Geochemical characterization of clay minerals in surface sediments of three major rivers along the east coast of Peninsular Malaysia

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Abstract: Clay mineral assemblages and major-element geochemistry of surface sediments of the tropical river-estuary system of Kelantan, Terengganu and Pahang Rivers were investigated. Clay minerals in these three major rivers mainly consist of kaolinite (72%-75%), illite (13%-20%), chlorite (7%-10%) and minor smectite (<1%). A change in clay mineral contents (chlorite+illit) from upstream to the downstream (kaolinite) pointed to the alteration sequence of more stable mineral under the hot and humid conditions. The geochemical study indicated that the concentrations of major elements decrease from the middle course to estuary. Elemental ratios suggest that CaO and Na₂O are the most chemically mobile elements while Fe₂O₃ is the least for the three investigated rivers. Formation of clay minerals (Al-rich) occur with enrichment of quartz (Si-rich) and feldspar (Na-rich). The illite chemistry index in these river basins averages 0.49 and is supported by the high chemical index of alteration (CIA) (>80) which shows that intensive chemical weathering had occurred in the Kelantan River, Terengganu River and Pahang River basins. The CIA values increase both north and southward directions from the Terengganu River pointing to the localized variations. The CIA values in clay fraction (<2µm) generally increased from the middle to the lower watershed.

Keywords: clay minerals, geochemistry, chemical weathering, tropical rivers, Peninsular Malaysia

INTRODUCTION

Geochemistry and mineralogy research on clay minerals are useful for evaluating the continental weathering process and mechanism through their geochemical and mineralogy compositions (Singh et al., 2005; Liu et al., 2007a, 2009). Distinct clay mineral composition can also be used as a tool to identify terrigenous contributions to estuarine and coastal deposits (Singh et al., 2005).

The east coast of Peninsular Malaysia has three main rivers that flow into the South China Sea, i.e. Kelantan, Terengganu and Pahang Rivers. The Kelantan River basin is located at the north-eastern part of Peninsular Malaysia. The river is about 248 km long and drains an area of 13,100 km² (Ibbitt et al., 2002). The Terengganu River basin covers approximately 5,000 km² of the State of Terengganu (Sultan & Shazili, 2010). The Pahang River is the largest river basin in Peninsular Malaysia. Its length is approximately 440 km and its basin area is about 25,600 km² (Tachikawa et al., 2004). Among these rivers, the Pahang River basin produces the highest suspended solid load in Peninsular Malaysia as a result of active chemical weathering and erosion processes induced by high rainfalls and temperature and also its basin size (Sathiamurthy, 2008). This study compared the surface sediments clay mineralogy and major-element geochemistry between the middle course and estuary of the Kelantan, Terengganu and Pahang Rivers. Earlier papers were limited to estuary data only (Wang et al., 2011; Liu et al., 2012) and explained regional distribution of clay mineral assemblages around the South China Sea.

Geologically, Peninsular Malaysia is divided into three belts; Western, Central, and Eastern Malaya, each of which is distinct in geology and tectonic history (Hutchinson, 1989). The study area is located in the central and eastern belts, an amalgamation of continental terranes, and is underlain with clastics, carbonates, granitoid bodies and volcanics ranging in age from Carboniferous to Quaternary. The Main Range Granite acts a natural divider of upper catchments of these rivers. The upper catchments of Kelantan and Pahang Rivers are dominated by interbedded sandstone, siltstone, shale and volcanics. Phyllite, slate and shale are the common lithologies of the Terengganu River catchment area. Granites are abundant forming elongated north-south trending bodies. The river drainage is characterized by a dense network of streams, a manifestation of tropical (humid and hot) conditions and a variability in lithology. Seasonal flooding in the East Coast rivers remove and transport sediments to the South China Sea, especially during the Northeast Monsoons.

METHODOLOGY

The Ponar grab sampler was used for the collection of surface sediments (penetration depth of 10 to 15 cm) from a boat in the middle and also near to the bank of a river. Sediment samples were collected at three major river sites in August 2009 and sampling locations are shown in Figure 1. The sediment samples were wet sieved (Hathway, 1955) into two sizes; <63 µm (bulk-fraction) and <2 µm (clay-fraction). Bulk-fraction sediments were de-carbonated using 1% HCl and washed repeatedly to neutral pH. Clay-fraction sediments were obtained from deflocculated suspensions, according to Stoke’s Law and concentrated using the centrifugation technique. The resultant pastes were mounted onto glass.