

## SHRIMP-RG U-Pb ZIRCON GEOCHRONOLOGY OF GNEISS FROM THE RIO CRESPO INTRUSIVE SUITE, SW AMAZONIAN CRATON, RONDÔNIA, BRAZIL: NEW INSIGHT ABOUT PROTOLITH CRYSTALLIZATION AND METAMORPHIC AGES

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### INTRODUCTION

On the basis of geological, petrological and conventional U-Pb and Sm-Nd geochronological data the basement rocks in the northeast-central part of the Rondônia state are grouped into five lithologic associations: (1) tonalitic gneiss (1.75 Ga); (2) enderbitic granulite (1.73 Ga); (3) paragneiss (1.64-1.59 Ga); (4) granitic and charnockitic augen gneisses of the Serra da Providência intrusive suite (1.57-1.53 Ga), and (5) fine-grained granitic gneiss and charnockitic granulite of the Rio Crespo intrusive suite (1.43-1.42 Ga) (Payolla et al., 2001 and 2002). Recent U-Pb and <sup>40</sup>Ar/<sup>39</sup>Ar data demonstrate that at least two high-grade tectonometamorphic events affected the region at 1.35-1.33 Ga and 1.18-1.15 Ga (Payolla et al, 2002; Silva et al., 2002; Santos et al., 2003; Tohver., et al., 2005).

The Rio Crespo intrusive suite (Payolla et al., 2001) is represented by pink or greenish, fine- to medium-grained, quartz-feldspathic banded gneisses showing amphibole to granulite metamorphic facies. Banding is defined by alternating quartz + plagioclase + K-feldspar layers and hornblende + magnetite + titanite + epidote ± garnet ± orthopyroxene ± clinopyroxene discontinuous layers, and enhanced by concordant, locally folded granitic veins. Metacharnockite (~1.56 Ga) and mafic granulites (~1.73 Ga) xenoliths support an intrusive origin for the protolith of the fine-grained gneisses and granulites. Although these rocks are minor areal expression within the study area, they are widespread further south and west,

suggesting a batholithic dimension for the magmatism.

Geochemically, the gneisses are characterized by strong iron enrichment, have metaluminous to marginally peraluminous compositions, and exhibit a high- to ultra-high-K signature (Payolla et al., 2002). Their trace element contents are comparable to the Phanerozoic A-type and are within plate granites. However, the distinct negative Nb and Ta anomalies, resembling those of high-K calc-alkaline and arc-related granites. Moreover, these rocks, can be classified as oxidized-type granites based on their high magnetite contents.

The crystallization age of the gneiss protolith is constrained by two conventional U-Pb zircon studies. Payolla et al. (2001) obtained an age of 1.42 Ga on the basis of discordant U-Pb ages of zircons from a charnockitic granulite sample (WB-223/A). Payolla et al. (2002) confirmed this age assignment with a 1.43 Ga age for a granitic gneiss sample (WB-51).

The slightly positive  $\epsilon_{Nd}$  (+ 1.2 to + 0.6) and the narrow range of  $T_{DM}$  (1.73 to 1.75 Ga) of these rocks suggest that they represent a mixture of younger juvenile material and older basement rocks (Payolla et al., 2002).

In this study we have re-examined the timing of crystallization and metamorphism of the Rio Crespo intrusive suite gneisses, using ion microprobe U-Pb zircon geochronology. The data obtained indicate that zircons in sample WB-51, previously dated at 1.43 Ga by Payolla et al. (2002) using conventional methods, are composed of ~1.50 Ga magmatic cores and 1.35-1.33 Ga metamorphic overgrowths.

## ANALYTICAL TECHNIQUES

Zircon U-Pb geochronology was carried out with the SHRIMP-RG (sensitive high-resolution ion microprobe-reverse geometry) ion microprobe at Stanford University, by J. S. Bettencourt, R. M. Tosdal and J. L. Wooden. The SHRIMP-RG employs magnetic analysis, of the secondary ion beam, before electrostatic analysis to achieve greater mass resolution in comparison with previous SHRIMP designs (Clement and Compston, 1994). The ~8nA primary beam of  $^{16}\text{O}_2^+$  ions produced a ~30  $\mu\text{m}$  diameter, ~1  $\mu\text{m}$  deep, flat-bottomed analysis pit. Concentration data were standardized against Sri Lankan zircon standard SL-13 and Duluth Gabbro zircon standard AS57, and isotope ratios were calibrated against AS57, with an assumed age of 1099 Ma.

## RESULTS AND DISCUSSION

Sample WB-51 is from a homogeneous portion of a pinkish, banded high-grade granitic gneiss collected near the town of Ariquemes. The gneiss consists of quartz + K-feldspar + plagioclase + hornblende + magnetite + garnet + titanite + epidote + zircon.

Zircon crystals are mainly euhedral, showing prismatic habit with rounded terminations. Their lengths range from ca. 130 to 600  $\mu\text{m}$ , and elongation ratios from 2:1 to 6:1. The SEM-CL (scanning electron microscope cathodoluminescence) imaging shows that the grains consist of a CL-high to medium core, with oscillatory zoning mantled by a homogeneous CL-dark rim (Figure 1).

Cores have highly variable sizes and euhedral to anhedral shapes. In most grains the primary core oscillatory zoning has been partially replaced by unzoned CL-bright zircon domains. The boundary between zoned and unzoned zircon is predominantly progressive in that zones are seen to fade into areas of unzoned zircon in which faint traces of original zoning are retained. The unzoned zircon is believed to record recrystallization after completion of primary crystallization of oscillatory zoned zircon from the magma, and provides a mechanism for resetting zircon U-Pb ages (Pidgeon, 1992).

Unzoned or weakly zoned CL-dark rims are present on all grains but vary in thickness from < 10  $\mu\text{m}$  to > 100  $\mu\text{m}$ . In zircons with higher elongation ratios the CL-dark rim abundance can cover up to 70% of the grains. The contact between the CL-dark rim and core is generally sharp with truncations in the zoning. In some grains, the outer boundaries of cores are strongly resorbed and embayments on the core surface are filled with CL-dark material.

The results of sixteen U-Pb-Th analyses conducted on zircons from sample WB-51 are presented on a conventional concordia plot in Figure 2.

Eight analyses of cores are homogeneous, with U contents ranging from 55 to 163 ppm, and Th/U ranging

from 0.30 to 0.40. The oscillatory zoning, U contents and Th/U ratios of the cores are diagnostic of a felsic igneous origin (Hanchar and Miller, 1993). The high elongation ratios of zircons suggested that the gneiss protolith was aplites or fine-grained granites emplaced at high-crustal levels (Vavra, 1990). The  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of the cores range from 1541 to 1440 Ma. The oldest age (1541 Ma) was obtained in a probable xenocrystic core, whereas the younger ages (~1450-1440 Ma) were found in the unzoned CL-bright zircon domains. Ignoring the oldest and the youngest ages and those which pass 2% discordance screening, results in a subset of five analyses which yielded a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1492 \pm 12$  Ma (MSDW=0.64). Due to the presence of unzoned CL-bright zircon in the cores, the  $1492 \pm 12$  Ma is interpreted as the minimum protolith crystallization age of the gneiss.

On the eight spots done, the CL-dark rims shown moderate to high U (1890 to 375 ppm) and low Th/U ( $\leq 0.20$ ). They have typical metamorphic features (non-zoning to weak zoning, low Th/U) and are interpreted as overgrowths that formed during a high-grade metamorphic event (Rubatto et al., 2001). A regression line calculation, using the eight analyses yields an upper intercept age of  $1351 \pm 20$  Ma and a lower intercept of  $639 \pm 460$  Ma (MSWD=0.46). However, two clusters of  $^{207}\text{Pb}/^{206}\text{Pb}$  ages may be recognized: 1347-1344 Ma (n=2) and 1338-1321 Ma (n=6). A more restricted sample of the second age cluster (ages with  $\leq 2\%$  discordance and U  $\leq 1,000$  ppm; n=5) yield a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1331 \pm 9$  Ma (MSWD=2.2). The period between 1.35-1.33 Ga is interpreted as the time that the region was affected by a high-grade metamorphic event.

## CONCLUSIONS

CL-imaging and ion microprobe geochronology indicate that zircons in granitic gneiss (sample WB-51) of the Rio Crespo intrusive suite are composed of 1.50 Ga igneous cores and 1.35-1.33 Ga metamorphic overgrowths. These ages contrast with the age of 1.43 Ga obtained by using UPb zircon conventional method.

The recalculated  $\epsilon_{\text{Nd}}$  at 1.50 Ga yields values between +1.0 and +1.8. These more positive values reinforced the interpretation that the fine-grained granitic gneisses represent juvenile material mixed with old basement rocks (1.75-1.53 Ga).

The age-correlation among the rocks from the Rio Crespo intrusive suite and the granites of the Santa Helena batholith in Mato Grosso state, in Brazil, proposed by Payolla et al. (2002) is not confirmed by our data. To date the 1.50 Ga felsic magmatism of the Rio Crespo intrusive suite have no temporal equivalents in the Mato Grosso and Eastern Bolivia. In Mato Grosso state, the orthogneisses were dated by the conventional U-Pb method (Ruiz, 2005; and references therein), and so the

use of a more precise method could change this scenario.

The high-grade metamorphic age reached at of 1.35-1.33 Ga is wide-spread in basement rocks of Rondônia state (Payolla et al., 2002; Silva et al., 2002; Santos et al., 2003; Tohver et al., 2005) and has been interpreted as the peak metamorphism of the Rondonian-San Ignacio Orogeny (Tassinari, et al., 1999). Recent U-Pb age data from igneous and metamorphic zircon constrain the San Ignacio Orogeny to between 1.34 and 1.32 Ga in Eastern Bolivia (Boger et al., 2005). No high-grade metamorphic event has been recorded in Mato Grosso at 1.35-1.33 Ga.

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## RESUMEN

O resultado da análise de imagens de catodoluminescência e os dados geocronológicos U-Pb obtidos com a técnica SHRIMP-RG indicaram que os zircões extraídos de um gnaisse de alto grau metamórfico da suíte intrusiva Rio Crespo, com idade prévia de 1.43 Ga obtida com a técnica U-Pb convencional, são compostos por um núcleo de origem ígnea com idade de cerca de 1.50 Ga e sobrecrescimentos de origem metamórfica com idades entre 1.35 e 1.33 Ga. Os núcleos exibem zonamento oscilatório primário e razões Th/U diagnósticas de origem a partir de magmatismo félsico. Zircões não zonados e com alta catodoluminescência substituem parcialmente os zircões zonados, e são interpretados como formados pela recristalização progressiva dos zircões primários. Consequentemente, a idade de 1.50 Ga é considerada como a idade de cristalização mínima para o protólito do gnaisse. Não há registro da ocorrência de evento ígneo temporalmente equivalente ao da suíte intrusiva Rio Crespo no estado do Mato Grosso no Brasil e na região oriental da Bolívia. Os sobrecrescimentos de origem metamórfica consistem de zircões não zonados, com baixa catodoluminescência e baixas razões Th/U, e são interpretados como formados durante o pico metamórfico da orogenia Rondoniana-San Ignacio. Zircões de origem metamórfica com características similares aos encontrados no gnaisse da suíte intrusiva Rio Crespo delimitam o desenvolvimento da orogênesis San Ignacio ao intervalo entre 1.35 e 1.32 Ga na região oriental da Bolívia. No estado do Mato Grosso não há registro ainda de evento metamórfico de alto grau com idade relacionada à orogenia Rondoniana-San Ignacio.

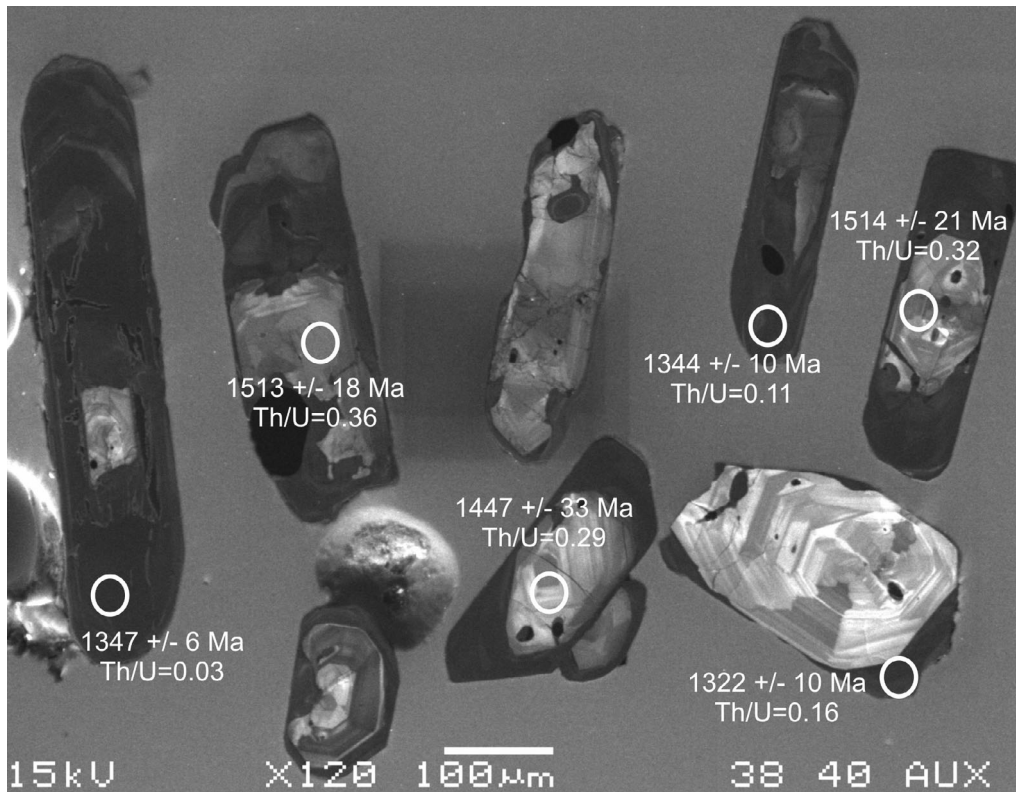


Figure 1. Cathodoluminescence images of zircon grains from the gneiss of the Rio Crespo intrusive suite (sample WB-51). Circles indicate the SHRIMP-RG analysis pits ( $\sim 30 \mu\text{m}$ ) for which Th/U ratio and age ( $^{207}\text{Pb}/^{206}\text{Pb}$  age) are reported.

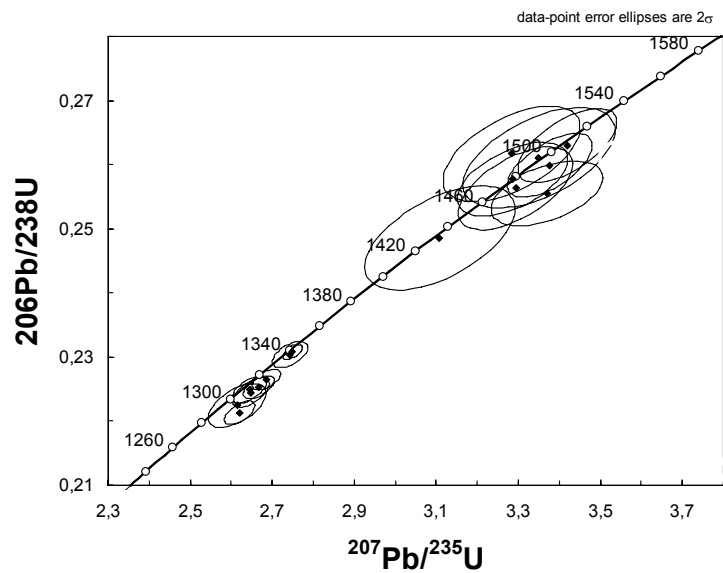


Figure 2. U-Pb concordia diagram showing SHRIMP-RG data for gneiss sample WB-51 of the Rio Crespo intrusive suite.