Ore Geology Reviews 95 (2018) 325–341

Contents lists available at ScienceDirect

Ore Geology Reviews

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

Application of in situ titanite U–Pb geochronology to volcanic-hosted magnetite deposit: New constraints on the timing and genesis of the Zhibo deposit, Western Tianshan, NW China

Zongsheng Jiang[a,*], Dachuan Wang[b], Zuoheng Zhang[a], Shigang Duan[a], Yongjian Kang[a], Fengming Li[c]

[a] MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China
[b] School of the Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China
[c] Xinjiang Bureau of Geology and Mineral Resources, Urumqi 83000, China

ARTICLE INFO

Keywords:
U–Pb geochronology
Titanite
LA-ICP-MS
Zhibo iron deposit
Western Tianshan

ABSTRACT

The Awulale metallogenic belt within the Western Tianshan orogenic belt of northwestern China includes four large iron oxide deposits with a total resource of ~1000 million metric tons (Mt) Fe. Among these, the Zhibo deposit is a large (337 Mt at 26–68 wt% Fe) volcanic-hosted magnetite deposit, where massive Ti-poor magnetite ores are hosted in the Carboniferous volcanic and volcaniclastic sequences. Here we use in situ U–Pb analyses of titanite and zircon by laser ablation ICP-MS to place tight constraints on the timing and genesis of iron mineralization at Zhibo. Titanite in the magnetite ore are closely associated with magnetite and Ca alteration assemblages consisting of actinolite, epidote, and calcite. The dated titanite exhibit strongly fractionated REE patterns with heavy REE enrichment, neutral to negative Eu anomalies, and have low Th and U concentrations, and low Th/U ratios. The textural and geochemical characteristics indicate that the titanite are hydrothermal in origin and coeval with magnetite in the paragenetic sequence. Titanite from three magnetite ores yield weighted mean ^{207}Pb-corrected ^{206}Pb/^{238}U ages of 310.3 ± 1.8 Ma (MSWD = 0.17), 310.1 ± 1.8 Ma (MSWD = 0.30), and 315.3 ± 2.5 Ma (MSWD = 0.26), constraining the iron mineralization at Zhibo to a time interval between 315 Ma and 310 Ma. Magmatic zircon from a host andesite sample yield U–Pb age of 316.3 ± 3.4 Ma (MSWD = 0.079). The overlapping ages for magnetite ores and the host volcanic rocks confirm a genetic relationship between them, and are consistent with a magmatic contribution to the mineralization system, as also indicated by Fe and O isotope data of magnetite in previous work. These new U–Pb results are also consistent with age estimates for mineralization and igneous activity in other major magnetite deposits in the Awulale iron metallogenic belt, indicating a significant iron mineralization event related to the ca. 315–300 Ma volcanism. Combined with previous geological and geochemical evidence, we conclude that the Zhibo magnetite deposit was formed mainly by iron-rich fluids derived from a mafic to intermediate magma in a volcano-plutonic structure.

1. Introduction

Titanite ($CaTiSiO_5$) is a common accessory mineral in igneous and metamorphic rocks (Enami et al., 1993; Higgins and Ribbe, 1976), and in a range of ore deposit types (Che et al., 2013; Li et al., 2010; Storey and Smith, 2017). Titanite commonly contains trace amounts of U and Th (usually 10's to 100's ppm) and has a high closure temperature to Pb diffusion (650–700 °C), making it a suitable mineral for U–Pb dating (cf. Frost et al., 2000). It has been widely used in U–Pb geochronology of magmatic intrusions (Corfu and Stone, 1998; Jiang et al., 2016; Pidgeon et al., 1996; Zhang and Schärer, 1996) and metamorphic terranes (Essex and Gromet, 2000; Gao et al., 2012; Mezger et al., 1991; Scott and St-Onge, 1995; Verts et al., 1996). Recent advances in the laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) technique permit the combined analyses of U–Pb isotope and trace element of titanite with petrographic context in thin sections. This method offers more accurate interpretations of the U–Pb data and has been increasingly applied to constrain the absolute age of mineralization in various types of ore deposits (Deng et al., 2015; Fu et al., 2016; Li et al., 2010; Seo et al., 2015; Smith et al., 2009; Storey et al., 2007;

* Corresponding author.
E-mail address: jzongsheng@126.com (Z. Jiang).

https://doi.org/10.1016/j.oregeorev.2018.03.001
Received 2 September 2017; Received in revised form 24 January 2018; Accepted 1 March 2018
Available online 02 March 2018
0169-1368/

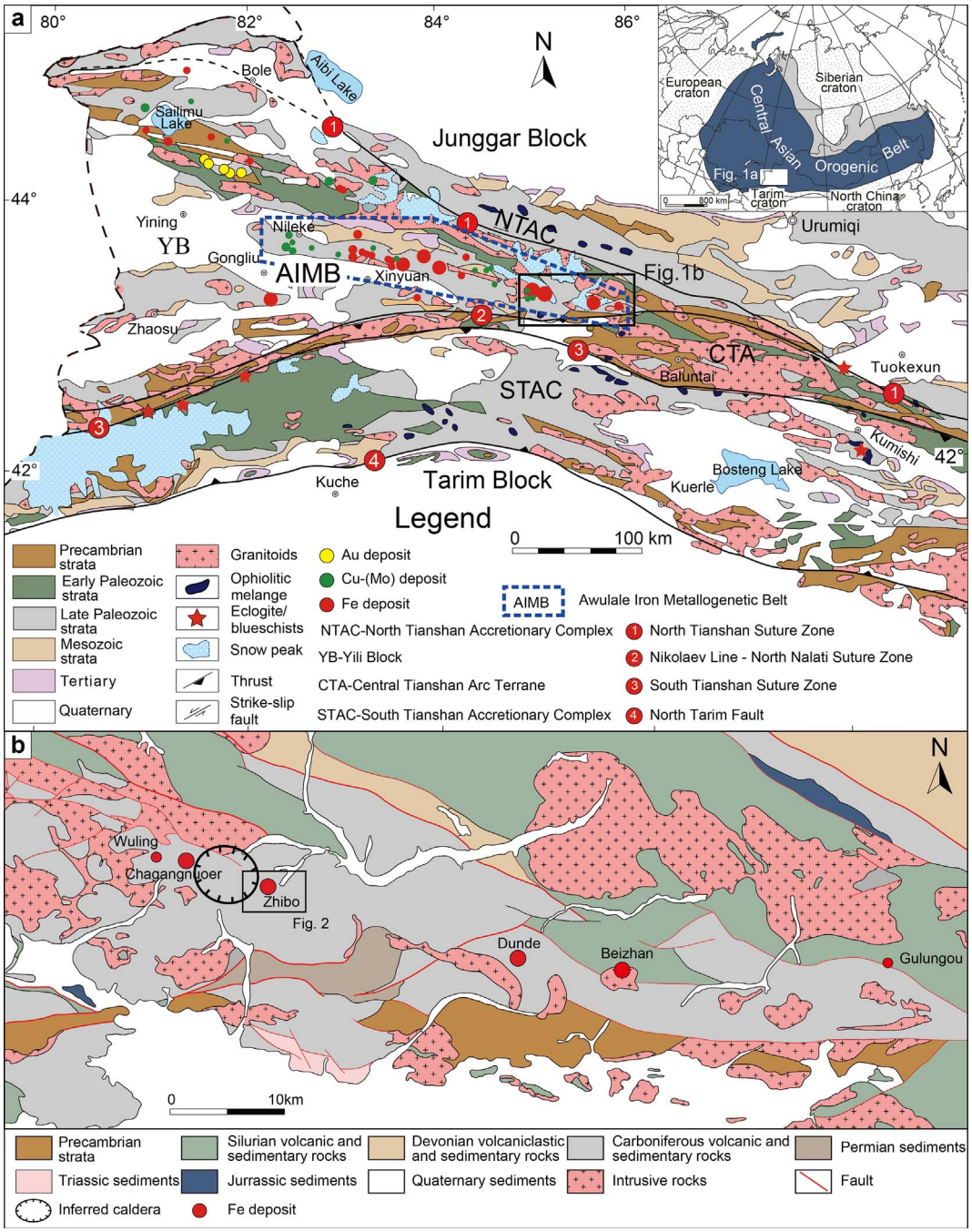

Fig. 1. (a) Geological map of the Western Tianshan region in NW China showing the Awulale iron metallogenic belt and the major volcanic-hosted iron deposits (simplified from Gao et al., 2009; Zhang et al., 2012a). Inset map shows the location of the Western Tianshan within the Central Asian Orogenic Belt (modified from Jahn, 2004). (b) Geological map of the eastern part of the Awulale iron metallogenic belt showing the location of the Zhibo iron deposit (modified from Zhang et al., 2012a).

Zhu et al., 2017).

The Awulale iron metallogenic belt (AIMB) within the Western Tianshan orogenic belt of northwestern China contains four large-tonnage iron oxide deposits and several minor deposits with a total resource of ~1000 million metric tons (Mt) Fe (Fig. 1a; Dong et al., 2011). These deposits are primarily hosted in the Carboniferous basaltic to intermediate volcanic rocks with extensive development of sodic-calcic, and potassic alteration assemblages (Zhang et al., 2014). The Zhibo deposit, the focus of this study, is a major and most investigated iron deposit of the belt. It contains massive Ti-poor magnetite with variable amounts of diopside and actinolite, sharing some common features with volcanic-hosted iron oxide-apatite (IOA) deposits in, for example, the Chilean iron belt (Knipping et al., 2015a, b; Tornos et al., 2016) and Southeast Missouri, USA (Day et al., 2016). Based on the close spatial association and geochemical similarities, previous studies proposed a genetic link between the magnetite ores and the host volcanic rocks that have been dated at 350–320 Ma (Feng et al., 2010; Jiang et al., 2014; Zhang et al., 2015). However, the absolute age of Zhibo magnetite ore remains unknown owing to the lack of suitable mineral for radiometric dating. Consequently, a temporal link between magnetite ore and the Carboniferous volcanism has not been clearly demonstrated and the genetic model for ore formation remains unresolved.

In this study, we present new LA-ICP-MS U–Pb and trace element data for titanite in thin sections of magnetite ore from the Zhibo deposit. The titanite U–Pb data represent the first direct age