

## Thucholite in Mesoproterozoic shales from northern north China: Occurrence and indication for thermal maturity



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### ABSTRACT

Thucholites have mostly been observed in the intergranular pores of sandstones and conglomerates. In this study, investigation of thucholites in Mesoproterozoic shales has been undertaken to explain the origin and maturation of the organic matter. An optical microscope and a scanning electron microscope equipped with an Oxford X-ray energy-dispersive spectrometer (SEM-XDS) were used to study the thucholite in the Hongshuizhuang Formation (1.4 Ga) from the Yanshan Basin of northern north China. The rare and scattered thucholites are present in the shales and do not occur in the dolomites/argillaceous dolomites. The thucholite contains an apparent radioactive mineral particle as the core. The inner rim around the radioactive mineral core generally shows higher reflectance and non-fluorescence, whereas the outer rim displays low reflectance and strong fluorescence. These contrasting observations indicate higher polymerization in the inner rim relative to the outer rim. The mineral grains in the thucholites are mostly monazite and less commonly, zircon. The radioactive mineral grains of granodiorite provenance fell into algal mats at the sediment–water interface through seawater transportation, followed by polymerization of organic matter by ionizing radiation from the radioactive mineral matter through geological time. This process of formation of thucholites in shales is different from that in sandstones and conglomerates. The outer rim of the thucholites shows strong fluorescence, indicating that the thermal maturity of these 1.4 Ga old sediments is still in the oil window, consistent with the low equivalent vitrinite reflectance values (0.82–0.88%) calculated from protobitumen reflectance. The reflectance of the outer rim is close to the average of protobitumen reflectance of the whole sample, suggesting that radioactive heat has limited effect on the thermal maturity of the organic matter.

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### 1. Introduction

The organic petrology of Mesoproterozoic rocks has not been well documented in the literature, although some studies have reported the characteristics of Mesoproterozoic Barney Creek and Velkerri formations from Australia and the Hongshuizhuang Formation from northern north China (Crick, 1992; Crick et al., 1988; Qin et al., 2010). The Velkerri and Hongshuizhuang Formations are of similar age, approximately 1.4 Ga (Gao et al., 2007; Kendall et al., 2009 and references therein; Li et al., 2009, 2010; Su et al., 2010). Although the biological inputs during the Mesoproterozoic are much simpler than those in the

post-Devonian, previous studies have shown that a variety of macerals exist in Mesoproterozoic sediments (Crick, 1992; Crick et al., 1988; Qin et al., 2010). Thucholites, which was first found in carbon mineral containing Th and U by Ellsworth (1928), have been mainly reported in sandstones and conglomerates, whereas they have been found in few shales (Alexandre and Kyser, 2006; Alexandre et al., 2009; Crick, 1992; Crick et al., 1988; Curiale et al., 1983; Hoekstra and Fuchs, 1960; Mossman and Dyer, 1985; Rasmussen et al., 1989, 1993; Welin, 1966). Thucholite in sandstones and conglomerates is regarded as an indicator of migration and charging of petroleum (England et al., 2001; Rasmussen et al., 1993). However, the geochemical significance of thucholites in shales has not been reported previously.

The tectonic subdivisions in the Yanshan Basin, from east to west, include the Liaoxi sag, Shanhaiguan uplift, Jibei sag, Jidong sag, Jingxi sag, Mihuai uplift and Xuanlong sag (Fig. 1). Meso-Neoproterozoic, Lower Paleozoic and Mesozoic oil seepages have been widely observed in the Liaoxi sag, Xuanlong sag and Jibei sag. For example, so far, 115 oil seepages have been found in the Jibei sag, 85.2% of which were found in the Meso-Neoproterozoic (Wang and Han, 2011). A bitumen vein has been

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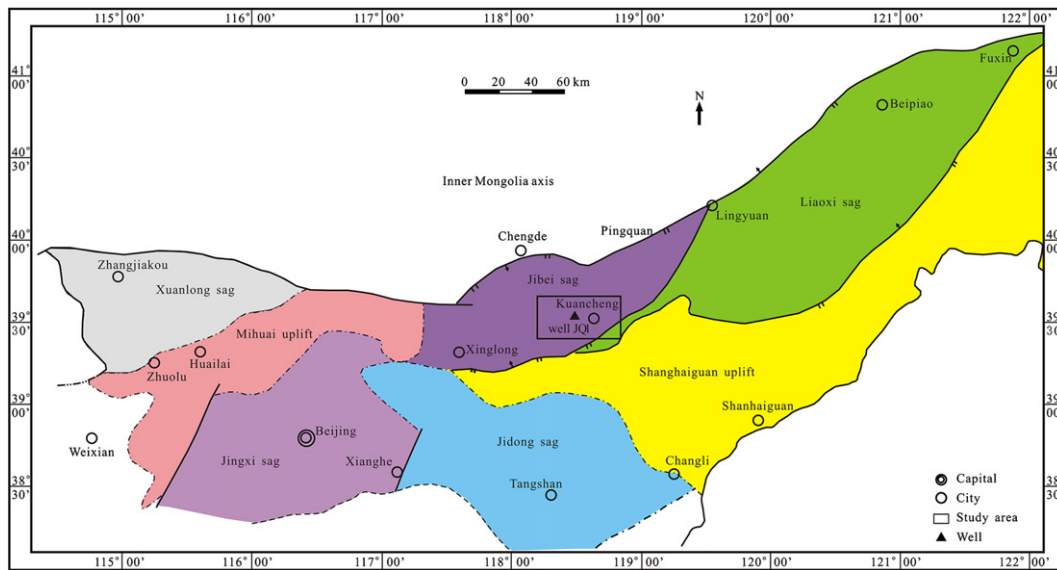


Fig. 1. Tectonic subdivisions of the North China and the location of well JQ1.

observed in the Hongshuizhuang Formation shale from Tashan, Kuancheng, Hebei province (Zhong et al., unpublished data). Previous work about the Hongshuizhuang Formation has focused on paleotectonic and paleogeographic environments, paleontology, organic geochemistry and element geochemistry (Chu et al., 2007; Li and Peng, 2003; Li et al., 2003; Liu and Fang, 1989; Liu et al., 2000; Luo et al., 2013a,b; Qiao et al., 2007; Qu et al., 2010; Sun, 2000; Wang and Han, 2011). The Hongshuizhuang Formation is mainly composed of black shales and dolomites. The black shales are rich

in organic matter, and are regarded as one of the oldest hydrocarbon source rocks in China (Luo et al., 2013b; Qin et al., 2010). There have been problems with the identification of thucholite in the Hongshuizhuang Formation. Because of similar properties, including external outline and optical characteristics, thucholite was easily mistaken as telalginite (Qin et al., 2010). In the present paper, organic petrological and element geochemical data are used to discuss the composition, origin and geochemical significance of the thucholites in the Hongshuizhuang Formation.

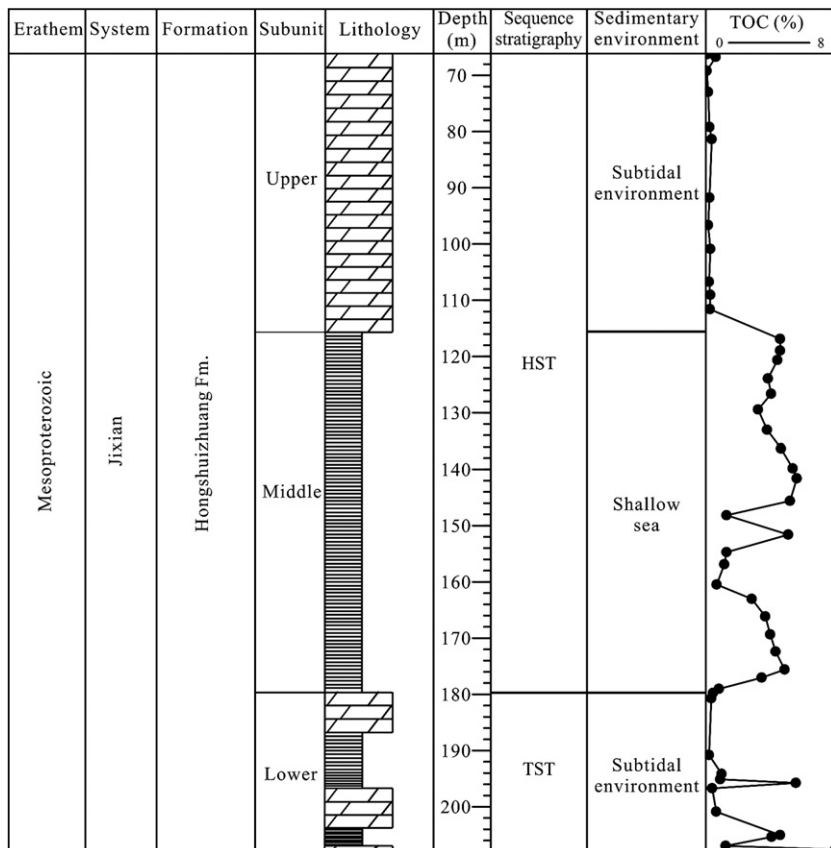


Fig. 2. Stratigraphic column for the JQ1 well showing sequence stratigraphy, sedimentary environment, and total organic carbon (TOC). Abbreviations: Fm = Formation, HST = Highstand System Tract, TST = Transgressive System Tract.

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