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The source of natural and anthropogenic heavy metals in the sediments of the Minjiang River Estuary (SE China): Implications for historical pollution

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HIGHLIGHTS

• Grain size, clay mineral and Pb isotope were used to identify sediment sources.
• The contribution of Yangtze River to northern of Taiwan Strait was quantified.
• Enrichment factors indicated Cu and Pb have increased over the last decades.
• Coal combustion was the prevailing contamination source.
• The anthropogenic Pb concentrations ranged from 6% in 1950 to 23.7% in 2010.

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ABSTRACT

Two sedimentary cores in the Minjiang River estuary (SE China) are documented for grain size, clay minerals, heavy metals, magnetic parameters and Pb isotopes to investigate the source and historical variation of heavy metals. The MJK9 core was collected outside of the Minjiang River estuary, and the core is composed of mixed sediments, of which ~70% from the Yangtze River and 30% from the Minjiang River. It is thus difficult to be used for tracing the human activity along the Minjiang River. In contrast, the sediments of MJK16 core which was collected in a nearshore area are primarily from the Minjiang River. The enrichment factors of the sediments were <1.5, indicating minor pollution. The results indicate that the sediments of the MJK16 core have Cu and Pb concentrations increasing since 1980, associated with the increase of magnetic mineral concentration and $^{206}Pb/^{207}Pb$ and $^{206}Pb/^{208}Pb$ of the sediments. We compared the Pb isotopic compositions between our results and those for the deposit mining in the Minjiang River basin, and aerosols and coal dust in south China, and considered that Pb in the sediments of the MJK16 core was derived primarily from weathered rocks as well as industrial emission (e.g. coal combustion). The sediments have anthropogenic Pb concentrations ranging from 6% in 1950 to 23.7% in 2010, consistent with the impact of rapid urban and industrial development in China.

1. Introduction

Serious environmental problems related to rapid economic development have been paid much attention in China in the past decade (Cheng, 2003; Zhu et al., 2007; Cheng and Hu, 2010; Li et al., 2012; Pan and Wang, 2012; Chen et al., 2012; Flegal et al., 2013). It is reported that the total anthropogenic lead emission in China was up to 56,000 t yr^{-1} (Niisoe et al., 2010). Estuaries and coastal areas that are densely populated and full of human activity are usually the catchments for various pollutants (Li et al., 2000; Ip et al., 2004, 2007; Choi et al., 2007; Zhang et al., 2008a; Hao et al., 2008; Chen et al., 2012; Pan and Wang, 2012; Yang et al., 2012; Larsen et al., 2012; Yao et al., 2013). It was reported that approximately 17.05 million tons of pollutants were carried into the sea by the Chinese rivers in 2012 (NBO, 2012). Heavy metals that go to atmosphere, soil, water, sediment and organisms may play a serious impact on ecological environment through a cumulative effect (Wang, 2002; Fung et al., 2004; Pan and Wang, 2012).

Identifying the sources of heavy metals is of particularly important in environmental investigation. Traditional approaches rely on the statistical analysis (e.g. principal component analysis and cluster analysis) of chemical compositions to track the sources of heavy metals (e.g. Facchinelli et al., 2001; Ip et al., 2007; Zhang et al., 2008b). However, this method requires a large database due to poor correlation between

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variables and confounding factors (Cheng and Hu, 2010). The Pb isotopic tracer technique has proved a powerful tool in tracking the source of heavy metal pollutants in sediments (Munksgaard et al., 1998; Hansmann and Koppel, 2000; Choi et al., 2007; Duzgoren-Aydin, 2007; Zhang et al., 2008a; Komárek et al., 2008; Kamenov et al., 2009; Cheng and Hu, 2010; Kylander et al., 2010; Bird, 2011; Heimbürger et al., 2012; Larsen et al., 2012).

The heavy metal pollution in the coastal area of the Fujian Province in Southeast China (Zhang and Liu, 2002; Fung et al., 2004; Zhang et al., 2007; Yu et al., 2008; Fang et al., 2009) has been concerned. The Minjiang River is the largest river in the Fujian Province (Fig. 1). The drainage basin of the river has an area of 61000 km^2 with an average flow of 1750 m^3/s and an annual average discharge of suspended sediment of 715.5×10^4 t (Liu et al., 2001). The concentrations of heavy metals that have been generated by human activities, mining, coal combustion and industrial sewage have substantially increased with the increase of industrialization along the Minjiang River drainage basin (e.g. cities of Sanming, Nanping and Fuzhou). The Minjiang River therefore is ranked as the third one in China in 2012 in terms of heavy metals discharge (NBO, 2012).

In this study, we present heavy metal, magnetic parameter and Pb isotope of two sediment cores from the Minjiang River estuary. We combine deposition rate to examine historical variation in heavy metal, track the pollutant source and assess the impact of human

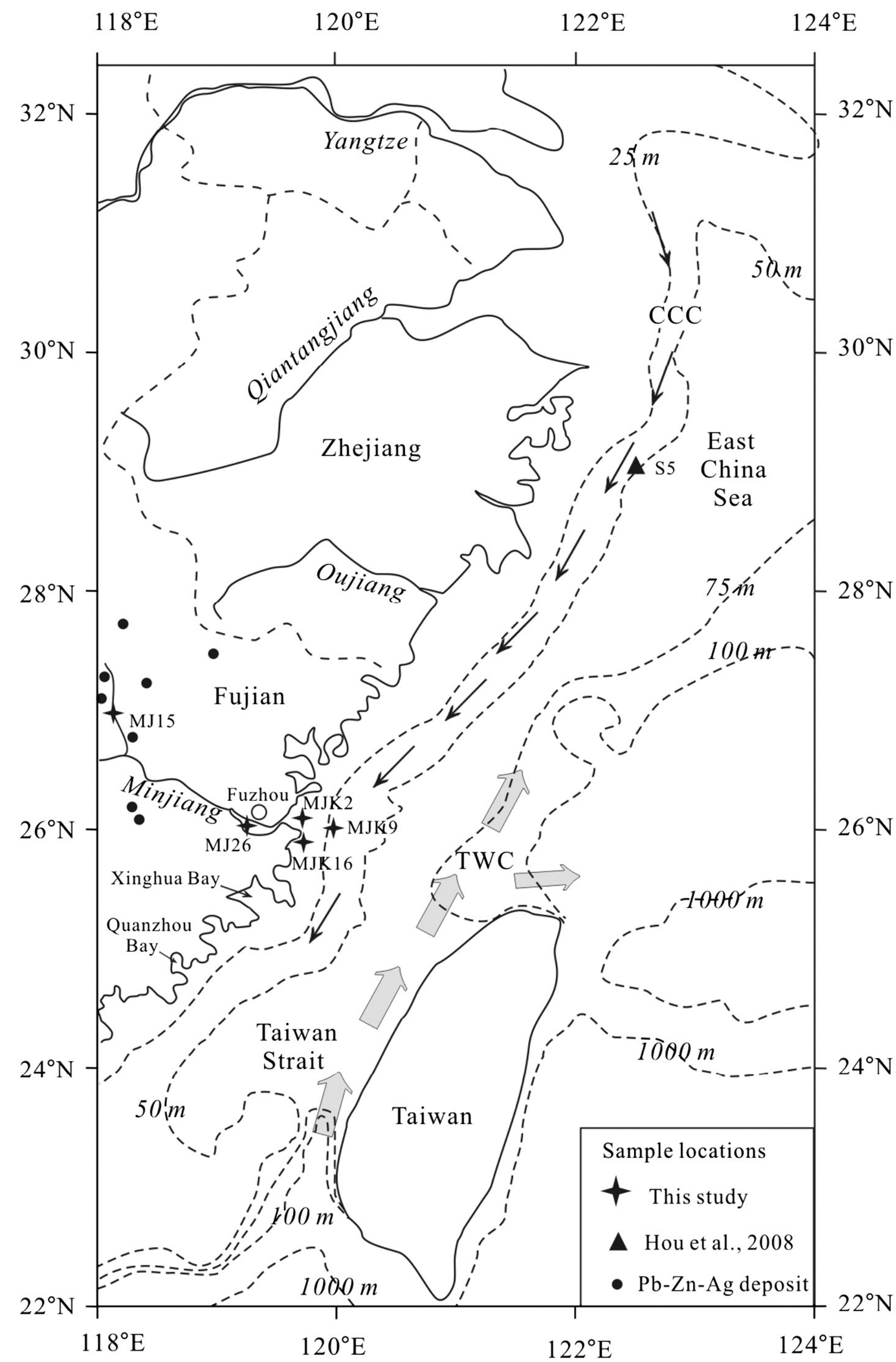

Fig. 1. Map of distribution of sampling sites and general circulation system in the East China Sea and Taiwan revised from Xu et al. (2009) Strait. CCC: China Coastal Current; TWC: Taiwan Warm Current.