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Morphological abnormalities in Late Cretaceous and early Paleocene foraminifer tests (northern Patagonia, Argentina)

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ABSTRACT

Morphological abnormalities are common in Late Cretaceous and early Paleocene foraminifer tests at two localities in northern Patagonia, Argentina. *Protelphidium* sp. in the Auca Mahuevo section (late Campanian–early Maastrichtian) exhibit abnormal size or shape of the later chambers, with the last chamber commonly larger than normal or inflated and variably extending onto one of the lateral sides of the test; modification of the coiling plane; protuberances near the proloculus or on one or more chambers; a double last chamber, and complex forms. *Protelphidium hofkeri* Haynes in the Cerro Azul section (Danian) exhibit abnormal size or shape of one or more chambers, producing peripheral irregularities. In addition, there are rare multiple tests in planktic species from the Cerro Azul section, probably teratological specimens. The sedimentology of the sections and the character of the accompanying faunas indicate that the abnormalities in the two benthic foraminiferal taxa were most probably caused by hypersalinity and/or fluctuations in salinity. The fossil occurrence of assemblages with abundant deformed specimens suggests that investigators should carefully look at many aspects of the environment before concluding that anthropogenic pollution is the only cause of deformations of living benthic foraminifera.

1. Introduction

Deformed tests are well known in benthic foraminifers, but also have been observed in planktic species, although less frequently (Boltovskoy, 1976, 1982; Boltovskoy and Wright, 1976). Test abnormalities have been reported from the fossil record as early as the end of the Carboniferous–Permian period in *Fusulina* (Nguyen, 1970, 1980). Abnormal tests of foraminifers are formed when the growth plan of the test is disrupted to give an irregular shape in comparison with other specimens of the same species. Some of these abnormalities develop during the life span of the individuals whereas others are the result of post-mortem changes. Agglutinated forms with loosely cemented walls (dominantly consisting of organic matter) are commonly preserved flattened and collapsed, as one example of post-morten change (Boltovskoy and Wright, 1976). Other examples include bioerosion, which may be responsible for the damage or partial destruction of calcareous tests. In addition, bacteria oxidise the organic matrix (lining) within in the wall leading to dissolution of calcite microcrystallites and endolithic algae and fungi dissolve calcite, thus producing hole and tunnels. Dissolution produces a spectrum of features, ranging from mildly etched surfaces to loss of large portions of the outer wall, exposing the underlying chamberlets in calcareous forms and the plucking of detrital grains out of agglutinated forms (e.g., Murray, 2006).

Abnormalities produced during the life and growth of the organisms, however, are more interesting from the point of view of their origin and environmental significance and may have more diverse origins. They may be due to either mechanical (high energy hydrodynamical or predation breakages healed or patched by the organism) or by ecological causes (Boltovskoy, 1965). Many irregularities are not due to damage of the test (post-mortem or during the life of the foraminifer), but reflect the influence of the substrate on attached tests.

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Others range from slight to severe deformity, including chambers in the wrong place, distorted spirals and additional apertures (which may lead to chamber formation outside the normal pattern of development), among others.

Up to ~1970 these abnormalities were explained mainly by natural causes, but more recently deformation of foraminiferal tests has been reported to be common in highly polluted areas (e.g., Alve, 1995; Yanko et al., 1998; Geslin et al.,

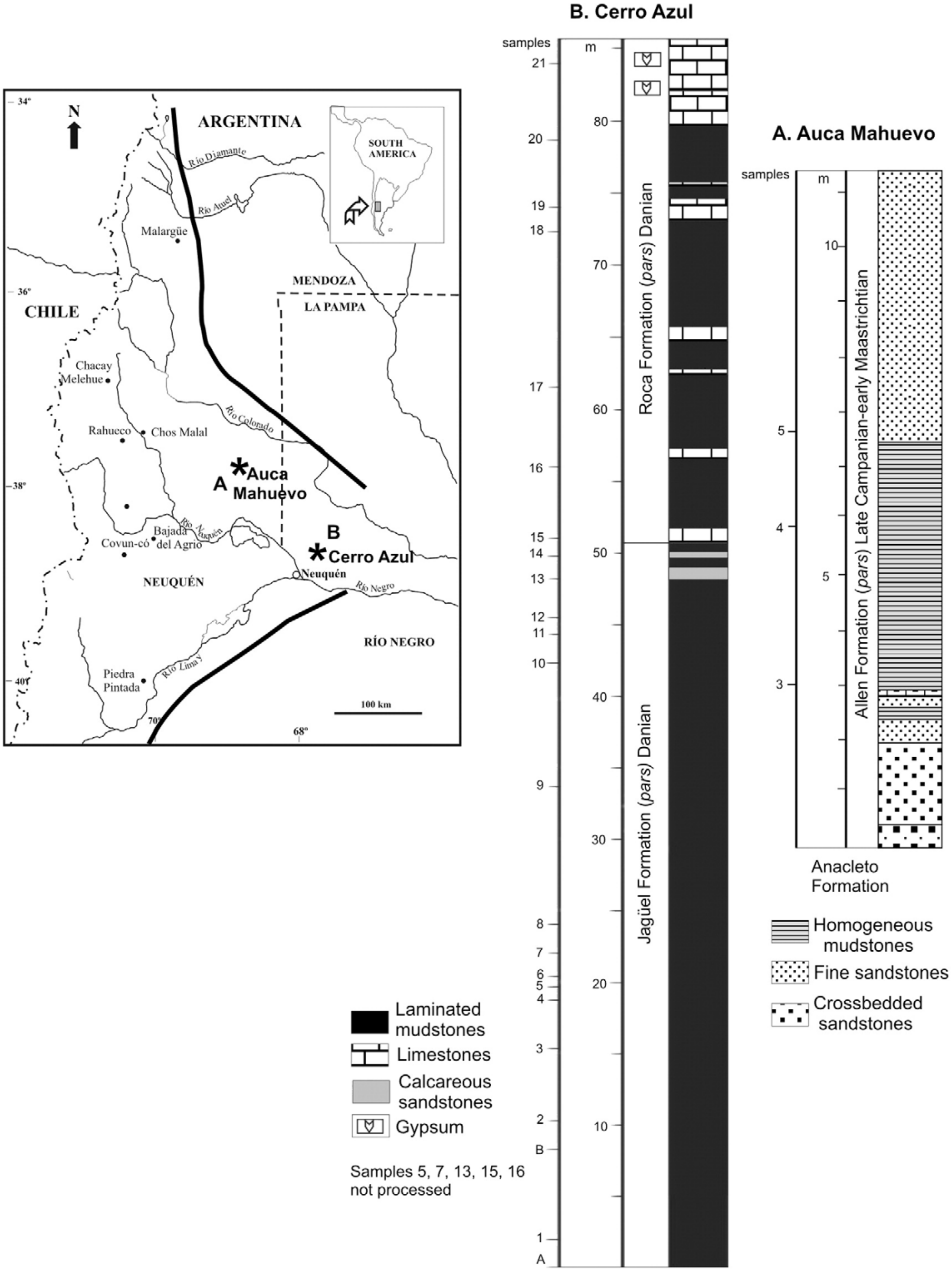


Fig. 1. The Argentinian part of the Neuquén Basin outline (thick line) and the position of fossiliferous localities, simplified lithological columns and sample locations (*). A. Auca Mahuevo section, basal part of I/99–I/02 profile, Neuquén Province (modified from Carignano and Garrido, 2006), B. Cerro Azul section, Río Negro Province (modified from Parras et al., 2007).

2002; Le Cadre and Debenay, 2006). We want to emphasize, however, that anthropogenic pollution is not always the cause of abnormal test formation (Stouff et al., 1999a), as also documented in a comprehensive synthesis of foraminiferal abnormalities and their causes (Geslin et al., 2000).

Here we describe the morphological abnormalities in hyaline benthic and planktic foraminiferal tests (suborders Rotaliina and Globigerinina) from Upper Cretaceous and lower Tertiary sections in northern Patagonia, Argentina, and attempt to explain the possible causes of the abnormal test formation as well as their possible use in paleoenvironmental reconstruction. We follow the suggestion by Stouff et al. (1999b, p. 152) who recommended using "deformation" for abnormalities formed during the life of the organism, but "malformation" for abnormalities resulting an anomaly during the ontogenetic development process, and "morphological abnormalities" or "abnormal tests" if the origin of the abnormality is not evident.

2. Geological setting and study localities

The Neuquén Basin is located in northern Patagonia (west-central Argentina) between latitude 34° and 41° S and contains deposits ranging in age from Late Triassic through Tertiary. The sections studied in this paper are located between latitude ≈37°30′ and ≈38°40′ S where Upper Cretaceous–lower Paleocene sediments are well exposed (Fig. 1).

One of the localities is section Auca Mahuevo (approximately 130 km northwest of Neuquén city, Fig. 1A), a well-known dinosaur nesting site (Chiappe et al., 1998; Chiappe and Coria, 2004). The levels that we sampled are part of the I/99–I/02 profile and comprise the lower 10 m of the Allen Formation, crossbedded sandstones that pass upwards into a homogeneous sequence of green and yellowish grey mudstones, with some fine-grained sandstone and evaporite beds (Carignano and Garrido, 2006). The age of the Allen Formation is restricted to late Campanian–early Maastrichtian, because magnetostratigraphical data place the underlying unit (Anacleto Formation) in the early to middle Campanian and micropaleontological data place the overlying unit (the lower part of the Jagüel Formation) in the middle through late Maastrichtian (Dingus et al., 2000; Náñez and Concheyro, 1997).

The other studied section, Cerro Azul (38°50′48″ S–67°52′20″ W), is located to the southeast of Lago Pellegrini (Fig. 1B). It comprises ≈50 m of laminated mudstones of the upper Jagüel Formation, overlain by 35 m of bioclastic packstones, marls, sandstones and heterolithic siltstones of the Roca Formation. Evaporites are common towards the top of the section. Nannofossil associations from the levels that we studied correspond to the *Cruciplacolithus tenuis* Zone (NP2) and the *Chiasmotithus danicus* Zone (NP3) of Martini (1971), thus indicating a Danian age (Parras et al., 2007).

Table 1
Auca Mahuevo section

Sample	Benthic specimens	*Protelphidium* sp.
5	859	Total 575 (abnormal tests 426)
4	~100	–
3	~100	–

Number of specimens of benthic species (agglutinated, hyaline, porcellaneous) and number of specimens of *Protelphidium* sp. (normal and abnormal tests).

3. Materials and methods

We studied 3 samples from the Auca Mahuevo section and 18 from the Cerro Azul section (Fig. 1). The samples were processed with concentrated hydrogen peroxide (10%), washed through a 63 μm sieve, and oven dried (30 °C). Specimens were picked in approximately 4 g of dried sample (>63 μm fraction). Selected specimens were mounted on stubs using carbon conductive adhesive tape and gold-coated for examination by scanning electronic microscope (SEM) at the Servicio de Microscopía Electrónica del Museo de Ciencias Naturales de La Plata. The classification follows Loeblich and Tappan (1988) and Olsson et al. (1992).

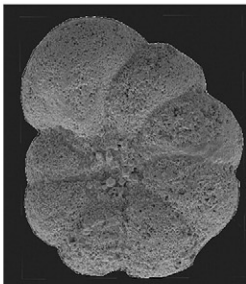
In this paper we concentrate on taxa with variable percentages of abnormal tests. These taxa include *Protelphidium* sp. (sample 5 of the Auca Mahuevo section) and *Protelphidium hofkeri* Haynes, 1956 (samples 19, 20, and 21 of the Cerro Azul section). In addition, rare planktic malformed tests occurred in the Cerro Azul section: a multiple test of *Parasubbotina pseudobulloides* (Plummer, 1926) in sample 2, and a few adult double tests of *Globoconusa daubjergensis* (Brönnimann, 1953) in samples 3 and 8. The figured specimens are deposited in the Museo de Ciencias Naturales de La Plata–Sección Micropaleontología (MLP-Mi 1628–1674).

4. Accompanying microfauna and paleoenvironment

4.1. Auca Mahuevo section

The microfossil assemblages include abundant *Protelphidium* sp. and less abundant hyaline forms such as *Patellina* and possible gavelinellids, porcellaneous forms as *Quinqueloculina* and agglutinated forms similar to *Ammobaculites*. Non-marine ostracod genera are abundant and include *Candona*, *Cypridopsis*, *Neuquenocypris* and *Paralimnocythere* (Carignano and Garrido, 2006). *Candona* Baird, *Cypridopsis* Brady, *Neuquenocypris* Musacchio and *Paralimnocythere* Carbonel tolerate fluctuations in salinity (Musacchio and Simeoni, 1991; Dias-Brito et al., 2001). The homogeneous mudstones

Plate I. *Protelphidium* sp., all specimens from the Auca Mahuevo section, sample 5, Neuquén Province, Argentina. Scale bar represents 0.050 mm. D = greatest spiral diameter. L = length. Measurements of specimens in mm. 1–2. Normal tests. 1. MLP-Mi 1628, lateral view, D = 0.300; 2. MLP-Mi 1630, apertural view, D = 0.280. 3–9. Abnormal tests, over-developed last chamber, variably extending onto one of the lateral sides of the test. 3. MLP-Mi 1632, lateral view, D = 0.350. 4. MLP-Mi 1633, lateral view, D = 0.325. 5. MLP-Mi 1634, apertural view, D = 0.290. 6. MLP-Mi 1636, lateral view, D = 0.375. 7. MLP-Mi 1640, apertural view, D = 0.440. 8. MLP-Mi 1641, lateral view, D = 0.335. 9. MLP-Mi 1644, lateral view, D = 0.275. 10–12. Abnormal tests, change of coiling plane (helicoidal tests). 10–11. MLP-Mi 1642, umbilical and spiral views, D = 0.470. 12. MLP-Mi 1650, lateral view, L = 0.220. 13. Abnormal test, protuberance near the proloculus, MLP-Mi 1645, lateral view, D = 0.310. 14–15. Abnormal test, protuberance near the proloculus and over-developed later chambers, MLP-Mi 1646, lateral views, D = 0.380. 16–18. Abnormal tests, double last chamber. 16. MLP-Mi 1647, lateral view, D = 0.250. 17. MLP-Mi 1648, lateral view, D = 0.285. 18. MLP-Mi 1649, lateral view, D = 0.260. 19–22. Abnormal tests, complex forms. 19. MLP-Mi 1651, L = 0.385. 20. MLP-Mi 1652, L = 0.350. 21. MLP-Mi 1653, D = 0.250. 22. MLP-Mi 1654, L = 0.250. 23. Multiple tests, MLP-Mi 1656, L = 0.260. 24–25. Abnormal tests, globular additional chamber, restored after damage. 24. MLP-Mi 1657, lateral view, L = 0.400. 25. MLP-Mi 1658, lateral view, L = 0.375.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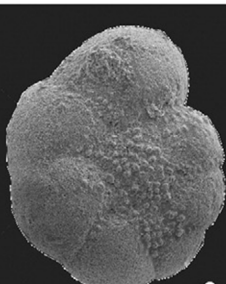
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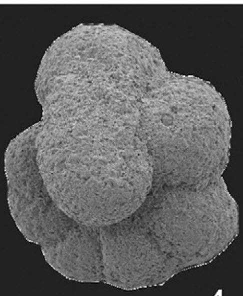
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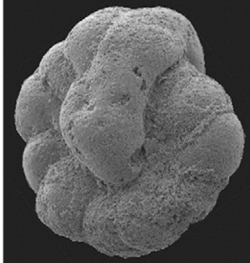
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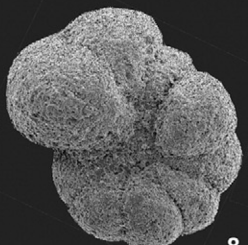
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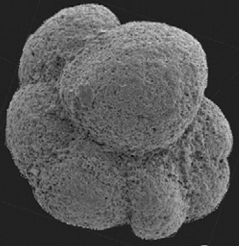
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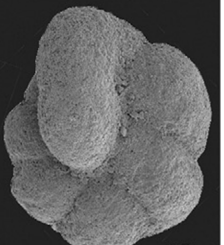
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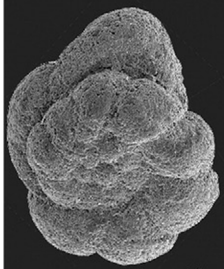
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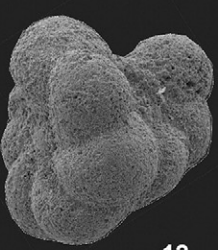
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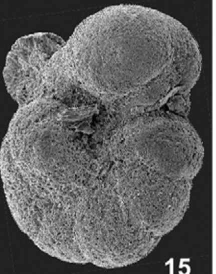
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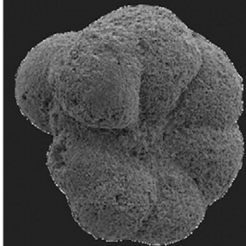
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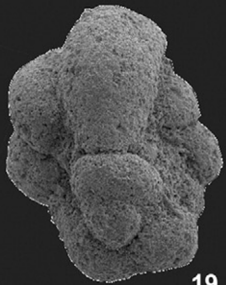
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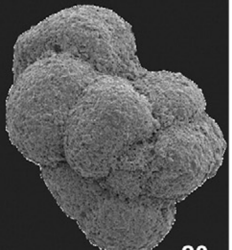
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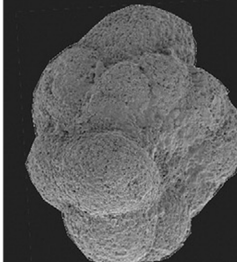
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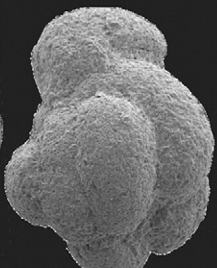
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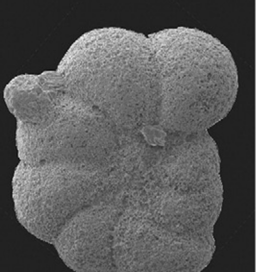
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Table 2
Cerro Azul section

Sample	Benthic specimens	*Protelphidium hofkeri*	Planktic specimens
21	8	1 (normal test)	–
20		total 170 (abnormal tests 38)	–
19	12	2 (abnormal tests)	–
18	245		1
17	31		–
14	86		4
12	38		9
11	109		3
10	203		35
9	358		188
8	116		109 (2 double tests)
6	168		29
4	340		47
3	139		21 (2 double tests)
2	142		31 (3 multiple tests)
B	167		45
1	294		75
A	340		69

Number of benthic, planktic and *Protelphidium hofkeri* specimens (normal and abnormal tests).

contain evaporite casts reflecting desiccation in very shallow waters (Barrio, 1990). The microfaunas are characterized by a mixture of marine and non-marine components, probably reflecting subtidal to intertidal environments in close proximity to a coast-line, with partially protected environments such as lagoons along an estuary (Carignano and Garrido, 2006).

4.2. Cerro Azul section

Bivalves (mainly oysters), gastropods, decapods, serpulids and corals, as well as ostracods, benthic and planktic foraminifers and calcareous nannofossils occur throughout the section (Parras et al., 2007). Towards the top of the section the fauna impoverishes with microfossils represented by monospecific assemblages of *P. hofkeri* Haynes with rare marine ostracods. The clays at the base of the section were deposited in an inner shelf to subtidal environment. The overlying bioclastic packstones, marls, sandstones, and heterolithic siltstones correspond to an intertidal environment. Towards the top, intercalated evaporites indicate supratidal deposits (Parras et al., 2007).

5. Results

5.1. Auca Mahuevo section

The test of *Protelphidium* sp. is stout, small (mean diameter 0.3–0.4 mm), hyaline, multilocular, biumbilicate planispiral and partially evolute, with a markedly lobulate peripheral outline. The primary aperture is a low, narrow, interiomarginal equatorial arch. Its wall is calcareous and perforate, and the surface is covered with small pustules in the umbilical areas and along the margins of the incised sutures, as well as on the lower part of the apertural face.

Abnormal tests (in sample 5, Table 1) reach nearly 74% of total specimens. The abnormalities correspond to the following six types with some specimens having more than one abnormality:

1. Abnormal size or shape of the last chambers, where usually the last chamber is too large or inflated and extends variably over one of the lateral sides of the test (Plate I, figs. 3–9).
2. Modification of the coiling plane, in which chambers are added in a helicoidal coil (trochospiral), so that the test has spiral and umbilical sides (Plate I, figs. 10–12).
3. Protuberances occur near the proloculus or on one or more chambers (Plate I, figs. 13–15).
4. Double last chamber (Plate I, figs. 16–18).
5. Complex forms in which the anomaly cannot be well determined. Some specimens show an unusual arrangement of the later chambers (Plate I, figs. 19–22) whereas in others (e.g. Plate I, fig. 23) the abnormal test might have resulted from the fusion of several embryonic or juvenile tests.
6. Deformations probably due to restoration after mechanical damage (Plate I, figs. 24–25).

5.2. Cerro Azul section

P. hofkeri Haynes has a hyaline, small, multilocular, planispiral partially evolute test, with a rounded periphery and relatively smooth peripheral outline. The surface is covered with tubercles on the lower part of the apertural face, on the earlier whorl adjacent to the aperture, in the umbilical areas and along the incised sutures. The primary aperture is a low interiomarginal arch, symmetrical with respect to the equatorial plane, but in part obscured by it's the surrounding tubercles.

Abnormal tests (in samples 19, 20, and 21, Table 2) reach near 22% of the total specimens. The abnormalities exist of an abnormal size or shape of one or more chambers, a too large last chamber and/or antepenultimate chamber, a reduced size of the last or earlier chambers resulting in an irregular outline (Plate II, figs. 4–8).

In addition, we recovered a few multiple tests of planktic species, including a multiple test of *P. pseudobulloides* (Plummer) (Plate II, fig. 14) in sample 2 (Table 2). The specimen comprises of three individuals joined at their lateral peripheral areas. The smallest individual is attached to the wall of the two larger specimens which are equal in size. The apertures are not in close association with one another.

In samples 3 and 8 (see Fig. 1 and Table 2), a few adult double tests of *Globoconusa daubjergensis* (Brönnimann) (Plate II, figs. 15 and 16) and *P. pseudobulloides* (Plummer) were found. The umbilical and spiral sides can be distinguished. Both tests are about equal in size and development, and joined by one of the chambers formed later than the proloculus.

6. Discussion

Boltovskoy et al., 1991 reviewed variation in morphology of benthic foraminiferal tests in response to changes in ecological parameters such as temperature, salinity, carbonate solubility, depth, nutrition, substrate, dissolved oxygen, illumination, pollution, water motion, concentrations of trace

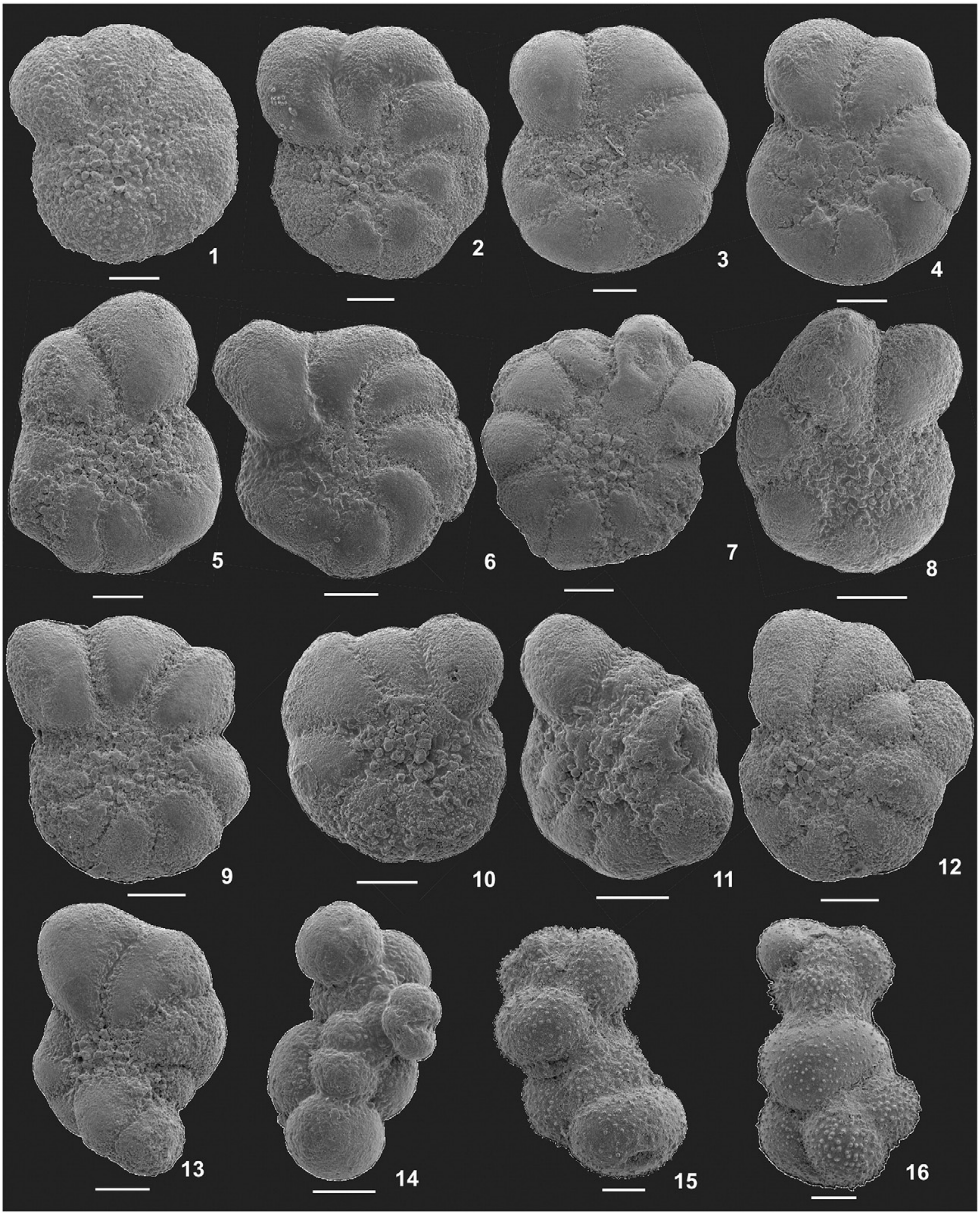

Plate II. Scale bar represents 0.050 mm. D = greatest spiral diameter. L = length. Measurements of specimens in mm. 1–13. *Protelphidium hofkeri* Haynes, all specimens from the Cerro Azul section, sample 20, Río Negro Province, Argentina. 1–3. Normal tests. 1. MLP-Mi 1659, lateral view, D=0.240. 2. MLP-Mi 1660, lateral view, D=0.275. 3. MLP-Mi 1661, lateral view, D=0.287. 4–8. Abnormal tests, uneven periphery. 4. MLP-Mi 1662, lateral view, D=0.300. 5. MLP-Mi 1663, lateral view, D=0.245. 6. MLP-Mi 1664, lateral view, D=0.270. 7. MLP-Mi 1667, lateral view, D=0.232. 8. MLP-Mi 1668, lateral view, D=0.200. 9–13. Abnormal tests, restored after damage? 9. MLP-Mi 1665, lateral view, D=0.230. 10. MLP-Mi 1666, lateral view, D=0.215. 11. MLP-Mi 1669, lateral view, D=0.190. 12. MLP-Mi 1670, lateral view, D=0.235. 13. MLP-Mi 1671, lateral view, L=0.245. 14. *Parasubbotina pseudobulloides* (Plummer), multiple tests, MLP-Mi 1672, L=0.235. 15–16. *Globoconusa daubjergensis* (Brönnimann), multiple tests. 15. MLP-Mi 1673, L=0.350. 16. MLP-Mi 1674, lateral view, L=0.310.

elements, and the occurrence of rapid environmental fluctuations. A more recent update can be found in Geslin et al., 2000.

In the present study, the most common abnormalities in *Protelphidium* sp. in the Auca Mahuevo section are: 1. an abnormal size or shape of the later chambers, where generally the last one is too large or over-inflated and extends over one of the sides of the test; and 2. modification of the coiling plane so that chambers are added in a helicoidal coil (trochospiral) and the test clearly has spiral and umbilical sides instead of being planispiral (Plate I, figs. 3–12).

Tests with abnormal size or shape of one or more chambers, and/or protuberances near the proloculus and irregular periphery have been reported as caused by environmental stress due to hyposalinity, hypersalinity or variations in salinity (Table 3).

The formation of a protuberance near the proluculus probably begins inside the asexual reproduction cyst, before the calcification of the young individuals. If only one whorl develops from one of the second chambers, a protuberance corresponding to the other one will remain on (or near) the proloculus. This kind of abnormality has been described as a "protuberant proloculus" or an "abnormally protruding chamber" (Stouff et al., 1999a, p. 197). We found a few specimens with this abnormality (see Plate I, fig. 13). When the formation of a double second chamber is followed by the development of two whorls, these develop generally synchronously and the two whorls usually show a similar number of chambers. Tests with two whorls are named "double tests". The specimen illustrated in Plate I, fig. 23, may be a "double test" or a juvenile test may be attached to a parental test after schizogony followed by the young's development (see below). Such double tests are very rare.

A distinctive feature of *Protelphidium* sp. is the markedly lobulate peripheral outline and the inflated last chambers. The formation of inflated or compressed chambers depends upon the environmental conditions under which foraminifers live (Wang and Lutze, 1986). Inflated chambers provide an equal volume for housing protoplasm while using less calcareous shell material than compressed chambers because an inflated chamber is closer to a sphere, the geometric body with the lowest surface-volume ratio. Compressed chambers are usually very similar to each other, but inflated chambers may vary considerably in shape and size. Overall, more marginally marine environments contain specimens with a higher percentage of inflated chambers, and more inflated specimens (Wang and Lutze, 1986).

Mechanical damage by strong wave or current action or by predators may be repaired by the organism. At the place of damage, the protoplasm immediately swells to fill the break and secretes material to heal the injury. The chambers built over the damaged spot are commonly thin-walled and inflated because fast restoration is necessary and (as said above) a sphere is the most economical shape to build (Wang and Lutze, 1986). Specimens illustrated in Plate I, figs. 24 and 25 (Auca Mahuevo section) and in Plate II, figs. 9–13 (Cerro Azul section) could be the result of regeneration after test damage. In both sections such deformed regenerated tests are rare.

In the Cerro Azul section, tests of *P. hofkeri* Haynes commonly have one or more chambers with abnormal size or shape resulting in a change in the shape of the periphery. Such changes have been explained as a result of growth during changes in salinity (Table 3). The chambers added during dry periods with a high salinity resulting from evaporation are smaller than those added during wet periods with lower salinity. The periods of hypersalinity may be marked by stagnation in test growth due to a less availability of the phytoplankton food source. Species formerly included in the genus *Protelphidium*, now included in *Haynesina* such as, *H. germanica* (Ehremberg) and *H. glabra* (He, Hu and K Wang) tend to form inflated, thinner-walled chambers late in ontogeny as response to environmental instability (cf. Wang and Lutze, 1986).

Abnormalities in foraminiferal tests in the present oceans have sometimes been attributed to eutrophication (Caralp, 1989; Alve, 1995) or to the presence of hydrocarbons. For instance, *Haynesina paralica* (Tintant) formed abnormally small chambers with an abnormal wall texture after an oil spill (Vénec-Peyré, 1984). An overabundance food supply may limit growth because it restricts pseudopodial activity and causes delay in the development (Boltovskoy et al., 1991). We find, however, no indications for eutrophication (e. g. high levels of organic matter) in the studied sections, and therefore do not think that eutrophication was implicated in the formation of the abnormal tests.

In conclusions, there is no doubt that hypersalinity, fluctuations in salinity and rapidly changing physical–chemical conditions perturb the growth and morphology of fora-

Table 3
Summary of the main abnormalities due to hyposalinity, hypersalinity and fluctuation of salinity reported in the literature

Reference	Area	Species	Observations	Causes of abnormalities
Boltovskoy (1957)	Río de La Plata	*Elphidium discoidale*	Irregular periphery	Fluctuation of salinity
Ayala-Castañares and Segura (1968)	Laguna Madre, Tamaulipas, eastern Mexico	*Ammonia–Elphidium*	Abnormal tests and abnormal hispid ornamentation	Hypersalinity
Sellier de Civrieux (1968)	Unare-Píritu lagoons, Venezuela	*Cribroelphidium poeyanum*	Irregular periphery	Fluctuation of salinity
Boltovskoy and Giussani de Kahn (1980)	Río de La Plata, Argentina	*Nonion? pseudotisburyense*	Abnormal tests (very large proloculus — few globular chambers)	Hyposalinity-fluctuation of salinity
Zabert (1984)	Northern Argentina (Miocene)	*Nonion demens* forma *santamariana*	Abnormal tests (very large proloculus — few globular chambers)	Hyposalinity-fluctuation of salinity
Almogi-Labin et al. (1992)	Dead Sea area, Israel	*Ammonia tepida*	Abnormal and multiple tests	Hypersalinity
Stouff et al. (1999b)	French Atlantic Coast	*Ammonia* sp.	Protuberance near the proloculus	Fluctuation of salinity
Debenay et al. (2001)	Araruama Lagoon, Rio de Janeiro, Brazil	*Ammonia tepida*	Abnormal, complex and multiple tests	Fluctuation of salinity

minifer tests. Geslin et al., 2002 (p. 163) explained that hypersalinity may induce an inhibition of polymerization and depolymerization processes in the microtubules, the most prominent components of the reticulopodial cytoskeleton (cf. Travis and Bowser, 1991) and responsible for cytoplasm movements. Events during chamber formation consist of emission and successive retraction of pseudopods (see the sequence of chamber formation in calcareous species in Le Calvez, 1938 and fig. 3 of Goldstein, 2002, p. 46). Consequently, hypersalinity, inhibiting or disturbing pseudopod emission may lead to the formation of chambers with a reduced size or an abnormal morphology. Accordingly, Stouff et al., 1999a (p. 201) suggested that hypersalinity inhibits or slows down the movements of the young and facilitates their fusion after schizogony, which results in the formation of double and multiple tests with complex abnormal forms.

Recent planktic twinned specimens have been briefly mentioned in Boltovskoy and Boltovskoy (1970) and Boltovskoy (1976) and fossil cases are figured and discussed in Boltovskoy and Wright (1976) and Boltovskoy (1982). Multiple tests could result from plastogamy, which is a type of sexual reproduction observed in several species of benthic foraminifers (Lee et al., 1991), but not in planktic foraminifers. These organisms appear to reproduce principally, if not solely, through sexual reproduction, where myriads of bi-flagellated gametes are released into the water (Lee et al., 1991, p. 312). Taking into account that at least 10^5 gametes are released from each parent cell (Bé and Anderson, 1976) it can be hypothesized that a zygote might remain in contact with one of its parents (cf. Boltovskoy, 1982). This author suggested that “perhaps owing to pseudopodia and, in some cases, to spines that prevented separation (*Globoconusa daubjergensis* is a spinose species) and by growth of the test material this contact was maintained so that the parent and its brood were “fused” (p. 80). During reproduction, additional calcite (known as gametogenic calcite) may be added (Lee et al., 1991). However, this explanation is unsatisfactory when the two participants of the twinned test are of the same size. Our specimens of twinned tests of *Globoconusa daubjergensis* are similar to those of *Paragloborotalia opima nana* (Bolli) -DSDP Site 360, East Atlantic, depth 2949 m, middle Oligocene—with both tests having the same size (Boltovskoy, 1982, Plate II, fig. 6), of uncertain origin.

We also do not have a specific explanation for the occurrence of the few multiple tests of *P. pseudobulloides* (Plummer) and *Globoconusa daubjergensis* (Brönnimann), possibly teratological specimens.

7. Conclusions

Morphological abnormalities are very common in Late Cretaceous and early Paleocene foraminifer tests from two localities in northern Patagonia, Argentina. Late Campanian–early Maastrichtian (Allen Formation, Auca Mahuevo section) abnormal tests of *Protelphidium* sp. constitute up to 74% of the total specimens, with several different types of deformation present, including abnormal size or shape of some chambers, a change in coiling from planispiral to trochospiral, protuberances near the proloculus, double chambers and complexly deformed individuals. Deformations probably due to restoration of damaged test are rare, but do occur. Abnormal tests of *P. hofkeri* Haynes from the Danian at the top of the Cerro Azul section reach near 22% of the total specimens, with most of them having one or more chambers of abnormal size or shape, thus an irregular outline. Sedimentological studies of both sections indicate that they were deposited relatively close to the coast, in marginally marine, fluctuating environments. We are considering fluctuations in salinity the most probable cause of the deformed chambers in benthic foraminiferal tests. Fluctuating salinity and hypersalinity may inhibit or disturb pseudopod function, thus leading to the formation of abnormal chambers. We do not know the cause of the occurrence of rare multiple tests in the planktic species *Globoconusa daubjergensis* (Brönnimann) and *P. pseudobulloides* (Plummer) in the lower part of the Cerro Azul section.

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