Summary of Proposed Research Program for Doctor of Philosophy

Title

Granitoid Evolution and Tectonic History of the Central Asian Orogenic Belt in Northeast China

Abstract

This study will focus on the granites of Northeastern China, which form part of the Central Asia Fold Belt extending through East-Central Asia from Kazakhstan to Siberia and emplaced from 250 to 125 million years ago. The isotopic signature of granites analysed from this region suggests that they were formed from significant amounts of mantle material, which has a quite different bulk chemical composition compared with average continental crust. It appears that this period of magmatism was a time of extensive chemical evolution of the planet, with the production of new continental crust from the deeper mantle. Furthermore, the timing of this magmatism is relatively young compared with the 4500 million year age of the Earth, and may provide evidence contrary to the prevailing view that most continental crust formed from the mantle in the first half of Earth history.

Geological fieldwork in China will be combined with laboratory analysis in Australia. Two 3-month field seasons are planned for geological mapping and sampling of the Northeast Chinese granites. In addition, an extra month at the end of each field season whilst samples are in transit to Australia will be spent at Jilin University, Changchun collecting and compiling Chinese geological maps and published data from the literature.

In Australia, all granite samples will be accurately described by quantifying mineral and chemical contents to enable groups related by a common source and/or tectonic environment to be identified. Sophisticated isotopic analyses of selected samples from these groups will provide both ages and an estimation of the proportion of mantle material present. These results and interpretations will be combined with Chinese data to produce a regional geological map showing the distribution of granite groups in Northeast China. Combined results from field observations, laboratory analyses and the spatial distribution of granites will enable the tectonic history of Northeast China to be better described and constrained.

Objectives

The overall objective is an investigation of the southern margin of the Central Asian Orogenic Belt (CAOB) in Northeast China in order to determine its evolution. This will be achieved by:

1: Production of a geological map of the Northeast China granitoids, showing the spatial and temporal distribution of recognized suites – distinguished on the basis of petrography, geochemistry and particularly geochronology.

2: Interpretation of the petrogenesis and tectonic environments of the granitoid suites, including estimates of the proportion of juvenile material to older Precambrian crust.

3: Use the Paleozoic to Mesozoic magmatic record to reconstruct the tectonic history of the region – particularly the timing and mechanisms of microcontinent collision and suturing, and the relative importance of post-orogenic and anorogenic magmatism.

Background

Continental crust is a unique feature of the Earth, although comprising only a very small proportion of the planet's total mass it is of central importance in Earth history. Not only has it provided the environment for the development of terrestrial life, but it is also the most accessible part of the Earth available for direct study of the planet's chemical differentiation.

There is, however, considerable debate on the rate of continental crust formation with two major hypotheses dominant. The first proposes that the present mass of crust was formed very early in Earth history and has subsequently remained in a steady-state, with any newly formed crust being balanced by older crust reabsorbed into the mantle (Armstrong, 1991). The second view holds that the volume of crust has increased though time, with addition of new crust always greater than destruction. Whether this increase is seen as gradual or episodic it is generally regarded as mostly having occurred during the Precambrian with Phanerozoic crustal growth being insignificant (Taylor and McLennan, 1985). However, recent work from East-Central Asia has suggested that this may not necessarily be the case (Chen and Jahn, in review; Han et al., 1997; Sengor et al., 1993; Wu et al., 2000).

International Geological Correlation Program (IGCP) Project 420 ("Continental Growth in the Phanerozoic: Evidence from Central Asia") has focused geological attention on the CAOB, which extends from Siberia and Northern China in the east, through Mongolia and Xinjiang to Kazakhstan in the west. There is evidence that this was an area of substantial crustal growth during the Phanerozoic, which is contrary to the commonly held view that major growth of continental crust was completed during the Precambrian. Evidence obtained from the region in the past few years indicates generation of huge volumes of late Paleozoic - Mesozoic granitic magma on a scale similar to that of the late Archaean. Preliminary geochemical work has revealed the juvenile nature of many of these granites; their isotopic signatures interpreted as containing an extensive mantle component - and as such this orogenic belt may represent the most voluminous block of young continental crust in the world (Jahn et al., 2000).

The extension of the CAOB in NE China (which includes the Chinese provinces of Jilin, Heilongjiang and eastern Inner Mongolia) contains over 500 late Paleozoic to Mesozoic granitoid plutons that intrude three microcontinental blocks (Jiamusi, Songliao and Xing'an). Recent collaborative investigation of this segment of the CAOB undertaken by scientists at Curtin (Prof. Simon Wilde, the Australian corresponding member of IGCP 420), Jilin University and Université de Rennes has identified features of the Phanerozoic granitoids which include: (1) Granitoids are either A-type or highly fractionated I-types, with no S-types present (Wu et al., 2000) (2) Within the A-type granitoids, two subgroups are identified on the basis of mineralogy and geochemistry; aluminous and peralkaline A-types (Wu et al., in review) (3) Preliminary U-Pb dating of zircons indicates 5 discrete intrusive episodes between the late Permian and mid-Cretaceous (Wilde and Wu, 2001) (4) Some intrusive episodes show consistently younger (by up to 20 Ma) Rb-Sr ages (Wilde and Wu, 2001) (5) While most studied granitoids have a significant juvenile component, Nd isotopic evidence indicates that an area of identified Precambrian crust (namely the Mashan Complex in the Jiamusi Block (Wilde et al., 2000)) has been locally involved in some granitoid generation (Wu et al., 2000).

Outstanding questions identified by the preliminary work and which are relevant to this research project include: (1) What is the regional distribution of the various granitoid groups identified to date? (2) What is the relationship between the metaluminous and peralkaline A-types? (3) Can the evidence for an older crustal contribution in granitoids of the Jiamusi Block be recognized in the other microcontinent blocks?

Significance

This study will provide an improved chronology for the magmatic and tectonic development of NE China, using a technique (U-Pb zircon dating) that has not been extensively applied within the region. Integrated petrographical, geochemical and Nd isotopic data will lead to improved understanding of petrogenetic and tectonic processes contributing to Phanerozoic continental crust formation.

Research Method

Objective 1

Recognition of granitoid suites requires the detailed description of individual plutons with the main objective being the recognition of distinctive criteria by which plutons can be grouped into suites – with the implication that each reflects a single magmatic event.

Field Geology

In the first year, geological mapping and sampling from all granitoid types will be concentrated in central NE China in conjunction with regional mapping by the Chinese Geological Survey. The second year's fieldwork will aim to extend the sampling area in a regional traverse line across the full exposed width of the CAOB. Additional samples in the second year may include lithologies suspected to be granitoid source rocks. All rock samples will be shipped to Perth (30-40 days in transit) for laboratory preparation and analysis. Over the two field seasons, up to 100 rock samples will be collected.

Petrography

All rocks will be point-counted (at least three slides required for each sample) for the determination of mineral content that is essential for granitoid classification. Other features to be described are the texture of the rock as seen in thin-section, particularly any exsolution and/or replacement textures of feldspars, which may reflect the cooling history of the pluton. The chemical composition of any mafic accessory minerals present can provide criteria for recognizing subtle but significant differences between granitoids (Barbarin, 1990; Bonin, 1990; Wu et al., in review). Thin-section work will recognize the various accessory species present with the chemical composition of representative examples determined by electron microprobe.

Geochemistry

Whole-rock geochemistry of granitoids provides a powerful discriminating tool (Eby, 1992; Maniar and Piccoli, 1989; Whalen et al., 1987) and all samples will be analysed for both major and trace elements. Samples will be prepared by crushing with Department facilities, with XRF major and trace element analysis at the University of Western Australia, and additional Neutron Activation Analysis of trace and REE at Becquerel Laboratories, Sydney.

U-Pb Geochronology
U-Pb dating of zircon crystals from granitoids provides the best estimate of crystallization age. Representative samples of provisionally recognized suites (from field, petrological and geochemical data) will be analysed. Samples will be crushed using the Department facilities, with zircons extracted by Diatech in Perth. U-Pb isotope analyses of zircons will be determined using the Ion Microprobe (SHRIMP II) at Curtin University. A conservative estimate of 14 working days (during two years) on the SHRIMP II averaging 1.5 samples per day should produce at least 20 new U-Pb zircon ages.

Nd-Sr isotope systematics
Selected granitoids from each recognized suite will be analysed along with samples of "basement" lithologies suspected to be source components. Sample preparation can be completed using Department rock crushing facilities and the isotope geochemistry laboratory with analyses by mass spectrometer in the Physics Department. Twelve Sm-Nd samples can usually be analysed in a month. Strontium isotopic work will also be undertaken, as appropriate.

Results from all the above methods will, eventually, be considered together and the granitoid plutons grouped into suites, the plutons within each suite showing mineralogical, geochemical, isotopic and chronological features that infer a single magmatic event. Using GIS software results will be combined with Chinese geological maps and published data to extend the spatial distribution of recognized suites and produce a regional map of the granitoid geology.

Objective 2
Interpretation of the petrogenesis and tectonic environments of recognized suites will be achieved by comparing each suite's characteristics with features described from experimental and theoretical models from the literature. The proportion of juvenile material involved in granitoid petrogenesis will be determined using Nd-Sr isotopic data, including Nd model ages and ε_{Nd} values calculated from Sm-Nd isotope values, with the results for the analysed plutons extended to their respective suites. On a regional scale the total volume of juvenile material present in the upper crust can be quantified from the regional map.

Objective 3
The results from objectives 1 and 2, particularly U-Pb geochronology, will provide important constraints on the tectonic history of the CAOB in Northeast China. For example, the timing of tectonic events can be recognized by the age of related granitoid suites. Alternatively one suite may be distributed over two or more microcontinents – suggesting that accretion had been completed prior to magmatism.

Ethical Issues

This research program does not require testing to be done on humans or animals and does not involve potentially dangerous equipment of any kind.

Facilities and Resources

Fieldwork: Accommodation within China and field logistics will be provided by Jilin University, Changchun through its cooperative agreement with Curtin University. Fieldwork will be in co-operation with geologists from the Geological Survey of China and Jilin University.

Sample preparation: Department of Applied Geology rock crushing and milling facilities.

Rock thin-sections: Department of Applied Geology facilities.

Petrography: Optical microscope with attached point-counter, optical microscope with camera, Electron microprobe (at UWA Centre for Microscopy and Microanalysis).

Geochemistry: Rock crushing and milling facilities only required, as all analyses will be undertaken commercially.

Geochronology: Rock crushing facilities, optical (transmitted and reflected light) microscope with camera for photographing sample grains. SHRIMP II ion microprobe.

Nd-Sr isotope systematics: Sample preparation using Department of Applied Geology rock crushing and isotope geochemistry laboratory. Analyses using VG354 Mass Spectrometer located in the Physics Department.

Data analysis: PC computer including software for geochemical analysis, U-Pb isotope data reduction and spatial analysis (Mapinfo). Access to Chinese geological maps and digitizer.

GIS software and large format printing facilities for map production.

Data Storage

The data storage provisions are outlined in the attached Research Data Management Plan and meet the Curtin University Research Data and Primary Materials Policy.

Time Line

Year 1:

February– June: Perth

Literature review, preparing research proposal.
April 10-12 successfully completed SHRIMP II course.
June 11-14 Scanning Electron Microscopy Course (UWA) prerequisite for:
June 18-20 Electron Microprobe Analysis Course (UWA)

June 25 – mid-October: China

June 25 leave Perth for fieldwork in China.
Late June – early September: Fieldwork (mapping and rock sampling of granitoids) in Northeast China based in Changchun.
(August 6 – 16 IGCP 420 Third Workshop and Field Excursion, Novosibirsk, Russia)

Early September: packing of rock samples and shipping to Perth. Acquisition of Chinese geological maps (digitized or scanned if possible) and published petrography and geochemical data.

mid-October: return to Perth; rock samples arrive in Perth from China.

mid-October– January: Perth

Sample preparation (rock crushing) for both geochemistry and zircon extraction, production of thin-sections, modal analysis and petrographical description of thin-sections, XRF and NAA geochemical analyses, zircon extraction by Diatech.

Year 2:

February– May: Perth

Provisional grouping of rocks into suites based on petrography and geochemical results. Electron microprobe analysis of individual minerals selected from provisional suites on the basis of earlier optical work, for recognizing subgroups within the A-type granitoids. Start U-Pb SHRIMP analyses of zirons. At the end of this period a number of suites of granitoids will be defined, together with a working hypothesis as to their origin and tectonic setting. This will provide the basis for planning the focus of Year 2 fieldwork.

June – September: China

June – August: Field work in NE China: Field mapping and sampling of granitoids will extend the area of the first year's sampling and also test the working hypothesis developed. If necessary, limited sampling of other lithologies (such as associated basic complexes, or older "basement") suspected to be possible granitoid sources (from either field relations and/or the working hypothesis) may be undertaken.

September: Rock samples in transit from China to Australia. Further acquisition and digitization of Chinese geological maps.

October– January: Perth

Completion of petrographical descriptions and geochemical analyses for all granitoid samples. Continued U-Pb SHRIMP analyses of zircons and start Sm-Nd isotopic work on both selected granitoids and possible source rocks.

Year 3:

February – June: Perth

Petrographical and geochemical data compilation, digital integration with Chinese maps and data from across the region to produce a regional geological map of the granitoid suite distribution. Continuing U-Pb SHRIMP geochronology and Sm-Nd isotope work if required.

July: China

It may be necessary to make one final field trip of two or three weeks duration to clarify any significant problems that have arisen and to discuss results personally with collaborators from Jilin University and the Geological Survey of China.

August– January: Perth

Final compilation of results, interpretations and completion of the thesis.

Year 4:

February:

Submission of thesis.

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