Ore Geology Reviews 59 (2014) 29–54

Contents lists available at ScienceDirect

Ore Geology Reviews

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

The Eastern Black Sea-type volcanogenic massive sulfide deposits: Geochemistry, zircon U–Pb geochronology and an overview of the geodynamics of ore genesis

Yener Eyuboglu [a,*], M. Santosh [b], Keewook Yi [c], Necati Tuysuz [a], Sadettin Korkmaz [a], Enver Akaryali [d], Francis O. Dudas [e], Osman Bektas [a]

[a] Department of Geological Engineering, Karadeniz Technical University, 61080 Trabzon, Turkey
[b] Journal Center, China University of Geosciences, 29 Xueyuan Road, Beijing 100083, China
[c] Korea Basic Science Institute, YangCheong 804-1, Ochang, Cheongwon, Chungbuk 363-883, South Korea
[d] Department of Geological Engineering, Gumushane University, 29000 Gumushane, Turkey
[e] Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

ARTICLE INFO

Article history:
Received 29 July 2013
Received in revised form 13 November 2013
Accepted 26 November 2013
Available online 11 December 2013

Keywords:
Volcanogenic massive sulfide
Subduction tectonics
Zircon geochronology
Arc magmatism
Eastern Pontides

ABSTRACT

The Meso-Cenozoic geodynamic evolution of the eastern Pontides orogenic belt provides a key to evaluate the volcanogenic massive sulfide (VMS) deposits associated with convergent margin tectonics in a Cordilleran-type orogenic belt. Here we present new geological, geochemical and zircon U–Pb geochronological data, and attempt to characterize the metallogeny through a comprehensive overview of the important VMS mineralizations in the belt. The VMS deposits in the northern part of the eastern Pontides orogenic belt occur in two different stratigraphic horizons consisting mainly of felsic volcanic rocks within the late Cretaceous sequence. SHRIMP zircon U–Pb analyses from ore-bearing dacites yield weighted mean $^{206}Pb/^{238}U$ ages ranging between 91.1 ± 1.3 and 82.6 ± 1 Ma. The felsic rocks of first and second horizons reveal geochemical characteristics of subduction-related calc-alkaline and shoshonitic magmas, respectively, in continental arcs and represent the immature and mature stages of a late Cretaceous magmatic arc. The nature of the late Cretaceous magmatism in the northern part of the eastern Pontides orogenic belt and the various lithological associations including volcaniclastics, mudstones and sedimentary facies indicate a rift-related environment where dacitic volcanism was predominant. The eastern Pontides VMS deposits are located within the caldera-like depressions and are closely associated with dome-like structures of felsic magmas, with their distribution controlled by fracture systems. Based on a detailed analyses of the geological, geophysical and geodynamic information, we propose that the VMS deposits were generated either in intra arc or near arc region of the eastern Pontides orogenic belt during the southward subduction of the Tethys oceanic lithosphere.

1. Introduction

Metallogeny associated with plate margins and intraplate settings related to both construction and destruction of continents and cratons has been a theme of several recent studies (e.g., Goldfarb et al., 2013; Li and Santosh, 2014; Pirajno et al., 2011; Yang et al., 2013; Zhai and Santosh, 2013, among others). Among the various types of ore mineralization, the hydrothermal ore deposits comprise one of the important sources for a variety of metals including Au, Ag, Cu, Pb, Pt, and U. Massive sulfide deposits occurring as stratabound concentrations precipitated from hydrothermal fluids in extensional seafloor environments (Koski and Mosier, 2010), constitute one of the important types of hydrothermal ore deposits. Based on their geodynamic settings, three main associations of massive sulfide deposits are recognized worldwide and classified as the Cyprus, Kuroko and Besshi types (e.g., Cox, 1986; Cox and Singer, 1986; Kanehira and Tatsumi, 1970; Pirajno, 2009; Sato, 1977). The Cyprus-type and Kuroko-type deposits are hosted in mafic and felsic volcanic rocks, respectively, whereas the Besshi-type deposits are hosted in sedimentary sequences (mainly shales and clastic sediments) with lesser tholeiitic basalt sills and stocks indicating source of heat.

The eastern Pontides orogenic belt, which is one of the important metallogenic provinces in the world, hosts various economic mineralizations such as volcanogenic massive sulfide, epithermal gold–silver, porphyry copper–molybdenum, and skarn-type and chromite (e.g., Abdioğlu and Arslan, 2009; Akaryalı and Tüysüz, 2013; Akçay et al., 1998; Eyuboglu, 2000; Eyuboglu et al., 2005, 2011a; Tüysüz, 2000). The volcanogenic massive sulfide deposits such as those in Murgul, Çayeli, Kutlular, Harköy and Lahanos are the major occurrences in the northern part of the eastern Pontides orogenic belt, which are related to the late Cretaceous magmatic activity. The geology and mineral paragenesis of these volcanogenic massive sulfide deposits (VMS) and also

* Corresponding author.
E-mail addresses: yenereyuboglu@gmail.com, eyuboglu@ktu.edu.tr (Y. Eyuboglu).

0169-1368/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.oregeorev.2013.11.009

the origin of ore-forming hydrothermal solutions have been investigated in many studies. However, the geodynamic setting of these ore deposits remains controversial due to lack of detailed geological, geochemical and geochronological data. Models which propose a northward subduction in the eastern Pontides belt correlate the massive sulfide deposits in the northern zone to a back-arc basin during the late Mesozoic (e.g., Çağatay, 1993; Çağatay and Eastoe, 1995; Çiftçi et al., 2005; Dilek et al., 2010; Okay and Sahintürk, 1997; Şengör and Yılmaz, 1981). In contrast, our detailed studies on the late Mesozoic and Cenozoic formations in the region do not support this model.

In this paper, we present an overview of the geology and stratigraphy of the eastern Pontides orogenic belt and also new geochemical and geochronological data in order to address the petrogenesis and age of the rocks hosting the massive sulfide deposits in the region. We also discuss the geodynamic setting of the eastern Pontides massive sulfide deposits in the light of the new data in conjunction with those from previous studies.

2. Geological background

The Alpine–Himalayan belt that was formed during the Alpine orogeny extends from the European Alps, through Carpathians, Anatolia, Caucasus, Zagros, Alborz to the Himalayan ranges of southern India and southern China (Fig. 1). The eastern Pontides orogenic belt is located in the northeastern part of Anatolia and is an integral segment of the Alpine–Himalayan belt (Eyuboglu et al., 2012; Fig. 1). The geodynamic evolution of this region is still controversial due to lack of systematic geological, geochemical, geochronological and paleontological data. Some workers believe that the eastern Pontides orogenic belt formed as a result of the northward subduction of an ancient oceanic lithosphere (Paleotethys) during the Paleozoic–Mesozoic (e.g., Adamia et al., 1977, 1981; Dilek et al., 2010; Rice et al., 2009; Ustaömer and Robertson, 1996). In this model, the ultramafic bodies exposed in the southern part of the orogenic belt have been considered to represent remnants of subducted oceanic lithosphere. However, many others propose that the eastern Pontides orogenic belt was produced by southward subduction of Tethys oceanic lithosphere that was located in the northern part of the orogenic belt during the Paleozoic–Mesozoic–Cenozoic and that the Black Sea is a remnant of the Tethys ocean (e.g., Bektaş et al., 1999; Dewey et al., 1973; Eyuboglu, 2010; Eyuboglu et al., 2007, 2012). Different from the others, Şengör and Yılmaz (1981) suggested that Paleotethys was located north of the Pontides, and hence southward subduction operated from the Palaeozoic until the early Mesozoic, followed by northward subduction from the late Mesozoic until the early Cenozoic.

The eastern Pontides orogenic belt consists of a mountain range that extends parallel to the southeastern coast of the Black Sea (Fig. 1). This range is approximately 200 km wide and 500 km long (Figs. 1 and 2) and is one of the excellent examples for well-preserved continental arcs in the Alpine–Himalayan belt (e.g., Bektaş et al., 1999; Eyuboglu et al., 2007, 2011b), with a variety of mineral systems (e.g., Akaryali and Tüysüz, 2013; Akçay et al., 1998; Eyuboglu et al., 2011a; Tüysüz, 2000). The belt can be divided into three subzones (Northern, Southern and Axial Zones) based on different lithological units, facies changes and tectonic characteristics (Bektaş et al., 1995; Eyuboglu et al., 2006; Fig. 2). In the Northern Zone, which is separated from the Southern Zone by the Niksar–Ispir–Ardanuc fault line (Fig. 2), the Hercynian basement is represented by the low-grade metamorphic rocks (Boynukalın, 1991) and unmetamorphosed granitic rocks (Kaygusuz et al., 2012). The basement rocks are unconformably overlained by the volcanic and sedimentary lithologies of the early to middle Jurassic Hamurkesen Formation (Fig. 3A). This volcano-sedimentary unit is conformably covered by the late Jurassic–early Cretaceous limestones (Berdiga limestone). However, in some locations, this unit occurs as large-scale blocks within the late Cretaceous sequence due to intense volcanic activity and/or emplacement of granite, gabbro and diorite intrusions (Eyuboglu, 2010). Most economic skarn deposits in the region occur around the contact between the limestones of the late Jurassic to early Cretaceous and

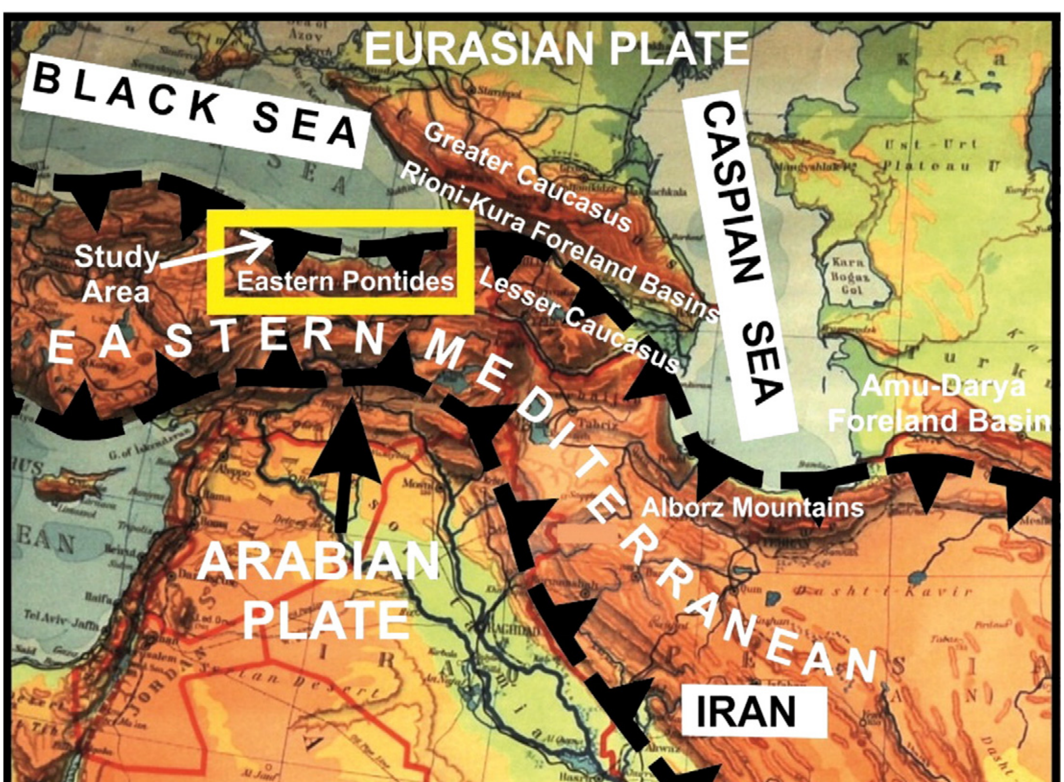

Fig. 1. Map showing the major subduction zones of the eastern Mediterranean region (after Eyuboglu et al., 2012).