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Magnesium in 19 Species of Eastern Canadian Holocene Foraminifera

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Article abstract

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In the samples examined low magnesium forms (Group I) occur in all three water-masses and in a late-glacial beach sample. The intermediate magnesium form Ephidiella arctica (Group 2) and the high magnesium forms (Group 3) Quinqueloculina arctica and 0. seminulum occur in the Upper Watermass. Populations of the low magnesium species Buccella inusitata, Islandiella helenae and Nonionellina labradorica are each found in both Upper and Deep Watermasses. The low magnesium Value of Quinqueloculina stalkeri may indicate that the form should be placed in another genus.

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MAGNESIUM IN 19 SPECIES OF EASTERN CANADIAN HOLOCENE FORAMINIFERA

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The tests of 18 benthonic and one planktonic species of modern Foraminiferida from 8 bottom samples recovered from the eastern Canadian shelf fall into two, or perhaps three groups with respect to mean mole percent MgCO₂, as follows: Group 1 - 0 to 2.5 % MgCO₂; Group 2 - 2 to 5 % MgCO₂; and Group 3 - 5 to 9 % MgCO₂. The watermass characteristics and depth of each population are: Upper Watermass, -1 to 3 or 5 C, 33 o/oo salinity, 62 m and 73 m; Intermediate Watermass, 0[°]C, 34 o/oo salinity, 99m; and Deep Watermass, 4 to 5 C, 35 o/oo salinity, 263 n, 431 m, 475 m, 479 m and 509 m.

In the samples examined low magnesium forms (Group 1) occur in all three watermasses and in a late-glacial beach sample. The intermediate magnesium form Ephidiella arctica (Group 2) and the high magnesium forms (Group 3) Quinqueloculina arctica and 0. seminulum occur in the Upper Watermass. Populations of the low magnesium species Buccella inusitata, Islandiella helenae and Nonionellina labradorica are each found in both Upper and Deep Watermasses. The low magnesium value of Quinqueloculina stalkeri may indicate that the form should be placed in another genus.

INTRODUCTION

Of the elements present in small quantities in the tests of foraminifera, magnesium is particularly significantly and worthy of close study. The reasons for this are several. (1) Knowledge of the chemical composition of the test, including, in particular, the magnesium content, is a necessary first step in the understanding of the mechanism of test formation. (2) The presence of magnesium in solid solution in the calcite of the test implies that it may be intimately involved in the metabolism of the organism whereby the test is secreted. (3) If the amount of magnesium present is due to hereditary factors, and if it is constant for the taxon, then it is of classificatory importance. (4) If the variation in amount of magnesium is ecologically controlled, it may be used as an ecological indicator of past environmental conditions in fossil forms, assuming that diagenetic changes can be evaluated. However, before inferences can be drawn concerning fossil forms, it seems to be advisable first to relate the magnesium variations in modern tests to the environments in which the animals live, for modern environments can be more precisely defined than ancient ones and diagenetic effects are absent.

Chave (1954) used the X-ray diffraction method in a study of magnesium in the calcitic shells of marine organisms. Because the method detects magnesium in substitution in the calcite lattice, it may be assumed to be biogenic if diagenesis can be ruled out. Chave found (1), a linear relationship between magnesium content and environmental water temperatures, and (2), in general, a decrease in magnesium content with increase in phylogenetic level of the organism. This latter conclusion was based upon the gradients of least square regression curves of temperature versus magnesium content for the taxonomic groups studied. The magnesium content of the Foraminiferida ranged from 0.33 to 15.9 mole percent MgCO₂.

Blackmon and Todd (1959) used the method of X-ray diffraction to determine the magnesium content MARITIME SEDIMENTS Vol. 14, No. 2, August 1978, pp. 73-77

of foraminiferal tests from many parts of the world. Their study was useful in several ways. It showed magnesium to be of classificatory and possibly of ecological importance. Many families, genera and species were represented in the study of a general way, and the specimens that were analyzed were collected from many different climatic zones and environments from the Arctic to the Tropics. The authors commonly analyzed only one (occasionally a few) specimen per species, or if several specimens were used, they were ground down, and an aggregate sample was used for analysis. Thus, the variance of the species population with respect to magnesium was not determined, Only four Canadian species were analyzed.

Dodd (1967) reviewed the literature with respect to magnesium and strontium in calcareous organisms and concluded that the concentration of these elements in carbonate skeletons is controlled by four major factors: (1) Water chemistry - other factors being equal, the Mg/Ca and Sr/Ca ratios in skeletal material should be constant relative to those ratios in the water in which they formed. (2) Other environmental factors - Magnesium shows a strong positive correlation with temperature in calcitic skeletons. (3) Mineralogy - Calcite is generally high in magnesium and low in strontium relative to aragonite. (4) Physiology of the organisms - In general the phylogenetically more advanced forms have lower magnesium and strontium values.

The magnesium content of modern species of the benthonic foraminiferal family Miliolidae of Cleveland Bay, North Queensland Shelf, Australia, were studied by Ponder and Glendenning (1974) using the X-ray diffraction method. The authors believed that environmental temperature variation was minimal for this relatively shallow tropical watermass. They concluded that magnesium content could not be used for determining paleotemperatures or paleodepth, nor as an aid to classification, because of its overlapping variance in the populations they examined. This report presents the results of X-ray diffraction analysis for magnesium in populations of 19 species of the Order Foraminiferida from the eastern Canadian continental shelf, and one species of late-glacial age from Mâtis Beach, Quèbec. All species are benthonic except only *Globigerina* pachyderma s.1.

METHOD

The X-ray diffraction method was employed utilizing the shift in diffraction lines that results when magnesium substitutes for calcium in the calcite lattice. The apparatus consisted of a Siemens Kristalloflex IV X-ray generator with copper target and nickel filter, and Debye-Scherrer cameras with revolving spindles. The excitation constants for the unit were 35kV and 20mA. Cuk wave length 1.5418A^O was used.

Because the wall of the foraminiferal test is fine-grained, the single test diffracts as a powder under the X-ray beam and non-destructive analysis is possible. The whole foraminiferal test was mounted on the revolving spindle of the Debye-Scherrer camera and was subjected to the X-ray beam. The films were read on a Kirem light box. The 112 and 444 lines were generally the most readable giving least variation in d-values and the most reproducible results.

ESTIMATE OF ACCURACY

An estimate of probable accuracy of the method including reading error is in the order of ± 1.0 mole percent MgCO₂.

The mean magnesium percentage and its variation are reported for each population, and an attempt is made to relate the values to factors of temperature, salinity and depth of the watermass in which the populations were living.

RESULTS

The results are tabulated in Table 1 which shows, for each species population, the mean mole percent MgCO₃, standard deviation and magnesium group, frequency, station number and position, geological age, depth of occurrence of the sample, name of the watermass layer, temperature and salinity of the watermass.

CONCLUSION

Reference to Table 1 shows that species have mean mole percent MgCO₃ values ranging from zero (*Globigerina pachyderma*) to 8.0 (*Quinqueloculina seminulum*), but most populations are less than 1.0. The estimated experimental error is in the order of 1 mole percent MgCO₃, and thus, for most species the error is a high value in relation to the mean. Similarly, values of standard deviation range from 0.2 (*Globobulimina auriculata*) to 1.3 (*Elphidium clavatum*), and thus experimental error is also high in relation to these values. It is therefore apparent that the method of X-ray diffraction is not sensitive enough to permit sufficiently precise analysis of mean and variance of magnesium amounts in these species populations. Nevertheless, although the experimental error is relatively high the species populations do appear to fall into at least two, possibly three, groups with respect to mean mole percent MgCO₃. The three groups are as follows:

GROUP l, low in magnesium, approximate range 0 to 2.5 mole percent MgCO₃: Globigerina pachyderma, Bulimina exilis, Brizalina subaenariensis, Buccella inusitata, Bulimina aculeata, B. marginata, Islandiella helenae, Elphidium bartletti, E. clavatum, E. incertum, E.sp., Globulimina auruculata, Quinqueloculina stalkeri, Nonionellina labradorica, Elphidium articulatum and Glandulina laevigata.

GROUP 2, intermediate in magnesium, approximate range 2 to 5 mole percent MgCO₃: *Elphidiella arctica*. Because this group is based upon only one specimen, it is tentatively suggested.

GROUP 3, high in magnesium, approximate range 5 to 9 percent MgCO or perhaps higher: *Quinqueloculina arctica* and 0^3 seminulum.

Three main watermasses are recognized in the region covered by the samples as follows: Upper Watermass, -1 to 3 or 5 °C, 33 o/oo salinity, 62 m and 73 m; Intermediate Watermass, 0 °C, 34 o/oo salinity, 99 m; and Deep Watermass, 4 to 5 °C, 35 o/oo salinity, 263 m, 431 m, 475 m, 479 m and 509 m.

In the samples examined low magnesium forms (Group 1) occur in all three watermasses and in the late-glacial beach sample. The species Buccella inusitata, Islandiella helenae, Nonionellina labradorica and Elphidium bartletti are each found in both Upper and Deep Watermasses. The first three species named are present in populations of adequate size, but *Elphidium bartletti* is represented by only one specimen in the deep sample S43-4 (263 m) and thus may be less reliable. The wide temperature tolerance of populations of Islandiella helenae (-1 to 3 C and 4 to 5 C) seems surprising because this species, under the names of Cassidulina teretis = Islandiella teretis, has been thought to be restricted to temperatures of $3^{\circ}C$ and below (Fillon and Hunt 1974, p. 15). Displacement into deep water is a possibility although not considered likely for sample S49-B. Alternately, more than one species, or subspecies, may be present in these two Islandiella helenae populations; if so, the differences are not obvious from the morphology. Another possibility is that the species, although preferring water below 3°C, is not seriously affected by slightly higher temperatures.

The miliolids are usually thought to be high magnesium forms, and *Quinqueloculina stalkeri* would be expected to be high in magnesium as are the other quinqueloculines *Q. arctica* and *Q. seminulum*. Its low magnesium values (mean % MgCO₂=0.9) are surprising and may indicate that the calcite metabolism of *Q. stalkeri*, a species that agglutinates sand grains on the wall, is profoundly different from that of *Q. arctica* and *Q. seminulum* which do not. All the quinqueloculines are from two bottom samples (depths, 62 and 73 m) with similar temperature and salinity values, which suggests that genetic rather than environmental

					1	TABLE 1						
		MOLE % MgCO 3										8
SPECIES	FREQUENCE	ESTIMATED EXPNT. ERRON	MOLE & MEAN	STANDARD DEVIATION	GROUP	STATION	POSITIC	DN AGE	ДЕРТН М	WATERMASS LAYER	TEMPERATURE C	APPROXIMATE SALINITY 0/0
Globigerina pachyderma s.l.	12	1	0.0	0.6	1	S43-28	46°52'N	Modern	Surface	Upper	Variabl	e 33
Brizalina subaenariensis	20	1	0.0	0.6	1	S43-18	46 ⁰ 49' 55 ⁰ 36'	Modern	73	Upper	-1 to 3	33
Buccella inusitata	21	1	1.1	0.8	1 •	S43-18	Ditto	Modern	73	Upper	-1 to 3	33
B. inusitata	11	1	0.0	0.4	1	S43-28	46 ⁰ 52'	Modern	479	Deep	4 to 5	35
Bulimina aculeata	5	1	0.0	0.6	1	S49-B	Cabot Strait 47 39' 59 46'	Modern	509	Deep	4 to 5	35
B. exilis	22	1	0.2	0.9	1	543-28	46 [°] 52' 58 [°] 04'	Modern	479	Deep	4 to 5	35
B. marginata	11	1	0.0	0.6	1	S43-28	Ditto	Modern	479	Deep	4 to 5	35
Elphídium articulatum	1	1	0.8	-	1	S43-15	46 ⁰ 23' 54 ⁰ 12'	Modern	99	Inter- mediate	0	34
E. bartletti	14	1	1.2	1.0	1	S43-18	46 ⁰ 49 ' 55 [°] 36 '	Modern	73	Upper	-1 to 3	33
E. bartletti	1	1	0.4	-	1	S43-3	43 ⁰ 52.3' 62 [°] 52.8'	Modern	263	Deep	4 to 5	35
E. clavatum	4	1	1.0	1.3	1	S43-18	46 ⁰ 49 ' 55 [°] 36 '	Modern	73	Upper	-1 to 3	33
E. clavatum	3	1	0.1	1.2	1	HV-19	Metis Beach P.Q.	Late- glacial	-	-	-	-
E. clavatum	8	1	0.2	0.7	1	HV-19	Metis Beach P.Q.	Late- glacial	-	-	-	- ·
E. clavatum (combined)	11	1	0.2	0.8	1	HV-19	Metis Beach P.Q.	Late- glacial	-	-	-	-
E. clavatum	15	1	1.0	0.7	1	\$43 - 18	46 [°] 49' 55 [°] 36'	Modern	73	Upper	-1 to 3	33
E. incertum	21	1	0.0	0.5	1	S43-28	46 ⁰ 52' 58 ⁰ 04'	Modern	479	Deep	4 to 5	35
E. sp.	19	1	1.0	0.6	1	S43-18	46 ⁰ 49' 55 [°] 36'	Modern	73	Upper	-1 to 3	33
Glandulina laevigata	1	1	0.0	-	1	S43-28	46 ⁰ 52' 58 ⁰ 04'	Modern	479	Deep	4 to 5	35
Globobulimina aurîculata	3	1	0.7	0.2	1	s43-27	46 ⁰ 37' 58 [°] 30'	Modern	431	Deep	4 to 5	35
Islandiella helenae	21	1	0.7	0.5	1	543-18	46 ⁰ 49' 55 ⁰ 36'	Modern	73	Upper	-l to 3	33
I. helenae	8	1	0.2	0.7	1	S49-B	Cabot Strait 47 ⁰ 39' 59 ⁰ 46'	Modern	509	Deep	4 to 5	35
Nonionellina labradorica	15	1	0.5	0.4	1	S43-18	46 ⁰ 49' 55 [°] 36'	Modern	73	Upper	-1 to 3	33
N. labradorica	16	1	1.2	0.5	1	S43-34	47 ⁰ 16' 59 ⁰ 47'	Modern	475	Deep	4 to 5	35
Q. stalkeri	5	1	0.9	0.8	1	S43-18	46 ⁰ 49 ' 55 [°] 36 '	Modern	73	Upper	-1 to 3	33
Elphidiella arctica	1	1	3.6	-	2	543-66	44 ⁰ 00' 50 [°] 52'	Modern	62	Upper	-1 to 5	33
Quinqueloculina arctica	1	1	7.5	-	3	S43-18	46 ⁰ 49' 55 ⁰ 36'	Modern	73	Upper	-1 to 3	33
Q. seminulum	1	1	8.0	-	3	S43-66	44 ⁰ 00' 50952'	Modern	62	Upper	-1 to 5	33
Q. seminulum	1	1	5.8	-	3	S43-18	46 ⁰ 49 ' 55 [°] 36 '	Modern	73	Upper	-1 to 3	33

factors may account for the large difference in magnesium content. Ponder and Glendening (1974) reported the mole percent MgCO, in tests of Quinqueloculina philippinesis range from 8.5 to 21.6 with a mean of 13.1 (s=4.0). There was a slight decrease of magnesium content with depth (range 3 to 20 fathoms). Adventitious agglutinated material on the test wall is not mentioned in the description of this species (Ponder 1975). Blackmon and Todd (1959) reported *Quinqueloculina sulcata* d'Orbigny, 26 to 28 C water temperature, 13 mole percent MgCO₂; O. lamarckiana d'Orbigny, 20 to 30°C water temperature, 12 to 16 mole percent MgCO₃; Q. seminulum Linné, 0°C water temperature, 10 mole percent MgCO,. Thus, magnesium values for the species of Quinqueloculina from the eastern Canadian shelf here presented are depressed when compared with those reported by Ponder and Glendenning (1974) and Blackmon and Todd (1959). This may be explained by the generally lower watermass temperatures experienced by the eastern Canadian shelf specimens (-1 to $5^{\circ}C$).

ACKNOWLEDGEMENTS

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ANNOTATED FAUNAL LIST

BRIZALINA SUBAENARIENSIS (CUSHMAN)

Bolivina subaenariensis CUSHMAN, 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 46, pl. 7, fig. 6; CUSHMAN, L937, Cushman Found. Foram. Res. Sp. Pub. No. 9, p. 156. The genus Brizalina Costa, 1856 is suggested for forms which lack basal chamber lobes, crenulations or retral processes.

BUCCELLA INUSITATA ANDERSON

Buccella inusitata ANDERSON, 1952, Washington Acad. Sci. Journ., v. 42, no. 5, p. 148, Figs. 10allc; LOEBLICH and TAPPAN, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 116, pl. 22, fig. 1.

BULIMINA ACULEATA D'ORBIGNY

Bulimina aculeata D'ORBIGNY, 1826, Tableau methodique de la classe Cephalopodes. Ann. Sci. Nat., Paris, v. 7, p. 269. Forms with apical spines are included.

BULIMINA MARGINATA D'ORBIGNY

Bulimina marginata D'ORBIGNY, 1826, Ann. Sco. Nat. v. 7, p. 269, no. 4, pl. 12, fig. 10-12. Forms without apical spines, but with small spines or crenulations on chamber marginsa are included.

BULIMINA EXILIS BRADY

- Bulimina elegans d'Orbigny var. exilis BRADY, 1884, Rep. Voy. Challenger (Zool.) v. 9, p. 399, pl. 50, figs. 5,6.
- Bulimina exilis Brady. CUSHMAN & PARKER, 1940. Contr. Cushm. Lab. Foram. Res., v. 16, pt.1, p. 11, pl. 2, figs. 18-21.

ELPHIDIELLA ARCTICA (PARKER & JONESO

- Polystomella arctica PARKER and JONES, 1864, in BRADY, Trans. Linn. Soc., London, Zooel., v. 24, p. 471, pl. 48, fig. 18.
- Elphidiella arctica (Parker and Jones). CUSHMAN, 1939, U.S.G.S. Prof. Pap. 191, p. 65, pl. 18, figs. 11-14.

ELPHIDIUM ARTICULATUM (D'ORBIGNY)

Polystomella articulata D'ORBIGNY, 1839, Voy. dans l'Amérique méridionale, Foraminifères, p. 30, pl. 3, figs. 9, 10.

ELPHIDIUM BARTLETTI CUSHMAN

Elphidium bartletti CUSHMAN, 1933, Smithsonian Misc. Coll. v. 89, no. 9, p. 4, pl. 1, fig. 9; 1939, U.S.G.S., Prof. Pap. 191, p. 64, pl. 18, fig. 10.

- Elphidium incertum (Williamson) var. clavatum CUSHMAN, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 20, pl. 7, fig. 10. (Not Polystomella umbilicatula var. incerta Williamson, 1858).
- Elphidium clavatum CUSHMAN. LOEBLICH and TAPPAN, 1953, Smithsonian Misc. Coll. v. 121, no. 7, p. 98, pl. 19, figs. 3-10. This form is referred to Elphidium excavatum (Terquem) forma clavata Cushman, by Feyling-Hanssen, (1972, The foraminifer Elphidium excavatum (Terquem) and its variant forms. Micropaleontology, v. 18, no. 3, p. 337-354, pl. 1-6).

ELPHIDIUM INCERTUM CUSHMAN

- Not *Polystomella umbilicatula* var. *incerta* WILLIAMSON, 1858, Recent Foraminifera of Great Britain, p. 44, pl. 3, fig. 82a.
- Elphidium incertum (WILLIAMSON). CUSHMAN, 1930, U.S. Nat. Mus., Bull. 104, pt. 7, p. 18, pl. 7, figs. 5-9. This forms is referred to Elphidium excavatum (Terquem) forma alba by Feyling-Hanssen, (1972, Micropaleontology, v. 18, no. 3, p. 337-354, pl. 1-6).

GLANDULINA LAEVIGATA (D'ORBIGNY)

- Nodosaria (Glanduline) laevigata D'ORBIGNY, 1826, Ann. Sci. Nat., v. 7, p. 252, pl. 10, fig. 1-3.
- Glandulina laevigata D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiare de Vienne, p. 29, pl. 1, figs. 4, 5.
- Pseudoglandulina laevigata (d'Orbigny) CUSHMAN & McCULLOCH, 1950, Allan Hancock Pacific Exped. v. 6, p. 325, pl. 42, fig. 4.

GLOBIGERINA PACHYDERMA (EHRENBERG) s.l.

- Aristerospira pachyderma EHRENBERG, 1861, K. Preuss. Akad. Wiss., Berlin, p. 276, 277, 303.
- Globigerina pachyderma (Ehrenberg), BE, 1960, Contr. Cush. Found. Foram. Res. v. 11, pt. 2, no. 209, p. 64-68, text fig. 1.
- Globorotalia pachyaerma (Ehrenberg), VILKS, 1975, Jour. Foram. Res. v. 5, no. 4, p. 313-325, pls. 1-3.

Thick-walled encrusted *C. pachyderma* specimens are not common in the sample. The specimens analyzed are not the encrusted type but are similar to Vilk's plate 1, figs. 1-3, and plate 2, fig. 1. *Globigerina incompta* Cifelli 1961, may also be synonymous. GLOBOBULIMINA AURICULATA (BAILEY)

Bulimina auriculata BAILEY, 1851, Smithsonian Contr., v. 2, art. 3, p. 12, pl. 0, figs. 25-27.

ISLANDIELLA HELENAE FEYLING-HANSSEN

- Cassidulina teretis LOEBLICH & TAPPAN, 1953. (not C. teretis Tappan, 1951), Smithsonian Misc. Coll., v. 121, no. 7, p. 121, pl. 24, figs. 3, 4.
- Islandiella helenae FEYLING-HANSSEN, 1976, Jour. Foram. Res., v. 6, no. 2, p. 154-158, t.fs. 1-4.

NONIONELLINA LABRADORICA (DAWSON)

Nonionina labradorica DAWSON, J.W., 1860, Can. Nat., v. 5, p. 191, fig. 4.

Nonion labradoricum (Dawson). LOEBLICH & TAPPAN, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 86, pl. 17, figs. 1, 2.

Nonionellina labradorica (Dawson). VOLOSHINOVA, 1958, Mikrofauna SSSR, Sbornik 9, VNIGRI, Trudy, no. 115, p. 117-191, pl. 1-16.

QUINQUELOCULINA STALKERI LOEBLICH & TAPPAN

- Quinqueloculina fusca Brady. CUSHMAN, 1948 (not Brady, 1870), Cushman Lab. Foram. Res. Spec. Pub. 23, p. 33, pl. 3, figs. 16, 17.
- Quinqueloculina stalkeri LOEBLICH & TAPPAN, 1953, Smithsonian Misc. Coll., v. 121, no. 7, p. 40, pl. 5, figs. 5-9.

This calcareous imperforate form is characterized by the presence of a small amount of fine sand grains which is incorporated into the wall.

QUINQUELOCULINA ARCTICA CUSHMAN

Quinqueloculina arctica CUSHMAN, 1933, Smithsonian Misc. Coll., v. 89, no. 9, p. 2, pl. 1, figs. 3a-c.

QUINQUELOCULINA SEMINULUM LINNAEUS

- Serpula seminulum LINNAEUS, 1767, Systema Natura, p. 1264, ed. 12.
- Quinqueloculina seminulum (Linnaeus) CUSHMAN, 1917, U.S. Nat. Mus., Bull. 71, pt. 6, p. 44, pl. 11, fig. 2.