34. EFFECTS OF BURROWING ORGANISMS IN DEEP OCEAN SEDIMENTS ON THE DISTRIBUTION OF CHEMICAL ELEMENTS AND THE PRESERVATION AND ORIENTATION OF MICROFOSSILS

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ABSTRACT

The trace fossils, *Chondrites, Teichichnus*, and *Zoophycos*, from deep ocean cores from Deep Sea Drilling Project Leg 41 were studied with scanning electron microscopy to determine the effects of burrowing organisms on chemical element distribution and microfossil preservation and orientation. SEM energy-dispersive X-ray analyzer analysis of sediment inside and outside the burrows showed no concentration of the elements silica, calcium, barium, iron, magnesium, manganese, cobalt, copper, sulfur, and potassium by the burrowing activity. SEM observations revealed no systematic effects on microfossil preservation or orientation within the burrowed sediment.

INTRODUCTION

Trace fossils have been studied and described as early as the mid 1800's by Massalongo (1855), Hall (1863) and others. Since these early works, trace fossils have been further described by Seilacher (1964), Plicka (1968, 1970), Simpson (1957, 1970), Hantzschel (1962), Bischoff (1968), and Lessertisseur (1955), for example, and used as environmental indicators by Seilacher (1967), Sellwood (1970), Selley (1970), Kennedy (1970), Ronjewicz (1970), Frey and Howard (1970), and Warme (1970). However, there have been exceptionally few studies done with respect to chemistry and microfauna of trace fossil, Tauber (1948) and Ronjewicz (1970), respectively.

PURPOSE

It is the purpose of this investigation to observe the trace fossils of *Chondrites, Teichichnus*, and *Zoophycos* in deep ocean cores with respect to the preservational and orientation effects on the microfauna and the concentrations of some chemical elements present. Samples ranged from Miocene to Cretaceous in age and were from Leg 41 of the Deep Sea Drilling Project off the northwest coast of Africa.

The preservation of microfauna, particularly the nannofossils, was compared between the burrow and the surrounding sediment.

The elements Si, Ca, K, Mn, Mg, Fe, Cu, Co, Ba, and S were scanned to check the chemistry of the interior of the burrow compared to surrounding sediment and to observe how the chemistry changes with respect to age.

CRITERIA FOR SAMPLING

The trace fossils *Chondrites, Teichichnus*, and *Zoophycos* were chosen for several reasons. They are very characteristic in their appearance and easily identifiable. They are abundant in deep ocean sediment cores (direct observation) and seem to be independent of lithology. They have a wide stratigraphic range: *Chondrites*—Cambrian to Miocene(?), *Teichichnus*—Cambrian to Oligocene(?), and *Zoophycos*—Cambrian to Recent. Samples were chosen only in the absence of visible bioturbation adjacent to specimens.

METHOD

Each sample was subdivided into a small portion of the burrow and a portion of the surrounding external sediment. All chemical measurements were made first using 200 sec counts per sample. Then, five samples of *Chondrites* and four of *Teichichnus* and *Zoophycos* were examined on the SEM for the types of microfossils present and their preservational characteristics.

MICROFOSSILS

Chondrites sample one (reference number 9) was taken from Sample 367-25-4, 101-103 cm. The age of the sediment is Lower Cretaceous. The burrow sample contained moderately well preserved to poorly preserved nannos (no visible detail) along with a few well preserved spicules. There were no foraminifera or radiolarians present. The surrounding sediment sample contained nannofossils in the same state of preservation as in the burrow sample. Again there were no foraminifera or radiolarians.

Chondrites sample two (reference number 1) was taken from Sample 366-51-4, 55-56 cm. The age of the core is Paleocene. The burrow sample revealed poorly recrystallized nannofossils with no other microfossils observed. The surrounding sample contained poorly recrystallized nannos with few diatom fragments.

Chondrites sample three (reference number 35) was taken from Sample 368-52-5, 110-112 cm. The age of the sediment is Paleocene-Upper Cretaceous. The burrow sample was devoid of microfossils as was the surrounding sediment sample.

Chondrites sample four (reference number 33) was taken from Sample 368-46-5, 76-78 cm. The age of the sediment is lower Eocene to Upper Cretaceous. This sample was devoid of microfossils.

Chondrites sample five (reference number 3) was taken from Sample 367-8-2, 143-145 cm. The age is upper Eocene. The burrow sample contained many radiolarians and diatoms, both whole and fragmented. Nannofossils were present but poorly preserved and scarce. The surrounding sediment sample was identical to the burrow sample.

Zoophycos sample one (reference number 34) was taken from Sample 368-47-2, 63-66 cm. The age of the sediment is lower Eocene to Upper Cretaceous. No microfossils were visible in this sample.

Zoophycos sample two (reference number 25) was taken from Sample 368-31-3, 60-62 cm. The age of the sediment is lower Eocene. The burrow sample had nannofossils, nearly indistinguishable, and was devoid of all other microfossils. The surrounding sediment sample contained more nannos than did the burrow sample, but preservation was the same. This sample was also devoid of other microfossils.

Zoophycos sample three (reference number 4) was taken from Sample 367-8-3, 27-29 cm. The age of the sediment is upper Eocene. The burrow sample consisted of many radiolarian and diatom fragments and whole specimens. Nannofossils were absent. The surrounding sediment sample was likewise filled with many radiolarian and diatom fragments and whole specimens, but had a few badly preserved nannofossils.

Zoophycos sample four (reference number 3) was taken from Sample 367-8-2, 143-145 cm. The age of the sediment is upper Eocene. The burrow sample contained many radiolarian and diatom fragments but was devoid of nannofossils. The surrounding sediment sample had many radiolarian and diatom fragments and some whole specimens along with a few poorly preserved fossils.

Teichichnus sample one (reference number 37) was taken from Sample 368-59-3, 11-13 cm. The age of the sediment is Upper Cretaceous. This sample was devoid of microfossils.

Teichichnus samples two and three (reference number 27, top and bottom, respectively) were taken from Sample 368-34-3, 62-64 cm. The age of the sediment is lower Eocene to Upper Cretaceous. Microfossils were absent in these samples.

Teichichnus sample four (reference number 39) was taken from Sample 369A-17-4, 127-129 cm. The age of the sediment is upper Oligocene. The burrow sample contained many well preserved nannofossils and many whole and fragmented diatoms. The surrounding sediment sample was the same as the burrow sample, with a few radiolarian fragments present.

There is no apparent effect with respect to orientation or distribution of the microfossils. Also, there is no apparent trend in preservational characteristics of the nannofossils or any other microfossils. By assumption, the living specimens of *Chondrites*, *Teichichnus*, and *Zoophycos* made no marked lasting effect on the porosity of the sediment or the orientation and distribution of microfossils.

CHEMISTRY

The elements silicon, calcium, iron, magnesium, manganese, potassium, barium, sulfur, copper, and cobalt were analyzed by an SEM energy-dispersive X-ray analyzer. The normalized data (Table 1) were run through a Q-mode factor analysis to determine the communality or percentage of the data in each sample. In the total percentage, silica and calcium accounted for 57.7% and 42.0%, respectively, or 99.7% of the total data. The remaining 0.3% was distributed into 42.3% iron, 25.4% potassium, 24.7% magnesium, 5.1% barium, 1.0% manganese, and 1.1% copper with sulfur and cobalt making up approximately 0.4%.

There is a concentration of some elements in some individual samples, but this does not hold true for every burrow of the same type. This is probably indicative of sediment variations in the stratigraphic column rather than a result from the activity of the burrowing organisms.

CONCLUSIONS

None of the three ichnofossils *Chondrites*, *Teichichnus*, or *Zoophycos* disturbed the random orientation or distribution of the microfossils. This, however, could be the result of mass disturbance by the meiobenthos (Cullen, 1973) e.g., ostracodes, nematodes, or other macrobenthic organisms, which left no visible trace in the particular sediments.

The chemical data in the Q-mode analysis show nothing more than a typical sediment composition. The chemical data are probably more indicative of sediment variations rather than the activity of burrowing organisms. It would improve future studies to use factors other than single elements and to run an R-mode analysis to see how the samples relate to each other individually. Also, samples should be limited in age and of a homogeneous sediment type.

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TABLE 1
Normalized Data

Sample	1 Mg	2 SI	3 S	4 K	5 CA	6 BA	7 MN	8 FE	9 CO	10 CU
1 IC	0.005	0.998	0.0	0.0	0.055	0.002	0.0	0.015	0.0	0.0
1 CC	0.0	0.998	0.0	0.0	0.049	0.001	0.002	0.027	0.0	0.0
3 ZIL	0.002	0.998	0.0	0.0	0.009	0.014	0.007	0.062	0.0	0.0
3 ZID	0.019	0.998	0.0	0.019	0.022	0.004	0.005	0.054	0.0	0.000
3 CI	0.031	0.998	0.0	0.017	0.028	0.003	0.0	0.045	0.002	0.0
3 CO	0.024	0.997	0.0	0.024	0.012	0.013	0.0	0.061	0.0	0.0
4 ZI	0.030	0.998	0.0	0.0	0.031	0.008	0.002	0.039	0.003	0.009
4 ZO	0.059	0.997	0.0	0.0	0.026	0.009	0.006	0.041	0.000	0.001
9 IC	0.0	0.113	0.0	0.0	0.994	0.0	0.001	0.007	0.0	0.0
9 O	0.0	0.098	0.0	0.0	0.995	0.0	0.002	0.005	0.0	0.0
18 CI	0.003	0.334	0.0	0.006	0.942	0.001	0.0	0.016	0.001	0.0
18 O	0.007	0.355	0.0	0.013	0.935	0.003	0.0	0.017	0.0	0.002
19 ZIL	0.004	0.910	0.0	0.0	0.415	0.0	0.010	0.017	0.001	0.003
19 ZID	0.002	0.916	0.0	0.015	0.399	0.002	0.004	0.020	0.004	0.0
19 ZOL	0.006	0.951	0.0	0.0	0.308	0.006	0.001	0.032	0.0	0.0
19 ZOD	0.003	0.938	0.0	0.033	0.342	0.004	0.008	0.037	0.001	0.0
23 ID	0.046	0.993	0.0	0.019	0.087	0.005	0.000	0.068	0.0	0.0
23 IL	0.028	0.995	0.0	0.021	0.091	0.002	0.0	0.021	0.0	0.0
23 O	0.056	0.993	0.0	0.045	0.069	0.007	0.002	0.057	0.0	0.002
24 O	0.066	0.990	0.0	0.027	0.102	0.004	0.009	0.061	0.0	0.0
24 OLO	0.031	0.986	0.0	0.023	0.157	0.007	0.0	0.050	0.0	0.0
24 OMI	0.097	0.942	0.0	0.018	0.293	0.0	0.003	0.133	0.010	0.009
24 ODI	0.042	0.938	0.173	0.0	0.104	0.013	0.0	0.279	0.0	0.0
25 ZI	0.059	0.997	0.0	0.030	0.008	0.009	0.0	0.042	0.0	0.0
25 ZOTL	0.068	0.997	0.0	0.023	0.009	0.009	0.0	0.039	0.001	0.001
25 ZORD	0.070	0.996	0.0	0.018	0.018	0.0	0.0	0.054	0.0	0.0
27 TOLT	0.130	0.985	0.0	0.043	0.086	0.014	0.013	0.060	0.008	0.009
27 TI	0.166	0.983	0.0	0.038	0.058	0.007	0.0	0.036	0.0	0.006
27 TODB	0.151	0.983	0.0	0.033	0.086	0.002	0.0	0.044	0.0	0.009
29 TI	0.053	0.984	0.0	0.014	0.169	0.005	0.001	0.031	0.0	0.0
29 TOD	0.095	0.986	0.0	0.021	0.132	0.006	0.001	0.041	0.0	0.0
29 TOL	0.062	0.955	0.007	0.065	0.263	0.049	0.038	0.079	0.0	0.0
33 IC	0.0	0.192	0.0	0.005	0.981	0.009	0.001	0.018	0.0	0.0
33 O	0.0	0.234	0.0	0.0	0.972	0.0	0.002	0.015	0.0	0.0
34 ZI	0.025	0.995	0.0	0.005	0.083	0.015	0.005	0.040	0.0	0.0
34 ZBL	0.030	0.995	0.0	0.005	0.092	0.005	0.005	0.022	0.0	0.0
34 ZO	0.022	0.992	0.0	0.001	0.121	0.000	0.003	0.020	0.0	0.0
36 ZI	0.000	0.998	0.0	0.006	0.017	0.010	0.006	0.064	0.0	0.0
36 O	0.008	0.998	0.0	0.0	0.034	0.015	0.005	0.060	0.0	0.0
37 I	0.006	0.990	0.0	0.047	0.089	0.013	0.000	0.100	0.0	0.0
37 O	0.005	0.991	0.004	0.050	0.088	0.017	0.007	0.084	0.0	0.0
38 CI	0.001	0.638	0.0	0.027	0.766	0.031	0.010	0.069	0.0	0.0
38 CO	0.007	0.776	0.0	0.035	0.624	0.014	0.002	0.082	0.0	0.0
39 TI	0.0	0.801	0.0	0.037	0.593	0.006	0.003	0.077	0.003	0.0
39 TO	0.0	0.807	0.0	0.043	0.586	0.008	0.0	0.061	0.0	0.008
40 ZIS	0.001	0.964	0.011	0.0	0.261	0.008	0.005	0.045	0.0	0.006
40 ZOS	0.013	0.976	0.0	0.0	0.206	0.006	0.002	0.062	0.0	0.004
40 ZILG	0.0	0.859	0.0	0.039	0.501	0.016	0.001	0.095	0.000	0.006
40 ZOL	0.005	0.975	0.0	0.064	0.162	0.007	0.001	0.136	0.0	0.005
41 CI	0.0	0.691	0.0	0.0	0.722	0.008	0.0	0.035	0.0	0.002
41 CO	0.001	0.698	0.0	0.017	0.714	0.006	0.0	0.057	0.0	0.0
42 ZOH	0.014	0.969	0.0	0.0	0.232	0.016	0.003	0.079	0.0	0.0
42 ZIH	0.0	0.726	0.0	0.017	0.685	0.008	0.004	0.060	0.0	0.0
42 ZOT	0.001	0.821	0.0	0.043	0.563	0.014	0.007	0.088	0.0	0.0
42 ZIT	0.006	0.805	0.0	0.027	0.582	0.017	0.002	0.111	0.0	0.0
43 ZIL	0.0	0.379	0.0	0.012	0.925	0.002	0.003	0.012	0.0	0.0
43 ZID	0.003	0.386	0.0	0.015	0.922	0.003	0.0	0.010	0.0	0.003
43 ZT	0.0	0.465	0.0	0.010	0.884	0.007	0.0	0.039	0.0	0.004
43 TI	0.005	0.421	0.0	0.0	0.907	0.005	0.0	0.012	0.0	0.001
43 TO	0.007	0.300	0.0	0.0	0.954	0.005	0.009	0.017	0.001	0.0
43 TT	0.003	0.505	0.0	0.009	0.863	0.0	0.001	0.008	0.001	0.0
44 ZI	0.0	0.899	0.0	0.0	0.437	0.015	0.0	0.005	0.002	0.019
44 ZO	0.0	0.899	0.0	0.0	0.437	0.0	0.003	0.006	0.0	0.0
45 CI	0.009	0.365	0.0	0.0	0.929	0.058	0.0	0.014	0.0	0.000
45 COL	0.003	0.389	0.0	0.012	0.921	0.026	0.0	0.014	0.005	0.001
45 COD	0.0	0.481	0.0	0.0	0.877	0.005	0.006	0.019	0.0	0.001
46 ZIT	0.010	0.506	0.0	0.007	0.862	0.001	0.0	0.019	0.0	0.0

TABLE 1 – *Continued*

Sample	1 Mg	2 SI	3 S	4 K	5 CA	6 BA	7 MN	8 FE	9 CO	10 CU
46 ZIM	0.007	0.429	0.0	0.0	0.903	0.003	0.0	0.006	0.001	0.001
46 ZIB	0.007	0.390	0.0	0.0	0.921	0.001	0.0	0.017	0.000	0.004
46 OD	0.013	0.458	0.0	0.0	0.889	0.001	0.0	0.016	0.0	0.0
46 OL	0.003	0.162	0.0	0.010	0.987	0.0	0.0	0.000	0.0	0.0
47 IC	0.007	0.560	0.0	0.0	0.828	0.004	0.001	0.030	0.0	0.0
47 OC	0.0	0.231	0.0	0.0	0.973	0.001	0.0	0.013	0.0	0.0
47 IZ	0.0	0.237	0.0	0.0	0.971	0.011	0.002	0.010	0.0	0.0
47 OZ	0.0	0.255	0.0	0.0	0.967	0.0	0.0	0.012	0.0	0.0
48 CI	0.006	0.251	0.0	0.001	0.968	0.002	0.0	0.015	0.001	0.0
48 OM	0.008	0.202	0.0	0.007	0.979	0.005	0.0	0.019	0.0	0.003
48 OL	0.007	0.250	0.0	0.015	0.968	0.021	0.0	0.015	0.0	0.001
48 OD	0.002	0.169	0.0	0.015	0.985	0.005	0.0	0.016	0.0	0.002
49 IC	0.018	0.710	0.0	0.048	0.698	0.002	0.006	0.076	0.0	0.0
49 OL	0.010	0.787	0.0	0.055	0.611	0.007	0.004	0.067	0.0	0.0
49 OD	0.0	0.889	0.0	0.0	0.453	0.004	0.0	0.071	0.0	0.0
51 TI	0.031	0.571	0.0	0.040	0.818	0.011	0.0	0.051	0.0	0.005
51 TO	0.067	0.562	0.0	0.049	0.822	0.003	0.001	0.030	0.0	0.0
52 PI	0.005	0.752	0.0	0.008	0.658	0.006	0.007	0.043	0.001	0.013
52 RS	0.019	0.854	0.0	0.003	0.497	0.005	0.000	0.150	0.0	0.009
53 CI	0.003	0.959	0.010	0.066	0.267	0.014	0.007	0.062	0.001	0.008
53 ZI	0.027	0.953	0.0	0.050	0.293	0.005	0.006	0.053	0.0	0.0
53 ZO	0.012	0.896	0.0	0.072	0.427	0.008	0.0	0.097	0.0	0.002
54 ZIL	0.002	0.918	0.0	0.0	0.392	0.012	0.0	0.061	0.0	0.0
54 ZID	0.002	0.974	0.0	0.072	0.199	0.017	0.0	0.076	0.0	0.0
54 O	0.008	0.913	0.0	0.021	0.403	0.011	0.0	0.059	0.0	0.0
54 RING	0.009	0.806	0.0	0.021	0.589	0.011	0.0	0.049	0.0	0.0
54 RING	0.0	0.967	0.0	0.021	0.040	0.017	0.0	0.249	0.0	0.0
55 RING	0.015	0.986	0.0	0.058	0.064	0.006	0.003	0.140	0.0	0.006
55 OR	0.019	0.992	0.0	0.077	0.042	0.008	0.0	0.089	0.0	0.0

Note: B = Bottom, C = *Chondrites*, D = Dark, H = Halo, I = Inside, L = Light, LG = Large, M = Medium, O = Outside, P = *Planolites*, R = Ring, S = Small, T = *Teichichnus* (if first), Top (other), Z = *Zoophycos*.

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