Lithos 153 (2012) 142–153

Contents lists available at SciVerse ScienceDirect

Lithos

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

Peraluminous I-type granites

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ARTICLE INFO

Article history:
Received 9 November 2011
Accepted 10 July 2012
Available online 25 August 2012

Keywords:
Granite
I-type
Peraluminous
Amphibole
Partial melting
Restite

ABSTRACT

S-type granites always contain more Al than the amounts of Na, Ca and K in the rock required to form feldspars, primarily owing to their derivation from source components that had previously been weathered. Those rocks are therefore always saturated in Al, or peraluminous. Many I-type granites are also peraluminous, despite I-type source rocks typically not being saturated in Al. It has previously been suggested that this may result from the fractional crystallisation of amphibole. However, data from compositionally zoned high-temperature plutons in the Lachlan Fold Belt show that it is difficult to generate large quantities of peraluminous melt by removal of amphibole.

Most of the I-type granites (~95%) in the Lachlan Fold Belt formed at lower temperatures and almost half of those rocks for which bulk chemical compositions are available are peraluminous. Among these granites there are 98 separate suites for which there are chemical data for two or more samples, with 47 suites that include both metaluminous more mafic and peraluminous more felsic compositions. The origin of those peraluminous compositions is fundamental to any understanding of I-type granite petrogenesis in this region. Compositional variations caused by the assimilation or by partial melting of supracrustal rocks are very small as the isotopic variations within these rocks are dominantly between different suites, not within suites. The partial melting of more mafic source rocks, rather than the fractional crystallisation of more mafic magmas, is favoured for the origin of these rocks.

Partial melting is the most likely process involved in the petrogenesis of felsic granites where broadly granodioritic–monzogranitic batholiths are associated with lesser amounts of tonalite and very minor amounts of mafic rock. Experimental studies have shown that the melts generated by the partial melting of basaltic to andesitic rocks under crustal conditions are mostly peraluminous. During the dehydrational melting of I-type granite source rocks at pressures below the garnet stability field, biotite and amphibole melt incongruently to yield pyroxenes. The excess Al is incorporated into the felsic liquid, resulting in the generation of peraluminous melts. In this instance, the excess Al in felsic I-type granites is a function of the melting process, and unrelated to the bulk composition of the source. The observed gradation from peraluminous felsic granites to metaluminous compositions in less felsic rocks in largely isotopically closed systems could happen in two ways. At higher temperatures of partial melting, Ca and other components of clinopyroxene could dissolve in the melt, with the melt eventually becoming metaluminous. Alternatively, minerals residual from partial melting, dominantly pyroxenes and plagioclase, could be incorporated in suspension in the melt, so that the resulting bulk magma is metaluminous. Examples of these two extremes, and of intermediate cases, are well developed among the granites of southeastern Australia.

1. Introduction

The granites of southeastern Australia (Fig. 1) can be assigned to two dominant groups, I- and S-type (Chappell and White, 1974), which have distinctive chemical and mineralogical features that indicate derivation from igneous (or infracrustal) and sedimentary (or supracrustal) source rocks, respectively (Chappell, 1984). One important feature of S-type granites is that they always contain more Al than is required to form feldspar, given the Na, K and Ca contents of the rock, and are therefore peraluminous. The excess Al is hosted in Al-rich biotite, generally accompanied by more Al-rich minerals such as cordierite or muscovite. In S-type granite suites the compositions generally become less peraluminous as the compositions become more felsic (e.g. Chappell et al., 1987).

In contrast, the least felsic I-type granites are metaluminous and always contain amphibole. However, many I-type granites, particularly the more felsic ones, are weakly peraluminous. Given that all of these I-type granites are thought to have been derived from metaluminous source rocks the question arises as to how those peraluminous granites were derived from such materials.

We develop the argument that the felsic granites in I-type suites, and also individual peraluminous felsic I-type plutons not known to

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0024-4937/$ – see front matter.
http://dx.doi.org/10.1016/j.lithos.2012.07.008

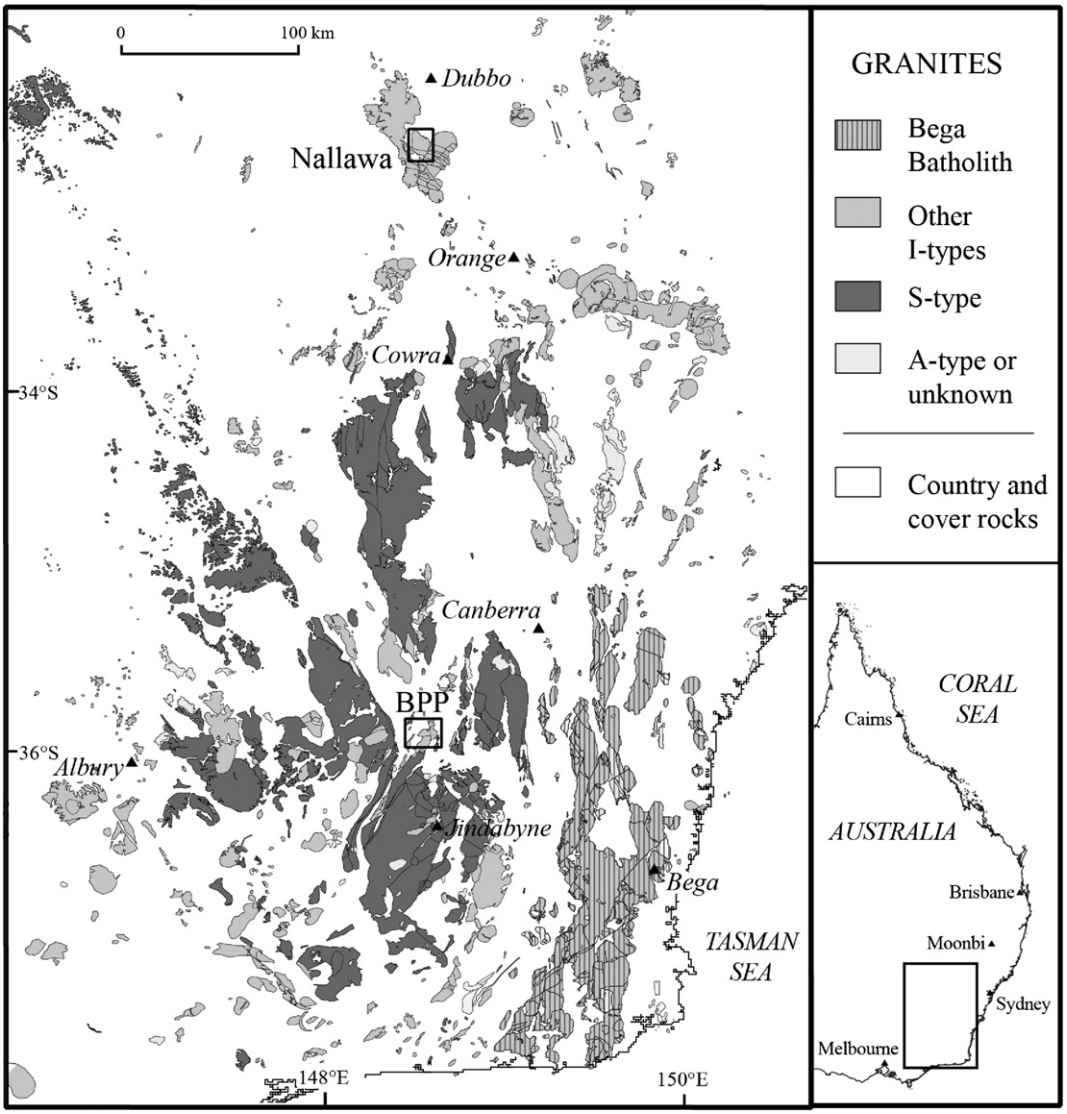

Fig. 1. Map of part of southeastern Australia showing the location of some granites of the Lachlan Fold Belt, Locations of granite complexes considered in this study, the Nallawa Complex and Boggy Plain pluton (BPP), are shown. The position of the granites of the Moonbi Suite in the New England Orogen, is indicated in the smaller-scale figure.

be associated with less felsic granites, probably resulted primarily from partial melting of metaluminous source rocks at close to minimum-melt temperatures. The less felsic and metaluminous parts of these suites acquired those characteristics from their source rocks either in solution (partial melting to higher temperatures) or suspension (entrainment of restite), or by a combination of those two processes.

2. Aluminium saturation in igneous rocks

If the amount of CaO is first corrected for the presence of apatite, then a rock in which the molar proportions $(Na_2O + K_2O + CaO) = Al_2O_3$, is said to be saturated in Al, containing just sufficient Al for all of the Na, K and Ca to be incorporated in feldspars. The ratio $Al_2O_3/(Na_2O + K_2O + CaO)$ has been termed the Aluminium Saturation Index (*ASI*) by Zen (1986), often referred to as A/CNK (Clarke, 1981). The terms peraluminous and metaluminous (or subaluminous) are used for rocks in which $ASI > 1$ and $ASI < 1$, respectively (Shand, 1927). For peraluminous rocks, the CIPW normative minerals include corundum (*C*) and for metaluminous rocks, the norm contains diopside (*di*).

These definitions are entirely descriptive. They are based on chemical compositions, and do not necessarily say anything about the minerals present in the rock or its petrogenesis. The presence of certain minerals may indicate, and in some cases show, whether a rock is metaluminous or peraluminous, but it is the bulk chemical composition that is definitive. Use of fine detail in *ASI* values requires chemical analyses of very high quality, and rocks free of hydrothermal alteration.

2.1. Metaluminous–peraluminous granites and the I-type–S-type subdivision

In proposing the I- and S-type subdivision, Chappell and White (1974) recognised that the boundary between metaluminous and peraluminous granites does not correspond exactly to corresponding compositional features in their source rocks, and that many granites that were derived from metaluminous igneous source rocks are peraluminous. Those authors suggested a boundary between the I- and S-types at $ASI = 1.1$, or 1% normative *C*. However, given that rocks with a common petrogenetic history cross the Al-saturation boundary, it would seem useful to classify all granites of a particular rock suite together, across that boundary. This is what has been done in southeastern Australia and is central to the "I–S" subdivision. This classification scheme differs from one based entirely on Al-saturation which is liable to separate granites that are cogenetic and even comagmatic (*cf.* Frost et al., 2001). Exemplifying a common but not ubiquitous misperception,