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Clay mineralogy of the riverine sediments of Hainan Island, South China Sea: Implications for weathering and provenance

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ABSTRACT

Clay mineralogy of 54 fluvial samples collected from 20 major rivers on Hainan Island are investigated in order to determine compositional changes of clay minerals and to assess the weathering processes. The clay mineral assemblages consist dominantly of kaolinite (31–66%), with a lesser abundance of chlorite (22–44%) and illite (4–33%), and a trace amount of smectite (0–15%). Fluvial sediments from the east and northwest of Hainan Island are characterized by a higher kaolinite content and illite chemical index and poorer illite crystallinity than those from southwest Hainan. Only minor smectite (mean of 7%) occurs in the sediments from west Hainan; smectite is total lacking in east Hainan. Compared with the adjacent basins, Hainan Island is characterized by moderate to intensive chemical weathering with strong hydrolysis. Our results suggest that rainfall is the principal factor controlling the intensity of chemical weathering on Hainan Island, with more intense chemical weathering occurring in eastern and northwestern Hainan. Another practical implication of this study is that it provides a "missing" end member (Hainan Island) in the provenance discrimination study focused on the northern South China Sea (SCS). Hainan fine-grained sediments likely play an important role in providing clay minerals to the northern SCS carried by the South China Sea Warm Current (SCSWC) during the summer.

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1. Introduction

The South China Sea (SCS) is the largest marginal sea in the western Pacific. It is bordered by the Asian continent and Taiwan Island to the north and west and by the Philippine Islands and Borneo to the east and south (Fig. 1a). Numerous rivers, including both large rivers (i.e., Pearl, Red, and Mekong Rivers) and small mountainous rivers in southwestern Taiwan, the Malay Peninsula, and Borneo, annually deliver huge amounts of fine-grained sediments to the SCS (Milliman and Farnsworth, 2011), making it as a significant sediment sink. Specifically, the predominant sediment sources in the northern SCS are the Pearl River, SW Taiwan and the Luzon Islands, which together deliver more than 265 Mt/yr of sediments to the sea (Liu et al., 2008, 2010b). These river-derived terrigenous sediments have formed high sedimentation-rate deposits in the geological past, especially sediment drifts on the northern slope of SCS (Bühring et al., 2004). Therefore, it is the ideal area to study high-resolution paleoenvironmental changes including the East Asian monsoon evolution (Boulay et al., 2003, 2005; Liu et al., 2003, 2004; Tamburini et al., 2003; Wan et al., 2008, 2010b), the uplift of the Himalaya (Wan et al., 2007, 2012), and the continental weathering history (Hu et al., 2012; Wan et al., 2009, 2012). Addressing the above information first requires in-depth understanding of the sediment provenance and its possible temporal variability. Accordingly, the sediment sources and transport pathways in the northern SCS, both in the present and in geological history, have thus attracted broad attention (Liu et al., 2003, 2005, 2008, 2010b, 2010c; Liu et al., 2010a, 2011, 2012a, 2013; Li et al., 2012b; Wan et al., 2010a).

Clay minerals are widely distributed in various sediment types, and their compositions have been used extensively to constrain the provenance of fine-grained terrigenous sediment, to decipher the climatic changes in the source area, and to illustrate the changes of transport agents (ocean currents, winds, ice drifts) (Chamley, 1989; Fagel, 2007; Singer, 1980; Thiry, 2000; Velde,

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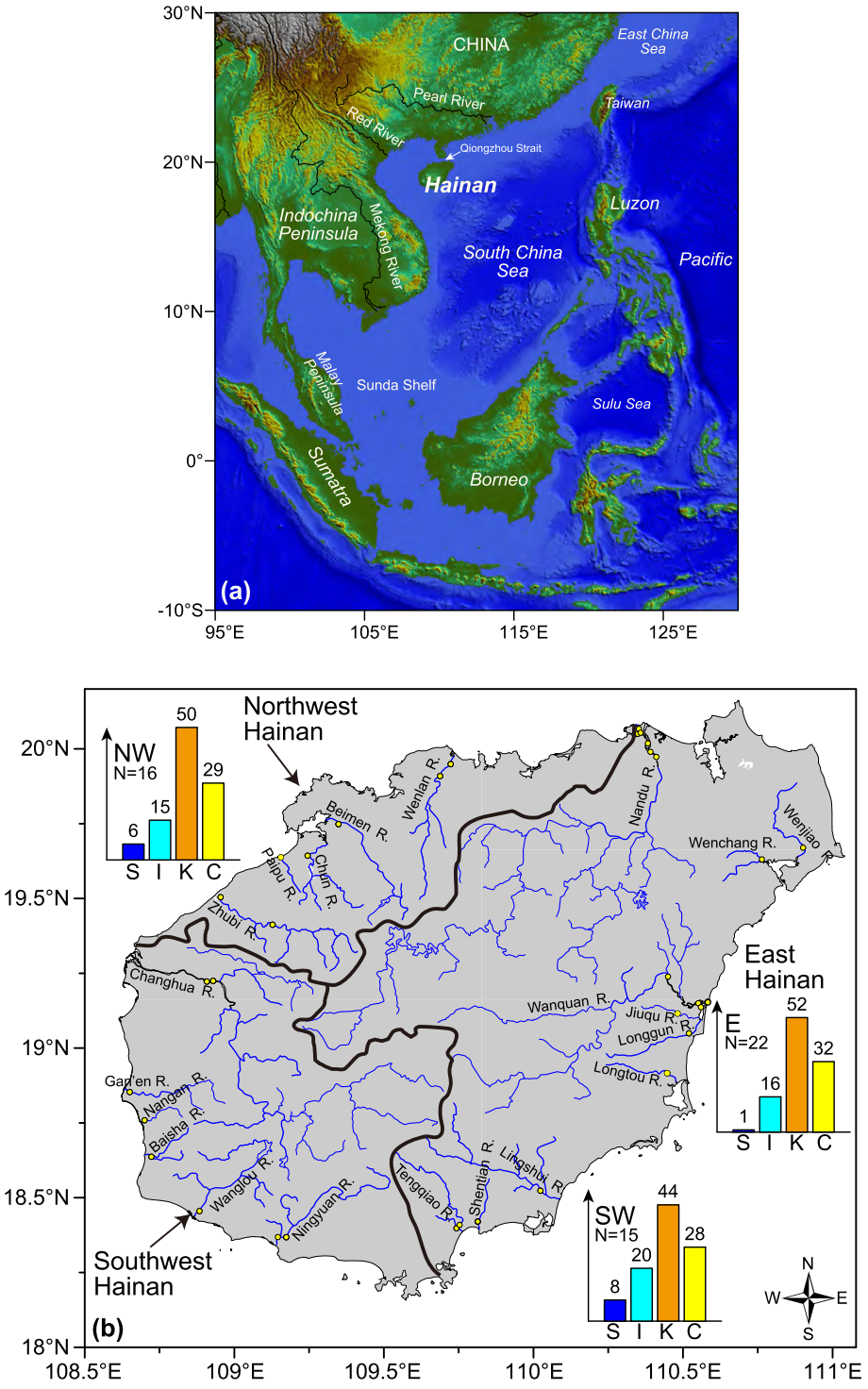

Fig. 1. (a) Sketch map of the South China Sea and surrounding basins. (b) Locations of the Hainan riverine samples and averaged clay mineral assemblages of three river systems. See Table 1 for detailed clay mineral contents of each river. S = smectite, I = illite, K = kaolinite, C = chlorite.

1995). Recently, Liu and his colleagues conducted comprehensive works on the clay mineralogy and geochemistry of riverine sediments surrounding the SCS, including the Pearl, Red, and Mekong Rivers in South China and the Indochina Peninsula (Liu et al., 2007a, 2007b), small mountainous rivers in southwestern Taiwan (Liu et al., 2008), major and moderate rivers in Luzon (Liu et al., 2009b), and small rivers in the Malay Peninsula, Borneo, and Sumatra (Liu et al., 2012b; Wang et al., 2011), and the controlling mechanisms of climatic, tectonic, and lithological forcing on the weathering processes have been summarized. Based on the distinct clay mineral compositions of the surrounding basins in the SCS, the source and transport of fine-grained sediments have been semi-quantitatively evaluated (e.g., Liu et al., 2008; Liu et al., 2011, 2013).

However, few studies have been conducted on the weathering products of Hainan Island, the second largest and highest island in the northern SCS. The island covers an area of 33,000 km^2 and has likely served as an important sediment source for the

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