Mineralogy of Tongue of the Ocean Sediments[1]

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ABSTRACT

The carbonate mineralogy of 25 short cores from the Tongue of the Ocean has been determined. Evidence presented in this paper indicates that carbonate mineralogy may reflect Pleistocene sea-level changes due to an increased contribution of low magnesium calcite from the subaerially exposed Bahama Banks when sea levels were low. It is suggested that this relationship of mineralogy to sea level may find wide application in the study of carbonate sedimentation in intermediate-depth water, proximal to carbonate banks.

Introduction. The Tongue of the Ocean is one of the two major re-entrants in the Bahama Banks (Fig. 1). It is a linear, steep-sided feature, 25 to 65 km wide and over 160 km long. Its depth ranges from 1,200 m in the south to over 1,800 m in the north.

Various aspects of sedimentation in the Tongue of the Ocean have been discussed by Ericson et al. (1952), Busby (1962), and Rusnak and Nesteroff (1964). The sediment is purely calcareous in composition. The median grain size typically falls within the silt range. The most important sources of sediment are pelagic calcareous skeletal materials slowly contributed from the overlying water mass and shallow-water calcareous material from the adjacent banks transported mainly by turbidity currents.

On the basis of small differences in sediment lithology and mass physical properties, Busby (1962) divided the Tongue of the Ocean into three sediment provinces: Cul de Sac, Axial, and Flanks (Fig. 2). According to Busby (1962) and Rusnak and Nesteroff (1964), sedimentation rates are most rapid on the Flanks, slower in the Cul de Sac region, and slower still in the Axial area. Sedimentation rates in the Axial area are such that the base of a core 150 cm long would be expected to penetrate sediment that is between 15,000 and 30,000 years of age. At a sediment depth of 150 cm in the Cul de Sac or

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Figure 1. Physiographic diagram of the study area (after Heezen et al. 1959). The large areal extent of the Bahama Banks is apparent in this figure. During glacial maxima the shallow banks were exposed subaerially and the unstable carbonate minerals recrystallized. Materials contributed to areas of active sedimentation adjacent to the exposed banks should reflect the more stable mineralogy of the banks. Arrow points to Tongue of the Ocean study area.

Flank areas the sediment would probably be less than 5,000 years old. Newell and Rigby (1957) and Busby (1962) have concluded that the northward slope of the Tongue of the Ocean floor is related to this difference in sedimentation rate.

Procedure. Twenty-five Phleger gravity cores ranging in length from 1 to 2 m were collected by the U. S. Naval Oceanographic Office from the Tongue of the Ocean. Textural and engineering properties of these samples were investigated by Busby (1962). Three or more subsamples from various depths in each core were analyzed for carbonate mineral composition by standard

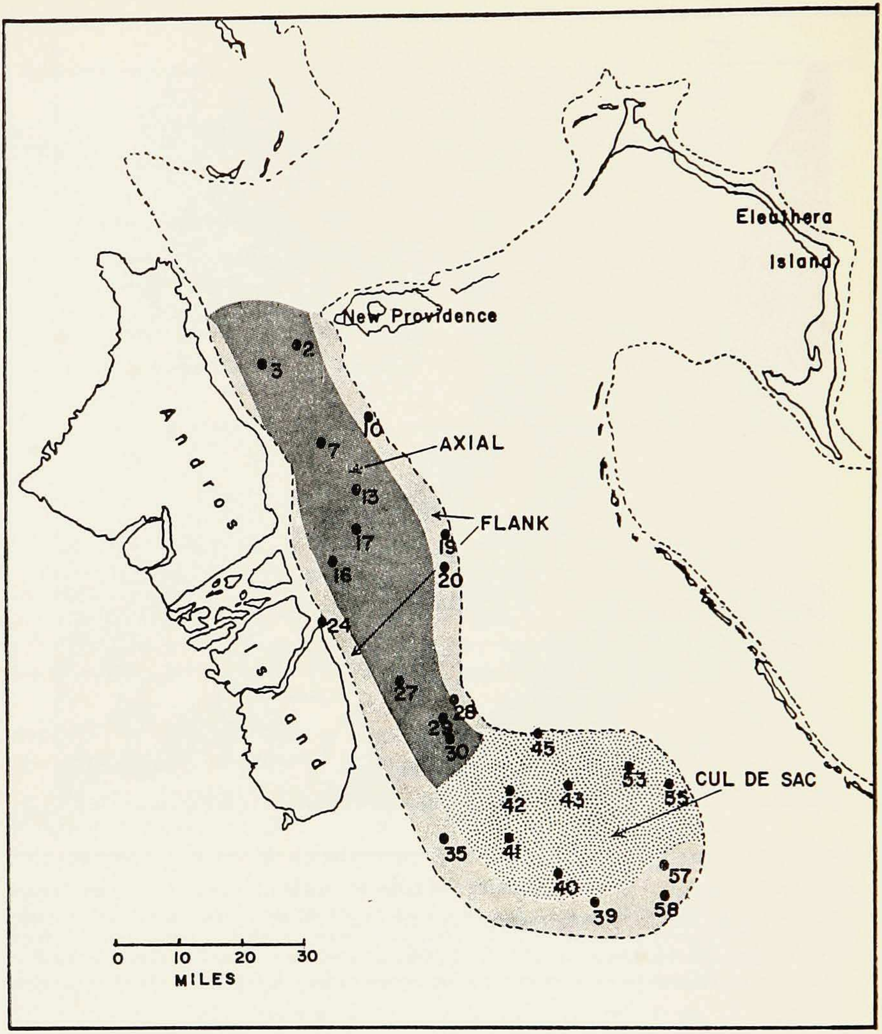

Figure 2. Map showing sample locations, sample numbers, and the outlines of the three sediment provinces discussed in the text.

X-ray diffraction methods. Percentages of aragonite, high magnesium calcite, and low magnesium calcite were determined according to methods described by Pilkey (1964a). The results of these analyses are shown in Figs. 3, 4, and 5.

Results and Discussion. In most samples, the carbonate minerals are dominated by aragonite and high magnesium calcite, and their proportions fall within the range commonly observed in shallow-water carbonate sediments.

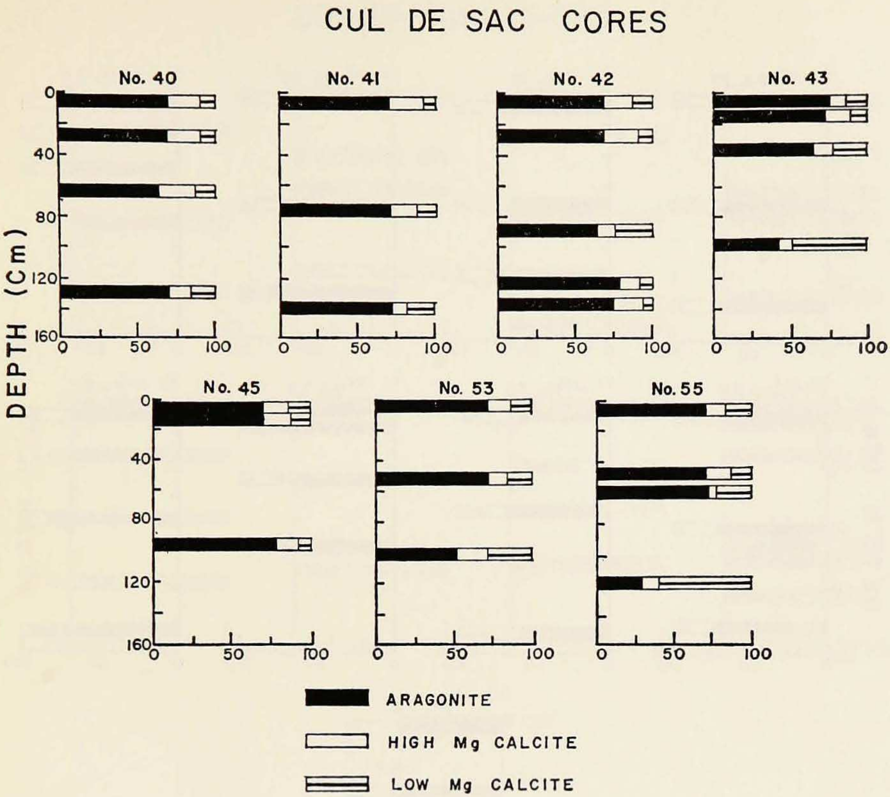

Figure 3. Bar graphs illustrating the carbonate mineralogy of Cul de Sac cores.

Table I. Percent difference of low magnesium calcite in top and bottom core subsamples. Plus designates increase between top and bottom. Minus indicates a decrease in low magnesium calcite between top and bottom.

Flank		Cul de Sac		Axial	
Core no.	Top-bottom difference	Core no.	Top-bottom difference	Core no.	Top-bottom difference
10	−4	40	+5	2	+36
19	−2	41	+9	3	+20
20	−3	42	−7	7	+23
24	−1	43	+16	13	+29
28	−2	45	−7	16	+23
35	+12	53	+10	17	+32
39	0	55	+25	27	−9
57	−7			29	+25
58	0			30	+34

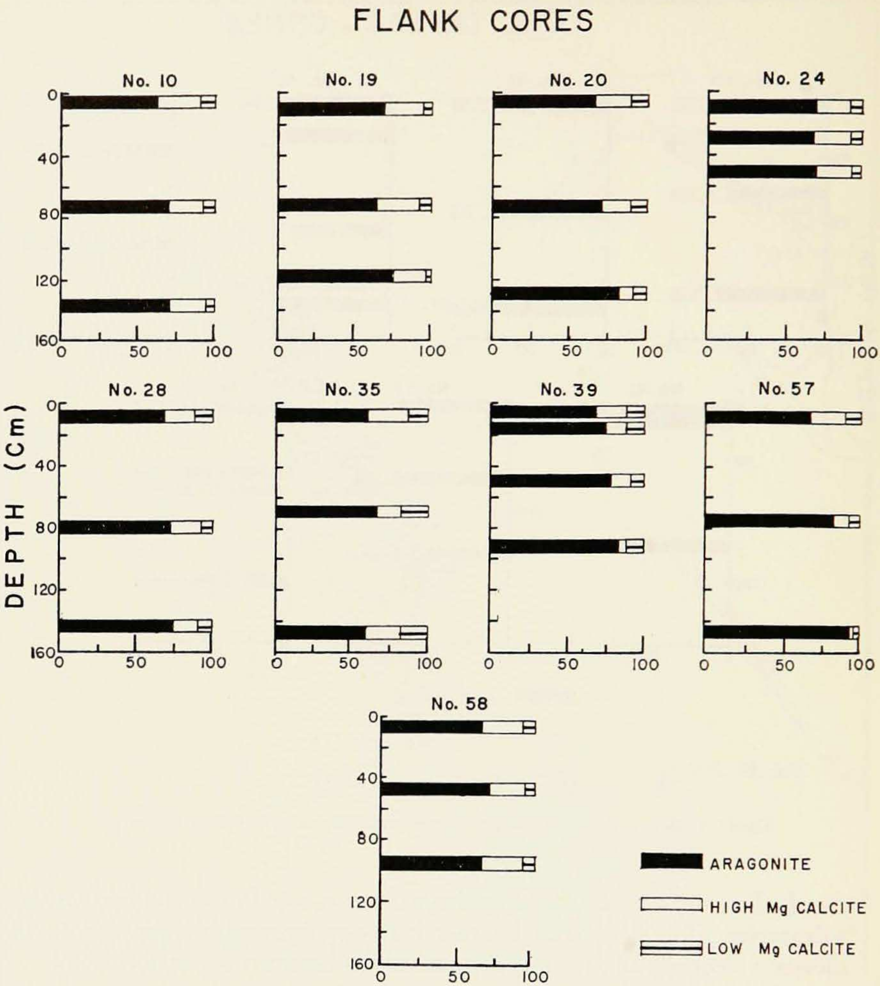

Figure 4. Bar graphs illustrating the carbonate mineralogy of Flank cores.

This range typically is 60% to 80% aragonite, 5% to 20% high magnesium calcite, and 20% or less low magnesium calcite (Stehli and Hower 1961, Chave 1962, and Pilkey 1964b). Previous work has established that low magnesium calcite is the most stable and high magnesium calcite the least stable of the three polymorphs (Stehli and Hower 1961, Chave et al. 1962). Friedman (1965) believes that in deep oceanic waters high magnesium calcite is less soluble than aragonite—the reverse of the shallow-water situation.

Differences in the percentages of low magnesium calcite in the top and bottom subsamples of each core are summarized in Table I. In Figs. 3, 4, and

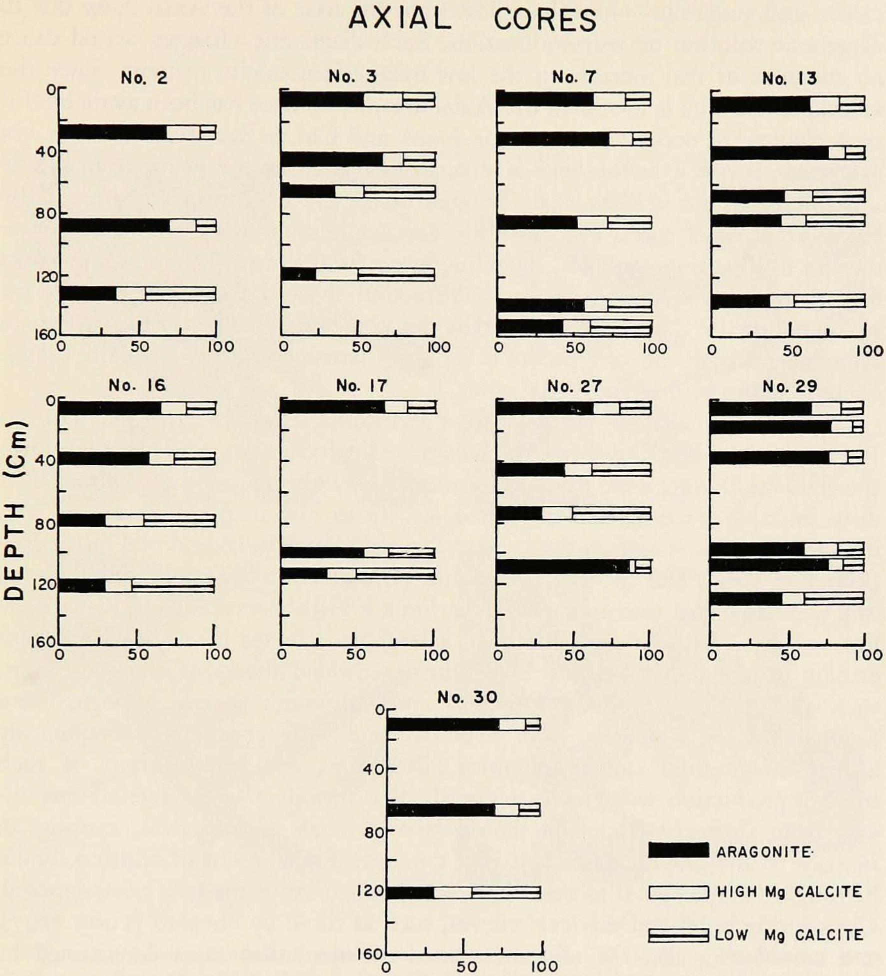

Figure 5. Bar graphs illustrating the carbonate mineralogy of Axial cores.

5 and Table I it is seen that the percentages of the various minerals in Cul de Sac and Flank cores do not vary in any consistent manner from top to bottom. However, a consistent top-to-bottom difference does exist in the Axial cores. Eight out of nine Axial cores contain a larger amount of low magnesium calcite at the bottom than at the top.

There are several possible explanations for the apparent consistent increase in low magnesium calcite at the base of most of the Axial cores as opposed to the lack of any consistent mineralogic trends in Flank and Cul de Sac cores. One possibility is that the unstable carbonate minerals—high magnesium calcite and aragonite—have been lost from the base of the Axial cores due to diagenetic solution or recrystallization. Such diagenetic changes would cause an apparent or real increase in the low magnesium calcite content. Since the sedimentation rate is lowest in the Axial area, more time has been available for such changes to occur relative to the Flank and Cul de Sac areas. That *in situ* diagenesis is not a factor here is strongly indicated by the presence of highly unstable aragonite needles in all Tongue of the Ocean cores, including at the base of the Axial cores. Fig. 6 shows electron microphotographs of aragonite needles from various samples, including some from the adjacent shallow banks for comparative purposes. Electron diffraction showed that these needles are still aragonite. We have concluded that the diagenetic changes in the carbonate minerals probably do not account for the increased low magnesium calcite content at the base of the Axial cores.

A second possibility pertains to Pleistocene sea-level changes. During Pleistocene sea-level lowerings carbonate sediments, such as those that form the Bahama Banks, were exposed to subaerial weathering, and the mineralogically unstable fraction was converted largely to low magnesium calcite. An indication of this is seen in the present-day sedimentary column of Florida Bay (Gorsline 1963) and the Bahama Banks (Cloud 1962). The column consists of a thin layer that unconformably overlies a lithified recrystallized Pleistocene limestone erosion surface. Moreover, a large drop in sea level should increase erosion potential, particularly along the steep-sided flanks of the re-entrant, such as the Tongue of the Ocean. Hence, although normal biological and physicochemical processes were operative and were producing subaqueously a high magnesium calcite-aragonite assemblage, the aerial extent of such organic production was greatly reduced. The introduction of detrital carbonates from the exposed banks should have diluted this material, causing an increase in the low magnesium calcite content. The amount of dilution should be roughly proportional to the relief and aerial extent of the land mass exposed. Considering published sea-level curves, such as those by Shepard (1963: 267), and considering also the aforementioned sedimentation rates determined by Rusnak and Nesteroff (1964), the probable age of the basal core sediment from the Axial area is about synchronous with the peak of the last glacial advance. On the other hand, most of the Flank and Cul de Sac cores do not penetrate sediment of this age.

Conclusions. The two principal explanations for the variation in carbonate mineralogy in Tongue of the Ocean cores are (i) differences in diagenetic effects and (ii) original differences related to sea-level changes. Available evidence favors the latter explanation.

A relationship between carbonate mineralogy and sea level could be of value in identifying glacial and interglacial sediment sequences in moderately deep waters proximal to carbonate banks everywhere. However, an important

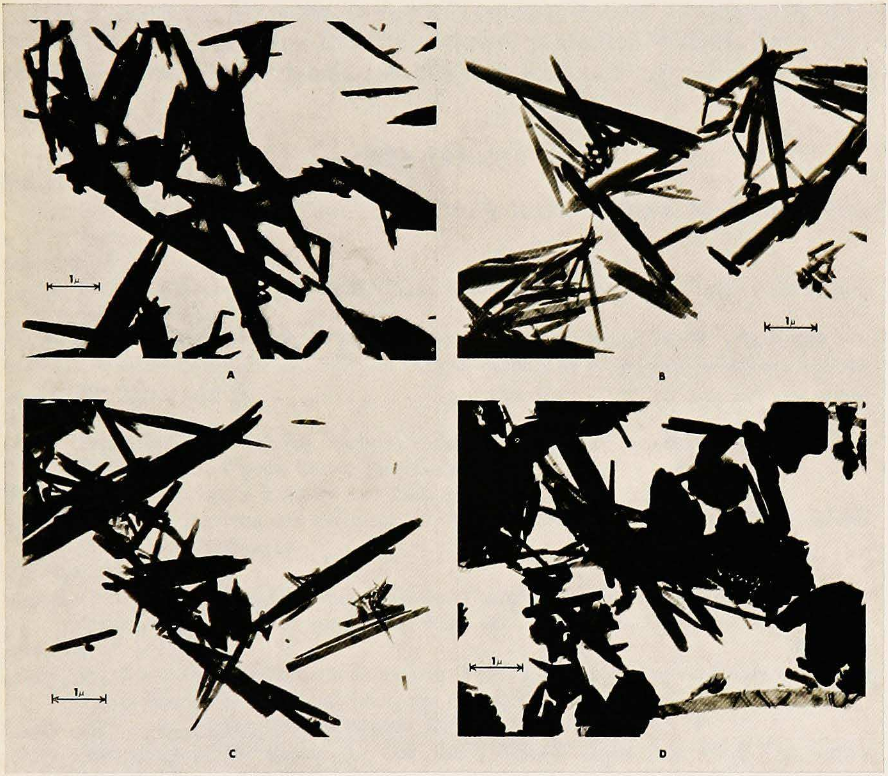

Figure 6. Electron photomicrographs showing aragonite needles X18,600. A, from shallow water west of Andros Island. B, from the Flank area, core No. 57, core depth 142–149 cm. C, from the Cul de Sac area, core No. 42, core depth 134–141 cm. D, from the Axial area, core No. 16, core depth 171–174 cm.

limiting factor in the application of this tool is the effect of differential solution of carbonate minerals with increasing oceanic depths (Friedman 1965).

Further investigation is needed to verify our suggestions. Future studies should require longer piston cores.

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