26. TRACE FOSSIL ASSEMBLAGES IN LEG 66 SEDIMENTS[1]

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ABSTRACT

Leg 66 drilling across the Middle America Trench provides an opportunity to study trace fossil distribution across an active margin. Variations in sedimentation rate and water depth, and higher primary productivity in the overlying water column, create conditions different from those in deep sea areas, far removed from continents, where traces have been studied in detail. Sandy trench sediments lack a significant trace fossil assemblage, but slope sediments contain *Chondrites, Planolites, Zoophycos*, and *Teichichnus*, typical of the deep sea. Occurrences of this assemblage in Leg 66 cores agree with independent estimates of water depth in excess of 3 km.

INTRODUCTION

Trace fossils are sedimentary structures produced by organisms and are often a conspicuous part of the geologic record. In deep sea cores they may be the dominant structures present and the only preserved evidence of the deep sea benthic fauna. Trace fossils do not provide much time-stratigraphic information, as they have long geologic ranges and their distribution is facies-controlled. However, they can provide useful information about ecology, sedimentation processes, and water depth.

In contrast to many published accounts of the trace fossil record in deep sea sediments (e.g., Donahue, 1971; Chamberlain, 1975; Ekdale, 1977, 1978) and shelf sediments (Frey, 1975; Basan, 1978), there are few studies of trace fossils of the modern slope environment. Sampling to date indicates that some characteristic deep sea traces are present in modern slope deposits (McMillen, 1975), but the youth and lack of diagenesis of recovered sediments make it difficult to recognize many traces. Studies of older sediments recovered in DSDP cores across a margin should, therefore, provide useful information on trace fossil preservation and distribution.

The purpose of the present study is twofold: (1) to describe trace fossils across a modern continental margin and (2) to obtain water depth information. Because of the tectonic instability of this margin, results of this study cannot be used to provide much additional data on trace fossil depth distribution. Rather, the distribution of traces in these cores will be interpreted on the basis of results from previous deep sea studies.

Continental margin environments should differ from open ocean deep sea areas. Slope sedimentation consists of a variety of downslope and hemipelagic processes contributing a great deal of coarse and fine terrigenous debris that may result in widely varying sediment types and sedimentation rates. Organic productivity is generally higher over ocean margins than over the open sea, which causes margin sediments to have a higher organic matter content than most deep sea sediments (Lisitzin, 1972). Therefore, sediment-grazing traces might be expected to predominate over suspension feeders. Also, the variety of sediment types and varying depositional rates might inhibit certain types of deep sea benthos. Therefore, a different benthic fauna should exist on continental margins than in the deep sea, but no evidence so far indicates any difference in the types of traces preserved on continental margins and in the deep sea away from margins.

Diagenesis often enhances trace fossil preservation. Since sediments cored by Leg 66 are young (post-Oligocene) and relatively unaffected by diagenesis, trace fossils are generally poorly preserved. The best-preserved trace fossils occur in lower Miocene sediments at Sites 489 and 493. In addition, there are few strong color contrasts in the hemipelagic sediments to increase trace fossil visibility.

DESCRIPTIONS

Geologists commonly assign trace fossils formal generic and specific names, even though they are sedimentary structures and not recognized as valid taxa. In this report, we use generic-level names only, owing to the difficulty in determining the detailed three-dimensional geometry of trace fossils in split core faces. We recognized four "genera" in Leg 66 cores: *Chondrites, Planolites, Zoophycos*, and *Teichichnus*, as well as borings and two problematical forms. Since many authors have provided detailed trace fossil morphologic descriptions, we refer the reader to summaries such as Hantzschel's (1975) or other descriptions of traces in DSDP cores such as Ekdale's (1977, 1978) and Chamberlain's (1975).

Planolites is a simple, subhorizontal to inclined burrow seen as nearly circular to elliptical in cross section. In Leg 66 cores, *Planolites* was often difficult to recognize because of low color contrast.

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Chondrites is a branching burrow system with side branches arising off a main burrow at angles of 30° to 40°, with burrow diameters of 1 to 2 mm. It is the most ubiquitous and easily recognized burrow system in Leg 66 cores. *Chondrites* are generally lighter in color than the enclosing sediment, indicating oxidation of organic matter in the burrow fill due to ingestion. *Chondrites* darker than the enclosing sediment often occur adjacent to a contact with darker sediment.

Zoophycos consists of a subhorizontal web of burrowed and backfilled sediment. Often, the three-dimensional form of the web is a spiral so that two or more traces appear on a vertical core face. The backfilled sediment is commonly pelleted (Plate 1, Fig. 1). *Zoophycos* is rare in Leg 66 cores, being most abundant in the lower Miocene portion of Sites 489 and 493.

Teichichnus is a vertical web of burrowed and backfilled sediment produced as an organism reworks a horizontal burrow upward to produce a filled trench (Plate 1, Fig. 2). Like *Zoophycos*, the forms may be pelleted. *Teichichnus* is very rare in Leg 66 cores, limited to two definite occurrences at Sites 490 and 492.

Two carbonate-cemented muddy nodules found in Site 490 core contain borings. One nodule (Plate 1, Fig. 3) has U-shaped and meandering borings 1 mm or less in diameter concentrated on the upper surface. The borings indicate that the nodule lay exposed on the seafloor during a period of erosion or nondeposition so it could be colonized by boring organisms. Age of the nodule is the same as the enclosing sediment and this, along with the fact that no steep scarps exist upslope from Site 490, makes it unlikely that the nodules have been transported.

Two problematical forms occur in Leg 66 cores. The first of these (Plate 1, Fig. 4) consists of a crude arrangement of irregular, curved, cone-shaped sheets of darker sediment that point up core, cut at nearly right angles by other dark-colored sheets. These sheets contain no backfill structures or pellets. The second form (Plate 1, Fig. 5), observed in Holes 490, Section 490-55-4, and 493, Section 493-33-1, also consists of curved, darker-colored sheets, but these are arranged in a crude concentric pattern around a subhorizontal axis. The sheets are discontinuous in cross section, and connections between them could not be proven. The first of these two forms could be an inorganic structure, but the second forms seems to be an actual biologic trace. As such, it appears to be a new form.

DISTRIBUTION

Leg 66 trace fossil occurrences are greatest in Pliocene or older sediments (Table 1) because of diagenetic enhancement of burrows and less pervasive drilling deformation downhole. Recognizable trace fossil taxa are virtually absent in intervals of low sediment accumulation owing to intense sediment reworking, as shown by mottling. Sediment homogenization in these intervals is probably a consequence of high organic matter content and relatively low rate of sedimentation. Sandy beds and turbidites have few or no burrows, consistent with similar observations in other turbidite facies. This lack

Table 1. Listing of trace fossil occurrences in Leg 66 Cores.

Core	Age	Sediment Accumulation Rate (m/m.y.)	*Chondrites*	*Planolites*	*Zoophycos*	*Teichichnus*
Hole 488						
31	Pleistocene	32	?			
33	Pleistocene	32	+			
34	Pleistocene	32	?			
Hole 489A						
4	Early Miocene	22	+	+		
5	Early Miocene	22	+	+		
6	Early Miocene	22	+	+		
7	Early Miocene	22	+	+		
8	Early Miocene	22	+	+		
9	Early Miocene	22	+	+		
10	Early Miocene	22	+	+		
11	Early Miocene	22	+	+		
12	Early Miocene	22	+	+	+	
13	Early Miocene	106	+	+	+	
15	Early Miocene	106	+	+		
16	Early Miocene	106	+	+		
17	Early Miocene	106	+	+		
18	Early Miocene	106	+	+		
19	Early Miocene	106	+	+	+	
20	Early Miocene	106	+	+		
21	Early Miocene	106	+	+		
22	Early Miocene	106	+	+		
23	Early Miocene	106	+	+		
24	Early Miocene	106	+	+		
25	Early Miocene	106	+	+		
26	Early Miocene	106	+	+		
27	Early Miocene	106	+	+		
28	Early Miocene	106	+	+		
29	Early Miocene	106	+	+		
31	Early Miocene	106	?	?		
Hole 490						
21	Pliocene-Pleistocene	320	+			?
27	Pliocene	93	+			
29	Pliocene	93	+			
34	Pliocene	93	+			
35	Pliocene	93	+			
36	Pliocene	93	+			
37	Pliocene	93	+	+		
38	Pliocene	93	+	+		
39	Pliocene	93	+	+		
40	Pliocene	93	+			
42	Pliocene	93	+			
43	Pliocene	93	+			
44	Pliocene	93	+			
47	Pliocene	93	+			
48	Pliocene	150	+	+		
49	Pliocene	150	+	+		
50	Pliocene	150	+	+		
51	Pliocene	150	+	+		
53	Pliocene	150	+	+		
54	Pliocene	150	+	+		
55	Pliocene	150	+	+		
56	Pliocene	150	+	+		
57	Pliocene	150	+	+		
58	Pliocene	150	+	+		
59	Pliocene	150	+	+		
60	Pliocene	150	+	+		
61	Pliocene	150	+	+		
62	Late Miocene	150	+	+		
63	Late Miocene	150	+	+		
64	Late Miocene	150	+	+		
Hole 491						
21	Pliocene	1050		+		
26	Pliocene	1050	+	+		
27	Pliocene	1050	+		+	+
28	Pliocene	1050	+			
29	Pliocene	1050	+			
30	Pliocene	1050	+	+		
31	Pliocene	1050	+	+		
50	Pliocene	1050		+		
54	Pliocene	1050		+		
55	Pliocene	1050		+		
58	Pliocene	1050		+		
Hole 492						
10	Late Miocene	38	+			
11	Late Miocene	38	+			
12	Late Miocene	38	+			
14	Late Miocene	38	+		+	+
15	Late Miocene	38	+			
16	Late Miocene	38	+			
17	Late Miocene	38	+	+		
18	Late Miocene	38	+			
19	Late Miocene	38	+			
20	Late Miocene	38	+		+	
21	Late Miocene	38	+			
22	Late Miocene	38	+			
24	Late Miocene	38	+			
27	Late Miocene	38	+			
Hole 493						
28	Early Miocene	39	+	+		
29	Early Miocene	39	+	+		
30	Early Miocene	39	+	+	+	
31	Early Miocene	39	+	+		
32	Early Miocene	39	+	+	+	

Table 1. (Continued).

Core	Age	Sediment Accumulation Rate (m/m.y.)	*Chondrites*	*Planolites*	*Zoophycos*	*Teichichnus*
33	Early Miocene	39	+	+		
34	Early Miocene	39	+	+		
35	Early Miocene	39	+	+		
36	Early Miocene	39	+	+		
37	Early Miocene	39	+	+		
38	Early Miocene	39	+	+	+	
39	Early Miocene	39	+	+		
40	Early Miocene	39	+	+		
41	Early Miocene	39	+	+		
42	Early Miocene	39	+	+	+	
43	Early Miocene	39	+	+		
44	Early Miocene	39	+	+		
45	Early Miocene	39	+	+		
46	Early Miocene	39	+	+		
47	Early Miocene	39	+	+		
48	Early Miocene	39	+	+		
49	Early Miocene	39	+	+		
50	Early Miocene	15	+	+		
51	Early Miocene	15		?		
54	Early Miocene	83		+		

of burrowing has been attributed to the presence of a non-burrowing fauna of surface grazers (Seilacher, 1967; Ekdale, 1980). Recognizable trace fossil forms in hemipelagic slope sediments include *Chondrites, Planolites, Zoophycos*, and *Teichichnus*. Since they can occur together, they constitute an assemblage. *Chondrites* and *Planolites* occur commonly together, with *Zoophycos* and especially *Teichichnus* much less abundant. All four forms coexist in hemipelagic sediments of different age, burial depth, and sediment accumulation rate (Table 1).

DISCUSSION

The most successful attempts to estimate ancient water depths using trace fossils have been based on assemblages of traces (e.g., Chamberlain, 1971; Kern and Warme, 1975). Seilacher (1967) proposed a scheme of four bathymetrically controlled marine trace fossil assemblages for Paleozoic rocks. His deep-water assemblages consisted of the *Zoophycos* assemblage of infaunal burrowers on the slope and the *Nereites* assemblage of horizontal grazers found in basinal turbidites. Leg 66 sediments fit Seilacher's model in that the *Zoophycos* assemblage does occur on the slope and is absent in basinal (trench) turbidites which might contain a grazing fauna that produces traces difficult to recognize in cores. Deep sea Mesozoic and Cenozoic pelagic sediments recovered in other DSDP cores often contain the *Zoophycos* assemblage (Warme et al., 1973; Van der Lingen, 1973; Ekdale, 1978), indicating that Seilacher's subdivision of deep sea trace fossil assemblages might be based more on differences in sedimentary facies rather than on actual water depth. Moreover, *Zoophycos* has been reported from outcrops of inferred shallow-water sediments by several workers (e.g., Osgood and Szmuc, 1972), although these and other shallow-water occurrences are mostly late Paleozoic.

The *Chondrites-Planolites-Zoophycos-Teichichnus* assemblage, like the one recovered in Leg 66 cores, is now generally thought to indicate deep-water environments (Kennedy, 1975; Ekdale, 1977, 1978), perhaps even depths greater than 4000 meters (Chamberlain, 1978). *Teichichnus* itself is relatively rare in most Cenozoic DSDP cores, and the remaining assemblage of *Chondrites, Planolites*, and *Zoophycos* has been documented in water depths as shallow as 1 to 2 km (Ekdale, 1978).

With this uncertainty, it may be unreasonable to attempt to use trace fossil assemblages to gain a precise indication of past water depths, especially in the largely unstudied margin environments. Nevertheless, the occurrences of trace fossil assemblages in Leg 66 cores are consistent with water depth estimates based on independent criteria (McMillen and Bachman, this volume). At both Sites 490 and 492, the *Chondrites-Planolites-Zoophycos-Teichichnus* assemblage occurs in carbonate-free sediments inferred to have been deposited below a calcite compensation depth (CCD) of nearly 3 km and above inferred trench sediments deposited in 5 to 6 km water depth, consistent with the postulated 4-km upper depth limit for this assemblage. Similarly, an assemblage of *Chondrites, Planolites*, and *Zoophycos* occurs at Sites 489 and 493 only in carbonate-free sediments deposited below a 3 km CCD.

Uncertainties regarding the water depth distribution of trace fossils will probably be better resolved on passive margins, where vertical tectonic rates are slower and ancient water depths can be inferred reasonably from the present. Until then, it appears that the *Chondrites-Planolites-Zoophycos-Teichichnus* assemblage does occur on Neogene continental margins and may be a potentially useful deep-water indicator.

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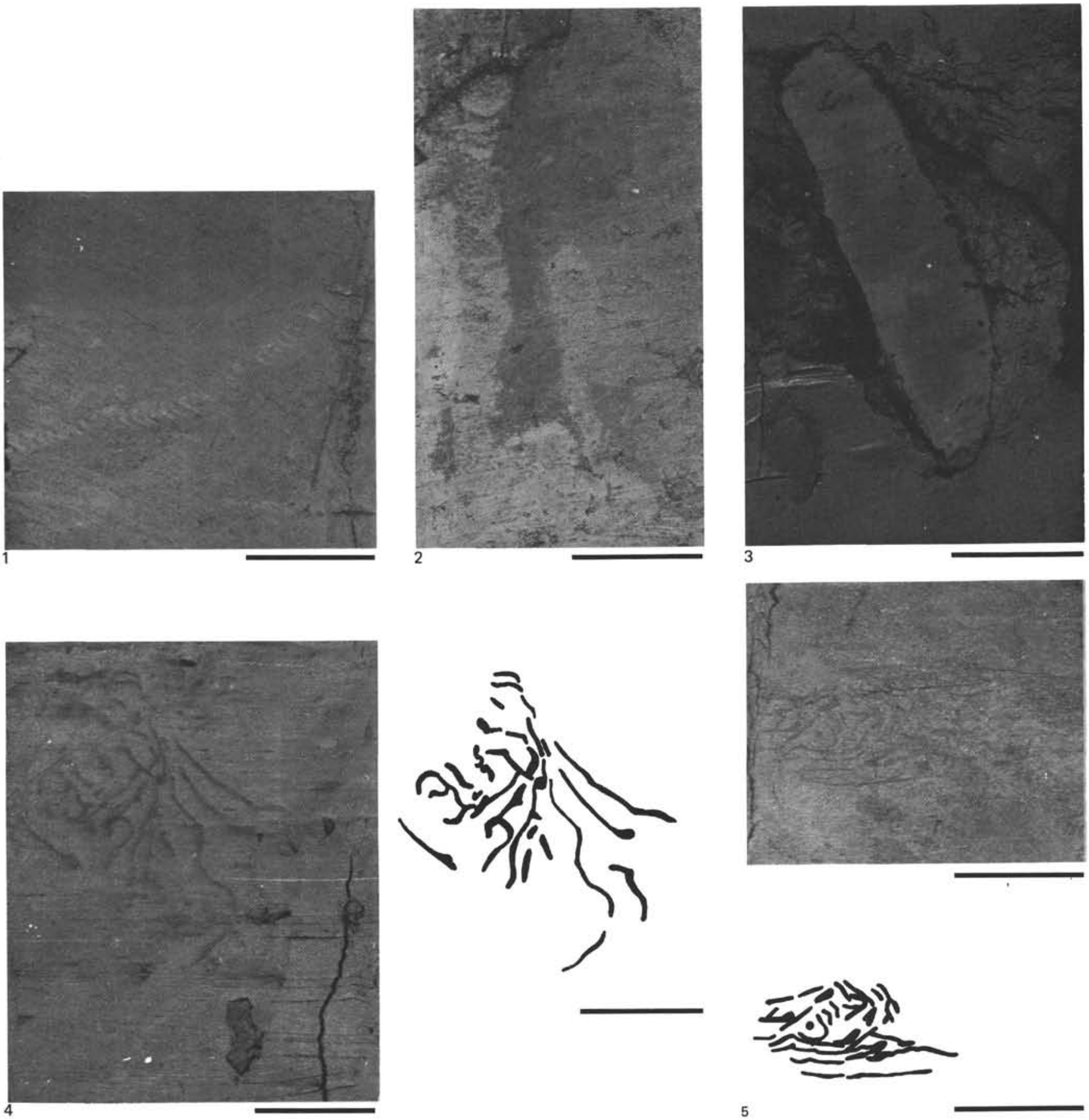

Plate 1. Distinctive trace fossils in Leg 66 cores. 1. *Zoophycos*, Sample 489A-19-2, 91–97 cm. 2. *Teichichnus*, Sample 492-14-1, 83–91 cm. 3. Borings in carbonate nodule, Sample 490-1-4, 79–90 cm. 4. Problematica I, Sample 489A-5-4, 89–97 cm. 5. Problematica II, Sample 490-37-2, 60–64 cm.