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Estuarine sediment geochemistry

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Abstract: Estuarine sediments can be used to target areas of mineralization in the hinterland. Geochemical anomalies invariably occur in estuaries draining from areas with proven mineral deposits. Relatively high geochemical contrasts between mineralised and unmineralised drainage basins are expressed in the metal content in the estuarine samples. These observations are based on the analyses of sediment samples collected from estuaries present in the Tawau-Semporna peninsula in Sabah.

INTRODUCTION

In places having poor accessibility, such as in Sabah, mineral exploration reconnaissance programmes can be very costly, and time and energy-consuming. Estuarine geochemistry can perhaps be used to provide a relatively reliable, cheap and fast method in locating drainage basins having areas with potential mineralization. A case study was undertaken to study the heavy metal distribution pattern in sediments present in estuaries occurring in the Tawau-Semporna Peninsula which is located in the south-eastern part of Sabah.

GEOLOGIC SETTING

The geology of the peninsula has been previously studied by Fitch (1955) and Kirk (1962). The area consists mainly of Miocene sedimentary rocks constituting the Kalumpang Formation. With the occurrence of late Miocene orogenesis, the sedimentary rocks were folded, faulted and intruded by ultrabasic rocks which outcrop in the west of the peninsula. Post-orogenic volcanic activities during Tertiary and Quaternary, resulted in most of the Kalumpang Formation overlain by lavas and pyroclastic rocks. Concurrent with the Tertiary volcanic eruptions, stocks and plugs of granite, diorite and dolerite were injected into the existing volcanics and the Kalumpang Formation (Figure 1). Base-metal mineralization, particularly that of copper as well as silification occurred not only in some of these plutonic rocks but also in the surrounding sedimentary and volcanic rocks.

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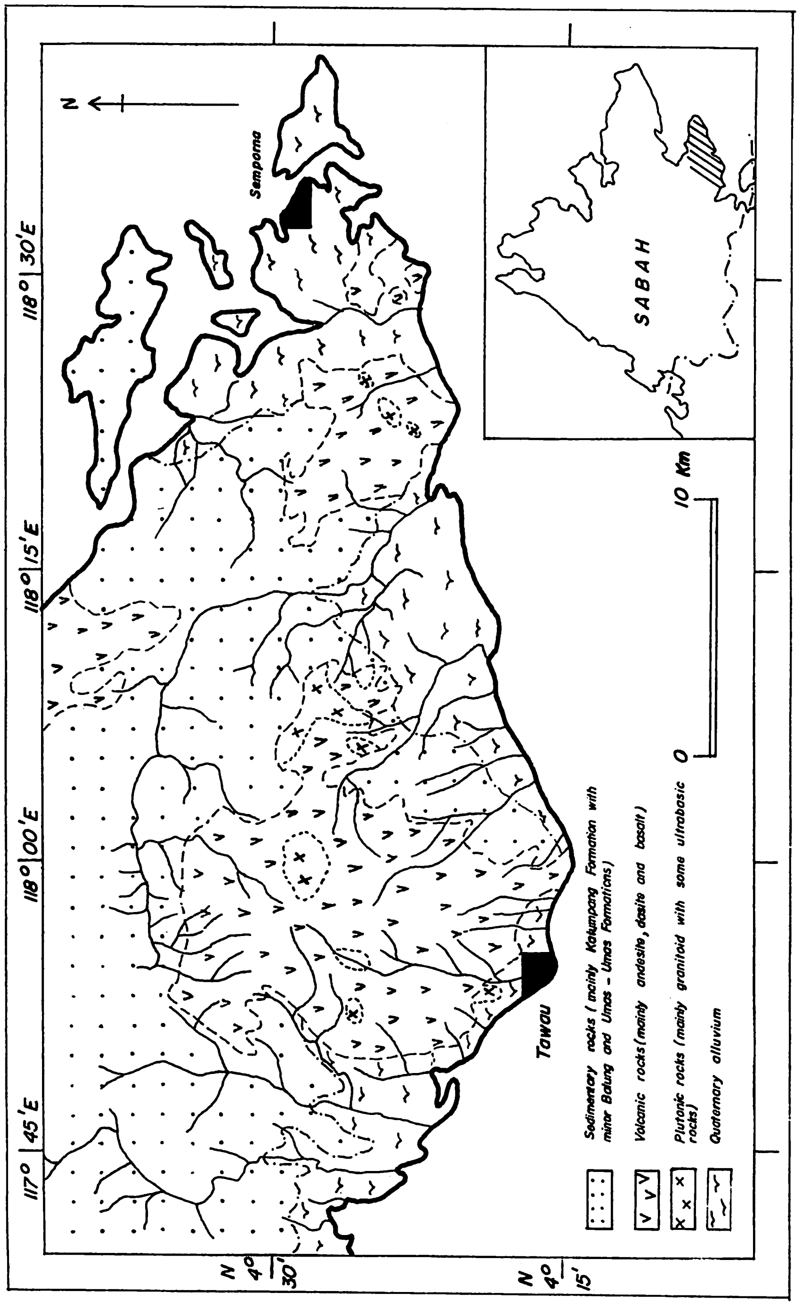

Figure 1 : Geology of Tawau – Semporna peninsula, S.E. of Sabah

METHOD

Two to three samples of bottom sediments, each weighing about 1 kg, were collected from each estuary present along the coast in the peninsula, using a self-closing bottom sampler dropped from a motorised dinghy. The samples were then dried, homogenised, seived to a minus 80 mesh and analysed for Cu, Pb and Zn using atomic absorption spectrophotometric methods.

HOMOGENEITY TEST

For the purpose of evaluating the homogeneity of metal content in sediments from an estuary, 30 samples were initially collected from Sungai Mantalitip estuary. Grain size studies indicate that the estuary consists of pockets of predominantly gravels, sand, silt and mud (Figure 2). The Cu, Pb and Zn values in the minus 80 mesh fractions, irrespective of the grain size, vary considerably with large standard deviations from the mean values (Figure 3). However, the analytical data when classified according to the type of sediments show that the mud samples have the highest mean metal values with lowest standard deviations, whilst the gravel samples have the lowest mean metal values with highest

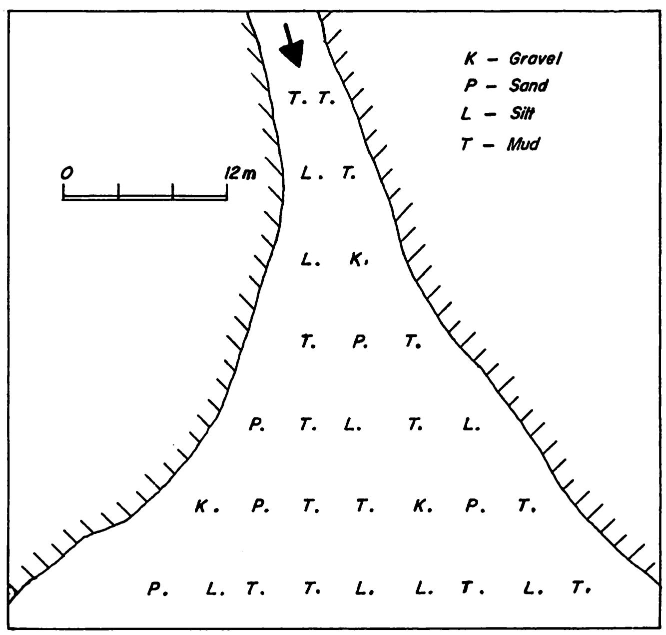

Figure 2: Sampling sites and types of sediments present at Sungai Mantalitip estuary (arrow indicating river flow direction).

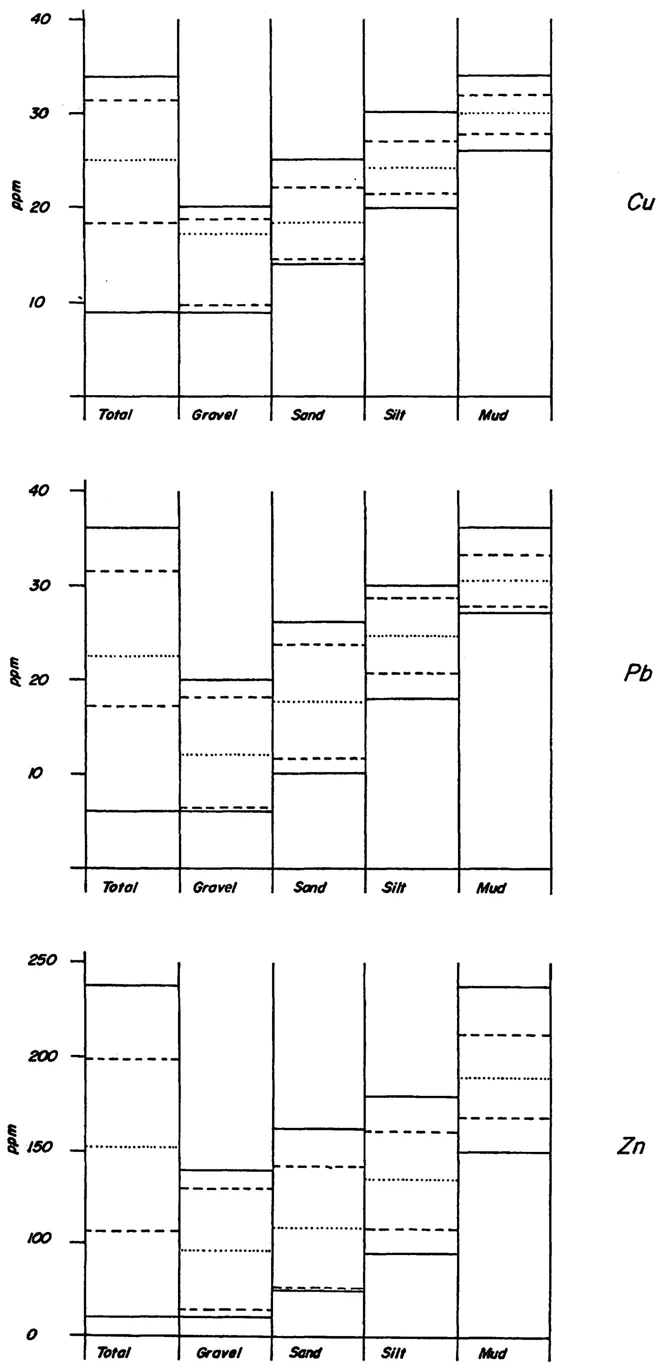

Figure 3 : Range, mean, and standard for Cu, Pb, Zn in unclassified sediments (total), and in sediments classified according to grain sizes present in Sungai Mantalitip estuary. (Solid line = range, dashed line = standard deviation, dotted line = mean).

standard deviations; with sand and silt samples having intermediate values. With increase in grain size from mud to gravels, the mean metal values decrease systematically with corresponding increase in standard deviations (Table 1).

Table 1: Cu-Pb-Zn distribution in types of estuarine sediments from Sungai Mantalitip (A=range of metal content, B=mean value, C=standard deviation; value in ppm).

Sample	Cu			Pb			Zn		
	A	B	C	A	B	C	A	B	C
gravel	9 – 20	14.33	4.50	6 – 20	12.00	5.89	60 – 140	96.67	33.00
sand	14 – 25	18.40	3.83	10 – 26	17.60	5.99	75 – 162	108.40	34.18
silt	20 – 30	24.25	2.77	18 – 30	24.63	4.09	95 – 180	135.25	27.89
mud	26 – 34	30.14	2.26	26 – 36	30.50	2.82	150 – 236	190.29	21.79

The above geochemical characteristics of the estuarine sediments indicate that mud samples, in having relatively homogeneous metal content, are the most suitable samples to be collected from an estuary for geochemical exploration. Hence, subsequent sampling in other estuaries in the Tawau-Semporna peninsula was confined only to those samples with high mud content.

BASE-METAL DISTRIBUTION PATTERN IN ESTUARINE SEDIMENTS

The data for each of the metals analysed (Cu, Pb and Zn) in the mud samples exhibit log-normal frequency distribution as shown in the histograms (Figure 4). Plots of their cumulative frequency distribution on log probability paper, using the method proposed by Lepeltier (1969), have inflections indicating that the data consist of more than one population (Figure 5). The partitioning of the data into background and anomalous populations for each of the metals was computed using the procedure suggested by Sinclair (1974, 1976). The mean and the standard deviation for each of the base-metals, determined from the background population are shown in Table 2.

Table 2: Mean, standard deviation and threshold value as determined from background population of Cu, Pb and Zn data.

metals	mean log ppm	mean ppm	standard deviation log ppm	threshold ppm
Cu	0.9534	9	0.1900	22
Pb	1..0714	12	0.2809	43
Zn	1.5993	40	0.2135	106

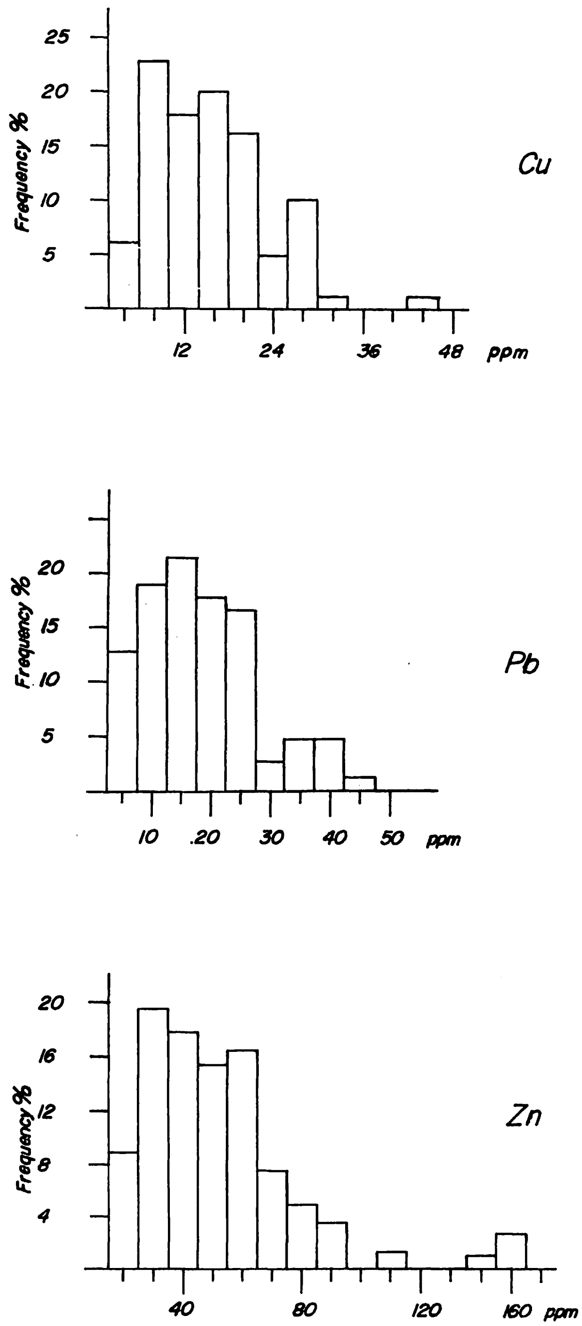

Figure 4: Histograms showing log - normal frequency distributions for Cu, Pb, Zn, contents in estuarine sediments

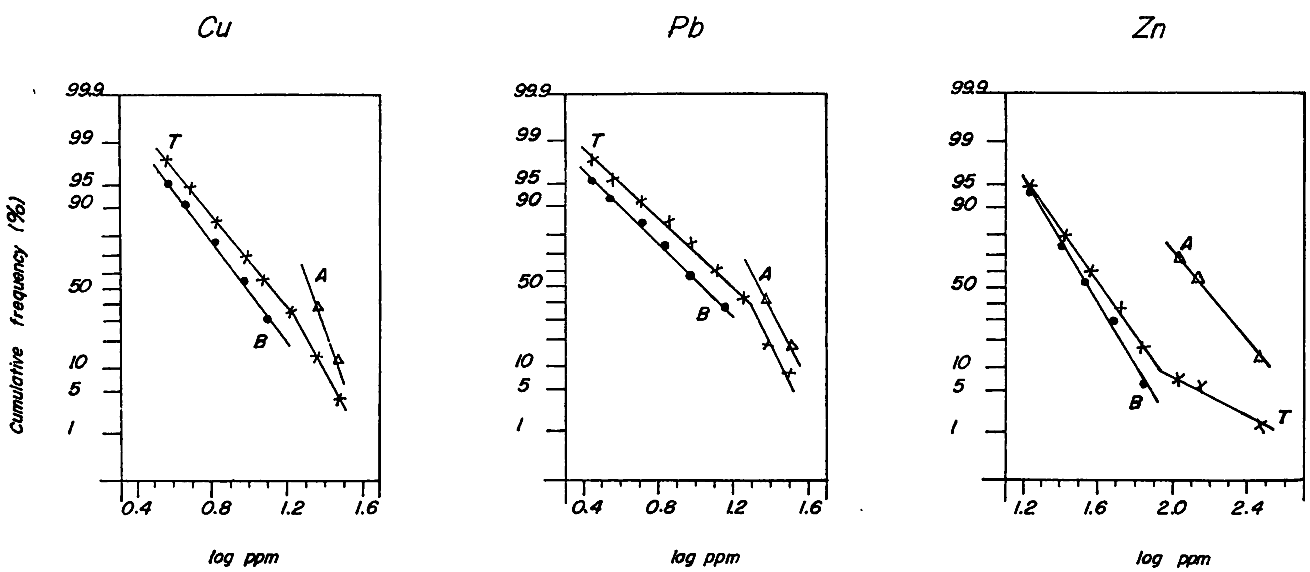

Figure 5: Log probability plots of Cu, Pb and Zn and their partitioning into background anomalous populations (T = total population, A and B projected anomalous and background populations respectively).

The threshold value at 97.5% level of significance for each of the base-metals is calculated from its mean value plus twice its standard deviation (Rose *et al*, 1979). Those estuarine samples with metal content exceeding the threshold values are anomalous and are possibly related to mineralization (Figures 6, 7 and 8).

The geochemical maps (Figures 6, 7 and 8) show superimposed Cu-Pb-Zn anomalies at the estuaries of Sungai Mantalitip and Sungai Kalumpang. The sediments in other estuaries, with the exception of Sungai Imam, have metal contents below the threshold values. Unlike the two rivers mentioned earlier, the Sungai Imam estuary has only zinc anomaly.

DISCUSSION

The upper reaches of Sungai Mantalitip and Sungai Kalumpang are at Gunung Pock and at Gunung Wullersdorf-Magdalena-Lucia respectively. These hills consist mainly of volcanic rocks intruded by stocks of diorite and granite. At Gunung Pock and at Wullersdorf where some of the plutonic rocks were intensively silicified, base-metal mineralization in the form of disseminated chalcopyrite and some associated sphalerite and galena, is evident. Thus, the presence of ore bodies in areas drained by the upper reaches of the rivers is reflected by the superimposed metalliferous anomalies present in the estuarine sediments.

Though a zinc anomaly was detected in the Sungai Imam estuary, mineralization was neither observed nor reported in its drainage basin. The high zinc concentration is probably due to waste affluence discharged from an oil palm factory situated near to the estuary.

The preservation of geochemical anomalies, derived from hinterland mineralization, in the estuarine sediments is probably due to:

(a) adsorption and ion exchange of ions and ion complexes present in the water onto colloidal particles such as clay, organic matter and Fe-Mn oxides and hydroxides ubiquitously present in the estuarine mud (Jenne, 1968, 1977; Tan and Nik, 1984; von Olphen, 1963);

(b) formation of precipitation barrier at river-sea interface where changes in pH and Eh conditions would cause precipitation of solid phases from ion and ion complexes (Garrels and Christ, 1965; Rose, *et al*, 1979);

(c) precipitation of undissolved and partly dissolved primary as well as secondary ore minerals distintegrated and transported from source.

CONCLUSION

Mineral exploration at reconnaissance level, particulary for base-metals, in areas with poor accessibility can be carried out at relatively fast rate using estuarine geochemistry. Employing a bottom-sampler and a motorised dinghy, sediment samples from all the estuaries in the Tawau-Semporna peninsula were

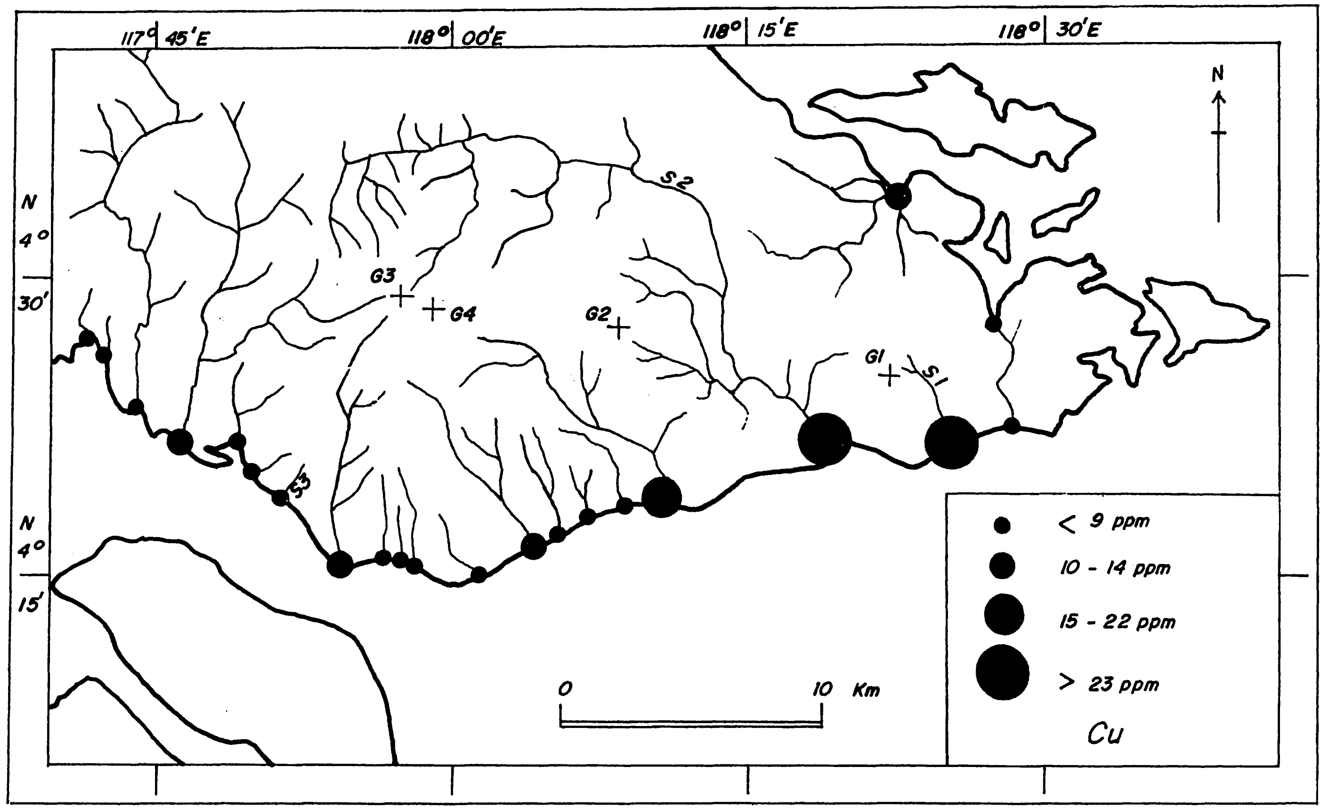

Figure 6 : Distribution of Cu in estuarine mud sediments, Tawau - Semporna peninsula. (S1 = Sungai Mantalitip, S2 = Sungai Kalumpang, S3 = Sungai Imam, G1 = Gunung Pock, G2 Gunung Wullersdorf, G3 = Gunung Magdalena, G4 = Gunung Lucia)

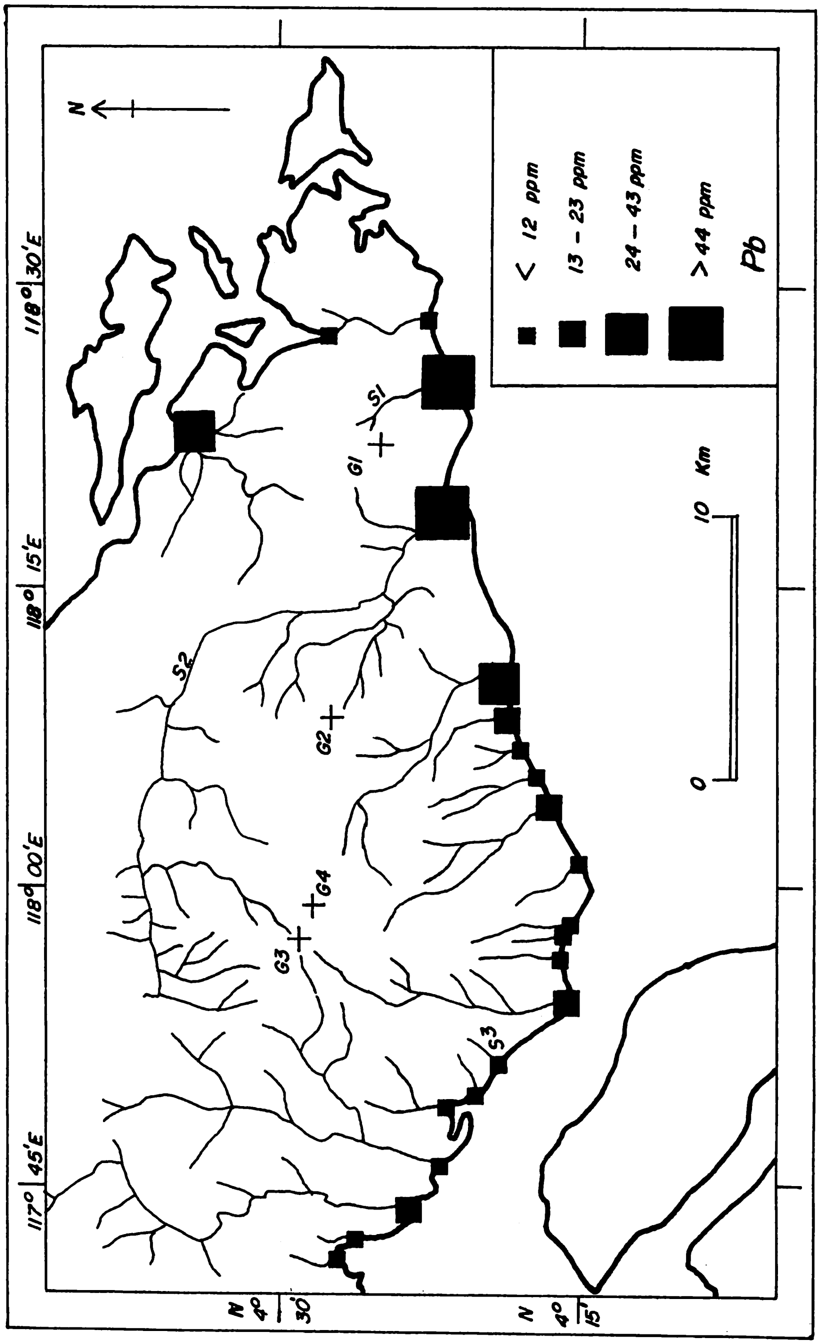

Figure 7 : Distribution of Pb in estuarine mud sediments, Tawau - Semporna peninsula (For explanations S1, S2, G1, G2, G3, and G4, see Figure 6)

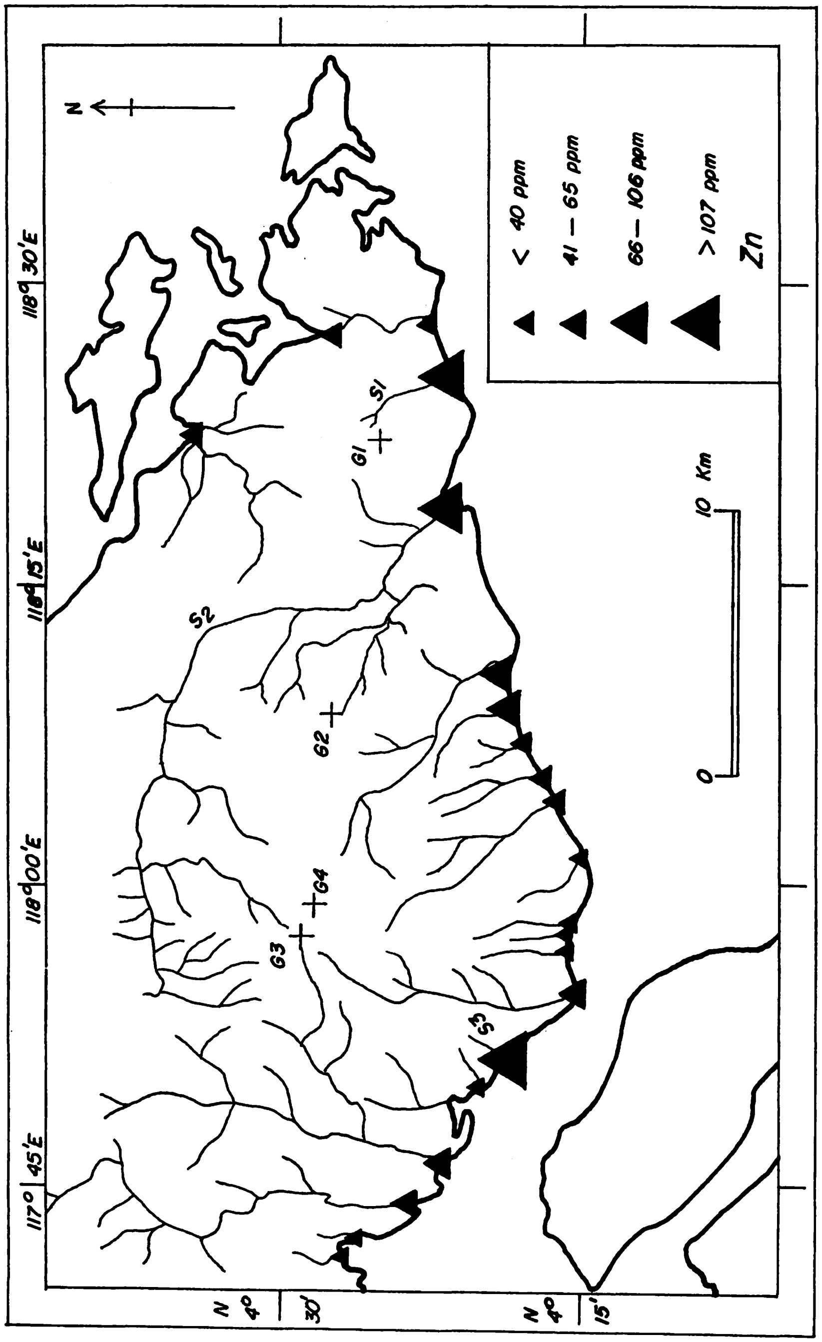

Figure 8 : Distribution of Zn in estuarine mud sediments Tawau - Semporna peninsula. (For explanations S1, S2, G1, G2, G3 and G4, see figure 6)

collected in 7 days. Field procedure involving stream sediment geochemical survey would have taken a much longer period.

In addition, enrichment of base-metals in estuarine sediments, largely through adsorption and reprecipitation of soluble phases and less importantly through deposition of transported solid phases from source, allows estuarine sediments, especially those with high mud content, to be used as samples for reconnaissance geochemical exploration. Estuarine mud samples invariably contain high concentrations of base-metals at minimum variations. The geochemical contrast between background and anomalous data enables the detection of hinterland ore-bearing drainage basins.

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