Journal of Asian Earth Sciences 80 (2014) 134–147

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Magnetic fabric and paleomagnetism of the Middle Triassic siliciclastic rocks from the Nanpanjiang Basin, South China: Implications for sediment provenance and tectonic process

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ARTICLE INFO

Article history:
Received 25 April 2013
Received in revised form 22 October 2013
Accepted 29 October 2013
Available online 8 November 2013

Keywords:
South China block
Nanpanjiang Basin
Siliciclastic rocks
Paleoflow
Provenance

ABSTRACT

A combined magnetic fabric and paleomagnetic study has been carried out on the siliciclastic rocks gathered from a stratigraphic cross-section through the Nanpanjiang Basin, South China, in an attempt to extract the paleoflow information preserved in and, thus, constrain the possible origins of these clastic rocks. The sediments used for this study were formed by sediment-gravity flows along the southern margin of the South China block in the Middle Triassic time (ca. 245–228 Ma). The results show a normal distribution of both low field magnetic susceptibility values and natural remanent magnetization intensities, which along with the monotonic detrital framework mode, mainly comprising quartz and lithic particles, may suggest a single provenance involved in deposition of these clastic deposits. Anisotropy of magnetic susceptibility (AMS) analysis acquires primarily the sedimentary magnetic fabrics, which, in this study, reveal paleoflow directions ranging from NNW to ENE with an overall mean orientation of NE. Demagnetization on a part of samples isolates a characteristic remanent component averaged at $D = 44.8°$, $I = 16.9°$, $\kappa = 9.7$, $\alpha_{95} = 6.5°$, $n = 55$, corresponding to a paleolatitude N8.6° and a clockwise rotation of ca. 45° since the Middle Triassic for the studied cross-section. This mean direction passes fold tests and is consistent with the reference direction expected from the South China block at the 95% confidence level. Restoring this ~45° declination renders an overall northward paleoflow, which, combined with other evidence, suggests a southern provenance for these sediments during deposition in the Middle Triassic time. In terms of the early Mesozoic plate framework of southeastern Asia, a tectonic scenario is proposed here, whereby the nearly N–S convergence of the Indochina and South China blocks and its related Indosinian orogeny in the Middle Triassic caused the formation of the Nanpanjiang foreland basin, which was filled by voluminous detritus shed from the uplifted orogenic belt on its southern side.

1. Introduction

It has been continuously disputed on the plate tectonics of the southern South China block in the Early Mesozoic (c.f., Hsü et al., 1990; Carter and Clift, 2008; Cai et al., 2008). One group of authors hold the idea of a NW–SE convergent orogeny across this region derived either from the collision between the Yangtze and Huanan blocks in the Triassic (Hsü et al., 1988, 1990) or the subduction of the Paleo-Pacific plate beneath the South China block (250–190 Ma; Li and Li, 2007). In contrast, other authors prefer a dominant NNE–SSW or NE–SW convergent orogeny that was attributed to the collision between the Indochina and South China blocks (250–230 Ma, Lepvrier et al., 2004, 2011; Zhou et al., 2006; Cai and Zhang, 2009). In addition, a mixed model also was proposed as the coexistence of the NW-directed subduction of the Paleo-Pacific plate beneath the South China block and the NE–SW tectonic activation of the already amalgamated Indochina and South China blocks (Carter et al., 2001; Carter and Clift, 2008). In all of these tectonic models, a foreland basin, either of a peripheral (e.g., Lehrmann et al., 2005, 2007; Cai and Zhang, 2009) or retroarc (e.g., Li and Li, 2007) setting, called the Nanpanjiang Basin, was described, due to its development of a huge succession of deep-water siliciclastic rocks in the Middle Triassic (245–228 Ma) (GXGMR, 1985; GZGMR, 1987; YNGMR, 1990). These clastic deposits were regarded as orogenic origin (e.g., Hsü et al., 1990; Li and Li, 2007; Carter and Clift, 2008; Cai and Zhang, 2009), and, therefore, tracing their provenance may help to clarify the Early Mesozoic geodynamics in this part of the South China plate.

In the past, the deposits were most commonly interpreted to be products from recycled orogens nearby in terms of their detrital framework mode, comprising primarily angular quartz and lithic fragments with extremely low feldspar contents (e.g., Gou, 1985; Xia et al., 1993; Ceng et al., 1995; Chen et al., 2003; Goers et al.,

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1367-9120/$ - see front matter
http://dx.doi.org/10.1016/j.jseaes.2013.10.033

2012). However, in detail there are various proposals as to the nature and location of the orogens. For example, limited geochemical data from clastic rocks have been used to characterize the orogen as either active margin, island arc (Xia et al., 1993; Chen et al., 2003) or uplifted passive margin (Mou et al., 1990; Zhang et al., 1997). Furthermore, facies models (e.g., Bouma sequence and submarine fan) and sequence stratigraphy along with various ratios of sandstone to mudstone beds as well as grain-size variation were routinely invoked to trace the location of the orogens by patterning the distribution trend of these clastic deposits basin wide (c.f., Gou, 1985; GXGMR, 1985; Ceng et al., 1995; Cai et al., 2008; Goers et al., 2012). These lines of evidence, when coupled with the paleocurrent information extracted from sedimentary structures such as cross-bedding and sole marks, however, have concluded various orogenic sources in the south (GXGMR, 1985; Cai et al., 2008), southeast (Xia et al., 1993), east (Gou, 1985; Ceng et al., 1995), or northeast (Chaikin, 2004) of the basin, or some blended sources (Mou et al., 1990; Chen et al., 2003; Goers et al., 2012; Wood et al., 2012). The arrival time of the Middle Triassic siliciclastic flux in the basin was also used to trace the source area in the south (Lehrmann et al., 2005, 2007). These diversified interpretations add further complexes to those plate tectonic models mentioned above (Carter and Clift, 2008; Cai et al., 2008), and therefore, the controversies seem to be continuing.

In spite of these disputes, previous studies did recognize the important role played by paleocurrent orientations in tracing the potential orogenic sources of this suite of flysch deposits (e.g., Gou, 1985; Xia et al., 1993; Ceng et al., 1995; Lehrmann et al., 2005; Carter and Clift, 2008; Goers et al., 2012; Wood et al., 2012). Nevertheless, in practice, the sparsity of paleocurrent indicators in the field often hinders the application of this method. As an alternative approach, magnetic fabric (e.g., anisotropy of magnetic susceptibility, AMS) analysis is a relatively well-founded method in determining grain shape fabrics of clastic rocks, and thus providing paleoflow direction information (Rees, 1961, 1965; Hamilton and Rees, 1970; Von Rad, 1970; Channell et al., 1979; Taira and Scholle, 1979; Piper et al., 1996; Baas et al., 2007; Lenhardt et al., 2013). Advantage of this method is that it can be applied to clastic rocks with no apparent depositional structures, particularly paleocurrent indicators, which are not often available for the majority of deep-sea deposits. In addition, if paleomagnetic direction can be retrieved, it can be applied to correct for potential block rotations experienced by the stratigraphic units. This is particularly useful when we deal with source regions that are located outside of blocks where clastic sediments finally settle down. Thus, a true paleoflow pattern can be obtained.

Here we report our recent study of paleocurrent directions through paleomagnetic and magnetic fabric analysis on the fine sandstones, and siltstones collected from a middle Triassic transection located in the east-central part of the Nanpanjiang Basin, South China, in an attempt to trace the origin of these clastics. Rationale for the use of this stratigraphic cross-section, combined with paleomagnetic data, is its potential for pinpointing the possible source regions, because it resides in a position with essentially equal distance to several uplifted blocks surrounding the basin that were frequently described in previous studies (e.g., Gou, 1985; Xia et al., 1993; Ceng et al., 1995; Chen et al., 2003; Cai et al., 2008; Carter and Clift, 2008; Cai and Zhang, 2009; Goers et al., 2012; Wood et al., 2012). The results indicate that most samples have preserved the primary depositional magnetic fabrics that reveal an interesting pattern of paleoflows. When corrected for magnetic declination and recovered for paleolatitude, a tectonic model of paleoplate reconstruction has been proposed thereof, which may be helpful in understanding the Early Mesozoic geodynamics of the southern South China block as well as the plate tectonics of the contemporary southeastern Asia.

2. Geological setting

2.1. General outline of the Nanpanjiang Basin

The Nanpanjiang Basin with a relict area of ca. 250,000 km^2 is located in the southern part of the South China block (Fig. 1A) and is adjoined to the south with the Indochina block through the Dian-Gui suture (Wu et al., 1999; Cai and Zhang, 2009). Several tectonic uplifts surround the basin, such as the Jiangnan oldland, the Kangdian massif, the Yunkai massif, and the northern Vietnam terrane (Fig. 1B). Among these, the former three units expose mainly continental basement, representing metamorphic rocks and enclaves of Caledonian (413–465 Ma) or earlier granitoids (GXGMR, 1985; GZGMR, 1987; GDGMR, 1988; YNGMR, 1990), whereas the latter one is almost covered by Paleozoic sedimentary sequences (Lepvrier et al., 2011). These uplifted areas also control the regional tectonic lineaments that show a systematic transition in strike from W to E from NE–SW through nearly E–W and WNW–ESE to again NE–SW.

The basinal region has developed three stratigraphic successions separated by two angular unconformities residing between the Lower and Upper Paleozoic and between the Middle and Upper Triassic, respectively, witnessing a relatively complex geological evolution (GXGMR, 1985; GZGMR, 1987; GDGMR, 1988; YNGMR, 1990). In the Early Paleozoic, the basinal region, together with the remaining part of the South China plate, was dominated by a neritic to hemipelagic setting until the Silurian when the Caledonian orogeny uplifted this region (Guo et al., 1989; Ren and Chen, 1989). Subsequently, a shallow sea environment occurred from the Early to latest Middle Devonian (GXGMR, 1985), which was succeeded by a deep-sea setting through much of the late Paleozoic with deposition of mudstone, shale, and intercalated siliceous rocks (Wang, 1994; Wang et al., 1995; Wu et al., 1994). Concurrent with this deep-sea setting was the development of several isolated shallow-water platforms within the basin region (DQGPG, 1992; Lehrmann et al., 2005, 2007) and sporadic eruptions of mafic to ultra-mafic volcanics in its central and southern parts (c.f., Cai and Zhang, 2009; Yang et al., 2012). Since the Late Permian, Indosinian orogeny (P_2-T) began to influence the basin area with a brief deposition of bauxite horizons in the northern Vietnam terrane (Lepvrier et al., 2011) and molasses in the Shiwandashan area (Liang and Li, 2005) in the earliest Late Permian. This orogeny was accompanied by amalgamation of several continental blocks (such as North China, South China, Indochina, Sibumasu) to form the southeastern Asian part of the Eurasian continent (e.g., Sengor et al., 1988; Hutchison, 1989, 1993; Metcalfe, 2002). From the late Early throughout Middle Triassic, this basin was filled by voluminous siliciclastic debris through sedimentary gravity-flow deposition (GXGMR, 1985; GZGMR, 1987; YNGMR, 1990). By the Late Triassic, the basin was essentially uplifted by the Indosinian (P_2-T) orogeny, resulting in deposition of shallow-sea coarse clastic rocks along its western margin (YNGMR, 1990), marine molasses in the Shiwandashan area (GXGMR, 1985), and braided-stream molasses along its northern margin (Enos et al., 1998). Molasses deposition of alternating marine and continental facies prevailed in its southeastern part until the Early Jurassic (GXGMR, 1985), but after that, the basin, accompanying the entire South China block, ended its long-term marine history since the late Paleozoic.

2.2. Stratigraphy of the Middle Triassic

In most part of the Nanpanjiang Basin, this suite of Middle Triassic siliciclastic rocks is marked at its base by a thin layer of acidic tuffs or tuffaceous clastic rocks and is terminated by an unconformity contact with the Upper Triassic or younger formations (Fig. 2)