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Late Triassic tuff intervals in the Ordos basin, Central China: Their epositional, petrographic, geochemical characteristics and regional implications

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ABSTRACT

Tuff intervals of Upper Triassic Yanchang Formation are laterally widespread in the Ordos basin, Central China. This paper focuses on magmatic origins and potential source regions of these tuff intervals through detail depositional, petrographic and geochemical analyses. Most of the tuff intervals are well-documented at the bottom of the Chang7 oil reservoir unit and can be correlated laterally, and certain tuff beds are reworked by turbidity current or seismic activity. Petrographic studies of the Chang7 tuffs indicate that they are composed of crystal shards, lithic shards and altered glass shards, and the crystal shards include plagioclase, quartz and biotite. Alteration of the Chang7 tuffs is ubiquitous, thus, most of these tuffs transformed into illite/smectite (I/S) mixed-layers which are identified by scanning electron microscopy (SEM) and X-ray diffraction (XRD). Less common minerals are also detected in the Chang7 tuffs such as zircon, hematite, siderite, anatase. Major elements are determined by the X-ray fluorescence (XRF) analysis, the results indicate that the Chang7 tuffs are enriched in K_2O (average 4.21%), the ratio of SiO_2/Al_2O_3 ranges from 1.73 to 2.85 (average 2.17), and the ratio of TiO_2/Al_2O_3 varies between 0.006 and 0.032 (average 0.017), which imply that the Chang7 tuffs originated from a felsic parental magma. Trace elements are determined by inductively coupled plasma mass spectrometry (ICP-MS), indicating the total rare earth element ($\sum$REE) concentrations are variable, and range from 117.46 to 466.83 ppm (average 251.88 ppm). REE distribution pattern of the Chang7 tuffs presents a LREE rightward incline with flat HREE curve. The value of δEu ranges from 0.151 to 0.837 (average 0.492), suggesting a strong to weak negative Eu anomaly. The Chang7 tuffs show positive anomalies in Rb, Th and U and negative anomalies in Nb, Sr and Eu on a primitive mantle normalized spidergram. A preliminary analysis of the geochemical composition of the Chang7 tuffs suggests a parental magma origin of rhyodacite/dacite, which came from volcanic arc-related setting along an active continental margin. Combined with the chronology and geochemical studies of the synchronous Tianshui rhyolite in the West Qinling Mountains, we propose that the west Qinling Mountains is one of the potential source regions of these tuffs, and the Middle-Late Triassic terminal closure of eastern Tethys provided the arc-related magma.

1. Introduction

Explosive volcanic eruptions can produce large amounts of fine-grained pyroclastic materials which may spread laterally by wind drift over large areas (Kolata et al., 1987; Huff et al., 1992; Königer and Lorenz, 2002; Königer et al., 2002; Huff, 2008). The volcanic ashes are preserved when deposited in marine and nonmarine sedimentary basins, and subsequently altered to clay minerals during diagenetic processes (Huff et al., 2010). However, based on the morphology, composition and mineralogy of unaltered phenocrysts in the volcanic ashes, the magmatic and tectonic setting of the source volcanoes can be inferred (Sharma et al., 2005; Su et al., 2009; Huff et al., 2010; Sell and Samson, 2011). The relatively immobile element compositions of the altered volcanic ashes can also be used to determine the tectonomagmatic setting of the parental magma by applying tectonic and magmatic discrimination diagrams (e.g. Huff et al., 1992; Kramer et al., 2001; Königer and Lorenz, 2002; Foreman et al., 2008; Fanti, 2009).

The Middle-Late Triassic closure of the east Tethys along the Mianlue suture belt was proposed owing to the presence of discontinuous ophiolite suites (Zhang et al., 1996; Lai et al., 1998; Dong et al., 2011), and the diachronous collision between Yangtze and

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North China blocks from the Late Permian in the east to the Middle-Late Triassic in the west is proposed by various workers (Zhao and Coe, 1987; Yin and Nie, 1993; Zhang et al., 1996; Zhu et al., 1998; He et al., 2007). The collision facilitated the uplift of the Qinling Mountains, and induced the development of synchronous foreland basin in the southwestern Ordos area (Zhang et al., 1996; Liu, 1998; Meng and Zhang, 1999). This mountain building event was recorded by widespread magmatism and metamorphism (Zhang et al., 1996), and a number of syn/post-collisional Indosinian granites have been studied in the west Qinling Mountains by many workers (Sun et al., 2002; Wang et al., 2007; Qin et al., 2008, 2009; Zhu et al., 2011), however, arc-related volcanic rocks of this age are yet to be reported from the area. Fortunately, many contemporaneous Yanchang Formation tuff intervals are preserved in the Ordos basin, especially at the bottom of the Chang7 oil reservoir unit, which represent frequently volcanic eruptions. The Chang7 tuffs can be traced easily due to their logging signatures of high gamma-ray (GR), sonic velocity (AC) and resistivity (R), and low self-potential (SP) (Zhang et al., 2006; Deng et al., 2008; Qiu et al., 2009), and the Chang7 tuffs present positive thorium (Th) anomaly that are revealed by natural gamma spectrometry logging data (Qiu et al., 2010). According to the drill core data and logging signatures, we created a preliminary isopach map of the Chang7 tuffs in the Ordos basin (Fig. 1a, Qiu et al., 2009), which shows clear decrease in the total Chang7 tuffs thickness toward the northeast, indicating that the original volcanic sources must have come from the southwestern part or southern part out of the present Ordos basin. The mineralogical and chemical compositions of the altered Chang7 tuffs tend to be very useful tools for deciphering the tectonomagmatic setting of the potential volcanic sources.

Although the tuff intervals in the Yanchang Formation have been recognized as very useful stratigraphic correlation tools by earlier workers (e.g. Deng et al., 2008; Qiu et al., 2009; Zhang et al., 2009; Li et al., 2009; Zou et al., 2012), their petrographic and geochemical data are limited. In this paper, the depositional, petrographic and geochemical data of the Chang7 tuffs in the Ordos basin is documented. We mainly focus on the tectonomagmatic setting of parental magma, and probe the potential volcanic sources of these tuffs.

2. Geological setting

The Ordos basin is an important nonmarine petroliferous basin, which accounts for about one third of the total oil and gas output of China and has huge resource potential (Yang and Deng, 2013). Mesozoic–Cenozoic Ordos basin developed on the Paleozoic North China craton, on top of a Paleoproterozoic crystalline basement (Wan et al., 2013), which is bounded by poly-phase mountain belts: the east–west trending Yinshan Mountains to the north and Qinling Mountains to the south, the south-north trending Taihang Mountains to the east and western Ordos thrust belts (Liu

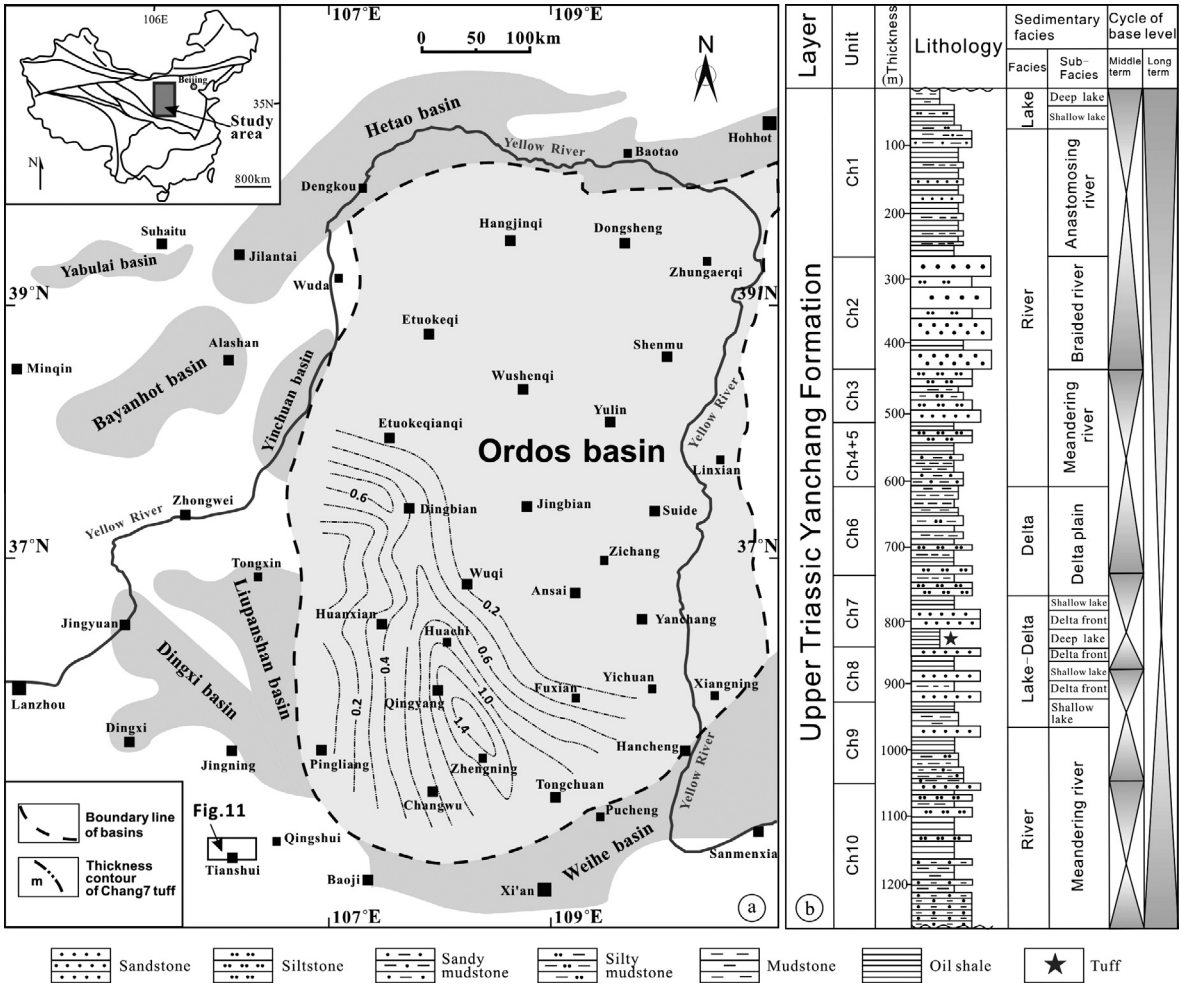

Fig. 1. (a) Isopach map (in meters) of the Chang7 tuff intervals in Ordos basin (after Qiu et al., 2009) and (b) stratigraphic column of Upper Triassic Yanchang Formation in Ordos basin Ch = Chang.