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Provenance and tectonic setting of middle-upper Devonian sandstones in the Qinling Orogen (Shanyang area): New insights from geochemistry, heavy minerals and tourmaline chemistry

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ABSTRACT

Devonian sandstones in the Shanyang area crop out in the southern part of the Qinling Orogenic Belt. Geochemical analyses show that the sandstones are enriched in Zr and have high Th/U and Rb/Sr ratios indicating the sandstones underwent repeated recycling. Zircon, tourmaline, apatite, rutile and anatase are the predominant heavy minerals while minor minerals include spinel, pyroxene, ilmenite and magnetite. The mineral compositions of detrital tourmaline grains indicate that the alkali compositional subgroup dominates; schorl and dravite are the main tourmaline species. A tourmaline composition environment discrimination diagram shows that about 70% grains are consistent with metapelite, metapsammite, and calc-silicates sources and about 30% of grains are from granitoids and associated pegmatites, and aplites. Metamorphic and granitic rocks in the Qinling Complex area are potential provenance. Overall data from geochemistry, heavy minerals and tourmaline chemistry suggests the Devonian sandstones were extensively recycled in a foreland basin setting rather than at a passive continental margin.

1. Introduction

The Qinling-Dabie-Sulu Orogens of central China extend WNW-ESE for about 1000 km (Fig. 1a). They were constructed by northward subduction of the Shangdan Ocean and subsequent collision between the North China Block (NCB) and South China Block (SCB) along the Shangdan suture zone (e.g. Mattauer et al., 1985; Şengör, 1985; Kröner et al., 1993; Hacker et al., 1998; Zhai et al., 1998; Faure et al., 2001, 2003). Their structural framework and division into litho-tectonic units have been debated for decades (Li et al., 1993; Ames et al., 1996; Zhang et al., 1997, 2001; Enkin et al., 1992; Faure et al., 2003, 2008; Dong et al., 2011a,b; Lin et al., 2015). Devonian sedimentary rocks exposed in the Southern part of the Qinling region have been variously interpreted as: i) a molasse trough in front of the Qinling belt (Mattauer et al., 1985), ii) a passive continental margin (Meng, 1994; Zhang et al., 2001), and iii) a foreland basin (Li et al., 1994; Dong et al., 2011a,b, 2013). The sandstones record important information about the Qinling Orogens and so determining their origin and provenance would help us to understand the tectonic setting and geodynamic evolution.

Geochemical analyses and heavy mineral studies of sedimentary rocks are frequently used for provenance studies (e.g. Yan et al., 2002; Yang et al., 2007; Long et al., 2008; Moosavirad et al., 2011; Lü et al., 2015). The chemical composition of clastic sediments is controlled by a complex interplay between several variables such as source composition, extent of weathering, transportation and diagenesis (e.g. Taylor and McLennan, 1985; Bhatia and Crook, 1986; Fedo et al., 1995, 1997a, b). Geochemical indicators for bulk-rock geochemistry, such as the major elements (Fe_2O_3 + MgO), TiO_2, Al_2O_3/SiO_2, K_2O/Na_2O, and trace elements like La, Th, Sc, Zr and their ratios are frequently used (e.g. Bhatia, 1983; Bhatia and Crook, 1986; McLennan et al., 1993; Cullers, 1994, 2000; Kemkin and Kemkina, 2015; Gao et al., 2016).

Heavy minerals such as garnet, tourmaline, apatite, spinel and zircon have been widely used in provenance analysis (e.g., von Eynatten and Gaupp, 1999; Morton et al., 2005; Bojar et al., 2010; Olivarius et al., 2014). Chemical analyses of heavy minerals may permit the determination of source rocks and subsequent sediment transport directions (e.g. Pinto et al., 2007; Morton et al., 2011; Tsikouras et al., 2011). Tourmaline is a mineral frequently found in igneous and metamorphic rocks (e.g., Dutrow and Henry, 2011; van Hinsberg et al., 2011a,b). The

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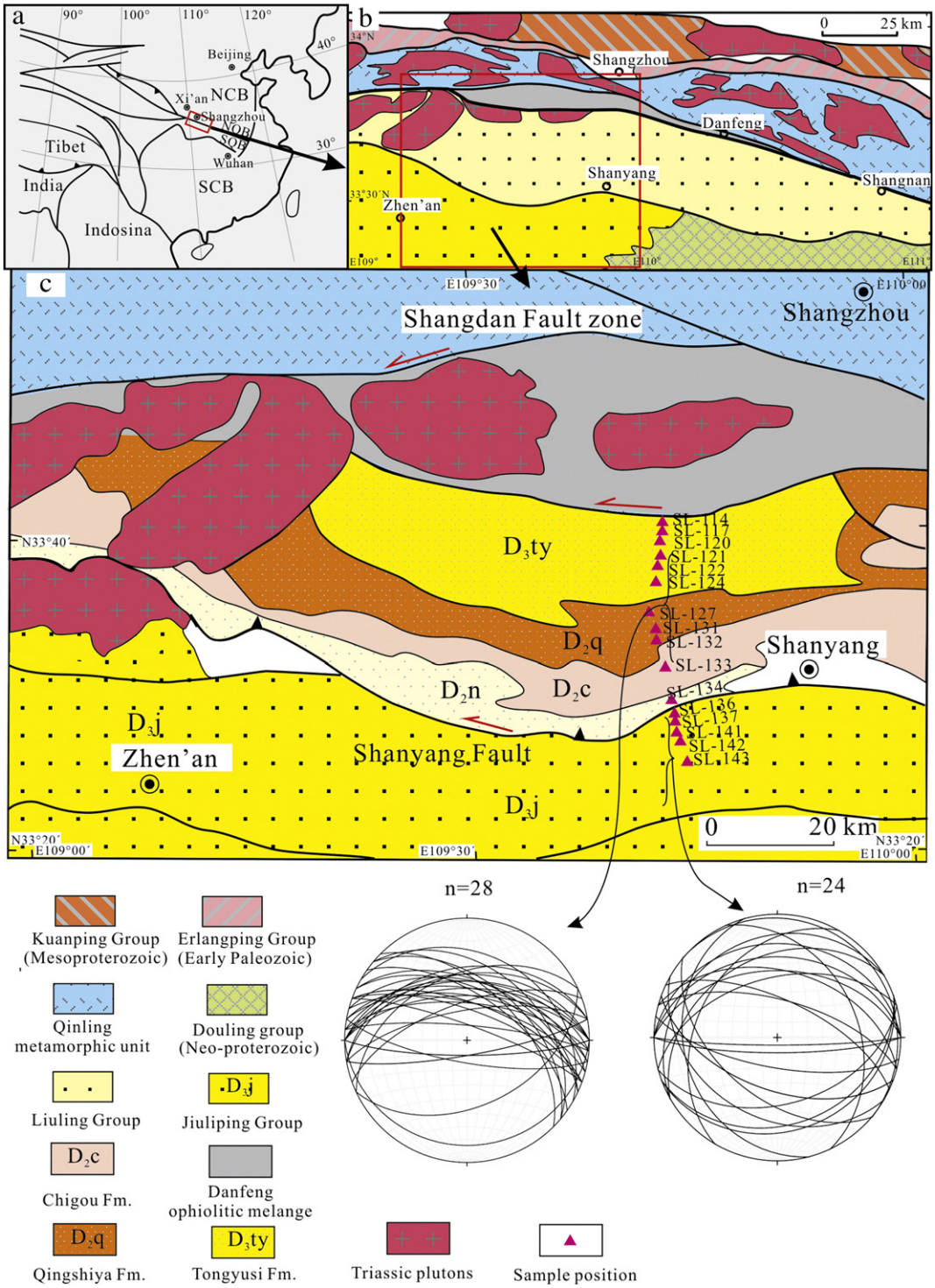

Fig. 1. (a) Tectonic divisions of the Qinling Orogenic Belt and location of the study area. (b) Simplified geological map showing the study area in the Qinling Orogenic Belt (After Dong et al., 2011a,b and 1: 20, 0000 geological map of Shang County). (c) Simplified geological map showing sample locations of Devonian sandstones in the Shanyang area (after He et al., 2005). (Red arrows represent post-Devonian fabrics).

environment diagram by comparing Al-Fe-Mg abundances connects tourmaline composition with parent rock types (Henry and Guidotti, 1985) and provides valuable information about provenance (e.g. Buriánek et al., 2003).

This paper presents new data on Qinling Devonian sandstone geochemistry, heavy mineral assemblages and tourmaline chemistry to constrain the source rocks and determine the tectonic setting.

2. Geological setting

2.1. Geological framework

The Qinling Orogen is divided into four zones, from north to south: the Southern North China Block (S-NCB), North Qinling Belt (NQB), South Qinling Belt (SQB) and Northern South China Block (N-SCB)