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Research paper

Late Miocene provenance change on the eastern margin of the Yinggehai-Song Hong Basin, South China Sea: Evidence from U–Pb dating and Hf isotope analyses of detrital zircons

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ABSTRACT

Understanding the provenance of the reservoir in a sedimentary basin is of great importance in hydrocarbon exploration and production. The Yinggehai-Song Hong Basin is one of the most important Cenozoic petroliferous basins in the South China Sea. To better understand the provenance characteristics of the Upper Miocene Huangliu Formation (Tortonian-Messinian) on the eastern margin of the basin and test the influence of uplift of the Tibetan Plateau in the South China Sea, 172 single zircons from two sandstone samples in the Lingtou gas field were dated by U–Pb chronometer, and 54 of these grains were spot analyzed for Hf isotopes. The results indicate that the upper member of the Huangliu Formation in this gas field shows two major peaks of U–Pb ages at ca. 250 Ma and ca. 432 Ma, along with four subordinate peaks at ca. 757 Ma, ca. 1926 Ma, ca. 2529 Ma and ca. 2775 Ma. The initial Hf isotope ratios [$\varepsilon_{Hf}(t)$] of these zircons are negative to positive for each age group, suggesting that existing crustal materials were mixing with new mantle melts in some magmatic episodes. In contrast, the lower member of the Huangliu Formation show two major age peaks at ca. 98 Ma and 248 Ma, with a subordinate peak at ca. 1453 Ma. The $\varepsilon_{Hf}(t)$ values are concentrated between −11.6 and −3.4, revealing that they were derived from older crust. Comparing with the source characteristics of tectonic units surrounding the basin, the source of the upper member in the gas field was mainly from the southern Yangtze Block, whereas the lower member was derived from the Hainan Uplift. Together with the change of climate and sedimentation rate after 10 Ma on the northern margin of the South China Sea, we attribute the provenance change to the uplift of the Tibetan Plateau at the same time.

1. Introduction

Studies on the provenance of a reservoir and its transport routes are critical to establish its tectonic evolution in a sedimentary basin (Morton et al., 2001; Tsikouras et al., 2011). Uncertainties in the provenance and distribution of the reservoir may contribute to operational risks in drilling. The Upper Miocene Huangliu Formation is an important hydrocarbon exploration target in the Yinggehai-Song Hong (Y-SH) Basin, South China Sea. During the last decade, much attention has been paid to the provenance of the deep marine sedimentary rocks of the Huangliu Formation due to its huge gas potential and commercial value. Several published research papers focused on the petrography, sequence stratigraphy, geochemistry, heavy mineral analysis, and whole-rock isotopes and geochronology (e.g. Gong et al., 1997; Wu, 1997; Huang et al., 2003; Yan et al., 2007; Xie, 2009; Lei et al., 2011; Yan et al., 2011; Wang et al., 2014), which greatly enhanced our understanding of the distribution of reservoir in the basin. Yan et al. (2011) used detrital zircon geochronology of the eastern slope of the basin (Fig. 1B) to show that two major age peaks at 110–90 Ma and 275–225 Ma, suggest the source was derived from Hainan Island. Wang et al. (2014) used the same methods to constrain the provenance of the

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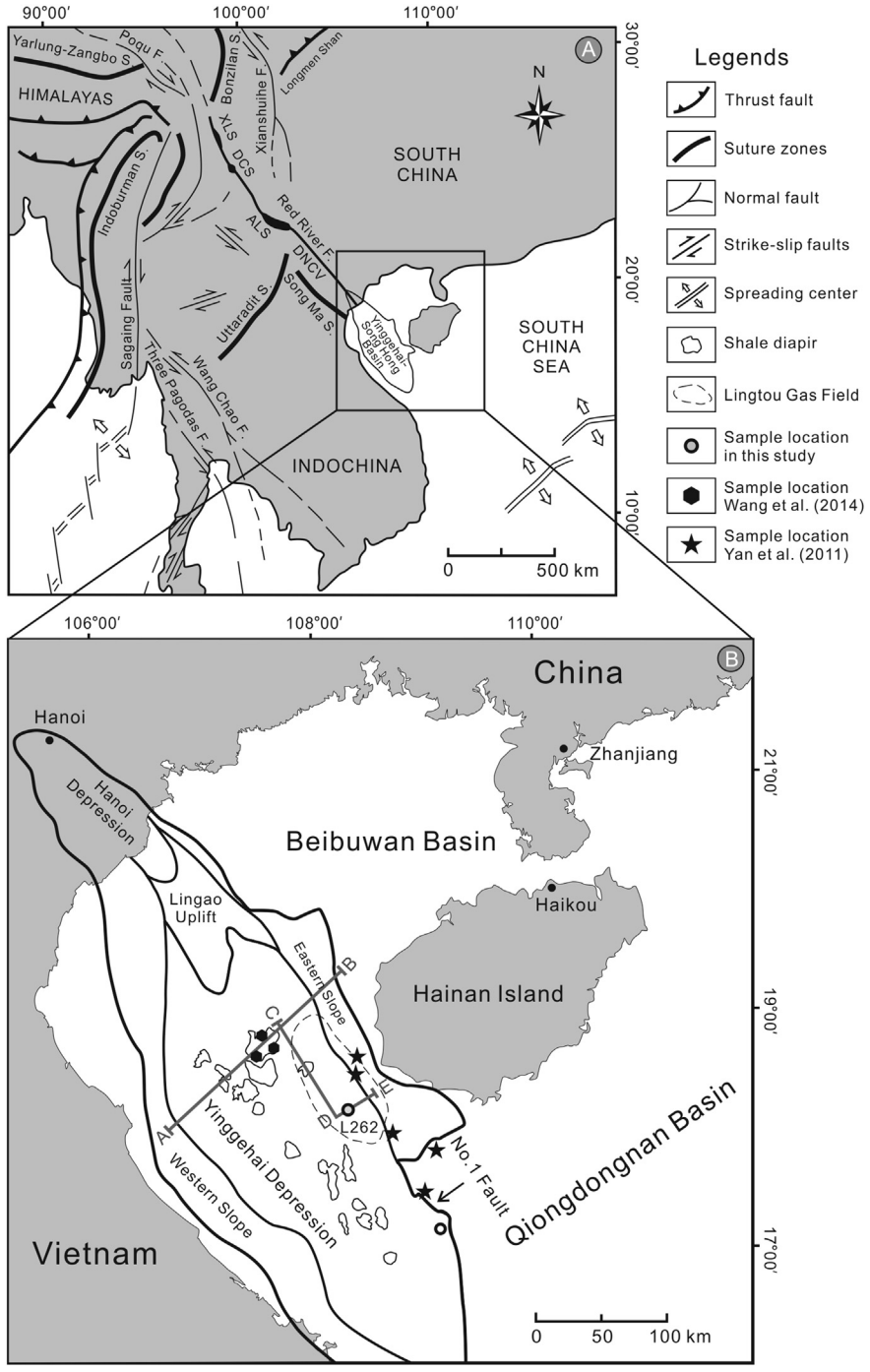

Figure 1. Geologic sketch map of the Yinggehai-Song Hong Basin, (A) Modified after Tapponnier et al. (1990), Leloup et al. (1995), Gilley et al. (2003) and Zhu et al. (2009); (B) Modified after Huang et al. (2005) and Lei et al. (2011).

sedimentary rocks in the Dongfang gas field in the central Y-SH Basin. The authors argued that the detritus in the Dongfang gas field was derived from multiple sources since the Late Miocene. Conventional heavy minerals, seismic profiles and sedimentary facies data suggest that the sediments of the Huangliu Formation in the Lingtou gas field are also derived from Hainan Island (Gong et al., 1997; Xie, 2009). However, the conclusion is skeptical because the basin is located in structurally complex regions with multiple source areas (e.g. Indochina and Yangtze blocks) (Wang et al., 2014), and lacks precise geochronologic and isotopic data. Therefore, the provenance of the sandstones in the Lingtou gas field remains unclear. Although conventional methods of determining provenance appear to reach their limits and cannot meet the needs of further hydrocarbon exploration, U–Pb ages add the time dimension to the provenance analysis (Beltrán-Triviño et al., 2013). U–Pb dating of detrital zircon is one of the most widely used methods in provenance studies, especially combined with Hf isotopes (e.g. Griffin et al., 2004; Meinhold et al., 2008; Wu et al., 2010; Zhao et al., 2013).

This study uses combined U–Pb and Lu–Hf isotope analyses of detrital zircons from marine core samples to constrain sedimentary provenance of the Huangliu Formation in the Lingtou gas field,