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Elemental composition and mineralogical characteristics of coastal marine sediments of Tutuila, American Samoa

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ABSTRACT

Surface sediment samples were collected from 5 pristine coastal areas and 1 potentially contaminated coastal site on Tutuila, the main island of American Samoa, an isolated island group in the South Pacific Ocean. Samples were analysed for total element analysis (15 elements) and mineralogy. The results indicated no evidence of trace element contamination at any site, including Pago Pago Harbour. Inter-site variations could be explained assuming the sediments consisted predominantly of coralline sand and rubble with varying quantities of basaltic materials derived from local catchments.

American Samoa is comprised of five volcanic high islands and two coral atolls, located in the eastern half of the Samoa Islands archipelago, in the region of 11°–14°S, 168°–171°W, in the South Pacific Ocean. Tutuila, located at 14°17′S, 170°41′W, is the main island of the group and is the site of Pago Pago, the capital and main port. Tutuila is globally a remote location, being 4200 km SSW of Honolulu, Hawaii, 2900 km NNW of Auckland, New Zealand and 1250 km E of Suva, Fiji. Landmasses between Tutuila and these points of reference are limited to small oceanic islands, many of which are uninhabited, amid large expanses of open ocean; Tutuila is therefore, remote from any major global sources of pollution, unless pollutants have been transported atmospherically over long distances (Peshut, 2009). At this remote location, trace elements in sediments would be expected to reflect naturally occurring background conditions for volcanic high island sites not influenced by potential anthropogenic impacts.

Tutuila Island is the largest (137 km^2) and most populous (~56,000) island in American Samoa and is the centre of Territorial government and commerce (Wingert, 1981; US Department of Commerce, 2001). Most land on Tutuila is in steep terrain (Fig. 1) with shallow soils, and consequently the amount of cleared land for agriculture, residences, and commerce is small compared to the total island land area. Habitation is almost exclusively confined to the southern coastal plain and southern coastal fringe, with a few small remote villages scattered along the north coast. The isolation of Tutuila, the small population, and limited commercial development (especially along the north coast) has provided an opportunity to assess the trace metal composition of coastal sediments in a relatively unpolluted part of the central South Pacific Ocean. An opportunity was also available to compare sediments within Pago Pago Harbour with those from much less developed areas, to determine if port development and operations, and dense residential and commercial development have had a significant pollution impact as has been observed in Suva, Fiji (Naidu and Morrison, 1994; Morrison et al., 2001) Apra Harbour, Guam (Denton et al., 2005) and Tanapag Lagoon, Saipan (Denton et al., 2009).

Tutuila is a rugged volcanic island dominated by olivine basalts (Stearns, 1944; Staudigel et al., 2006), with consistent warm temperatures, high humidity, and abundant rainfall, throughout the

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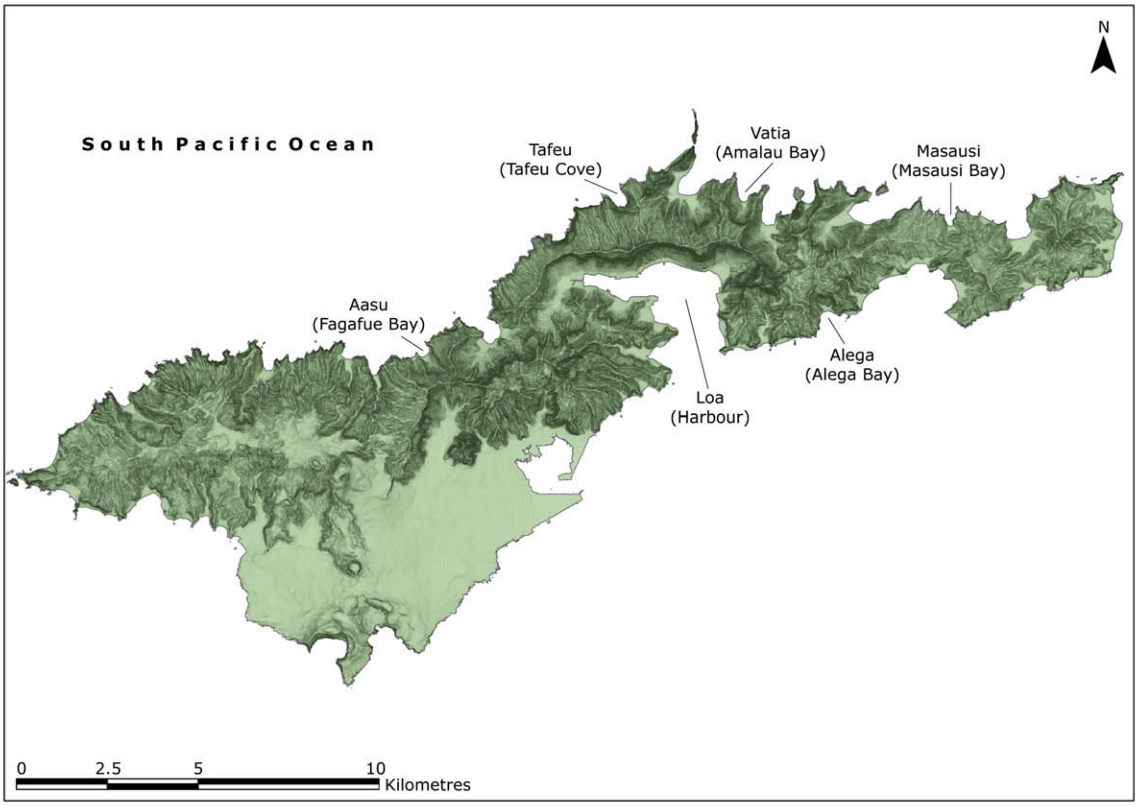

Fig. 1. Tutuila Island – topography (study sites indicated) (*Source*: GIS Users Group, American Samoa Government, 2006).

year (US National Climatic Data Center, 2004). Annual rainfall on Tutuila varies from less than 1800 mm/yr at Cape Matatula on the eastern end, to 3000 mm/yr on the SE coastal plain, to >5000 mm/yr in the mountainous interior (Izuka, 1999; Mefford, 2002; US National Climatic Data Center, 2002). Seasonal variations in rainfall are inconsistent, due mainly to the influence of the South Pacific Convergence Zone (SPCZ) (Wright, 1963; Giambelluca et al., 1988). The coastline (200 km long) is extremely irregular with numerous small bays open to the sea, which lack bars or barrier reefs, and are subject to the sea conditions of exposed coasts. Pago Pago Harbour is one of the few protected areas and maintains most of its natural shoreline, except for some filled areas near the main port, which have been developed for commercial shipping activities and two fish canneries. Tutuila has no estuaries and most of the coastline is rocky with abrupt elevation changes immediately above breaking waves. Surface waters are limited to a few dozen perennial streams, most of which have short, steep reaches, and typically low base flows. Coral reefs are the dominant marine habitat for Tutuila near-shore waters, with 60% of the coastline occupied by narrow fringing reefs.

As part of a larger ecological study, six study sites on Tutuila (Aasu, Tafeu, Vatia, Masausi, Alega, and Loa – see Fig. 1) were investigated. The first five are in near pristine areas while Loa is located in Pago Pago Harbour, the most human-impacted zone in Tutuila. As part of a larger study (Peshut, 2009), 32 sediment samples were collected from each site, from which six sub-samples were selected (random number generation) for trace element analysis. Samples were collected at each site using certified trace-metal clean, pre-labelled wide-mouthed 250 mL glass jars, as supplied by the analytical laboratory. Undisturbed sediments, representative of long-term *in situ* conditions were selected for study. Redox horizon depths were evaluated for reef sediments to show that sediment samples were obtained consistently from the oxic sediment layer among reef study sites. The redox horizon for *in situ* sediments was estimated using clear PVC tubing (50×5 cm) to identify the colour change that is often associated with the change in conditions from a reducing to an oxidizing environment. For each core, a distinct line of colour change was visible, although the contrast and definition varied among cores. The depth of colour change in the cores was measured directly to 0.1 cm with a fine-line stainless steel rule. In most cores, the colour change was sharp and distinct and $\leqslant$0.5 cm in width.

Sediment samples were collected by hand via SCUBA from stable bottom sediments, generally 1–2 m seaward from where the reef matrix terminated in sand at a shallow-grade slope (~10–30 m depth). At each sampling station (approximately 10 m apart) surficial sediment was collected by carefully dredging sediments with a jar held horizontal, to a depth not greater than the width of the jar mouth (~6 cm). Dredging was done slowly and carefully so to not disturb sediments, and so that not more that ~75% of the jar volume contained sediment. At the surface, samples were placed on ice for transport to the on-island laboratory. All field procedures were conducted wearing clean powder-free latex gloves. The sediments were mainly coarse-grained coral dominated materials with small inclusions of volcanic materials and minimal (<5%) contents of silt + clay.

At the on-island laboratory, jars were allowed to settle for ~2 h in complete darkness at 4 °C. After settling, jars were carefully opened and water decanted by gently rolling each at a shallow angle so that water slowly poured off at a steady rate over the entire circumference of the jar lip. This process removed excess water from the jar to allow for expansion during freezing, and washed loose sediment particles from the rim to ensure a tight seal. Care was taken to minimise the loss of fines during decanting. After decanting, sediment samples were stored at −20 °C until shipped to the analytical laboratory.

Samples were received frozen at the analytical laboratory, and were stored at −80 °C until start of analysis. Samples were