Gondwana Research 26 (2014) 755–771

Contents lists available at ScienceDirect

Gondwana Research

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

Geochemistry and U–Pb zircon geochronology of metagranites in Istranca (Strandja) Zone, NW Pontides, Turkey: Implications for the geodynamic evolution of Cadomian orogeny

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ARTICLE INFO

Article history:
Received 19 February 2013
Received in revised form 11 July 2013
Accepted 23 July 2013
Available online 27 July 2013

Handling Editor: M. Santosh

Keywords:
Istranca Zone
U–Pb zircon age
Cadomian orogeny
NW Pontides
Turkey

ABSTRACT

New zircon U–Pb dating and whole-rock geochemical analysis were carried out on meta-intrusive rocks (Çatalca and İhsaniye metagranites) of the Istranca Zone, Western Pontides, with the aim of constraining the magmatic evolution of the Cadomian orogeny of the northern Gondwana margin during Late Precambrian–Early Paleozoic times. The Istranca zone is composed of metamorphic basement intruded by large granitic bodies and overlain by a Paleozoic–Mesozoic meta-sedimentary cover. The metamorphic rocks of the Istranca zone extend from Bulgaria, Istranca Mountains to NW Turkey and reach the area near Istanbul (Çatalca region).

The Çatalca and İhsaniye metagranites have a subalkaline, high-K calc-alkaline and peraluminous character. Trace element geochemistry displays decreasing normalized concentrations from large-ion lithophile (LIL) elements to high field strength (HFSE) elements and from light (LREE) to heavy rare earth elements (HREE). A negative Eu anomaly is both types of metagranites. On tectonic discrimination diagrams, the samples from both metagranites plot in the subduction-related fields.

The SHRIMP-II U–Pb zircon ages of the Çatalca metagranite range from 534.5 ± 4.7 Ma to 546.0 ± 3.9 Ma and LA-ICP-MS U–Pb zircon dating yields 535.5 ± 3.6 Ma age for the İhsaniye metagranite. The new ages together with the geochemical constraints allow a new geodynamic interpretation for the Istranca zone and we compare these metagranites with other Upper Ediacaran to Lower Cambrian granitoids of Turkey and Alpine–Himalayan orogenic belt. We deduce an origin of these elements from the northern Gondwana-Land margin.

1. Introduction

Significant insights can be gained on the composition of the middle and lower crust by the study of granitoids, which form major constituents of most orogenic belts worldwide. For the understanding of mountain building and other geodynamic processes, the plutonism and metamorphism of such zones must be investigated from the point of structural evolution and geodynamics. In Europe, several superimposed orogens were determined by many researchers in recent studies (Dörr et al., 2002; Gubanov, 2002; Murphy et al., 2002; Neubauer, 2002; Meert and Torsvik, 2003; Carrigan et al., 2006). Although Variscan and Alpine orogens are the best studied orogenic events of orogenies in Central and Western Europe, there are several places where Late Neoproterozoic to Early Paleozoic basement units (700–425 Ma) are well preserved (Murphy et al., 2002; Ustaömer et al., 2009; Fig. 1). These basement units are called products of the "Cadomian orogeny" and were interpreted to have formed along the northern, Andean-type margin of Gondwana (e.g., Nance and Murphy, 1994). From west to east along the northern margin of Gondwana these are the Rodope–Istranca massif, İstanbul Zone, Bolu Massif, Menderes Massif, Pötürge–Bitlis Massifs, Takab Complex of Iran and Trans-Caucasus. These units include granitoids and a metamorphic basement formed during Late Neoproterozoic to Early Paleozoic times (Fig. 1). The remnants of this "Cadomian" orogen compose some tectonic fragments exposed in Armorican, Bohemian and Iberian Massifs originally located along the northern Gondwana margin. Murphy et al. (2002) collectively refer to these as peri-Gondwanan terranes. Some peri-Gondwanan terranes may also extend to the east along the Trans-European Suture Zone in Romania, Bulgaria and Turkey (Peytcheva et al., 2005; Carrigan et al., 2006; Haydoutov et al., 2012; Fig. 1). The existence of the "Cadomian" orogen within Southeast European Alpine-Mediterranean mountain belts was recognized in the early 1980s by means of U–Pb zircon geochronology (Neubauer, 2002 and references therein; Dyulgerov et al., 2006; Kiselinov et al., 2008) and areas related to this orogen were recently also discovered in Turkey and in the terranes surrounding the Red Sea (e.g., Murphy et al., 2002), as well as in Central Iran and Trans-Caucasus (Ramezani and Tucker, 2003; Zakariadze et al., 2007).

The Pontides represent one of the main tectonic units of Turkey and have been divided into western, central and eastern Pontides according

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1342-937X/$ – see front matter
http://dx.doi.org/10.1016/j.gr.2013.07.011

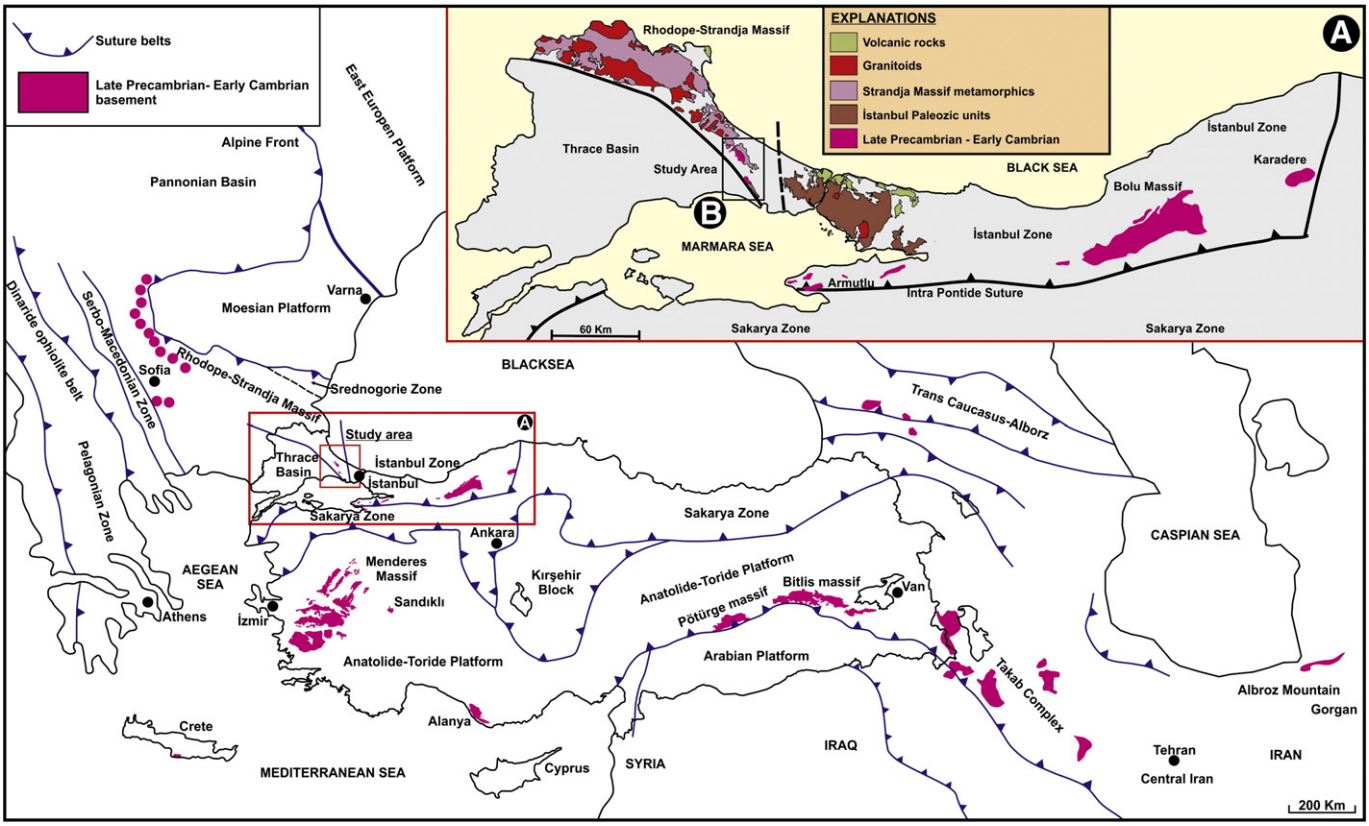

Fig. 1. Revised tectonic map of Southeastern Europe and the Mediterranean region composed of the major Cadomian (Upper Precambrian–Lower Cambrian) basement rocks (compiled from Okay and Tüysüz, 1999; Okay et al., 2008; Hassanzadeh et al., 2008; Badr et al., 2013; Ustaömer et al., 2009; http://www.unil.ch/igp/page22669_fr.html).

to their geological features. The western part of the Pontides is subdivided into three tectonic sub-units such as the İstanbul, Sakarya and Istranca zones. The Istranca zone is composed of metamorphic basement (Istranca massif) intruded by large granitic bodies and overlain by a Paleozoic–Mesozoic metasedimentary cover. İstanbul zone consists of a Neoproterozoic crystalline basement overlain by Paleozoic–Cenozoic sedimentary rocks (Okay et al., 2001; Yiğitbaş et al., 2004; Ustaömer et al., 2005). The basement rocks that include Cadomian magmatic rocks are similar to each other in İstanbul and Istranca Zones.

According to the new U–Pb zircon ages, granitic Cadomian and Pan-African basement units in Turkey are widespread within the Menderes massif (Kröner and Şengör, 1990; Bozkurt and Oberhänsli, 2001; Gessner et al., 2001, 2004; Neubauer, 2002; Koralay et al., 2004; Bozkaya et al., 2006; Candan et al., 2011; Zlatkin et al., 2013), Bolu massif (Ustaömer et al., 2005), Karadere basement (Chen et al., 2002) in the İstanbul Zone and the Bitlis massif (Ustaömer et al., 2009, 2012, Fig. 1). The 570–520 Ma age granites within the Menderes Massif (Hetzel et al., 1998; Koralay et al., 2006; Oberhänsli et al., 2010; Candan et al., 2011) and the İstanbul zone generally occurred along an Andean-type active continental margin. These areas reveal a close similarity of timing and nature of magmatic processes in the northern margin of Gondwana.

Recently, Late Precambrian–Early Paleozoic and Early Permian–Triassic ages of granitic, metamorphic and sedimentary rocks in the Istranca zone were determined by single zircon analysis methods (Okay et al., 2001; Sunal et al., 2006, 2008; Natal'in et al., 2012). Our new geochronological data from metagranites were determined from two samples of Çatalca metagranite (ÇMG-11, 29) (Yılmaz Şahin et al., 2009) and one sample from İhsaniye metagranite (IMG-1) in the Çatalca town.

Cadomian basement units are restricted to small zones crossing from Southeastern via Central Europe to Western Europe and their relationship to other areas such as the Appalachian and Caledonian belts are poorly known because most parts were reworked during the Variscan orogeny and/or are buried under thick Paleozoic cover (Kröner et al., 1995; Dörr et al., 2002). Cadomian arc-type granitoids are found in the basement units of various Caledonian, Variscan and Alpine orogenic belts such as East Avalonia and Northwestern Europe. Especially the Bohemian Massif of the Central European Variscides includes fragments of Cadomian rocks with protolith ages ranging from 585 to 520 Ma (Dörr et al., 2002). It has recently been suggested that paleotectonic reconstruction shows that Baltica and Siberia were close to Gondwana-Land at 550 Ma (Cocks and Torsvik, 2005; Natal'in et al., 2012). Searching for detrital zircon provinces, some authors (e.g. Okay et al., 2008; Ustaömer et al., 2009; Sunal et al., 2011) equate Baltica with the basement of the Russian Craton (Bogdanova et al., 2008) and disregard it as possible zircon sources of the Istanbul zone. In addition, new detrital zircon age groups were found in sedimentary rocks of the Istranca massif by some researchers (Yanev et al., 2006; Sunal et al., 2008; Natal'in et al., 2012).

In this paper, we present new in-situ SHRIMP and LA-ICP-MS U–Pb zircon ages and geochemical data on metagranites from the southeastern edge of the Istranca massif – the Çatalca region (Figs. 1, 2). Geochemical and geochronological methods, as well as the analyses of the zircon morphology and composition (U content) are combined to define the geochemical characteristics and age of metagranite and to make implication for their tectonic position. We found an arc signature for these Lower Cambrian metagranites. This new data allow place this Cadomian-aged magmatic arc on the northern margin of Gondwana-Land.

2. Regional geology

The Istranca zone is situated at the northwestern part of the Pontides, which comprise the Istranca, İstanbul and Sakarya zones (Okay and