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JSE
RESEARCH PAPER

POSSIBLE FUNCTIONS OF BIOMINERALIZATION OF SOME TEXTULARIID (FORAMINIFERA) SPECIES OF THE NW IBERIAN MARGIN

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Abstract

The main goal of this work is to analyze the elemental composition of the test's wall of some species/specimens of Textulariids (sub-class Subclass Textulariia), collected in surface sediments of the NW Iberian Margin. The elemental analysis was based on the Energy Dispersive Spectroscopy (EDS) on the Scanning Electron Microscope (SEM; Hitachi, S4100) of *Textularia deltoidea, Textularia agglutinans, Sahulia conica, Karrerotextularia flintii, Siphotextularia heterostoma, Karreriella bradyi, Spiroplectammina sagittula* and *Arenoparrella mexicana*. The elemental concentrations of the species wall were compared with the mineralogical composition (X-Ray diffraction) of the sediments of the stations where these specimens were collected. The results evidence that whereas the test's wall of *T. deltoidea*, *T. agglutinans*, *K. flintii* and *S. heterostoma* is characterized by the highest concentrations of Ca, Mg and Y and lowest Si and Al contents; *S. conica, S. sagittula* and *K. bradyi* present intermediate concentrations of the referred variables but display the highest K content; *A. mexicana* contains the highest Si and Al contents and lowest Ca, Mg and Y concentrations. Some species that live in siliciclastic sediments contain high calcium content in their tests (such as *T. deltoidea* and *T. agglutinans*), whereas some species much common in the deep-sea display high concentrations of lithogenic elements. Results of this work suggest that some Textulariid species can use the test for "storage" and "excretion" of toxic or useless elements that can be used when necessary. These features seem to be functions of biomineralization of the

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analyzed species and not only the intention of building a protective envelope.

Keywords: Agglutinated foraminifera. Wall composition. Elemental analysis. SEM. EDS. Biomineralization.

1. Introduction

Benthic foraminifers inhabit a wide range of aquatic environments including open marine, brackish, and freshwater environments (Murray, 2006). Agglutinated foraminifera are benthic organisms with records in sedimentary strata since the Vendian, latest Pre-Cambrian (Gaucher and Sprechmann, 1999) to the Holocene age deposited in most marine and brackish environments (Sen Gupta, 1999). The term "agglutinated" refers to the tests formed by foreign particles that bounded together by organic, calcareous, siliceous, or ferruginous cement (Loeblich and Tappan, 1989). The sedimentary particles may include silt or sand grains, glauconite, sponge spicules, or even other foraminiferal tests (Loeblich and Tappan, 1987). Some species are highly selective in the material used and in its arrangement (Loeblich and Tappan, 1987). Agglutinated tests may be composed of very small particles cemented together and have a very smooth surface, or may be made of larger particles and have a rough surface.

Agglutinated foraminifera can be used in relative age determination but they are particularly valuable as paleoenvironmental indicators (Alve and Murray, 1995; Kaminski and Kuhnt, 1995). The ecology of this group in the deep sea includes for instance: mobile epifaunal forms such as the trochospiral forms and flat disk-shaped forms like *Paratrochammina* and *Discammina*; sessile suspension feeders such as the tubular forms like *Marsipella* and *Rhabdammina*; opportunistic taxa such as *Reophax, Psammosphaera* and *Textularia* in dysaerobic environments; deep infaunal microhabitats in severely dysaerobic environment like *Textularia* (Kaminski et al., 1995).

The marginal marine habitats, ranging from coastal marshes to inner parts of continental shelves, which are areas of high organic productivity and relatively high environmental variability, are populated by several species of agglutinated benthic foraminifera (Sen Gupta, 1999). For instance, species such as *Ammotium salsum, Arenoparrella mexicana, Entzia macrescens, Miliammina fusca, Tiphotrocha comprimata* and *Trochammina inflata* are in general found in typical coastal salt-marshes (Murray, 1991).

According to Margulis and Schwartz (1998), foraminifera can be included in a Phylum in which five Classes and one Subclass can be considered: Foraminifera incertae sedis, Globothalamea, Monothalamea and Tubothalamea. The Class Globothalamea includes the Orders: Carterinida, Robertinida and Rotaliida and the Subclass Textulariia.

Kaminski (2004) considered four orders in the Subclass Textulariia (here named Textulariids) based mainly on the morphology, wall structure, and cement composition. According to this author, the cement used to agglutinate the particles to form the test's wall may be organic (as in the Astrorhizida), calcareous and canaliculate (as in the Textulariida), or of mixed nature (as in the Lituolida and Loftusiida, which contains both organically-cemented, calcareous, and microgranular types). The organic cement occupying the intergranular space within the wall may be present in the form of strands, meshwork, or foam (Bender and Hemleben, 1988).

1.1 Aim of the research

The main goal of this work is to document the elemental composition of the test's wall of selected species of Textulariids collected in surface sediments of a siliciclastic continental margin, NW Iberian Margin. Textulariids species are quite common in the Iberian Continental Margin (Levy et al., 1993, 1995; Mendes et al., 2004; Martins et al., 2012a, 2015a). Their preferred microhabitat is commonly 0-0.5 cm, or the first or the first two centimeters below the surface of the sediment where the abundance of living organisms is maximal (Corliss, 1991). Sediment granulometry can greatly influence the distribution of species of textulariids (Arnold, 1983).

2. Material and methods

On the basis of Energy Dispersive Spectroscopy (EDS) on the Scanning Electron Microscope (SEM; Hitachi, S4100), this work analyses the elemental composition of selected specimens belonging to the Subclass Textulariia Mikhalevich, 1980 (according to Hayward, 2013):

Textularia deltoidea Reuss, 1850, *Textularia agglutinans* d'Orbigny, 1839, *Sahulia conica* (d'Orbigny, 1839), *Karrerotextularia flintii* (Cushman, 1911), *Siphotextularia heterostoma* (Fornasini, 1896), *Karreriella bradyi* (Cushman, 1911), *Spiroplectammina sagittula* (Defrance, 1824) and *Arenoparrella mexicana* (Kornfeld, 1931). The species taxonomy was based on Hayward (2013) also considering specific references cited along the text.

The analyzed specimens were collected in surface sediments long the NW Iberian Continental Margin

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between 0 and 2765 m water depth (coordinates in Appendix 1; Fig. 1).

The sedimentary mineralogy was also used in this work. The sedimentological data of the Aveiro continental shelf and slope (Stations 1-5, 8-10) were obtained by Martins et al. (2012a).

The sediments' mineralogy was determined by X-Ray diffraction techniques according to the procedures described by Martins et al. (2007).

The pore water sedimentary pH, and TOC values of Station 7 at the Ria de Aveiro, were based on Martins et al. (2015b).

The EDS on SEM analysis were performed in the Department of Materials Engineering (Universidade de Aveiro, Portugal). Four specimens of *T. deltoidea* collected in different localities were analyzed. The chemical composition of different parts of the test was also evaluated in one of the four analyzed specimens of *T. deltoidea* (Appendix 1).

Pearson correlations and R-mode cluster analyses (CA) using "Weighted pair group average method" and "1 Pearson r" based on the elemental composition of the analyzed specimens were performed.

The variables were logarithmically transformed [log (X+1)] before the analyses. The CA was carried out in Statistica 12.0 software.

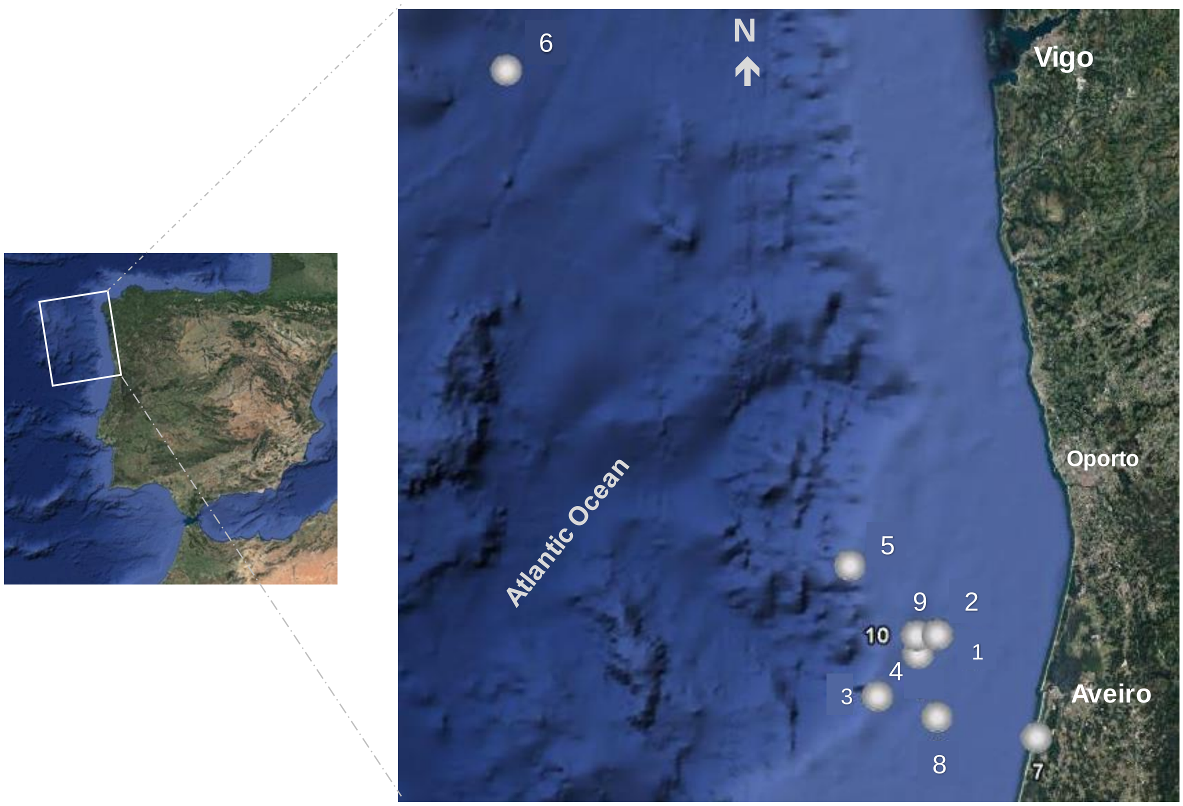

Fig. 1. Samples location from where the analyzed specimens were collected in surface sediments along the NW Iberian Continental Margin between 0 and 2765 m water depth. Adapted from Google Earth.

4. Results

3.1 Notes about the species taxonomy and morphology and results of EDS on SEM analyses

Phylum Foraminifera (d'Orbigny, 1826)
Class Globothalamea Pawlowski, Holzmann and Tyszka, 2013
Subclass Textulariia Mikhalevich, 1980
Order Textulariida (Delage and Hérouard, 1896)
Suborder Textulariina Delage and Hérouard, 1896
Superfamily Textularioidea Ehrenberg, 1838
Family Textulariidae Ehrenberg, 1838
Subfamily Textulariinae Ehrenberg, 1838
Genus *Textularia* Defrance, 1824

Textularia deltoidea **Reuss, 1850**

(Figs. 2, 3)

1850 *Textularia deltoidea* Reuss; p. 381, pl. 49, fig. 4.
1995 *Textularia deltoidea* Reuss; Levy et al., p. 20, pl. 3, fig. 6.

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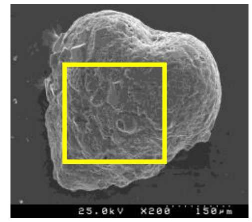
Morphological description

The biserial test with a delta shape has the lateral margin compressed and a greater thickness in its central zone. Its initial extremity is acute and triangular whereas more dilated in the oral portion. Chambers separated by horizontal sutures are generally sub-arched. The last two chambers, more inflated, show a less compressed outline. The aperture is a slit at the base of the oral face.

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===============================   ===============================
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                     *** PUzaf results ***
elem/line____P/B_____B_______F_________c______c(100%)__%error__h_
Fe K-alpha     3.9  1.03555 1.04113    0.42      1.09     75.5
Mg K-ser    @  1.1  1.00297 1.01129    0.20      0.51    209.1  <
Al K-ser    @  2.0  1.00638 1.02035    0.32      0.83     89.5
Y  L-ser    @  0.2  1.01152 1.05852    0.03      0.08    728.1  <
Si K-ser    @  7.2  1.00952 1.03349    1.01      2.62     26.9
K  K-alpha     3.8  1.02239 1.35677    0.32      0.84     49.5  *
Ca K-alpha   336.7  1.02455 1.00823   36.31     94.05      9.4
-----------------------------------------------------------------
standardless                          38.61    100.00     [2s]
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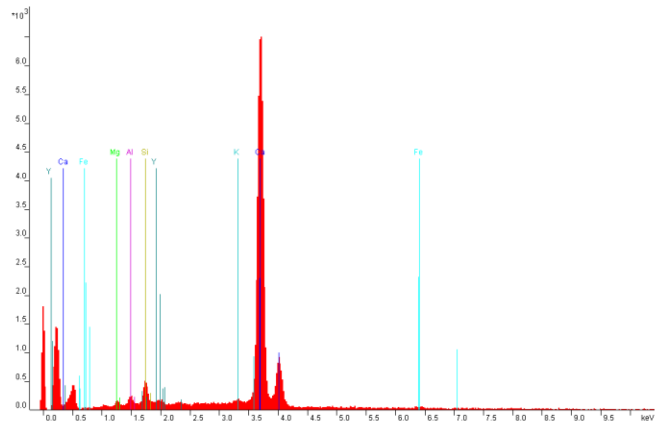
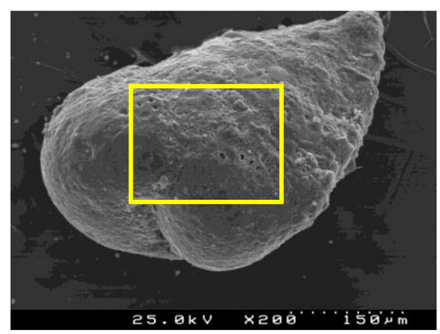


Specimen 1

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                     *** PUzaf results ***
elem/line____P/B_____B_______F_________c______c(100%)__%error__h_
Fe K-alpha    13.8  1.03492 1.04226    1.43      2.87     37.5
Mg K-ser    @ 17.0  1.00292 1.00971    3.01      6.03     24.9
Al K-ser    @  5.9  1.00627 1.01695    0.94      1.89     39.0
Y  L-ser    @  1.6  1.01132 1.04490    0.32      0.64    184.4  <
Si K-ser    @ 20.5  1.00936 1.02550    2.81      5.63     18.5
K  K-alpha    10.7  1.02200 1.25794    0.95      1.91     26.9  *
Ca K-alpha   385.0  1.02412 1.00951   40.37     81.02     10.1
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standardless                          49.83    100.00     [2s]
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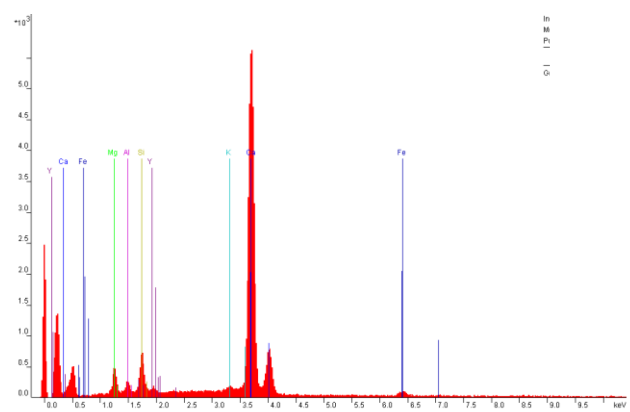

Specimen 2

Fig. 2. Results of the EDS Analysis on the SEM of the general elemental composition of the test of *Textularia deltoidea.*

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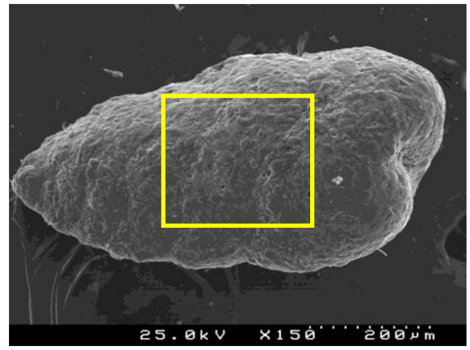


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                    *** PUzaf results ***
elem/line____P/B______B_______F________c______c(100%)__%error__h_
Fe K-alpha     7.9  1.03507 1.04251    0.83      1.79     43.8
Mg K-ser    @  5.1  1.00293 1.01064    0.91      1.98     42.4
Al K-ser    @  4.2  1.00629 1.01879    0.68      1.47     40.1
Y  L-ser    @  1.7  1.01136 1.04570    0.36      0.78    169.4  <
Si K-ser    @ 28.8  1.00940 1.02622    3.97      8.61     14.2
S  K-ser    @  2.7  1.01496 1.07017    0.30      0.65    100.7  <
K  K-alpha     6.6  1.02209 1.26503    0.59      1.27     32.3  *
Ca K-alpha   364.3  1.02422 1.00892   38.50     83.45      9.7
----------------------------------------------------------------
standardless                          46.14    100.00     [2s]
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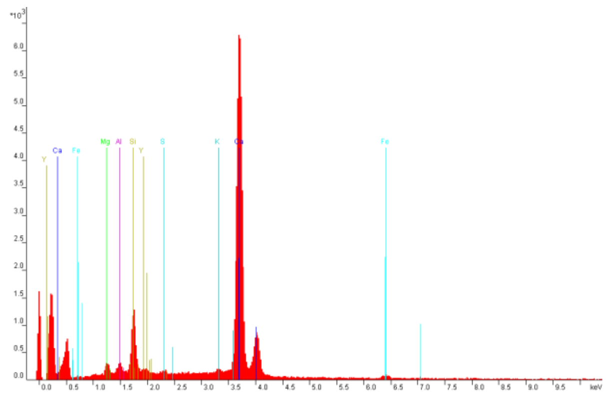
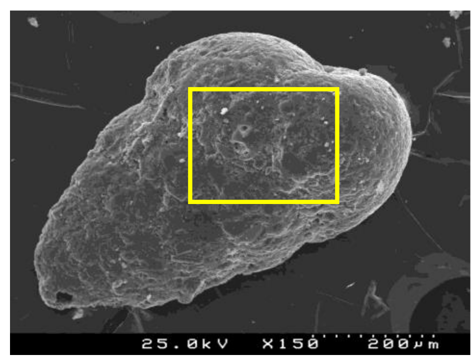


Specimen 3

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                    *** PUzaf results ***
elem/line____P/B______B_______F________c______c(100%)__%error__h_
Fe K-alpha     3.3  1.03481 1.04212    0.34      2.52    137.5  <
Mg K-ser       2.0  1.00291 1.01110    0.36      2.66     89.2
Al K-ser       2.2  1.00625 1.01917    0.35      2.59     82.9
Si K-ser       8.7  1.00933 1.02710    1.18      8.73     35.9
K  K-alpha    -4.2  1.02193 1.29252    0.00      0.01      3.1  *
Ca K-alpha   108.1  1.02404 1.00928   11.32     83.50     14.3
----------------------------------------------------------------
standardless                          13.56    100.00     [2s]
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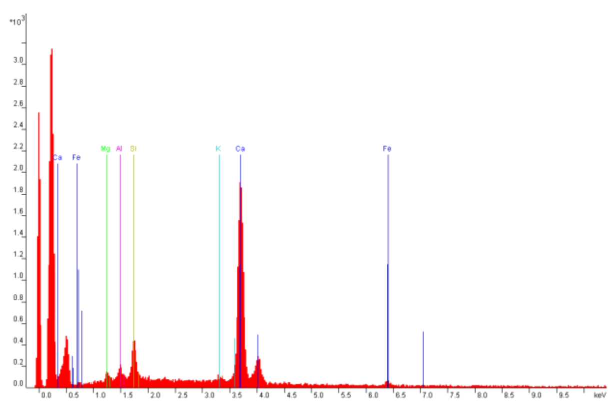

Specimen 4

Fig. 2. (cont) Results of the EDS Analysis on the SEM of the general elemental composition of the test of *Textularia deltoidea*

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      version: 3.1 eng             Eo:25.0 keV   (TO:35.0   TI:28.0)

                    *** PUzaf results ***
elem/line___P/B______B_______F________c______c(100%)__%error__h_
Fe K-alpha   14.5  1.03369 1.04355    1.44     3.75     31.5
Mg K-ser     51.7  1.00282 1.00772    8.88    23.13     13.0  *
Si K-ser      1.0  1.00902 1.02435    0.13     0.35    131.6  <
Ca K-alpha  277.9  1.02327 1.01051   27.93    72.77     10.9
----------------------------------------------------------------
standardless                          38.38   100.00     [2s]
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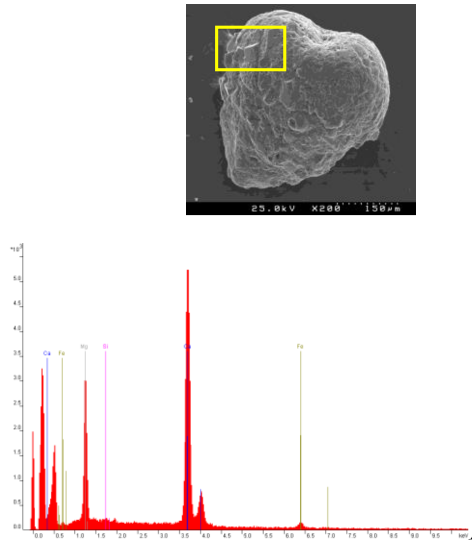

A

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RESULT REPORT        X-RAY SPECTROMETRY WITH RONTEC WinTools
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                    *** PUzaf results ***
elem/line___P/B______B_______F________c______c(100%)__%error__h_
Fe K-alpha    4.8  1.03566 1.04080    0.52     1.30     78.5
Al K-ser      1.8  1.00640 1.02127    0.30     0.76     85.1
Si K-ser      5.5  1.00955 1.03565    0.77     1.95     37.1
P  K-ser     -0.8  1.01248 1.06082    0.00     0.00      3.1  <
Ca K-alpha  352.2  1.02463 1.00827   38.20    96.00     10.9
----------------------------------------------------------------
standardless                          39.79   100.00     [2s]
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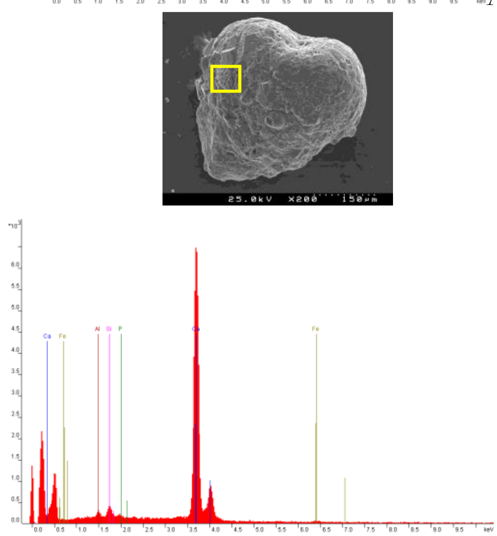

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                    *** PUzaf results ***
elem/line___P/B______B_______F________c______c(100%)__%error__h_
Y  L-ser    -16.7  1.01159 1.06742    0.00     0.00      2.9  <
Ca K-alpha  455.8  1.02471 1.00763   49.61   100.00     12.2
----------------------------------------------------------------
standardless                          49.61   100.00     [2s]
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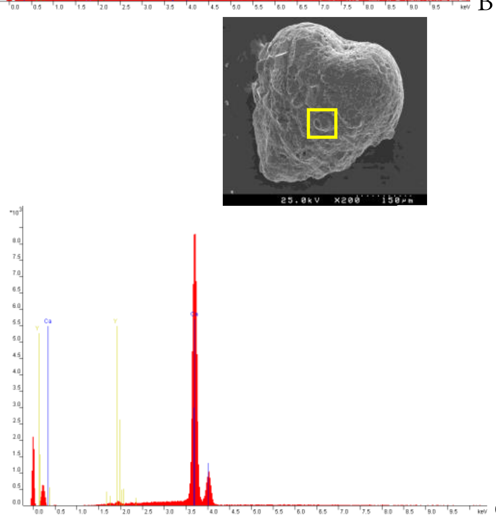

C

Fig. 3. Results of the EDS Analysis on the SEM of different particles included in the test of specimen 1 of *T. deltoidea*. A – cubes; B – a carbonated perforated particle (perhaps a bioclast); C – A pore surrounded by an elevation of the text similar to a volcano-like shape.

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EDS Analysis on the SEM

The results of the analysis of the elemental composition of four different specimens of *T. deltoidea* are presented in Figure 2 and Appendix 1. Maximum, minimum and mean values were included in Table 1. The results for the overall composition of the test's wall of these species indicate that the most abundant elements are Ca (80-95%) and Si (<10%). The test's wall also includes other elements such as Mg (mean 3%), Fe (mean 2%), Al (mean 2%), K (mean 1%) and sometimes Y (<1%) and S (<1%).

The results presented in Figure 3 evidence considerable differences in elemental concentrations in selected particles of the wall of the specimen 1 of *T. deltoidea*. In Figure 3A, the elemental composition of a particle with a cube shape is composed essentially by Ca (72.77%), Mg (23.13%) and reduced concentrations of Fe (3.75%) and Si (0.35%). In Figure 3B a carbonated perforated particle (bioclast perhaps from a carbonated foraminifera) is essentially composed of Ca (96.00%) with minor contributions of Si (1.95%) and Fe (1.30%). In Figure 3C, a pore surrounded by an elevation of the test with a volcano shape is composed only by Ca (100%). In this specimen, several similar structures to that one were observed.

Tab. 1. Maximum, minimum and mean values of the elemental composition of four different specimens of *T. deltoidea*.

Elements	Max	Min	Mean
Ca (%)	94.05	81.02	85.50
Si (%)	8.73	2.62	6.40
Fe (%)	2.87	1.09	2.10
Al (%)	2.59	0.83	1.70
Mg (%)	6.03	0.51	2.80
K (%)	1.91	0.01	1.00
Y (%)	0.78	0.08	0.50

***Textularia agglutinans* d'Orbigny, 1839**

(Fig. 4A)

1839 *Textularia agglutinans* d'Orbigny, p. 144, pl. 1, Figs. 17-18, 32-34.
1899 *Textularia agglutinans* d' Orbigny, Flint, p.284, pl. 29, Fig. 1.
2015 *Textularia agglutinans* d'Orbigny, Merkado et al., pp. 1-21.

Morphological description

Test biserial, elongated, conical, pointed in the initial portion and laterally convex. The wall is agglutinated, rough, and whitish. The chambers become more inflated as they are added, sutures are sometimes not clearly visible due to the irregular agglutinated materials. The aperture has a low archshape.

EDS Analysis on the SEM

The general composition of *T. agglutinans* (Fig. 4A, Appendix 1), evidences that the wall of the analyzed specimens is mainly composed of Ca (85%), also including a small proportion of Si (≈5%), K (≈5%), Al (≈3%), K (≈2%) and Mg (≈1%).

Genus *Sahulia* Loeblich and Tappan, 1985

***Sahulia conica* (d'Orbigny, 1839)**

(Fig. 4B)

1839 *Textularia conica* d'Orbigny, p. 143, pl. 1, Figs. 19-20.
1986 *Textularia conica* d'Orbigny; Mathieu, p. 230, pl. 2, Fig. 3.
1995 *Textularia conica* d'Orbigny; Levy et al., p. 20, pl. 3, Fig. 5.
1995 *Textularia conica* d'Orbigny; Yassini and Jones, p. 75, Figs. 101, 109.
1998 *Textularia conica* d'Orbigny; Robertson, p. 30, pl. 5, Fig. 3.
2012 *Textularia conica* d'Orbigny; Debenay, p. 96.

Morphological description:

Test biserial, conical, commonly wider than high, slightly compressed. In cross-section, there is an oval shape and a triangular longitudinal contour with the apex bluntly pointed. The width of the oral face is greater than the length of the test. The thickest zone is in the middle region, rapidly tapering towards the periphery. Its wide and low chambers are not clear; the sutures slightly arched, nearly horizontal, are in general undistinguishable. The wall is agglutinated and shiny consisting of grains of several sizes. The aperture, a nearly straight slit, with a distinct flaplike lip bordering the opening, is located at the inner base of the apertural face, of the last chamber.

EDS Analysis on the SEM

The general composition of the test's wall of *S. conica* (Fig. 4B) includes mostly Si (34.91%), Ca (26.76%), K (23.03%) and a small proportion of Al (7.84%), Mg (4.04%), S (2.03%) and (Fe 1,37%).

Subfamily Siphotextulariinae Loeblich and Tappan, 1985
Genus *Karrerotextularia* Le Calvez, de Klasz and Brun, 1974

***Karrerotextularia flintii* (Cushman, 1911)**

(Fig. 5A)

1911 *Textularia flintii* Cushman, p. 21, text-fig. 36.
1988 *Siphotextularia flintii* (Cushman); Zheng, p. 125; pl. 35; figs 1-2.
1995 *Siphotextularia flintii* (Cushman); Levy et al., p. 21-22, pl.3, fig. 2.
2012 *Siphotextularia flintii* (Cushman); Debenay, p. 93.

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doi: 10.12957/jse.2016.26888


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RESULT REPORT          X-RAY SPECTROMETRY WITH RONTEC WinTools
Institution:
Operator:
Customer:
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===============================   ===============================
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                       *** PUzaf results ***
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Fe K-alpha    21.7  1.03540 1.04053    2.29      4.57     23.8
Mg K-ser   @  2.6  1.00296 1.01049    0.46      0.92    119.3  <
Al K-ser   @  9.0  1.00635 1.01792    1.45      2.88     29.8
Y  L-ser   @  0.0  1.01147 1.04976    0.00      0.00    999.0  <
Si K-ser   @ 17.0  1.00948 1.02785    2.36      4.70     16.7
K  K-alpha     9.1  1.02230 1.29066    0.80      1.60     22.3  *
Ca K-alpha  402.3  1.02445 1.01004   42.86     85.34      8.5
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standardless                          50.22    100.00      [2s]
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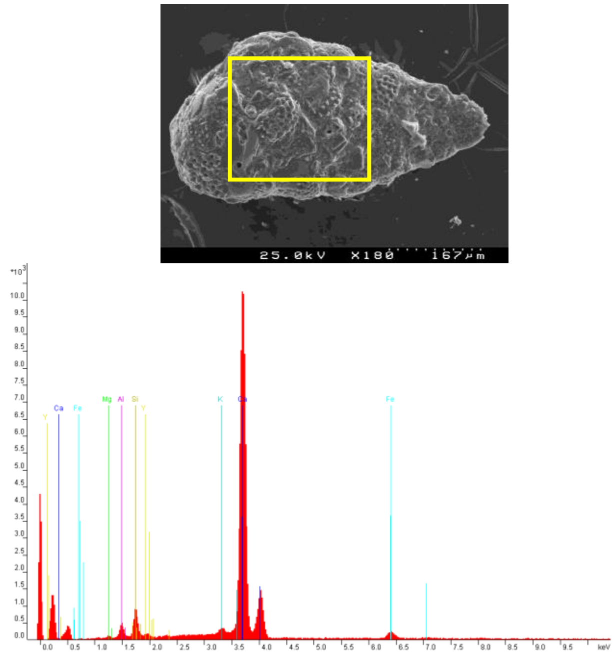

A

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RESULT REPORT          X-RAY SPECTROMETRY WITH RONTEC WinTools
Institution:
Operator:
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===============================   ===============================
      version: 3.1 eng             Eo:25.0 keV  (TO:35.0  TI:-18.0)


                       *** PUzaf results ***
elem/line____P/B______B_______F________c______c(100%)__%error__h_
Fe K-alpha     6.2  1.03167 1.05237    0.56      1.37     71.2
Mg K-ser      10.6  1.00265 1.01481    1.66      4.04     42.2  *
Al K-ser      22.9  1.00568 1.02222    3.22      7.84     31.7  *
Si K-ser     116.6  1.00848 1.01124   14.35     34.91     23.4  *
S  K-ser       8.3  1.01351 1.02863    0.84      2.03     50.0  *
K  K-alpha    99.9  1.01995 1.04431    9.47     23.03     15.9
Ca K-alpha   118.9  1.02187 1.01094   11.00     26.76     13.7
-----------------------------------------------------------------
standardless                          41.11    100.00      [2s]
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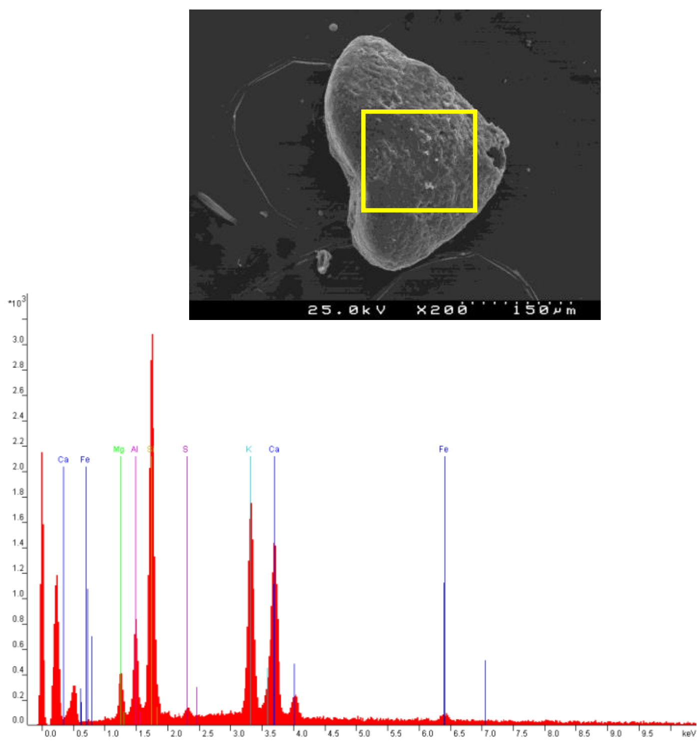

B

Fig. 4. Results of the EDS Analysis on the SEM of the general composition of the test of: A. *Textularia agglutinans;* B. *Sabulia conica.*

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Morphological description:

Test biserial, triangular in front view, irregularly rhombic in end view, rapidly increasing in size from the early portion, rather thick, but somewhat laterally compressed, chambers numerous, low and broad, inflated, separated by curved sutures; wall composed by fine and coarser grained particles. The aperture is a wide elongated slit slightly above the inner base of the chamber, with a slightly raised lip. Length about 1 mm.

EDS Analysis on the SEM

The general composition of the test's wall of *K. flintii* (Fig. 5A) is essentially composed of Ca (81.05%) and Si (8.8%) and small proportion of Fe (2.29%), K (2.19%), Y (2.13%), Al (2.06%), Na (0.97%) and Mg (0.42%).

Genus Siphotextularia Finlay, 1939

***Siphotextularia heterostoma* (Fornasini, 1896)**

(Fig. 5B)

1896 *Textularia heterostoma* Fornasini, p. 2, figs. 7-9.
1988 *Siphotextularia heterostoma* (Fornasini); Zheng, p. 126; pl. 38, fig. 4.
1994 *Siphotextularia heterostoma* (Fornasini); Loeblich and Tappan, p. 31; pl. 40, figs 17-18.
2012 *Siphotextularia heterostoma* (Fornasini); Debenay, p. 94.

Morphological description:

Test biserial, elongated, laterally compressed, triangular in lateral view, with rounded edges; chambers increasing progressively as they are added; sutures distinct, oblique; the wall has perforations and includes fine grained material and coarser one; the aperture areal is an elliptical slit at the end of an everted neck in the last chamber.

EDS Analysis on the SEM

The general composition of the test's wall of *S. heterostoma* (Fig. 5B) contains mostly Ca (92.77%) and small proportion of Si (2.63%), Na (1.68%), Al (1.16%), K (1.06%), Y (0.48%) and Mg (0.22%).

Superfamily Eggerelloidea Cushman, 1937
Family Eggerellidae Cushman, 1937
Subfamily Eggerellinae Cushman, 1937
Genus *Karreriella* Cushman, 1933

***Karreriella bradyi* (Cushman, 1911)**

(Fig. 6A)

1911 *Gaudryina bradyi* Cushman; p. 67, pl. 67, Fig. 107 a-c
1937 *Karreriella bradyi* (Cushman); Cushman, p. 135; pl. 16, figs 6-11.
1988 *Karreriella bradyi* (Cushman); Zheng, p. 94; pl. 45, fig. 10; pl. 46, fig. 1.
1994 *Karreriella bradyi* (Cushman); Loeblich and Tappan, p. 25; pl. 30, figs 8-16.
1990 *Karreriella bradyi* (Cushman); Sprovieri and Hasegawa, p. 455, pl. 1, Figs. 9-10.
1994 *Karreriella bradyi* (Cushman); Jones, p. 50, pl. 46, Figs. 1-4.
1998 *Karreriella bradyi* (Cushman); Robertson, p. 26, pl. 4, Fig. 1.

Morphological description:

The stout test initially presents a trochospiral winding, becoming triserial and later biserial. The biserial portion comprises the major part of the test total length. The test with an elongated longitudinal axis has a cylindrical, oval or subcircular cross-contour. The relatively large inflated chambers gradually increase in size as they are added. The sutures are depressed and sharp. The finely agglutinated wall has a smooth appearance and is perforated, displaying small pores. The aperture areal, composed by a slit situated at the base of the last chamber, is surrounded by a distinct lip.

EDS Analysis on the SEM

The general composition of the test's wall of *K. bradyi* (Fig. 6A) encompasses mainly Ca (63.96%) Si (22.60%) and Al (4.51%) and small proportion of K (3.11%), Na (2.28%), Mg (1.78%), S (1.18%) and Fe (0.58%).

Order Lituolida Lankester, 1885
Suborder Spiroplectamminina Mikhalevich, 1992
Superfamily Spiroplectamminoidea Cushman, 1927
Family Spiroplectamminidae Cushman, 1927
Subfamily Spiroplectammininae Cushman, 1927
Genus Spiroplectammina Cushman, 1927

***Spiroplectammina sagittula* (Defrance, 1824)**

(Fig. 6B)

1824 *Textularia sagittula* Defrance; p. 177, fig. 2.
1987 *Textularia sagittula* Defrance; Jörissen, p. 46, pl. 3, fig. 12.
1994 *Spiroplectinella wrightii* (Silvestri); Jones, p. 47, pl. 42, figs. 17-18.
1995 *Textularia sagittula* Defrance; Yassini and Jones, p. 76, figs. 105-108.

Morphological description:

The test is elongate, with an early planispiral coil of few chambers followed by biserially arranged chambers; the chambers are distributed in opposite pairs, gradually increasing in size. The chambers are numerous, longer than high, presenting defined sutures, slightly depressed and horizontally arranged. The test is compressed, with subangular borders and the maximum thickness located in the median region. The aperture in the form of a small interiomarginal arch, without lip, extends along the sutural line separating the last two chambers. The agglutinated wall integrates grains of different sizes and very fine material.

EDS Analysis on the SEM

The general composition of the test's wall of *S. sagittula* (Fig. 6B) comprises mostly Ca (63.96%) Si (22.60%) and Al (4.51%) and small proportion of K (3.11%), Na (2.28%), Mg (1.78%), S (1.18%) and Fe (0.58%).

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Operator:
Customer:
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Fe K-alpha   11.1  1.03543 1.04278    1.17      2.29     42.6
Na K-ser   @  2.3  0.99926 1.00552    0.49      0.97    175.7  <
Mg K-ser   @  1.2  1.00296 1.01031    0.22      0.42    203.6  <
Al K-ser   @  6.5  1.00636 1.01787    1.05      2.06     34.6
Y  L-ser   @  5.2  1.01148 1.04095    1.08      2.13     84.7
Si K-ser   @ 32.5  1.00949 1.02439    4.52      8.89     14.6
K  K-alpha   12.1  1.02232 1.23302    1.11      2.19     25.0  *
Ca K-alpha  387.8  1.02447 1.00926   41.24     81.05     10.0
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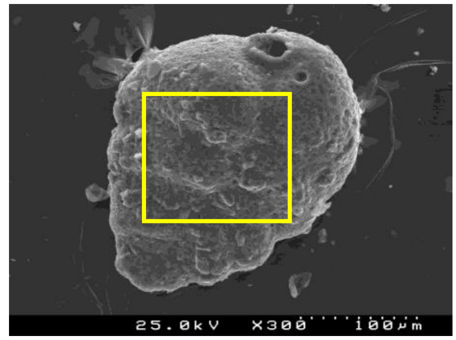

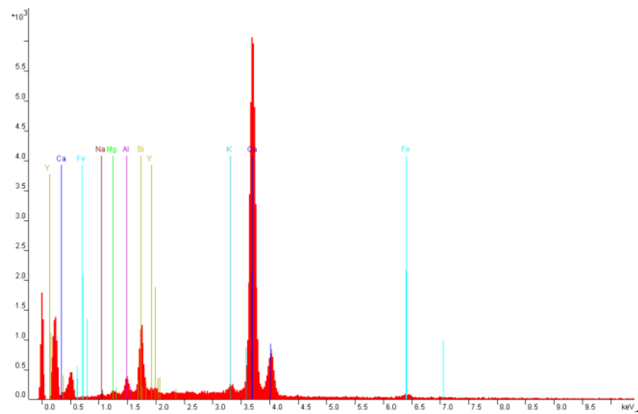

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RESULT REPORT          X-RAY SPECTROMETRY WITH RONTEC WinTools
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                    *** PUzaf results ***
elem/line____P/B_____B_______F________c______c(100%)__%error__h_
Na K-ser   @  3.4  0.99926 1.00587    0.74      1.68     61.0
Mg K-ser   @  0.5  1.00296 1.01108    0.10      0.22    281.1  <
Al K-ser   @  3.1  1.00635 1.01979    0.51      1.16     57.4
Y  L-ser   @  1.0  1.01146 1.05616    0.21      0.48    199.1  <
Si K-ser   @  8.3  1.00947 1.03246    1.15      2.63     25.0
K  K-alpha    5.5  1.02228 1.33975    0.47      1.06     39.6  *
Ca K-alpha  379.7  1.02442 1.00783   40.72     92.77      9.3
-----------------------------------------------------------------
standardless                         43.89    100.00     [2s]
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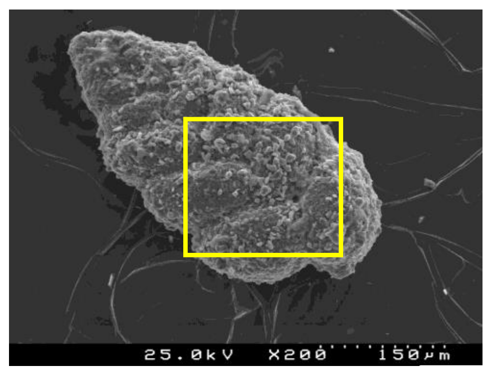

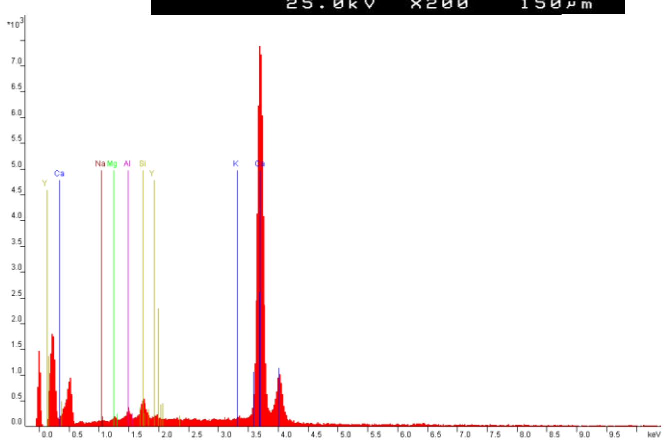

B

Fig. 5. Results of the EDS Analysis on the SEM of the general composition of the test of: A. *Siphotextularia flintii;* B. *Siphotextularia heterostoma*.

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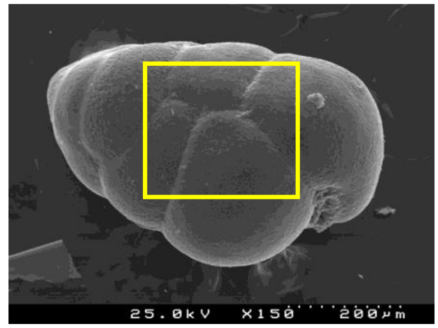
doi: 10.12957/jse.2016.26888

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                    *** PUzaf results ***
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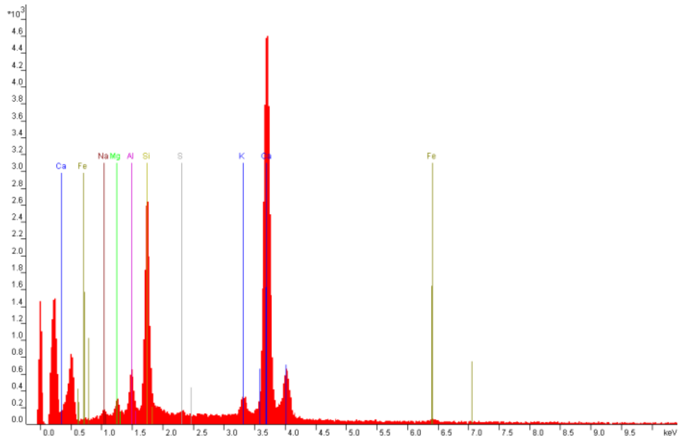
elem/line	P/B	B	F	c	c(100%)	%error	h
Fe K-alpha	2.5	1.03315	1.04684	0.24	0.58	123.7	<
Na K-ser	4.8	0.99931	1.00672	0.95	2.28	45.7	*
Mg K-ser	4.5	1.00277	1.01219	0.74	1.78	44.1	*
Al K-ser	12.6	1.00595	1.01990	1.89	4.51	25.7	*
Si K-ser	72.5	1.00888	1.01735	9.46	22.60	16.1	*
S K-ser	4.7	1.01414	1.04647	0.50	1.18	68.4	
K K-alpha	14.4	1.02088	1.16638	1.30	3.11	25.4	
Ca K-alpha	271.0	1.02290	1.00913	26.77	63.96	11.4	
standardless				41.86	100.00	[2s]	



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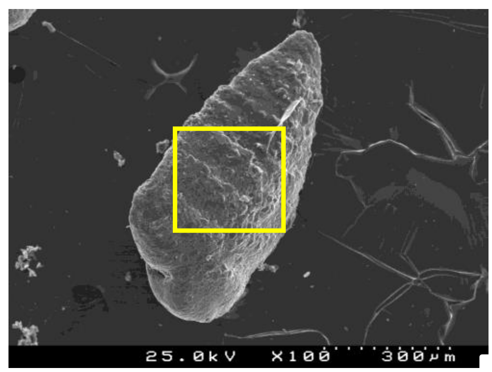


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                    *** PUzaf results ***
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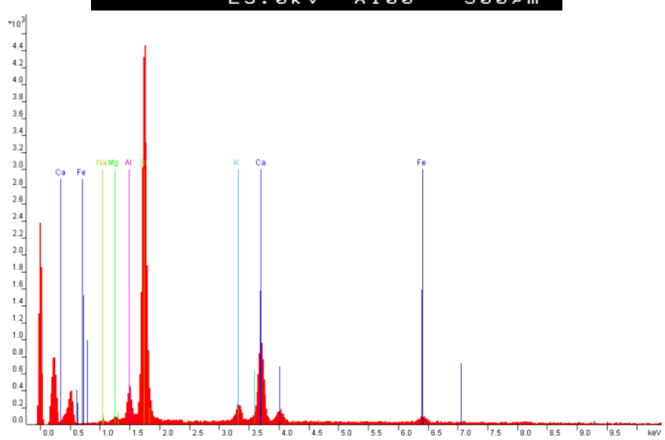
elem/line	P/B	B	F	c	c(100%)	%error	h
Fe K-alpha	12.5	1.03051	1.05686	1.08	3.06	42.9	
Na K-ser	1.7	0.99937	1.01202	0.31	0.88	120.6	<
Mg K-ser	-0.9	1.00255	1.02317	0.00	0.00	17.2	<
Al K-ser	12.7	1.00548	1.03897	1.69	4.78	38.7	*
Si K-ser	188.5	1.00817	1.00633	22.41	63.26	25.4	*
K K-alpha	17.9	1.01922	1.05169	1.62	4.56	26.4	
Ca K-alpha	93.8	1.02107	1.01389	8.31	23.45	15.4	
standardless				35.42	100.00	[2s]	



B

Fig. 6. Results of the EDS Analysis on the SEM of the general composition of the test of: A. *Karreriella bradyi;* B. *Spiroplectammina sagittula*

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Suborder Trochamminina Saidova, 1981
Superfamily Trochamminoidea Schwager, 1877
Family Trochamminidae Schwager, 1877
Subfamily Arenoparellinae Saidova, 1981
Genus *Arenoparrella* Andersen, 1951

***Arenoparrella mexicana* (Kornfeld, 1931)**
(Fig. 7)

1931 *Trochammina inflata* (Montagu) var. *mexicana* Kornfeld, p. 86; pl. 13, figs 5a, c.
1992 *Arenoparrella mexicana* (Kornfeld); Brönnimann et al., p. 20; pl. 1, figs 8-10; pl. 13, figs 1-6.
2012 *Arenoparrella mexicana* (Kornfeld); Debenay, p. 76

Morphological description:

Test trochoid, with a very low trochospira, periphery rounded. Test composed of about three whorls; the last formed coil consisting of five or six chambers; all chambers are visible from the dorsal side, sutures radiate, slightly depressed, nearly straight. Wall finely agglutinated, surface smooth; primary aperture a straight to curved slit surrounded by a thin and delicate lip, begin near the base of the apertural face and is directed upward across the median plane with an angle to the plane of coiling; supplementary openings are present in the final chamber.

EDS Analysis on the SEM

The composition of the test's wall of *A. mexicana* (Fig. 7) includes mostly Si (77.15%), Al (10.60%) and K (7.84%) and small proportions of Ca (1.58%), Fe (1.17%), Na (0.92%) and Mg (0.75%).

3.2 Statistical results

Results of Pearson correlations between the elemental composition of the analyzed specimens are included in Table 2. This table shows, for instance, that: i) A. *mexicana* and *S. conica* have the lowest correlations with most of the other species; ii) *T. agglutinans, K. flintii, S. heterostoma* and *K. bradyi* have high significant positive correlation with the analyzed specimens of *T. deltoidea* and iii) the four analyzed specimens of *T. deltoidea* have strong significant positive correlations among each other.

The CA dendrogram is reported in Figure 8. Based on these results and Pearson correlations, three groups of species can be identified: Group I (*T. deltoidea, T. agglutinans, K. flintii* and *S. heterostoma),* Group II (S. *conica, S. sagittula and K. bradyi*) and Group III (*A. mexicana*).

4. Discussion

4.1 Ecology and distribution and test composition of the analyzed species and specimens

4.1.1 *Textularia deltoidea*

This species occurs in all regions and at all depths of the Iberian Continental shelf, with a frequency <4% (Levy et al., 1995) such as in the external sector of the Ria de Vigo, NW Spain, at 39 m (core KSGX 24; Martins et al., 2013); in the Muddy Deposit of Galicia, at 115 m (core KSGX 40; Martins et al., 2006; 2007); in the continental slope of Galicia, at 2,000 m, in the core PE 109-13 (Martins and Gomes, 2004), at the Muddy Deposit of Douro, N of Portugal, at 87 m (core W90; Martins et al., 2012b); in the W Portuguese continental shelf was identified between 40-190 m with a relative abundance <2% (Martins et al., 2012a, 2015a) as well as, in the Gulf of Cadiz, off the Guadiana River, Algarve, it is present in all sectors (<2%) of the continental shelf (Mendes et al., 2004). *Textularia deltoidea* was observed in all regions of the Moroccan continental shelf, being more abundant between 25-150 m. In this zone, it is slightly influenced by the granulometry of the sediment and is associated to salinity (35.9-36.2) and to temperatures of 13-16 ºC (Mathieu, 1986).

The elemental composition indicates that this species builds its test using manly carbonated materials (Figs. 2, 3). The particles added to the wall seems to include cubes of dolomite [$CaMg(CO_3)_2$], bioclasts of other foraminifera and purely carbonated parts and a few lithogenic material (probably quartz and phyllosilicates).

4.1.2 *Textularia agglutinans*

It is a non-symbiont bearing and comparatively large benthic foraminiferal species with a widespread distribution across all oceans. Textularia agglutinans have an epiphytic life mode at natural hard bottom habitats along the Israeli Mediterranean coast, being commonly found attached to stalk or roots of coralline algae or turf's algal substrates (Merkado et al., 2015). This species is rare in the Portuguese continental shelf; only a few occurrences were reported by Levy et al. (1995) and Martins et al. (2015a), in the outer continental shelf.

Living organisms of *T. agglutinans* were observed in Bay of Biscay in 140 m depth and the average living depth was 0.6 cm (Fontanier et al., 2002). In this site the bottom waters are not seriously influenced by the exported organic flux and is characterized by oxygen concentration of 4.9 ml/l under the influence of Northern Atlantic Central Waters (Fontanier et al., 2002).

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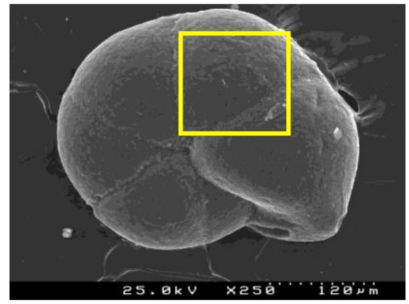


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Operator:
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                     *** PUzaf results ***
elem/line____P/B_____B_______F________c______c(100%)__%error__h_
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Na K-ser       3.0  0.99941 1.01663    0.50     0.92    76.1  *
Mg K-ser       3.0  1.00239 1.03160    0.41     0.75    76.5  *
Al K-ser      47.3  1.00512 1.04680    5.78    10.60    35.4  *
Si K-ser     381.2  1.00764 1.00332   42.10    77.15    29.2  *
K  K-alpha    49.4  1.01798 1.01389    4.28     7.84    16.4
Ca K-alpha    10.6  1.01971 1.01547    0.86     1.58    36.7
----------------------------------------------------------------
standardless                          54.57   100.00    [2s]
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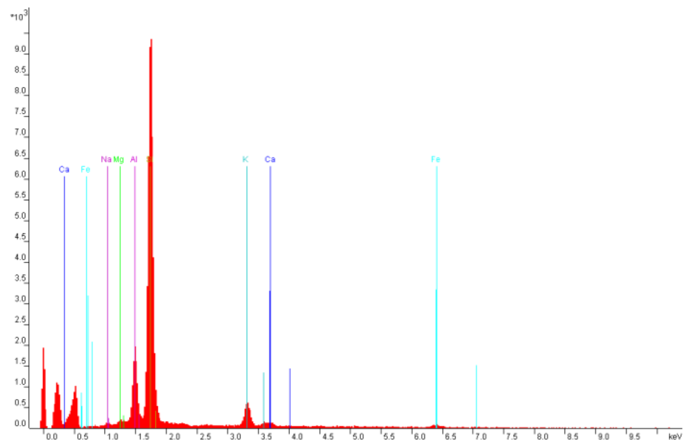

Fig. 7. Results of the EDS Analysis on the SEM of the general composition of the test of *Arenoparrella mexicana*.

Tab. 2. Pearson correlations between the elemental composition of the analyzed specimens, namely four different specimens of *T. deltoidea* (T. delt.1- T. delt.4) and species. Legend: T. delt. - *Textularia deltoidea;* T.agglut - *Textularia agglutinans* S.conica - *Sahulia conica*; S.sagitt - *Spiroplectammina sagittula*; K.flintii - *Karrerotextularia flintii;* S.heter - *Siphotextularia heterostoma*; K.bradyi - *Karreriella bradyi*; A.mexic - *Arenoparrella mexicana.* Significant correlations are marked.

Species	T. delt.1	T. delt.2	T. delt.3	T. delt.4	T.agglut	S.conica	S.sagitt	K.flintii	S.heter	K.bradyi	A.mexic
T. delt.1	1.00										
T. delt.2	**0.94**	1.00									
T. delt.3	**0.97**	**0.96**	1.00								
T. delt.4	**0.93**	**0.95**	**0.96**	1.00							
T.agglut	**0.96**	**0.94**	**0.95**	**0.95**	1.00						
S.conica	0.61	0.66	0.69	0.63	0.67	1.00					
S.sagitt	0.66	0.63	**0.73**	**0.72**	**0.74**	**0.81**	1.00				
K.flintii	**0.95**	**0.87**	**0.94**	**0.89**	**0.92**	0.61	**0.78**	1.00			
S.heter	**0.95**	**0.83**	**0.89**	**0.84**	**0.86**	0.53	0.62	**0.93**	1.00		
K.bradyi	**0.85**	**0.80**	**0.88**	**0.86**	**0.83**	**0.80**	**0.85**	**0.85**	**0.87**	1.00	
A.mexic	0.16	0.21	0.27	0.30	0.28	**0.73**	**0.81**	0.31	0.15	0.55	1.00

The results of the EDS Analysis on the SEM of the general composition of *T. agglutinans* (Fig. 4A), evidences that the wall of this species is essentially composed of carbonated particles (Ca 85%) with the inclusion of a small amount of

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clay minerals (probably illite, the most abundant clay mineral in the sediments of NW Iberian Margin (Martins et al., 2012a) as suggested by the presence of Si (≈5%), K (≈5%), Al (≈3%), K (≈2%) and Mg (≈1%).

4.1.3 *Sahulia conica*

It is a cosmopolitan species occurring in neritic and bathyal environments, for example, in the Atlantic and Pacific oceans and in the Mediterranean Sea. *Sahulia conica* is frequently found in the continental shelf of North America and the Gulf of Mexico (Culver and Buzas, 1982), being abundant in the outer shelf and continental break of Georgia and South Carolina (Arnold, 1983). It dominates (20-25%) in the bathyal area of California, between 200-2,000 m depth: with temperature ranges from 8.8ºC at 200 m and down to 1.8 ºC at 2,000 m water depth; the oxygen content of 3.6 ml/l, at 200 m, and 0.4 ml/l at 660 m, increasing to 3.0 ml/l at the abyssal zone (Bandy, 1953).

Sahulia conica is common in the circalittoral zone (Pujos, 1976) of the Bay of Biscay, between 60-3,200 m, with frequency <3%. The highest relative abundance (1.5-3.3%) of this species was recorded in this region at 135-190 m (Caralp et al., 1970; Blanc-Vernet et al., 1984).

In the NW Iberian Continental Margin, it normally accounts for <2% of the benthic foraminifera assemblages. It was identified in Holocene and Pleistocene sedimentary strata, for instance in the external sector of the Ria de Vigo, NW of Spain, 39 m deep (core KSGX 24; Martins et al, 2013); in the Muddy Deposit of Galicia, at 115 m (core KSGX 40; Martins et al., 2006; 2007); in the continental slope of Galicia, at 2,000 m, in the core PE 109-13 (Martins and Gomes, 2004); in the Douro Muddy Deposit, N of Portugal, at 87 m (core W90; Martins et al., 2012b). *Sahulia conica* occurs in the Portuguese continental shelf (Levy et al., 1995): it is common (<4%) in the western Atlantic Margin (Martins et al., 2012a, 2015a) and in Gulf of Cadiz, off the Guadiana River, Algarve (Mendes et al., 2004).

According to Arnold (1983), the wall of the test of *S. conica* is constructed almost exclusively by terrigenous material, and therefore, the distribution of these components in the sediments is one of the factors that regulates the occurrence of this species. Species that agglutinate terrigenous materials are generally rare where the abundance of these components is reduced (Arnold, 1983).

The results of the EDS on SEM of this work also indicates that the test's wall of *S. conica* includes mostly lithogenic particles but also some carbonated material. The lithogenic component should contain aluminosilicates, such as microcline ($KAlSi_3O_8$), orthoclase ($KAlSi_3O_8$), lepidolite ($K(Li,Al)_3(Si,Al)4O_{10}(F,OH)_2$), muscovite ($KAl_2(Si_3Al)O_{10}(OH,F)_2$), biotite ($K(Mg,Fe^{++})_3[AlSi_3O_{10}(OH,F)_2)$ and illite ($(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$. The wall of *S. conica* also includes a small proportion of S.

However, the proportion of K in the mentioned minerals is inferior to that found in the wall of *S. conica*. Potassium levels influence multiple physiological processes, including the transport of substances through the cellular-membrane, acid–base homeostasis fluid and electrolyte balance (Solomon, 1962; Kernan, 1980; Hellgren et al., 2006, Lockless et al., 2007; Malnic et al., 2013).

Sulfur is an essential element for all life. It commonly occurs in the form of organosulfur compounds or metal sulfides. Some amino acids, vitamins, as cofactors, disulfides, S–S bonds, confer mechanical strength and insolubility to proteins such as keratin. Sulfur is also one of the core chemical elements needed for biochemical functioning and is an elemental macronutrient for all organisms.

4.1.4 *Karrerotextularia flintii*

This species was recorded in some stations along all the Portuguese continental shelf (Levy et al., 1995), Southwestern Pacific: New Caledonia, northern shelf, 600 m (Debenay, 2012). According to Debenay (2012), this species agglutinates the particles using a carbonate cement. The results of the EDS analysis on the SEM (Fig. 5A) evidence that the wall is essentially composed of carbonated particles also including some lithogenic component namely phyllosilicates and feldspars. Ytrium concentrations are relatively high in the test's wall of this species.

4.1.5 *Siphotextularia heterostoma*

This species was identified in the upper slope off Aveiro (465 m deep; Appendix 1). The results of the EDS analysis (Fig. 5B) suggest that this species mainly agglutinates carbonated material and a small lithogenic component.

No iron was identified in the test's wall of *S. heterostoma*. The elemental composition of the wall of this species (mainly composed by Ca and small proportion of Si, Na, Al, and K) indicates that it should include mostly muscovite [$KAl_2(Si_3Al)O_{10}(OH,F_2)$] and plagioclase (calcosodic series) and a few dolomite and/or magnesite particles that are common in the sediments of Iberian Margin (Martins et al., 2012a).

S. heterostoma species wall is grainy; the grains are irregular in size and shape. Most of the grains are probably carbonated and seem to be agglutinated with a carbonated cement.

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4.1.6 *Karreriella bradyi*

Karreriella bradyi is a shallow infaunal (Fontanier et al., 2002), bahyal species, common in the Pacific (Murray, 1991), for instance in New Caledonia at 600 m water depth (Debenay, 2012) and in the Southwest region of the Indian Ocean (Corliss, 1979). It is commonly collected in the North American continental margin, as well as in the Gulf of Mexico (Culver and Buzas, 1982; Robertson, 1998), in the outer continental shelf and slope and abyssal plain (Culver and Buzas, 1983).

Karreriella bradyi is a rare species on the Portuguese continental shelf (Levy et al., 1995) and presents in the Quaternary sedimentary strata (<1%) of the Galicia continental slope (N Spain), at 2,000 m water depth (in core PE 109- 13; Martins and Gomes, 2004) and in core KSGX24, at 2765 m water depth (Appendix 1). According to Cushman (1911), the finely agglutinated test's wall of *K. bradyi* is composed of arenaceous or calcareous materials. The results of the EDS analysis on the SEM (Fig. 6A) agree with this description. Like *S. conica*, the wall of this species also includes significant proportion of K and S and has similar characteristics to those observed in *S. conica.*

4.1.7 *Spiroplectammina sagittula*

The assemblage of *S. sagittula* has been identified in the European and African continental margin, in several places, between 20-600 m deep, in muddy substrates and sandy muds; in temperatures between 7-16°C and; salinities of 35-36.5 (Murray, 1991, Debenay and Basov, 1993). It dominates on sandy substrates between 51-59 m depth in the Eddysttone-Plymouth region and between 84-95 m in the Channel of England (Murray, 1970). It is related to fine grained sediments in the Celtic Sea (Le Calvez, 1958).

Spiroplectammina sagittula is frequent in the continental shelf of the South of Gascon, from 40-60 m, where it is very abundant in sandy substrates (Pujos, 1976). It is well represented in the North of Spain, in shallow muddy bottoms, in the Cantabria and Galician regions (Colom, 1974). It only represents a proportion <1% in Baiona Bay and Ria de Vigo (Alejo et al., 1999), as well as in Holocene and Pleistocene strata: in the Douro Muddy Deposit, N of Portugal, at 87 m (core W90; Martins et al., 2012b); in the Galicia Muddy Deposit, 115 m deep (core KSGX 40; Martins et al., 2006; 2007); in the continental slope of Galicia, at 2,000 m (core PE 109-13; Martins and Gomes, 2004).

Spiroplectammina sagittula is quite common in other regions of Portuguese continental shelf (Levy et al., 1993), in areas with depths >50 m (Galhano, 1963; Martins et al., 2012a, 2015a). In Gulf of Cadiz, southern Spain, in the zone between the mouth of the Guadalquivir River and Cape Trafalgar, *S. sagittula* was found (<2.5%) in sandy and sandy-mud sediments between 50-500 m (Guimerans et al., 1999).

In the Spanish Mediterranean, *S. sagittula* is common in muddy bottoms of the Catalan coast, between 70-100 m (Mateu, 1970), and between 50-200 m, on the coast of Nerja and Montril (Sánchez Ariza, 1983). It also occurs in other parts of the Mediterranean Sea, such as the Gulf of Ajaccio, where it is most abundant in fine sediments between 150-200 m (Bizon and Bizon, 1984), and in the upper continental slope of the Adriatic Sea (Jörissen, 1987; Stigter et al., 1998).

The highest abundance of living organisms of *S. sagittula* has been found in the superficial sediments (0-0.5 cm; Stigter et al., 1998, Fontanier et al., 2002). This species can however penetrate the sediment up to 5 cm below the surface, as observed by Stigter et al. (1998).

The wall of *S. sagittula* is rich in Ca, Si and Al also including K, Na, Mg, S and Fe (Fig. 6B), which may indicate that this species essentially includes carbonated materials with significant amount of lithogenic particles.

4.1.8 *Arenoparrella mexicana*

Arenoparrella mexicana is dominant or common in coastal transitional areas with low salinity occurring for instance in mangrove swamps and marshes (Debenay, 2012; Martins et al., 2015b). The wall of this species (Fig. 7) is essentially composed of fine sand particles grains (lithoclastic materials) probably including quartz grains, plagioclase, K-feldspar and phyllosilicates.

4.2 Comparison between the analyzed species

The cluster analysis results (Fig. 8), correlations (Table 2) and the elemental composition of the test's wall of the analyzed specimens allowed to verify gradients of elements enrichment. The species of Group I, *T. deltoidea, T. agglutinans, K. flintii* and *S. heterostoma*, are characterized by the highest concentrations of Ca, Mg and Y and the lowest Si and Al contents. The species of Group II, *S. conica, S. sagittula* and *K. bradyi*, present intermediate concentrations of these elements but display the highest K content. Group III, represented by *A. mexicana*, contains the highest Si and Al contents and the lowest Ca, Mg and Y concentrations.

According to Nørvang (1966), the Textulariida (Sub-Class) includes organisms with calcarenitic and arenitic wall. The tests' particles are cemented by low-Mg calcite (Sen Gupta, 1999). It is not known how much Ca is being retained in the composition of the cement used to build the test.

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The species with a test's wall with low amount of Ca (1.58 %) is *A. mexicana*. This species is typical of hypohaline-brackish (0.5 – 9.5 ‰) waters in transitional environments such as lagoon systems and mangrove swamps intersected by small rivers and tidal creeks (Semensatto-Jr and Dias-Brito, 2004) and estuaries (Camacho et al., 2015; Murray, 2006).

The Ca content should be used in the cement and is probably related to the mineralogical composition of the particles agglutinated by this organism, such as plagioclase that is present in the sediments composition (4.2%; Appendix 2).

The localities where this species was collected has normally low TOC content but relatively low pH value (7.4; Appendix 2). It is known that below 7.6, the pH is a stressing factor for calcareous benthic foraminifera. These conditions may not be favorable to the production of a thick layer of carbonate cement and this species probably use the available lithological component present in the environment such as quartz, phyllosilicates, plagioclase and K-feldspars. Regardless of the amount of Ca present in the cement of the test's wall, the species of Group 1 essentially use carbonated particles to build their tests. The particles (38-49%) seem to be abundant in the localities where the analyzed species were collected (Appendix 2).

The specimen 1 of *T. deltoidea* seems to present structures that may be composed by 100% carbonate or constituted by magnesium carbonate (dolomite). Dolomite is relatively abundant in the localities where this specimen was collected (12%, Appendix 2) as well as carbonates. The test's wall of the species of Group 2 displays relatively high K content, namely in *S. conica* (K: 23.03%). In these species were also found significant S concentrations (2.3%).

As mentioned K is an essential chemical element that regulates important cellular activities (Solomon, 1962; Kernan, 1980; Hellgren et al., 2006; Lockless et al., 2007; Malnic et al., 2013) as well as S that may have an important structural function.

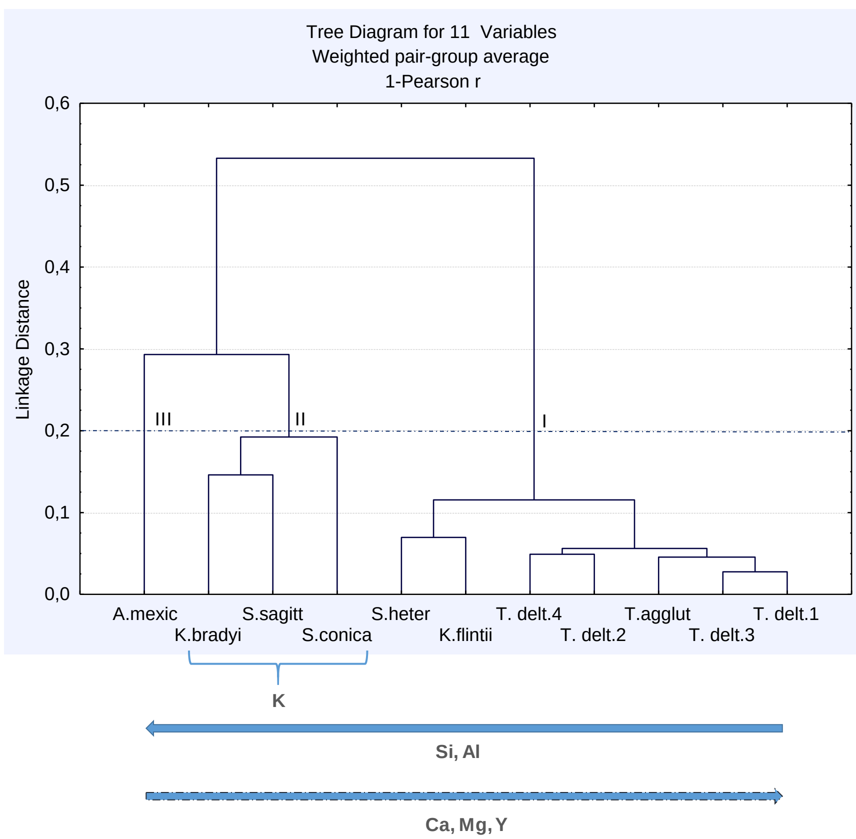

Fig. 8. Grouping of species by Cluster Analysis based on the elemental composition of the test's wall of the analyzed specimens, namely four different specimens of *T. deltoidea* (T. delt.1- T. delt.4). Legend: T. delt. - *Textularia deltoidea;* T.agglut - *Textularia agglutinans* S.conica - *Sahulia conica*; S.sagitt - *Spiroplectammina sagittula*; K.flintii - *Karrerotextularia flintii;* S.heter - *Siphotextularia heterostoma*; K.bradyi - *Karreriella bradyi*; A.mexic - *Arenoparrella mexicana*.

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As hypothesized by Lovelock (1979) foraminifera may use "storage" and "excretion" as functions of biomineralization. According to this author whereas some useful minerals which are undersaturated in the milieu (such as silica and apatite for planktonic foraminifera) would be concentrated in the biosphere, whereas supersaturated minerals may be toxic (such as calcium carbonate) being "pumped down". On the other hand, $CaCO_3$ often reaches supersaturated conditions, especially in shallow shelf seas. In such environments Ca^{++} has a tendency to enter in the cells and becomes toxic (Simkiss, 1977)

Thus the mechanism of biomineralization can pump it out some toxic or useless chemical elements at a given moment so they can be used when needed. Skeletons provide a protective envelope that can be adapted toward more specific ends, such as passive regulation of buoyancy, storage of silica or other chemical elements, and excretion of toxic calcium (Brasier, 1986).

5. Conclusion

The results of this work indicate that the main constituent of the wall of *T. deltoidea, T. agglutinans, K. flintii* and *S. heterostoma* tests are carbonate particles whereas *Sahulia conica, Karreriella bradyi, Spiroplectammina sagittula* include significant amount of lithogenic particles in the wall. The test composition of *A. mexicana* is essentially composed by lithogenic particles with low abundance of a carbonated cement. Thus carbonates are the main constituent both in mainly siliciclastic sediments and in the deep sea where the sediments ae composed mainly by a carbonated oose. The inverse also was observed. *Karreriella bradyi* for instance a quite common species in the deep sea in essentially carbonated sediments, select a relatively high amount of silisiclastic materials.

There are some evidences that at least *T. deltoidea* may segregate some carbonated particles that are used in its test building. *Sahulia conica, K. bradyi,* and *S. sagittula* should also use the wall to accumulate some elements that they can use again to regulate the fluids of the cell or to vital functions if necessary. Textulariids also should use the text to pump toxic elements if they are retained by the cell in high concentrations. "Storage" and "excretion" seems to be functions of biomineralization of some Textulariid species.

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Appendices 1 and 2 are attached as supplementary materias (SM1-SM2) in http://www.e-publicacoes.uerj.br/index.php/jse/article/view/26888

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