

Preface

IGCP project 510 — A-type Granites and Related Rocks
through Time

Abstract

This introductory article of the IGCP-510 Special Issue of *Lithos* presents the goals of IGCP Project 510 (A-type Granites and Related Rocks through Time), activities in the first two years (2005–2006) of the project, and plans for the years 2007–2009. The 11 research papers in this issue are based on papers presented at the inaugural meeting of IGCP-510 in conjunction with the 15th Goldschmidt Conference in Moscow, Idaho, USA in 2005.

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1. Introduction

An IGCP Project entitled “A-type Granites and Related Rocks through Time” was established in 2005 to correlate the petrology, geochronology, geochemistry, and metallogeny of A-type granites and related rocks found in various tectonic settings, throughout geologic time. A-type granites (including their volcanic equivalents) and related rocks (mafic intrusions, anorthosites, basaltic dikes and lavas, rare alkaline rocks) form a conspicuous part of the granite spectrum. They have been recognized by the geological community only recently (Loiselle and Wones, 1979) and they are characterized by several attributes that clearly set them apart from other granitic rocks. A-type granites have been originally defined as relatively dry (anhydrous), and they have high contents of alkali metals (either sodium or potassium) and most high field strength trace elements. They commonly have been emplaced in an extensional tectonic regime not directly related to lithospheric convergence (i.e., they have been considered “anorogenic” or “post-tectonic”). In terms of age, the A-type granites span almost three billion years (~2.7 Ga to Recent) of Earth’s history and they are associated with a

variety of different mineralization types (e.g., Sn, F, Nb, Ta, Au, Fe, U, and rare earth elements).

To pursue project’s goals and to promote international collaboration between scientists working in these fields of geology, the project has organized several symposia, workshops and field trips in North America, South America, and Europe. This special issue of *Lithos* comprises a selection of 11 original papers that deal with various themes of the project, and are based on presentations given in the IGCP-510 meeting in 2005 that was held as part of the 15th Goldschmidt Conference in Moscow, Idaho, USA. In this introductory article, the aims and activities of the project, which will run until the end of 2009, are described and the main results of the 11 papers reviewed.

2. Aims of IGCP-510

To understand the origin and significance of A-type granites and related rocks through time, the project has focused in particular on (1) the petrogenesis of the A-type granites; (2) their metallogenic significance; (3) classification schemes for granites and A-type granites specifically; and (4) the tectonic setting of A-type magmatism and implications for lithospheric evolution.

2.1. Petrogenesis of the A-type granites

Since their definition in the late 1970s, it has become evident that the A-type granites span a wide range of petroTECTONIC associations. Granites and other felsic igneous rocks belonging to this category are found in both continental and oceanic settings and comprise plutons (and minor hypabyssal and supracrustal rocks) that sharply transect the surrounding cratonic or oceanic crust. The oldest (~2.73 and 2.75 Ga) A-type granites have been described, respectively, from southern Botswana where they are associated with contemporaneous mafic (mostly anorthositic) rocks, and Carajás, Brazil. The end of the Paleoproterozoic and Mesoproterozoic times (~1.9 to 1.0 Ga) were characterized by the emplacement of voluminous A-type granites (often rapakivi-textured) and associated mafic rocks (gabbro-anorthosites, diabase dikes, rare volcanic rocks) that constitute continent-wide belts, e.g., in northern Europe and North America, and Amazonia. Near the end of the Brasiliano–Pan-African cycles, Upper Proterozoic to Cambrian, post-tectonic A-type granites are common in Atlantic provinces of Brazil and also in Africa (e.g., Algeria). Phanerozoic examples of A-type granites include the Permian Oslo Graben, the Devonian in southeastern Australia and New England, the Tertiary intrusions of the British Isles, the Younger Granites of Nigeria, and the Permo-Triassic Western Mediterranean province. The Cenozoic topaz rhyolites and synextensional granites of the western United States, the rhyolites of the Yellowstone hotspot track, as well as alkali granites of oceanic islands (e.g., Kerguelen Archipelago) are prime examples of young A-type granite magmatic activity. Petrogenetic models applicable to these occurrences are obviously many, including extreme fractionation of mantle-derived mafic melts (a particularly likely scenario for the oceanic A-type granites), partial melting of a (juvenile) mafic underplate (consistent with the strongly reduced character of many A-type granites), and anatexis of a source in pre-existing (refractory or fertile) continental crust. It is probable that no single mechanism can account for the wide range of petroTECTONIC associations recorded by the A-type granites, and one prime aim of the project is to comprehensively scrutinize the possible petrogenetic scenarios, and whether or not they show secular variation with geologic time.

2.2. Metallogenic significance of the A-type granites

A-type granite associations have a significant role as carriers of several metallic commodities and their global

correlation and resultant enhancement of prospecting and exploration will be the principal applied result of the project. Proterozoic A-type (rapakivi) granites are hosts of significant tin-polymetallic deposits particularly in South America (Brazil) and such occurrences are also found in Missouri, Finland, the Ukraine, and India. They are also associated with Fe–Cu deposits in southeastern Missouri, and the huge Olympic Dam Cu–U–Au–Ag deposit of South Australia is also hosted by an A-type granite. Moreover, one of the major rare earth element resources currently in production, the Mountain Pass deposit of southern California, is associated with a ~1.4 Ga shonkinite that is presumably related to the mid-Proterozoic A-type granites of the southwestern United States. One goal of the project is to examine how mineralization types vary with time, tectonic setting, and A-type granite characteristics, and the new results may well lead to establishment of further occurrences of valuable resources related to A-type granites.

2.3. Granite typology

The geological literature includes a myriad of different schemes for the classification of granitic rocks and no generally accepted practice exists for their typology. The “alphabet classification” involving A-, I-, S-, M-, and C-type granites that is largely based on compositional criteria reflecting the ultimate source of the granite magmas, has been relatively widely applied but has also been criticized. The alphabet categories often show some overlap and, within the individual groups themselves, the need for a more detailed subdivision has emerged. [Frost et al. \(2001\)](#) have proposed a classification scheme based solely on the major element composition of granites, as an alternative to the other schemes that often build on trace element contents that can be more vulnerable for redistribution in the post-magmatic stage and thus cause problems in classification. The data presented here and collected during the project will be utilized in the evaluation of the proposed classification and in pursuit of a comprehensive granite classification scheme.

2.4. Relation to lithospheric evolution

Overall, the tectonic setting of the A-type granites is non-compressional, including such regimes as oceanic islands near spreading ridges, apparently stable cratons, and intraplate extensional continental rifts which, in many cases, imply a principal role of mantle processes in the initiation of the magmatism. However, post-

collisional or post-orogenic settings have also been invoked and some of the “anorogenic” A-type complexes have been associated with concurrent subduction processes in distant craton margins. The project will gather a global database of the tectonic settings of the A-type granites and assess the variation in their tectonic regimes through space and time. We will also aim to locate the oldest A-type granite assemblages to see how much earlier than 2.75 b.y. ago processes creating these rocks have been in operation.

3. Activities of IGCP-510

In 2005–2006, IGCP-510 has arranged or sponsored six meetings; these have been attended by researchers from more than 20 countries:

- The inaugural meeting “*A-type Granites and Related Rocks through Time*” was arranged in conjunction with the 15th Annual V.M. Goldschmidt Conference in May 20–25, 2005 in Moscow, Idaho, USA. Abstracts of 22 papers on various themes of the project can be found in *Geochimica Cosmochimica Acta* (Podosek, 2005).
- IGCP-510 field trip “*Extrusive A-type magmatism of the Yellowstone hot spot track*” was arranged May

26–30, 2005, to examine the Neogene to Recent extrusive A-type magmatism of the Snake River Plain — Yellowstone region (Fig. 1). Specific themes on the field trip included the 2.0, 1.2, and 0.6 Ma A-type rhyolitic eruptions of the Yellowstone caldera and Recent ferrobasalts that are the extrusive equivalents of the ferrodiortites associated with A-type granites and anorthosite complexes (see Frost et al., 2005).

- IGCP-510 co-sponsored the Eurogranites field conference to southern and central Finland held September 11–17, 2005 (Rämö et al., 2005). The conference examined the origin and significance of Proterozoic and Archean granitoid rocks along a traverse from southern to east-central Finland. Specific targets included (i) the classic A-type ~1.64 Ga rapakivi granites and related mafic rocks of southeastern Finland; (ii) the orogenic granitoids of the ~1.9 Ga Svecofennian orogen; and (iii) the sanukitoids, TTG suites, and A-type granites of the late Archean Karelian craton.
- The third scientific field trip of IGCP-510 visited the Pitinga Mine in northern Amazonia, Brazil, August 2–5, 2006 (Fig. 2). The trip focused on the Paleoproterozoic (~1.82 Ga) Zr–Nb–Sn-mineralized A-type granites and their Paleoproterozoic



Fig. 1. Dr. Robert Christiansen explains features of hydrothermally-altered rhyolites exposed in the Grand Canyon of the Yellowstone from the overlook at Artists Point to participants of the IGCP-510 field trip along the Snake River Plain–Yellowstone hotspot track, May 2005. Photo by O.T. Rämö.



Fig. 2. IGCP-510 participants examine the contact between albite granite (base of outcrop) and biotite alkali feldspar granite (upper part of outcrop) of the Madeira pluton, Pitinga Mine, Amazonas, Brazil in August 2006 on a field trip that examined mineralization associated with A-type granites and their country rocks. Photo by O.T. Rämö.

country rocks in the Pitinga province on the southern flank of the Guiana shield in northern Brazil. The principal targets were the Madeira and Água Boa plutons (Costi et al., 2006).

- The second annual meeting of IGCP-510 was held August 6–9, 2006 in Belém, Brazil, in conjunction with the symposium “Symposium on Magmatism, Crustal Evolution, and Metallogenesis of the Amazonian Craton”. 44 presentations covered timely topics related to A-type granite suites (Dall’Agnol et al., 2006a).
- The fourth scientific field trip of IGCP-510 was held August 10–15, 2006, and focused on Paleoproterozoic A-type granites (reduced and oxidized) and Archean TTGs, sanukitoids, leucogranites, and A-type granites, as well as associated iron, copper, and gold mineralization (Dall’Agnol et al., 2006b).

Upcoming activities of the project include:

- The third annual meeting will be arranged in conjunction with the 6th Hutton Symposium on Granites and Related Rocks that will be held in Stellenbosch, South Africa in July 2007. Regional field trips will run in South Africa and Namibia.
- A field conference will be arranged in the Colorado River extensional corridor–southern Death Valley–

northern Mojave Desert region, focusing on the Miocene plutonic and subvolcanic A-type suites of the Basin and Range Province in the southwestern United States. The field conference will be followed by an IGCP-510-oriented thematic session at the Geological Society of America Annual Meeting in Denver in October 2007.

- A joint technical session entitled “Granite classification — a never-ending problem” with the IUGC Subcommittee of Systematics of Igneous Rocks at the 33rd International Geological Congress in Oslo (August 2008).
- A four-day field trip to the Oslo Rift in August 2008. The field trip will examine the geology and petrology of the classic Paleozoic anorogenic rocks of the Oslo Rift.
- A field trip to Corsica in the Propriano–Bonifatto area in October 2008. This excursion will cover a varied collage of A-type suites: volcanic calderas, layered mafic chamber and a complete set of felsic rock types ranging from monzonite to syenite to alkali-feldspar granite, with hypersolvus to transsolvus to subsolvus alkali-feldspar mineralogy, and metaluminous to peraluminous or peralkaline compositions.
- The fifth annual meeting will be held in Helsinki, Finland, in 2009 accompanied by regional field trips to Finland and vicinity.

4. Papers in this volume

The 11 papers in this special issue of IGCP-510 “A-type Granites and Related Rocks through Time” deal with A-type suites ranging in age from Proterozoic to Cenozoic in age. They cover a wide selection of the topics of the project and are briefly introduced in the following.

4.1. Review of the A-type concept

Bonin (2007-this issue) summarizes evolution of the concept of A-type magmas and the petrochemical characteristics of A-type granites, which include hypersolvus to subsolvus alkali feldspar textures, iron-rich mafic silicates, and bulk-rock ferroan, alkali-calcic to alkalic geochemical compositions and high LILE + HFSE abundances. A-type granites have isotopic characteristics that suggest sources containing a large mantle input. Bonin identifies mantle-derived transitional to alkaline basaltic to intermediate parental magmas. Based upon felsic materials from the lunar and meteoritic record, Bonin suggests that A-type magmatism may be more typical of lunar and other planetary environments than of Earth.

4.2. Precambrian A-type suites

Four of the papers deal with Proterozoic A-type suites that range in age from 1.35 Ga to 580 Ma. The oldest of these is the Chimakurti, Errakonda and Uppalapadu suite of plutons of the Eastern Ghats Belt, India. Vijaya Kumar et al. (2007-this issue) suggest that the pyroxenite, anorthosite and gabbro of the Chimakurti pluton were derived from a tholeiitic parental magma. The ferrodiorite of the Errakonda pluton has A-type affinities and is inferred to form by differentiation or partial melting of a tholeiitic source. The nepheline syenites of the Uppalapadu pluton, on the other hand, were derived from an alkaline parental magma. This study thus documents an unusual spatial and temporal association of both tholeiitic and alkaline parental magmas in continental rift magmatism. Y. Li et al. (2007-this issue) document at ca. 1.1 Ga bimodal A-type suite of plutonic rocks in the subsurface of Texas and eastern New Mexico, southwestern USA. These rocks are coeval with xenoliths from Potrillo maar volcano, southern Rio Grande rift of New Mexico, granites of the Llano uplift of central Texas, and the A-type Pikes Peak batholith of Colorado. Two papers deal with Proterozoic A-type magmatism in Brazil. Rosa et al. (2007-this issue), present age information on the blue sodalite

syenites of the southern Bahia alkaline province. Their new U–Pb and Pb–Pb dates suggest that anorogenic alkaline magmatism persisted in this area for approximately 60 Ma, during rifting prior to the formation of the Araçuaí orogen at 700 Ma. In their study of A-type granites and syenites from the Graciosa Province of southern Brazil, Vlach and Gualda (2007-this issue) focus on the occurrence of allanite and chevkinite. These minerals are the main reservoir for rare earth elements in A-type granitoids. Chevkinite is restricted to the alkaline intrusions, whereas primary allanite is present in rocks formed by magma mixing and mingling. Vlach and Gualda conclude that magma composition is an important control on the stability fields for these minerals.

4.3. Phanerozoic A-type suites

Six papers describe A-type granites and rhyolites of Phanerozoic age. Hergt et al. (2007-this issue), investigate granites and rhyolites of the Grampians region of western Victoria, Australia, and determine that the 396 Ma Victoria Valley batholith, part of the Lachlan Fold Belt, shares important similarities with A-type magmas. They suggest that these characteristics were inherited from the Cambrian mafic and intermediate rocks that they identify as the magma sources of the batholith. Konopelko et al. (2007-this issue), examine Hercynian-age (280–300 Ma) post-collisional A-type granites in the southern Tien Shan orogen, Kyrgyzstan. A number of post-tectonic A-type plutons occur in the easternmost portion of the orogen, including biotite-hornblende granites, topaz-bearing leucogranites, syenites, and coeval tholeiitic mafic rocks. The authors call on an asthenospheric mantle source for the mafic rocks, interaction of that magma with Precambrian crust to form the felsic rocks, and lithosphere-scale strike-slip shear zones to provide magma conduits to the near-surface. Mesozoic A-type granites and coeval associated tin deposits of Hunan Province, China, are the subject of the paper by Z. Li et al. (2007-this issue). These authors interpret He, Pb and S isotopic data to suggest that the same magmas that produced the A-type granites also yielded the ore-forming fluids. They suggest that lithospheric extension allowed for mantle upwelling and the input of heat and magma into the crust. Haapala et al. (2007-this issue), describe Cretaceous topaz-bearing granites from Namibia in their contribution to the special issue. These peraluminous topaz-bearing granites, which are found in the Grosse Spitzkoppe and Klein Spitzkoppe stocks in the bimodal Paraná-Etendeka Large Igneous Province, are

associated with gem-quality topaz and beryl, and locally with wolframite-bearing greisen. The authors call upon the interplay of plume-related mantle magmas with crustal sources in the petrogenesis of these and other A-type intrusions in the Paraná-Etendeka province. Somewhat younger bimodal A-type intrusions are described by Boztuğ et al. (2007-this issue), from east-central Anatolia, Turkey. New hornblende and biotite K–Ar dates of 68 to 77 Ma on monzonitic and syenitic felsic rocks and on monzogabbros and monzodiorites suggest that this extension-related magmatism followed collision between the Tauride–Anatolide platform and an oceanic island arc. The authors call on an enriched mantle source for the mafic rocks of the suite, and the interaction of this source with crustally-derived silicic melts to form the felsic intrusions. The paper dealing with the youngest rocks is presented by Christiansen et al. (2007-this issue) who compare Cenozoic topaz rhyolites of the western USA with Proterozoic rapakivi granites. These rhyolites, which range in age from 50 to 0.06 Ma, share many mineralogical and geochemical characteristics with older A-type granite complexes. The topaz rhyolites appear to have formed by small degrees of partial melting of continental crust containing a significant juvenile mantle component. Magmatism is related to regional extension, lithospheric thinning, and high heat flow. The authors suggest that the origin of the Cenozoic topaz rhyolites may be relevant to studies of their more ancient intrusive counterparts.

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