U/Pb AND Sm/Nd CONSTRAINTS ON THE AGE AND ORIGIN OF PROTEROZOIC CRUST IN SOUTHWESTERN MATO GROSSO, BRAZIL: EVIDENCE FOR A 1450 Ma MAGMATIC ARC IN SW AMAZONIA

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INTRODUCTION

Amazonia is a key piece of the puzzle for many supercontinent reconstructions. For example, Hoffman [1] and Dalziel [2] show Amazonia joined to Laurentia-Baltica in Rodinia as a result of 1.1 to 1.0 Ga fusion. Bettencourt et al. [3] presented paleomagnetic data that support the juxtaposition of Amazonia with Laurentia-Baltica ca. 1000 Ma, and Sadowski and Bettencourt [4] suggested that Amazonia was also joined to Laurentia-Baltica at 1.6 Ga and separated from it during Mesoproterozoic rifting [5] that began a Wilson cycle which ended with formation of Rodinia. The ages, structures, and compositions of rock units and orogenic events within Amazonia are still imperfectly known, in spite of significant recent advances [6,7]. We report here new U/Pb and Sm/Nd isotopic data and ages that place important constraints on ages of SW Amazonia, as exposed in SW Mato Grosso, and discuss their implications for potential correlations of Amazonia with Laurentia-Baltica during the Proterozoic.

SW Amazonia consists of several NW-SE trending belts that become younger to the southwest. New Nd data [6] suggest that there is a major accretionary belt, the 2.0 to 1.8 Ga Ventuari-Tapajós Province (VTP), that trends NW-SE, southwest of Manaus. Next youngest is the Rio Negro-Juruena province (RNJP). The basement of this belt is dominated by granitic, granodioritic and tonalitic gneisses and migmatites. Limited Rb-Sr, U-Pb, and Pb-Pb dating of these rocks yields primary crystallization ages of 1.80 to 1.63 Ga, and limited isotopic data indicate that it is a juvenile accretionary province. RNJP basement is locally overlain by undeformed, ca. 1.6 Ga felsic to intermediate volcanic rocks, which are overlain in turn by 1.6 to 1.4 Ga metasedimentary rocks. Several suites of 1.6 to 1.0 Ga undeformed plutons having rapakivi characteristics intrude the RNJP in this region. This spectrum includes groupings at ca. 1.0 Ga, 1.2 Ga, 1.4-1.5 Ga and 1.57 Ga [7]. K-Ar and Ar-Ar mineral ages on country rocks and intrusives indicate major thermal events at 1.4 to 1.2 Ma and 1.2 to 1.0 Ma.

The Rondonia-San Ignacio Province (RSIP) of SW Amazonia are exposed in Brazil and Bolivia. The RSIP is parallel to and outboard of the RNJP; it consists of older sialic basement metamorphosed between 1.45 and 1.25 Ga (_ 1.30 Ga San Ignacio orogeny [8]); limited data suggest that some of the basement in the RSIP is a SW extension of the RJNP. This belt was also intruded by many of the Mesoproterozoic granitic suites found in the RNJP. Low-grade to undeformed supracrustal sequences (e.g., Aguapei Group) locally overlie the Rondonian basement.

The Sunsas Province (SP) is sub-parallel to and west of RSIP. The SE part, which is mostly in Boliva, is the best exposed. Major metamorphism and plutonism in the Sunsas orogen occurred from 1.1 to 0.9 Ga [3,4]. K. Sato [9] found Sunsas rocks with Sm/Nd T_{DM} ages of ca. 1.1 Ga, indicating that juvenile basement occurs in parts of this belt, contrary to the case for the Rondonian belt. The RSIP and SP are similar in many ways to the Grenville province, which has lead to suggestions regarding spatial as well as temporal correlation [4]. Although this correlation has been based on a chronology for SW Amazonia that is largely controlled by K-Ar and Rb-Sr ages, Bettencourt et al. [3] reported paleomagnetic data for ca. 1000 Ma that support the spatial relationships. The SP also includes several granitic suites that were emplaced at various stages of the Sunsas orogenic cycle.

SW MATO GROSSO

The Proterozoic basement in SW Mato Grosso consists of igneous and metamorphic rocks that are SE extensions of the RSIP and the RNJP. The Aguapei thrust belt (ATB) separates the two main basement complexes. Basement to the east of the ATB includes several domains of distinctly different rock types, including several volcano-sedimentary belts (Jauru, Araputanga, and Cabaçal), felsic plutonic-gneiss belts (Quatro Marcos, Agua Clara, Cachoeirinha), and intrusive granitoids (Sta. Helene

suite) [10,11]. Tassinari et al. [6] reported a Pb/Pb isochron age of 1717 ± 120 Ma for gneisses in the Jauru River area, and Carneiro et al. [10] reported a Rb/Sr age of 1971 ± 70 Ma for gneisses in the São José dos Quatro Marcos (SJQM) area, showing that much of the basement complex in the east is 1.7 to 1.9 Ga.

Several undeformed 1.47 Ga granites intrude the basement complex in the SJQM (eastern) area [12], and some workers [11] have suggested that they are "stitching plutons" associated with assembly of older terranes to Amazonia ca. 1450 Ma. In this scenario, the San Ignacio orogeny [8] may be related to deformation associated with this event, since the current age of the San Ignacio orogeny is only controlled by limited Rb-Sr and K-Ar data.

The basement is locally overlain by undeformed to slightly deformed sedimentary rocks that have been considered to belong to the Aguapei group. These units are deformed within the Aguapei thrust belt and the Sunsas orogenic belt, but are less deformed where they overlie the Paragua block and undeformed to the east [8], in the Rio Branco area. Some younger, undeformed granites (Guapé, São Domingo) that may be related to 1.0 Ga Sunsas magmatism intrude basement complex in the Pontes e Lacerda region. The Rio Branco volcanic-plutonic suite in the NE part of the Jauru region has also been interpreted as coeval with the Sunsas orogeny.

NEW RESULTS

We have carried out U/Pb analyses of zircons separated from four units in the Pontes e Lacerda area in the western part of the region and one sample from the Rio Branco area in the eastern part of the area. The zircon separations were done in CPGeo (IG-USP), and the isotopic analyses were carried out in the Isotope Geochemistry Lab (IGL) of the University of Kansas. In most instances the zircons we analysed consisted of single zircon grains or small groups of similar grains that had been hand-picked for quality from non-magnetic splits and air abraded to improve concordance. We also analysed whole-rock powders from other samples of the same units for their Sm and Nd concentrations and Nd isotopic composition in order to calculate crustal formation ages (TDM). Our results are summarized in Table 1.

Santa Helena Granite-Gneiss (SHGG). The batholith represented by SHGG occurs over a large area. In the Pontes e Lacerda map sheet, SHGG shows restricted compositional and textural variations and is represented by gray to pink, usually equigranular, foliated biotite granites. A Rb-Sr whole rock best-fit isochron yielded an age of 1318 ± 24 Ma [13]. Zircon fractions from this unit yield an upper intercept (crystallization age) of 1434 ± 07 Ma on the U-Pb concordia. The Sm/Nd crustal formation age (TDM) for this unit is 1.62 Ga, indicating that the original granitic magma was derived from a source containing significant older crust.

Maraboa Granite. The Maraboa Granite is an isotropic granite included in the SHGG in the geologic map by Menezes et al. [14]. Its post-kinematic isotropic characteristics and Rb-Sr whole rock errorchron of 1257 ± 125 Ma [13] were used to separate it from SHGG. The rocks are coarse grained, pink to red, biotite granites, which are sometimes inequigranular due the presence of K-feldspar phenocrysts. Zircon, apatite, and fluorite are common accessory minerals. The U-Pb results of MG, when plotted on a U-Pb concordia diagram, yield an upper intercept (crystallization age) at 1475 ± 35 Ma. The Sm/Nd crustal formation age (TDM) for this unit is 1.70 Ga, indicating that the original granitic magma was derived from a source containing a significant older crustal component.

Table 1. U/Pb ages and Sm/Nd Isotopic Properties of Samples Studied.

Unit No.	Sample Number	Rock Description	U/Pb age (Ma) ± 2 sigma	ENd(0)	ENd(t)	TDM (Ga)
1.	30-546	Orthogneiss, AGC	1450 ± 13	nd	nd	nd
	97-102	Orthogneiss, AGC	nd	-15.4	3.1	1.55
2.	29-698	Gneissic granite, SHGG	1434 ± 07	nd	nd	nd
	29-656	Gneissic granite, SHGG	nd	-8.9	3.1	1.62
3.	29-697	Maraboa Granite	1475 ± 35	nd	nd	nd
	12.802	Maraboa Granite	nd	7.1	2.6	1.70
4.	30-545	Lavrinha Tonalite	1463 ± 04	nd	nd	nd
	31.212	Lavrinha Tonalite	nd	-13.1	3.8	1.53
5.	31-503	Syenite, RBS	1427 ± 10	nd	nd	nd

AGC = Alto Guaporé Complex; RBS - Rio Branco Suite; SHGG = Santa Helene Granite-Gneiss.

Lavrinha Tonalite. Three zircon fractions from hornblende tonalite collected in the Pontes e Lacerda area were analyzed. The Aguapei sandstone overlies this tonalite a few hundred meters from the outcrop. This rock is informally denominated here as the Lavrinha Tonalite. The rocks are gray to green, isotropic, with medium to coarse grain size. The presence of sericite, biotite, clorite, epidote and titanite are due to post-crystallization hydrothermal alteration. The three analyses plotted on a U-Pb concordia diagram yield an upper intercept (crystallization age) at 1463 ± 4 Ma. All three analyses fall near concordia, resulting in a high-precision age.The Sm/Nd crustal formation age (TDM) for this unit is 1.53 Ga, indicating that the original magma was derived from a source containing a very little, if any, older crust.

Gneiss of Alto Guaporé Metamorphic Complex. This rock belongs to the Alto Guaporé Metamorphic Complex and was interpreted as basement of the region **[14]**, with an inferred age of 1900 Ma. The sample was collected in the NE part of the Pontes e Lacerda area, where the unit was divided into granodioritic orthogneiss and garnet-muscovite paragneiss. In this region the paragneiss is marked by a banding due to the alternation of layers rich in mafic minerals with layers rich in quartz and feldspar. Pegmatites also are observed. A homogeneous, unbanded sample was collected. It contains K-feldspar, quartz, amphibole, and biotite and probably represents the orthogneiss phase of the complex. Three zircon fractions plotted on a U-Pb concordia diagram yield an imprecise upper intercept at 1450 ± 13 Ma.The Sm/Nd crustal formation age (TDM) for another sample from this unit is 1.55 Ga, indicating that the protolith for this gneiss contained very little older crustal component.

Syenite of Rio Branco Suite. This rock is from syenite that crops out in the vicinity of the Rio Branco igneous suite. These rocks have traditionally been interpreted as ca. 1000 Ma and related to Sunsas magmatism. However, zircons from the syenite are nearly concordant and yield an age of 1427 ± 10 Ma. No Sm/Nd data are available for this unit at the time this abstract is written.

DISCUSSION

Our results clearly show that much of the inferred chronology for the region, which was based on Rb/Sr and K/Ar ages, needs to be revised as new U/Pb ages using zircons and Sm/Nd crustal formation ages are obtained. As a preliminary working model, we present the following interpretations:

1. Igneous and metaigneous rocks in the Pontes e Lacerda region represent magmatic activity that occurred about 1440 to 1470 Ma. This includes not only the Santa Helene granite and related units, but also includes the proximal host terrain for these plutons. We tentatively conclude that the granites, orthogneisses, and tonalite are all components of a ca. 1450 Ma NW-trending volcano-plutonic arc (Santa Helene Arc).

2. The relatively low Sm/Nd crustal formation ages for rocks of this complex suggest that parts of it represent juvenile crust, while other parts may include a significant contribution from older crust. We suggest that this complex was developed along the (now) western margin of a continent which was comprised of 1.7 to 1.8 Ga units of the volcanic and gneissic complexes to the east of Jauru (Jauru, Araputanga, and Cabaçal volcano-sedimentary belts; Quatro Marcos, Agua Clara, and Cachoeirinha felsic gneiss belts).

3. The undeformed 1.47 Ga granites which intrude the older volcano-sedimentary and gneiss belts **[12]** probably represent cratonic manifestations of igneous activity associated with the Santa Helene Arc, suggesting that the associated subduction zone dipped east under the 1.7 to 1.8 Ga continental margin.

4. The Rio Branco syenite is also apparently related to the Santa Helene Arc magmatism, and is a more easterly relative of the 1.47 Ga granites mentioned above (3). The implications of this age for the age of the Rio Branco volcanic rocks and the proximal Aquapei Group sedimentary rocks must await re-examination of field relationships.

5. Rb/Sr ages of 1.2 to 1.4 Ga previously reported in the region, and which defined the age of the San Ignacio orogeny **[8]** may either represent partial resetting due to the 1.0 Ga Sunsas orogeny or may represent thermal effects due to a true San Ignacio orogeny intermediate in age between the Sunsas orogeny and 1.45 Ga. Therefore we do not, at this time, propose that our ages at ca. 1450 be used to redefine the age of the San Ignacio orogeny.

REGIONAL AND GLOBAL IMPLICATIONS

The eastern volcano-sedimentary and gneiss belts represent SE extensions of the Rio Negro-Juruena Province **[6]**, and the Santa Helene Arc probably represents the eastern part of SE extensions of the Rondonia-San Ignacio Province **[6]**. We have so far found no evidence of rapakivi-type granites in Mato Grosso, even though they are common in these belts to the NW in Rondonia. The age pattern of

1450 Ma rocks intruded into or adjacent to 1.7 to 1.8 Ga continental crust is similar to relationships along the eastern and southern margin of Laurentia prior to 1400 Ma **[15,16,17]** and would be compatible with tectonic models **[4,5]** which propose proximity between Laurentia and Amazonia about 1800 to 1400 Ma.

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