21. INTERSTITIAL WATER STUDIES ON SMALL CORE SAMPLES,[1] DEEP SEA DRILLING PROJECT: LEG 10

Frank T. Manheim, U.S. Geological Survey, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
Fred L. Sayles and Lee S. Waterman, Department of Chemistry, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

ABSTRACT

Leg 10 interstitial water analyses provide new indications of the distribution of rock salt beneath the floor of the Gulf of Mexico, both confirming areas previously indicated to be underlain by salt bodies and extending evidence of salt distribution to seismically featureless areas in the Sigsbee Knolls trend and Isthmian Embayment. The criterion for presence of salt at depth is a consistent increase in interstitial salinity and chlorinity with depth.

Site 86, on the northern margin of the Yucatan Platform, provided no evidence of salt at depth. Thus, our data tend to rule out the suggestion of Antoine and Bryant (1969) that the Sigsbee Knolls salt was squeezed out from beneath the Yucatan Scarp. Cores from Sites 90 and 91, in the central Sigsbee Deep, were not obtained from a great enough depth to yield definite evidence for the presence of buried salt.

INTRODUCTION

Materials cored at Leg 10 sites consist largely of rapidly deposited Tertiary marly sediments. One of the chief areas of interest in the Gulf of Mexico is the documented presence of salt at depth, both under the northern margin of the gulf (Uchupi and Emery, 1968; Murray, 1966; Paine and Meyerhoff, 1970; Lehner, 1969) and in the Sigsbee Knolls area (Burk et al., 1969, and references cited therein).

Study of pore fluids in DSDP Leg 1 cores (Manheim and Sayles, 1970, and references cited therein) extended the previous study of pore fluids from the northern margin of the gulf (Manheim and Bischoff, 1969) and demonstrated that diffusion of salt establishes a characteristic salinity and chlorinity gradient in sediments that lie above rock salt. Where enough geologic time has elapsed, the presence of salt more than 3 km below the lowest penetrated horizon can be established by pore fluid studies. This happened in the case of Site 3, where the hole bottomed at 620 meters, while seismic basement was estimated to be 4000 meters below the sea floor (J.L. Worzel, oral communication). The age of the presumed salt layer is Jurassic, correlative with the Louann and Salinas salt of the northern gulf provinces and Isthmian Salt Embayment, respectively.

Of the twelve sites of Leg 10 from which core material was obtained, five showed evidence of increase in interstitial salinity and chlorinity, while four showed no significant increase in salinity with depth. Three sites (90, 91, and 97) showed slight increases in chlorinity and salinity, but not sufficiently large to permit any conclusions about the presence of salt at depth.

Analytical methods follow those employed in previous leg reports by the Woods Hole group. The major and minor element pore water data are given in Tables 1 and 2 respectively. We should point out that there is a possibility of loss of alkalinity and calcium during transport of samples to this laboratory owing to precipitation of calcium carbonate in the heat-sealed plastic pipes used to store pore fluid squeezed on board ship. This may account for some erratically low values of calcium in the upper parts of the sediment column, although other elements are not appreciably affected. Another factor to be considered is an increase in potassium values and decrease in magnesium values for samples that were seqeezed on board ship at a presumably higher than in situ temperature. Based on the results of Sayles et al. (in press) for sediments from the Caribbean Sea, the expected change in concentration would be up to +0.05 g/kg for K and −0.07 g/kg for Mg on warming from 4° to 23° C.

Warming of the samples before squeezing has also been shown to substantially increase silica concentration in interstitial water (Fanning and Pilson, 1971; Sayles et al., in press), and the values shown in Table 2 are therefore likely to be too high. Special laboratory difficulties (in Leg 10 samples) probably account for the poorer than usual agreement between cation and anion sums (Table 1). We do not however, believe that the artifacts discussed above materially affect the major trends in ionic composition.

[1]Contribution No. 2919 of the Woods Hole Oceanographic Institution. Publication approved by the Director, U.S.G.S.

TABLE 1
Major Constituents of Pore Fluids. Values in g/kg Fluid Unless Otherwise Indicated[a]

Sample Designation	Depth (m)	Age	Description	Na[b]	Na[c]	K	Ca	Mg	Total Cations (meq/kg)	Cl	SO_4	Alk. (meq/kg)	HCO_3[d]	Total Anions (meq/kg)	Sum[e]	Refractometer	H_2O[f] (‰)	pH
Hole 85 (22°50.5′N, 91°25.4′W, water depth 3749 m, seaward of Campeche Scarp)																		
1-4	33	Middle Pleistocene	Gray mud with some laminae of nanno-rich mud.	10.5	10.2	0.24	0.61	1.18	579	19.8	1.48 (1.43)[g]	4.3	0.26	591	34.0	34.2	38	7.5
2-3	61	Middle Pleistocene	Gray mud with some deformed silt/sand laminae.	10.9	10.6	0.22	0.42	1.06	573	20.6	0.06	8.2	0.50	588	33.7	34.0	–	7.5
3-2	111	Middle Pleistocene	Gray mud with quartz silt laminae; strongly disturbed.	11.9	11.8	0.33	0.48	1.26	649	22.7	(0.49)	5.3	0.33	656	37.5	38.0	–	8.2
Hole 86 (22°52.5′N, 90°57.8′W, water depth 1481 m, Campeche Scarp)																		
1-2	16	Pleistocene	Greenish gray, clayey foram-coccolith ooze.	10.9	–	0.45	0.41	1.23	–	19.4	2.68	3.3	0.20	604	35.2	35.2	47	7.9
3-5	167	Late Middle Pliocene	Greenish gray, clayey coccolith ooze; some forams.	10.8	–	0.42	0.23	0.78	–	19.1	0.51	6.0	0.36	554	32.2	32.7	–	7.6
4-5	262	Earliest Pliocene	Greenish gray, clayey coccolith ooze; some forams; hard beds of coccolith ooze.	11.0	–	0.43	0.38	0.85	–	19.5	1.06	4.0	0.25	574	33.4	33.1	–	7.6
Hole 88 (21°22.9′N, 94°00.2′W, water depth 2532 m, Sigsbee Knolls area)																		
1-4	5	Pleistocene	Greenish gray, clayey foram-coccolith ooze; H_2S odor.	11.0	10.8	0.45	0.31	1.21	594	19.7	2.03	6.8	0.42	604	35.1	35.2	–	7.9
2-3	54	"Early Late" Pleistocene	Greenish gray, clayey coccolith ooze; some forams, mottled; slight H_2S odor.	12.8	12.5	0.42	0.24	0.86	637	22.7	0.12	6.1	0.37	649	37.5	37.1	37	7.5
4-5	108	Late Pliocene	Greenish gray, clayey foram-coccolith ooze; gassy.	14.6	14.5	0.39	0.52	0.91	743	26.4	0.03	3.3	0.20	748	42.9	42.9	–	7.4
5-6	135	Middle Pliocene	Grayish green, clayey coccolith ooze; some forams; gassy.	(15.2)	–	0.37	0.58	0.92	–	27.2	0.37	–	–	775	–	44.3	–	7.1
Hole 89 (20°53.4′N, 90°06.7′W, water depth 3067 m, Bay of Campeche)																		
1-3	3	Late Pleistocene	Olive brown, clayey foram-coccolith ooze.	10.8	10.6	0.43	0.39	1.21	591	19.4	2.33	2.4	0.15	598	34.7	34.8	–	7.6
3-3	121	Early Pleistocene	Greenish gray, foram-coccolith ooze; some clay and ash; gassy.	13.5	–	0.42	0.35	1.24	–	25.2	0.02	6.3	0.38	718	41.2	41.2	–	7.4
4-4	224	Middle Pliocene	Greenish gray clayey foram-coccolith ooze; ash filled burrows; gassy.	15.7	15.6	0.40	0.93	1.62	866	30.8	0.11	1.2	0.07	870	49.5	50.6	–	7.4
Hole 90 (23°47.8′N, 94°46.1′W, water depth 3713 m, Sigsbee Plain)																		
1-6	7	Late Pleistocene	Olive gray mud with some forams and coccoliths; disturbed.	11.0	–	0.42	0.39	1.15	–	19.5	2.39	5.1	0.31	603	35.1	35.1	–	7.6
2-3	73	Late Pleistocene	Dark olive gray mud.	10.8	–	0.28	0.21	0.90	–	19.6	0.22	5.6	0.34	561	32.3	31.9	–	7.5

TABLE 1 – *Continued*

Sample Designation	Depth (m)	Age	Description	Na[b]	Na[c]	K	Ca	Mg	Total Cations (meq/kg)	Cl	SO_4	Alk. (meq/kg)	HCO_3[d]	Total Anions (meq/kg)	Sum[e]	Refractometer	H_2O[f] (‰)	pH
3-3	133	Early Pleistocene	Olive gray greenish coccolith rich mud/clay; severely mottled.	11.0	–	0.25	0.27	0.86	–	19.9	0.22	3.0	0.19	568	32.7	32.7	–	7.7
5-3	238	Late Miocene	Greenish gray mud/clay brecciated.	11.2	–	0.24	0.37	0.87	–	19.8	0.71 (1.21)	2.7	0.16	576	33.7	33.8	27	7.9
Hole 91 (23°46.4′N, 93°20.8′W, water depth 3763 m, Sigsbee Plain)																		
1-4	65	Late Pleistocene	Olive gray mud and silty mud faintly laminated.	10.4	10.2	0.22	0.39	1.01	550	19.7	0.04	4.3	0.26	560	32.0	32.0	28	7.6
2-4	127	Late Pleistocene	Olive gray sandy mud.	10.8	–	0.26	0.34	0.76	–	19.5	0.22	4.9	0.30	557	32.1	31.9	33	7.6
3-5	167	Late Pleistocene	Olive gray silty to sandy mud interbedded with sand beds.	(11.5)	–	0.21	0.34	0.82	–	20.0	(1.08)	2.7	0.17	590	34.2	34.0	–	7.4
9-6	538	Late Pliocene	Gray silty to fine sand.	(11.6)	–	0.25	0.30	0.73	–	19.8	(1.37)	2.2	0.14	587	34.2	(31.8)	26	8.0
Hole 92 (25°50.7′N, 91°49.3′W, water depth 2573 m, edge of Sigsbee Scarp)																		
2-5	35	Late Pleistocene	Brown gray to olive gray silty mud and mud; faintly laminated.	10.7	(10.0)	0.19	0.71	1.23	578	20.2	1.65	3.6	0.22	608	34.9	35.5	–	7.0
3-5	92	Late Pleistocene	Olive gray silty mud faintly laminated.	12.5	12.7	0.17	0.80	1.46	718	24.9	0.15	3.1	0.19	706	40.1	41.8	–	6.3
4-5	131	Late Pleistocene	Brownish gray silty mud and mud.	18.4	18.5	0.27	0.97	1.82	1010	35.6	<0.2	1.9	0.11	(1007)	57.4	59.4	22	6.4
5-5	180	Late Pleistocene	Brownish gray silty mud and clay.	27.3	28.4	0.42	0.89	1.59	1421	47.0	2.06	3.3	0.20	1371	79.4	79.8	20	7.0
6-cc	233	Early Pleistocene	Dark olive gray silty clay and mud; very thin quartz laminae.	64.0	64.8	0.44	0.84	1.15	2964	102.2	2.30	2.4	0.15	2929	171.1	170.5	–	6.9
Hole 94 (24°31.6′N, 88°28.2′W, water depth 1793 m, Campeche Scarp)																		
1-2	2	Late Pleistocene	Pinkish to greenish gray foram-coccolith ooze.	10.7	10.6	0.46	0.40	1.23	595	19.4	2.37	4.2	0.26	599	34.8	32.5	–	7.8
2-4	57	Late Pleistocene	Light greenish gray foram-coccolith ooze; mottled; H_2S odor.	11.0	10.7	0.45	0.29	1.12	582	19.5	1.87	7.4	0.45	596	34.7	34.4	–	7.4
3-4	105	Middle Pliocene	Light greenish gray foram-coccolith ooze.	10.9	10.6	0.44	0.35	1.04	576	19.5	1.52	8.9	0.54	589	34.2	34.1	–	7.2
4-3	132	"Late Early" Pliocene	Very light greenish gray foram-coccolith ooze; H_2S odor.	11.1	10.0	0.39	0.29	0.96	539	19.4	1.66 (1.56)	3.4	0.20	586	34.0	34.1	–	7.2
5-4	173	Early Pliocene	Light greenish gray foram-coccolith ooze; slight H_2S odor.	11.0	–	0.44	0.44	0.95	–	19.3	1.74	6.5	0.40	587	34.3	34.1	–	7.4
6-4	211	Early Pliocene	Light greenish gray foram-coccolith ooze.	10.9	–	0.45	0.39	1.00	–	19.4	1.61	6.6	0.40	586	34.1	34.2	–	7.4
7-4	247	Late Miocene	Light greenish gray foram-coccolith ooze.	10.8	10.7	0.46	0.42	1.03	584	19.4	1.74	5.5	0.34	587	34.2	34.1	–	7.4

TABLE 1 – *Continued*

Sample Designation	Depth (m)	Age	Description	Na[b]	Na[c]	K	Ca	Mg	Total Cations (meq/kg)	Cl	SO_4	Alk. (meq/kg)	HCO_3[d]	Total Anions (meq/kg)	Sum[e]	Refractometer	H_2O[f] (‰)	pH
10-3	334	Late Oligocene	Very light greenish gray foram-coccolith ooze.	–	–	0.46	0.45	–	–	19.4	2.24	3.4	0.21	597	–	34.5	–	7.4
11-3	367	Late Oligocene	Greenish white foram-coccolith ooze.	10.9	–	0.44	0.46	1.06	–	19.4	2.20	2.9	0.18	595	34.6	34.1	–	7.5
Hole 95 (24°09.0'N, 86°23.8'W, water depth 1633 m, Campeche Scarp)																		
2-5	88	"Early Late" Oligocene	Greenish white foram-coccolith ooze, mottled.	10.8	10.8	0.44	0.48	1.16	600	19.5	2.42	3.5	0.22	603	35.0	34.6	–	7.4
3-6	130	"Early Late" Oligocene	Light greenish white foram-coccolith ooze; mottled.	10.9	10.7	0.44	0.50	1.15	596	19.5	2.51	3.6	0.22	604	35.2	34.9	35	7.5
5-4	205	Early Oligocene	Very light greenish white chalk.	10.8	–	0.42	0.54	1.13	–	19.5	2.61	3.1	0.19	607	35.2	35.2	–	7.5
Hole 95 (23°44.6'N, 85°45.8'W, water depth 3439 m, Yucatan Channel)																		
1-6	109	Late Pleistocene	Olive gray terrigenous mud and clay.	10.6	10.3	0.25	0.71	1.12	584	19.4	2.24	5.2	0.32	597	34.6	35.2	36	7.4
2-4	203	"Early Late" Oligocene	Light greenish gray foram-coccolith ooze.	10.8	10.5	0.44	0.58	1.16	593	19.6	2.33	5.0	0.30	604	35.2	35.2	–	7.4
Hole 97 (23°53.0'N, 84°26.7'W, water depth 2930 m, Yucatan Channel)																		
2-4	109	Late Miocene	Light greenish gray foram-coccolith ooze; some clay.	(11.7)	–	0.44	0.52	0.82	–	20.2	2.00	3.8	0.23	615	35.9	35.2	30	7.2
3-3	144	Late Miocene	Light greenish gray foram-coccolith ooze; some clay.	11.3	–	0.42	0.58	1.07	–	20.4	1.88	5.2	0.32	620	36.0	36.0	–	7.3

[a]Refractometer indicates total salt content determined in laboratory on fluid from tubes sealed on board ship. The refractive index is related to salt content using standard seawater relationships ($S = (N - N_{water}) \times 0.550$). Total cations do not include ammonia, which was not determined, nor minor constituents. Replicate values in parenthesis.

[b]Na determined by difference between total anions and cations except Na. This value is generally more accurate than that referred to in e).

[c]Na determined directly by atomic absorption.

[d]Calculated from total alkalinity assuming that all alkalinity is in the form of bicarbonate.

[e]Includes Na' (sodium by difference).

[f]Shipboard determination on samples near that used for extraction of fluid.

TABLE 2
Minor Constituents. Values in mg/kg. Si(col) Refers to Silica Determined Colorimetrically

Sample Designation	Depth (m)	Age	Description	Sr	Ba	Si (col.)
Hole 85						
1-4	33	Middle Pleistocene	Gray mud with some laminae of Nanno-rich mud.	13	<0.2	1.4
2-3	61	Middle Pleistocene	Gray mud with some deformed silt/sand laminae.	12	2.0	–
3-2	111	Middle Pleistocene	Gray mud with quartz silt laminae; strongly disturbed.	13	2.3	10.0
Hole 86						
1-2	16	Pleistocene	Greenish gray, clayey foram-coccolith ooze.	10	<0.2	4.9
3-5	167	Late Middle Pliocene	Greenish gray, clayey coccolith ooze; some forams.	72	<0.2	1.0
4-5	262	Earliest Pliocene	Greenish gray, clayey coccolith ooze; some forams; hard beds of coccolith ooze.	64	0.2	7.5
Hole 88						
1-4	5	Late Pleistocene	Greenish gray, clayey foram-coccolith ooze; H_2S odor.	8	<0.2	8.4
2-3	54	"Early Late" Pleistocene	Greenish gray, clayey coccolith ooze; some forams, mottled; slight H_2S odor.	20	10.0	8.4
4-5	108	Late Pliocene	Greenish gray, clayey foram-coccolith ooze; gassy.	22	13.0	3.2
5-6	135	Middle Pliocene	Grayish green, clayey coccolith ooze; some forams; gassy.	29	3.0	–
Hole 89						
1-3	3	Late Pleistocene	Olive brown, clayey foram-coccolith ooze.	9	<0.2	4.2
3-3	121	Early Pleistocene	Greenish gray, foram-coccolith ooze; some clay and ash; gassy.	24	14.0	4.2
4-4	224	Middle Pliocene	Greenish gray clayey foram-coccolith ooze; ash filled burrows; gassy.	40	–	2.5
Hole 90						
1-6	7	Late Pleistocene	Olive gray mud with some forams and coccoliths; disturbed.	(12)	0.2	11.5
2-3	73	Late Pleistocene	Dark olive gray mud.	11	3.3	4.5
3-3	133	Early Pleistocene	Olive grayish greenish coccolith rich mud/clay; severely mottled.	(16)	(~4)	3.8
5-3	238	Late Miocene	Greenish gray mud/clay brecciated.	(16)	0.3	2.9
Hole 91						
1-4	65	Late Pleistocene	Olive gray mud and silty mud faintly laminated.	12	1.3	10.5
2-4	127	Late Pleistocene	Olive gray sandy mud	11	1.1	5.0
3-5	167	Late Pleistocene	Olive gray silty to sandy mud interbedded with sand beds.	14	0.5	–
9-6	538	Late Pliocene	Gray silty to fine sand	21	1.6	5.6
Hole 92						
2-5	35	Late Pleistocene	Brown gray to olive gray silty mud and mud; faintly laminated.	16	0.2	14.6
3-5	92	Late Pleistocene	Olive gray silty mud faintly laminated.	13	3.1	7.2
4-5	131	Late Pleistocene	Brownish gray silty mud and mud.	31	6.5	1.8
5-5	180	Late Pleistocene	Brownish gray silty mud and clay.	–	<0.2	9.9
6-cc	233	Early Pleistocene	Dark olive gray silty clay and mud; very thin quartz laminae.	20	<0.2	6.1
Hole 94						
1-2	2	Late Pleistocene	Pinkish to greenish gray foram-coccolith ooze.	16	0.2	12.3
2-4	57	Late Pleistocene	Light greenish gray foram-coccolith ooze; mottled; H_2S odor.	(59)	<0.2	17.5
3-4	105	Middle Pliocene	Light greenish gray foram-coccolith ooze	85	<0.2	19.0
4-3	132	"Late Early" Pliocene	Very light greenish gray foram-coccolith ooze; H_2S odor.	67	<0.2	17.0
5-4	173	Early Pliocene	Light greenish gray foram-coccolith ooze; slight H_2S odor.	58	<0.2	24.7
6-4	211	Early Pliocene	Light greenish gray foram-coccolith ooze.	59	<0.2	22.2
7-4	247	Late Miocene	Light greenish gray foram-coccolith ooze.	(65)	<0.2	23.2
10-3	334	Late Oligocene	Very light greenish gray foram-coccolith ooze.	42	<0.2	29.4
11-3	367	Late Oligocene	Greenish white foram-coccolith ooze.	33	<0.2	25.1
Hole 95						
2-5	88	"Early Late" Oligocene	Greenish white foram-coccolith ooze, mottled.	18	<0.2	23.8
3-6	130	"Early Late" Oligocene	Light greenish white foram-coccolith ooze; mottled.	(15)	<0.2	21.9
5-4	205	Early Oligocene	Very light greenish white chalk.	–	<0.2	–
Hole 96						
1-6	109	Late Pleistocene	Olive gray terrigenous mud and clay.	18	<0.2	11.4
2-4	203	"Early Late" Oligocene	Light greenish gray foram-coccolith ooze.	21	<0.2	20.9
Hole 97						
2-4	109	Late Miocene	Light greenish gray foram-coccolith ooze; some clay.	56	<0.2	22.2
3-3	144	Late Miocene	Light greenish gray foram-coccolith ooze; some clay.	(53)	<0.2	20.4

RESULTS

Site 85

This site, seaward of the Campeche Scarp, shows an increase in chlorinity from 19.8 to 22.7 per cent at 111 meters (middle Pleistocene gray mud). Given the rapid sedimentation rate, the 15 per cent increase in chlorinity strongly suggests salt at depth, even though no diapiric structures are present. Sulfate is strongly depleted, with an accompanying increase in bicarbonate alkalinity. K and Mg are both strongly depleted. These changes are expected for clayey muds. However, in the lowest sample (111 m) there is an increase in K, Mg, and sulfate, which may possibly reflect influence of dissolved evaporitic materials and dolomite diffusing up through the section.

Site 86

Located on the edge of the Yucatan Platform, this site is significant because there are no signs of chloride increase with depth. There is substantial depletion in Mg and marked enrichment in Sr (to 72 ppm). These reflect the recrystallization of coccolith and foraminiferal ooze, similar to that observed on Legs 7 and 8 in the equatorial Pacific. Unfortunately, no samples were taken from below 262 meters to the total depth of 686 meters; however, the early Pliocene age of the lowest sample, and the relative thinness of sediment between it and inferred Jurassic, should have allowed the formation of a discernible chlorinity gradient were buried salt present.

Site 88

Clayey coccolith oozes yielded pore fluids that increase in salinity with depth, indicating the presence of salt. This can be deduced from the rise in chlorinity from 19.7 to 27.2 per cent at 135 meters. As at Site 85, strong intermediate sulfate depletion, with a modest increase in the deepest core, suggests the possibility that sulfate of evaporitic origin may be involved. Large (to 13 ppm) concentrations of Ba occur in the sulfate-depleted sections. The site was on a diapiric knoll in the Sigsbee Salt Dome Province; salt was expected to occur at the seismic basement at about 300 meters.

Site 89

Although no diapiric structure is present beneath the site, and it is located in the Bay of Campeche outside the salt area postulated by Antoine and Bryant (1969), the chlorinity gradient suggests salt at depth. A chlorinity maximum of 30.8 per cent was obtained at 224 meters in gassy middle Pliocene clayey foram-coccolith oozes, and Mg is concentrated to 1.62 g/kg; this possibly reflects the influence of evaporitic materials or diagenetic reactions related to them. The hole was abandoned at 440 meters; no samples were taken for pore fluid below 224 meters.

Sites 90 and 91

These sites in the Sigsbee Basin show very slight increases in chlorinity with depth and typical diagenetic depletion in K, Mg, and sulfate. Thus, although chlorinity is slightly greater than that of sea water, salinity is some 3 per cent less than would be expected for sea water of comparable chlorinity.

Site 92

This site, at the edge of the Sigsbee Scarp, penetrated 282 meters of an estimated 300-meter sedimentary section. At 233 meters chlorinity had reached 102 per cent. This phenomenon, and the overconsolidated nature of the sediments (see also Amery, 1969), indicates that a salt mass lies at or near a depth of 300 meters at the location. The ionic composition of the waters indicates that chiefly halite and anhydrite, typical of early stage evaporites, is present at depth. However, some extraneous Mg and K are present.

Sites 94 to 96

The section at these sites, off the northern margin of the Yucatan Platform, consists dominantly of foram-coccolith ooze and chalk, and reaches to or near Mesozoic strata at depth. No increases in chlorinity, signifying buried salt, were observed, and ionic variations are rather minor, with the exception of a marked increase in Sr at Site 94. This phenomenon is similar to that seen at Site 86, and previous Pacific Ocean sites, and implies recrystallization of calcite to a form containing less Sr.

Site 97

This site lies west of the Florida Straits and Cuba, and is the easternmost of the drilling locations. A chlorinity of 20.4 per cent (at 144 m depth in Late Miocene ooze) appears to be anomalously high with respect to sea water unless it is due to evaporation on board ship. Yet, it is too low to allow firm conclusions linking the site to subsurface evaporites. Strontium enrichment at this site is attributable to diagenetic carbonate reactions.

DISCUSSION

Evaporites Beneath the Sea Floor and Diffusive Migration of Salt

As mentioned earlier, previous interstitial water studies of locations in the Gulf of Mexico area have shown that the presence of rock salt at depth invariably produces an interstitial chlorinity gradient extending more or less continuously upward to the sea floor. Such gradients are lacking at sites drilled to nonevaporite basement, or where other evidence indicates the absence of evaporites. Accordingly, a pattern of consistent increases in chlorinity with depth can be used as a predictor of buried rock salt.

Profiles combining DSDP sites from Legs 1 and 10 in the central Gulf of Mexico (Figures 1-4) show either one or the other of two interstitial chlorinity patterns. There are either no anomalous chlorinities (that is, deviations of more than about 1 per cent from the 19.3 per cent chlorinity which presently characterizes bottom water in much of the Gulf of Mexico), or chlorinity increases consistently with depth. The increases are very abrupt where salt is located at shallow depth (Site 92, Figure 2) or may be very gradual where evaporites are at great depth (for example, Sites 3 and 85).

Where a steady state diffusion gradient has been reached, and sediments have constant diffusional permeability (diffusion constant), a straight-line gradient should be observed. The gradient normally steepens with depth, because (a) sediments often become less permeable with

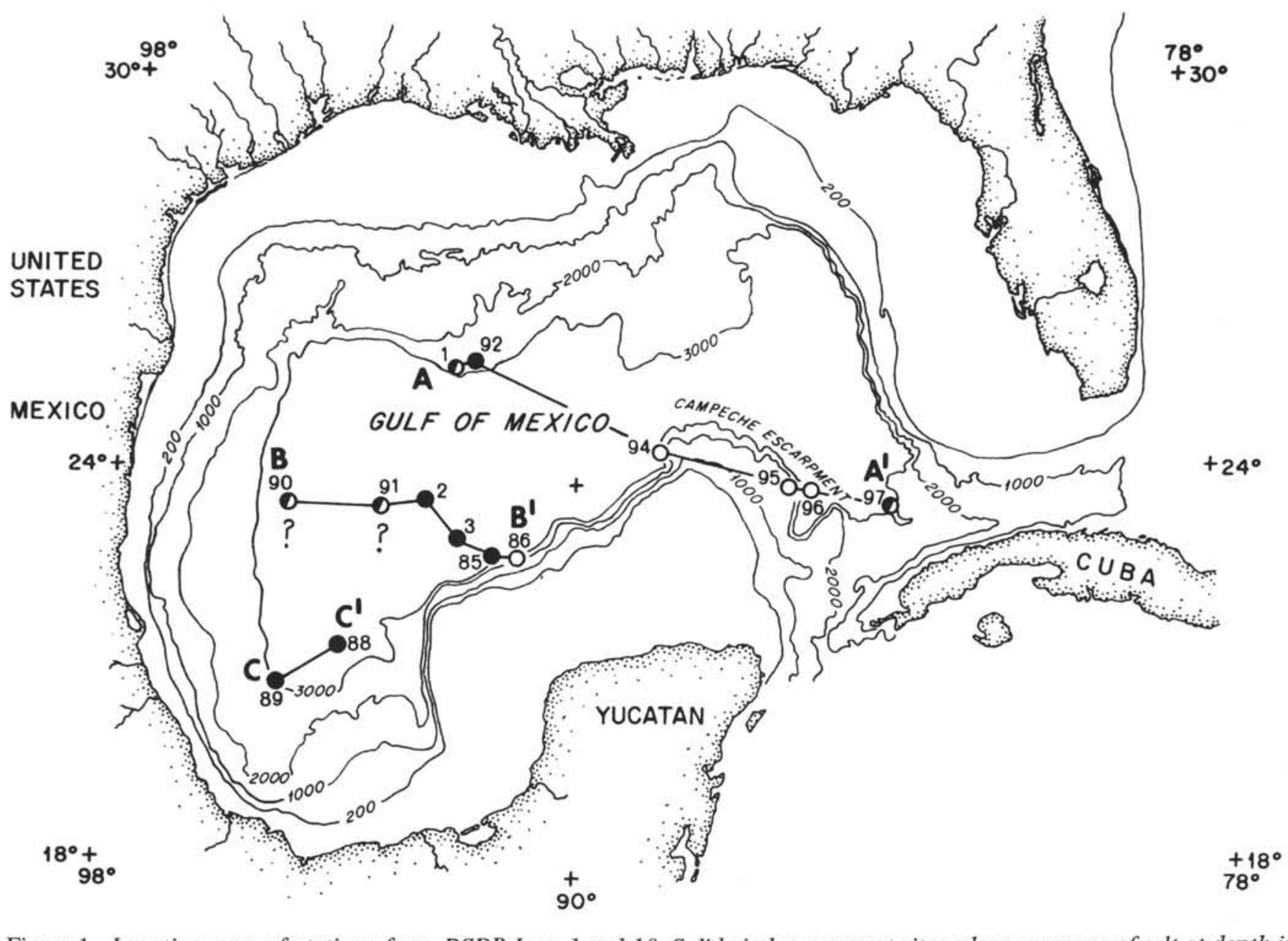

Figure 1. *Location map of stations from DSDP Legs 1 and 10. Solid circles represent sites where presence of salt at depth is inferred from interstitial water gradients. Open circles indicate no salt; half-open circles indicate minor increases in salt content with depth, insufficient to confirm presence of evaporites at depth. Depth contours in meters.*

depth due to consolidation or cementation; (b) rapid sedimentation, especially during Pleistocene time, will stretch out the gradient by moving the upper reference boundary upward; and (c) steady state may not have been established where relatively young features are involved (at Site 92, for example; believed to be situated on a salt mass still in the process of moving upward).

The pattern of anomalies indicates presence of salt at depth both in areas showing diapiric features, such as Sites 2, 92, and 88, and in areas without such structural features, such as Sites 89 and 85. Some domal features, like that at Site 96, between Yucatan and the Florida peninsula, have no salinity anomaly and are therefore considered not to be of evaporitic origin.

Chlorinity increases of only a few tenths of one part per thousand were noted at the sites in the deep Sigsbee Basin (90 and 91). If the lithostratigraphy at these sites were identical to that at Site 3, which was also located over relatively flat-lying strata but already showed clearly anomalous chlorinity values at 200 meters depth, one would be tempted to assume that no salt were present below sites 90 and 91. Our deepest samples from these sites are at 238 and 538 meters, whereas total penetration was 768 and 899 meters, respectively. However, J.L. Worzel (oral communcation) pointed out to us the increasing proportion of terrigenous (turbidite) material at sites 90 and 91, as well as the greater consolidation observed in the sediments. Decreases in the diffusional permeability of sediments several kilometers thick could slow diffusional migration of salt enough to prevent significant anomalies from reaching the levels we studied. In view of the numerous uncertainties involved, we can therefore draw no conclusions about the presence of evaporites at depth.

Site 92 (Sigsbee Scarp) provides a puzzling phenomenon with regard to the ionic composition of interstitial water above evaporites. In DSDP samples studied to date, Mg is usually depleted with respect to sea water. Such depletion may proceed through various mechanisms, including uptake in recrystallized carbonates (Manheim and Sayles, 1971), replacement of Fe in clays (Drever, 1971; Sayles et al., in press), and other silicate reactions. Enrichment of Mg has been observed only over evaporitic deposits, and not only over late-stage evaporites, as indicated by their K and Br content, but even over normal early-stage halites and anhydrite. Table 3 shows the quantity of Ca and Mg added to the pore fluids at various depths in the column. The added portion was computed by subtracting from the total concentration (in moles per kg fluid) of the element an amount proportional to the sea-water component of the sample. No evaporite minerals were reported

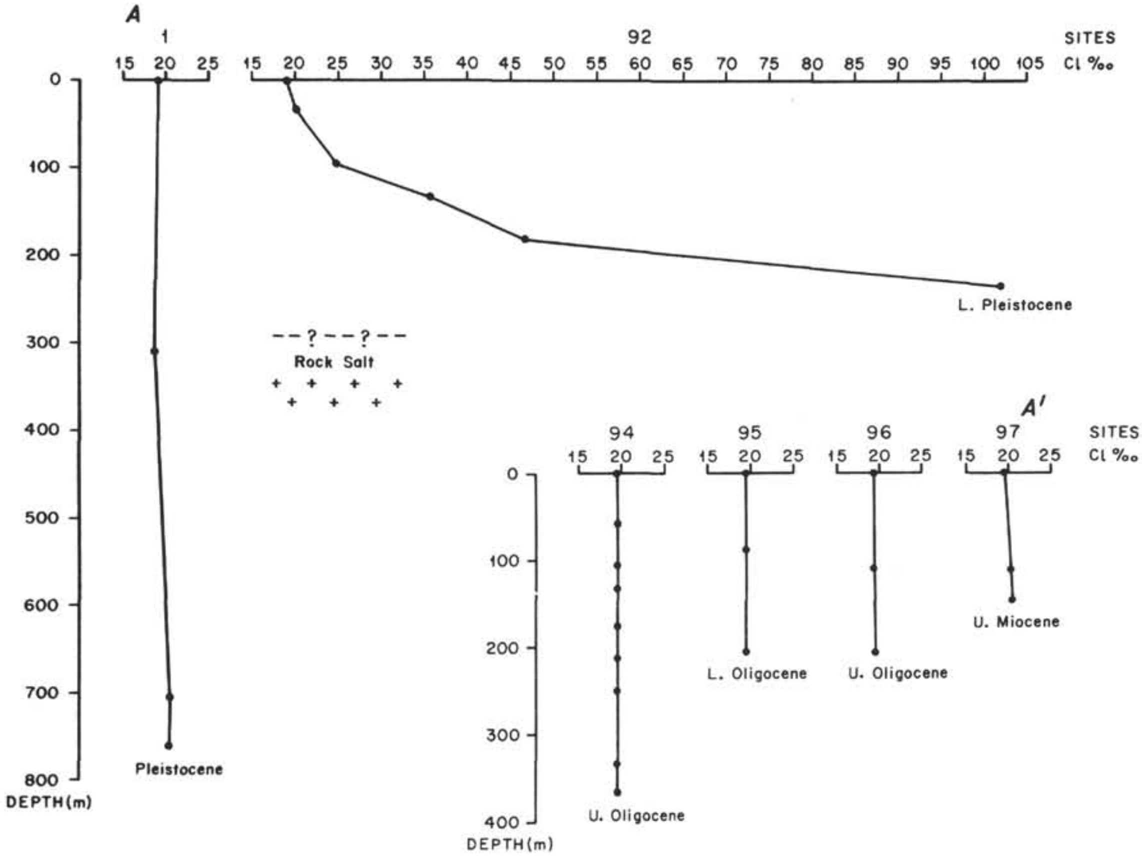

Figure 2. *Interstitial chlorinity profiles along traverse A-A′ (Figure 1). Age refers to sediment from which bottommost interstitial water sample was obtained.*

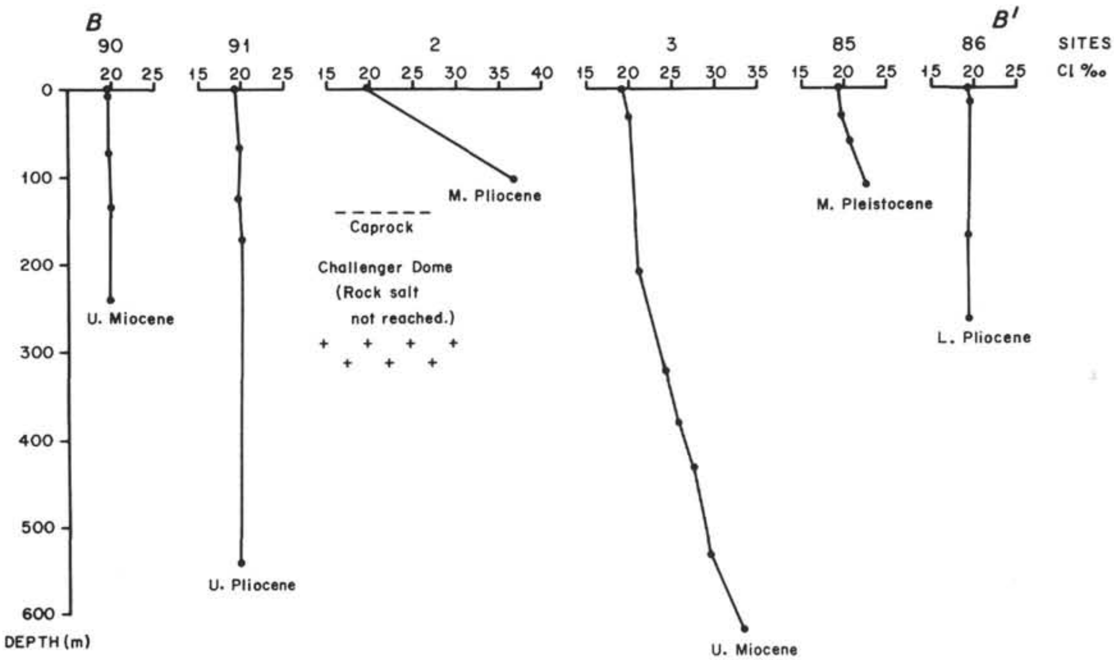

Figure 3. *Interstitial chlorinity profiles along traverse B-B′ (Figure 1). Age refers to sediment from which bottommost interstitial water sample was obtained.*

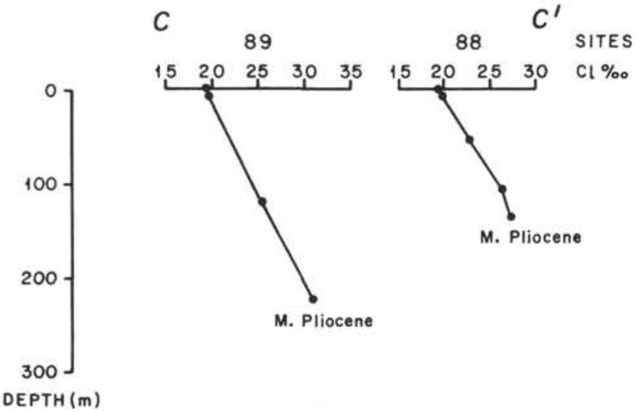

Figure 4. *Interstitial chlorinity profiles along traverse C-C' (Figure 1). Age refers to sediments from which bottommost interstitial water sample was obtained.*

in the sediment column itself. Therefore, barring reactions not heretofore seen in pore fluid systems, we assume that the extra Mg must come from dissolution of evaporite minerals and subsequent diffusion of component ions from deeper levels to their present position.

Diagenesis

In those sites not showing the influence of salts of evaporitic origin, two general patterns of fluid-solid interaction prevail. In clayey samples, there is a characteristic depletion of interstitial K, Mg., and minor enrichment in Sr. In carbonate-rich oozes, recrystallization phenomena yielded variable concentrations of interstitial Ca, but often high concentrations of Sr (over 60 ppm) without significant depletions of sulfate. Biogenic oozes yield much higher concentrations of silica (more than 20 ppm). Such enrichment in silica may be attributed to the dissolution of siliceous organisms (Radiolaria and diatoms) and relatively low concentrations of reactive aluminosilicates.

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TABLE 3
Total and Incremental Ca and Mg Values for Site 92 (Sigsbee Scarp)[a]

Depth	Cl (‰)	Ca (‰)	meg/kg	Δmeg/kg	Mg (‰)	meg/kg	Δmeg/kg
35	20.2	0.71	35.5	16.3	1.23	101	1.5
92	24.8	0.80	40.	23.	1.46	120	31.
131	35.6	0.97	48.4	37.5	1.82	150	93.
180	47.0	0.89	44.5	36.2	1.59	131	88.
233	102.0	0.84	42.	38.	1.15	95	75.

[a]ΔCa and ΔMg refer to quantities of ions (in milliequivalents) corrected for proportion presumed to be due to seawater component. Values are obtained by the relationship:

$$\Delta Ca = Ca_{tot} - Ca_{sw} \times \frac{19.4}{Cl_{tot}}$$

where 19.4 is presumed to represent the chlorinity of bottom-water originally incorporated in sediments in question.