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Dating of faults and estimation of surface uplift and erosion rates in the northern margin of Dabie Mountains, China

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ABSTRACT

Absolute timing of fault movement provides information about tectonic deformation history. The K–Ar dating method has been applied to determine the absolute timing of fault movement. The key to K–Ar dating of fault gouge is to verify that the illite is of authigenic origin. Here we show effective and convincing evidences for authigenic illite in fault gouge. The characteristics of the authigenic illite reveal that the host rocks were under near-surface environment during fault activities. The result indicates fault movement in Late Cretaceous in the northern margin of Dabie Mountains orogenic belt. According to the absolute timing, the uplift and erosion rates of the northern margin of Dabie Mountains are also estimated.

1. Introduction

Tectonic deformation of near-surface rocks is generally associated with brittle fault movement, which leads to the presence of fault gouge. The fault gouge is usually composed of detrital minerals and secondary authigenic clay minerals. Particularly, illite forms due to retrograde hydration reactions (Zwingmann and Mancktelow, 2004). Lyons and Snellenberg (1971) first applied isotopic dating technique in absolute timing of fault activities. The key to the K–Ar isotopic dating method is to verify that the illite is of authigenic origin (Lyons and Snellenberg, 1971). Authigenic illite separated from fault gouge has been used as the test object for isotopic dating and to analyze the characteristics of fault activities (e.g. Yurtmen et al., 2002; Zwingmann and Mancktelow, 2004; Tonguç et al., 2006; Sasseville et al., 2008; Zwingmann et al., 2010). van der Pluijm et al. (2001) discussed ^{40}Ar–^{39}Ar dating of illite in fine-grained fault gouge using microencapsulation technique. In the oil industry, isotopic dating on authigenic illite has been widely applied to determine the evolution process of basin and hydrocarbon reservoir formation process (Hamilton et al., 1989; Zhao et al., 1997; Zhang et al., 2005, 2011).

The Dabie Mountains region is the collision orogen between Yangtze Block and Northern China Block in Indosinian Epoch (Ayers et al., 2002; Okay and Sengor, 1992; Li et al., 1993; Hacker et al., 1995, 1998; Grimmer et al., 2003). Delimited by the Xiaotian-Mozitan fault (XMF in Fig. 1), on the north of Dabie Mountains is Northern Huaiyang epirock zone, where Mesoproterozoic–Neoproterozoic to Carboniferous metamorphic rocks were formed. The Northern Huaiyang tectonic zone has various strata and is featured by mélange. Among the strata containing mélange, the Devonian system is rapidly deposited low-maturity terrigeneous clastic rocks. In the late Yanshanian, a large amount of granite magma intruded into the Dabie Mountains orogen and the Northern Huaiyang tectonic zone. As plate collision had finished, the magmatism was caused by intraplate tectonic activities and led to the formation of orogenic granite. The magma intrusion depth in the Northern Huaiyang zone is 3.5–4.2 km in average (Yang et al., 1999a,b). In the Late Cretaceous epoch, a large amount of NW or NE-trending faults were developed both in the Dabie Mountains orogen and the Northern Huaiyang zone, cutting late Yanshanian igneous rocks. Constraining the timing of faults is the focus of the article.

2. Methods and test procedure

The samples for K–Ar dating were late Yanshanian monzontic granite, collected from Laoshan Mountain in the Northern Huaiyang tectonic zone (Fig. 2). The monzontic granite is located near the tectonic suture line (Suo et al., 2000). The surrounding rocks are quartz schist and granulite of Nanwan Formation of Devonian origin. The testing samples were divided into four groups, namely, fresh monzontic granite (GA), partially altered monzontic granite in the fault influential zone (GB), fault gouge (GC) and surrounding quartz schist (GD). Samples GB and GC were taken from the fresh to slightly weathered zone 100–300 m below the ground

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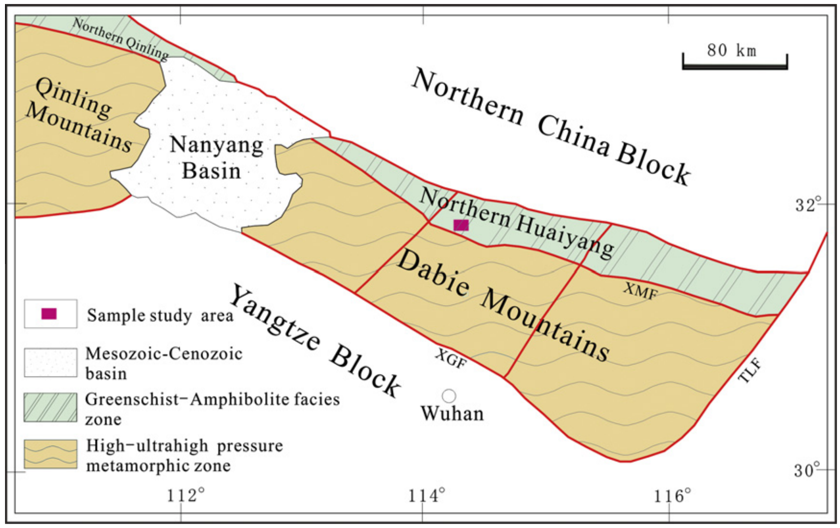

Fig. 1. Simplified geological map for Dabie Mountains region (after Ma et al., 2004).

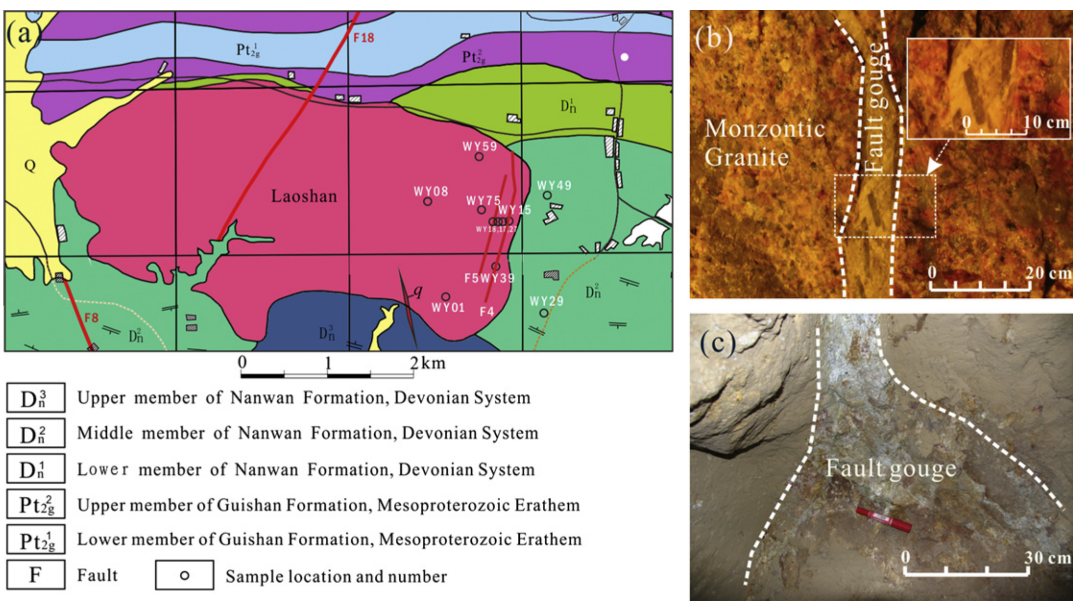

Fig. 2. (a) Geological map of the study area and sample location; (b) outcrop of the fault gouge in fractured zone; (c) a branch fault and fault gouge.

surface. They were located between two NE-trending faults, which were severely fractured and the width of fragmented zone reached 100 m. A quartz schist sample was collected from surrounding rock of the Nanwan Formation near the contact zone of the monzontic granite. The partially altered rock features fragmentation of crystals in all mineral components, illitization and montmorillonization of some feldspar components and micro-porosity caused by contraction of altered feldspar, and sedimentation and crystallization of colloids in the rock pores. Scanning electronic microscope (SEM) and energy disperse spectrum (EDS) analyses indicate that the crystalline colloid is composed of SiO_2. The accompanying authigenic illite formed in these crystalline colloids (Fig. 3), which indicates water–rock interaction and groundwater movement during fault activities. We interpret that the illite is of authigenic origin. Based on the presented evidence, we interpret that fragmentation and alteration of mineral components in the fault zone is caused by fault activities. Furthermore, the host rocks were under near-surface conditions during fault activities, which resulted in participation of groundwater in the formation process of fault and clay minerals. Therefore, the absolute age of last fault activity can be determined by using K–Ar dating of authigenic illite in fault gouge (Lyons and Snellenberg, 1971).

The freeze–thaw technique was applied in sample preparation for disaggregation to avoid overcrushing and extensive size separation to reduce the amount of detrital phases (Zwingmann et al., 2004; Zwingmann and Mancktelow, 2004; Zhang et al., 2011). There were two clay fractions, i.e. 0.3–0.15 μm, and less than 0.15 μm, separated from samples. The 0.3–0.15 μm fraction was obtained by vacuum filtration and the less than 0.15 μm fraction was obtained by high-speed centrifuging.

The mineralogy of the fractions was determined by XRD. Diffractograms were obtained from air-dried slides and analyzed using a Rigaku D/max-2000 X-ray diffractometer. Glycolated XRD analyses were conducted to check for expandable mixed-layer