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Evidence of Early Cretaceous transpression in the Sulu orogenic belt, eastern China

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ABSTRACT

Recent studies have documented marine turbidites with syn-sedimentary deformation features in the central Sulu orogenic belt of eastern China. These units preserve essential information on the Late Mesozoic evolution of the Sulu orogenic belt. Referred to as the Baxiandun Formation, the turbidites exhibit similar lithologic characteristics to nearby units such as the Lingshandao Formation that have been well studied even though precise geochronologic constraints are lacking for a more precise correlation. This study reports detrital zircon U—Pb age data that correlate the Baxiandun Formation turbidites of the central Sulu orogenic belt to the Early Cretaceous Lingshandao Formation. We also report Al-in-hornblende emplacement depth estimates for granitic intrusions of the Sulu orogenic belt's Laoshan mountain. A sharp contact between the Laoshan granites and the marine Baxiandun Formation indicates that the Baxiandun basin rapidly subsided to the emplacement depth of the Laoshan plutons. Lateral correlation among the marine turbidites, the Lingshandao and Baxiandun Formations, combined with information established by previous studies indicates initiation of transpressional tectonics at 122–121 Ma. Transpression ceased with the emplacement of the Laoshan granites, whose A1-type composition indicates a return to extensional tectonics at ca. 111 Ma.

1. Introduction

Eastern China experienced large-scale cratonic destruction during an Early Cretaceous extensional event marked by intensive volcanic activities and formations of a series of extensional continental basins (Menzies et al., 1993, 2007; Griffin et al., 1998; Xu, 2001; Carlson et al., 2005; Wu et al., 2006; Zhu et al., 2012). Recent research has shown that eastern Shandong shifted from an extensional tectonic regime to a transpressional setting during Early Cretaceous, and then changed back to extensional tectonism by the Late Cretaceous (e.g. Zhu et al., 2005; Sun et al., 2007). This hypothesis has not been thoroughly tested however, due to limited geological evidence concerning paleoenvironments and structure of the Sulu orogenic belt (SOB). Late Mesozoic marine sedimentary rocks recently have been identified in east Shandong, eastern China (e.g. Fu and Yu, 2010 Wu et al., 2010; Lu et al., 2011; Zhang et al., 2013; Sun et al., 2014), which preserve essential information concerning uplift and erosion of the SOB following the final collisional episode between the North China and Yangtze blocks. Understanding these records is crucial in reconstructing Cretaceous paleogeography as it relates to interactions between the subducting Pacific plate and the overriding Eurasian plate. Preliminary detrital zircon geochronology (e.g. Xie et al., 2012; Wang et al., 2014) and structural observations in the field (e.g. Dong et al., 2013, 2014; Shao et al., 2014) have provided initial constraints on the evolution of late Mesozoic basins and established potential sedimentary provenance models. Both syn-sedimentary features (Dong et al., 2013, 2014; Wang et al., 2014) and detrital zircon age data from the recently identified Lingshandao formation (LSF) of Lingshan Island, Qingdao, east Shandong (Wang et al., 2014) have highlighted distinct sedimentary facies, deformation features and provenance relative to contemporaneous sedimentary strata of the Jiaolai basin (JLB).

The Lingshan Island and Baxiandun units were previously correlated to the Early Cretaceous Laiyang or Qingshan Groups of the JLB, to the north of the SOB (e.g. Bureau of Geology and Mineral Resources of Shandong, 1991; Fourth Geological and Mineral Resources Survey of Shandong, 2003). Wang et al. (2014) suggested a depositional age of ~121 Ma for the base of the LSF with the Yangtze block as a sedimentary source area, in contrast to that of the Laiyang Group, which was derived from the JLB. Structural features of the LSF, including syn-sedimentary deformation features such as syn-sedimentary slump folds in the interbedded sandstones, with hinge line direction of NE-SW and axial plane

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dip direction of NW that indicate the slumps migrated from the SE, support this interpretation and indicate source material transport from the SE (Lu et al., 2011). In addition, the Baxiandun Formation (BXF) has been previously interpreted as a set of Late Ordovician marine turbidites associated with the Yangtze block (e.g. Fu and Yu, 2010; Wu et al., 2010). In this paper, we present geochronologic and Al-in-hornblende data for the Laoshan granites that intruded into the BXF, as well as geochronologic data for the BXF sandstones, to revise previous interpretations on the depth of emplacement and age of deposition, respectively. We specifically use U—Pb ages from detrital and igneous zircons to constrain the depositional age of the BXF. Al-in-hornblende barometers are used to determine emplacement depths for the neighboring Laoshan granites in the central SOB. Correlation with the Lingshan Island units further helps to constrain the SOB's Mesozoic tectonic history.

2. Geological background

The Shandong peninsula, located east of the Tanlu fault, consists of the Jiaobei terrane (JBT), the JLB and the SOB (Fig. 1). The Baichihe-Qingdao-Yantai fault (BQYF) separates the SOB from the adjacent JBT and JLB blocks. Three episodes of syn- and post-collisional high pressure and ultrahigh pressure metamorphisms caused by continent-continent collision between the North China and Yangtze blocks from the Middle to Late Triassic with the accompanied formation of the SOB were identified in precious studies (e.g. Ernst and Liou, 1995; Yang et al., 2003; Chen et al., 2003a; Wallis et al., 2005; Liu et al., 2006; Zhao et al., 2007; Tang et al., 2008). According to petrologic and geochronological studies of these metamorphic belts in the Shandong peninsula (e.g. Ernst and Liou, 1995; Liou et al., 1996; Chen et al., 2003b; Xu et al., 2006; Liu et al., 2006, 2007; Wang et al., 2014), the SOB divides into three assemblages. These include Late Triassic alkaline and Late Jurassic intrusions (NE assemblage), high pressure-ultrahigh pressure metamorphic rocks and Early Cretaceous granitoids (SW assemblage), and an intervening assemblage dominated by Mesozoic terrestrial sedimentary units and Early Cretaceous granitoids (Fig. 1a and b). The Late Triassic alkaline complex occurs along the northeastern edge of the SOB, and its emplacement ages are ca. 225–201 Ma (Chen et al., 2003b; Guo et al., 2005; Yang et al., 2005; Zhao et al., 2013). The Late Jurassic granitoids consist primarily of granodiorites, monzogranites and leucogranites, which intruded into the SOB's NE assemblage (Fig. 1b) with emplacement ages of 161–142 Ma (Guo et al., 2005). The SOB also hosts large bodies of NE-SE trending Early Cretaceous granitoids (Fig. 1b) that exhibit intermediate to felsic compositions and their intrusive ages range from 143 Ma to 111 Ma with a peak at ca. 130–125 Ma (Zhao and Zheng, 2009, and references therein). The Laoshan granitic complex includes Early Cretaceous granitoids emplaced in the central SOB (Fig. 1b and c), which exhibit alkaline and A1-type granitic compositions (Yan and Shi, 2014). (See Fig. 2.).

Two Mesozoic marine sedimentary successions occur in the central SOB (e.g. Fu and Yu, 2010; Wu et al., 2010; Lu et al., 2011; Wang et al., 2014). The LSF of Lingshan Island, to the southwest of Qingdao City, has a maximum depositional age of ~121 Ma according to U—Pb detrital zircon geochronology (Wang et al., 2014). The BXF, occurs in eastern areas of the Laoshan mountain, northeast of Qingdao City. The thicknesses of these metasedimentary units reach ca. ~2 km. Generally, grain sizes in these units fine upwards with younging depositional ages from NW to SE, dip directions of SE and SW, as well as dip angles ranging from 10 to 40° (Fig. 1d). Since the Laoshan granites intruded the northern section, these units were slightly metamorphosed to hornfels, while original sedimentary structures such as graded beddings, syn-sedimentary structures, load casts and boring pores are preserved. These units mainly include nearshore marine sandstones with interbedded conglomerates in areas to the NW (Fig. 3a), as well as bathyal turbidites with syn-sedimentary slump folds (Fig. 3b–d) and cross bedding (Fu and Yu, 2010) in areas to the SE, indicating a continuous change of the sedimentary environment from deep to shallow marine. These marine facies rocks, especially the turbidites, show similar lithological characteristics to those strata in the LSF that were identified as turbidites in Lu et al. (2011) and Zhang et al. (2013), which occur ~60 km in the southwest of Lingshan Island. Turbidites in the LSF are featured by grayish sandstones and dark mudstones interbedded with graded

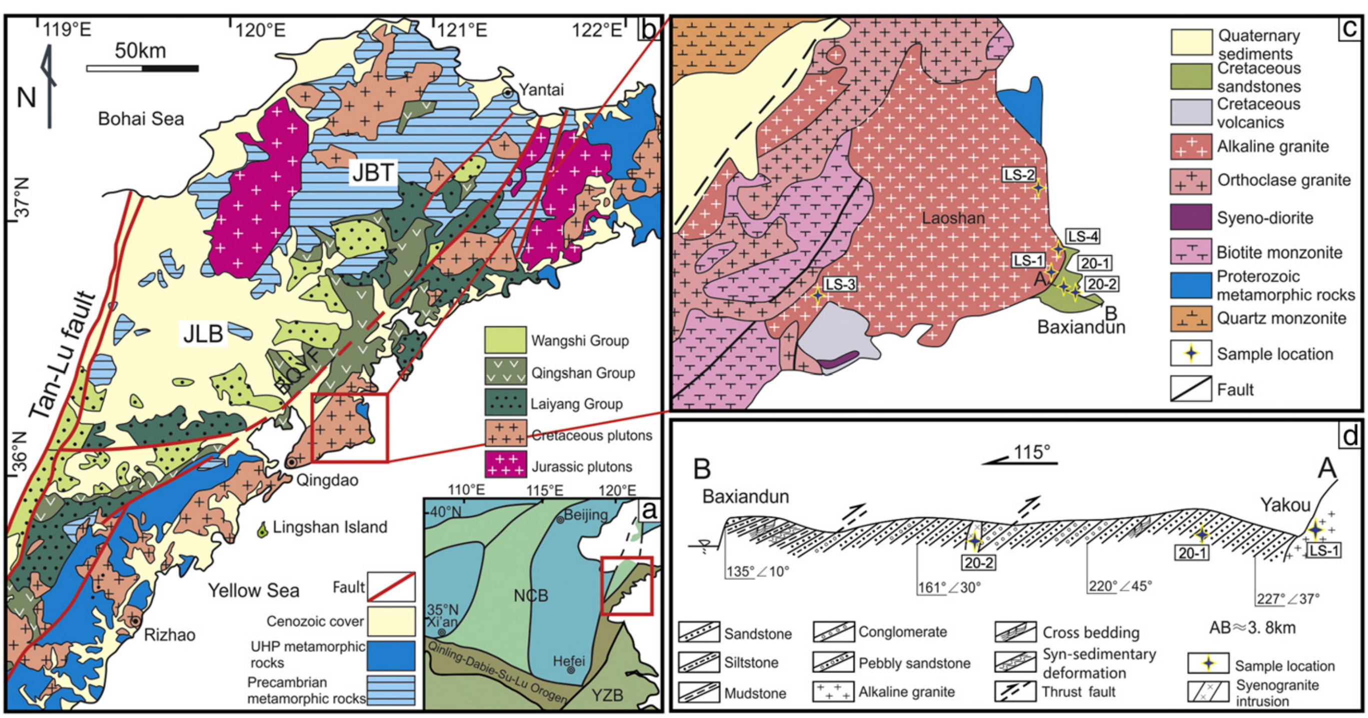

Fig. 1. Geologic maps of the study area and sample locations. (a) Tectonic setting of eastern Shandong (modified after Zhao et al., 2005); (b) Geologic map of eastern Shandong (modified after Xie et al., 2012); (c) Geologic map of Laoshan mountain and Baxiandun, with sample locations (after Yan and Shi, 2014); (d) Geologic cross section of the Baxiandun Formation shown with sample locations.