect eggs, from the Aptian of Brazil (Regali & Sarjeant 1986); a single, possibly decayed egg from within a shrimp from the Santana Formation (Briggs *et al.*, 1993); and an eggshell with a well-preserved lepidopteran sculpture of an Upper Cretaceous moth from North America (Gall & Tiffney, 1983). None of these fossilized spheres resembles the Santana spheres in occurrence, size, numbers or surface sculpture.

DISCUSSION

The Santana spheres resemble the eggs of Recent ostracods, particularly those of the species *Heterocypris incongruens*, *Herpetocypris chevreuxi* and *Cypridopsis vidua.* Although there is no evidence of an outer coating on the Santana spheres, their size, mode of occurrence and smooth surface are all consistent with that of Recent ostracod eggs. However, as Recent ostracod eggs do not have any external diagnostic morphology, except for possibly the eggs of *Eucypris virens*, it is not certain that the Santana spheres do in fact represent ostracod eggs. The calcitic spar and the phosphatic mass within the Santana spheres do not reflect the known morphology of ostracod embryos (Weygoldt, 1960; Roessler, 1982b), indicating that only the eggshell was replaced by apatite. The association of the phosphatic mass with holes through the surface of the spheres possibly indicates that this mass is not a primary feature, but rather is secondary introduced matter. As the holes are too small to be a result of hatching (as shown by hatched Recent ostracod eggs: Plate 2, figs 2, 4; Plate 3, figs 2, 6) they are possibly a result of predation or due to preservational factors. This would account for the fact that only some of the spheres have holes, that the holes may be one or two in number and are different in size.

Other possible affinities of the spheres are that they are the eggs of copepods or shrimps; both these groups are present in small numbers in the Santana Formation. Shrimps are generally found in the stomachs of the Santana fish, but a small number have also been found in the surrounding matrix. The copepods are parasitic and only found on the gills of the Santana fish. Both of these arthropod groups in the Santana Formation are rare compared with the ostracods and are therefore unlikely to have deposited such a large number of eggs into the environment; thus the spheres in the Santana Formation are unlikely to represent the eggs of the copepods or shrimps.

CONCLUSIONS

Though not certain, it is considered likely that the small spheres present in the Santana Formation represent the eggs of *Pattersoncypris micropapillosa* because of reasons of association and because they are a similar size, shape and have a similar smooth surface to that of Recent ostracod eggs. Moreover, *Pattersoncypris micropapillosa* was the only animal present in any abundance in the benthic environment and is, therefore, the best potential candidate for their origin.

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