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Turbidity Currents and Cable Breaks in the Western New Britain Trench

ABSTRACT

The western New Britain Trench is receiving abundant sediment from the west. Evidence for earthquake-triggered turbidity currents has been detected in the New Britain Trench through breaks in a submarine telephone cable in 1966 and 1968. The average velocity of the turbidity currents is 50 and 30 km/hr, respectively, assuming that the most likely single source of the turbidity currents is the Markham River delta at Lae, New Guinea. Bottom photographs and sediment samples support these conclusions. Deep-sea channels are present.

INTRODUCTION

Evidence of turbidity currents has been found in the western New Britain Trench, which is part of a complex island arc in the Solomon Sea of the western Pacific Ocean (Fig. 1). Two cable failures (Table 1) in a submarine telecommunications cable (SEACOM of Cable and Wireless Ltd.) in the trench give direct evidence of sediment movement. Both cable failures occurred where the cable crossed deep-sea channels, and both followed large earthquakes by several hours. The cable failure of 23 December 1966 was a tension break, with some length of the cable so deeply or extensively buried that it could not be recovered. In contrast, the cable fault of 17 September 1968 consisted mainly of tangling and mauling. This suggests that the damage was caused by earthquake-triggered turbidity currents, the 1966 turbidity current probably being much larger than the 1968 one. The average velocities of the turbidity currents can be calculated and are presented.

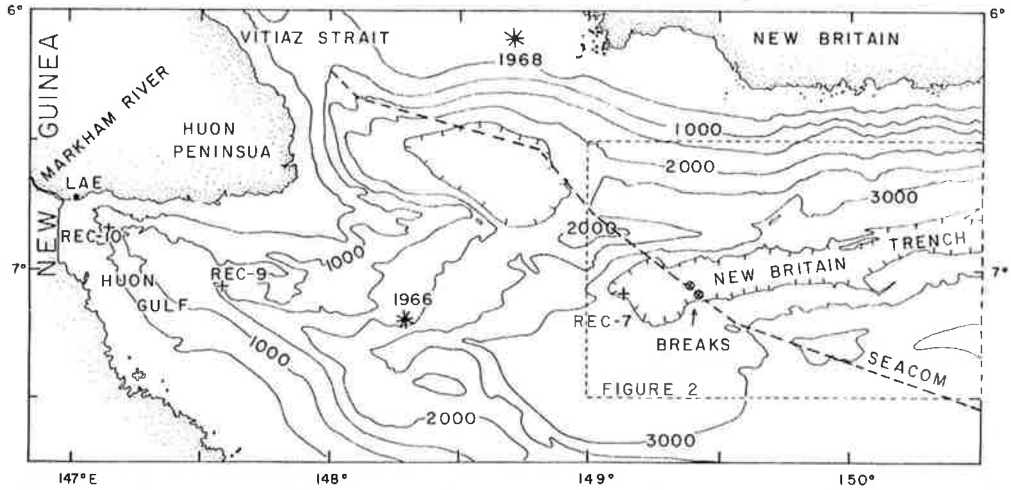

Figure 1. Bathymetry of the western Solomon Sea (500 fathom contours, depths corrected for sound velocity). Earthquake epicenters, cable breaks, *Recorder* stations, and Figure 2 locations are shown.

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Table 1. Cable Failures and Earthquakes

Defect observed:	Associated earthquake:
2123 GMT, 23 December 1966 7°06'S., 149°23.2'E., 3613 fm (6608 m) Cause: tension break	1550 GMT, 23 December 1966 7.2°S., 148.3°E., Richter M = 6, 150 km depth, Huon Gulf
Defect observed:	Associated earthquake:
0009 GMT, 17 September 1968 7°03.5'S., 149°23.8'E., 3627 fm (6636 m) Cause: faults in mauled cable	1356 GMT, 16 September 1968 6.1°S., 148.7°E., Richter M = 6.7, 59 km depth, southwestern New Britain Is.

This study will trace the birth and existence of turbidity currents in this region, past and present, through the associated environmental evidence. Although turbidity currents may originate from many different causes and may be of several different forms, we will deal specifically with the inferred relatively high density type caused by slope failure.

The New Britain Trench lies along the northern margin of a deep basin bounded by New Guinea on the west, New Britain on the north, and the Solomon Islands on the east. The very active regional tectonism is associated with frequent large earthquakes and volcanic eruptions, although no known volcanism exists in the area of the trench itself. The very high submarine and subaerial relief shows abundant evidence of geologically rapid elevation changes. Such subaerial high relief in areas of high tropical rainfall leads to very rapid erosion, with the concomitant introduction of large amounts of sediment into the sea. In New Guinea, at the western end of the trench, several rivers (the largest being the Markham) bring down abundant sediment to the Huon Gulf (western Solomon Sea), most of which temporarily accumulates at the mouth of the river, while the rest is transported to sea as suspended material. Evidence will be presented to show that the river deltas are the probable sources of the inferred turbidity currents.

This study is based on two surveys, a reconnaissance survey in July, 1961, by White and Krause with the C.S. *Recorder* (E. J. M. Reilly, Acting Commander) of Cable and Wireless Ltd., and a buoy-controlled, detailed survey in October, 1968, by Cable and Wireless' C.S. *Retriever* (G. Garrett, Commander) equipped with a precision depth recorder. Depths have been corrected for sound velocity.

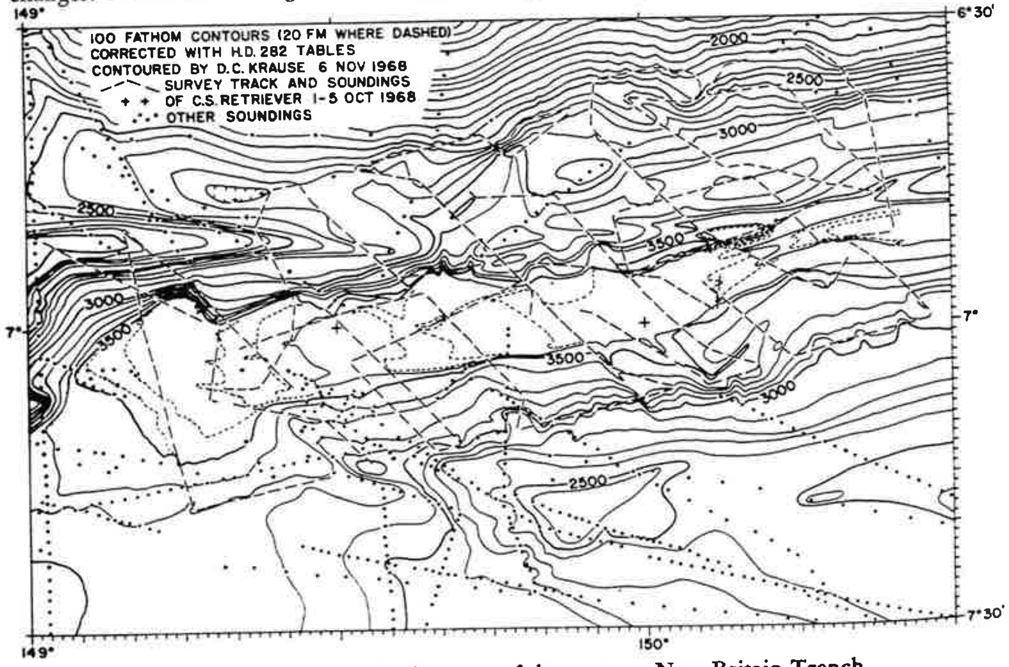

Figure 2. Detailed bathymetry of the western New Britain Trench.

BATHYMETRY

A cross section across New Britain Island and the New Britain Trench shows typical features of an island arc, from the volcanoes on the island to the rise seaward of the trench, despite the peculiarity that westward the trench can be followed onto land at Lae, New Guinea (Fig. 1). The marine features are (Figs. 1–3): (1) a rise of the sea floor south of the trench; (2) the trench itself; (3) a swell or ridge on the trench's landward side; and (4) the stepped, steep slope of the land. To the west, the New Britain Trench divides into two branches which become rapidly shallower westward (Fig. 1). The main branch passes into the Huon Gulf and becomes a deep submarine valley leading directly to the subaerial Markham River valley at Lae. The other branch leads northwesterly to Vitiaz Strait and the line of volcanism (Krause, 1965) via a flat-bottomed, silled basin, floored with very fluid gray silt below a depth of 2900 fm (5300 m). The basin is separated from the main trench floor by a low ridge which rises and broadens majestically westward to become the impressive Huon Peninsula of eastern New Guinea. Most of the sediment derived from the northeastern end of the Huon Peninsula and from the volcanic districts at the western end of New Britain probably collects in the flat-bottomed basin, both through pelagic sedimentation and through slides and turbidity currents.

The *Retriever* profiles show that the detailed characters of the bottom of the New Britain Trench can be attributed mainly to turbidity current deposition and transportation but modified by tectonism (Figs. 2–4). The main fill of the trench has been from the direction of Lae. In the west, under the Huon Gulf, the trench valley is steep and narrow. At the point where this emerges into the flat main trench below 3500 fm (6400 m) depth, the bottom is irregular, probably a small deep-sea fan (profile AB, Fig. 4). Eastward, the gradient rapidly flattens to 1:200 in the vicinity of the cable where at least two deep-sea channels are present. The 1966 cable break is associated with a very large channel on the southern margin of the trench. The 1968 cable failure seems to be associated with another channel in the center of the trench.

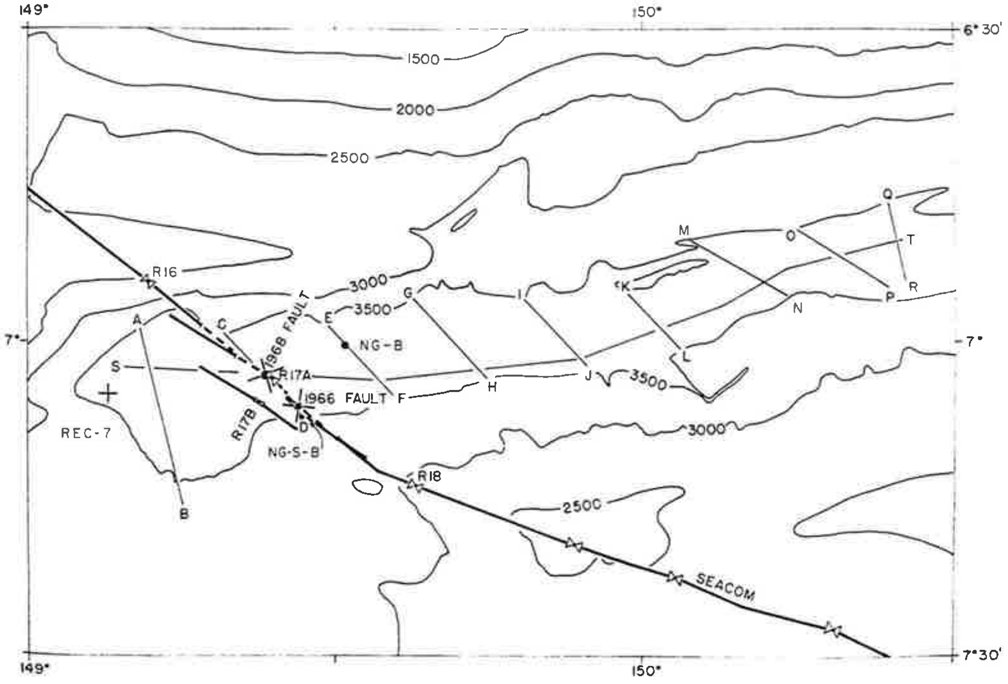

Figure 3. Index to bathymetric profiles (Figs. 4 and 5) and station locations noted in text. Positions of the cable faults and the SEACOM cable with its repeaters are given.

Some 25 nautical miles (45 km) to the east of the cable, the gradient decreases and no channel is obvious (profile KL, Fig. 4). A topographic dam evidently has blocked the sediment transport here. Beyond this, the trench is much more irregular, narrower and deeper.

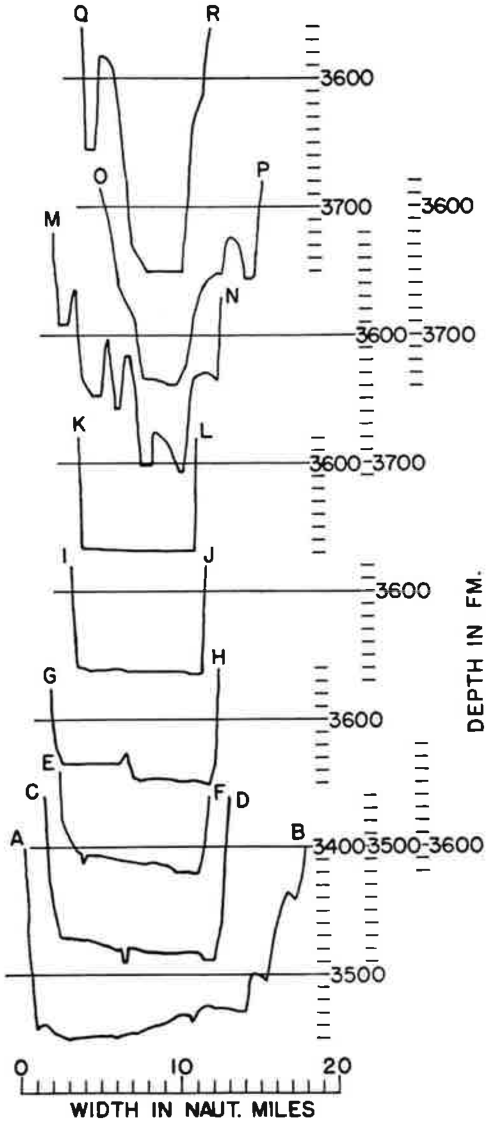

Figure 4. Bathymetric profiles of the western New Britain Trench made by C.S. *Retriever.* Depths corrected for sound velocity.

INFERRED AVERAGE TURBIDITY CURRENT VELOCITIES

Given both the time of the earthquake and of the cable fault occurrence, the average velocity of the turbidity current can be calculated by assuming a point of origin. If the 1966 New Britain Trench turbidity current originated within 30 nautical miles (55 km) of the earthquake epicenter, its velocity would have been 8 to 20 knots (15–37 km/hr) for the 5.6 hrs time separation of events (Figs. 5, 6). Assuming the Markham delta source, 28 knots (52 km/hr) is obtained. This is a limiting value as the Markham delta is the most distant possible source. For the 1968 event, assuming the delta source, the average velocity is 15 knots (28 km/hr) (10.22 hrs). The 1968 turbidity current is by inference much smaller and less dense than the 1966 one, and thus would be expected to travel more slowly. For comparison, the turbidity currents which damaged cables off the Grand Banks, Orleansville and Messina, all traveled at velocities in excess of 10 knots (18 km/hr), with a maximum at Orleansville of 40 knots (75 km/hr), and a similar velocity off the Grand Banks (Heezen, 1963).

SOURCE OF THE TURBIDITY CURRENTS

Background

Many turbidity currents and submarine slides are thought to have formed from masses of unconsolidated sediment that have failed (in the sense of soil mechanics) and moved downslope, the turbidity current forming as the sediment mass incorporates water and then becoming a heavy, turbulent fluid moving along the bottom (Chamberlain, 1964; Shepard, 1963). Such failure occurs generally as the sediment accumulation approaches a condition of instability. The actual failure is often triggered by earthquakes or large storms (Chamberlain, 1964). The situation in the Huon Gulf fits this description.

Earthquakes as a Triggering Mechanism

The Solomon Sea region is an area of extremely high seismic activity, having 5 to 10 percent of the world's earthquakes (Brooks, 1965). Not only is the area affected by the local earthquakes but also by earthquakes with epicenters as far away as the Solomon Islands. Earthquakes there are often associated with very large, low frequency ground motions at long distances (Richter, 1958), which can be expected to affect water-saturated ground.

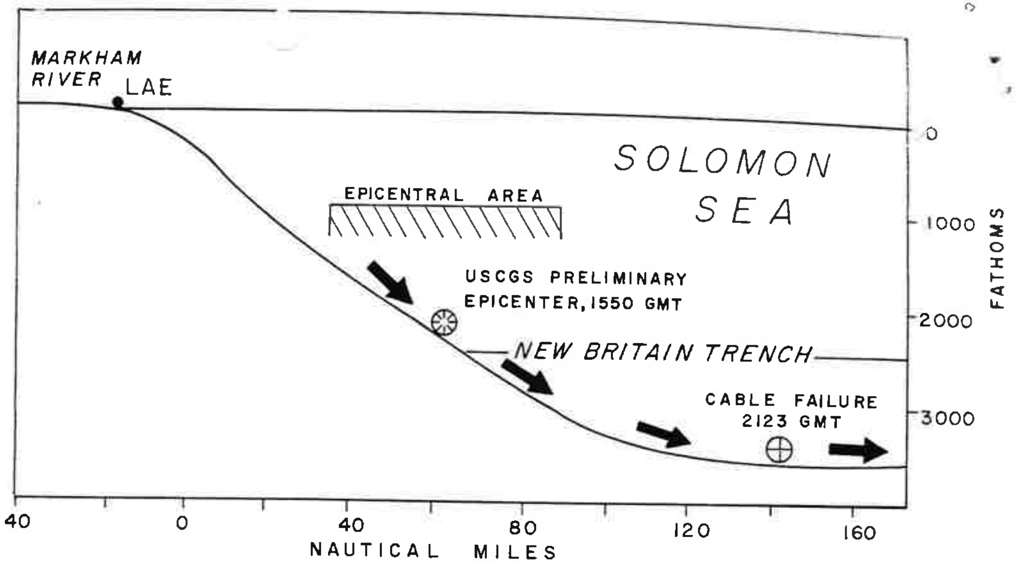

Figure 5. Diagram of the 1966 turbidity current path.

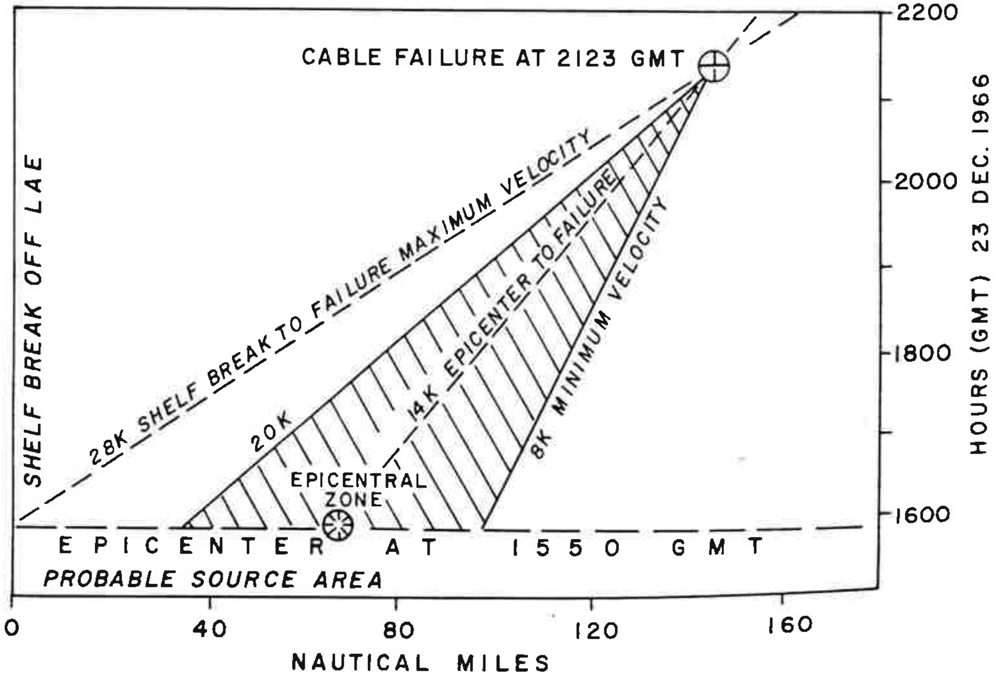

Figure 6. Velocity in knots of the 1966 turbidity current.

Because the exact effect of the earthquakes on the river deltas is difficult to estimate, let us assume that a delta is affected by any earthquake of magnitude equal to or greater than M = 6 (large to very large earthquakes) within a radius of 180 nautical miles (330 km). Such earthquakes within this radius occur twice each year (Denham, 1969). In addition, about one very large earthquake (M = 7 +) per 3 yrs affects the larger New Guinea-Solomon region (Denham, 1969). Thus, enough earthquakes exist to trigger any accumulating sediment mass whenever it approaches instability. Therefore, the question of slump frequency hinges on the available unstable sediment, rather than the frequency of earthquakes.

Sediment Sources

The turbulent, sediment-laden Markham River is the largest source of sediment finding its way into the western New Britain Trench, representing 42 percent of the Huon Gulf watershed. A deep submarine canyon with many side branches leads down from the Markham River, according to a 1944 Royal Australian Navy survey. Several smaller rivers of northeastern Papua also have active submarine canyons, such as the Francisco, the Waria, the Eia and the Gira Rivers (von der Borch, 1969). The aggregate sediment contribution of the smaller rivers to the Gulf and trench is undoubtedly similar to that of the Markham River, although any one river delta is probably less active than the Markham delta. The Markham River can be used as an exaggerated example for these smaller rivers. The bed load and most of the suspended load of the Markham River is temporarily deposited in the unstable Markham delta near Lae, but aerial photos show large quantities of suspended sediment from the river carried several miles to sea. The deposition of such suspended material on the steep, tectonically active trench slopes can also produce unstable sediment masses, but the river deltas are probably the most important sources of the mobile sediment.

Sediment Availability

For the purpose of evaluating the sediment availability, the Markham River is here compared to the larger Magdalena River of Colombia (Table 2) because of its well-studied turbidity currents (Heezen, 1956; Menard, 1964). The submarine cable there was broken 17 times in 26 yrs, in depths ranging from 500 to 1500 fm (1000 to 3000 m).

The drainage basin of the Magdalena River is much the larger and has high relief, but the annual rainfall is less (Anonymous, 1950, 1959). Both rivers are extremely turbid with fast currents and carry abundant suspended sediment and debris many miles to sea. Both have unstable deltas. Docks and shores have disappeared at the Markham River, and breakwaters have disappeared at the Magdalena River, in association with slides or turbidity currents, or both. No gauging of actual riverflow and no estimate of sediment load is available for either river, but the flow of the Magdalena River is obviously much greater with a probable proportionately greater suspended load. The Magdalena slides probably will be much larger than for the Markham River because of a greater rate of deposition and of fewer triggering earthquakes (Barazangi and Dorman, 1969). Also, the submarine slopes are steeper at the Markham River, leading to instability for smaller masses (Krause, 1971). Thus, submarine slide frequency off the two rivers will tend to be more similar than the river flow.

The sediment contribution of the whole Huon Gulf watershed is at least twice that of the Markham River. This contribution to the frequency of turbidity currents is unknown, but an indication of the total frequency is that the recorded frequency of the Magdalena cable breaks and of the two breaks of the SEACOM cable are similar.

Table 2. Comparison of Markham and Magdalena Rivers*

	Markham River	Magdalena River
Length	110 stat. mi (175 km)	950 stat. mi (1500 km)
Drainage area	5000 sq mi (14,000 sq km)	110,000 sq mi (285,000 sq km)
Annual rainfall range	100–250 + inches	30–250 + inches
Gross estimate of average rainfall	150 ± inches	60 ± inches
Gross relative flow	1	7?

* Anonymous, 1950, 1959.

Evidence of Sediment Instability and Slumping

Foreshore instability at the mouth of the Markham River is seen in past events, such as the disappearance of part of the beach and a landing jetty at Voco Bay (in front of Lae), and as erosion and slumping between Voco Bay and the end of the Lae airstrip.

The beach at Lae was slowly aggrading in July, 1961. Beneath the few inches of sand and gravel then being deposited on the beach is a very soft, wet clay similar to that in the extensive swamp which backs the beach. Any beach deposited rapidly on such a weak, well-lubricated foundation is liable to slump seaward, whether from the weight of sand deposited, the effect of earth tremors, or the scouring action of the local, variable, strong currents.

Furthermore, rapid depositional changes occur along the shore due to the highly variable currents, which are in turn influenced by the constantly shifting sand bars at the Markham River mouth. Such changes at Lae in July, 1961, consisted of the rapid deposition of very fluid silt at the wharf, the position changes of the nearby small Butibum River mouth and the rapid growth of the Voco Point sand-spit.

Huon Gulf, Sediment Accumulation and Transport

The rapid deposition of suspended sediment in Huon Gulf is revealed by animal tracks at *Recorder* station REC-10 on a prominent bench 150 fm (270 m) above and south of the canyon axis (6°51′S., 147°09′W., 670 fm = 1225 m depth, 13 nautical mi = 23 km east-southeast of the Markham delta). Bottom photographs showed a diverse but relatively sparse fauna of gastropods, crinoids, sea-feathers, deep-sea crabs and burrowing organisms, and debris of palm fronds, bits of wood, and the like. The tracks of the snails and crabs are all fresh, with a few examples of newer tracks crossing older ones. Even the newest tracks (where, for example, a snail is visible) are partly masked by deposition of fine sediment with the appearance of having been sprinkled with fine powder. The bottom consists of very fluid, poorly sorted, fine sediment, mainly clayey silt.

In contrast, the existence of strong currents in the deep axis of the main canyon is demonstrated by a few bottom photographs which, through the muddy water, show large current ripple marks, cobbles of dark rock swept clear of sediment, except on their "lee" side, and other marks of strong currents (*Recorder* station REC-9, 7°03.8′S., 147°35.4′E., 1556 fm = 2846 m, 41 nautical mi = 76 km east-southeast of Lae). No evidence of bottom life is present except for a few possible worm casts.

COMPARISON WITH THE PAST BY THE TRENCH SEDIMENTS

The trench floor sediments consist of two types, the major one of thin alternating layers of very fine sand and green silt, the other of coarse sand and pebbles with mud, as shown by two gravity cores and six grab samples taken by the C.S. *Retriever*.

In gravity core NG-B (7°00.5′S., 149°31′E., 3612 fm = 6606 m depth, 133 cm long), taken on the flattish interchannel plain, thin (0.1 to 3.2 cm) layers of very fine sand alternate with thicker (0.2 to 7.1 cm) green silt layers. In addition, the sand layers occur in two populations, several (2 to 10) very thin (0.1 to 0.5 cm) layers being followed by a single thicker (0.5 to 3.2 cm) layer showing disturbance, burrows or grading. Average thicknesses with standard deviations are: very thin sand layers, 0.2 ± 0.1 cm; thicker sand layers, 1.0 ± 0.3 cm; green silt layers, 1.0 cm with 85 percent of the layers between 0.7 and 3.5 cm; and a sand-silt unit, 1.9 ± 1.2 cm (excluding the four thickest units). The mode of the sand-silt units is 1.0 cm. The other core and grab samples show confirmatory results. Rates of deposition calculated from the core data are too sensitive to the necessary assumptions to do more than confirm to an order of magnitude the cable break record of one turbidity current per 2 yrs.

The gravel probably marks existing channels. Gravel (maximum length 5 cm) with coarse sand occurs in grab sample NG-S-B (7°07′S., 149°27′E., 3550 fm = 6493 m depth). The gravel size suggests that the turbidity current in the inferred channel flowed at 5 to 8 knots (10 to 15 km/hr) at 1 m above the bottom (Sundborg, 1956). A 9-cm, angular rock is also shown resting on silt at *Recorder* camera station REC-7 (7°05′S., 149°08′E., 3490 fm = 6383 m depth). The soft bottom here is shown to have much bottom life, mainly Holothurians. Old, indistinct Holothurian tracks and faecal pellets are crossed by successive sets of newer tracks, indicating that deposition of the cored fluid silt has been discontinuous or is slow relative to the Huon Gulf.

Investigations elsewhere on such submarine channels as found in the trench (Menard, 1964; Piper, 1970) show that powerful turbidity currents are usually confined to the channels with only the tops of such currents overflowing onto the surrounding sea floor. Such overflowing currents are not very powerful and rapidly deposit fine sand. The western New Britain Trench conforms to this pattern. The frequency of very fine sand layers in the cores and the paucity of burrowing structures suggest that deposition is rapid, with overflowing turbidity currents frequently occurring. Each sand-silt unit represents one such event with probable additional contributions to the silt layer from diffuse turbidity currents and pelagic sedimentation. The thicker sand-silt layers show that larger events occasionally occur.

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