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Editorial: Granite Petrogenesis and Geodynamics

J. Gregory Shellnutt[1], Steven W. Denyszyn[2] and Kwan-Nang Pang[3]*

[1]Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan, [2]School of Earth and Environment, University of Western Australia, Perth, WA, Australia, [3]Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan

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Editorial on the Research Topic

Granite Petrogenesis and Geodynamics

Granite, *sensu stricto*, is a coarse grained and granular igneous rock comprising 20–60 vol% quartz and 35–90 vol% total feldspar whereas a granitic rock, *sensu lato*, is texturally similar but has variable proportions of quartz, alkali feldspar, and plagioclase (Streckeisen, 1976). Granites have interested geologists for centuries because of their ubiquity on continents, association with ore deposits, and their use in the construction of ancient buildings. The origin and formation of granitic rocks was at the forefront of geological debate before and after the pioneering work of James Hutton and Charles Lyell, and played an important role in the development of continental drift theory (Wegener, 1924; Du Toit, 1937; Holmes, 1945; Bowen, 1948). Early concepts of granite formation include crystallization from a fluid, precipitation from a primordial ocean, or transformation of pre-existing rocks into granite (i.e., granitization) by metasomatism (Marmo, 1967). Furthermore, if granites were indeed derived from a fluid (e.g., a magma), then a question arises as to how such enormous space can be created in the crust to accommodate their emplacement (Marmo, 1967). It was not until the mid-20th century that the debate regarding the fundamental origin of granitic magma was resolved. The recognition that granite crystallizes from magma refuted many opposing theories including the granitization theory (Tuttle and Bowen, 1958).

Granitic magmas form by a variety of processes including melting of crustal lithologies at various depths in the presence or absence of fluids, fractional crystallization of mafic magmas, and mixing between magmas derived from the crust and from the mantle (Pitcher, 1997; Barbarin, 1999; Brown, 2013; Janoušek et al., 2020). Thus, studying the origins of granite (*sensu lato*) is a challenging proposition because of the complex relationship between the effects of magma crystallization superimposed on the varied source components that might have contributed to initial melt composition. Most granitic magmas are emplaced as plutonic to hypabyssal intrusions of various sizes at subduction zone settings and during orogenesis, whereas comparatively minor volumes are emplaced within stable cratons, sites of active continental rifting, and within oceanic crust (Pitcher, 1997; Barbarin, 1999; Bonin, 2007). Thus, the formation of granitic rocks is crucial for understanding the creation and recycling of continental crust (Brown, 2013).

With the advent of modern geochemical methods, it was recognized that there is a relationship between the composition of granite and tectonic setting (Pearce et al., 1984; Maniar and Piccoli, 1989; Bonin, 1990; Barbarin, 1999). Consequently, nomenclature of granitic rocks rapidly expanded and no fewer than 30 classification schemes have been developed (e.g., Streckeisen, 1976; Pearce et al., 1984; Maniar and Piccoli, 1989; Barbarin, 1999; Frost et al., 2001). Classification of granites is based on a number of factors including mineralogy, geology, and geochemistry, leading to the creation of the widely used but petrogenetically linked 'letter based' (e.g., I-type, M-type, S-type, A-type) classification scheme (Chappell and White, 1974; Loiselle and Wones, 1979; White, 1979). Non-genetic classification schemes based on major element geochemistry are also used, and have the

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****Correspondence:***
J. Gregory Shellnutt
jgshelln@ntnu.edu.tw

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advantage of not being interpretive (Frost et al., 2001; Frost and Frost, 2011). The scientific benefits of granite classification are clear, but the debate around their application continues and new methods of classification are frequently proposed (c.f, Glazner et al., 2019; Bonin et al., 2020). Nevertheless, the discovery that there is an association between the type of granite and tectonic setting presents an opportunity to extrapolate the possible geodynamic processes that operated in the past, even in regions where a complete geological record is not preserved.

This Special Topic of Frontiers in Earth Science comprises papers that discuss the formation of granitic rocks and their relationship to the geodynamic evolution of continental crust. To address the outstanding issues regarding the formation of granitic rocks, the authors apply modern analytical techniques in geochronology, elemental geochemistry, and isotope geochemistry, coupled with geological and structural observations to quantify and constrain the tectonomagmatic processes associated with granite petrogenesis. The manuscripts present a variety of approaches that address the role of hydrothermal and hydromagmatic fluids in the formation of mineral deposits and magma emplacement, magma differentiation, and the importance of polygenetic (i.e., crust/mantle) sources in the formation of granitic melts. Moreover, the manuscripts provide critical insight on the importance of the geodynamic setting in creating juvenile crust and recycling of older continental crust. The manuscripts in this volume cover a broad range of subjects related to crustal evolution, formation of granite-hosted ore deposits, magma genesis, enclave textural variation, and structural controls during emplacement, and propose new views on the lithotectonic development of Eurasia, Western North America, and Africa. Below is a summary of the contents of this Special Topic.

Through field observations, petrography, and geochemistry Ardill et al. focus on formation mechanisms in the Tuolumne Intrusive Complex (TIC). Small scale (1 mm–1 m), local scale (1 m–1 km), and regional scale (10s of km) observations indicate there is evidence for crystal flow-sorting, magmatic faulting and folding, fluidization within a hydrogranular medium, and magma pulse-induced convection. The structural patterns are consistent with a magma mixing region of ~150 km^2 and that melt-present reservoirs were derived from multiple magma pulses.

Pang et al. document zircon U-Pb age, mineral compositional, elemental and Sr-Nd isotopic data for the Late Oligocene Takht batholith, Iran, which is part of the Arabia-Eurasia collision zone. Results show that the batholith is a Cordilleran-type batholith formed at ~25 Ma beneath a continental or transitional arc of normal crustal thickness. As no geochemical evidence is found for collision-induced crustal thickening, the implication is that Arabia and Eurasia might have collided in a diachronous manner.

Ji et al. explore the early evolution of the Himalayan Orogenic Belt and delineate an expanded Eocene magmatic belt that predates most Himalayan igneous activity. They accomplish this through LA-ICPMS and SIMS U-Pb geochronology of zircons and titanites, and this data is combined with major-, trace-, and radiogenic-element geochemistry to elucidate the petrogenesis of these granodiorites.

The Ladakh Batholith is one of the largest intrusions of the Alpine-Himalayan orogenic belt. It is composed of silicic and intermediate rocks and hosts a variety of mafic and microgranular enclaves. Kumar provides detailed field observations on the type, orientation, and mineralogy, of enclaves of the Ladakh Batholith. The diversity of enclaves suggests that the Ladakh Batholith developed over time via multi-stage interactions of mafic to hybrid magmas coeval with silicic magma pulses.

Asokan et al.'s contribution presents a close examination of the Kanker Granites, a suite of felsic intrusions in the Bastar Craton of central India, in the context of crustal growth and evolution. Emplaced at the geodynamically active Archean-Proterozoic transition time, the compositional variability of these granitic rocks preserves a complex history of melt and heat sources, and provides a geological record of a tectonically significant period of Earth history.

Shellnutt et al. present new zircon geochronology, mineral chemistry, whole rock and isotope geochemistry of spessartine-bearing biotite leucogranite from Macau Special Administrative Region, SE China. The leucogranites are Late Jurassic in age and compositionally similar to post-collisional S-type granite. The rocks are considered to be formed during decompressional melting associated with a period of crustal relaxation that occurred during the transition from low angle subduction to high angle subduction of the Paleo-Pacific plate.

Huang and Yeh present field mapping results, detailed structural data and petrographic analysis for granitic rocks in Kinmen Island, which occurs along the southeastern edge of the South China Block. By integrating the structural data with published radiometric ages and strain patterns, it is proposed that rollback of the subducting Paleo-Pacific plate changed from northeastward to southeastward at ~114–107 Ma.

Suga and Yeh examine published elemental data for Cretaceous granitic rocks from Kyushu, SW Japan to investigate compositional secular variations and evaluate the potential role played by subduction-related mélange rocks. Secular variations in aluminum saturation index and Sr-Nd isotopes during the Albian are taken to indicate a change of geodynamic setting from subduction-accretion to continental arc. Also, the Albian granitic rocks are consistent with derivation from mélange rocks as demonstrated by Rhyolite-MELTS modeling.

Dostal et al. investigate the Tukhum granitic pluton, a member of the Early Jurassic composite Khentei batholith, North-Central Mongolia. The Tukhum pluton is shallow-seated and comprises two distinct biotite-bearing post-collisional granites. The granites are considered to be derived from Neoproterozoic crustal sources but, the younger of the two intrusions was derived from a biotite/phlogopite-bearing source that was enriched in tungsten and tin. They suggest melting was related to the passage of a mantle plume across Central Asia.

Büttner et al. present the petrogenesis of Mesoproterozoic granites from the Namaqua Belt, South Africa. A petrographic, geochemical, and isotopic study of these granites tells a complex story of mantle enrichment, crustal contamination, and metasomatism during their formation, and identifies a prevailing regional tectonic setting that drove their emplacement.

Kwékam et al. explore the origin of the Late Ediacaran Batié granitic massif in western Cameroon. The massif is composed of biotite granite and amphibole granite that were emplaced during and after the final collisional stages of the Central African Orogenic Belt. It is thought that the granites were likely derived by partial melting of Paleoproterozoic lower crust and that magma was subsequently mixed with felsic melts derived from the upper continental crust.

Pham et al. examine the biotite chemistry from a series of granitic plutons from the Guéra Massif (South-Central Chad) that were emplaced at: 595–590 Ma, ~570 Ma, and ~560 Ma. The older granites (595–590 Ma) are compositionally similar to collisional granites whereas the younger granites (≤570 Ma) are compositionally similar to post-collisional granites. The magmatic conditions display a broad secular change in their temperatures and pressures but their redox conditions appear to be spatially controlled.

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