Lithos 252–253 (2016) 76–91

Contents lists available at ScienceDirect

Lithos

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

Crustal melting and magma mixing in a continental arc setting: Evidence from the Yaloman intrusive complex in the Gorny Altai terrane, Central Asian Orogenic Belt

Ming Chen [a,b], Min Sun [a,b,*], Mikhail M. Buslov [c,d], Keda Cai [e], Guochun Zhao [a], Anna V. Kulikova [c,d], Elena S. Rubanova [c,d]

[a] Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China
[b] HKU Shenzhen Institute of Research and Innovation, Shenzhen, China
[c] Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences, Novosibirsk 630090, Russia
[d] The Novosibirsk State University, Pirogova Street 2, Novosibirsk 630090, Russia
[e] Xinjiang Research Center for Mineral Resources, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China

ARTICLE INFO

Article history:
Received 2 September 2015
Accepted 15 February 2016
Available online 27 February 2016

Keywords:
Mafic enclaves
Granitoids
Subduction zone
Crustal melting
Magma mixing
Gorny Altai terrane

ABSTRACT

Granitoids and their hosted mafic enclaves may retain important information on crust–mantle interaction, and thus are significant for study of crustal growth and differentiation. An integrated petrological, geochronological and geochemical study on the granitoid plutons of the Yaloman intrusive complex from the Gorny Altai terrane, northwestern Central Asian Orogenic Belt, was conducted to determine their source nature, petrogenesis and geodynamics. Mafic enclaves are common in the plutons, and a zircon U–Pb age (389 Ma ± 4 Ma) indicates that they are coeval with their granitoid hosts (ca. 393–387 Ma). Petrographic observations reveal that these mafic enclaves probably represent magmatic globules commingled with their host magmas. The relatively low SiO_2 contents (46.0–60.7 wt.%) and high $Mg^{\#}$ (38.9–56.5) further suggest that mantle-derived mafic melts served as a crucial component in the formation of these mafic enclaves. The granitoid hosts, including quartz diorites and granodiorites, are I-type in origin, possessing higher SiO_2 contents (60.2–69.9 wt.%) and lower $Mg^{\#}$ (32.0–44.2). Their zircon Hf and whole-rock Nd isotopic compositions indicate that the magmas were dominated by remelting of Neoproterozoic (0.79–1.07 Ga) crustal materials. Meanwhile, the geochemical modeling, together with the common occurrence of igneous mafic enclaves and the observation of reversely zoned plagioclases, suggests that magma mixing possibly contributed significantly to the geochemical variation of the granitoid hosts. Our results imply that mafic magmas from the mantle not only provided substantial heat to melt the lower crust, but also mixed with the crust-derived melts to form the diverse granitoids.
The oxidizing and water-enriched properties inferred from the mineral assemblages and compositions imply that the granitoid plutons of the Yaloman intrusive complex were possibly formed in a continental arc-related setting, which is also supported by their geochemistry. The Devonian granitoids from the Gorny Altai terrane show remarkable temporal–spatial–petrogenetic affinities to the counterparts from the Altai-Mongolian terrane, indicating that these two terranes were possibly under subduction of the same oceanic plate (i.e., the Ob-Zaisan Ocean). The voluminous granitoids signify significant crustal recycling and growth as a response to the underplating of extensive mantle-derived basaltic melts.

1. Introduction

The Earth is distinct from other rocky planets by its unique continental crust with an average composition similar to that of andesite (e.g., Taylor and McLennan 1985; Rudnick 1995). It has been proposed that lateral accretion of island arcs and basaltic underplating beneath the lower crust contribute dominantly to the crustal growth (e.g., Rudnick 1990, 1995; Frost et al. 2001; Xiao et al. 2010). However, mantle-derived melts, either in subduction zones or intra-plate settings, are predominantly basaltic in composition (Rudnick 1990; Debari and Sleep 1991; Holbrook et al. 1999). Processes, such as differentiation of basaltic magmas and/or partial melting of basaltic rocks, are therefore required to drive these mafic components toward more evolved composition. This inferred geochemical differentiation is supported by geophysical investigations, showing that the lower part of the continental crust is dominated by mafic rocks, while the proportion of intermediate-felsic rocks increases upward (e.g., Rudnick and Fountain 1995). Various models, including partial melting of pre-existing lower crust by

* Corresponding author at: Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China.
E-mail address: minsun@hku.hk (M. Sun).

http://dx.doi.org/10.1016/j.lithos.2016.02.016
0024-4937/

underplating of basaltic magmas with/without magma mixing (e.g., Borg and Clynne 1998; Petford and Gallagher 2001; Dufek and Bergantz, 2005) and differentiation of basaltic magmas through middle- to high-pressure fractional crystallization (e.g., Jagoutz et al. 2013; Lee and Bachmann 2014) or silicate liquid immiscibility (e.g., Charlier et al. 2011), have been proposed. Granitoids and their volcanic equivalents constitute a major proportion of the upper continental crust, and thus are critical to understand the crustal growth and differentiation.

The Central Asian Orogenic Belt (CAOB) is considered to be the most important site for the Phanerozoic crustal growth on the Earth (e.g. Sengör et al. 1993; Jahn 2004). The Gorny Altai terrane, situated southwest off the Siberian continent (present coordinate; Figs. 1a, b), is dominated by late Neoproterozoic to early Ordovician basaltic rocks, which have been proposed to be formed in an intra-oceanic island arc setting (i.e., the Kuznetsk–Altai arc; Buslov et al. 1993, 2002, 2013; Simonov et al. 1994; Ota et al. 2007; Safonova et al. 2011; Utsunomiya et al. 2009; Kruk et al. 2010). After a period of tectono-magmatic quiescence from the Ordovician to early Devonian, the Gorny Altai terrane underwent extensive magmatic activities in the Devonian to early Carboniferous, as recorded by voluminous granitoids and their volcanic equivalents (Buslov et al. 1993, 2013; Yolkin et al. 1994; Daukeev et al. 2008; Kruk et al. 2008, 2011; Buslov and Safonova 2010; Glorie et al.

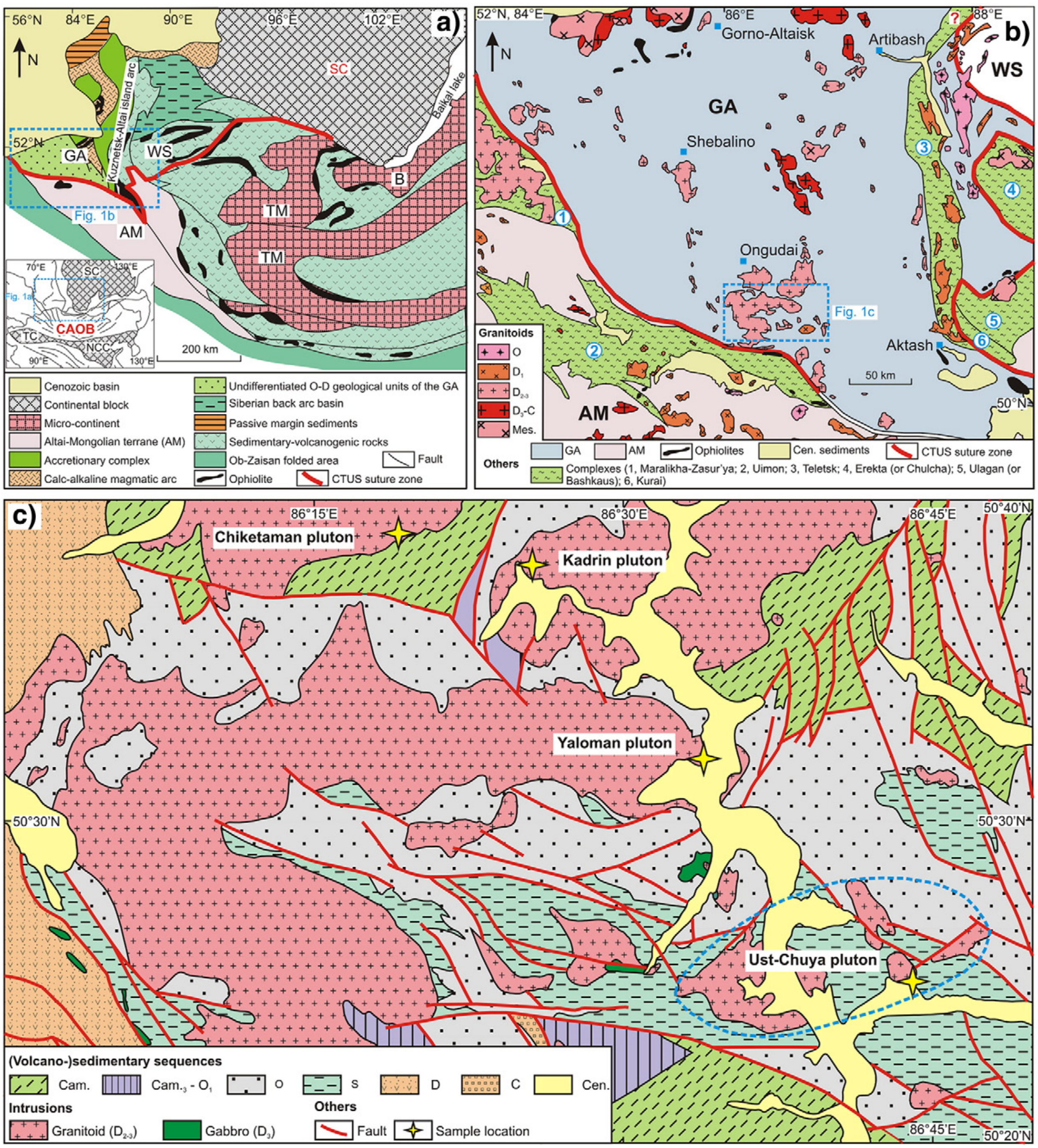

Fig. 1. (a) Simplified tectonic architecture of the northwestern Central Asian Orogenic Belt (CAOB, modified after Buslov and Safonova (2010) and Buslov (2011)). (a) Inset shows that the CAOB is situated among the Siberian, Tarim and North China continents. (b) Distribution of intrusive rocks in the Gorny Altai terrane (GA), northern segment of the Altai-Mongolian terrane (AM) and the Charysh–Terekta–Ulagan–Sayan (CTUS) suture zone between these two terranes. Complexes along this suture zone are also shown. This map is modified after Daukeev et al. (2008), Glorie et al. (2011) and Kuibida et al. (2014). (c) The investigated granitoid plutons of the Yaloman intrusive complex and surrounding volcano–sedimentary units (modified after the Russian geological map). Abbreviations: SC, Siberian continent; TC, Tarim continent; NCC, North China continent; WS, West Sayan; B, Barguzin; TM, Tuva–Mongolian terrane; Cam., Cambrian; O, Ordovician; S, Silurian; D, Devonian; C, Carboniferous; Mes., Mesozoic; and Cen., Cenozoic.