Secondary Calcification in the Foraminiferal Genus Globorotalia

Abstract. *Populations of four species of the planktonic foraminiferal genus* Globorotalia *from sediments in the Gulf of Mexico show the effects of secondary thickening of the test. Quantitative tabulation of the distribution of thin- and thick-walled specimens illustrates an abrupt and separate depth at which the thickening takes place for each species.*

The accretion of a secondary crust of calcite over the surface of the test of some species of planktonic foraminifera has been reported by a number of authors (*1–3*). The secondary crust may be up to 50 μ thick, compared to an average of 20 μ for the underlying foundation wall, and it imparts a sugary, snow-white appearance to the outside of the test due to minute terminations of calcite crystals, of which the *c*-axes are oriented normal to the test wall.

Ericson *et al.* (*1*) have reported the occurrence of the secondary crust on eight separate species of planktonic foraminifera from deep-sea cores from the Atlantic Ocean. Bé and Ericson (*4*) and Bé (*2*) have considered in detail the structure of the secondary crust on selected species of foraminifera. Two important conclusions were reached in these studies. (i) The secondary thickening of the protozoan test is not an inorganic diagenetic process taking place after the death of the individual organism, and (ii) the acquisition of the secondary crust is a response by the protozoan to some extrinsic stimulus which prevails in deep waters below the epipelagic zone.

My study offers some observations on the depth at which the thickening process begins in these organisms, as well as on other quantitative basinward changes in populations in the Gulf of Mexico.

Specimens were studied from seven traverses normal to the coast from the beach to 1000 m in the northwest Gulf of Mexico (Fig. 1) (*5*). Planktonic foraminifera from the marine sediments were identified, measured (maximum diameter), and counted as either having or not having the secondary crust (*6*). Bé and Ericson (*4*) have reported live specimens, from plankton hauls, which had incipient thickening of the test in the form of short, blunt calcite crystals over the surface of the test. Most of the specimens counted from the Gulf of Mexico sediments either lacked the thickening completely or had a well-developed, sugary white crust. The disparity between dead populations and the standing crop with respect to the number of individuals in the intermediate stage of thickening suggests that the thickening process itself may be very rapid.

Examination of the size distributions of the four species of *Globorotalia* reveals a gradual basinward increase in average specimen size (maximum diameter, Fig. 2, A-D). Populations of each of the four species attain a maximum average specimen size at around 200 m in the bathymetric profile. Bé (*7*) noted a similar distribution of live juveniles and adults from plankton hauls in the Atlantic. Average specimen size invariably increases at the deep ends of the traverses from 700 to 1000

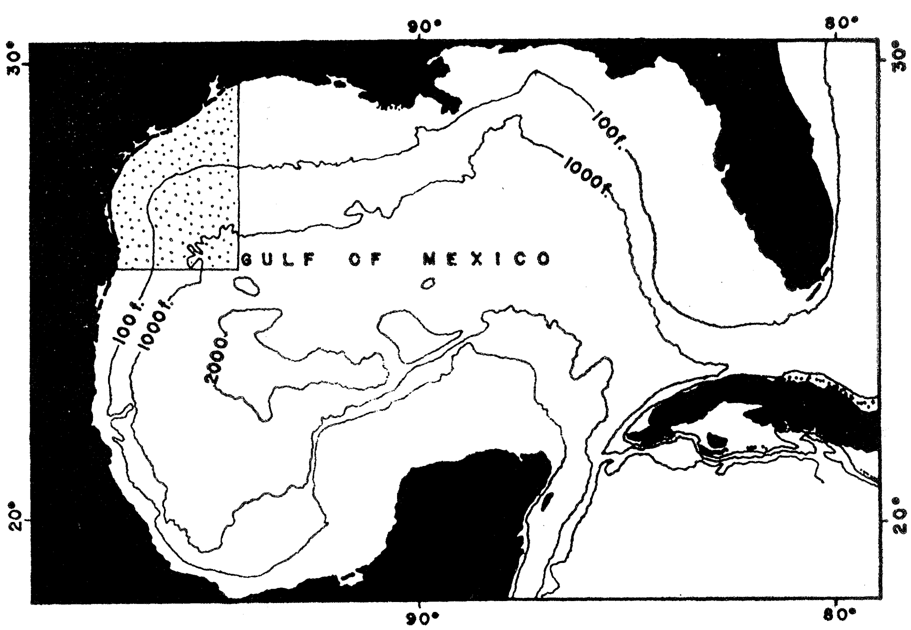

Fig. 1 (below). Locality map of area studied (stippled) in the northwest Gulf of Mexico.

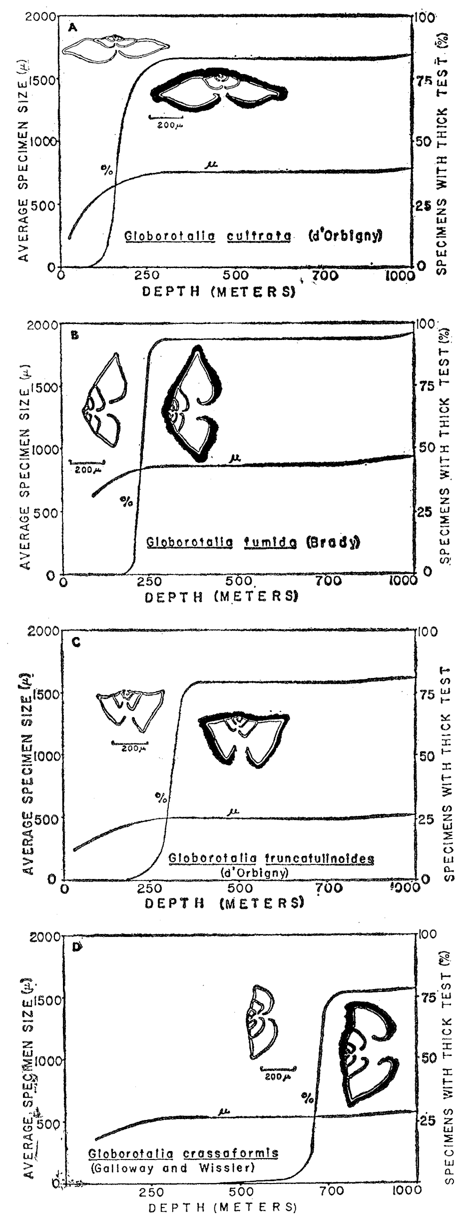

Fig. 2 (right). Average specimen size and percentage of secondary thickening in populations of four species of *Globorotalia*. Each graph represents a composite of seven traverses in the northwest Gulf of Mexico. Vertical sections showing secondary thickening in deep-water specimens are schematic.

m. This increase is a reflection of the destruction of the fragile juvenile tests in the sediments at this depth by solution. Berger (*8*) has reported a similar selective solution of juvenile specimens under experimental conditions in the Pacific at depths greater than 1000 m. The basinward change from predominantly nonthickened to thick-walled populations is remarkably abrupt, taking place over a very short areal distance (Fig. 2, A–D). Each of the four species exhibits the change from thin to thick-walled populations at a different depth from the other species. For each species, the depth at which the secondary thickening takes place is constant over the entire area of the northwest Gulf of Mexico.

Bé and Ericson (see *4*) have given 300 to 500 m as the depth below which secondary thickening takes place in living specimens of *Globorotalia truncatulinoides* (d'Orbigny). The upper limit of this 300- to 500-m zone is manifest in populations of this species from sediments in the northwest Gulf. The depths recorded at which thickening takes place in the remaining three species in this study undoubtedly represent the upper limit of the thickening zone in the bathymetric column for living specimens: *G. crassaformis* (Galloway and Wissler), 700 m; *G. cultrata* (d'Orbigny), 120 m; and *G. tumida* (Brady), 200 m. The destructive solution of juvenile specimens in deep water is further reflected in the distribution of specimens with the thickened test. Because secondary thickening is primarily an adult characteristic, the loss of juvenile nonthickened specimens at mesopelagic depths causes a corresponding increase in the percentage in the specimens with the secondary crust at the same depth (Fig. 2, A–D).

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References and Notes

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5. The tops of some 700 marine sediment samples (mostly shallow cores) were supplied by Scripps Institute, Lamont Observatory, Humble Oil Company, Shell Oil Company, Standard Oil Company, and Texas A & M.
6. In all samples, except those from shallow water with limited planktonic populations, the first 200 globorotalid specimens encountered in a random strew were counted. All specimens counted were measured.
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Isotopic Analysis of Rare Gases with a Laser Microprobe

Abstract. *A ruby-pulsed laser and high-sensitivity mass spectrometer are used to analyze isotopic abundances of rare gases from microgram samples of polished sections. The feasibility of the technique is demonstrated by the analysis of primordial helium and neon from the Kapoeta and Fayetteville meteorites.*

The variation in the abundance of primordial rare gases from meteorites is extremely important in understanding the early history of meteorites, the solar system, and the earth. Excellent discussions of the subject have been presented recently by Signer and Suess (*1*), by Suess, Wänke, and Wlotzka (*2*), and by Pepin and Signer (*3*). Of particular importance is the extreme variation of the primordial rare-gas abundances between different portions of the meteorite. Consequently, a system was developed that now extends isotopic analysis of rare gases to the microgram range and allows a direct comparison between isotopic abundance of rare gases and other chemical, mineralogical, and petrographic data.

A ruby-pulsed laser (*4*) was used to volatilize, in vacuum, approximately 1 μg per pulse of material from polished sections of meteorite. The extracted gases were separated cryogenically and were then analyzed under static conditions with a high-sensitivity 60°-sector mass spectrometer.

Details of the experimental arrangement are shown in Fig. 1. Polished sections of the meteorites are set on a stainless-steel shelf mounted inside a Varian vacuum window. The vacuum window is connected to a Grenville Philips vacuum valve by flexible stainless steel tubing. The other side of the valve goes directly to the ionization region of the mass spectrometer. Pumping and baking the system at 200°C for 10 hours, with the samples removed from the system, resulted in a static pressure of 2×10^{-7} torr.

The Varian window is readily adaptable to a microscope stage mounted on the table rather than on the laser unit. The flexible stainless-steel tubing readily permits 3 degrees of freedom for focusing and alignment of the meteorite samples.

The ruby-pulsed laser is shown with a microscope attachment. Low magnification of the sample at ~ 50 × and one pulse of the laser resulted in a crater diameter of ~ 100 μ and a crater depth of ~ 30 μ.

In order to test the feasibility of the technique and the possibility that ionized rare gases may be lost to the vacuum walls, ten pulses were fired and roughly 10^{-5} g of material was extracted from various dark portions of a polished section of the Fayetteville and Kapoeta meteorites. Primordial He^3, He^4, Ne^{20}, and Ne^{22} were measured; the results are given in Table 1 with previously published data that were measured from 0.1- to 1-g samples.

Table 1. Abundances of primordial helium and neon from the Fayetteville and Kapoeta meteorites (abundance $\times 10^{-6}$ cm^3 per gram at standard temperature and pressure).

Source	He^3	He^4	Ne^{20}	He^4/Ne^{20}	Ne^{20}/Ne^{22}
		Fayetteville			
Dark vein	3	20,000	130	150	11.2
Dark vein	4.7	22,000	160	140	11.9
Dark border	< 0.4	< 170	< 5		
Chondrule	< .3	< 170	< 5		
Literature					
(*5*)			307		10.6
(*5*)			164		10.8
(*6*)	7.2	20,300	50.4	402	12.6
(*3*)	6.65	22,500	62.4	360	12.3
(*3*)	7.05	21,000	55.0	380	12.1
(*3*)	2.0	7,000			12.0
		Kapoeta			
Dark vein	<0.4	1,300	23	57	12.0
Literature					
(*7*)	.38	1,360	24	56.5	14.0
(*8*)	.50	2,040	22.2	91.0	13.5
(*9*)	.52	2,220	23	96.5	12.8
(*1*)	.39	1,320	19.3	68.5	12.8
(*6*)	.53	1,560	17.2	91.0	13.0

Primordial He^4 and Ne^{22} abundances from a dark vein of Fayetteville are reproducible to within 12 percent. The poorer reproducibility of He^3 and Ne^{20} is attributed to the background of the mass spectrometer and sample line. The peak at mass-to-charge ratio (m/e) 3 was corrected 60 percent because of a large hydrogen background, and the peak at m/e 20 was corrected 30 per-