

Table 1. Rates of accumulation of the South Atlantic deep-sea sediments in three LGO cores.

Yale No.	Sample depth (cm)	Mid-point	Age (yr)	Depth difference	Age difference	Accumulation rate per 1000 yr			
						Total (cm)	Total (g/cm ²)	CaCO ₃ (g/cm ²)	Clay (g/cm ²)
<i>Core V15-142, 44° 33.7' S, 51° 32' W, 5885 m, Argentine Basin*</i>									
	0	0	>0						
Y 1344	23-35	29	10,200±400	29	<10,200	>2.8	>2.7	~0	>2.7
Y 1345	35-50	42.5	12,200±300	13.5	2,000	6.8	6.6	~0	6.6
<i>Core V16-36, 19° 22.5' S, 11° 26.5' W, 3329 m, Mid-Atlantic Ridge†</i>									
	0	0	>0						
Y 1346	2-8	5	5,940±120	5	<5,940	>1.9	>1.3	>1.25	>0.05
Y 1347	23-29	26	19,700±350	21	13,760	0.66	0.47	0.45	0.02
Y 1348	61-71	66	30,100±800	40	10,400	0.38	0.26	0.25	0.01
<i>Core V12-66, 22° 59' S, 07° 01' E, 2759 m, Walvis Ridge‡</i>									
Y 1341	0-5	2.5	4,320±160	21	5,990	3.5	2.52	2.39	0.13
Y 1342	20-27	23.5	10,310±100	80	26,690	3.0	2.16	2.05	0.11
Y 1343	100-107	103.5	37,000±2,000						

* Very low in calcium carbonate; salt free, water free, uncompressed density is 0.97 g/cm³ (20- to 21-cm interval). † Top of core has 96 percent CaCO₃; salt free, water free, uncompressed density is 0.69 g/cm³ (38- to 41-cm interval). ‡ Top of core has 95.1 percent CaCO₃; salt free, water free, uncompressed density taken as 0.72 g/cm³.

any segment of a core was used for the entire length sampled of that core.

The results are presented in Table 1.

Although the rates of clay accumulation in the Argentine Basin core are the highest of the three southern Atlantic cores studied, they are not much higher than some rates in the northwestern Atlantic (1). The clay-accumulation rate at Walvis Ridge is as low as the lowest figures found for the north and equatorial Atlantic.

The lowest clay-accumulation rates found to date in the Atlantic Ocean by the method of radiocarbon dating are

those in V16-36. An average rate of about 0.03 g/cm² per 1000 years is one-tenth the average rates for the Mid-Atlantic and eastern Atlantic areas at the equator and north.

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References and Notes

1. K. K. Turekian, *Trans. N.Y. Acad. Sci.* **26**, 312 (1964).
2. Supported by NSF grants.
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Electrolytic Conductance of Sea Water: Effect of Calcium Carbonate Dissolution

Abstract. Calcium carbonate dissolution in the presence of excess carbon dioxide increased the specific conductance of sea water by approximately 6×10^{-5} ohm⁻¹cm⁻¹ per millimole of carbonate dissolved. The observed conductance increase can be explained by the partial equivalent conductance of calcium bicarbonate and by the hindrance effect of uncharged carbon dioxide dissolved in sea water.

Oceanographers use the electrical conductance of sea water to estimate its density and salinity. In order to understand how certain factors may alter the conductance, we previously studied the partial equivalent conductances of electrolytes in sea water (1) and the effect of carbon dioxide on the

electrolytic conductance of sea water (2). Since calcium carbonate precipitation and dissolution are active processes occurring in the oceans, the effect of calcium carbonate dissolution on the conductance of sea water is of interest.

For this experiment, 200-ml samples

of sea water with a chlorinity of 19.7 parts per thousand and a carbonate alkalinity of 2.55 meq/liter were mixed with 1 gram of oolite (aragonite). In order to facilitate the dissolution of the carbonate, the mixtures were equilibrated with varying amounts of carbon dioxide gas for 5 days. A temperature-compensated inductive (electrodeless) conductivity and salinity meter, a-c, 10 kcy/sec oscillation (3), was used to measure the relative conductances of the samples at room temperature (23°C). Concurrently, the pH and alkalinity were determined. The amount of dissolution of calcium carbonate was calculated from the increase in alkalinity. The conductance of the sea water sample without any addition of carbon dioxide gas was arbitrarily taken as 1.0000.

Figure 1 shows the changes in pH and electrical conductance with calcium carbonate dissolved. The pH decreased from nearly 8 to 6. The conductance increased about 0.12 percent per millimole of calcium carbonate dissolved.

In the presence of excess carbon dioxide (carbonic acid) the carbonate ion resulting from the dissolution of calcium carbonate crystal reacts with carbon dioxide to form bicarbonate ion. Thus, the observed conductance increase is due to the addition of calcium bicarbonate to sea water.

The partial equivalent conductance of calcium bicarbonate in sea water is not reported, but it can be estimated from earlier data (1). For sea water with a chlorinity of 19.4 parts per thousand at 23°C, values of 90 ohm⁻¹cm² per equivalent for sodium chloride, 78 for calcium chloride, and 47 for sodium bicarbonate were obtained.

From these values, the calculated partial equivalent conductance of calcium bicarbonate in sea water is 35 ohm⁻¹cm² per equivalent. The dissolution of one millimole of calcium carbonate crystal into dissolved calcium bicarbonate, therefore, should increase the specific conductance by 7×10^{-5} ohm⁻¹cm⁻¹. Since the specific conductance of the sea water was about 0.05 ohm⁻¹cm⁻¹, the dissolution of one millimole of calcium carbonate should change the conductance by about 0.14 percent (Fig. 1).

In addition, in the presence of excess carbon dioxide, the carbonate ion present initially will transform into bicarbonate ion. Sodium carbonate and

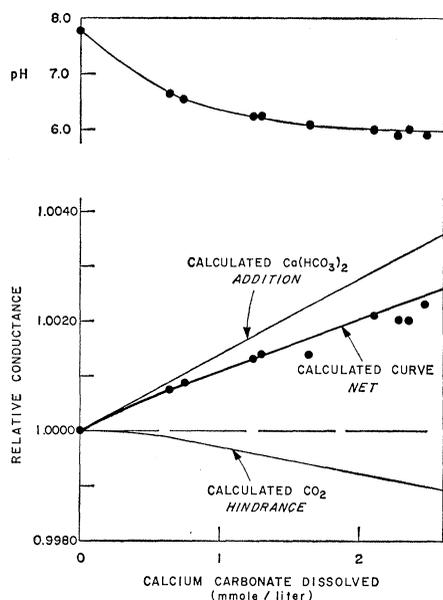


Fig. 1. Changes in pH and electrical conductance of sea water with calcium carbonate dissolution.

bicarbonate conductance data (1) may be used to show that replacing one equivalent of carbonate by bicarbonate will increase the specific conductance by $2.4 \times 10^{-2} \text{ ohm}^{-1}\text{cm}^{-1}$ (2). Since the initial carbonate ion concentration was calculated to be only 13×10^{-5} mole/liter, the maximum specific conductance change by the transformation would be $6 \times 10^{-6} \text{ ohm}^{-1}\text{cm}^{-1}$, which is 0.01 percent of the specific conductance of the sea water. This transformation effect is much smaller than the calcium bicarbonate effect on the conductance.

The effect of uncharged carbon dioxide on the decrease in conductance (4) was reported to be approximately 0.013 percent per millimole of carbon dioxide in a liter of sea water (2). In this experiment, the molecular carbon dioxide concentration was calculated from the carbonate alkalinity, the pH , and the apparent dissociation constants of carbonic acid in sea water. Independent gas chromatographic determination of total carbon dioxide (5), instead of carbonate alkalinity, gave similar calculated values for the concentration of molecular carbon dioxide. The calculated decrease in conductance due to the addition of uncharged carbon dioxide is shown in the lower part of Fig. 1 as a function of calcium carbonate dissolved.

The net conductance change by this experiment is the summation of the three effects already described. This is shown by the calculated net curve in

Fig. 1. The observed values agree fairly well with the calculated curve.

In the world oceans, specific alkalinity (the ratio of alkalinity to chlorinity) generally increases with depth, and has a range of about 0.12 to 0.13 meq/g (6). If we assume the observed specific alkalinity increase is mainly due to the dissolution of calcium carbonate (7), then the maximum dissolution of carbonate is about 0.1 millimole per liter of sea water for deep sea water.

The pH of sea water is generally in the range of 7.6 to 8.3. In the deep sea, the pH range narrows to below 8. At such pH , most of the carbonate ion formed from the dissolution of calcium carbonate is transformed into bicarbonate. Therefore, the conductance increase from the carbonate dissolution can be interpreted as the introduction of calcium bicarbonate into sea water. The effect of uncharged carbon dioxide may be neglected because it is quite small at pH near 8. The maximum conductance change due to the dissolution of calcium carbonate in the present oceans, therefore, may be as large as 0.014 percent of the conductance of sea water. When conductivity measurements are used to

estimate salinity, this calculated change will correspond to about 0.006 parts per thousand.

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References and Notes

1. K. Park, *Deep-Sea Res.*, in press.
2. K. Park, P. K. Weyl, A. Bradshaw, *Nature* **201**, 1283 (1964).
3. N. L. Brown and B. V. Hamon, *Deep-Sea Res.* **8**, 65 (1961).
4. The exact mechanism of the effect of uncharged carbon dioxide on the conductance of sea water has not been elucidated experimentally. In earlier paper (2), we attempted to explain the mechanism by partial molar volume of carbon dioxide.
5. K. Park, G. H. Kennedy, H. H. Dobson, *Anal. Chem.* **36**, 1686 (1964).
6. F. F. Koczy, *Deep-Sea Res.* **3**, 279 (1956).
7. Most of calcium carbonate deposition in the world oceans is biological. Therefore the dissolution of organogenic calcium carbonate is not a simple process, since most carbonate crystals are embedded in organic matter. However, increase in specific alkalinity in deep sea appears mainly due to the dissolution of carbonate, which is supported by disappearance of calcium carbonate crystals with increase of depth. J. Murray and J. Højort [*The Depth of the Oceans* (Macmillan, London, 1912), p. 173] observed that approximately 90 percent of the calcium carbonate deposit from the shell of pelagic organisms remain in the deposit around a depth of 1500 m, 66 percent at 3500 m, 20 percent at 5000 m, and 1 percent at 7000 m, respectively. Their observation indicates that organogenic calcium carbonate is being dissolved in deep sea.
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Guinea Fracture Zone in the Equatorial Atlantic

Abstract. *The east-west Guinea fracture zone is situated off Sierra Leone, West Africa. The estimated topographic left lateral displacement is about 230 kilometers. This fracture zone is the eastern analog of the Vema fracture zone, with its associated troughs, and of the Barracuda Fault. The Guinea fracture zone marks the northern boundary of the African coast of a wide zone of left lateral shear in the equatorial Atlantic.*

Fracture zones characterize the eastern Pacific (1, 2), and it has been reported (3, 4) that in the Atlantic there are fracture zones in the region

of the Mid-Atlantic Ridge, especially near the Equator. Heezen *et al.* (3) postulate that the Mid-Atlantic Ridge has been offset in a left lateral direction

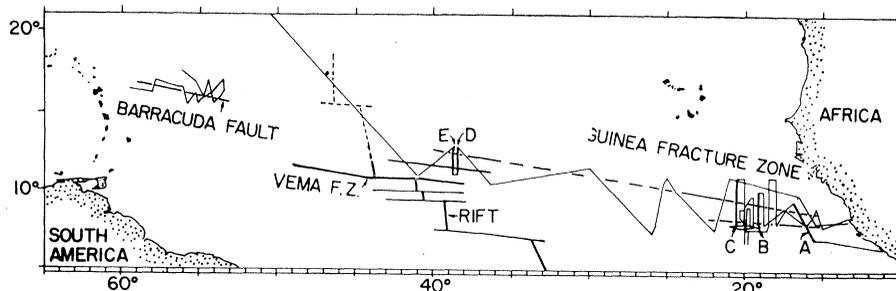


Fig. 1. Some of the structures in the equatorial region of the Atlantic Ocean. Lines at the Guinea fracture zone show approximate limits of this zone. Lines near Vema fracture zone show additional troughs along the north-south rift in the crest of the Mid-Atlantic Ridge. Lines are dashed where uncertain. Survey tracks of the R.V. Trident are shown. Letters refer to the profiles shown in Fig. 3.