

AGE OF THE RIBEIRÃO DA FOLHA OPHIOLITE, ARAÇUAÍ OROGEN: THE U-Pb ZIRCON (LA-ICPMS) DATING OF A PLAGIOGRANITE

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RESUMO

O Orógeno Araçuaí, de idade neoproterozóica, se estende da margem sudeste do Cráton do São Francisco ao Oceano Atlântico, entre os paralelos 15° e 21° S. O estágio rifte da bacia precursora do Orógeno Araçuaí é balizado pela idade U-Pb SHRIMP de ca. 875 Ma dada por granitos anorogênicos. A evolução orogênica é subdividida nos estágios pré-colisional (ca. 630-585 Ma), sin-colisional (ca. 585-560 Ma), tardi-colisional (ca. 560-530 Ma) e pós-colisional (ca. 530-490 Ma). Remanescentes de rochas magmáticas de assoalho oceânico, localizados no setor central deste orógeno, têm sido descritos na literatura geológica desde 1990. O mais completo destes registros oceânicos é o ofiolito de Ribeirão da Folha, situado nos arredores da vila homônima, no município de Minas Novas, MG. O ofiolito de Ribeirão da Folha é uma associação litológica tectonicamente desmembrada, composta por fatias de rochas meta-ultramáficas e metamáficas que foram embutidas por empurrões em pacotes da Formação Ribeirão da Folha (unidade distal do Grupo Macaúbas). Esta formação, na área enfocada, consiste de micaxistos e cianita-grafita xistos (pelitos pelágicos), com intercalações de metacherts sulfetados, diopsiditos sulfetados, corpos de sulfetos maciços, formações ferríferas bandadas dos tipos óxido, sulfeto e silicato, e orto-anfibolitos finos (metabasaltos), metamorfisados nas zonas da cianita da fácies anfibolito médio. Dados geotermobarométricos dos micaxistos peraluminosos revelaram condições metamórficas em torno de 550° C a 5,5 kbar. As assinaturas litoquímicas das rochas metamáficas e meta-ultramáficas revelam afinidade ofiolítica e origem em assoalho oceânico. Os dados isotópicos Sm-Nd destas rochas mostram valores positivos de epsilon Nd (+3 a +7), e as idades modelo e isocrônica sugerem desenvolvimento de litosfera oceânica durante o Neoproterozóico. Todas as tentativas anteriores de recuperação de zircão a partir de volumosas amostras das rochas metamáficas foram infrutíferas. Contudo, corpos leucocráticos semelhantes a plagiogranito foram reconhecidos poucos anos atrás e se tornaram um dos principais alvos da tese de doutorado da primeira autora. Estes corpos ocorrem sob a forma de veios irregulares com dimensões milimétricas a centimétricas (até 50 cm), e são encaixados por orto-anfibolito bandado de granulação média a grossa (metadolerito a metagabro). Os corpos leucocráticos consistem de metaplagiogranito foliado, composto essencialmente por plagioclásio cálcico com bordas albiticas, quartzo, hornblenda e epidoto, com titanita, sulfeto, apatita e zircão como os principais minerais acessórios. Os cristais de zircão da amostra de plagiogranito são euétricos e muito límpidos, e mostram morfologia prismática alongada (3:1), sugerindo origem magmática. Análises U-Pb por LA-ICPMS (Laser Ablation Inductively Coupled Mass Spectrometry) foram realizadas em dezoito cristais de zircão e mostram resultados concordantes, indicando idade de cristalização magmática de 660 ± 29 Ma. Esta idade baliza a época de geração de crosta oceânica na bacia precursora do Orógeno Araçuaí. O espalhamento de algumas das análises ao longo da curva concórdia sugere perda de Pb devido ao metamorfismo de fácies anfibolito em ca. 580 Ma. A idade de ca. 660 Ma plagiogranito precede a maior idade U-Pb (ca. 630 Ma) de tonalitos deformados do arco magmático pré-colisional, bem como a idade U-Pb (ca. 582 Ma) dos granitos sin-colisionais mais antigos.

Keywords: plagiogranite, oceanic crust, ophiolite, Ribeirão da Folha, Araçuaí Orogen

INTRODUCTION

The Neoproterozoic Araçuaí Orogen extends from the eastern margin of the São Francisco Craton to the Atlantic Ocean, between the 15° and 21° S parallels, in southeastern Brazil (Pedrosa-Soares *et al.* 2001, 2007, 2008). This paper focuses on the Ribeirão da Folha area (Minas Novas region, Minas Gerais State),

located in the western-central sector of the Araçuaí Orogen (Fig. 1).

The discovery of Neoproterozoic oceanic remnants in the Ribeirão da Folha area was published in the international literature by the beginning of the 1990th decade (Pedrosa-Soares *et al.* 1992). Since then several

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studies have been carried out on metamagmatic and metasedimentary rocks from this and other ophiolite slivers of the Araçuaí Orogen (*e.g.*, Pedrosa-Soares *et al.* 1998, 2001, Aracema *et al.* 2000, Suita *et al.* 2004, Queiroga *et al.* 2006). Although a Neoproterozoic age was suggested by Sm-Nd isotopic analysis on metamafic and meta-ultramafic rocks, all attempts to recover zircon crystals from large amounts of metamafic rock samples have been unsuccessful. However, leucocratic bodies resembling plagiogranite were recognized a few years ago (Suita *et al.* 2004) and became one of the main study targets of the first author's doctorate thesis.

This paper presents a preliminary characterization of the plagiogranite bodies, and summarizes the U-Pb dating carried out by using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) on zircon crystals recovered from them.

GEOLOGICAL SETTING

The geotectonic setting, stratigraphy and tectonic evolution of the Araçuaí Orogen are synthesized in Pedrosa-Soares *et al.* (2001, 2007, 2008) and Alkmim *et al.* (2006, 2007). This orogen shows lithological records of all evolutionary stages, from the precursor basin to the post-collisional plutonism. The early rift stage of the precursor basin is constrained by the *ca.* 906 Ma mafic dykes and 875 Ma anorogenic granites. U-Pb dates of detrital zircon grains suggest a maximum sedimentation age of *ca.* 900 Ma for the continental rift-related units of the Macaúbas Group, and of *ca.* 864 Ma for sand-pelite deposits of the proximal passive margin. Distal passive margin and oceanic successions are represented by the Ribeirão da Folha Formation (distal unit of the Macaúbas Group) that mainly consists of sand-pelite turbidites, pelagic pelites and chemical-exhalative sediments. Metamafic and meta-ultramafic rocks of ophiolite affinity record the generation of oceanic lithosphere in the distal sector of the precursor basin. The orogenic evolution has been subdivided into the pre-collisional (*ca.* 630-585 Ma; formation of a calc-alkaline magmatic arc and related basins), syn-collisional (*ca.* 582-560 Ma; regional deformation and metamorphism, and generation of a huge amount of S-type granites), late collisional (*ca.* 560-530 Ma; S-type granites) and post-collisional (*ca.* 530-490 Ma; gravitational collapse of the orogen, and latest S-type and I-type plutonisms) stages.

THE RIBEIRÃO DA FOLHA OPHIOLITE

In spite of the intense tropical weathering and thick soil covers, metamafic and meta-ultramafic rocks, as well as sulfide-rich rocks can be clearly recognized in the Ribeirão da Folha area (Fig. 1). This ophiolite is a tectonic dismembered rock-assemblage composed of slices of meta-magmatic rocks thrust onto packages of the Ribeirão da Folha Formation. The main structures are shear zones and complex folding related to the

regional foliation of the Araçuaí Orogen.

The thickest ophiolite slice, named Córrego do Rubinho ultramafic body (Fig. 1), is mainly composed of tremolite schists and carbonate-tremolite-anthophyllite schists (Pedrosa-Soares *et al.* 1992). Some metamafic rocks are massive coarse-grained ortho-amphibolites interpreted as metamorphosed gabbros. They are associated with medium-grained banded ortho-amphibolites, with fine-grained borders, that resemble metamorphosed dolerite (and could represent strongly deformed sheeted dikes). The geochemical signatures of the metamafic and meta-ultramafic rocks indicate ophiolite affinity and ocean-floor origin. Sm-Nd isotopic data from both the metamafic and meta-ultramafic rocks yielded positive epsilon Nd values (+3 to +7). Their Sm-Nd whole-rock isochrons, as well as Sm-Nd T_{DM} model ages, suggested development of oceanic lithosphere in Neoproterozoic times (Pedrosa-Soares *et al.* 1992, 1998, 2001).

The Ribeirão da Folha Formation consists of micaschists and kyanite-graphite schists (pelagic pelites), with intercalations of sulfide-bearing metacherts and diopsideites, massive sulfide bodies, banded iron formations (oxide, silicate and sulfide types), and rare fine-grained ortho-amphibolites (basalts), metamorphosed in the kyanite zone of the intermediate pressure amphibolite facies (Fig. 1). Geothermobarometric data indicate metamorphic PT conditions around 550 °C and 5,5 kbar (Pedrosa-Soares *et al.* 1992, 1998, Queiroga *et al.* 2006).

THE PLAGIOGRANITE AND U-Pb AGE

Leucocratic bodies resembling plagiogranite were recognized a few years ago (Suita *et al.* 2004). These leucocratic bodies show irregular vein-like shapes, ranging in size from millimeters to 50 cm, and are hosted by medium- to coarse-grained ortho-amphibolites (Fig. 2).

The leucocratic veins consist of foliated meta-plagiogranite composed of plagioclase, quartz, amphibole and epidote, with titanite, chlorite, sulfide, apatite and zircon as the main accessory minerals. The plagioclase is generally anorthite (An_{90-95}) with albitic rims and its alteration produced very significant amounts of epidote. The amphibole is hornblende with tremolite cores. It can be partially altered to Mg-chlorite. Modal proportions of felsic minerals suggest quartz diorite to diorite composition, in agreement with modern and old plagiogranites (*e.g.*, Coleman & Peterman 1975, Aldiss 1981, Mukasa & Ludden 1987).

The zircon crystals recovered from a plagiogranite sample are euhedral and very clean, and show elongated prismatic (3:1) morphology, suggesting magmatic origin. U-Pb analyses using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) were carried out on eighteen zircon crystals which yielded concordant results, indicating a crystallization age of 660 ± 29 Ma (Fig. 3). This age constrains the timing

of oceanic crust generation in the precursor basin of the Araçuaí Orogen. The spread of analyses along the concordia curve suggests Pb loss due to the amphibolite facies metamorphism at ca. 580 Ma.

The ca. 660 Ma plagiogranite predates the oldest U-Pb ages (ca. 630 Ma) of tonalites of the pre-collisional magmatic arc of the Araçuaí Orogen, as well as the U-Pb

age (ca. 582 Ma) of the oldest syn-collisional granites (cf. Pedrosa-Soares et al. 2007, 2008).

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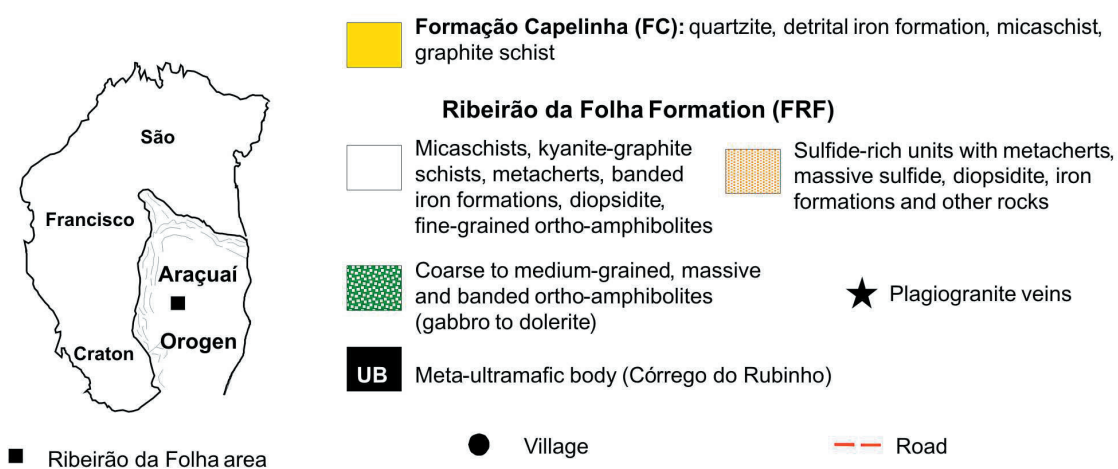
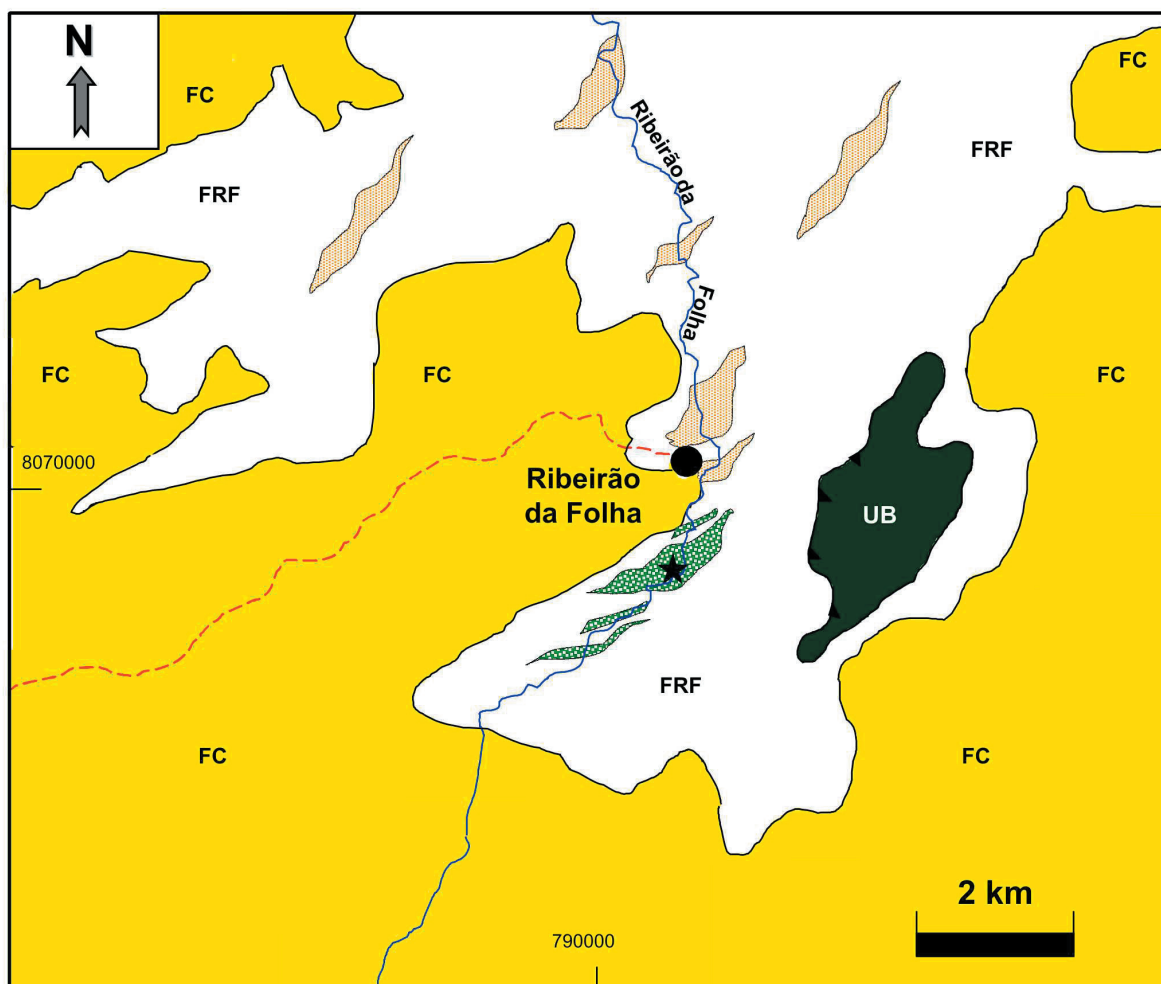


Figure 1. Sketch geological map of the Ribeirão da Folha area (modified from Pedrosa-Soares et al. 1992 and Queiroga et al. 2006).

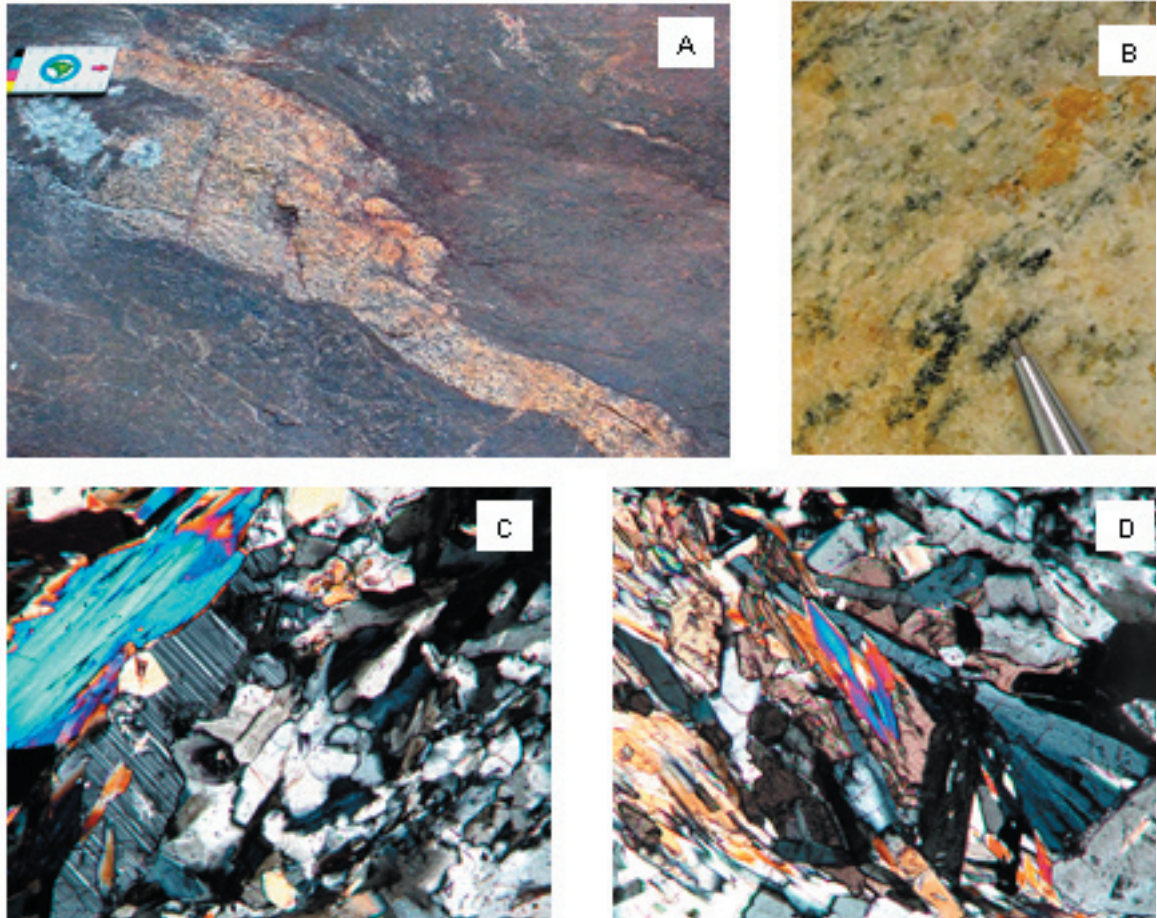


Figure 2. One of the biggest meta-plagiogranite veins (~ 50 cm long) found in the Ribeirão da Folha area is shown in photo A. The regional foliation is marked by oriented amphibole crystals and light minerals in the meta-plagiogranite vein (photo B). Photomicrographies C and D show mineralogical assemblages (plagioclase, amphibole, quartz, epidote, titanite) and textures of the meta-plagiogranites.

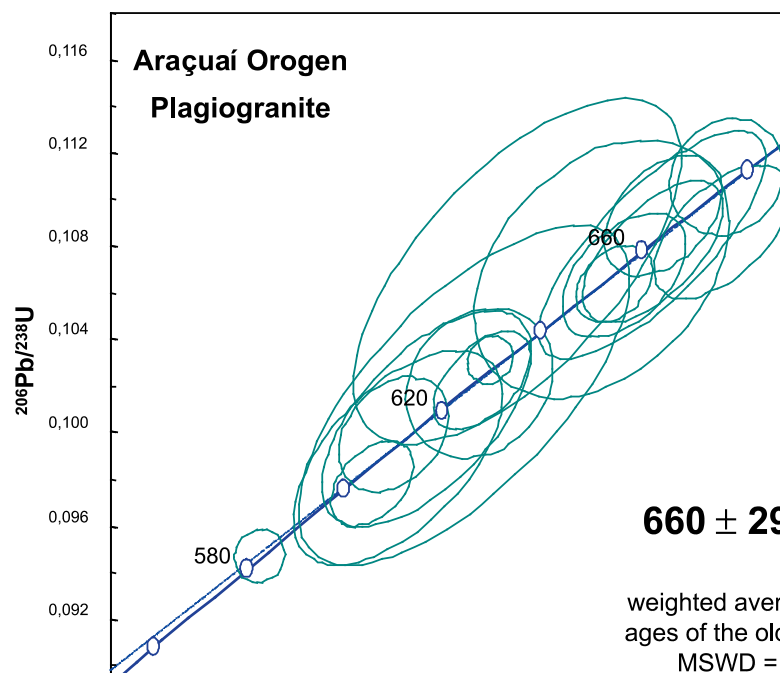


Figure 3. Concordia diagram for the U-Pb (LA-ICPMS) data from zircons of the Ribeirão da Folha plagiogranite. Analysis performed by Laboratório de Geocronologia da Universidade de Brasília.

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