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Zircon Hf–isotopic mapping for understanding crustal architecture and metallogenesis in the Eastern Qinling Orogen

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ABSTRACT

The Eastern Qinling Orogen (EQO) is a major composite collisional zone located between the North China and the Yangtze cratons. This contribution combines geological and Hf–isotopic data from magmatic rocks associated with mineralization to gain insights into links between the crust architecture and metallogeny, and to focus exploration in the orogen.

The new zircon U–Pb dates reported in this study are 434 ± 2 Ma for diorite, 433 ± 2 and 436 ± 2 Ma for monzogranite, and 454 ± 2 Ma for granodiorite in the Nanzhao area; 225 ± 2 Ma for syenite and 160 ± 1 Ma for monzogranite at Songxian; and 108 ± 1 and 102 ± 1 Ma for syenogranite in eastern Fangcheng. Combining our data with those from the entire EQO reveals seven major magmatic events since the Cambrian. These magmatic events took place during the Cambrian–Silurian associated with subduction, Early Devonian magmatism related to a collisional event, Early Permian to Late Triassic magmatism related to subduction, Late Triassic collisional magmatism, Late Triassic to Early Jurassic post–collision magmatism, and Jurassic–Cretaceous magmatism during intra–continental subduction.

Lu-Hf isotopic data collected from granitic rocks for this study give εHf(t) values of: −1.4 to 10.9 for diorite and monzogranite at Nanzhao; −27.1 to −15.6 for syenite and −27.5 to −25.1 for monzogranite at Songxian; and −12.9 to −3.4 for syenogranite in the eastern Fangcheng. Combining Hf isotopic data for the EQO from previous studies, we have evaluated the spatio–temporal distribution of Hf isotopic compositions. The resultant Hf isotopic maps highlight the location of the Kuanping Suture as an important tectonic boundary between the North China and the Yangtze cratons, which separates the EQO into a north part with an old and reworked lower crust and a southern part representing a juvenile lower crust.

The Hf isotopic mapping of the EQO also provides information on the distribution of mineral deposits. Porphyry and porphyry–skarn Mo(–W) deposits are associated with magmatic rocks were emplaced in zones with low–εHf and high T^c_{DM} values representing old and reworked crustal components. In contrast, porphyry and porphyry–skarn Cu(–Mo) deposits are associated with magmatic rocks emplaced in domains with variable εHf and T^c_{DM} values characterized by dominantly reworked old crustal components with minor juvenile material. The magmatic source for the intrusions is characterized by low–εHf and high T^c_{DM} values, which are granite–related Mo or Pb–Zn–Ag mineralization.

Contents

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1. Introduction

Conventional geochemical mapping is a useful tool providing important and fundamental surface information for many purposes in many countries and regions, such as environmental studies and mineral exploration (e.g. Webb et al., 1973; Xie et al., 1997; Mikoshiba et al., 2011; Cheng et al., 2014). In addition, isotopic mapping, using systems such as bulk-rock Sr-Nd-Pb isotopes and Lu-Hf isotopes, is a new tool for evaluating the nature of the crust at depth and its interaction with the mantle, it helps to highlight the location of terrane boundaries, and defines the distribution pattern of mineral deposits at a regional scale (Bennett and Depaolo, 1987; Guo et al., 2010; Wang et al., 2009b; Mole et al., 2012, 2014; Wyche et al., 2012; Champion and Huston, 2015; Hou et al., 2015; Du et al., 2016; Dolgopolova et al., 2016; Wang et al., 2016a).

The "Tethyan Ocean" between Gondwana in the south and Laurasia in the north has attracted attention by many researchers (e.g. Metcalfe, 2013; Deng et al., 2014b). The greater Qinling Orogen (QO), which includes the East Qinling, Qilian, and Kunlun domains in central China, is thought to represent a collisional zone bound by sutures related to the opening and closure of the Tethyan Ocean, and subsequent accretion of terranes. Earlier studies propose that the greater Qinling Orogen represents the boundary between the North China Craton (NCC) to the north and the Yangtze Craton (YC) to the south. These regions were thought to represent allochthonous Precambrian metamorphic blocks with younger cover sequences (Ratschbacher et al., 2003; Dong et al., 2011b; Fig. 1). However, due to the present of the Kuanping, Shangdan, and Mianlue sutures in the EQO, the precise location of the boundary between the cratons is still conjectural. The Shangdan Suture is commonly interpreted as the boundary between the cratons (e.g. Dong and Santosh, 2016, and references therein), but the Kuanping Suture has also been interpreted as the boundary (e.g. Cao et al., 2016). In addition, the EQO hosts many economic deposits, including combinations of copper, molybdenum and gold, which has gained the interest of many in the recent past (e.g. Wang et al., 2008). However, the relationship between the crustal architecture and magma–related deposits in the orogen are poorly understood. It is for this reason that the orogen has been chosen for this study of its crustal evolution and its mineral systems using zircon U–Pb age constraints and Hf isotopic mapping.

In this study, we present new zircon geochronology and Lu-Hf data from magmatic rocks in the EQO. In combination with previous geochronological and Hf isotopic data from the orogen, the spatio–temporal distribution of magmatic rocks, mineral deposits and crustal architecture are here evaluated. This includes the delineation of terrane boundaries, and the analysis of the relationship between mineral deposit and Hf isotopic composition of crustal components using zircon U–Pb age constraints and Hf isotopic mapping.

2. Tectonic framework and evolution

The QO links the Qilian and Kunlun mountains in the west with the Dabie Mountains in the east (Wang et al., 2015; Deng et al., 2014c). The orogen is separated into the Eastern Qinling, Western Qinling and Dabie domains (also known as orogens) by the Huixian–Chengxian and Nanyang basins (Fig. 2; Ratschbacher et al., 2003; Dong et al., 2011b; Wang et al., 2016b,c).

The EQO and adjacent areas include the southern part of the North China Craton (S–NCC), the North Qinling Domain (NQD) and South Qinling Domain (SQD), and northern Yangtze Craton (N–YC) (Figs. 1 and 2). The Shangdan Suture separates the NQD and SQD, the Mianlue Suture separates the SQD and the N–YC, and the Kuanping Suture separates the NQD and the S–NCC (Fig. 2b).