Copper and Zinc Distribution in the Sediments of the Fly Delta and Torres Strait

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Abstract

The Fly delta extends for approximately 30 kilometers offshore from the southern coast of Papua New Guinea. The area is dominated by fine grained terrestrially derived muds. To the south the region of Torres Strait is represented by predominantly carbonate sediments.

High levels of zinc and copper (maximum values of 110 and 35 ppm respectively) were found to be associated with the terrigenous sediments. These concentrations are comparable to those reported for industrialized areas around the world. Possible sources of the metals include erosion and drainage of the highly mineralized rocks found in the catchment area and the input of contaminated mine waste into the system.

A linear correlation was found to exist between the copper and zinc concentration and the distance of sample sites from the estuary. A correlation was also found between the percentage of fine grained particles (< 63 mm) and copper concentrations.

This study indicates that future work should investigate historical changes in copper and zinc concentrations in the sediments and the ultimate fate of metals associated with the particulate matter in the Fly River.

Introduction

Torres Strait is an important ecosystem with a cultural identity that supports a subsistence fishery for indigenous peoples and more recently a commercial fishing industry. Changes to the integrity of the system, as a result of resource development, could have major repercussions for the island communities.

The Strait is a shallow stretch of continental shelf, transected by a number of passages, that separates Australia from Papua New Guinea to the north. Surficial sediment maps of the area illustrate a predominance of carbonate sediments, with terrestrially derived material mostly restricted to the north in the vicinity of the Fly River (Harris and Baker, 1989).

Recent mining developments in the catchments of the Fly and Strickland Rivers have the potential to increase metal levels in the sediments of the Strait. At present mine waste and overburden dumped into the river system contains elevated levels of both copper and zinc. Increased erosion and runoff caused by associated land clearing may also contribute to an increase in metal levels in the sediments.

This study is concerned with the distribution of copper and zinc in the offshore sediments. Both of these metals are essential for metabolic activity in marine and estuarine organisms. However, they become highly toxic when natural concentrations are exceeded. Acute toxicity is generally caused by interference in enzyme systems and death is fairly rapid (Bryan, 1976). Sublethal or chronic effects however, can be very subtle and not immediately discernible. They usually result in changes to growth and reproductive success (Bryan, 1976). Mammals are far less sensitive to copper and zinc than invertebrates, and freshwater organisms are more sensitive than marine organisms (Hart, 1982).

Heavy metals like copper and zinc can be transported down river in dissolved or particulate form. The suspended particulate material may be deposited when it enters the estuary and encounters the reduced energy conditions of the adjacent mangrove swamps, or it may continue to be carried in the water column out into the Strait. The process of deposition in the estuary is aided by the increasing salinity and pH which causes the colloidal clay particles to flocculate and settle. A large amount of the metal ions present may be adsorbed on to this particulate matter, which means that estuaries are often viewed as sinks for heavy metals (eg. Olsen *et al.*, 1982). The desorption of metals from particulates has also been observed in estuaries. This is important as metals in solution are generally more available to be taken up by organisms. The dissolved metals may exist as free metal ions, or form complexes with iron and manganese hydroxides and organic molecules. Evidence also exists indicating that metals associated with the mud accumulating in estuaries can escape (Summerhayes *et al.*, 1985). This remobilization can be bought about by changes in the chemical and physical conditions, which include resuspension by bottom currents, dissociation into pore water during diagenesis and the action of bacteria and bioturbating organisms.

The model of the Fly estuary as a sink for heavy metals is also complicated by the presence of strong tidal currents that continually rework the estuarine sediments, effectively winnowing away the finer grained material, leaving a predominantly sandy deposit (Spencer 1975). Fine grained material is deposited in the delta, or further off shore (Harris, this volume)

Methods

Surficial sediment grab samples were collected from the HMAS Cook and the HMAS Flinders during 1989 and 1990 (see Harris, this volume Figure 11), using a Shipek sediment sampler. Prior to analysis the samples were stored in double acid washed polycarbonate containers kept in a cool room at 3°. A portion of the sample was sieved to determine gravel/sand/mud ratios (reported in Harris *et al.*, 1990). The samples used for metal analysis were oven dried then crushed using a tungsten carbide mill. Following this, duplicates were digested in high purity NHO3 and HClO4. Measurements were carried out in triplicate using flame atomic absorption. A number of international standards were also analysed, the results of which were within ± 7% of the recorded values.

Results and Discussion

Copper distribution in the surficial sediments is illustrated in Figure 1. The isograms parallel the coastline, illustrating a general decline in concentration with distance from the Fly River. The highest concentrations, of greater than 35 ppm, are found in the fine grained muddy samples of the delta, whereas the carbonate rich samples to the south have less than 10 ppm of copper. These contour lines may also indicate that the major transport pathway for copper associated with sediments is to the east or west rather than south into Torres Strait. This is further indicated by the pattern of carbonate distribution in the surficial sediments (Harris and Baker, 1991) which shows that the terrestrially derived muds are primarily restricted to the delta in the study area. Calculations by Harris (this volume) also indicate that only a small percentage of the Fly River sediment is deposited in Torres Strait.

That the Fly River is the most important source of copper in the area is confirmed by the correlation (r^2= 0.64) of copper concentration with distance from the delta (Figure 2). The concentration of copper in the surficial sediments may be influenced by the release of copper from particulate matter as it encounters the increasing pH and salinity of the estuarine water. There is also a significant correlation (r^2=0.709) between copper concentration and percentage mud in the sediments (fraction < 63 µm; Figure 3). This demonstrates that the copper is associated with the fine grained fraction of material that originates from the Fly River.

The general distribution of zinc (Figure 4) is similar to that of copper (Figure 1). The highest concentrations of greater than 110 ppm are found in the delta samples and the lowest concentrations of less than 70 ppm are found in the samples away from the coast. As with copper, there is a significant correlation between zinc concentration and distance from the delta (r^2=0.724, Figure 5). However, unlike copper there is not a significant correlation between zinc concentration and percentage mud in the sediments (r^2=0.374, Figure 6). This is due to high zinc concentrations associated with a band of sandy sediments extending just south of the delta front (see Harris, this volume). These sands are composed of relic carbonate grains that have been reworked and deposited as a lag, most probably following storm activity. The reason for the high zinc content is not yet clear.

There is no evidence to indicate whether increases in the concentration of either copper or zinc have occurred in the sediments in recent times. Schneider (1990) examined copper concentrations in one 5 metre core from the Fly Delta, collected in 1988.

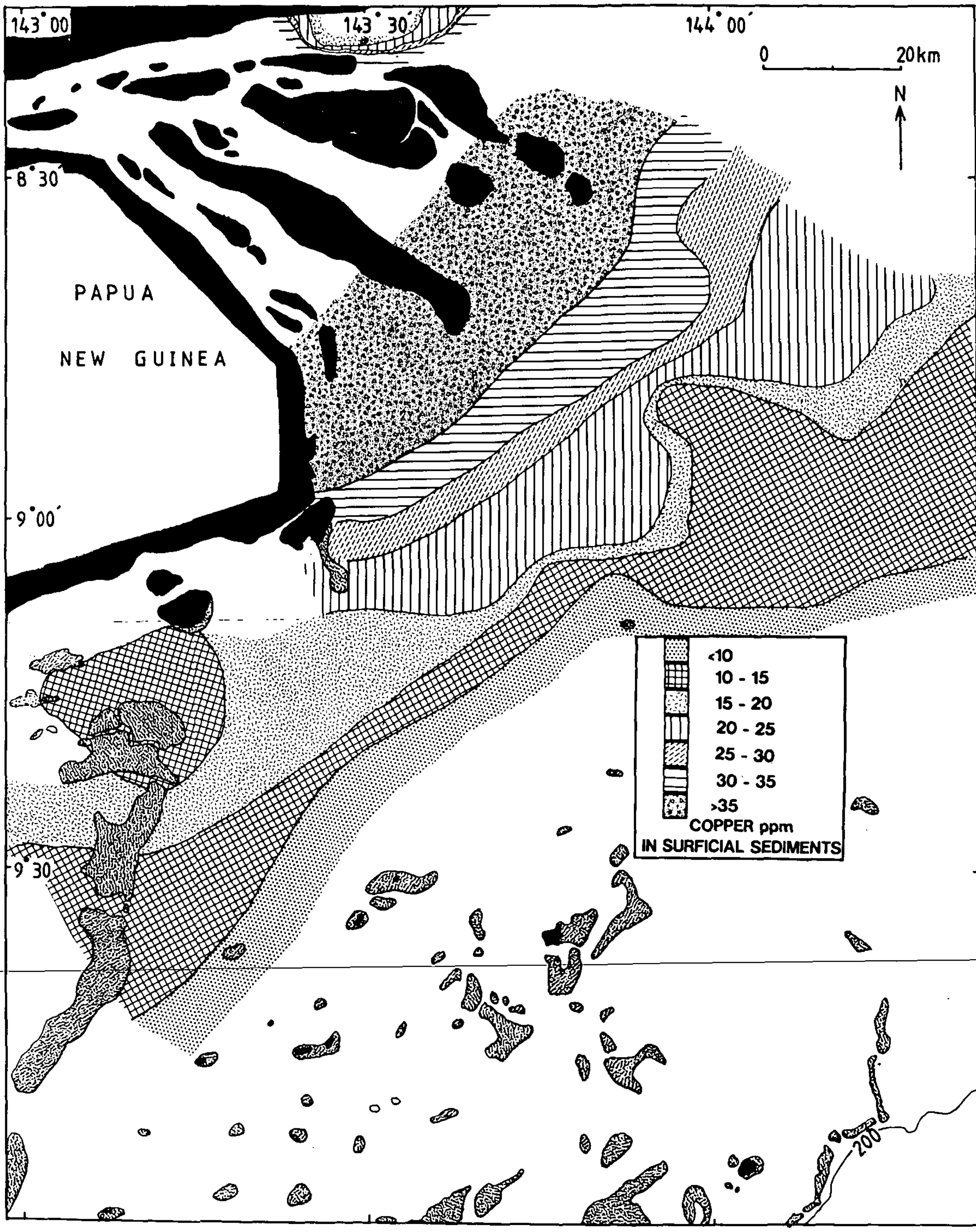

Figure 1. Map showing the distribution of copper (ppm) in the surficial sediments of the Fly River Delta and Torres Strait.

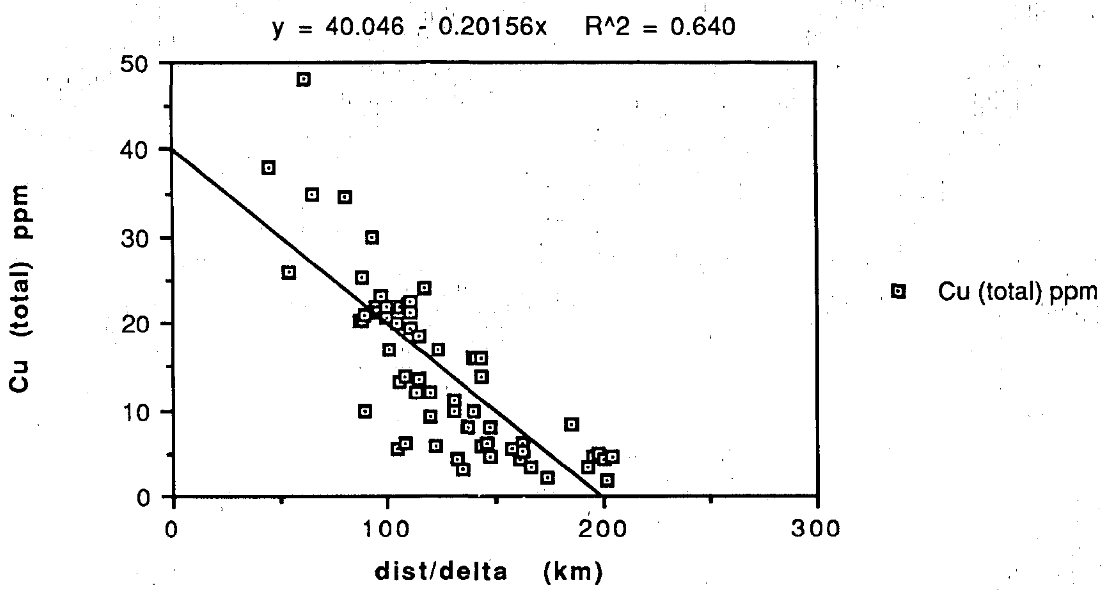

Figure 2. Graph of copper concentration (ppm) in the surficial sediments versus distance from the Delta (km).

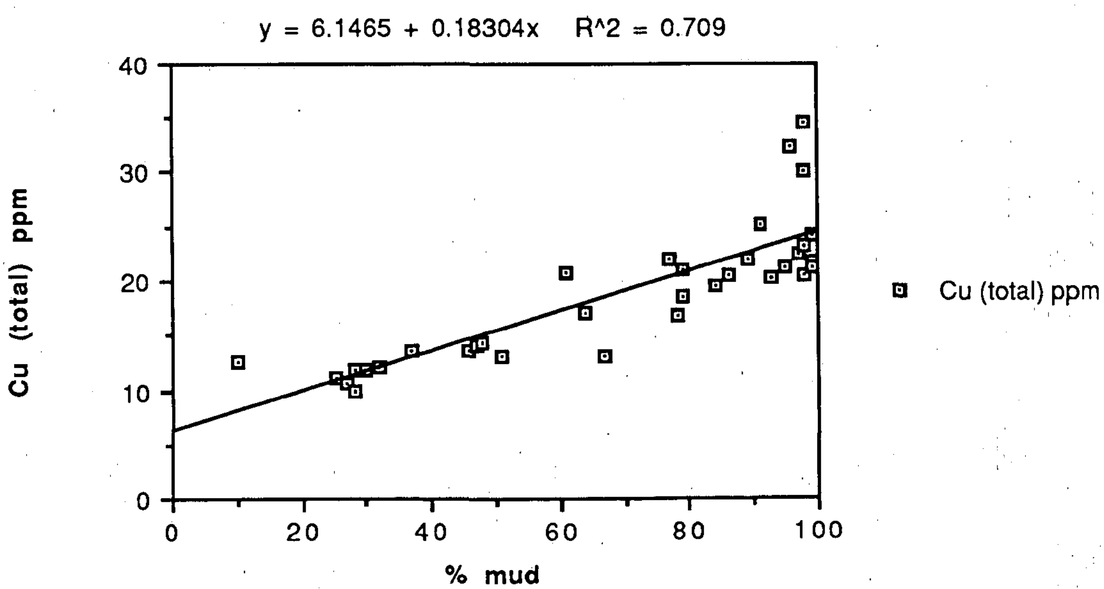

Figure 3. Graph of copper concentration (ppm) in the surficial sediments versus percentage mud (63 µm).

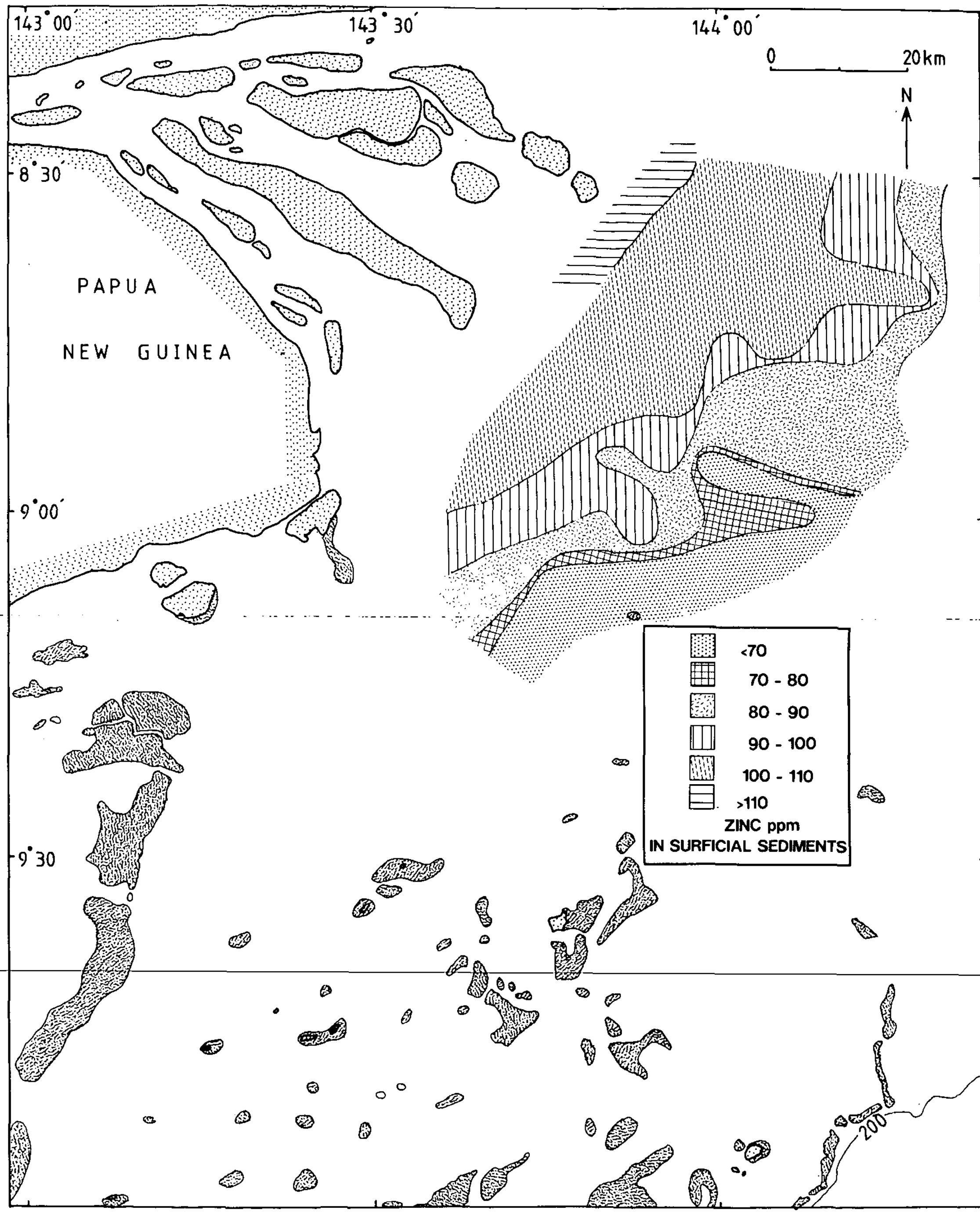

Figure 4. Map showing the distribution of zinc (ppm) in the surficial sediments of the Fly River Delta and Torres Strait.

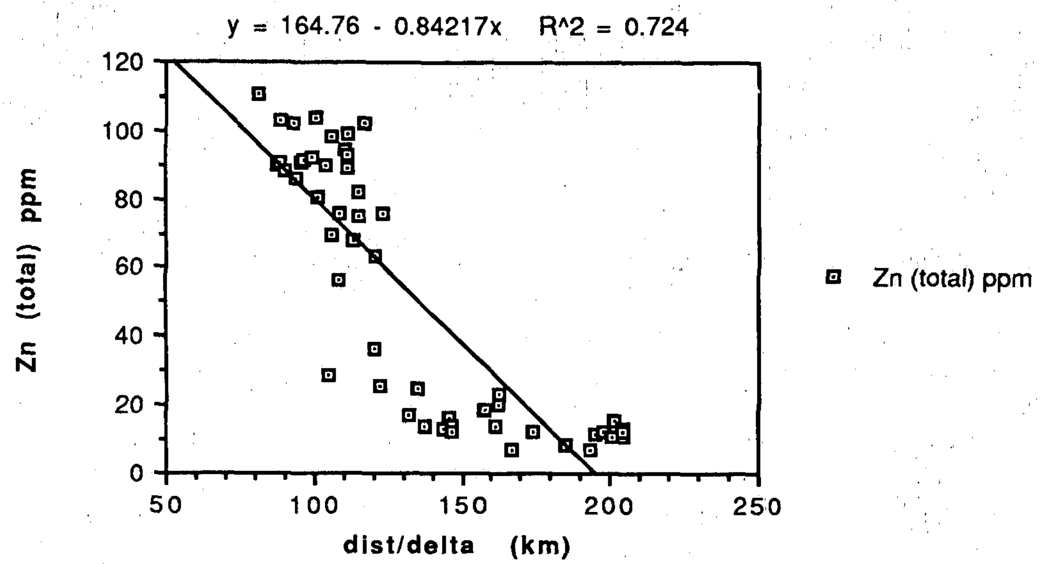

Figure 5. Graph of zinc concentration (ppm) in the surficial sediments versus distance from the Delta (km).

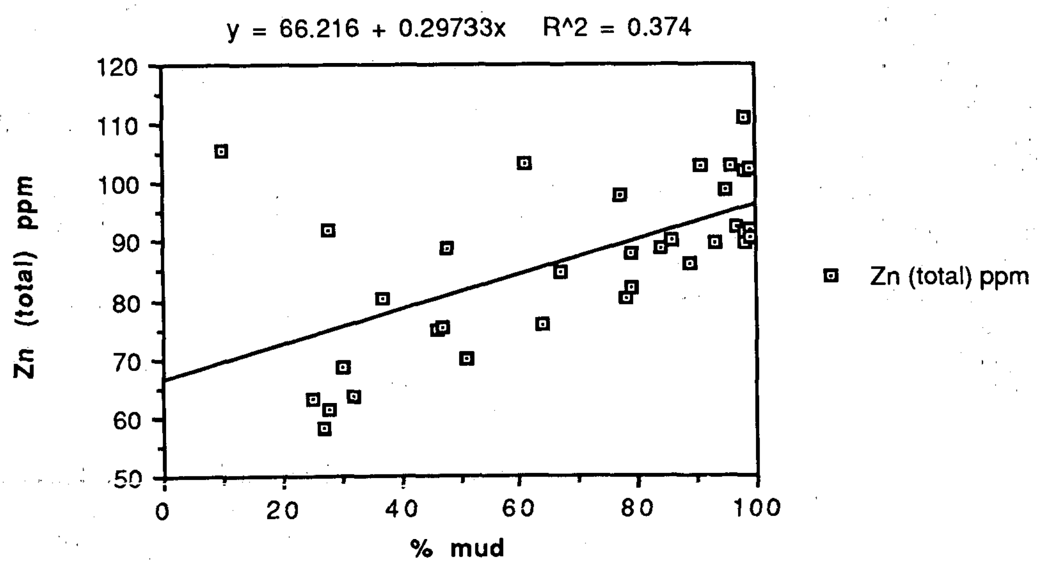

Figure 6. Graph of zinc concentration (ppm) in the surficial sediments versus percentage mud (63 μm).

Sedimentation rates calculated from Pb 210 ratios indicate this to represent over 100 years of sedimentation (Harris, this volume). Schneider (1990) found no apparent increase in metal levels at the top of the core. In fact this study found that there was a slight increase in concentration down the core. This may be due to mobilization of copper into the overlying water or migration of metals in the core following collection and exposure to oxidizing conditions. Alternatively, these values may represent background levels in this area, indicating that at least until 1988 there had been no effect on copper levels in the sediments as a result of mining activity or increased erosion and runoff in the catchment. However, this is the result of the analysis of one core and since 1988 there has been at least another 10 cm of sediment deposited in this location. Further work is required to generate a statistically meaningful conclusion.

If the concentrations of copper and zinc measured in the delta sediments represent background levels they may be naturally high due to the mineralized terrain of the catchment. Figure 7 compares the copper and zinc concentrations found in the Fly Delta with other locations around the world, illustrating that even if natural, these concentrations are on a par with many industrialized locations. The Ok Tedi mining company has constructed a model to predict the degree of copper contamination likely to occur in the delta sediments as a result of their operation. They have calculated a maximum value of 200ppm (Ok Tedi Mining limited, 1988), which is similar to the level found at the Los Angeles industrial outfall (Figure 7).

It should be noted that the copper and zinc concentration associated with the particulates may only represent a small fraction of the total metal input from the river. For example in the Gironde estuary it was found that 80% of the up-estuary trace metal input is in the particulate form, whereas the output to the ocean occurs mainly (80%) in dissolved form (Jouanneau, 1982). Such a situation may also occur in the Fly Delta (Solomons and Eagle, 1990).

Conclusions

The limited data collected to date point to the Fly River as the major source of copper and zinc in the Torres Strait area. The fate of sediment from the Fly River is not fully understood, although in the area examined the highest copper and zinc levels were found associated with the fine grained sediment of the delta. The relatively low levels of copper and zinc found in the Strait appear to indicate limited deposition of terrestrially derived sediments in this area. Levels of copper and zinc found in the delta sediments may represent background levels. This could be confirmed by analysis of core samples.

Specific conclusions of the present study are as follows:

- Copper and Zinc concentrations correlate well with distance from the delta, indicating that the Fly River is a point source for metals in the area.
- Copper is predominantly associated with the <63 µm fraction of the surficial sediments.
- Zinc correlates poorly with the fine grained fraction due to high concentrations associated with some sandy carbonate sediments.

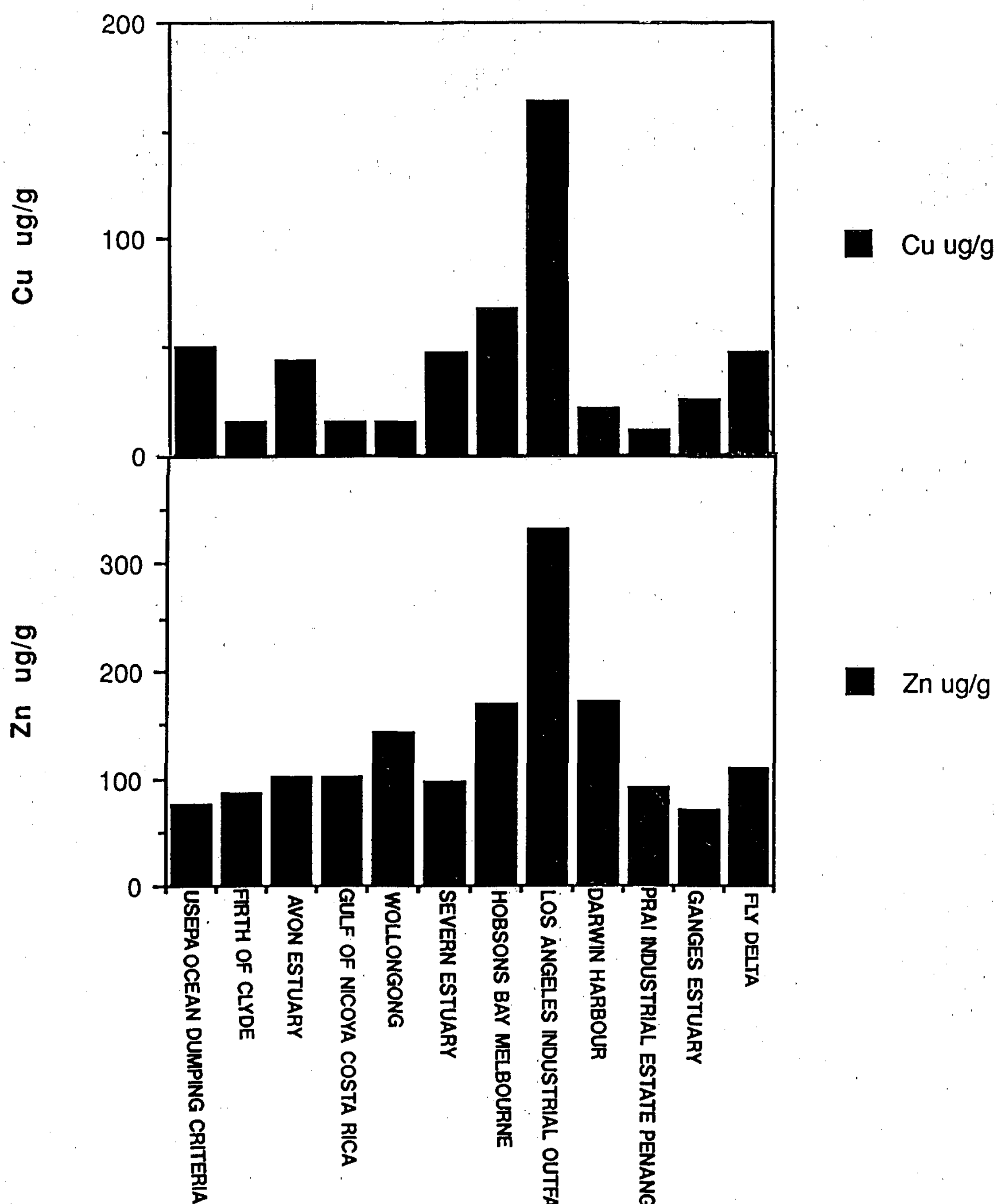

Figure 7. Bar Graphs showing copper and zinc concentrations in sediments from various locations including the Fly Delta (Adapted from Schneider, 1990)

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