



UNIVERSIDADE ESTADUAL DE CAMPINAS

Instituto de Geociências

Veronica Godinho Trevisan

EVOLUÇÃO CRUSTAL E FERTILIDADE MAGMÁTICA DO SETOR LESTE DA
PROVÍNCIA MINERAL DE ALTA FLORESTA, CRÁTON AMAZÔNICO

CRUSTAL EVOLUTION AND MAGMA FERTILITY OF THE EASTERN PORTION OF
THE ALTA FLORESTA MINERAL PROVINCE, AMAZONIAN CRATON

CAMPINAS

2020

VERONICA GODINHO TREVISAN

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GEOSCIENCES OF THE UNIVERSITY OF CAMPINAS TO
OBTAIN THE DEGREE OF DOCTOR IN SCIENCES IN THE
AREA OF GEOLOGY AND NATURAL RESOURCES

TESE APRESENTADA AO INSTITUTO DE GEOCIÊNCIAS
DA UNIVERSIDADE ESTADUAL DE CAMPINAS PARA
OBTENÇÃO DO TÍTULO DE DOUTORA EM CIÊNCIAS
NA ÁREA DE GEOLOGIA E RECURSOS NATURAIS

ORIENTADOR: PROF. DR. ROBERTO PEREZ XAVIER

CO-ORIENTADOR: PROF. DR. STEFFEN GERD HAGEMANN

ESTE EXEMPLAR CORRESPONDE À VERSÃO FINAL DA
TESE DEFENDIDA PELA ALUNA VERONICA GODINHO
TREVISAN ORIENTADA PELO PROF. DR. ROBERTO
PEREZ XAVIER E CO-ORIENTADA PELO PROF. DR.
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Caetano Juliani

Felipe Grandjean da Costa

Elson Paiva de Oliveira

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- ORCID do autor: <https://orcid.org/0000-0003-0704-0817>

- Currículo Lattes do autor: <http://lattes.cnpq.br/7420068728214948>

UNIVERSIDADE ESTADUAL DE CAMPINAS
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AUTORA: Veronica Godinho Trevisan

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ORIENTADOR: PROF. DR. ROBERTO PEREZ XAVIER

CO-ORIENTADOR: PROF. DR. STEFFEN GERD HAGEMANN

Aprovado em: 17 / 12 / 2020

EXAMINADORES:

Prof. Dr. Roberto Perez Xavier - Presidente

Prof. Dr. Caetano Juliani

Prof. Dr. Felipe Grandjean da Costa

Prof. Dr. Elson Paiva de Oliveira

Prof. Dr. Wagner da Silva Amaral

*A Ata de Defesa assinada pelos membros da Comissão Examinadora consta no processo
de vida acadêmica do aluno.*

Campinas, 17 de dezembro de 2020.

SÚMULA BIOGRÁFICA



Veronica Godinho Trevisan é geóloga (2012) e mestra em Geociências (2015) pela Universidade Estadual de Campinas (Campinas, Brasil). No seu mestrado desenvolveu um estudo comparativo entre depósitos de Au-Cu e Au-Zn-Pb-Cu do tipo venular, localizados no setor leste da Província Mineral de Alta Floresta (Mato Grosso, Brasil) através do uso de petrografia, química mineral, inclusões fluidas e geocronologia. Em 2014, foi premiada no XXXII Curso Latino-Americano de Metalogenia, realizado em Quito (Equador), pela apresentação do pôster “*Intrusion-hosted gold-sulphide-vein systems in The Alta Floresta Gold Province, Amazon Craton (Brazil)*”. Também em 2014, publicou como co-autora um capítulo do livro *Metalogênese das Províncias Tectônicas Brasileiras* do Serviço Geológico do Brasil. Iniciou seu Doutorado na Universidade Estadual de Campinas em 2016, com o objetivo de investigar a evolução crustal e geodinâmica do setor leste da Província Mineral de Alta Floresta, e o potencial das unidades geológicas que ocorrem nesta região para a prospectividade em ouro e cobre. Durante sua pesquisa de doutorado realizou análises petrográficas, geoquímicas (rocha-total e in-situ em zircão), geocronológicas e isotópicas. Recebeu uma bolsa da Chinese Academy of Sciences em maio de 2017, através de uma parceria de colaboração científica entre a Universidade Estadual de Campinas e o governo chinês, para realizar estágio de pesquisa de um mês no State Key Laboratory of Ore Deposit Geochemistry em Guiyang (Guizhou, China), sob supervisão do Prof. Dr. Jian-Feng Gao. Em 2018, foi premiada com uma bolsa de pesquisa da Society of Economic Geologists, financiada pela Newmont Mining Corporation, para cobrir parte dos gastos do projeto de pesquisa de Doutorado. De 2018 a 2019, foi pesquisadora visitante na The University of Western Australia (Perth, Western Australia), sob supervisão dos Profs. Drs. Steffen Hagemann, Robert Loucks e Tony Kemp, desta vez financiada pelo Programa de Doutorado-Sanduiche no Exterior (PDSE), da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). Durante o mestrado e doutorado, participou diversas vezes do Programa de Estágio Docente (PED) como monitora em diferentes disciplinas do curso de graduação em Geologia do Instituto de Geociências. Também nos anos 2012-2020, publicou diversos resumos em eventos nacionais e internacionais, e participou de cursos de aperfeiçoamento e trabalhos de campo no Brasil e no exterior. Seu trabalho de conclusão de curso de graduação (TCC), mestrado e doutorado foram orientados pelo Prof. Dr. Roberto Xavier. Seu doutorado foi co-orientado pelo Prof. Dr. Steffen Hagemann.

BIOGRAPHY



Veronica Godinho Trevisan holds a bachelor degree in Geology (2012) and a Master's degree in Geosciences from the University of Campinas (Campinas, Brazil). During her Masters, she developed a comparative study between Au-Cu and Au-Zn-Pb-Cu vein-type deposits, located in the eastern portion of the Alta Floresta Mineral Province (Mato Grosso state, Brazil), through the use of petrography, mineral chemistry, fluid inclusions and geochronology. In 2014, she received an award in the XXXII Latin American Metallogeny Course, held in Quito (Ecuador), for the poster presentation entitled "Intrusion-hosted gold-sulphide-vein systems in The Alta Floresta Gold Province, Amazon Craton (Brazil)". Also in 2014, she published as a co-author a chapter in a book from the Geological Survey of Brazil. She started a Ph.D. at the University of Campinas (Brazil) in 2016 aiming to better understand the crustal and geodynamic evolution of the eastern portion of the Alta Floresta Mineral Province, and the potential of the geological units from this region to be prospective for gold and copper. During the doctorate research, she performed petrographic, geochemical (whole-rock and *in-situ* analyses on zircon), geochronological and isotopic analyses. She was awarded a research scholarship in 2017 by the Chinese Academy of Sciences to conduct a research intership at the State Key Laboratory of Ore Deposit Geochemistry (Guiyang, Guizhou, China), under the supervision of Prof. Dr. Jian Feng-Gao. In 2018, she was awarded a Student Research Grant (SRG) by the Society of Economic Geologists and funded by the Newmont Mining Corporation, to cover part of the expenses with the doctorate research project. From 2018 to 2019, she was a visiting researcher at The University of Western Australia (Perth, Western Australia), under the supervision of Profs. Drs. Steffen Hagemann, Robert Loucks and Tony Kemp, this time funded by the *Programa de Doutorado-Sanduiche no Exterior (PDSE)* of *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)*. During the Master's and Ph.D, she acted as a graduate teaching assistant of several disciplines of the undergraduate Geology course at the University of Campinas as part of the *Programa de Estágio Docente (PED)*. Also, from 2012-2020, she published numerous abstracts in national (Brazil) and international events, and participated of courses, workshops and fieldwork training in Brazil and overseas. Her ungraduated thesis, Master's and Ph.D. were supervised by Prof. Dr. Roberto Xavier. Her Ph.D. was co-supervised by Prof. Dr. Steffen Hagemann.

DEDICATÓRIA

Dedico este trabalho a minha família. Aos meus pais Lúcia e Olair, ao meu irmão Rodrigo, às minhas tias Regina e Beatriz, e à minha avó Maria José (*in memoriam*). Obrigado pelo amor, apoio, união e compreensão incondicionais durante esta minha breve passagem pela Terra. Este trabalho também é dedicado a todos os jovens estudantes e pesquisadores que veem o estudo como ferramenta para descobrir e mudar seu mundo interior e exterior, e a todas às mulheres incrivelmente fortes e corajosas de todas as profissões e classes sociais.

DEDICATORY NOTE

This work is devoted to my family. To my parents Lúcia and Olair, to my brother Rodrigo, to my aunts Regina and Beatriz, and to my grandmother Maria José (*in memoriam*). Thank you for your unconditional love, support, union and comprehension throughout all the years. This work is also dedicated to all students and young scientists who see the study as a tool to discover and change their inner and outer world, and to all the incredibly strong and courageous women of all professions and social classes.

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There is a bit of each one of you in the pages of this work!

Thank you!

EPÍGRAFE

" O mais importante e bonito, do mundo, é isto: que as pessoas não estão sempre iguais, ainda não foram terminadas, mas que elas vão sempre mudando. Afinam ou desafinam.
Verdade maior.

O correr da vida embrulha tudo, a vida é assim: esquenta e esfria, aperta e daí afrouxa, sossega e depois desinquieta. O que ela quer da gente é coragem. O que Deus quer é ver a gente aprendendo a ser capaz de ficar alegre a mais, no meio da alegria, e inda mais alegre ainda no meio da tristeza!

A vida inventa! A gente principia as coisas, no não saber por que, e desde aí perde o poder de continuação porque a vida é mutirão de todos, por todos remexida e temperada. Viver é muito perigoso; e não é não. Nem sei explicar estas coisas. Um sentir é o do sentente, mas outro é do sentidor."

João Guimarães Rosa – Grande Sertão: Veredas

RESUMO

A Província Mineral de Alta Floresta, sul do Cráton Amazônico, constitui um cinturão de aproximadamente 500 km de comprimento por 100 km de largura composto por intrusões ácidas, rochas vulcânicas ácidas a intermediárias e, subordinadamente, rochas vulcanoclásticas e gnaisses graníticos. Estas rochas hospedam diversos depósitos e prospectos de Au-Cu-Mo, Cu-Mo-Au e Au-Zn-Pb-Cu do tipo disseminado, filoniano e venular. Estas ocorrências têm sido interpretadas como sistemas do tipo pórfiro e epitermal paleoproterozóicos. Apesar das inúmeras informações na literatura sobre alteração hidrotermal, mineralogia do minério, regime de fluidos, mecanismos de precipitação dos metais e relações temporais entre mineralização e magmatismo, pouco se sabe sobre a origem e evolução dos magmas em escala regional e com uma abordagem integrada em toda a porção leste da província. Este cenário dificulta uma melhor compreensão da história magmática, o estabelecimento de correlações com eventos tectônicos em escala regional, bem como a identificação de unidades geológicas potencialmente férteis para Cu e Au. O principal objetivo deste estudo é entender a evolução crustal e o potencial de fertilidade dos magmas para Cu e Au na porção leste da Província Mineral de Alta Floresta, através da reconstrução da evolução temporal e química do magmatismo; reinterpretação da estratigrafia e estabelecimento de um novo contexto geológico; definição da evolução geodinâmica; investigação da composição química das rochas através da geoquímica de rocha-total e de zircão para caracterizar magmas potencialmente férteis para Cu e Au; e, indicação de unidades geológicas prospectivas para a mineralização de Cu e Au. Os resultados obtidos revelam que: i) o magmatismo na porção leste da Província Mineral de Alta Floresta entre 2037 e 1757 Ma; ii) a região evoluiu através de um orógeno acrescionário marcado pela alternância entre subducção de baixo ângulo e *slab-rollback*; iii) mineralizações do tipo pórfiro e epitermal se formaram entre 1,83-1,75 Ga durante períodos de extensão/relaxamento da crosta; iv) a porção leste da província correlaciona-se a leste com a Província Mineral do Tapajós e registra o magmatismo do Cinturão Ígneo da Amazônia Ocidental; v) a evolução desta região e de outros terrenos proterozoicos sugere que partes do supercontinente Columbia operavam de maneira similar aos orógenos acrescionários fanerozóicos do tipo andino; vi) a geoquímica de rocha-total representa uma ferramenta de exploração com limitações para a avaliação da prospectividade para Cu e Au devido à presença de alteração hidrotermal em rochas em toda a província; vii) as análises químicas em zircão podem ser utilizadas como uma ferramenta de exploração eficiente para identificar unidades geológicas potencialmente férteis para o Cu e Au; viii) a integração da geoquímica de rocha-total e de zircão com informações geocronológicas é útil para identificar o regime tectônico ao longo do tempo na província; ix) a geoquímica do zircão sugere que o Grupo Colíder e, subordinadamente, as suítes Matupá e Teles Pires são as unidades geológicas com maior potencial prospectivo para Cu e Au devido aos seus altos conteúdos de água e elevado estado de oxidação; x) a identificação de magmas potencialmente férteis para Cu e Au na porção leste da Província Mineral de Alta Floresta pode ajudar na orientação dos programas de exploração mineral com ênfase nestes metais (e.g., descoberta de depósitos do tipo pórfiro e epitermal) no sul do Cráton Amazônico.

Palavras-chave: geoquímica de rocha-total; geocronologia U-Pb; orógeno acrescionário Paleoproterozóico; elemento traço em zircão; fertilidade magmática

ABSTRACT

The Alta Floresta Mineral Province lies in the southern portion of the Amazonian Craton and constitutes a belt of approximately 500 km long by 100 km wide. The province comprises numerous, compositionally heterogeneous acidic intrusions, acidic to intermediate volcanic rocks, and, to a lesser extent, volcanoclastic rocks and granitic gneisses. These rocks are hosts to several disseminated and vein-type intrusion-hosted Au-Cu-Mo, Cu-Mo-Au, and Au-Zn-Pb-Cu primary deposits and prospects. These mineral occurrences have been interpreted as Paleoproterozoic porphyry and epithermal-style systems. Despite the well constrained, valuable information in the literature about the hydrothermal alteration, ore mineralogy, fluid regime, mechanisms of precipitation of the metals, and timing relationships between mineralization and magmatism, relatively little is known about the source and evolution of the magmatism in a regional scale and with an integrated approach across the eastern portion of the province. This scenario makes difficult a better understanding of the magmatic history, establishing links to regional scale tectonic events, as well as identifying potentially Cu- and Au-fertile geological units. The main objective of this study is to constrain the crustal evolution and magma fertility potential of the eastern portion of the Alta Floresta Mineral Province through the reconstruction the chrono-chemical evolution of the magmatism; reinterpretation of the stratigraphy and establishment of a novel magmatic framework; definition of the geodynamic evolution; examination of whole-rock and zircon chemical compositions to characterize Cu- and Au-ore-related magmas; and, indication of potential geological units as prospective for Cu and Au mineralization. The obtained results revealed that: i) magmatism in the eastern portion of the Alta Floresta Mineral Province occurred from 2037 to 1757 Ma; ii) the region evolved within an accretionary orogenic system with tectonic switching that alternates between low-angle subduction and slab-rollback; iii) precious- and base-metal porphyry- and epithermal-style systems formed from 1.83-1.75 Ga during crustal extension or relaxation; iv) the eastern portion of the province correlates with the eastward Tapajós Mineral Province and records magmatism of the Western Amazonia Igneous Belt; v) the evolution of this region and other Proterozoic terranes worldwide suggests that parts of the Columbia supercontinent operated in similar fashion to Phanerozoic Andean-type accretionary orogens; vi) the whole-rock geochemistry represents an exploration tool with some limitations to assess Cu- and Au-prospectivity because of the strong hydrothermal alteration that affect the rocks across the province; vii) zircon chemical analyses can be used as an efficient exploration tool to identify geological units potentially fertile for Cu and Au; viii) the integration of whole-rock and zircon geochemistry with geochronology information is particularly useful to track the tectonic stress regime (e.g. compressive versus non-compressive) over time in the province; ix) the zircon geochemistry suggests that the Colíder group and, to a lesser extent, the Matupá and Teles Pires suites are the geological units prospective for Cu and Au in the eastern portion of the province due to their high water content and high oxidation state; x) the identification of potentially prospective hydrous and oxidized magmas for Cu and Au mineralization across the eastern portion of the Alta Floresta Mineral Province is encouraging and can help guiding exploration for Cu and Au (e.g. porphyry- and epithermal-style deposits) in southern Amazonian Craton.

Keywords: whole-rock geochemistry; U-Pb geochronology; Paleoproterozoic accretionary orogeny; zircon trace elements; magma fertility

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1. Introduction

The Alta Floresta Mineral Province (AFMP) represents one of the various important mineral provinces in the Amazonian Craton (AC). Its importance is particularly due to the occurrence of multiple metallic occurrences, mostly auriferous, in the limits of the Paleoproterozoic to Mesoproterozoic Tapajós-Parima (2.03-1.88 Ga) and Rondônia-Juruena (1.82-1.54 Ga) tectonic provinces (Santos *et al.*, 2000) in the southern margin of the AC (Fig. 1A). The Tapajós-Parima province consists of arc-type sequences that vary in composition from granite to tonalite, volcanoclastic units, porphyry intrusions and, to a lesser extent, gneisses and back-arc sedimentary rocks. This province is divided into four distinctive domains from north to south (Parima, Uaimiri, Tapajós, and Peixoto de Azevedo) separated from each other by three Phanerozoic sedimentary basins (Solimões, Amazon, and Cachimbo/Alto Tapajós; Santos *et al.*, 2004; Santos *et al.*, 2006; Fig. 1B). The Rondônia-Juruena province comprises calc-alkaline arc-type granitoids and volcano-sedimentary sequences (Santos *et al.*, 2006).

The AFMP (Fig. 1C) is an approximately 500 km long by 100 km wide belt comprising (Rizzotto *et al.*, 2019b): the 2.8-1.86 Ga Peixoto de Azevedo Domain, the 1.85 Ga São Marcelo-Cabeça group, the 1.81–1.75 Ga Juruena supersuite, the 1.81–1.76 Ga Nova Monte Verde Complex, the 1.81–1.76 Ga Colíder group, the 1.79–1.75 Ga Teles Pires suite, the 1.76–1.74 Ga Roosevelt group, the 1.98–1.37 Ga Caiabis group, and the ca. 0.30 Ga Alto Tapajós basin. The Peixoto de Azevedo Domain and the São Marcelo-Cabeça group are part of the Tapajós Domain within the Tapajós-Parima tectonic province (Fig. 1A–B), while the Juruena Supersuite, Roosevelt, and Caibis groups belong to the Rondônia-Juruena tectonic province (Fig. 1A–B). Additionally, the Roosevelt group, Juruena supersuite, Nova Monte Verde Complex, Colíder group, and Teles Pires intrusive suite are collectively denominated Western Amazonia Igneous Belt (Rizzotto *et al.*, 2019a,b). A summary of these lithostratigraphic units is presented in Table 1.

This province has historically been an important gold-producing region in Brazil (~4 Moz from 1990 and 1999), especially its easternmost segment (Fig. 2), where the number of mining sites totals over a hundred placer and medium to high-grade and low-tonnage (< 0.2 Moz) “hard rock” gold deposits, mainly exploited by local artisanal prospectors (*garimpeiros*; Paes de Barros, 2007). However, since the 1980’s junior companies, and more recently (2015 to today) major companies, have been prospecting large-scale “hard rock” polymetallic deposits. The scarcity of outcrops, the Mesoproterozoic to Quaternary sedimentary cover over

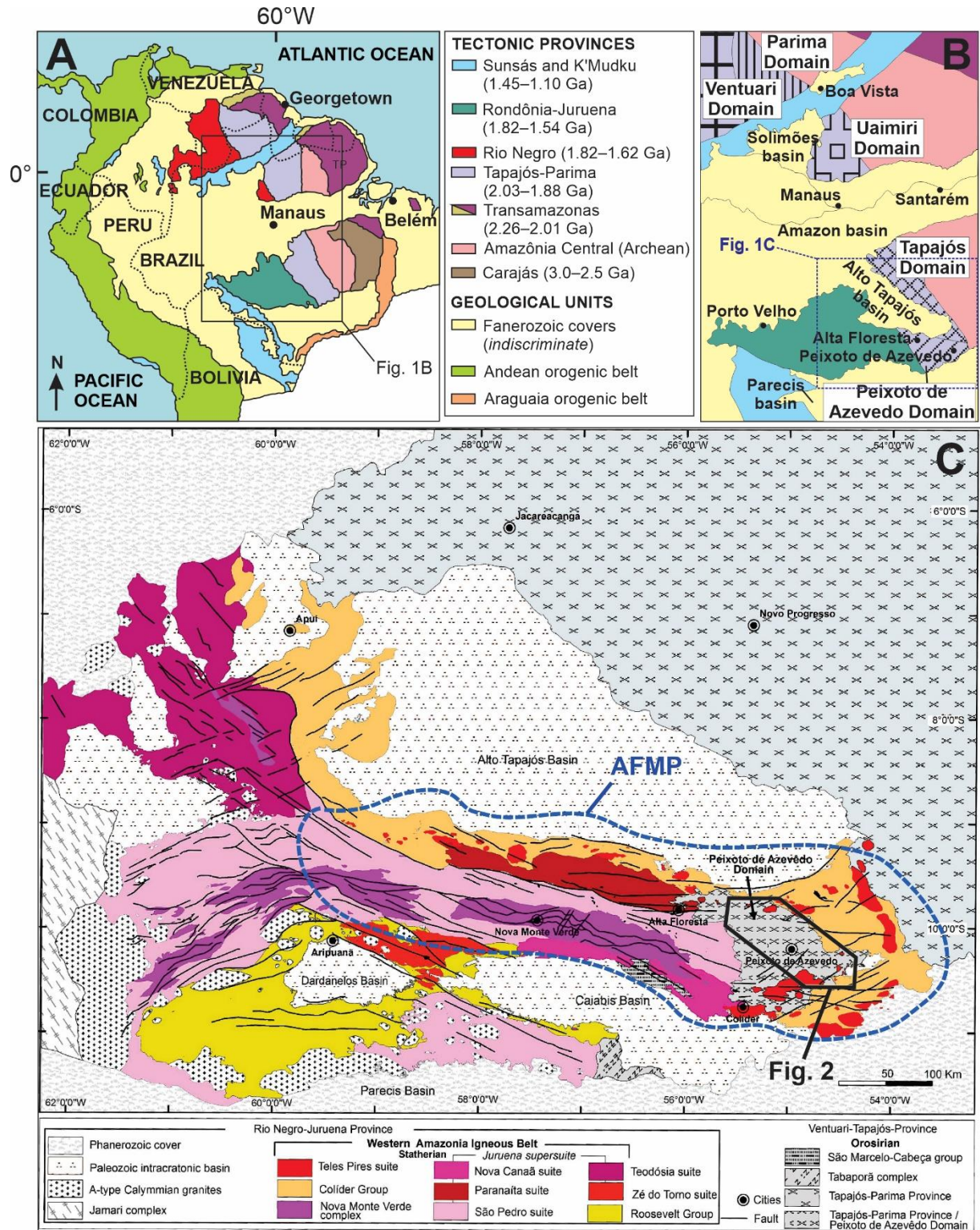


Figure 1. (A) Tectonic provinces of the Amazonian craton (Santos *et al.*, 2000); (B) Location of the four domains of the Tapajós-Parima tectonic province (modified from Santos *et al.*, 2004); (C) Simplified geological map of the southwestern Amazonian Craton, showing part of the Tapajós-Parima province, Western Amazonia Igneous Belt, and the location of the Alta Floresta Mineral Province (AFMP; modified from Rizzotto *et al.*, 2019b).

the plutonic-volcanic sequences, and limited geological data have made discovering and exploration challenging in this region.

The geological framework of the eastern AFMP is separated into five main lithostratigraphic units and has been simplified from [Assis *et al.* \(2017\)](#) according to new proposals by [Rizzotto *et al.* \(2019b\)](#) and [Alves *et al.* \(2020\)](#) into: (i) 2.86–1.78 Ga Peixoto de Azevedo Domain; (ii) 1.82–1.78 Ga Colíder group; (iii) 1.78–1.75 Ga Teles Pires suite; (iv) unconstrained rocks; and (v) 1.98–1.37 Ga Caibis group (Dardanelos Formation), and Cenozoic sedimentary cover sequences ([Fig. 2](#)). The unconstrained rocks represent poorly documented areas with reduced or no lithological, geochemical, and/or geochronological information. A detailed outline of the geology along the eastern portion of the AFMP is presented in [Table 2](#).

Based on the metallic association and mineralization style, the prospects across the eastern AFMP are clustered into four main groups ([Xavier *et al.*, 2011](#); [Assis, 2015](#); [Trevisan, 2015](#); [Trevisan *et al.*, 2017](#)): (1) disseminated Au-Cu-Mo mineralization (e.g. Luizão, Pé Quente, X1 and Serrinha prospects); (2) vein-type Au-Cu-Mo mineralization (e.g. Paraíba, Pezão, and Peteca prospects); (3) disseminated Cu-Mo mineralization (e.g. Ana, Jaca, and Paraíba deposits); and, (4) vein-type Au-Zn-Pb-Cu mineralization (e.g. Francisco, Bigode, Carrapato and Luiz prospects) ([Fig. 3](#)). These prospects have been classified as magmatic-hydrothermal systems and are considered to share broad similarities with porphyry and epithermal-style deposits ([Moura *et al.*, 2006](#); [Xavier *et al.*, 2011](#); [Assis, 2015](#); [Trevisan, 2015](#); [Trevisan *et al.*, 2017](#); [Assis *et al.*, 2017](#); [Matos *et al.*, 2018](#)). A summary of their main characteristics is presented in [Table 3](#).

Despite the presence of numerous metalliferous occurrences and well constrained, valuable information in the literature about the hydrothermal alteration, ore mineralogy, fluid regime, mechanisms of precipitation of the metals, and timing relationships between mineralization and magmatism, relatively little is known about the source and evolution of the magmatism in a regional scale and with an integrated approach across the eastern portion of the province. Available works in this part of the province are mainly focused on deposit-scale studies from mostly unpublished BSc's, MSc's and PhD's and reports by mining companies or regional reports by the Brazilian Geological Survey ([Moreton and Martins, 2005](#); [Souza *et al.*, 2005](#); [Silva and Abram, 2008](#); [Alves *et al.*, 2019](#)).

Additionally, only one BSc work attempted to compare the chemistry of mineralized and non-mineralized intrusions ([Ramos, 2011](#)). Furthermore, a large portion of this part of the province still lacks systematic geological mapping and geochemical and geochronological data. Collectively, this scenario makes difficult a better understanding of the magmatic history, as

well as establishing links to regional scale tectonic events that may effectively aid exploration targeting in this region.

Table 1. Summary of the main lithostratigraphic units identified at the Alta Floresta Mineral Province.

Tectonic Province	Domain	Lithostratigraphic Unit		Age (Ga)	Description	Reference	
-	-	Alto Tapajós basin (or Cachimbo graben)		Silurian-Devonian	sandstones, siltstones, arkoses, conglomerates, and claystones	Juliani <i>et al.</i> (2014); Toczeck <i>et al.</i> (2019); Alves <i>et al.</i> (2020)	
Rondônia-Juruena	Western Amazoni a Igneous Belt	Caiabis group (Dardanelos Formation)		1.98–1.37	clastic sediments	Leite and Saes (2003); Alves <i>et al.</i> (2020)	
		Roosevelt group		1.76–1.74	mudstone interdigitated with chert, manganiferous siltstone, BIFs, tuffs, ignimbrites, volcaniclastic conglomerates, dacites, and rhyolites		
		Teles Pires suite		1.79–1.75	granitic rocks		
		Colíder group		1.81–1.76	pyroclastic and effusive volcanic rocks with rhyolitic, dacitic, and, to a lesser extent, andesitic and basaltic compisition	Rizzotto <i>et al.</i> (2019b)	
		Nova Monte Verde complex		1.81–1.76	granulitic-migmatitic gneissic rocks		
		Juruena supersuite	Zé do Torno suite	1.81–1.75	granitic rocks		
			Teodósia suite				
Nova Canaã suite							
São Pedro suite							
Paranaíta suite							
Tapajós-Parima	Tapajós Domain	São Marcelo-Cabeça group		1.85	granites, monzogranites, granodiorites, diorites, syenites, rhyolites, rhyodacites, metapelites, metaconglomerates, metagreywackes, metacherts, schists, and quartzites	Silva and Abram (2008)	
		Peixoto de Azevedo Domain	Matupá intrusive suite	1.88–1.86	non-metamorphosed granitic rocks	Rizzotto <i>et al.</i> (2019b); Alves <i>et al.</i> (2020)	
			Guarantã do Norte intrusive suite	1.90–1.89			
			Nhandu intusive suite	1.97–1.95			
			Pé Quente intrusive suite	1.99–1.97			
			Cuiú Cuiú complex	2.04–1.98	tonalitic-granodioritic gneisses, amphibolite, and deformed, metamorphosed granitic rocks		

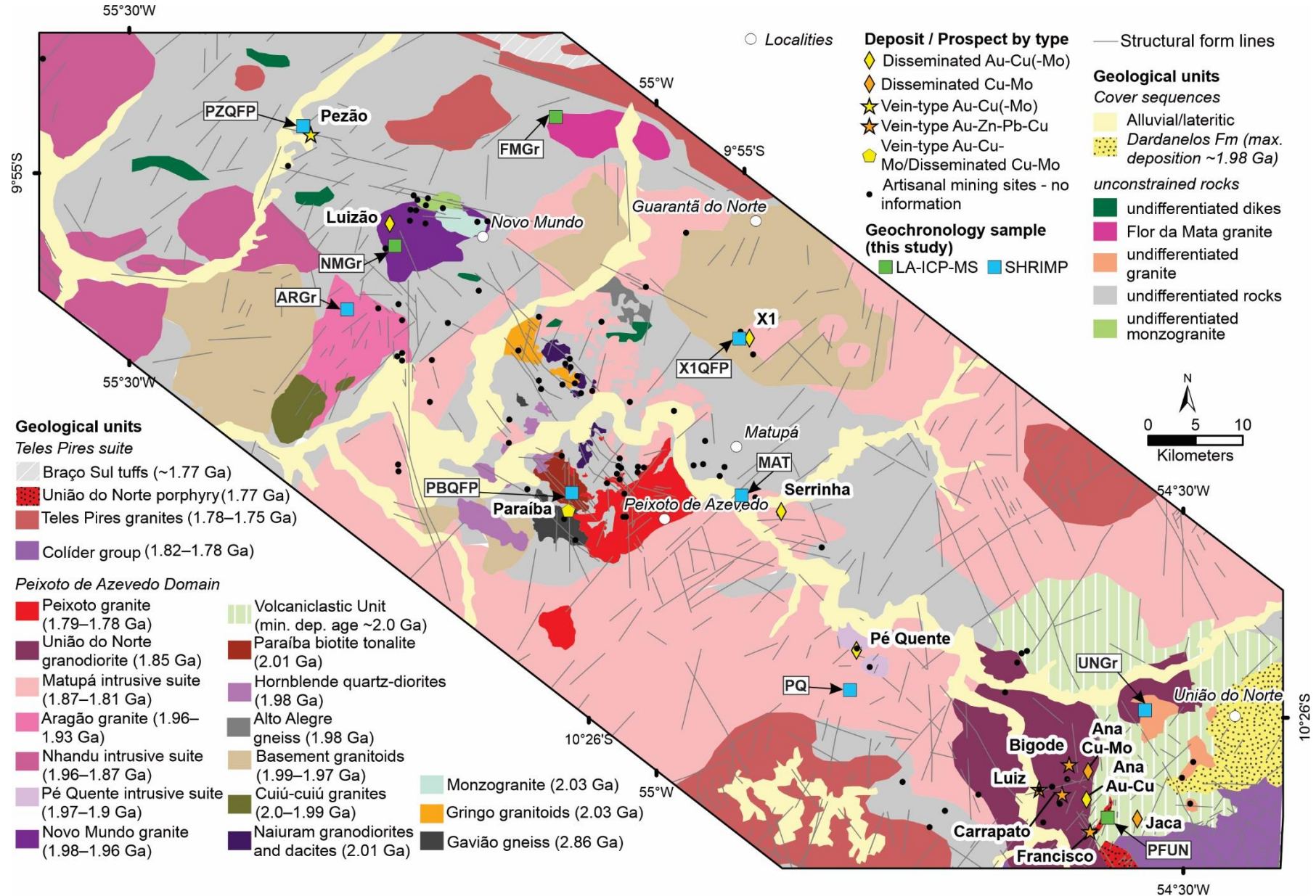


Figure 2. Geological map of the eastern portion of the AFMP (modified from Miguel Jr, 2011; Assis *et al.*, 2017).

Table 2. Detailed information of the geology and compilation of geochronological data across the eastern Alta Floresta Mineral Province.

							Coordinates (WGS 84)		εNd(t)	whole-rock Nd depleted mantle model TDM ages (Ga)	Reference
Domain	Unit	Rock types - Modal composition	Lithogeochemistry	Age (Ma)	Method	Sample	Lat	Long			
Cover sequences	Alluvial deposits	rock fragments	-	Quaternary	-	-	-	-	-	-	Souza <i>et al.</i> (2005)
	Lateritic covers	laterite	-	Cenozoic	-	-	-	-			Souza <i>et al.</i> (2005)
	Caiabis group - Dardanelos Formation	quartzite, arenite, calystone, conglomerate*	-	1987 ± 4 to 1377 ± 13	Pb-Pb, Zr	TBP10	-10.95	-54.08			Leite and Saes (2003)
Unconstrained rocks	undifferentiated dikes	basalt, diorite, gabbro, andesite, dacite	calcic to alkalic, low to high-K, magnesian to ferroan	-	-	-	-	-	-	-	Assis <i>et al.</i> (2014); Medeiros (2016)
	undifferentiated granite	monzogranite, syenogranite, syenite, quartz-monzonite	metaluminous to peraluminous, calc-alkaline to alkaline, medium-K to shoshonitic, magnesian to ferroan, I-type	-	-	-	-	-			Assis (2008)
	Flor da Mata granite	monzogranite	peraluminous to slightly metaluminous, calc-alkaline to alkali-calcic, magnesian, I-type	-	-	-	-	-			Ramos (2011)
	undifferenatiated monzogranite	monzogranite	metaluminous to peraluminous, calc-alkaline, magnesian to ferroan, I-type	-	-	-	-	-			Da Costa Testa (2018)
	undifferentiated rocks	-	-	-	-	-	-	-			-
Teles Pires suite (1.78–1.75 Ga)	Braço Sul tuffs	tuff	-	-	-	-	-	-	-	-	Paes de Barros (2007)
	União do Norte porphyry	porphyritic alkali-feldspar granite*, monzogranite	metaluminous to peraluminous, calc-alkaline to alkali- calcic, high-K, ferroan, A-type	1774 ± 7	U-Pb, LA, Zr	EF-31	-10.53	-54.57			Assis (2011); Miguel-Jr (2011)
	Teles Pires suite	monzogranite	metaluminous to peraluminous, calc-alkaline to alkali- calcic, ferroan, medium to high-K, A-type	1757 ± 16	-	-	-	-			Santos <i>et al.</i> (2000)
		monzogranite		1760 ± 12	-	-	-	-			Silva and Abram (2008)
		leucogranite		1782 ± 17	-	-	-	-			
Colíder group (1.82–1.78 Ga)	Colíder suite	monzogranite	metaluminous to peraluminous (volcanics) or peralkaline to peraluminous (granites), calc-alkalice to alkali-calcic (volcanics) or calc-alakline to alakline (granites), ferroan, high-K to shoshonitic, I to A-type (granites)	1781 ± 8	U-Pb, SHRIMP, Zr	-	-10.88	-55.04	-	-	Pimentel (2001)
		rhyolite		1785 ± 6	-	-	-	-			Silva and Abram (2008)
				1786 ± 14	-	-	-	-			JICA/MMAJ (2001/2002)
				1789 ± 6	-	-	-	-			Saar de Almeida (2017)
				1790 ± 4	-	-	-	-			
		ignimbrite		1792 ± 14	-	-	-	-			Silva <i>et al.</i> (2018)
		rhyolite		1792 ± 8	-	-	-	-			Alves <i>et al.</i> (2013)
		ignimbrite		1800 ± 7	-	-	-	-			Saar de Almeida (2017)

Peixoto de Azevedo Domain (2.86–1.78 Ga)		rhyodacite		1809 ± 6	-	-	-	-			Duarte <i>et al.</i> (2019)
		rhyolite		1810 ± 6	-	-	-	-		Santos <i>et al.</i> (2019)	
		ignimbrite		1823 ± 33	-	-	-	-		Duarte <i>et al.</i> (2019)	
	Peixoto granite	biotite granodiorite	metaluminous to peraluminous, calc-alkaline to alkali-calcic, magnesian, high-K, I-type	1781 ± 10	U-Pb, SHRIMP, Zr	FR02	-10.24	-55.05	-7.63 to +3.09	2.76 to 2.15	Da Silva <i>et al.</i> (2014)
		biotite monzogranite		1792 ± 2	Pb-Pb, Zr	AJ-118	-10.24	-55.05			Paes de Barros (2007)
	União do Norte granodiorite	granodiorite	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, high-K, magnesian to weakly ferroan, I-type	1853 ± 23	U-Pb, LA, Zr	EF-61	-10.57	-54.58			Assis (2011); Miguel-Jr (2011)
	Matupá Intrusive suite	monzogranite	metaluminous to peraluminous, calc-alkaline, magnesian, I-type	1819 ± 6	U-Pb, TIMS, Zr	-	-10.01	-55.01			JICA/MMAJ (2001/2002)
		biotite synoegranite		1837 ± 13	U-Pb, SHRIMP, Zr	-	-	-			Rocha (2016)
				1851 ± 12	U-Pb, SHRIMP, Zr	-	-	-			
		biotite granodiorite (Jorge quarry)		1863 ± 5	U-Pb, SHRIMP, Zr	DOC9-91	-10.22	-54.91			Assis (2015)
		biotite monzogranite		1869 ± 10	U-Pb, SHRIMP, Zr	FR-29	-10.3	-54.96			Da Silva <i>et al.</i> (2014)
		biotite granite		1872 ± 12	Pb-Pb, Zr	-	-10.23	-54.88			Moura (1998)
		biotite synoegranite		1878 ± 7	U-Pb, SHRIMP, Zr	-	-	-			Rocha (2016)
	X1 prospect	quartz-feldspar porphyry	metaluminous to peraluminous, calc-alkaline, magnesian to ferroan, I-type	1773 ± 6	U-Pb, SHRIMP, Zr	A08	-10.07	-54.92			Rodrigues (2012); Assis (2015)
		biotite granodiorite		1904 ± 5	U-Pb, SHRIMP, Zr	SEX1-51	-10.06	-54.91			
	Aragão granite	syeno-monzogranite	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, ferroan, A-type	1931 ± 12	U-Pb, LA, Zr	EF-12	-10.04	-55.26			Vitório (2010); Miguel-Jr (2011)
		granite		1964 ± 11	U-Pb, SHRIMP, Zr	SD-03	-10.09	-55.32			Dezula <i>et al.</i> (2018)
				1967 ± 2	U-Pb, SHRIMP, Zr	SD-05	-10.118	-55.31			
	Nhandu Intrusive suite	biotite granite	metaluminous to peraluminous, calc-alkaline to shoshonite, high-K, magnesian to ferroan, I-type	1879 ± 5	U-Pb, LA, Zr	MA-009-A	-10.06	-55.56			Silva and Abram (2008)
				1889 ± 17	U-Pb, LA, Zr	MA-009	-10.06	-55.56			
		biotite monzogranite		1946 ± 21	U-Pb, SHRIMP, Zr	-	-	-			Rocha (2016)
				1954 ± 4	U-Pb, SHRIMP, Zr	-	-	-			

				1969 ± 7	U-Pb, SHRIMP, Zr	TRBY-08	-9.801	-55.57		
	Luiz prospect	quartz-feldspar porphyry	-	1974 ± 6	U-Pb, SHRIMP, Zr	LZPF	-10.5	-54.62		Trevisan (2015)
		biotite granodiorite	-	> 1974	-	LZH	-10.5	-54.62		
	Pé Quente Intrusive suite	biotite tonalite	metaluminous to peraluminous, calc-alkaline, medium-K, magnesian, I-type	1901 ± 7	U-Pb, SHRIMP, Zr	FD15	-10.36	-54.81		Assis (2015)
		monzonite		1979 ± 31	U-Pb, LA, Zr	EF-19	-10.37	-54.81		Assis (2011); Miguel-Jr (2011)
	Novo Mundo granite	syenogranite	slightly peraluminous, calc-alkaline to alkali-calcic, medium to high-K, magnesian to ferroan, I-type	1964 ± 1	Pb-Pb, Zr	NM15	-9.97	-55.23		Paes de Barros (2007); Trevisan (2012)
		monzogranite		1970 ± 3	Pb-Pb, Zr	AJ33	-9.98	-55.25		Da Costa Testa (2018)
		granite		1987 ± 7	U-Pb, LA, Zr	LN46	-9.95	-55.22		
	Porteira prospect	porphyritic biotite granodiorite	metaluminous, calc-alkaline, I-type	-	-	-	-	-		Oliveira (2017)
		biotite monzogranite (Porteira prospect)		1875 ± 13	U-Pb, LA, Zr	PO-10	-10.24	-55.02		
		hornblende-biotite monzogranite		1982 ± 8	U-Pb, LA, Zr	P20-48,60	-10.24	-55.02		
	Pezão prospect	quartz-feldspar porphyry	-	-	-	-	-	-		Trevisan (2015)
Peixoto de Azevedo Domain (2.86–1.78 Ga)	Pezão prospect	syenogranite	-	1987 ± 4	U-Pb, SHRIMP, Zr	PEH	-9.87	-55.33	-7.63	Trevisan (2015)
	Volcaniclastic unit	feldspathic-wacke*, feldspathic-sandstone, lithic-sandstone, conglomerate	source of fragments: intermediate volcanic rocks	Minimum age: 2009	U-Pb, LA, Zr	GR-50	-	-		Assis (2011); Miguel-Jr (2011)
	Paraíba prospect	porphyritic syenogranite	-	1792 ± 17	U-Pb, LA, Zr	PB-PF	-10.22	-55.08		Trevisan <i>et al.</i> (in prep)
		biotite tonalite	-	2014 ± 5	U-Pb, SHRIMP, Zr	PBH	-10.22	-55.08		Trevisan (2015)
		biotite gneiss	-	-	-	-	-	-		Assis (2015)
	Foliated biotite tonalite	biotite tonalite	peraluminous, calc-alkaline, high-K, magnesian, I-type	1978 ± 8	U-Pb, SHRIMP, Zr	DOC-4-P1	-10.07	-55.44		Assis (2015)
	Nova Guarita monzogranitic gneiss	monzogranitic gneiss	peraluminous, calc-alkaline, high-K, magnesian to ferroan, I-type	1980 ± 9	U-Pb, SHRIMP, Zr	DOC4-P1	-10.16	-55.3		Assis (2015)
	Honblende-quartz diorites	honblende-quartz diorite	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, medium-K, magnesian, I-type	1981 ± 8	U-Pb, LA, Zr	PFS-066	-10.17	-55.13		Quispe (2016)
	Alto Alegre granodioritic gneiss	granodioritic gneiss	-	1984 ± 7	U-Pb, LA, Zr	NM41	-10.04	-55.04		Paes de Barros (2007)
	Cuiú-Cuiú gneisses	granitic*, monzonitic, tonalitic	metaluminous to peraluminous, calc-alkaline, low-K	1992 ± 7	U-Pb, SHRIMP, Zr	CC-02	-10.09	-54.75		Souza <i>et al.</i> (2005)

	Basement granitoids	monzogranite*, granodiorite, tonalite	metaluminous to peraluminous, calc-alkaline to alkali- calcic, low to medium-K, magnesian to ferroan, I-type	1998 ± 1	Pb-Pb, Zr	AJ-76	-10.82	-55.18	to +3.09		Paes de Barros (2007)
	Braço Norte leucogranites	garnet muscovite leucogranite	peraluminous, calc-alkaline to alkali-calcic, high-K, magnesian, I to S-type	2006 ± 7	U-Pb, LA, Zr	PET-002	-10.11	-55.07			Quispe (2016)
	Cuiú-Cuiú granites	monzogranite	metaluminous to slightly peraluminous, calc-alkaline, magnesian to ferroan, I-type	1995 ± 5	U-Pb, SHRIMP, Zr	SD-18	-10.15	-55.33			Dezula <i>et al.</i> (2018)
				2008 ± 4	U-Pb, SHRIMP, Zr	SD-20	-10.15	-55.3			
	Naiuram granodiorites and dacites	foliated hornblende to hornblende-biotite granodiorites, and phyric plagioclase dacites*	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, medium-K, magnesian, I-type	2012 ± 13	U-Pb, LA, Zr	PET-005	-10.06	-55.11			Quispe (2016)
	Monzogranite	anisotropic (compositional banding and foliation), inequigranular to porphyritic monzogranite	peraluminous, calc-alkaline, ferroan	2033 ± 4.3	U-Pb, LA, Zr	LNM25	-9.97	-55.19			Da Costa Testa (2018)
	Gringo granitoids	biotite granite*, porphyritic biotite monzogranite, garnet-biotite granodiorite	peraluminous, calc-alkaline to alkali-calcic, high-K, magnesian to ferroan, I-type	2037 ± 6	U-Pb, LA, Zr	PFS-022	-10.11	-55.07			Quispe (2016)
	Gavião granitic- tonalitic gneiss	granitic-tonalitic gneiss	-	2816 ± 4	Pb-Pb, Zr	PXT101	-10.25	-55.11			Paes de Barros (2007)

*rock type with age and coordinates reported

**LA = LA-ICPMS or LA-MC-ICPMS

***Zr = zircon

Table 3. Summary of the major prospects and deposits of the eastern portion for the Alta Floresta Mineral Province.

Prospect / Deposit		Pé Quente	Luizão	Dionísio	Basílio	Serrinha	Pezão	Ana	Bigode	Francisco	Luiz	Jaca
Geological unit		Pé Quente and Guarantã do Norte intrusive suites	Cuiú-Cuiú complex	Cuiú-Cuiú complex	Cuiú-Cuiú complex	Matupá intrusive suite	Pé Quente and Nhandu intrusive suites	Cuiú-Cuiú complex (?) and Pé Quente intrusive suite (?)	Matupá intrusive suite	Cuiú-Cuiú complex	Pé Quente intrusive suite	Colider group (?)
Host Rock		Leucomonzonite, quartz diorite, (quartz-) monzodiorite, monzogranite, albitite, biotite tonalite and aplitic granodiorite	Syenogranite, monzonite and (biotite-) hornblende syenogranite to tonalite	Hornblende monzogranite to tonalite	Biotite-hornblende granodiorite to tonalite	Equigranular to porphyritic biotite granite to monzogranite (Matupá Intrusive suite)	Syenogranite and quartz-feldspar porphyry	Quartz-feldspar porphyry	Biotite-hornblende granodiorite.	Feldspathic-wake and volcanoclastic lithic-sandstone, besides quartz-feldspar porphyry	Biotite granodiorite and quartz-feldspar porphyry	Quartz-feldspar porphyry
Host rock age (Ma)		1979 ±31Ma (monzonite) and 1901 ± 6.8 Ma (leucomonzonite)	1970 ± 3 Ma (monzogranite) and 1964 ± 1Ma (syenogranite)	-	-	1872 ±12 (monzogranite)	1987 ±4 (syenogranite)	-	1853 ±23 Ma (granodiorite)		1974 ± 6 Ma (quartz-feldspar porphyry)	-
Alteration mineralogy	Proximal	Alb, Kf, Qtz, Hem, Ser, Py	Ser, Chl, Qtz, Py	Ser, Chl, Qtz, Py, Cpy	Ser, Chl, Qtz, Py, Cpy	Ser, Chl, Kf, Qtz, Py	Qtz, Chl, Ser, Py, Cpy	Ser, Qtz, Alb, Bt, Py, Cpy, Mo	Qtz, Ser, Py, Sph, Gn, Cpy	Qtz, Ser, Py, Sph, Gn, Cpy	Ser, Qtz, Chl, Py, Cpy, Sph, Gn	Ser, Bt, Chl, Qtz, Py, Cpy, Mo
	Intermediate	Qtz, Cal, Ser	Alb, Qtz, Kf, Hem	Kf, Hem, Qtz, Cal, Chl	Kf, Hem, Qtz, Cal	Cal	Kf, Qtz, Cal, Qtz	Kf, Qtz, Hem	Kf, Hem, Qtz, Kln	Kf, Hem, Qtz, Kln	Kf, Qtz, Hem	Chl, Ep, Qtz
	Distal	Ep, Czo, Chl, Ser, Kf, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz, Ser	Ep, Czo, Chl, Cal, Qtz	Alb, Kf, Qtz	Kf, Qtz, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Qtz
Mineralization style		Disseminate	Disseminate	Disseminate / vein-type	Disseminate / vein-type	Disseminate	Vein-type	Disseminate	Disseminate	Disseminate / vein-type	Vein-type	Disseminate / vein-type
Ore minerals		Py, Cpy, Gn, Bi-tellurides	Py, Cpy, Sph, Gn	Py, Cpy, Bn, Sph, Cv, Gn	Py, Cpy, Gn, Sph, Bi-tellurides, Hessite	Py, Cpy, Sph, Po, Cbn, Gn	Py, Cpy, Gn, Sph, Bi-tellurides, Hessite, Cv	Py, Cpy, Mo	Py, Sph, Gn, Cpy	Py, Sph, Gn, Dg, Cpy, Bn, Po, Cct	Py, Sph, Gn, Cpy, Brt, Bi-tellurides	Py, Cpy, Mo, Sph, Gn, Cv
Mineralization age (Ma)		1787 ± 5 (pyrite NTIMS Re-Os)	1787 ± 6 (pyrite NTIMS Re-Os)	-	-	-	-	-	-	1779 ± 6 and 1777 ± 6 (sericite ⁴⁰ Ar- ³⁹ Ar)	-	-

Geochemical associations	Au, Cu, Bi, Te, Pb	Au, Cu, Ag, Te	Au,Cu, Pb, Zn	Au, Cu, Pb, Zn, Bi, Te	Au, Cu, Zn, Pb	Au, Cu, Zn, Pb	Cu, Mo	Au, Ag, Zn, Pb	Au, Ag, Zn, Pb, Cd	Au, Zn, Pb, Cu	Cu, Mo
Fluid regime	Coexistence of two-phase aqueous fluids and aqueous-carbonic fluids.	Coexistence of saline aqueous fluids (33,6-37% eq. NaCl) with moderate temperature (Tht= 200 to 280°C) and low salinity aqueous fluids (2,5-15% eq. NaCl) and Tht = 61-185°C.	-	-	Coexistence of high saline aqueous fluids (45-57% eq. NaCl and Tht: 375 to 480 °C) and low salinity aqueous-carbonic fluids (2-11,89% eq. NaCl and Tht = 220-360 °C).	Coexistence of two-phase aqueous and monophasic fluids.	-	-	Low to moderate aqueous fluids (>24% eq. NaCl) with variable filling degree of the vapor phase (10-70%).	Coexistence of two-phase aqueous and monophasic fluids.	-
References	Miguel Júnior (2011); Assis (2011, 2015); Stabile Júnior (2012); Assis <i>et al.</i> (2017)	Assis (2006); Paes de Barros (2007); Assis <i>et al.</i> (2017)	Trevisan (2012)	Trevisan (2012)	Moura <i>et al.</i> (2006)	Trevisan (2015)	Matos <i>et al.</i> (2018)	Assis (2008)	Assis (2008, 2011, 2015)	Trevisan (2015)	Novo (2015)

Abbreviations: Alb-albite, Kf-potassium feldspar, Qtz-quartz, Hem-hematite, Ser-sericite, Chl-chlorite, Bt-biotite, Cal-calcite, Kln-Kaolinite, Czo-clinozoisite, Py-pyrite, Bn-bornite, Cpy-chalcocopyrite, Gn-galena, Sph-sphalerite, Cv-covellite, Po-pyrrhotite, Cbn-cubanite, Mo-molybdenite, Dg-digenite, Cct-chalcocite.

Given the above-described problems, further work on the characterization of the magmas source and evolution, geodynamic settings, along with the investigation of the differences between potentially copper- and/or gold-fertile and barren geological units, are critical to understand the crustal evolution and magma fertility within the Alta Floresta Mineral Province, and thus help industry focus exploration on prospective areas. The availability of an extensive diamond drill core library and a moderate number of exposed intermediate to felsic plutonic and volcanic rocks within the eastern portion of the province, which is the study area of this thesis, provided an opportunity to investigate the crustal evolution and magma fertility of this region.

2. Objectives

The main objective of this thesis is to constrain the crustal evolution and magma fertility potential of the eastern portion of the Alta Floresta Mineral Province. Specific objectives include:

- (1) Reconstruct the chrono-chemical evolution of the magmatism;
- (2) Reinterpret the stratigraphy and establish a novel magmatic framework for the eastern portion of the province;
- (3) Define the geodynamic evolution of this region over time and space;
- (4) Examine whole-rock and zircon chemical compositions as effective tools to characterize copper- and/or gold-ore-related magmas;
- (5) Indicate potential geological units as prospective and non-prospective for copper and/or gold mineralization across the eastern portion of the province.

3. Sampling and analytical methods

Samples for this study were collected across the eastern portion of the Alta Floresta Mineral Province mainly from surface exposures and, subordinately, from drill cores. Additional samples for petrography, geochemistry and geochronology were collected approximately 16 km to the north of the Garantã do Norte town and 7 km to the east of the Colíder town from the Teles Pires suite and Colíder group, respectively.

Analytical methods utilized in this study included:

- Compilation of the existing geochemical and isotopic data available in the region (Manuscripts 1 and 2)

- Petrographic descriptions (Manuscript 1)
- Whole-rock major, minor and trace elements analyses (Manuscripts 1 and 2)
- U-Pb SHRIMP geochronology on zircon (Manuscript 1)
- Laser ICP-MS geochronology on zircon (Manuscript 1)
- Laser ICP-MS trace elements analyses on zircon (Manuscript 2)
- The methods for each of these analyses is described in the respective manuscript.

4. Organization of the thesis

This thesis is presented in the format of two manuscripts:

- Manuscript 1 (Appendix A): “Tectonic switches recorded in a Paleoproterozoic accretionary orogen in the Alta Floresta Mineral Province, southern Amazonian Craton”.
- Manuscript 2 (Appendix B): “Assessments of copper and gold prospectivity in the Paleoproterozoic Alta Floresta Mineral Province, southern Amazonian Craton: magma fertility indicators from whole-rock and zircon geochemistry”.

5. Research summary

The broad topic developed in the thesis has been covered in two scientific manuscripts (Appendix A and B). An overview of the manuscripts is provided below. An additional manuscript with the candidate as a co-author and several abstracts of varied length have been produced during this work for the presentation of partial results in conferences and are presented in appendixes but not discussed here.

The manuscript entitled “Tectonic switches recorded in a Paleoproterozoic accretionary orogeny in the Alta Floresta Mineral Province, southern Amazonian Craton” (Appendix A) covers petrography, whole-rock geochemistry and zircon U-Pb geochronology (SHRIMP and LA-ICP-MS) analyses on the eastern portion of the Alta Floresta Mineral Province. The combined interpretation of the different data revealed a long-lived magmatism (280 Myr) and allowed a reinterpretation of the stratigraphy. It provides constraints for a new geological framework featuring an accretionary orogenic system with tectonic switching that alternates between low-angle subduction and slab-rollback, which has direct implications for the generation of porphyry- and epithermal-style mineralization in this region. Additionally, this study has direct implication for the evolution of the part of southern Amazonian Craton and

for the tectonics operating in the Columbia supercontinent. This manuscript has been submitted to the journal *Precambrian Research* (impact factor 4.4) in October 2020.

The manuscript “Assessments of copper and gold prospectivity in the Paleoproterozoic Alta Floresta Mineral Province, southern Amazonian Craton: magma fertility indicators from whole-rock and zircon geochemistry” (Appendix B) covers the application of whole-rock and zircon geochemistry to assess the copper and/or gold prospectivity of the eastern AFMP geological units. It provides constraints on the oxidation state and water content of the magmas as well as indications of the most favorable tectonic setting for generation and emplacement of the fertile magmas in this region. This study represents the first assessment of magma fertility in Paleoproterozoic rocks and the first investigation that has used zircon compositions to track gold-ore-forming magmas in the literature. This has direct implications for guiding the current and future exploration in the eastern portion of the province as well in other Proterozoic cratonic, underexplored and under-covered areas worldwide. This manuscript will be submitted to the journal *Economic Geology* (impact factor 3.3) in early 2021.

6. Discussion and Conclusions

The thesis outcomes point to a positive contribution to a better understanding of the crustal and geodynamic evolution of the eastern portion of the AFMP, and to the assessment of potential prospective geological units for copper and gold in this region, as follows:

- a) Magmatism in the eastern portion of the Alta Floresta Mineral Province occurred from 2037 to 1757 Ma.
- b) The region evolved within an accretionary orogenic system with tectonic switching that alternates between low-angle subduction and slab-rollback.
- c) Precious- and base-metal porphyry- and epithermal-style systems formed from 1.83-1.75 Ga during crustal extension or relaxation.
- d) The eastern AFMP correlates with the eastward Tapajós Mineral Province and records magmatism of the Western Amazonia Igneous Belt
- e) The evolution of this region and other Proterozoic terranes worldwide suggests that parts of the Columbia supercontinent operated in similar fashion to Phanerozoic Andean-type accretionary orogens.
- f) The whole-rock geochemistry represents an exploration tool with some limitations to assess Cu- and/or Au-prospectivity in search for buried deposits in the

eastern portion of the AFMP. This is due to the strong hydrothermal alteration that affect the rocks across the province.

g) Zircon chemical analyses can be used as an efficient exploration tool to identify geological units potentially fertile for copper and/or gold in this region.

h) The integration of whole-rock and zircon geochemistry with geochronology information is particularly useful to track the tectonic stress regime (e.g. compressive versus non-compressive) over time in the studied region.

i) The zircon geochemistry suggests that the Colíder group and, to a lesser extent, the Matupá and Teles Pires suites are the geological units prospective for Cu and/or Au in the eastern portion of the AFMP. Zircon grains from these three geological units present high-water content represented by $\text{Eu}/\text{Eu}^* > 0.3$, $(\text{Eu}/\text{Eu}^*)/\text{Yb} > 1$ and $(\text{Ce}/\text{Nd})/\text{Y} > 1$, and high oxidation state characterized by FMQ in the range 0 to +3.

j) The periods of crustal extension or relaxation during slab-rollback are the most favorable for copper and gold metallogeny in the eastern portion of the AFMP, in particular the period from ca. 1.83-1.77 Ga.

k) The identification of potentially prospective hydrous and oxidized magmas for Cu and/or Au mineralization across the eastern portion of the AFMP is encouraging and can help guiding current and future exploration for Cu and Au (e.g. porphyry- and epithermal-style deposits) in southern Amazonian Craton.

7. Ongoing research

A research outreach of this Ph.D. thesis is the development of a manuscript using *in-situ* Hf and oxygen isotopes on zircon to further advance on the understanding of the source and crustal evolution of the geological units already investigated in the two manuscripts presented in this thesis. Hf-isotopes are used to differentiate whether magmas are derived from reworked ancient or juvenile crust, while O-isotopes to indicate whether the magma source was derived from mantle melts or recycled crustal components and, moreover, to constrain the nature of these crustal components in the magmas. Secondary ion mass spectrometry (SIMS) at the Centre of Microscopy, Characterization & Analysis – The University of Western Australia (CMCA - UWA) was used to acquire oxygen isotope data from the same sector in the zircons analyzed by SHRIMP in manuscript 1, whereas laser ablation IPC-MS at the School of Earth Sciences (UWA) was used to acquire the Lu-Hf data. The oxygen analyses were performed by the candidate and the Lu-Hf data acquired by Drs. Andreas Petersson and Anthony Kemp. All writing will be performed by the candidate with editing and revisions by

Drs. Anthony Kemp, Andreas Petersson, Laure Martin, and Profs. Roberto Xavier and Steffen Hagemann.

8. Research output

The following summary comprises publications that are immediately related to the current thesis and other production developed by the candidate during her time period as a Ph.D. candidate from 2016 onwards.

Submitted manuscript directly related to Ph.D.

- **Trevisan VG**, Hagemann SG, Loucks RR, Xavier RP, Motta JG, Parra-Avila LA, Petersson A, Gao J-F, Kemp A.I.S, Assis RR. Tectonic switches recorded in a Paleoproterozoic accretionary orogeny in the Alta Floresta Mineral Province, southern Amazonian Craton. Submitted to Precambrian Research (manuscript number PRECAM-D-20-00122) in October 10th, 2020.

Manuscript in preparation directly related to Ph.D.

- **Trevisan VG**, Loucks RR, Hagemann SG, Henríquez GJ, Petersson A, Kemp A.I.S, Xavier RP. Assessments of copper and gold prospectivity in the Paleoproterozoic Alta Floresta Mineral Province, southern Amazonian Craton: magma fertility indicators from whole-rock and zircon geochemistry. To be submitted to the journal Economic Geology in early 2021.

Submitted manuscripts on parallel research topics

- Motta JG, Betts PG, Meira VT, **Trevisan VG**, Souza Filho C.R. Unwrapping reworked crust at the Rodinia supercontinent margin within the Amazonian Craton using satellite potential field data synergy. Submitted to Geophysical Research Letters (manuscript #2020GL087698).

Conference proceedings and posters directly related to Ph.D.

- **Trevisan VG**, Xavier RP, Rodrigues RM, Assis RR, Bartolomeu JO, Matos JHSN, Mesquita MJ. Paleoproterozoic porphyry-related Au $\pm$ Cu ($\pm$ Mo) systems in the Alta Floresta Gold Province, southern Amazonian Craton, Brazil: the case of the X1

and Paraíba deposits. In: 14th SGA Biennial Meeting, 2017, Quebec City. (extended abstract/poster)

- Almeida TN, Mesquita MJ, **Trevisan VG**, Moreira I. 2017. Análise geoquímica das rochas graníticas do setor leste da Província Aurífera de Alta Floresta, MT: caracterização de séries magmáticas e ambientes geotectônicos. In: XXV Congresso Interno de Iniciação Científica da Unicamp, Campinas. Anais do XXV Congresso Interno de Iniciação Científica da Unicamp. (abstract/poster)

- **Trevisan VG**, Xavier RP, Gao JF, Matos JHSN, Assis RR. 2018. Fertility of Paleoproterozoic granites constrained by zircon trace element geochemistry in the Alta Floresta Gold Province, Southern Amazon Craton, Brazil. In: VIII Brazilian Symposium on Mineral Exploration - SIMEXMIN, Ouro Preto. (abstract/poster)

- Matos JHSN, Xavier RP, Santos TJS, **Trevisan VG**. 2018. Paleoproterozoic porphyry-related Cu-Mo and Au-base metal systems of the Alta Floresta Gold Province, Southern Amazon Craton, Brazil. In: VIII Brazilian Symposium on Mineral Exploration - SIMEXMIN, Ouro Preto. (abstract/poster)

- **Trevisan VG**, Hagemann SG, Kemp AIS, Loucks RR, Gao JF, Xavier RP. 2019. Geology setting and metallogenesis of the Alta Floresta Province, southern Amazon Craton (Brazil). In: 15th SGA Biennial Meeting, 2019, Glasgow, Scotland. (extended abstract/poster)

- **Trevisan VG**, Loucks RR, Hagemann SG, Henriquez GJ, Xavier RP. 2019. Whole-rock geochemistry fingerprints of Paleoproterozoic copper-molybdenum and gold-copper-molybdenum-ore-related magmas in the Alta Floresta Province, Amazon Craton. In: SEG 2019 Conference – South American Metallogeny: Sierra to Craton, 2019, Santiago, Chile. (extended abstract/poster)

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APPENDIXES

APPENDIX A: Manuscript 1 - Tectonic switches recorded in a Paleoproterozoic accretionary orogeny in the Alta Floresta Mineral Province, southern Amazonian Craton (submitted to Precambrian Research)



Veronica Godinho Trevisan <vgtrevisan@gmail.com>

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Tectonic switches recorded in a Paleoproterozoic accretionary orogen in the Alta Floresta Mineral Province, southern Amazonian Craton

Veronica G. Trevisan (vgtrevisan@gmail.com)^{1,*}, Steffen G. Hagemann (steffen.hagemann@uwa.edu.au)^{2,3}; Robert R. Loucks (robert.loucks@uwa.edu.au)²; Roberto P. Xavier (robxav@unicamp.br)¹; João G. Motta (jgmotta@gmail.com)¹; Luis A. Parra-Avila (luis.parraavila@uwa.edu.au)³; Andreas Petersson (andreas.petersson@uwa.edu.au)^{3,4}; Jian-Feng Gao (gaojianfeng@mail.gyig.ac.cn)⁵; Anthony I. S. Kemp (tony.kemp@uwa.edu.au)^{2,3}; Rafael R. Assis (assis.rafael@usp.br)⁶

¹Institute of Geosciences, University of Campinas, São Paulo, Brazil

²Centre for Exploration Targeting, School of Earth Sciences, The University of Western Australia, Crawley, Australia

³School of Earth Sciences, The University of Western Australia, Crawley, Australia

⁴Swedish Museum of Natural History, Stockholm, Sweden

⁵State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, Guizhou, China

⁶Institute of Geosciences, University of São Paulo, São Paulo, Brazil

*corresponding author

Abstract

The Alta Floresta Mineral Province (AFMP), southern Amazonian Craton, experienced extensive magmatic activity from ca. 2.03 to 1.75 Ga in a controversial geodynamic setting. New and pre-existing geological, petrographic, geochemical, and zircon geochronological data show that magmatic rocks in the eastern AFMP comprise three magmatic sequences: 2.03–1.93, 1.90–1.80, and 1.79–1.75 Ga. Earlier magmas had garnet-bearing sources, whereas younger ones were derived from shallower, garnet-free sources. We propose a new, four-stage geological framework, comprising five domains, and featuring an accretionary orogen with tectonic switching that alternates between low-angle subduction and slab-rollback. During low-angle subduction and crustal thickening in stages A (2.03–1.97 Ga) and C (1.90–1.81 Ga), calc-alkalic to alkali-calcic I-type magmatism was produced, whereas alkali-calcic to alkalic A-type magmatism, and localized I-type granites were generated during slab-rollback and crustal extension in stages B (1.96–1.94 Ga) and D (1.83–1.75 Ga). The last stage is associated with precious- and base metal porphyry- and epithermal-style systems. We interpret the eastern

AFMP as a part of and correlated eastward with the 2.03–1.86 Ga Tapajós Domain, and recording 1.85–1.74 Ga magmatism of the Western Amazonia Igneous Belt. Similarities between the AFMP and the Svecofennian orogen (Fennoscandian Shield) suggest that parts of the Columbia supercontinent margins operated in similar fashion to Andean-type accretionary orogens.

Keywords: U–Pb geochronology; Whole-rock geochemistry; Long-lived magmatism; Proterozoic mineral deposits; Columbia supercontinent.

1. Introduction

Accretionary orogens develop at intraoceanic and continental margin convergent plate boundaries, and are grouped into advancing (e.g. Andes) and retreating (e.g. modern western Pacific) types. The former develops when the overriding plate advances towards the downgoing plate, resulting in the formation of foreland fold and thrust belts and crustal thickening. In contrast, the second type forms due to trench rollback, accompanied by intra-arc extension and back-arc basins (Cawood *et al.*, 2009). For some authors, accretionary orogens have been operating for the past 3.2 Ga and possibly earlier, and constrains the commencement of lateral movement of lithospheric plates (Cawood *et al.*, 2009). These orogens have contributed to growth of continental lithosphere by addition of juvenile material to the crust, but also represent sites of continental crust consumption and reworking (Cawood *et al.*, 2009).

Tectonic switching is a geodynamic model (Collins, 2002; Lister and Forster, 2009) that has been proposed as operative in Proterozoic orogens (e.g. accretionary orogens) such as the Svecofennian orogen (Fennoscandian Shield; Hermansson *et al.*, 2008), Gawler Craton and Mount Isa (southern and eastern Australia; Betts *et al.*, 2016), and Birimian terrane (West African Craton; Petersson *et al.*, 2016). This model entails rapid and repeated changes in the tectonic regime and angle of the subducting plate in alternating periods of crustal thickening during low-angle subduction and crustal extension during steep subduction and slab-rollback at convergent margins of accretionary orogens (Collins, 2002). According to Collins (2002), tectonic switching cycles effectively generate continental crust. Additionally, Betts *et al.* (2016) contend that tectonic mode switches enhance mineral endowment and that tectonic switching during the Paleo-Mesoproterozoic transition overlaps with a remarkable period of base-metal and gold mineralization in these settings (e.g. Mount Isa belt, Australia).

Substantial crustal growth is recorded from 2.1 to 1.7 Ga (Cawood and Hawkesworth, 2014) during the construction of the supercontinent Columbia (Rogers and Santosh, 2002). One of its components, Amazonia, records one of the main episodes of Paleoproterozoic continental growth (Zhao *et al.*, 2002, 2004; Kara *et al.*, 2018). In the south of the craton, Orosirian (2.05–1.80 Ga) to Statherian (1.80–1.60 Ga) additions of continental crust and reworking events between ca. 2.03 and 1.75 Ga are recorded in the Alta Floresta Mineral Province (hereafter AFMP; Souza *et al.*, 2005). The AFMP hosts numerous, compositionally heterogeneous acidic intrusions of calc-alkalic to alkali-calcic affinity, acidic to intermediate volcanic rocks, and, to a lesser extent, volcanoclastic rocks and granitic gneisses (Moura *et al.*, 2006; Bettencourt *et al.*, 2016; Scandolaro *et al.*, 2017; Assis *et al.*, 2017; Rizzotto *et al.*, 2019a,b; Santos *et al.*, 2019; Duarte *et al.*, 2019; Alves *et al.*, 2020). Recent studies have indicated the polymetallic potential of the province represented by disseminated and vein-type intrusion-hosted Au-Cu-Mo, Cu-Mo-Au, and Au-Zn-Pb-Cu primary deposits and prospects (Trevisan *et al.*, 2017; Assis *et al.*, 2017). These deposits have been interpreted as Paleoproterozoic porphyry and epithermal-style systems (Moura *et al.*, 2006; Assis *et al.*, 2017), which have attracted attention from the mining industry and scientific community. A similar scenario is recognized in the neighboring Tapajós Mineral Province (Juliani *et al.*, 2002, 2005; Bettencourt *et al.*, 2016), highlighting the mineral potential of Paleoproterozoic magmatic provinces worldwide.

Although geochronological, geochemical, and, to a lesser extent, structural, tectonic, geophysical, and isotopic studies have been carried out across the AFMP, particularly over its eastern portion (Moura *et al.*, 2006; Paes de Barros, 2007; Da Silva *et al.*, 2014; Assis *et al.*, 2017; Dezula *et al.*, 2018; Santos *et al.*, 2019; Rizzotto *et al.*, 2019a; Alves *et al.*, 2020), most of them are focused on specific geological units or mineral deposits, and lack integrative studies combining geochronological and geochemical data. That situation compromises the understanding of the magmatic events, geochemistry, stratigraphy, geological framework, and tectonic evolution of this region over time and space, hampering correlations across the southern Amazonian Craton (e.g. Tapajós Mineral Province) or correlations on a global scale, and has constricted the scope of mineral exploration strategy in the AFMP and adjoining regions.

In this study, we present evidence from field observations and petrographic description along with 76 new whole-rock chemical analyses and 12 U–Pb zircon ages (eight SHRIMP II and four LA-ICP-MS) on the main plutonic and volcanic units within the 2.03–1.75 Ga interval in the eastern AFMP. Furthermore, 310 whole-rock chemical analyses and 75 zircon crystallization ages reported in the literature across this region are compiled and discussed to

address the regional magmatic and tectonic context. We reconstruct the chrono-chemical evolution, reinterpret the stratigraphy, propose a novel geological framework, and provide new insights into the geodynamic evolution of this region. Furthermore, we discuss the implications of our findings relative to the geological evolution of part of the southern Amazonian Craton, and possible connections with other orogens and terranes worldwide during the Columbia supercontinent assembly.

2. Geological setting

2.1 The Amazonian Craton

The craton is a tectonically stable area of approximately 4.5 million km² (Santos *et al.*, 2000) covered in its central part by the Phanerozoic Amazonian Sedimentary Basin (Almeida *et al.*, 1981; Santos *et al.*, 2000). It is bounded by the Andes to the west-northwest, Atlantic Ocean at its northeast limit and Araguaia belt to the south-southeast (Santos *et al.*, 2000; Fig. 1A).

Evolution models based on reconnaissance geochronological, isotopic and geochemical data (Cordani and Brito Neves, 1982; Teixeira *et al.*, 1989; Tassinari and Macambira, 1999; Santos *et al.*, 2000; Cordani and Teixeira, 2007) divide the craton into several, predominantly NW–SE-oriented, geochronological (Tassinari and Macambira, 1999) or tectonic (Santos *et al.*, 2000; Fig. 1A) provinces, which have been interpreted as successive continental accretionary events, followed by granitic magmatism and tectonic reworking from 3.0 to 1.1 Ga (Vasquez *et al.*, 2008). Based on reconnaissance structural, geophysical and geochronology data (Amaral, 1974; Hasui *et al.*, 1993; Costa and Hasui, 1997), it has been argued that thorough reworking along the pre-existing Archean framework occurred during the ca. 2.1 Ga Trans-Amazonian thermo-tectonic event. The entire craton has been tectonically stable since the end of the ca. 1.2–0.9 Ga Grenvillian orogeny (Dall’Agnol *et al.*, 1994).

The AFMP lies in the southern portion of the Amazonian Craton between the ca. 2.03–1.88 Ga Tapajós-Parima and the ca. 1.82–1.54 Ga Rondônia-Juruena tectonic provinces (Santos *et al.*

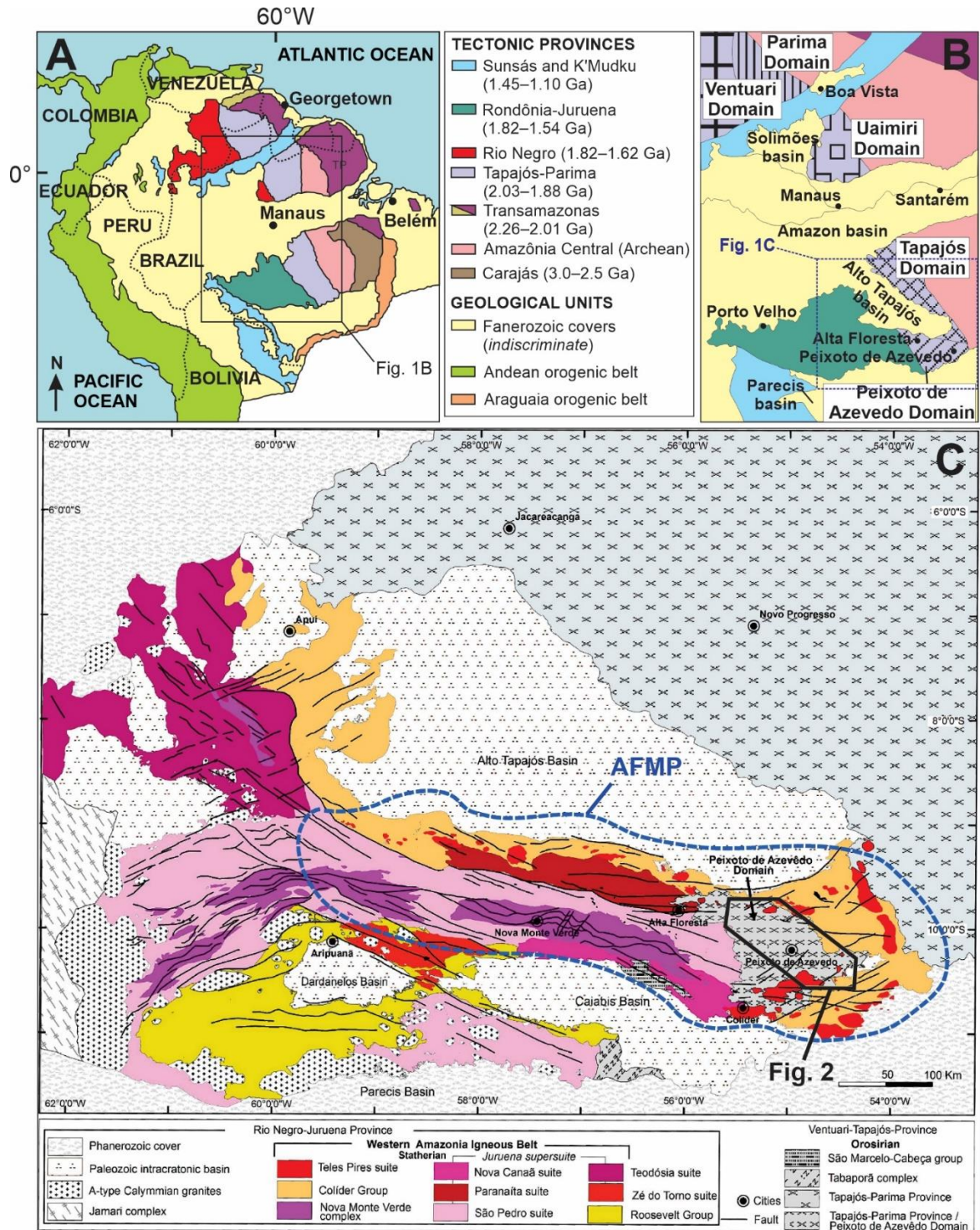


Figure 1. (A) Tectonic provinces of the Amazonian Craton (Santos *et al.*, 2000); (B) Location of the four domains of the Tapajós-Parima tectonic province (modified from Santos *et al.*, 2004); (C) Simplified geological map of the southwestern Amazonian Craton, showing part of the Tapajós-Parima province, Western Amazonia Igneous Belt, and the location of the Alta Floresta Mineral Province (AFMP; modified from Rizzotto *et al.*, 2019b).

al., 2000). The Tapajós-Parima province consists of arc-type sequences that vary in composition from tonalite to granite, volcaniclastic units, porphyry intrusions and, to a lesser extent, gneisses and back-arc sedimentary rocks. This province is divided into four distinctive domains from north to south (Parima, Uaimiri, Tapajós, and Peixoto de Azevedo) separated from each other by three Phanerozoic sedimentary basins (Solimões, Amazon, and Cachimbo/Alto Tapajós; Santos *et al.*, 2004; Santos *et al.*, 2006; Fig. 1B). The Rondônia-Juruena province comprises calc-alkaline arc-type granitoids and volcano-sedimentary sequences (Santos *et al.*, 2006)

2.2 Geological evolution of the southern portion of the Amazonian Craton

The Precambrian evolution of the southern Amazonian Craton is still emerging, given the lack of significant geological data to constrain the limits or existence of the geochronological/tectonic provinces proposed in previous studies (Tassinari and Macambira, 1999; Santos *et al.*, 2000; Cordani and Teixeira, 2007). However, alternative models have emerged mainly in the last decade for the south of the craton based on multidisciplinary data, and are presented below.

The Tapajós Mineral Province, within the Tapajós Domain of the Tapajós-Parima tectonic province (Fig. 1B), and the São Félix do Xingú region, within the Amazonia Central tectonic province (Santos *et al.*, 2000; Fig. 1A), are considered to represent an E–W Andean-type subduction zone with time-varying dip of the oceanic plate (Juliani and Fernandes, 2010; Fernandes *et al.*, 2011, Roverato *et al.*, 2017, 2019; Fernandes and Juliani, 2019). According to Fernandes *et al.* (2011), the subduction angle flattened as the continental arc migrated from south to north until it stabilized, leading to the production of A-type magmas in the back-arc. Geophysical data for the Tapajós Mineral Province were interpreted by Carneiro *et al.* (2019) as featuring deep, regional-scale E–W-oriented crustal structures associated with north-dipping blocks, representing an E–W-trending mobile belt and older magmatic arcs (ancient basement) generated in the southern Amazonian Craton. This deeper framework is cross-cut by shallower NW–SE and NE–SW lineaments interpreted as major brittle faults controlling the emplacement of post-tectonic A-type felsic volcanic and plutonic rocks. That provides support to the Andean-like evolution inferred in previous studies (Juliani and Fernandes, 2010; Fernandes *et al.*, 2011, Roverato *et al.*, 2017, 2019; Fernandes and Juliani, 2019).

Varied tectonic interpretations have been proposed on the basis of interdisciplinary studies in the AFMP, which is separated from the Tapajós Mineral Province to the north by the

Cachimbo graben (or Alto Tapajós basin, [Rizzotto et al., 2019a](#)) and bounded to the south by the Caiabis basin ([Paes de Barros, 2007](#); [Fig. 1C](#)). Some authors propose a succession of continental ([Duarte et al., 2019](#); [Scandolaro et al., 2017](#); [Alves et al., 2020](#)) or island ([Assis et al., 2017](#)) arcs accreted to one another from southwest to northeast of the craton against the southwestern margin of the Archean Amazonia Central tectonic province ([Fig. 1A](#)). In contrast, others ([Neder et al., 2002](#); [Barros et al., 2009](#); [Rizzotto et al., 2019a,b](#)), propose an intraplate extensional environment (or continental rift setting) for the generation of part of the rocks of the southern Amazonian Craton.

2.3 The Alta Floresta Mineral Province

The AFMP ([Fig. 1C](#)) constitutes a belt approximately 500 km long by 100 km wide belt comprising ([Rizzotto et al., 2019b](#)): the 2.8–1.86 Ga Peixoto de Azevedo Domain, the 1.85 Ga São Marcelo-Cabeça group, the 1.81–1.75 Ga Juruena supersuite, the 1.81–1.76 Ga Nova Monte Verde Complex, the 1.81–1.76 Ga Colíder group, the 1.79–1.75 Ga Teles Pires suite, the 1.76–1.74 Ga Roosevelt group, the 1.98–1.37 Ga Caiabis group, and the ca. 0.30 Ga Alto Tapajós basin. The Peixoto de Azevedo Domain and the São Marcelo-Cabeça group are part of the Tapajós Domain within the Tapajós-Parima tectonic province ([Fig. 1A–B](#)), while the Juruena supersuite, Roosevelt, and Caiabis groups belong to the context of the Rondônia-Juruena tectonic province ([Fig. 1A–B](#)). Additionally, the Roosevelt group, Juruena supersuite, Nova Monte Verde Complex, Colíder group, and Teles Pires intrusive suite are collectively denominated Western Amazonia Igneous Belt ([Rizzotto et al., 2019a,b](#)). A summary of these lithostratigraphic units is presented in [Table 1](#).

2.3.1 The Eastern Alta Floresta Mineral Province

The geological framework of the eastern AFMP is separated into five main lithostratigraphic units and has been simplified from [Assis et al. \(2017\)](#) according to new proposals by [Rizzotto et al. \(2019b\)](#) and [Alves et al. \(2020\)](#) into: (i) 2.86–1.78 Ga Peixoto de Azevedo Domain; (ii) 1.82–1.78 Ga Colíder group; (iii) 1.78–1.75 Ga Teles Pires suite; (iv) unconstrained rocks; and (v) 1.98–1.37 Ga Caiabis group (Dardanelos Formation), and Cenozoic sedimentary cover sequences ([Fig. 2](#)). The unconstrained rocks represent poorly documented

Table 1. Summary of the main lithostratigraphic units identified at the Alta Floresta Mineral Province.

Tectonic Province	Domain	Lithostratigraphic Unit		Age (Ga)	Description	Reference
-	-	Alto Tapajós basin (or Cachimbo graben)		Silurian-Devonian	sandstones, siltstones, arkoses, conglomerates, and claystones	Juliani <i>et al.</i> (2014); Toczeck <i>et al.</i> (2019); Alves <i>et al.</i> (2020)
Rondônia-Juruena	Western Amazonian Igneous Belt	Caiabís group (Dardanelos Formation)		1.98–1.37	clastic sediments	Leite and Saes (2003); Alves <i>et al.</i> (2020)
		Roosevelt group		1.76–1.74	mudstone interdigitated with chert, manganeseiferous siltstone, BIFs, tuffs, ignimbrites, volcaniclastic conglomerates, dacites, and rhyolites	Rizzotto <i>et al.</i> (2019b)
		Teles Pires suite		1.79–1.75	granitic rocks	
		Colíder group		1.81–1.76	pyroclastic and effusive volcanic rocks with rhyolitic, dacitic, and, to a lesser extent, andesitic and basaltic compisition	
		Nova Monte Verde complex		1.81–1.76	granulitic-migmatitic gneissic rocks	
		Juruena supersuite	Zé do Torno suite	1.81–1.75	granitic rocks	
			Teodósia suite			
Nova Canaã suite						
	São Pedro suite					
	Paranaíta suite					
Tapajós-Parima	Tapajós Domain	São Marcelo-Cabeça group		1.85	granites, monzogranites, granodiorites, diorites, syenites, rhyolites, rhyodacites, metapelites, metaconglomerates, metagreywackes, metacherts, schists, and quartzites	Silva and Abram (2008)
		Peixoto de Azevedo Domain	Matupá intrusive suite	1.88–1.86	non-metamorphosed granitic rocks	Rizzotto <i>et al.</i> (2019b); Alves <i>et al.</i> (2020)
			Guarantã do Norte intrusive suite	1.90–1.89		
			Nhandu intusive suite	1.97–1.95		
			Pé Quente intrusive suite	1.99–1.97		
			Cuiú Cuiú complex	2.04–1.98	tonalitic-granodioritic gneisses, amphibolite, and deformed, metamorphosed granitic rocks	

areas with reduced or no lithological, geochemical, and/or geochronological information. A detailed outline of the geology along the eastern portion of the AFMP is presented in [Table 2](#).

3. Methods

3.1 Data compilation

In this study, published Pb–Pb and U–Pb (LA-ICP-MPS and SHRIMP) isotopic ages on metamorphic, igneous or detrital zircon from 75 Archean to Mesoproterozoic samples in the eastern AFMP were compiled ([Supplementary Figure SM1; Table 2](#)). Published chemical analyses (whole-rock major, minor, and trace elements) from Paleoproterozoic rocks in the eastern AFMP were compiled (310 samples). Analyses were screened with the following criteria: analyses yielding a SiO₂ content greater than 80 wt.% and/or low Zr values (< 70 ppm) were discarded as unlikely to represent primary igneous compositions. Analyses done by wet-chemical, acid-digestion methods, without prior fusion with Li-borate, do not completely dissolve refractory minerals (e.g. zircon, barite, monazite, sphene, chromite, gahnite, garnet, ilmenite, rutile, cassiterite, magnetite, monazite), REE, and other high-field strength elements ([Act-Labs, 2016](#)), so analyses entailing total-fusion and/or XRF were selected.

3.2 Investigated samples

Samples from various units across the eastern AFMP were selected for hand-specimen and petrographic description as well as geochronological and geochemical analyses. New analyses done in this study are summarized in [Supplementary Table SM1](#), and sample locations are shown in [Supplementary Figure SM2](#).

3.3 Hand-specimen and petrographic descriptions

Hand-specimen description was conducted on 133 samples ([Supplementary Table SM1](#)). Polished thin sections were prepared by GEV Lâminas Delgadas LTDA ME (Brazil) from 44 samples collected from diamond drill holes and outcrops representing the main plutonic-

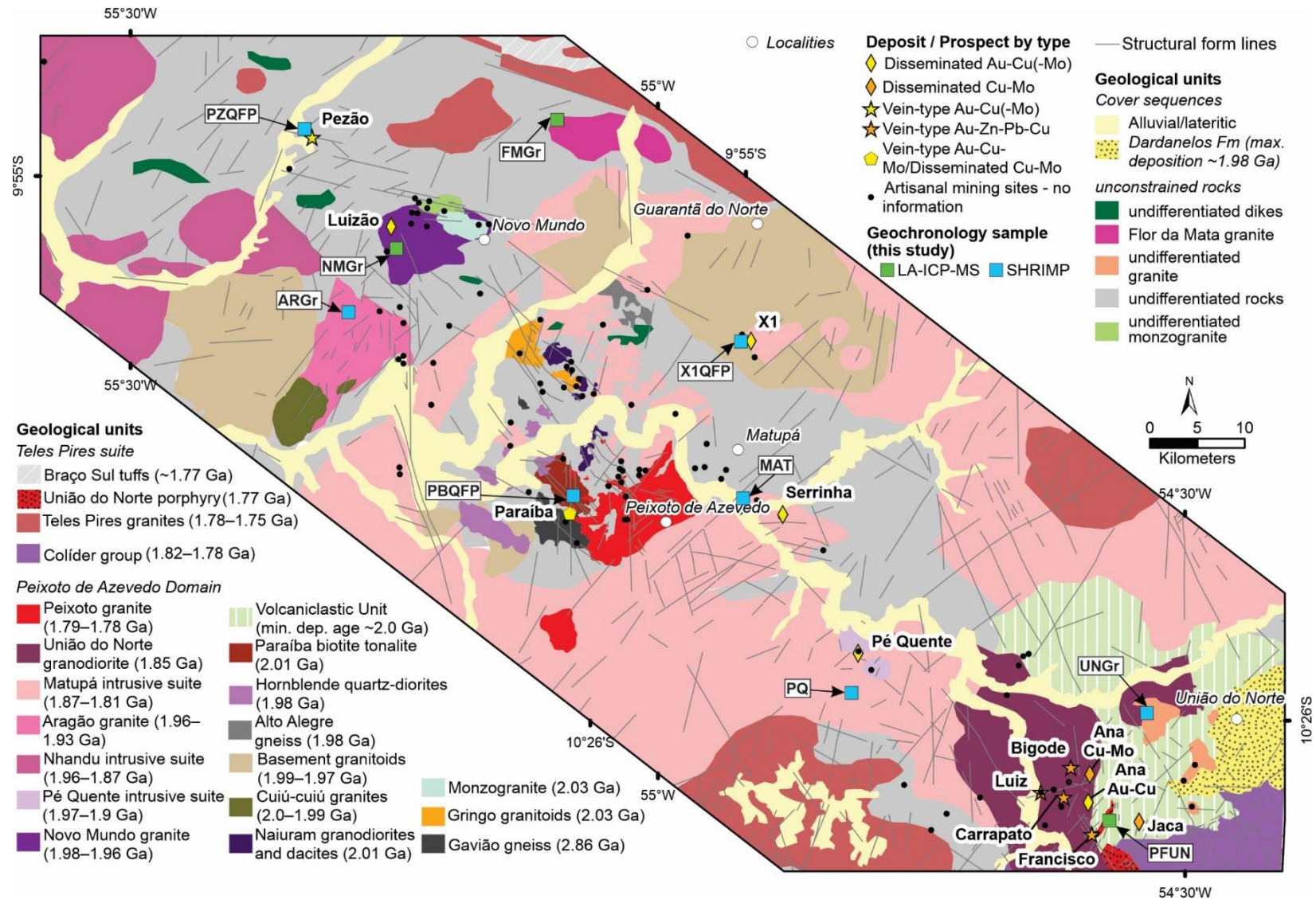


Figure 2. Geological map of the eastern portion of the AFMP (modified from Miguel Jr, 2011; Assis *et al.*, 2017).

Table 2. Detailed information of the geology and compilation of geochronological data across the eastern Alta Floresta Mineral Province.

Domain		Unit	Rock types - Modal composition	Lithogeochemistry	Age (Ma)	Method	Sample	Coordinates (WGS 84)		ε _{Nd(t)}	whole-rock Nd depleted mantle model TDM ages (Ga)	Reference
								Lat	Long			
Cover sequences	Alluvial deposits	rock fragments	-	Quaternary	-	-	-	-	-	-	-	Souza <i>et al.</i> (2005)
	Lateritic covers	laterite	-	Cenozoic	-	-	-	-	-			Souza <i>et al.</i> (2005)
	Caiabís group - Dardanelos Formation	quartzite, arenite, calystone, conglomerate*	-	1987 ± 4 to 1377 ± 13	Pb-Pb, Zr	TBP10	-10.95	-54.08	Leite and Saes (2003)			
Unconstrained rocks	undifferentiated dikes	basalt, diorite, gabbro, andesite, dacite	calcic to alkalic, low to high-K, magnesian to ferroan	-	-	-	-	-	-	-	-	Assis <i>et al.</i> (2014); Medeiros (2016)
	undifferentiated granite	monzogranite, syenogranite, syenite, quartz-monzonite	metaluminous to peraluminous, calc-alkaline to alkaline, medium-K to shoshonitic, magnesian to ferroan, I-type	-	-	-	-	-	-			Assis (2008)
	Flor da Mata granite	monzogranite	peraluminous to slightly metaluminous, calc-alkaline to alkali-calcic, magnesian, I-type	-	-	-	-	-	-			Ramos (2011)
	undifferenatiated monzogranite	monzogranite	metaluminous to peraluminous, calc-alkaline, magnesian to ferroan, I-type	-	-	-	-	-	-			Da Costa Testa (2018)
	undifferentiated rocks	-	-	-	-	-	-	-	-			-
Teles Pires suite (1.78–1.75 Ga)	Braço Sul tuffs	tuff	-	-	-	-	-	-	-	-	-	Paes de Barros (2007)
	União do Norte porphyry	porphyritic alkali-feldspar granite*, monzogranite	metaluminous to peraluminous, calc-alkaline to alkali-calcic, high-K, ferroan, A-type	1774 ± 7	U-Pb, LA, Zr	EF-31	-10.53	-54.57	Assis (2011); Miguel-Jr (2011)			
	Teles Pires suite	monzogranite	metaluminous to peraluminous, calc-alkaline to alkali-calcic, ferroan, medium to high-K, A-type	1757 ± 16	-	-	-	-	-			Santos <i>et al.</i> (2000)
		monzogranite		1760 ± 12	-	-	-	-	-			Silva and Abram (2008)
		leucogranite		1782 ± 17	-	-	-	-	-			
Colíder group (1.82–1.78 Ga)	Colíder suite	monzogranite	metaluminous to peraluminous (volcanics) or peralkaline to peraluminous (granites), calc-alkalics to alkali-calcic (volcanics) or calc-alkaline to alkaline (granites), ferroan, high-K to shoshonitic, I to A-type (granites)	1781 ± 8	U-Pb, SHRIMP, Zr	-	-10.88	-55.04	-	-	Pimentel (2001)	
		rhyolite		1785 ± 6	-	-	-	-			Silva and Abram (2008)	
				1786 ± 14	-	-	-	-			JICA/MMAJ (2001/2002)	
				1789 ± 6	-	-	-	-			Almeida (2017)	
				1790 ± 4	-	-	-	-			Silva <i>et al.</i> (2018)	
				ignimbrite	1792 ± 14	-	-	-			-	
		rhyolite		1792 ± 8	-	-	-	-			Alves <i>et al.</i> (2013)	

		ignimbrite		1800 ± 7	-	-	-	-			Almeida (2017)
		rhyodacite		1809 ± 6	-	-	-	-			Duarte <i>et al.</i> (2019)
		rhyolite		1810 ± 6	-	-	-	-			Santos <i>et al.</i> (2019)
		ignimbrite		1823 ± 33	-	-	-	-			Duarte <i>et al.</i> (2019)
Peixoto de Azevedo Domain (2.86–1.78 Ga)	Peixoto granite	biotite granodiorite	metaluminous to peraluminous, calc-alkaline to alkali-calcic, magnesian, high-K, I-type	1781 ± 10	U-Pb, SHRIMP, Zr	FR02	-10.24	-55.05	-7.63 to +3.09	2.76 to 2.15	Silva <i>et al.</i> (2014)
		biotite monzogranite		1792 ± 2	Pb-Pb, Zr	AJ-118	-10.24	-55.05			Paes de Barros (2007)
	União do Norte granodiorite	granodiorite	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, high-K, magnesian to weakly ferroan, I-type	1853 ± 23	U-Pb, LA, Zr	EF-61	-10.57	-54.58			Assis (2011); Miguel-Jr (2011)
	Matupá Intrusive suite	monzogranite	metaluminous to peraluminous, calc-alkaline, magnesian, I-type	1819 ± 6	U-Pb, TIMS, Zr	-	-10.01	-55.01			JICA/MMAJ (2001/2002)
		biotite synoegranite		1837 ± 13	U-Pb, SHRIMP, Zr	-	-	-			Rocha (2016)
				1851 ± 12	U-Pb, SHRIMP, Zr	-	-	-			
		biotite granodiorite (Jorge quarry)		1863 ± 5	U-Pb, SHRIMP, Zr	DOC9-91	-10.22	-54.91			Assis (2015)
		biotite monzogranite		1869 ± 10	U-Pb, SHRIMP, Zr	FR-29	-10.3	-54.96			Silva <i>et al.</i> (2014)
		biotite granite		1872 ± 12	Pb-Pb, Zr	-	-10.23	-54.88			Moura (1998)
		biotite synoegranite		1878 ± 7	U-Pb, SHRIMP, Zr	-	-	-			Rocha (2016)
				X1 prospect	quartz-feldspar porphyry	metaluminous to peraluminous, calc-alkaline, magnesian to ferroan, I-type	1773 ± 6	U-Pb, SHRIMP, Zr			A08
	biotite granodiorite	1904 ± 5	U-Pb, SHRIMP, Zr		SEX1-51		-10.06	-54.91			Vitório (2010); Miguel-Jr (2011)
	Aragão granite	syeno-monzogranite	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, ferroan, A-type	1931 ± 12	U-Pb, LA, Zr	EF-12	-10.04	-55.26			Dezula <i>et al.</i> (2018)
		granite		1964 ± 11	U-Pb, SHRIMP, Zr	SD-03	-10.09	-55.32			
				1967 ± 2	U-Pb, SHRIMP, Zr	SD-05	-10.118	-55.31			
	Nhandu Intrusive suite	biotite granite	metaluminous to peraluminous, calc-alkaline to shoshonite, high-K, magnesian to ferroan, I-type	1879 ± 5	U-Pb, LA, Zr	MA-009-A	-10.06	-55.56			Silva and Abram (2008)
				1889 ± 17	U-Pb, LA, Zr	MA-009	-10.06	-55.56			
		biotite monzogranite		1946 ± 21	U-Pb, SHRIMP, Zr	-	-	-			Rocha (2016)
				1954 ± 4	U-Pb, SHRIMP, Zr	-	-	-			
				1969 ± 7	U-Pb, SHRIMP, Zr	TRBY-08	-9.801	-55.57			
	Luiz prospect	quartz-feldspar porphyry	-	1974 ± 6	U-Pb, SHRIMP, Zr	LZPF	-10.5	-54.62			Trevisan, 2015
		biotite granodiorite	-	> 1974	-	LZH	-10.5	-54.62			

Peixoto de Azevedo Domain (2.86–1.78 Ga)	Pé Quente Intrusive suite	biotite tonalite	metaluminous to peraluminous, calc-alkaline, medium-K, magnesian, I-type	1901 ± 7	U-Pb, SHRIMP, Zr	FD15	-10.36	-54.81			Assis (2015)
		monzonite		1979 ± 31	U-Pb, LA, Zr	EF-19	-10.37	-54.81			Assis (2011); Miguel-Jr (2011)
		syenogranite	slightly peraluminous, calc-alkaline to alkali-calcic, medium to high-K, magnesian to ferroan, I-type	1964 ± 1	Pb-Pb, Zr	NM15	-9.97	-55.23			Paes de Barros (2007); Trevisan (2012)
		monzogranite		1970 ± 3	Pb-Pb, Zr	AJ33	-9.98	-55.25			Da Costa Testa (2018)
		granite		1987 ± 7	U-Pb, LA, Zr	LN46	-9.95	-55.22			
		porphyritic biotite granodiorite	metaluminous, calc-alkaline, I-type	-	-	-	-	-			Oliveira (2017)
	Porteira prospect	biotite monzogranite (Porteira prospect)		1875 ± 13	U-Pb, LA, Zr	PO-10	-10.24	-55.02	-7.63 to +3.09	2.76 to 2.15	Trevisan (2015)
		hornblend-biotite monzogranite		1982 ± 8	U-Pb, LA, Zr	P20-48,60	-10.24	-55.02			
		quartz-feldspar porphyry	-	-	-	-	-	-			Trevisan (2015)
	Pezão prospect	syenogranite	-	1987 ± 4	U-Pb, SHRIMP, Zr	PEH	-9.87	-55.33			Trevisan (2015)
	Volcaniclastic unit	feldspathic-wacke*, feldspathic-sandstone, lithic-sandstone, conglomerate	source of fragments: intermediate volcanic rocks	Minimum age: 2009	U-Pb, LA, Zr	GR-50	-	-			Assis (2011); Miguel-Jr (2011)
	Paraíba prospect	porphyritic syenogranite	-	1792 ± 17	U-Pb, LA, Zr	PB-PF	-10.22	-55.08			Trevisan <i>et al.</i> (in review)
		biotite tonalite	-	2014 ± 5	U-Pb, SHRIMP, Zr	PBH	-10.22	-55.08			Trevisan (2015)
		biotite gneiss	-	-	-	-	-	-			Assis (2015)
	Foliated biotite tonalite	biotite tonalite	peraluminous, calc-alkaline, high-K, magnesian, I-type	1978 ± 8	U-Pb, SHRIMP, Zr	DOC-4-P1	-10.07	-55.44			Assis (2015)
	Nova Guarita monzogranitic gneiss	monzogranitic gneiss	peraluminous, calc-alkaline, high-K, magnesian to ferroan, I-type	1980 ± 9	U-Pb, SHRIMP, Zr	DOC4-P1	-10.16	-55.3			Quispe (2016)
	Honblende-quartz diorites	honblende-quartz diorite	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, medium-K, magnesian, I-type	1981 ± 8	U-Pb, LA, Zr	PFS-066	-10.17	-55.13			Paes de Barros (2007)
	Alto Alegre granodioritic gneiss	granodioritic gneiss	-	1984 ± 7	U-Pb, LA, Zr	NM41	-10.04	-55.04			Souza <i>et al.</i> (2005)
	Cuiú-Cuiú gneisses	granitic*, monzonitic, tonalitic	metaluminous to peraluminous, calc-alkaline, low-K	1992 ± 7	U-Pb, SHRIMP, Zr	CC-02	-10.09	-54.75			Paes de Barros (2007)
	Basement granitoids	monzogranite*, granodiorite, tonalite	metaluminous to peraluminous, calc-alkaline to alkali-calcic, low to medium-K, magnesian to ferroan, I-type	1998 ± 1	Pb-Pb, Zr	AJ-76	-10.82	-55.18			Quispe (2016)
	Braço Norte leucogranites	garnet muscovite leucogranite	peraluminous, calc-alkaline to alkali-calcic, high-K, magnesian, I to S-type	2006 ± 7	U-Pb, LA, Zr	PET-002	-10.11	-55.07			Dezula <i>et al.</i> (2018)
	Cuiú-Cuiú granites	monzogranite	metaluminous to slightly peraluminous, calc-alkaline, magnesian to ferroan, I-type	1995 ± 5	U-Pb, SHRIMP, Zr	SD-18	-10.15	-55.33			
				2008 ± 4	U-Pb, SHRIMP, Zr	SD-20	-10.15	-55.3			

	Naiuram granodiorites and dacites	foliated hornblende to hornblende-biotite granodiorites, and phyric plagioclase dacites*	metaluminous to slightly peraluminous, calc-alkaline to alkali-calcic, medium-K, magnesian, I-type	2012 ± 13	U-Pb, LA, Zr	PET-005	-10.06	-55.11			Quispe (2016)
	Monzogranite	anisotropic (compositional banding and foliation), inequigranular to porphyritic monzogranite	peraluminous, calc-alkaline, ferroan	2033 ± 4.3	U-Pb, LA, Zr	LMN25	-9.97	-55.19			Da Costa Testa (2018)
	Gringo granitoids	biotite granite*, porphyritic biotite monzogranite, garnet-biotite granodiorite	peraluminous, calc-alkaline to alkali-calcic, high-K, magnesian to ferroan, I-type	2037 ± 6	U-Pb, LA, Zr	PFS-022	-10.11	-55.07			Quispe (2016)
	Gavião granitic-tonalitic gneiss	granitic-tonalitic gneiss	-	2816 ± 4	Pb-Pb, Zr	PXT101	-10.25	-55.11			Paes de Barros (2007)

*rock type with age and coordinates reported

**LA = LA-ICPMS or LA-MC-ICPMS

***Zr = zircon

volcanic units of the eastern AFMP ([Supplementary Table SM1](#)). Petrographic description of thin sections was carried out with transmitted light microscope at the Institute of Geosciences, University of Campinas (UNICAMP), Brazil, and at the School of Earth Sciences, The University of Western Australia (UWA). Rock classification was made based on hand-specimen macroscopic description, and modal proportions of quartz, alkali feldspar, and plagioclase determined from microscopic characterization of thin sections. Some hydrothermally altered specimens of Colíder porphyritic volcanics, Luiz quartz-feldspar porphyry, and Pezão quartz-feldspar porphyry no longer preserve the original igneous texture of the groundmass, which makes ascribing a descriptive name to these samples challenging. For the sake of simplicity, the modal composition of these three rock units are based on phenocrysts, and the rock name established using textural terms.

3.4 Zircon separation and sample processing

Approximately 2-5 kg of rock was crushed, ground, sieved, and panned to obtain a heavy mineral concentrate at the Institute of Geosciences, University of Campinas (UNICAMP), Brazil. At the School of Earth Sciences, The University of Western Australia (UWA), zircon grains from eight samples ([Supplementary Table SM1](#)) were concentrated via magnetic Frantz (isodynamic magnetic separator) and density (LST heavy liquid) separation. Zircon grains from each sample were handpicked, and mounted in three epoxy resin mounts along with standards CUYZ ([A. Kennedy, Personal Communication, 2019](#)), OGC1 ([Stern et al., 2009](#)), TEMORA-2 ([Black et al., 2014](#)) and NIST-610 glass ([Jochum et al., 2011](#)). The epoxy mounts containing the zircon grains were then polished to expose their interiors. After polishing, mounts were imaged using transmitted and reflected light microscopy. Further imaging by secondary electron (SE), back scattered electron (BSE), and cathodoluminescence (CL) methodologies was done to identify internal growth patterns, fractures, and inclusions in order to facilitate selection of analysis spots, using a Vega 3 Tescan Scanning Electron Microscope (SEM-EDS) at the Centre for Microscopy, Characterization and Analysis (CMCA), UWA. See Supplementary Material for additional details of the methodology.

After heavy mineral separation, zircon grains from four samples ([Supplementary Table SM1](#)) were concentrated via magnetic Frantz followed by hand picking. Grains were mounted in epoxy resin disks and polished to expose their interiors. The previously described procedures were conducted at the Institute of Geosciences, University of Campinas, Brazil. At the State Key Laboratory of Ore Deposit Geochemistry (SKLOGD), Institute of Geochemistry, Chinese

Academy of Sciences, the mounts were imaged with transmitted and reflected light using conventional microscope. Further imaging taken in secondary electron (SE), back-scattered electron (BSE), and cathodoluminescence (CL) imaging modes to look for internal growth patterns, fractures, and inclusions in order to facilitate the spot emplacement, were performed using a JSM-7800F Scanning Electron Microscope (SEM-EDS). See Supplementary Material for additional details of the methodology.

3.5 SHRIMP and LA-ICP-MS zircon U–Pb analyses

Zircon U–Pb isotopic analyses were performed on grains from twelve samples of twelve lithostratigraphic units of the eastern AFMP ([Supplementary Table SM1](#)). Analysis of selected zircons from eight samples were conducted using the SHRIMP II B at the John de Laeter Research Centre, Curtin University, Australia. Details of instrument operating conditions are described in [Kennedy and De Laeter \(1994\)](#), and [De Laeter and Kennedy \(1998\)](#). Analytical conditions are described in detail in [Compston *et al.* \(1984\)](#), [Claoué-Long *et al.* \(1995\)](#), [Williams \(1998\)](#), and [Wingate and Kirkland \(2014\)](#). LA-ICP-MS data collection on four samples was performed at the State Key Laboratory of Ore Deposit Geochemistry (SKLOGD), Institute of Geochemistry, Chinese Academy of Sciences (Guiyang), China. Detailed procedures have been described in [Jackson *et al.* \(2004\)](#). See Supplementary Material for additional details of each method. Complete results of the geochronological analyses are reported in [Supplementary Tables SM2 \(SHRIMP\)](#), [SM3 \(LA-ICP-MS\)](#), [SM4 \(SHRIMP standards data\)](#), and [SM5 \(LA-ICP-MS standards data\)](#).

3.6 Whole-rock analysis

Whole-rock chemical analysis for major, minor, and trace elements were conducted on 70 samples from twelve lithostratigraphic units of the eastern AFMP ([Supplementary Table SM1](#)). Samples were screened for having little hydrothermal alteration and weathering overprint, and were free of veins. Of the 75 samples, 37 were collected from outcrops, and 33 from diamond drill cores. All analyses were conducted at the ALS Minerals Global Group laboratory, Canada. Analyses consisted of lithium borate fusion Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) for major element oxides, aqua regia digestion ICP-AES for base metals, and lithium borate fusion Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) for minor and trace elements. See Supplementary Material for additional details of the

methodology. Complete results of the whole-rock geochemistry analyses are reported in [Supplementary Table SM6](#).

4. Results

A compilation of existing geochronological data, coupled with the new U–Pb zircon data presented in this study (section 5.2) indicate a 280-Myr period of magmatic activity from 2037 to 1757 Ma in the eastern AFMP. Three age intervals are identified giving three major peaks of magmatic activity shown in [Figure 3](#). The first magmatic event starts at ~2037 Ma, peaks between 2002 and 1962 Ma, and finishes at ~1931 Ma. After a gap of nearly 27 Myr, magmatism resumes and remains active between 1904 and 1800 Ma. This was followed by a younger pulse of magmatism from 1793 to 1757 Ma characterizing a third magmatic event. The igneous rocks with ages from 2037 to 1931 Ma, 1904 to 1800 Ma, and 1793 to 1757 Ma will be addressed below as the older magmatic sequence (OMS), intermediate age magmatic sequence (IMS), and younger magmatic sequence (YMS), respectively. The units that compose each magmatic sequence are summarized in [Table 3](#).

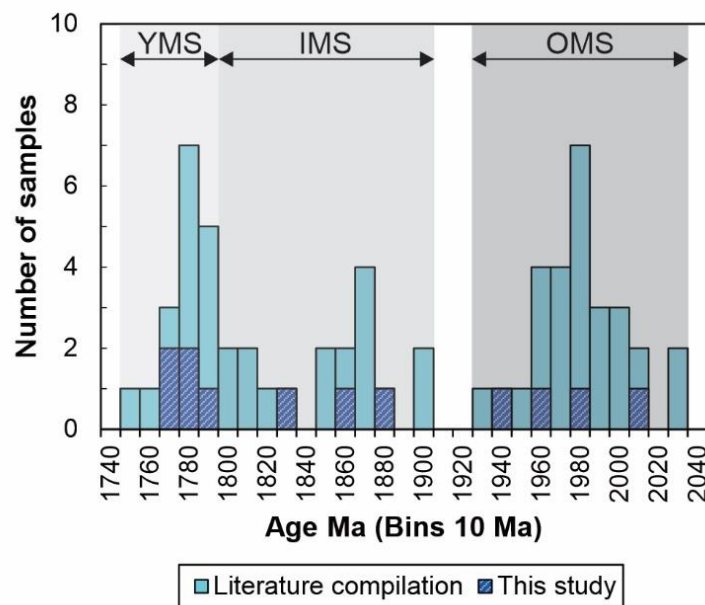


Figure 3. Histogram of crystallization ages for the eastern portion of the AFMP with identification of the older (OMS, 2037-1931 Ga), intermediate age (IMS, 1904-1800 Ga), and younger (YMS, 1793-1757 Ga) magmatic sequences.

Table 3. Lithostratigraphic units composing the older (OMS), intermediate (IMS), and younger (YMS) magmatic sequences of the eastern AFMP.

Magmatic Sequence	Lithostratigraphic Unit
YMS: 1793–1757 Ma	União do Norte quartz-feldspar porphyry
	Paraíba prospect porphyritic syenogranite
	Teles Pires suite rocks
	undifferentiated porphyritic alkali-feldspar granite
	X1 prospect quartz-feldspar porphyry
	Colíder monzogranite
	Peixoto biotite granite
IMS: 1904–1800 Ma	Flor da Mata biotite-hornblende monzogranite
	Colíder porphyritic rhyolite
	Uniao do Norte granodiorite
	Matupá intrusive suite rocks
	X1 prospect biotite granodiorite
	Nhandu biotite granite
	Pé Quente biotite tonalite
OMS: 2037–1931 Ma	Porteira prospect biotite monzogranite
	Pé Quente monzonite
	Aragão granite
	Nhandu biotite monzogranite
	Luiz prospect rocks
	Novo Mundo granite
	Porteira prospect hornblende-biotite monzogranite
	Pezão prospect rocks
	Paraíba prospect biotite tonalite
	Foliated biotite tonalite
	Nova Guarita monzogranitic gneiss
	Hornblende-quartz diorite
	Alto Alegre granodioritic gneiss
	Cuiú-Cuiú granitic gneiss
	Basement granitoids (monzogranite)
	Braço Norte garnet muscovite leucogranite
	Cuiú-Cuiú monzogranite
	Naiuram dacite
	Monzogranite
	Gringo granitoids

4.1 Hand specimen and thin section description

Table 4 summarizes descriptions of hand specimens and thin sections performed in this study. Investigated OMS rocks include the Aragão hornblende-biotite granite, the Novo Mundo biotite granite, the Pé Quente quartz-monzonite, the Paraíba biotite tonalite (occurring in the Paraíba Au-Cu-Mo/Cu-Mo-Au deposit area), the Pezão syenogranite (Pezão Au-Cu prospect), the Luiz quartz-feldspar porphyry (Luiz Au-Zn-Pb-Cu prospect), and the Pezão quartz-feldspar porphyry (Pezão Au-Cu prospect). Studied IMS rocks comprise the Flor da Mata biotite-hornblende monzogranite, the Jorge biotite granodiorite/monzogranite (Matupá intrusive suite), and the Colíder porphyritic volcanics. The studied YMS rocks comprise the undifferentiated porphyritic alkali-feldspar granite, the Teles Pires alkali-feldspar granite, the Paraíba porphyritic granite (Paraíba Au-Cu-Mo/Cu-Mo-Au prospect), and the União do Norte quartz-feldspar porphyry. Hand specimen photos and thin section photomicrographs of these rocks are shown in **Figures 4 and 5**.

Table 4. Hand specimen and thin-section petrographic description summary.

Rock	Field description (hand specimen)	Petrographic description	Figure
OMS (2037–1931 Ma)			
Aragão hornblende-biotite granite	Very fine to very coarse-grained, greyish to reddish, isotropic, holo-leucocratic with inequigranular texture. Felsic minerals include quartz, plagioclase, and microcline. Quartz crystals vary from very fine to medium-grained, whereas feldspars range from very fine to very coarse-grained (up to 1.3 cm). Green biotite and hornblende are the mafic minerals.	Microcline often shows microperthitic texture, and quartz commonly exhibits undulose extinction. Accessory phases are represented by magnetite, titanite, and zircon. Modal count returns a continuum between monzogranite through syenogranite to alkali-feldspar granite composition, with predominant monzogranite. The primary mafic minerals are overprinted by an assemblage of chlorite-titanite-epidote-magnetite, whereas plagioclase, and, to a lesser extent, microcline, are altered into feldspars and muscovite.	4A, B
Novo Mundo biotite granite	Reddish, isotropic to locally anisotropic with a weak foliation, holo-leucocratic with inequigranular and locally porphyritic textures. The phenocrysts comprise about 5% of the rock volume and are represented by sub-euhedral K-feldspar crystals up to 2cm. Biotite represents the main mafic mineral.	The groundmass is very fine to medium-grained (0.01–3 mm) quartz, plagioclase, and microcline. Occasionally, plagioclase exhibits deformation. Accessory minerals include magnetite and zircon. Modal mineralogy of plagioclase-quartz-K feldspar forms a continuum between monzogranite to syenogranite. The primary plagioclase and microcline are overprinted by feldspars and muscovite, and, to a lesser extent, epidote-clinzoisite. The biotite is altered to an assemblage consisting of chlorite-epidote-clinzoisite.	4C, D
Pé Quente quartz-monzonite	Fine to medium-grained (0.2–1 mm), grayish to reddish, isotropic, holo-leucocratic with inequigranular texture. Quartz, plagioclase and microcline represent the felsic minerals.	Accessory phases include magnetite and zircon. The primary plagioclase and microcline are overprinted by feldspar-quartz, muscovite-quartz, and epidote-chlorite-carbonate-quartz assemblages.	4E, F

Paraíba biotite tonalite (Paraíba Au-Cu-Mo/Cu-Mo-Au prospect)	Medium to coarse-grained, whitish to grayish, isotropic to locally anisotropic (weak foliation), holo-leucocratic with inequigranular texture. Microcline (35%), quartz (40%), and plagioclase (20%) represent the felsic minerals. The mafic mineral is characterized by biotite (5%).	Accessory phases include titanite, apatite, zircon, and magnetite. The primary orthoclase, microcline and biotite are commonly overprinted by K-feldspar and/or muscovite. Igneous biotite can also be altered to chlorite.	4G, H
Pezão syenogranite (Pezão Au-Cu prospect)	Fine to coarse-grained, reddish, isotropic, magnetic, holo-leucocratic with inequigranular texture. The main mineral assemblage consists of microcline (55%), quartz (30%), and plagioclase (15%).	Accessory phases comprise zircon and magnetite. Both plagioclase and microcline have been altered to K-feldspar and muscovite.	4I, J
Luiz quartz-feldspar porphyry (Luiz Au-Zn-Pb-Cu prospect)	Reddish, isotropic with a seriate porphyritic texture.	The phenocrysts comprise about 10 to 15% of the rock volume and are represented by euhedral to anhedral plagioclase (up to 7 mm in size) and quartz (0.04–0.3 mm) in an aphanitic microcrystalline and strongly metasomatized groundmass defined by secondary quartz, sericite and pyrite. Undulose extinction is a common feature observed in quartz phenocrysts. Locally, a strong foliation is observed and characterized by preferential orientation of the phenocrysts and groundmass. The primary plagioclase phenocrysts are partially altered to K-feldspar and muscovite. Additionally, late-stage veinlets composed of quartz, quartz-carbonate and/or epidote commonly crosscut the phenocrysts and groundmass.	4K, L
Pezão quartz-feldspar porphyry (Pezão Au-Cu prospect)	Greenish, isotropic with seriate porphyritic texture. The phenocrysts comprise about 10% of the rock volume.	Phenocrysts are defined by sub-euhedral to anhedral 0.06–5 mm plagioclase and 0.04–0.25 mm quartz in an aphanitic and strongly metasomatized groundmass consisting of quartz, muscovite, carbonate, hematite, pyrite, and chalcopyrite. The plagioclase phenocrysts are partly overprinted by feldspars, and muscovite-carbonate.	4M, N

Flor da Mata biotite-hornblende monzogranite	Very fine to very coarse-grained, greenish to reddish, anisotropic, holo-leucocratic with inequigranular texture. Felsic minerals include quartz, plagioclase, and microcline. Mafic minerals are represented by biotite and hornblende.	Quartz crystals vary from very fine to medium-grained and occur as oriented aggregates. Feldspars range from very fine to very coarse grained (up to 1 cm), and plagioclase crystals are occasionally deformed. Accessory minerals include magnetite, titanite, apatite, and zircon. Biotite, hornblende, feldspar and, subordinately, titanite, define a weak foliation together with quartz. The primary mafic minerals are commonly altered to an assemblage consisting of chlorite-quartz-epidote-biotite-magnetite-carbonate, whereas plagioclase, and, to a lesser extent, microcline, are overprinted by feldspars, muscovite, and epidote-clinozoisite.	40, P
Jorge biotite granodiorite/monzogranite (Matupá intrusive suite)	Very fine to very coarse-grained, greyish, isotropic, holo-leucocratic with inequigranular texture. It is mainly composed of felsic minerals represented by quartz, plagioclase and microcline. Biotite represents the main mafic mineralogy. Disseminated fine-grained pyrite is frequently observed along with the main rock-forming minerals. Locally, this rock is crosscut by pegmatites composed of coarse to very coarse-grained K-feldspar and quartz. At places, rhyolite dikes of up to 10 meters height and 150 meters width, intrude the granodiorite/monzogranite with no evidences of contact metamorphism.	Quartz crystals vary from very fine to medium-grained, whereas feldspars range from very fine to very coarse-grained (up to 0.9 mm). Undulose extinction is very common in quartz crystals, and microcline occasionally show microperthitic texture. Biotite is on rare occasions deformed and/or exhibit undulose extinction. Accessory phases are represented by magnetite, zircon and coarse to very coarse-grained titanite. Modal mineralogy of plagioclase-quartz-K feldspar forms a continuum between granodiorite to monzogranite. The primary biotite is altered to an assemblage of chlorite-epidote-magnetite-titanite, where plagioclase and, subordinately, microcline, are overprinted by feldspars and muscovite.	

Colíder porphyritic volcanics	Brownish to grayish, isotropic with a dense seriate porphyritic texture. The phenocrysts comprise about 40 to 50% of the rock volume and are defined by sub-euhedral to anhedral, coarse-grained (up to 9 mm in size) sodic feldspar, plagioclase, magnetite and bipyramidal quartz within an aphanitic groundmass.	Undulose extinction and embayed texture are very common features observed in quartz, whereas spherulitic texture is locally observed in sodic feldspar crystals. The microcrystalline and strongly metasomatized groundmass consists of secondary feldspar, quartz, sericite, epidote and carbonate. These rocks frequently include accessory apatite and zircon. Phenocrysts modal mineralogy suggests a composition varying from andesite, dacite to rhyolite for the Colíder porphyritic volcanics. The plagioclase phenocrysts are partially overprinted by feldspars, muscovite-carbonate, epidote, and chlorite.	5C, D
YMS (1793–1757 Ma)			
undifferentiated porphyritic alkali-feldspar granite	Medium to coarse-grained, reddish, isotropic, holo-leucocratic with seriate porphyritic texture. The phenocrysts comprise about 10% of the rock volume and are represented by sub-euhedral to anhedral (1.1 mm to 1 cm) plagioclase crystals. Locally, the phenocrysts show anti-rapakivi texture defined by plagioclase mantled by potassic feldspar rims.	The groundmass is fine to medium-grained (0.1–5 mm) defined by quartz and K-feldspar. These minerals commonly form micrographic, granophyric, and symplectic textures at the margins of the phenocrysts, and, to a lesser extent, penetrating the phenocrysts. Zircon represent the accessory phase. The primary plagioclase phenocrysts are altered to K-feldspar and muscovite-carbonate, whereas a non-preserved mafic mineral (hornblende? biotite?) is completely overprinted by an assemblage consisting of chlorite-magnetite-carbonate-epidote.	5E, F
Teles Pires alkali-feldspar granite	Reddish, isotropic, holo-leucocratic with inequigranular and locally porphyritic textures. The phenocrysts comprise about 10% of the rock volume and are represented by sub-euhedral, coarse-grained (up to 2 cm in size) K-feldspar crystals in a groundmass of very fine to coarse-grained (up to 1.3 cm) quartz and microcline.	Microcline often shows microperthitic texture, and quartz commonly exhibits undulose extinction. Accessory minerals include magnetite, apatite, zircon and pyrite. Primary microcline is overprinted by an assemblage of feldspar-hematite, whereas the non-preserved mafic mineral (biotite?) is completely altered to chlorite-epidote-magnetite. Fluorite occurs with quartz overprinting the primary igneous minerals.	5G, H

Paraíba porphyritic granite (Paraíba Au-Cu-Mo/Cu-Mo-Au prospect)	Grayish-reddish to greenish, isotropic, holo-leucocratic with inequigranular to porphyritic textures. The phenocrysts comprise about 10–50% of the rock volume and are defined by sub-euhedral, coarse-grained (up to 2cm in size) microcline, orthoclase and bipyramidal quartz crystals in a medium to coarse-grained groundmass of quartz, plagioclase and microcline.	Microperthitic texture is frequently observed in microcline crystals. Accessory minerals include biotite, magnetite, and zircon. Modal mineralogy of plagioclase-quartz-K feldspar forms a continuum between monzogranite and syenogranite. The primary feldspars are overprinted by feldspars, muscovite or epidote-quartz-magnetite, whereas biotite is altered to bluish-purplish (Fe-rich) chlorite. A secondary assemblage consisting of pyrite-chalcopyrite-molybdenite is also observed in a disseminated-style or as late-stage veinlets crosscutting the granite.	5I, J
União do Norte quartz-feldspar porphyry	Reddish, isotropic, leucocratic with inequigranular to seriate porphyritic textures. The phenocrysts comprise about 10% of the rock volume and are defined by anhedral to sub-euhedral, fine to coarse-grained (0.3–5 mm) quartz, alkali-feldspar and plagioclase in a medium to coarse-grained (0.1–5 mm) groundmass of plagioclase (25%), quartz (30%), and K-feldspar (30%). Mafic minerals are represented by magnetite (10%) and biotite (5%).	Micrographic, granophyric, myrmekitic, symplectic, and skeletal textures are observed at the margins of the phenocrysts, and occasionally penetrates them. The primary biotite is overprinted by chlorite, whereas plagioclase altered to K-feldspar.	5K, L

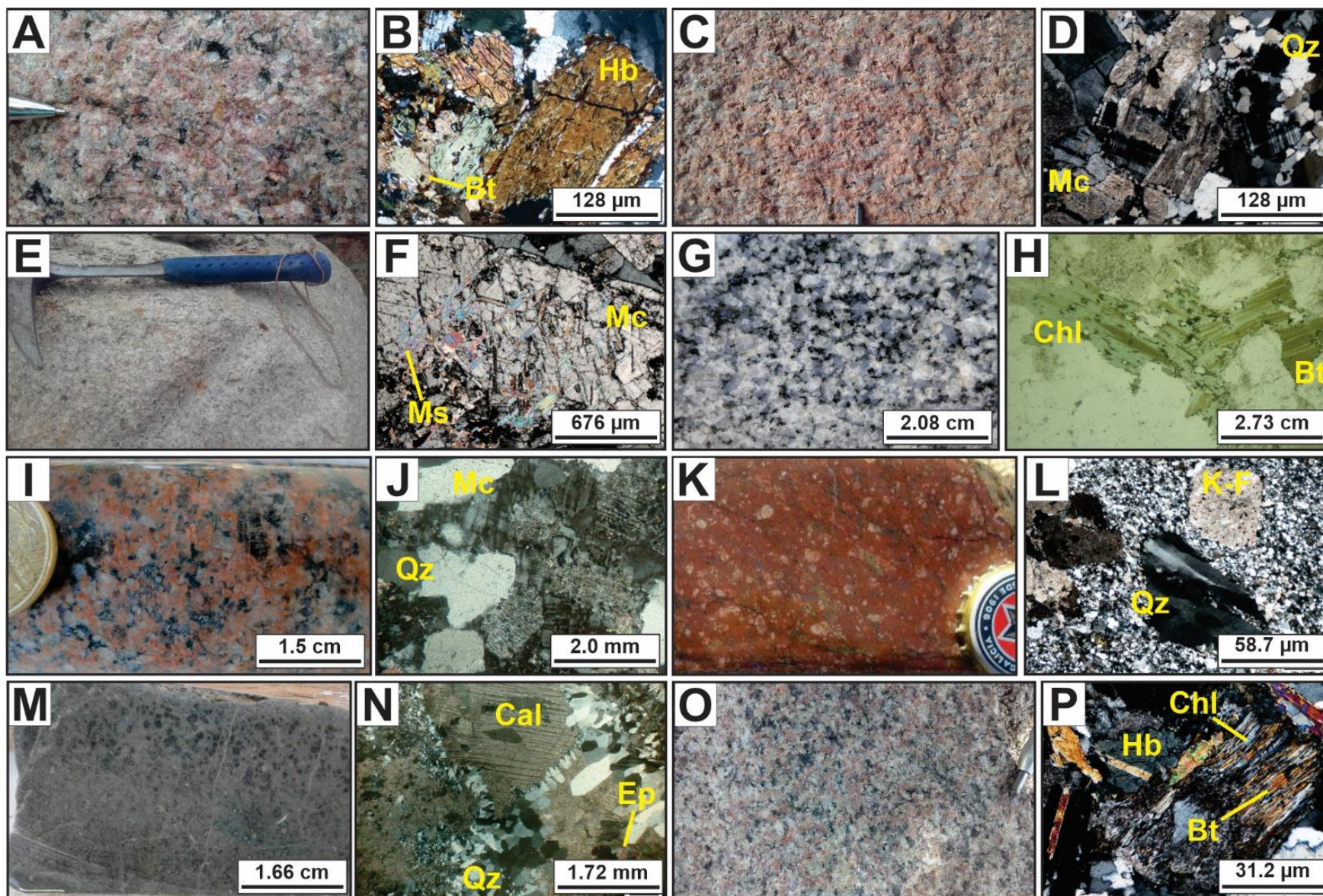


Figure 4. Granitoids rocks samples at the eastern AFMP in hand specimen and thin section (cross-polar light and plain-polar light). (A) Aragão hornblende-biotite granite; (B) Igneous hornblende and biotite in the Aragão granite; (C) Novo Mundo biotite granite; (D) Deformed primary microcline altered to secondary feldspar in the Novo Mundo granite; (E) Pé Quente quartz-monzonite; (F) Igneous plagioclase overprinted by hydrothermal muscovite in the Pé Quente monzonite; (G) Paraíba biotite tonalite; (H) Primary biotite altered to secondary chlorite in the Paraíba tonalite; (I) Pezão syenogranite; (J) Igneous microcline overprinted by hydrothermal sericite in the Pezão syenogranite; (K) Luiz quartz-feldspar porphyry; (L) Porphyritic texture defined by quartz and feldspars phenocrysts in the Luiz quartz-feldspar porphyry; (M) Pezão quartz-feldspar porphyry; (N) Strongly altered phenocrysts in a very-fine grained groundmass in the Pezão quartz-feldspar porphyry; (O) Flor da Mata biotite-hornblende monzogranite; (P) Primary biotite altered to secondary chlorite and igneous hornblende in the Flor da Mata monzogranite. Abbreviations: Hb = hornblende; Bt = biotite; Chl = chlorite; Qz = quartz; Mc = microcline; Ttn = titanite; Ms = muscovite; Plg = plagioclase; K-F = potassium feldspar; Cal = calcite; Ep = epidote.

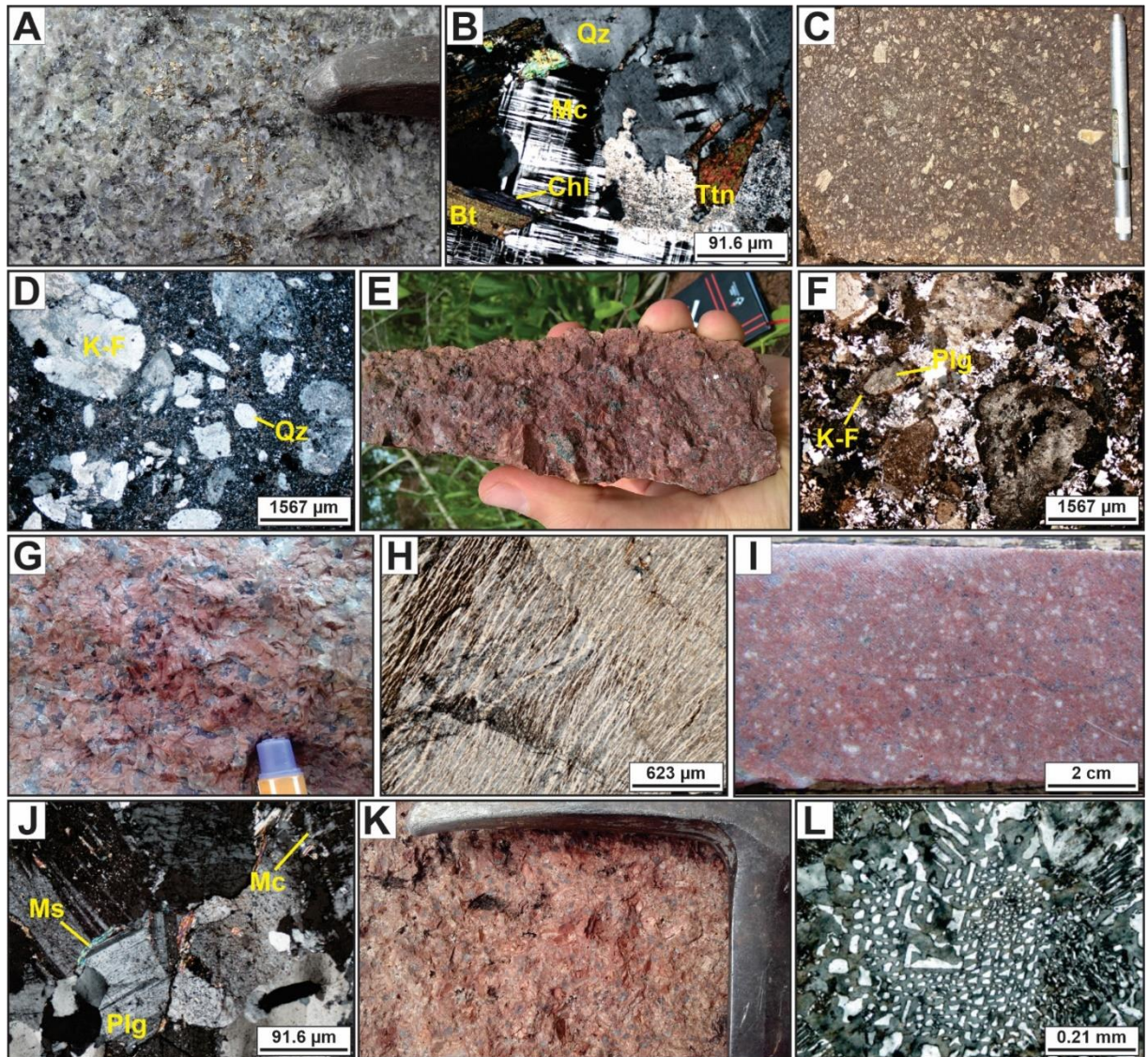


Figure 5. Granitoids and volcanic rocks samples at the eastern AFMP in hand specimen and thin section (cross-polar light and plain-polar light). (A) Jorge biotite granodiorite/monzogranite; (B) Coarse-grained igneous titanite and primary biotite overprinted by hydrothermal chlorite in the Jorge granodiorite/monzogranite; (C) Colíder porphyritic rhyolite; (D) Detail of the porphyritic texture in the Colíder rhyolite. Note quartz with embayed texture; (E) Undifferentiated alkali-feldspar granite near the União do Norte locality in Fig. 2; (F) Porphyritic and anti-rapakivi textures in the undifferentiated granite. Note the micrographic, granophyric and symplectite textures in the groundmass; (G) Teles Pires alkali-feldspar granite; (H) Microperthitic texture in the Teles Pires granite; (I) Paraíba porphyritic granite; (J) Igneous feldspars overprinted by hydrothermal sericite-muscovite in the Paraíba granite; (K) União do Norte quartz-feldspar porphyry; (L) Micrographic texture in the União do Norte quartz-feldspar porphyry. Abbreviations: Hb = hornblende; Bt = biotite; Chl = chlorite; Qz = quartz; Mc =

microcline; Ttn = titanite; Ms = muscovite; Plg = plagioclase; K-F = potassium feldspar; Cal = calcite; Ep = epidote.

4.2 SHRIMP and LA-ICP-MS zircon U–Pb analyses

The geochronological results obtained in this study are summarized in **Table 5**.

Table 5. Synthesis of the U–Pb LA-ICP-MS and SHRIMP II geochronological data obtained in this study. All crystallization ages are $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average.

Sample	UTM coordinates		Elevation (meters)	Mineral	Method	Age (Ma)	MSWD	σ
	North	East						
OMS (2037–1931 Ma)								
NMGr - Novo Mundo biotite granite	8895661	692039	320	Zircon	U–Pb LA-ICP-MS	2013 ± 33	1.5	2
ARGr - Aragão hornblende-biotite granite	8889008	687047	335	Zircon	U–Pb SHRIMP II	1964 ± 9	0.18	2
PQ - Pé Quente quartz-monzonite	8848730	739075	298	Zircon	U–Pb SHRIMP II	1984 ± 16	0.24	2
PZQFP - Pezão quartz-feldspar porphyry	8908246	682586	245	Zircon	U–Pb SHRIMP II	1943 ± 11	0.12	2
IMS (1904–1800 Ma)								
FMGr - Flor da Mata biotite-hornblende monzogranite	8909086	708862	305	Zircon	U–Pb LA-ICP-MS	1887 ± 11	0.47	2
MAT - Jorge biotite granodiorite/monzogranite	8869226	727944	287	Zircon	U–Pb SHRIMP II	1866 ± 10	0.1	2
COL - Colíder porphyritic rhyolite	8802871	675046	335	Zircon	U–Pb SHRIMP II	1834 ± 16	0.055	2
YMS (1793–1757 Ma)								
TPS - Teles Pires alkali-feldspar granite	8909603	732354	283	Zircon	U–Pb LA-ICP-MS	1778 ± 8	0.22	2
PFUN - União do Norte quartz-feldspar porphyry	8835150	765723	322	Zircon	U–Pb LA-ICP-MS	1779 ± 10	0.41	2
UNGr - undifferentiated porphyritic alkali-feldspar granite	8846395	769744	278	Zircon	U–Pb SHRIMP II	1788 ± 14	0.057	2
PBQFP - Paraíba porphyritic granite	8869594	710287	287	Zircon	U–Pb SHRIMP II	1793 ± 9	0.19	2
X1QFP - X1 quartz-feldspar porphyry	8885732	727809	350	Zircon	U–Pb SHRIMP II	1781 ± 7	0.3	2

4.2.1 Sample NMGr – Novo Mundo biotite granite

From 22 mounted zircons, only ten zircons were analyzed, while the remaining grains were unsuitable for analysis (e.g. metamict or fractured). The selected zircons are clear to light brown and prismatic. Most of the analyzed zircons range in length from 85–252 μm with a length to width ratio between 1.3 and 2.1. CL imaging shows rims with oscillatory zoning and recrystallized cores. Grains are strongly fractured and commonly contain mineral inclusions (Fig. 6). Five analysis were discarded from the calculation for large negative discordance, one analysis for high U content (1010 ppm), and one spot is distinctly older (2092 ± 47 Ma; Supplementary Table SM3). Remaining analyses yield a discordia age of 2015 ± 34 Ma ($n = 3$; MSWD = 3.5; Fig. 7A, B) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 2013 ± 33 Ma ($n = 3$; MSWD = 1.5; Fig. 7C; Table 5). Th/U range from 0.46 to 1.12. Given the limited number of zircons available from this sample, the weighted average age is provisional.

4.2.2 Sample ARGr – Aragão hornblende-biotite granite

From a total of 205 mounted zircons, seventeen were selected for analysis. Grains are clear to light brown, prismatic, and with abundant mineral inclusions and fractures. The analyzed zircons ranged in length from 81–172 μm with a length to width ratio of 1.24–1.47. CL imaging show oscillatory and sector zoning although some grains appear to be completely unzoned (Fig. 6). Four analyses were discarded from the calculation due to a combination of recent and ancient Pb-loss associated with $^{207}\text{Pb}/^{206}\text{Pb}$ discordant ages, two analyses are significantly older (1979 ± 12 Ma and 1982 ± 10 Ma), and one analysis for its large positive discordance (+25%; Supplementary Table SM2). Remaining analyses provide a discordia age of 1962 ± 24 Ma ($n = 10$; MSWD = 0.2; Fig. 7D, E) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1962 ± 9 Ma ($n = 10$; MSWD = 0.18; Fig. 7F; Table 5). Th/U range from 0.43 – 1.04.

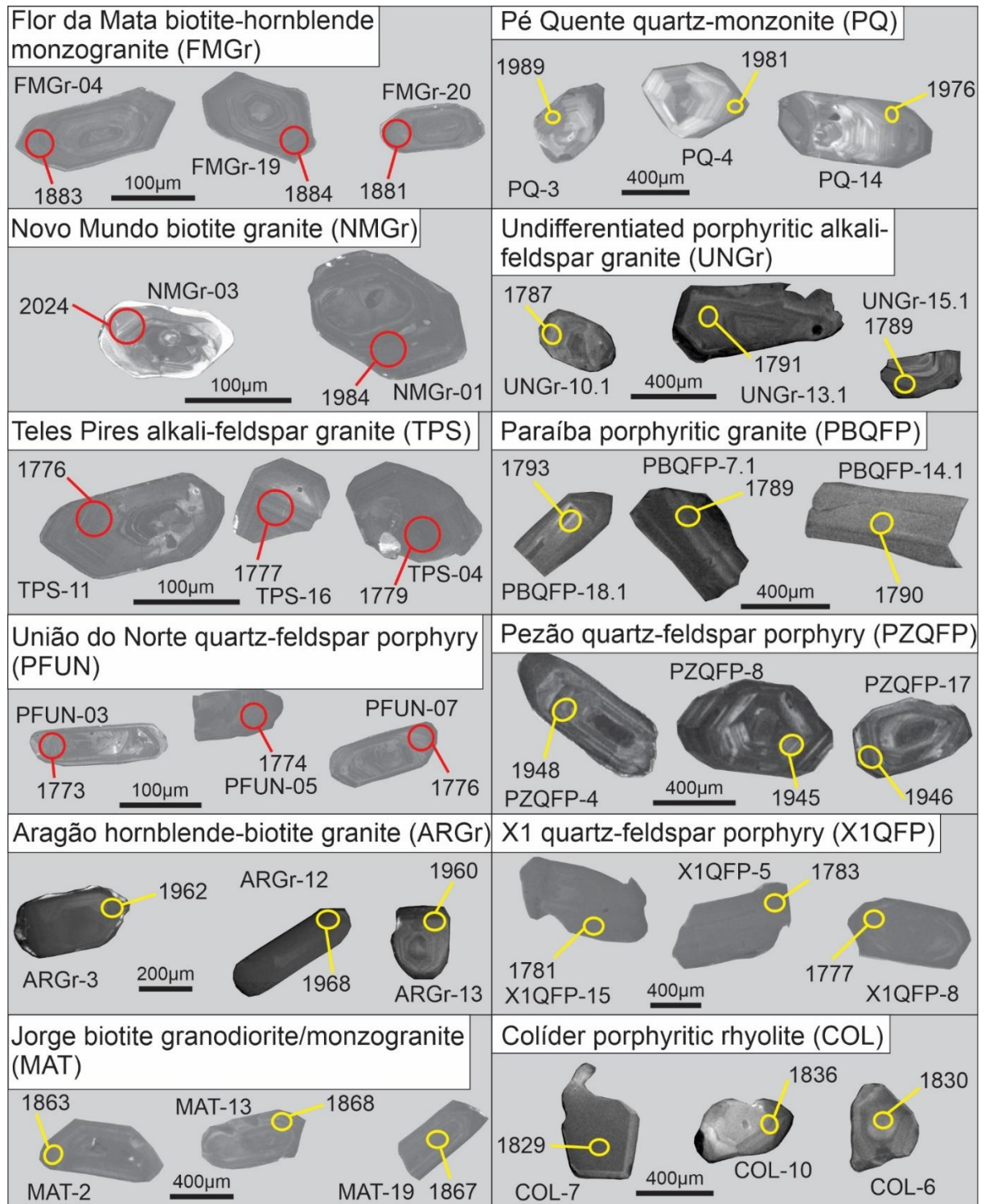


Figure 6. Cathodoluminescence images of zircon grains with individual $^{207}\text{Pb}/^{206}\text{Pb}$ -dates and ion-microprobe/LA-ICP-MS spot location. LA-ICP-MS spot (32 μm) in red, and SHRIMP spot (20 μm) in yellow.

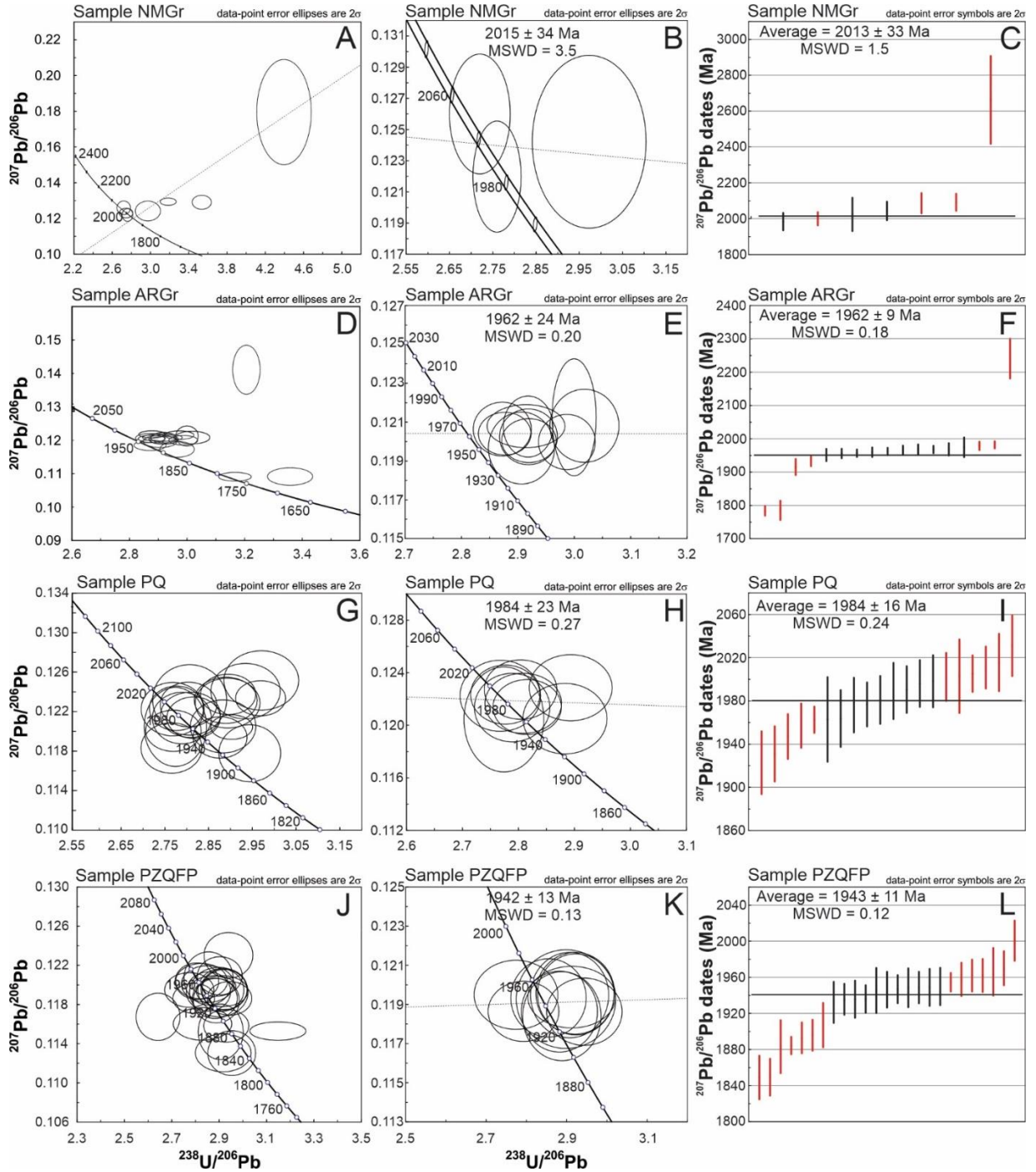


Figure 7. (A-L) Zircon U-Pb Tera-Wasserburg plots of all analyses (left), and analyses used in age calculations (center). $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age plots (right). Red bars denote analyses not used in weighted average age calculations.

4.2.3 Sample PQ - Pé Quente quartz-monzonite

From a total of 193 mounted zircons, twenty were analyzed. Zircons are prismatic, clear to light brown, and locally medium brown. The analyzed zircons range from 134 to 294 μm long

with a length to width ratio between 3.42 and 3.55. Grains have fractures and mineral inclusions. CL imaging shows oscillatory zoning and, occasionally, sector zoning (Fig. 6). Six analyses were discarded from the age calculation because they are distinctly older, ranging from 2002 ± 22 Ma to 2031 ± 28 Ma, three due to a combination of recent and ancient Pb-loss associated with $^{207}\text{Pb}/^{206}\text{Pb}$ discordant ages and two other analyses were discarded for their U-gain (Supplementary Table SM2). Remaining analyses yield a discordia age of 1984 ± 23 Ma ($n = 9$; MSWD = 0.27; Fig. 7G, H) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1984 ± 16 Ma ($n = 9$; MSWD = 0.24; Fig. 7I; Table 5). Th/U range from 0.68 to 1.37.

4.2.4 Sample PZQFP - Pezão quartz-feldspar porphyry (Pezão Au-Cu prospect)

From 147 mounted zircons, 25 were analyzed. The grains are prismatic, clear to light brown, and commonly have fractures and mineral inclusions. The analyzed zircons range from 118 to 269 μm long with a length to ratio between 1.67 and 2.66. CL imaging shows four different internal patterns: oscillatory rim surrounding core with sector zoning; recrystallized core or dark, featureless core; oscillatory zoning across the entire grain; brighter core with oscillatory zoning overgrown by a fine, dark rim; and recrystallized core surrounded by featureless rim (Fig. 6). Analyses discarded from the calculation include: seven spots with significantly older ages (1955 ± 10 Ma, 1958 ± 18 Ma, 1962 ± 18 Ma, 1962 ± 18 Ma, 1966 ± 26 Ma, 1970 ± 19 Ma, and 2001 ± 22 Ma); six spots discarded for their U-gain; and one analysis due to recent Pb-loss associated with a $^{207}\text{Pb}/^{206}\text{Pb}$ discordant age (Supplementary Table SM2). Remaining analyses yield a discordia age of 1942 ± 13 Ma ($n = 11$; MSWD = 0.13; Fig. 7J, K) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1943 ± 11 Ma ($n = 11$; MSWD = 0.12; Fig. 7L; Table 5) with a Th/U from 0.6–2.17.

4.2.5 Sample FMGr – Flor da Mata biotite-hornblende monzogranite

From a total of 110 mounted zircons, 24 were analyzed. Zircons are clear to light brown and prismatic. The analyzed grains range in length from 45–193 μm with a length to width ratio between 1.3 and 2.7. The CL imaging shows: rims with oscillatory zoning and homogeneous cores; brighter cores having oscillatory zoning or homogenous texture overgrown by dark, thin homogeneous rims; and zones of recrystallization (Fig. 6). Grains frequently have mineral inclusions and fractures. Analyses discarded from the calculation include one spot for its uranium content > 1000 ppm (1653 ppm), and six spots with distinctly older ages ranging from

1967 $\pm$ 85 Ma to 2067 $\pm$ 47 Ma (Supplementary Table SM3). Remaining analyses yield a discordia age of 1888 $\pm$ 9 Ma (n = 17; MSWD = 0.49; Fig. 8A, B) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1887 $\pm$ 11 Ma (n = 17; MSWD = 0.47; Fig. 8C; Table 5). Th/U range from 0.49–1.2.

4.2.6 Sample MAT –Jorge biotite granodiorite/monzogranite (Matupá intrusive suite)

From 200 mounted zircons, twenty grains were analyzed. Zircons are light to medium brown and prismatic. The analyzed zircons range in size from 107–227 μm with a length to width ratio between 2.35 and 3.8. CL imaging shows varied internal structures: a core with oscillatory zoning overgrown by dark, fine rim; faint to well-developed oscillatory zoning; and dark, featureless core surrounded by rim with oscillatory zoning. Most grains have fractures and mineral inclusions (Fig. 6). Four analyses were discarded from the age calculation because they are significantly older, ranging from 1882 $\pm$ 15 Ma to 1942 $\pm$ 28 Ma; two analyses were discarded for U-gain and large error associated with the $^{207}\text{Pb}/^{206}\text{Pb}$ age (Supplementary Table SM2). Remaining analyses yield a discordia age of 1868 $\pm$ 16 Ma (n = 14; MSWD = 0.1; Fig. 8D, EL) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1866 $\pm$ 10 Ma (n = 14; MSWD = 0.1; Fig. 8F; Table 5). Th/U is between 1.18 and 2.53.

4.2.7 Sample COL – Colíder porphyritic rhyolite

From 203 mounted zircons, 15 were analyzed. The grains are prismatic, clear to light brown, commonly with mineral inclusions and few fractures. The analyzed grains range in size between 88 and 165 μm with a length to width ratio from 1.03 to 1.72. CL imaging shows some featureless grains, some with sector zoning, and some with faint to well-developed oscillatory zoning (Fig. 6). One analysis was discarded from the age calculation for U-gain, six spots due to a combination of recent and ancient Pb-loss associated with $^{207}\text{Pb}/^{206}\text{Pb}$ discordant ages, and one other discarded analysis considered to be distinctly older (1854 $\pm$ 23 Ma; Supplementary Table SM2). The remaining analyses yield a discordia age of 1845 $\pm$ 66 Ma (n = 7; MSWD = 0.032; Fig. 8G, H) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1834 $\pm$ 16 (n = 7; MSWD = 0.055; Fig. 8I; Table 5) with Th/U between 0.84 and 1.68.

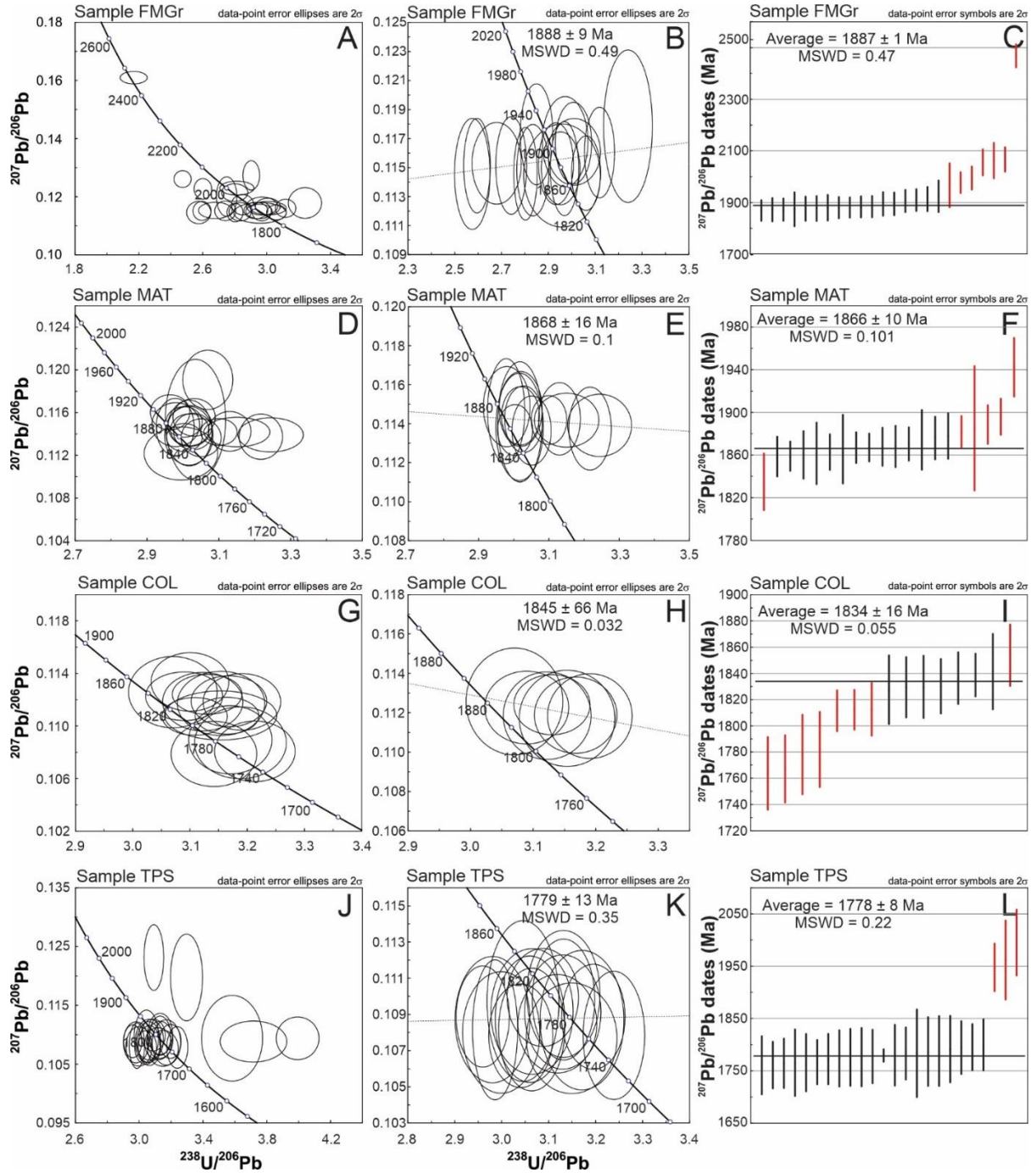


Figure 8. (A-L) Zircon U-Pb Tera-Wasserburg plots of all analyses (left), and analyses used in age calculations (center). $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age plots (right). Red bars denote analyses not used in weighted average age calculations.

4.2.8 Sample TPS - Teles Pires alkali-feldspar granite

From a total of 108 mounted zircons, 24 were analyzed. Zircons are clear to light brown and prismatic. The analyzed grains range in length from 70–195 μm with length to width ratios

between 1.6 and 1.95. Most grains show mineral inclusions and few fractures. CL images show locally recrystallized cores overgrown by rims with oscillatory zoning. In some grains sector zoning is observed (Fig. 6). For the weighted mean age calculation, one analysis was discarded for large negative discordance (-21%), two for significantly older ages (1948 ± 45 Ma and 1995 ± 63 Ma), and three due to recent Pb-loss associated with $^{207}\text{Pb}/^{206}\text{Pb}$ concordant ages (Supplementary Table SM3). Remaining analyses yield a discordia age of 1779 ± 13 Ma ($n = 18$; MSWD = 0.35; Fig. 8J, K) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1778 ± 8 Ma ($n = 21$; MSWD = 0.22; Fig. 8L; Table 5). Th/U is between 0.85 and 1.48.

4.2.9 Sample PFUN – União do Norte quartz-feldspar porphyry

From 97 mounted zircons, 21 were analyzed. Grains are prismatic, colorless to light brown with few fractures and abundant mineral inclusions. The analyzed zircons vary in length from 71 to 205 μm with length to width ratios between 1.32 and 2.04. CL images show rims with oscillatory zoning, and, locally, recrystallized cores. Occasionally, some grains present sector zoning or double core (Fig. 6). One analysis presents large negative discordance (-26%) and three analyses are distinctly older (1991 ± 161 Ma, 1835 ± 61 Ma, and 1861 ± 85 Ma). These analyses were not included in the weighted average age calculation. Additionally, four analyses were discarded for U-gain and three others due to recent Pb-loss associated with $^{207}\text{Pb}/^{206}\text{Pb}$ concordant and discordant ages (Supplementary Table SM3). Remaining analyses yield a concordia age of 1773 ± 9 Ma ($n = 10$; MSWD = 1.15; Fig. 9A, B) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1779 ± 10 Ma ($n = 17$; MSWD = 0.41; Fig. 9C; Table 5). Th/U range from 0.44 to 0.79.

4.2.10 Sample UNGr - Undifferentiated porphyritic alkali-feldspar granite

From 207 mounted zircons, nineteen grains were analyzed. Zircons are prismatic and clear to light brown. The analyzed zircons range in size between 93 and 200 μm with a length to width ratio from 1.58 to 2.24. Grains present mineral inclusions and fractures. CL images show commonly either oscillatory and sector zoning and, locally, a recrystallized core overgrown by a featureless rim (Fig. 6). Six analyses were discarded for Pb-loss, one analysis for large positive discordance (+10%), and other four spots for significantly older ages ranging from 1806 ± 19 Ma to 1831 ± 28 Ma (Supplementary Table SM2). Remaining analyses yield a discordia age of

1788 ± 19 Ma (n = 8; MSWD = 0.066; Fig. 9D, E) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1788 ± 14 Ma (n = 8; MSWD = 0.057; Fig. 9F; Table 5). Th/U is between 0.74 and 1.5.

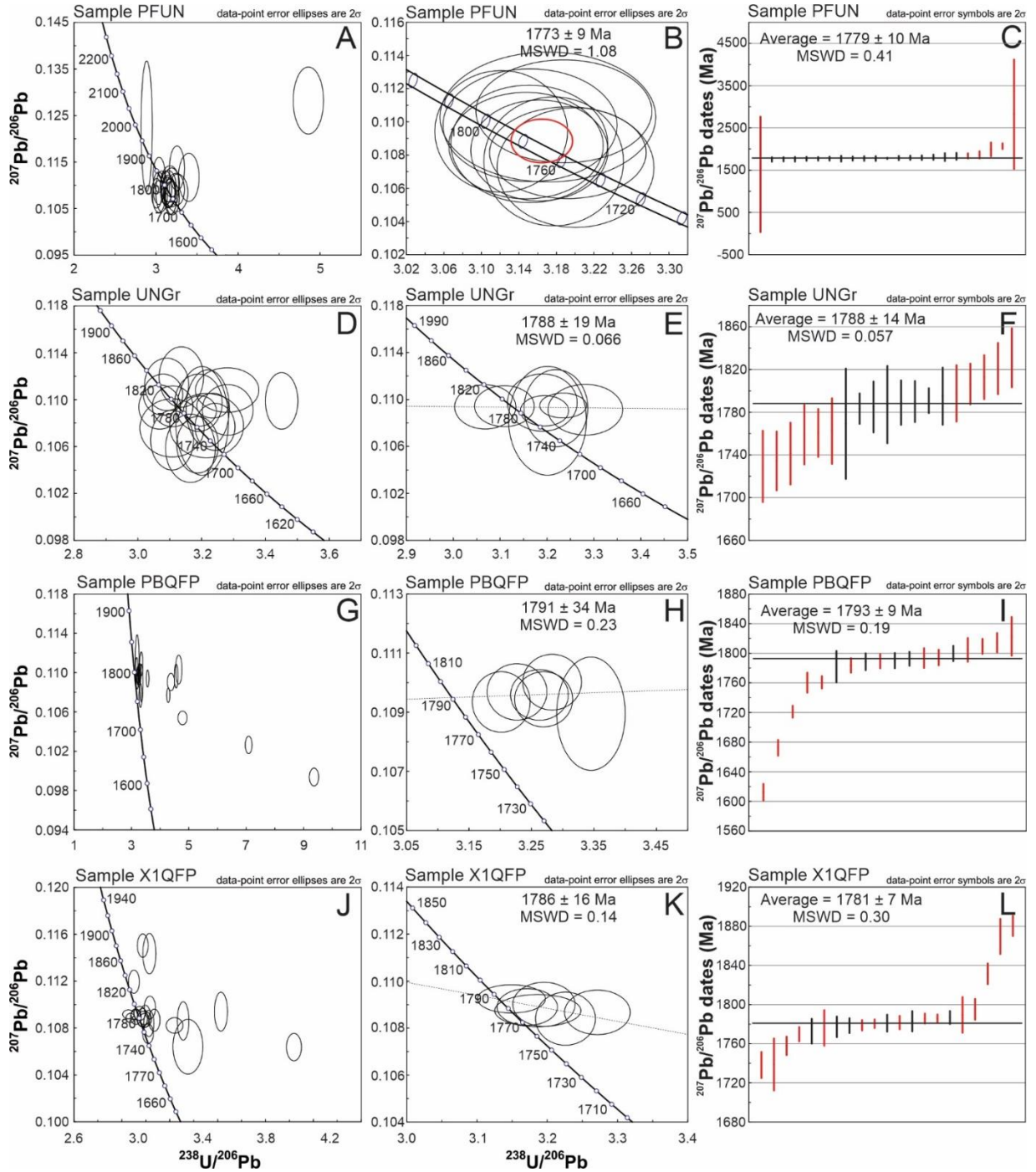


Figure 9. (A-L) Zircon U-Pb Tera-Wasserburg plots of all analyses (left), and analyses used in age calculations (center). $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age plots (right). Red bars denote analyses not used in weighted average age calculations.

4.2.11 Sample PBQFP - Paraíba porphyritic granite (Paraíba Au-Cu-Mo/Cu-Mo prospect)

From a total of 211 mounted zircons, 27 were analyzed. Zircons are medium to dark brown, prismatic, densely fractured and contained few mineral inclusions. The analyzed grains range in size from 71–241 μm with a length to width ratio between 1.51 and 3.04. CL images show: faint oscillatory zoning; some featureless grains; and some having a fine, dark rim surrounding brighter featureless core (Fig. 6). Eight analyses were discarded for large positive discordance, three analyses for distinctly older ages (1809 ± 10 Ma, 1814 ± 13 Ma, and 1823 ± 26 Ma), and one analysis due to recent Pb-loss associated with a $^{207}\text{Pb}/^{206}\text{Pb}$ discordant age (Supplementary Table SM2). The remaining analyses yield a discordia age of 1791 ± 34 (n = 9; MSWD = 0.23; Fig. 9G, H) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1793 ± 5 Ma (n = 12; MSWD = 0.21; Fig. 9I; Table 5) with Th/U between 0.51 and 1.03.

5.2.12 Sample X1QFP – X1 quartz-feldspar porphyry (X1 Au-Cu-Mo prospect)

From a total of 175 mounted zircons, 21 were analyzed. Zircons are dark to medium brown and prismatic. Mineral inclusions and fractures are abundant. The analyzed grains range in length from 78–240 μm with a length to width ratio between 1.23 and 3.16. CL images show featureless grains and, locally, zircons with faint oscillatory zoning or core with faint oscillatory zoning overgrown by a fine, bright, featureless rim (Fig. 6). Five analyses were discarded from the calculation for U content greater than 1000 ppm. Ten other analyses were excluded for large positive discordance, recent Pb-loss associated with $^{207}\text{Pb}/^{206}\text{Pb}$ discordant ages, and/or significantly older ages (1831 ± 11 Ma, 1870 ± 18 Ma, and 1880 ± 10 Ma; Supplementary Table SM2). The remaining analyses provide a discordia age of 1786 ± 16 (n = 6; MSWD = 0.14; Fig. 9J, K) and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age of 1781 ± 7 Ma (n = 6; MSWD = 0.3; Fig. 9L; Table 5) with Th/U between 0.72 and 1.07.

4.3 Whole-rock analyses

The whole-rock chemical results compiled from literature and obtained in this study are summarized in Table 6.

Table 6. Summary of whole-rock major, minor, and trace elements geochemistry results (median values).

Unit		Number of samples	Major, minor (wt.%) and trace (ppm) elements																
			SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI	Total	Ba	Y	Zr	Ga	
Literature	OMS	93	69.61	0.29	14.51	2.40	0.30	0.66	1.35	3.59	4.80	0.21	1.20	100.41	555.50	13.60	153.75	17.70	
	IMS	163	69.80	0.41	14.60	2.84	0.50	0.60	1.71	3.61	4.59	0.21	0.90	100.69	465.00	25.95	178.90	17.85	
	YMS	50	74.65	0.21	13.10	1.76	0.50	0.25	0.55	3.74	5.12	0.20	0.71	100.86	195.00	29.70	156.65	17.25	
	Nhandu quartz-feldspar porphyry (unknown age)	5	65.97	0.30	15.97	2.67	0.63	1.78	2.77	3.39	3.37	0.14	3.57	100.55	444.00	5.50	93.10	19.00	
This study	OMS	Aragão hornblende-biotite granite	6	75.80	0.20	12.23	1.85	0.35	0.37	0.45	3.70	5.24	0.25	0.24	100.50	53.25	27.70	277.00	16.15
		Luiz quartz-feldspar porphyry	5	71.80	0.45	14.00	2.54	0.50	0.88	1.33	4.42	4.20	0.17	0.96	101.10	1495.00	19.00	231.00	17.00
		Novo Mundo biotite granite	4	75.90	0.20	12.50	1.39	0.35	0.26	0.68	3.63	4.92	0.30	0.46	101.15	457.00	24.15	159.00	17.80
		Paraíba biotite tonalite	10	66.00	0.62	15.63	4.87	0.35	1.65	3.54	3.89	2.36	0.20	1.30	99.58	202.00	6.55	206.50	20.35
		Pezão syenogranite	7	68.40	0.41	15.00	2.38	0.70	0.89	1.12	3.74	5.75	0.30	1.57	100.01	166.00	18.90	339.00	17.80
		Pezão quartz-feldspar porphyry	3	56.20	0.35	19.50	3.69	0.47	2.72	2.51	0.80	6.93	0.11	6.94	100.35	788.00	1.20	136.00	21.60
	IMS	Colíder porphyritic rhyolite	5	66.50	0.56	14.10	4.38	0.80	0.79	1.91	3.44	4.89	0.27	1.82	100.86	251.00	26.00	325.00	19.20
		Flor da Mata biotite-hornblende monzogranite	6	72.55	0.20	14.13	1.57	0.40	0.45	1.47	4.22	4.00	0.20	0.62	100.94	50.80	7.65	71.50	18.25
		Jorge biotite granodiorite/monzogranite	4	68.70	0.48	14.75	3.23	0.60	1.04	2.39	3.86	4.42	0.18	0.56	99.30	729.00	23.45	354.00	11.30
	YMS	Paraíba porphyritic granite	9	77.80	0.50	12.70	0.70	0.10	0.50	0.47	3.70	4.94	0.10	0.60	101.77	41.90	28.10	59.00	18.60
		União do Norte quartz-feldspar porphyry	3	76.10	0.11	11.85	2.00	0.20	0.34	0.40	3.37	4.70	0.10	0.69	98.83	54.00	92.80	359.00	22.80
		Teles Pires alkali-feldspar granite	8	75.65	0.26	12.45	1.76	0.30	0.26	0.35	3.95	4.89	0.25	0.36	100.81	146.75	26.70	225.50	19.50

Table 6. (cont.)

Unit		Number of samples	Trace and Rare Earth elements (ppm)																
			Rb	Nb	Cs	Hf	Ta	Pb	Th	U	Sr	Co	La	Ce	Pr	Nd	Sm	Eu	
Literature	OMS	93	82.10	9.70	0.72	4.70	0.60	11.20	8.70	1.55	123.05	2.50	37.65	61.20	6.54	24.90	4.32	0.76	
	IMS	163	135.00	13.10	1.50	5.45	1.11	11.50	14.30	3.42	169.85	3.35	42.20	73.10	9.87	36.80	6.23	1.23	
	YMS	50	149.55	17.10	0.70	4.25	1.10	15.30	17.80	4.50	84.75	1.20	34.40	65.65	7.91	27.25	5.24	0.67	
	Nhandu quartz-feldspar porphyry (unknown age)	5	65.40	2.94	1.56	3.26	0.14	1.99	0.97	0.36	141.00	6.50	7.90	14.20	2.20	8.78	1.79	0.50	
This study	OMS	Aragão hornblende-biotite granite	6	59.65	6.50	0.55	7.75	0.55	13.22	7.80	1.01	35.10	0.44	72.90	145.25	18.08	65.65	11.40	0.79
		Luiz quartz-feldspar porphyry	5	85.30	8.50	1.16	6.10	0.60	5.54	11.15	2.27	241.00	2.45	47.00	87.80	1.95	35.80	5.85	1.35
		Novo Mundo biotite granite	4	97.75	15.95	2.91	4.65	1.45	7.10	20.40	3.05	43.70	1.01	56.90	65.00	7.63	35.20	5.67	0.66
		Paraíba biotite tonalite	10	79.75	5.35	2.00	5.50	0.30	3.36	3.62	1.16	510.00	8.45	23.95	49.35	5.61	19.65	2.70	1.35
		Pezão syenogranite	7	122.50	9.20	0.77	8.60	0.60	1.79	6.24	0.96	162.50	2.61	58.80	92.10	13.60	47.30	7.27	1.24
		Pezão quartz-feldspar porphyry	3	36.00	3.80	2.10	3.70	0.30	1.45	1.49	0.72	7.40	0.54	8.20	18.50	2.43	9.30	2.26	0.41
	IMS	Colíder porphyritic rhyolite	5	123.00	17.00	1.48	5.30	1.00	9.36	14.80	3.66	44.30	4.92	39.80	143.00	16.60	32.60	7.37	1.94
		Flor da Mata biotite-hornblende monzogranite	6	106.40	7.30	0.52	3.20	0.70	7.36	10.85	2.84	492.00	2.67	20.75	27.60	4.29	9.25	2.60	0.61
		Jorge biotite granodiorite/monzogranite	4	145.85	18.00	3.83	6.85	1.30	8.22	16.21	4.02	234.00	6.65	56.95	68.50	16.13	30.55	12.14	1.86
	YMS	Paraíba porphyritic granite	9	186.50	25.60	0.57	3.70	2.4	13.70	17.75	9.91	13.80	0.67	7.70	26.60	3.50	14.50	4.48	0.22
		União do Norte quartz-feldspar porphyry	3	128.50	37.30	1.67	12.90	2.80	24.60	32.00	1.42	21.10	0.51	23.00	117.50	13.85	15.50	1.90	0.16
		Teles Pires alkali-feldspar granite	8	182.50	17.20	0.72	6.30	1.25	9.65	19.25	3.87	55.86	0.74	36.60	45.95	8.68	32.70	4.00	0.96

Table 6. (cont.)

Unit		Number of samples	Rare Earth Elements (ppm) and selected element ratios															
			Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Sr/Y	(La/Yb) _N	Dy/Yb	(Eu/Eu*) _N	ΣLREE	ΣHREE	ΣLREE/ΣHREE	
Literature	OMS	93	3.65	0.52	2.76	0.55	1.71	0.30	1.83	0.35	16.01	14.31	1.71	0.61	156.67	27.28	5.09	
	IMS	163	5.38	0.83	4.61	0.95	2.77	0.46	2.72	0.49	6.70	12.15	1.73	0.66	184.04	35.80	4.64	
	YMS	50	4.80	0.63	4.46	0.69	3.14	0.38	3.46	0.58	3.46	9.45	1.52	0.42	153.69	32.74	5.18	
	Nhandu quartz-feldspar porphyry (unknown age)	5	1.44	0.19	1.50	0.18	0.51	0.80	0.45	0.70	26.31	12.99	3.26	0.92	43.51	27.14	1.55	
This study	OMS	Aragão hornblende-biotite granite	6	7.83	1.09	5.78	1.03	2.95	0.44	2.53	0.37	0.79	23.60	2.29	0.25	334.93	45.43	7.71
		Luiz quartz-feldspar porphyry	5	4.29	0.56	3.66	0.66	1.98	0.27	1.84	0.24	13.46	19.62	1.93	0.82	173.54	29.61	6.11
		Novo Mundo biotite granite	4	4.04	0.63	3.93	0.80	2.56	0.38	2.81	0.47	2.18	14.15	1.36	0.40	203.62	38.91	5.12
		Paraíba biotite tonalite	10	2.16	0.32	1.71	0.34	0.73	0.32	0.76	0.20	51.26	13.44	2.38	1.47	115.87	20.44	4.43
		Pezão syenogranite	7	4.96	0.73	3.47	0.78	2.16	0.30	1.93	0.30	8.60	25.10	2.04	0.63	210.27	31.57	7.98
		Pezão quartz-feldspar porphyry	3	1.92	0.33	1.85	0.33	1.24	0.11	0.93	0.19	6.00	4.32	1.70	0.65	47.53	16.87	2.81
	IMS	Colíder porphyritic rhyolite	5	5.83	1.30	4.45	1.57	4.15	0.68	4.14	0.66	1.59	12.58	1.98	0.85	281.13	67.25	4.20
		Flor da Mata biotite-hornblende monzogranite	6	1.73	0.25	1.56	0.26	0.76	0.14	0.84	0.13	77.42	17.19	1.88	0.88	77.67	12.94	6.03
		Jorge biotite granodiorite/monzogranite	4	8.68	1.22	7.04	1.29	4.15	0.54	3.66	0.49	9.98	13.29	1.98	0.48	295.23	57.98	5.02
	YMS	Paraíba porphyritic granite	9	4.41	0.77	4.95	0.84	2.50	0.38	2.46	0.36	0.51	2.95	1.91	0.15	64.75	39.21	1.76
		União do Norte quartz-feldspar porphyry	3	11.15	2.14	13.50	2.92	9.53	1.52	9.82	1.50	0.18	4.14	1.37	0.12	259.22	136.52	2.26
		Teles Pires alkali-feldspar granite	8	4.49	0.74	4.38	0.92	2.81	0.44	2.92	0.50	2.12	11.24	1.40	0.67	178.27	42.76	4.37

4.3.1 Classification diagrams and characteristics of the magmatic series

According to the R1-R2 chemical variation diagram (De La Roche *et al.*, 1980), the OMS and IMS samples from this study plot in the alkali-feldspar granite, granite, granodiorite, tonalite, and quartz monzonite fields, while the YMS rocks fall in the alkali-feldspar granite and granite fields (Fig. 10A). In the volcanic rock classification diagram of Winchester and Floyd (1977), IMS porphyritic volcanics from the Colíder group fall predominantly into the rhyodacite/dacite, and rhyolite fields (Fig. 10B).

On the basis of K/Rb ratios (Blevin, 2004), samples from all magmatic sequences are strongly evolved ($K/Rb < 200$), except for some OMS and IMS samples with K/Rb ratios within the range of the moderately evolved granitoids (Fig. 10C). In the FeO_t/MgO vs. $Zr+Nb+Ce+Y$ diagram of Whalen *et al.*, (1987), OMS and IMS rocks show similarities with A-Type along with unfractionated M-, I- and S-type granites, whereas most of the YMS samples plot in all fields (Fig. 10D). See Whalen *et al.* (1987) for S-I-A-M classification of granitic rocks.

The samples generally fit into the subalkaline field, but a few OMS samples plot within the alkaline field (e.g. Pezão syenogranite; Fig. 10E; Irvine and Baragar, 1971). On the K_2O vs. SiO_2 diagram (Le Maitre *et al.*, 1989), OMS samples plot within the medium-K to shoshonite series fields, except for one sample (e.g. Paraíba tonalite), while IMS and YMS samples fall predominantly into the high-K calc-alkalic series field. However, the majority of OMS samples fall between the medium to high-K calc-alkalic series fields (Fig. 10F).

In the Modified Alkali-Lime Index (MALI index; Frost *et al.*, 2001), OMS samples are classified as calcic to slightly alkalic, while IMS and YMS samples from this study are predominately calc-alkalic to alkali-calcic (Fig. 10G). In the Th vs. Co discrimination diagram (Hastie *et al.*, 2007), which involve elements of low solubility in hydrothermal fluids (i.e. immobile trace elements), OMS and IMS samples are classified as calc-alkaline to high-K calc-alkaline and shoshonite, whereas YMS samples are predominantly high-k calc-alkaline and shoshonite. A few OMS and IMS samples plot into the island arc tholeiite field (Fig. 10H). Evaluation of the Aluminum Saturation Index (ASI index) shows that most OMS and IMS samples are metaluminous, whereas most YMS samples are peralkaline (Fig. 10I). Moreover, based on the Fe-index diagram, OMS samples are classified as magnesian to ferroan, whereas overall IMS and YMS rocks from this study are predominately ferroan with a few plotting into the magnesian field (Fig. 10J).

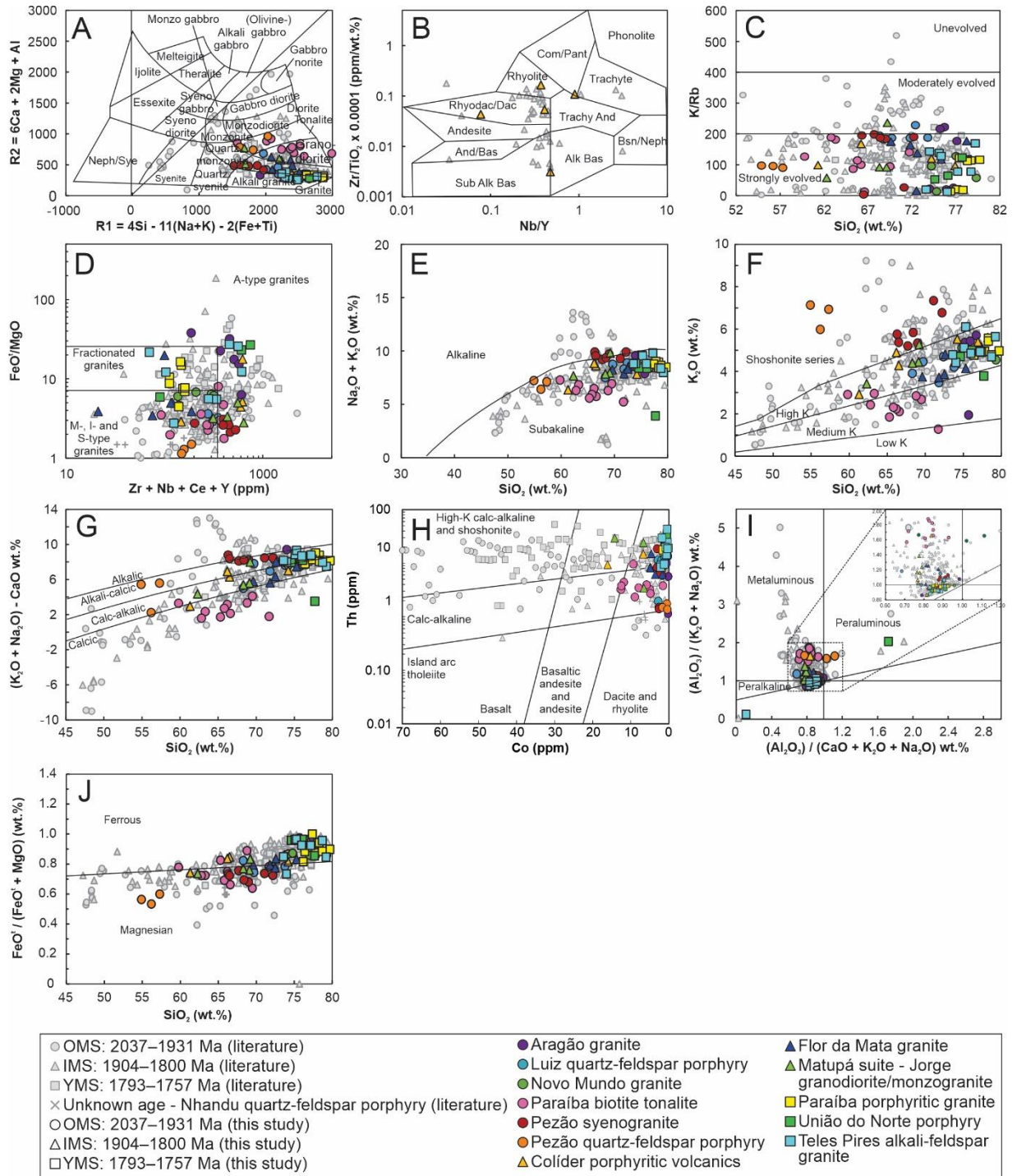


Figure 10. Geochemical classification diagrams showing new data in colors and published data as gray symbols: (A) R1-R2 chemical variation diagram (De La Roche *et al.*, 1980); (B) Plutonic and volcanic rocks classified by Zr/Ti vs. Nb/Y (Winchester and Floyd, 1977); (C) K/Rb vs. SiO₂ (Blevin, 2004); (D) FeO^t/MgO vs. Zr+Nb+Ce+Y (Whalen *et al.*, 1987); (E) (K₂O + Na₂O) vs. SiO₂ (Irvine and Baragar, 1971); (F) K₂O vs. SiO₂ (Le Maitre *et al.*, 1989); (G) Modified Alkali-Lime Index (MALI index; Frost *et al.*, 2001); (H) Th vs Co (Hastie *et al.*, 2007); (I)

Aluminum-saturation index (Frost *et al.*, 2001); (J) $(\text{FeO})^t/(\text{FeO}^t+\text{MgO})$ vs. SiO_2 (Frost *et al.*, 2001).

4.3.2 Major, minor, and trace element variations and normalized diagrams

OMS and IMS samples are intermediate to acid in composition as indicated by their similar SiO_2 content and greater silica value range (59.8–79.3 wt.% and 61.3–78.2 wt.%, respectively), while YMS samples are strictly acid as shown by their higher silica content and narrow SiO_2 value range (73.6–79.7 wt.%; Fig. 11; median values in Table 6).

On Harker diagrams, the chemical variations of major (Fe_2O_3 , Al_2O_3 , Na_2O , CaO , K_2O , and MgO) and minor (TiO_2 and P_2O_5) elements relative to SiO_2 show comparatively simple linear trends with negative slope correlations for most elements, except for the most mobile elements such as Na, K and P which exhibit some scatter (Fig. 11A-H). OMS samples have a greater value range for most of major and minor elements in relation to silica and present the highest contents for these elements (Table 6), whereas IMS samples, although also show a systematic variability of elements content relative to SiO_2 , have lower contents of major and minor elements when compared to the older samples (Table 6). In turn, YMS samples have a narrow value range of elements relative to SiO_2 , and lower content of these elements in relation to silica. In the Na_2O vs. SiO_2 plot (Fig. 11C), samples of different ages show relatively constant, and, to some extent, overlapping Na_2O contents in relation to silica with OMS samples being slightly more sodic (0.06–5.94 wt.%) than IMS (2.29–4.53 wt.%) and YMS (0.13–4.39 wt.%) samples (median values in Table 6). Additionally, in the case of K_2O vs. SiO_2 (Fig. 11E), although OMS samples also show greater K_2O value range (1.27–7.34 wt.%), followed by intermediate (2.92–5.53 wt.%) and lower (3.78–6.01 wt.%) K_2O value range in IMS and YMS rocks, respectively, overall the entire data set show that K_2O content is randomly grouped (median values in Table 6).

Based on Large-Ion Lithophile Elements (LILE) abundances (Ba, Rb, and Sr), the rocks investigated in this study are collectively characterized by scattered fractionation trends in many cases. Exceptions are slight depletions of Ba, and Sr with increasing SiO_2 , and enrichments of Rb with differentiation (silica increasing) in most units. OMS samples show a greater value range of Ba, Sr, and Rb, whereas the IMS and YMS rocks have a narrower range of wt.% SiO_2 and LILE's (Fig. 11I-K; median values in Table 6).

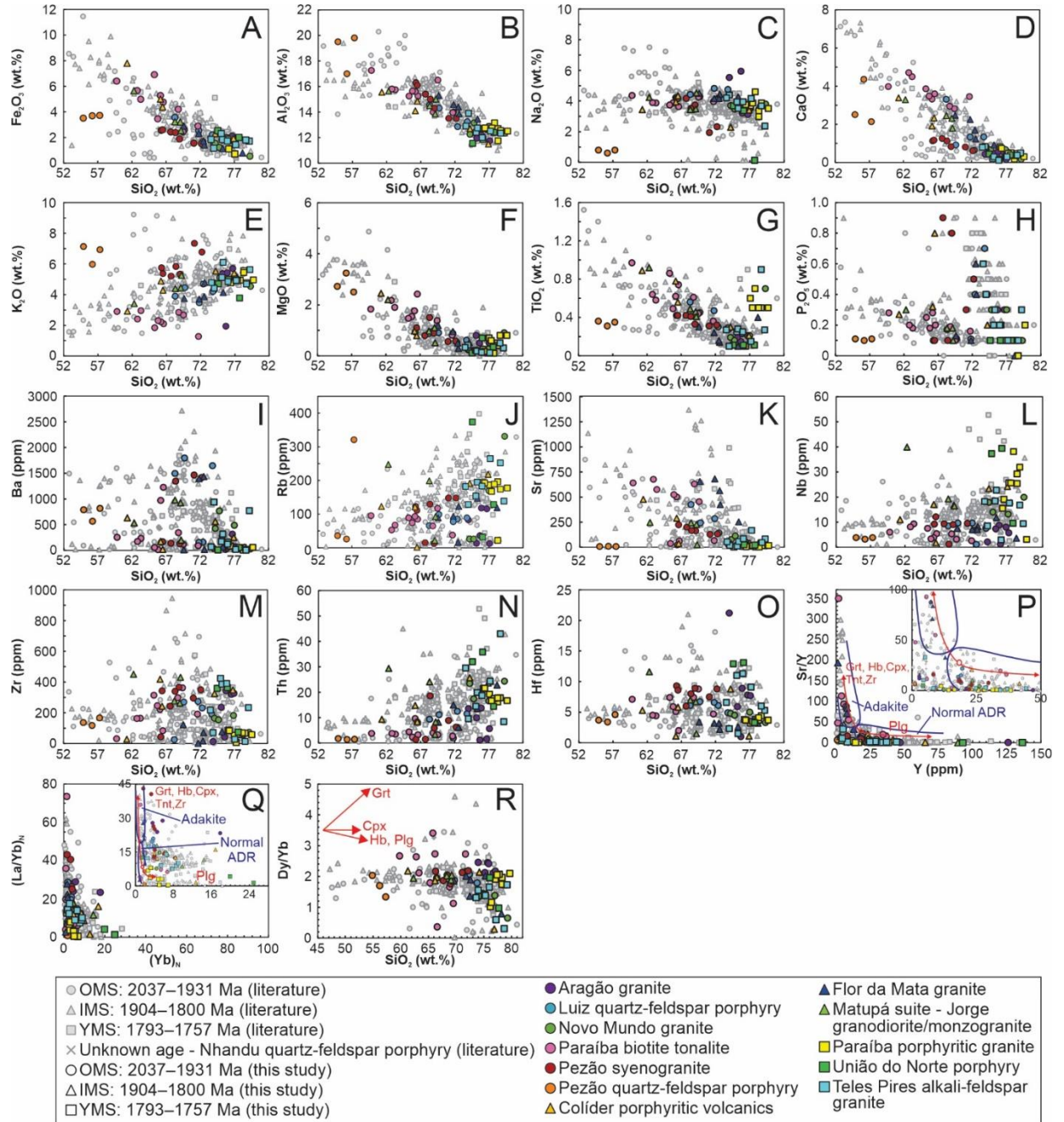


Figure 11. Harker and geochemical classification diagrams showing new data in colors and published data as gray symbols: (A) Fe_2O_3 vs. SiO_2 ; (B) Al_2O_3 vs. SiO_2 ; (C) Na_2O vs. SiO_2 ; (D) CaO vs. SiO_2 ; (E) K_2O vs. SiO_2 ; (F) MgO vs. SiO_2 ; (G) TiO_2 vs. SiO_2 ; (H) P_2O_5 vs. SiO_2 ; (I) Ba vs. SiO_2 ; (J) Rb vs. SiO_2 ; (K) Sr vs. SiO_2 ; (L) Nb vs. SiO_2 ; (M) Zr vs. SiO_2 ; (N) Th vs. SiO_2 ; (O) Hf vs. SiO_2 ; (P) U vs. SiO_2 ; (Q) Sr/Y vs. Y (Defant and Drummond, 1990) showing fields for adakite and ordinary arc andesite-dacite-rhyolite (ADR) magmas of Castillo *et al.* (1999). Differentiation paths resulting from fractionation of various minerals are from Richards and Kerrich (2007). The circle connecting the two paths represents the average medium-K andesite (Gill, 1981); (R) $(\text{La}/\text{Yb})_N$ vs. Yb (Defant and Drummond, 1990). Fields and

differentiation paths from [Castillo *et al.* \(1999\)](#) and [Richards and Kerrich \(2007\)](#), respectively; (S) Dy/Yb vs. SiO₂ ([Davidson *et al.*, 2007](#)). Insets in (P) and (Q) represent a zoom where the data are concentrated. Abbreviations: Grt = garnet; Cpx = clinopyroxene; Hb = hornblende; Plg = plagioclase; Ttn = titanite.

Concerning the High Field Strength Elements (HFSE; Nb, Zr, Th, and Hf), overall, the analyzed units are generally characterized by enrichments in Nb and Th with increasing SiO₂. Zr in OMS and IMS samples shows a peak at around 67–68 wt.% SiO₂, indicating onset of zircon saturation at that stage of differentiation. Th and Hf are more incompatible, so their contents in the magmas seem to rise or remain steady after zircon saturation. Additionally, contents of Nb and Th are generally lower in the OMS samples, followed generally by intermediate contents in IMS rocks, and, in most cases, higher contents in the YMS samples. In the case of Zr and Hf contents, no systematic distinction among age groups is observed ([Figs. 11L, O; Table 6](#)).

The Sr/Y shows high to low fractionation values that range between 0.32-349, 0.28-193, and 0.02-33 for the OMS, IMS, and YMS samples, respectively, with most of the “adakite-like” values > 20 occurring in the OMS samples that are spatially associated with most of the Au and Cu mineralization ([Fig. 11P](#); median values in [Table 6](#)). The (La/Yb)_N behaves in the same way, with values for the OMS, IMS, and YMS samples ranging between 0.77-73, 1.55-28, and 0.24-17, respectively, and most of the “adakite-like” values > 20 occurring among OMS samples ([Fig. 11Q](#); median values in [Table 6](#)). [Figure 11R](#) shows that there is no significant difference of the Dy/Yb between OMS (0.36-3.40), IMS (0.29-2.18), and YMS (0.30-2.10) samples (median values in [Table 6](#)). However, there are significant differences among OMS and IMS samples ([Fig. 11O-P](#)). The Paraíba biotite tonalite appears to be a composite intrusion having multiple sources. One component has substantial garnet control as restite or cumulate, whereas other components of Paraíba lack garnet, but have strong hornblende control. The Novo Mundo granite has strong plagioclase ($\pm$ clinopyroxene) control, without garnet. The Flor da Mata granite has strong hornblende control and high Sr/Y values, whereas the Matupá suite has weaker hornblende control and lower Sr/Y values compared to Flor da Mata.

Primitive Mantle normalized ([Sun and McDonough, 1989](#)) trace-elements spidergrams display negative Nb and Ta anomalies regardless the samples’ ages, while K anomalies are positive. Normalized P, Ti, Ba, and Y values vary from negative to positive within distinct age intervals. Th and Pb are commonly characterized by negative to positive anomalies in OMS and IMS age samples, whereas YMS samples show positive anomalies. Sr shows depletion for

most samples regardless of the age group (Fig. 12A-L), except for the Luiz quartz-feldspar porphyry, Paraíba biotite tonalite, and Flor da Mata granite (Fig. 12B, D, H). In turn, Rb shows positive anomalies for almost half of the OMS samples (e.g. Aragão granite, Luiz quartz-feldspar porphyry, and Paraíba biotite tonalite; Fig. 12A, B, D) and two of three YMS samples (e.g. União do Norte porphyry, and Teles Pires alkali-feldspar granite; Fig. 12K, L), while the IMS and remaining OMS and YMS samples exhibit depletion to enrichment of Rb (Fig. 12A-L).

All investigated samples in Primitive Mantle normalized (Sun and McDonough, 1989) REE diagrams are more enriched in light rare-earth elements (LREE) than in heavy rare-earth elements (HREE) regardless of the age (Figs. 12M-Z). A greater $(\sum_{LREE}/\sum_{HREE})_N$ range characterizes OMS samples (2.41-14.19), decreasing towards IMS (1.57-9.22), and YMS (1.11-8.35) rocks, respectively (median values in Table 6). The LREE show steep patterns regardless of age (Figs. 12M-Z), whereas for the HREE, OMS samples show predominately slightly steep to relatively flat patterns, except for the Novo Mundo granite that has a flat to concave upwards pattern (Fig. 12O), while IMS and YMS rocks present mostly flat to concave upwards patterns (Figs. 12M-Z).

Overall OMS to IMS samples show slightly negative to positive Eu anomalies, except for the Aragão and Novo Mundo granites (Fig. 12A, C, M, O), which along with most YMS samples show a marked depletion of Eu (Fig. 12). The Eu anomalies $(Eu/Eu^*)_N$ values (where $Eu_N/Eu_N^* = 2 * Eu_N / (Sm_N + Gd_N)$) are 0.22-3.62, 0.27-1.57, and 0.07-4.07, for the OMS, IMS, and YMS samples from this study, respectively (Fig. 12M-Z; median values in Table 6).

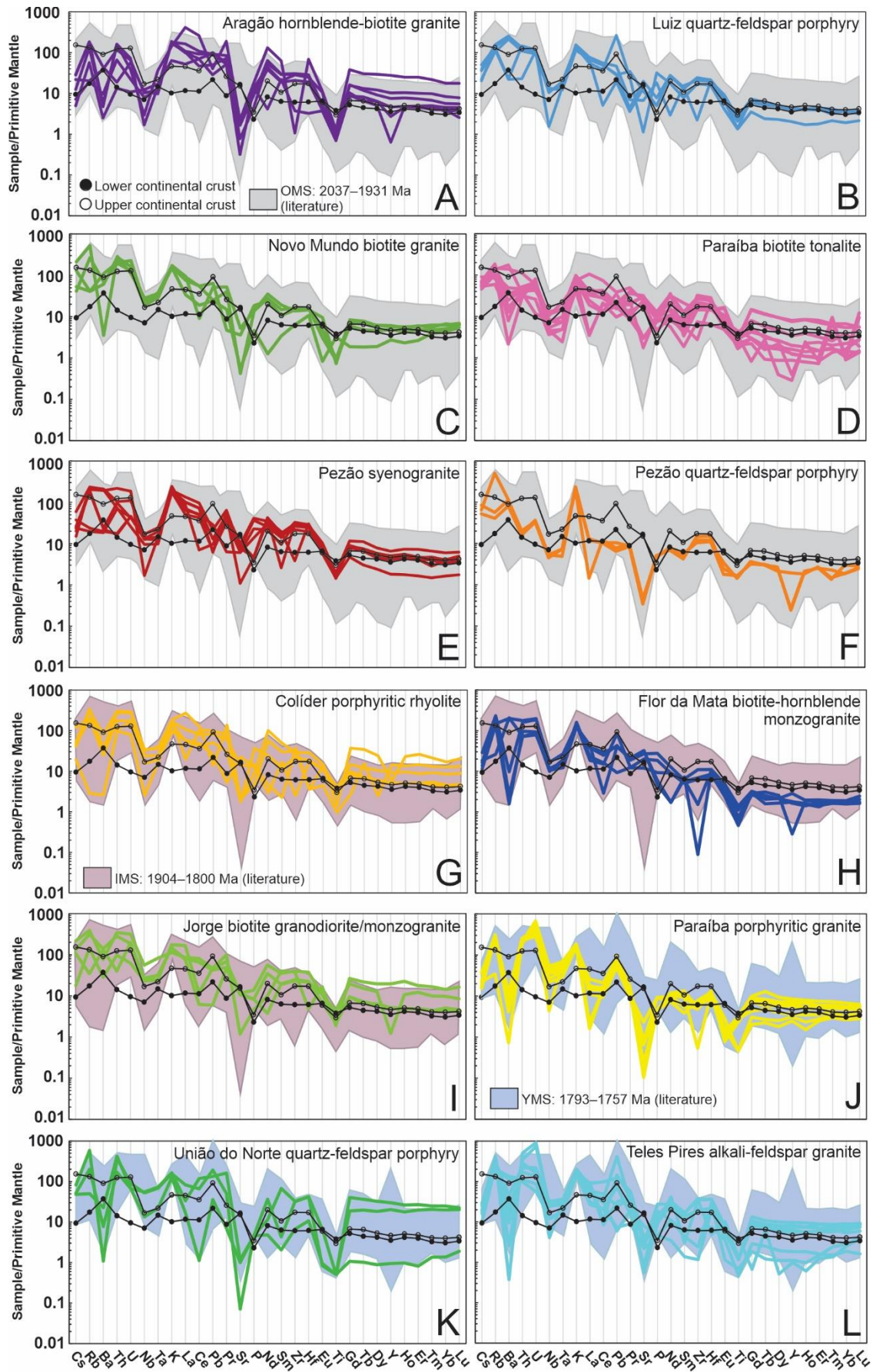


Figure 12. (A-L) Spidergrams and (M-Z) REE plots by unit. New data as lines and published data as envelopes in the background. Upper and Lower Crust values from [Rudnick and Gao \(2003\)](#). All samples and reference reservoirs normalized with respect to Primitive Mantle as defined by [Sun and McDonough \(1989\)](#).

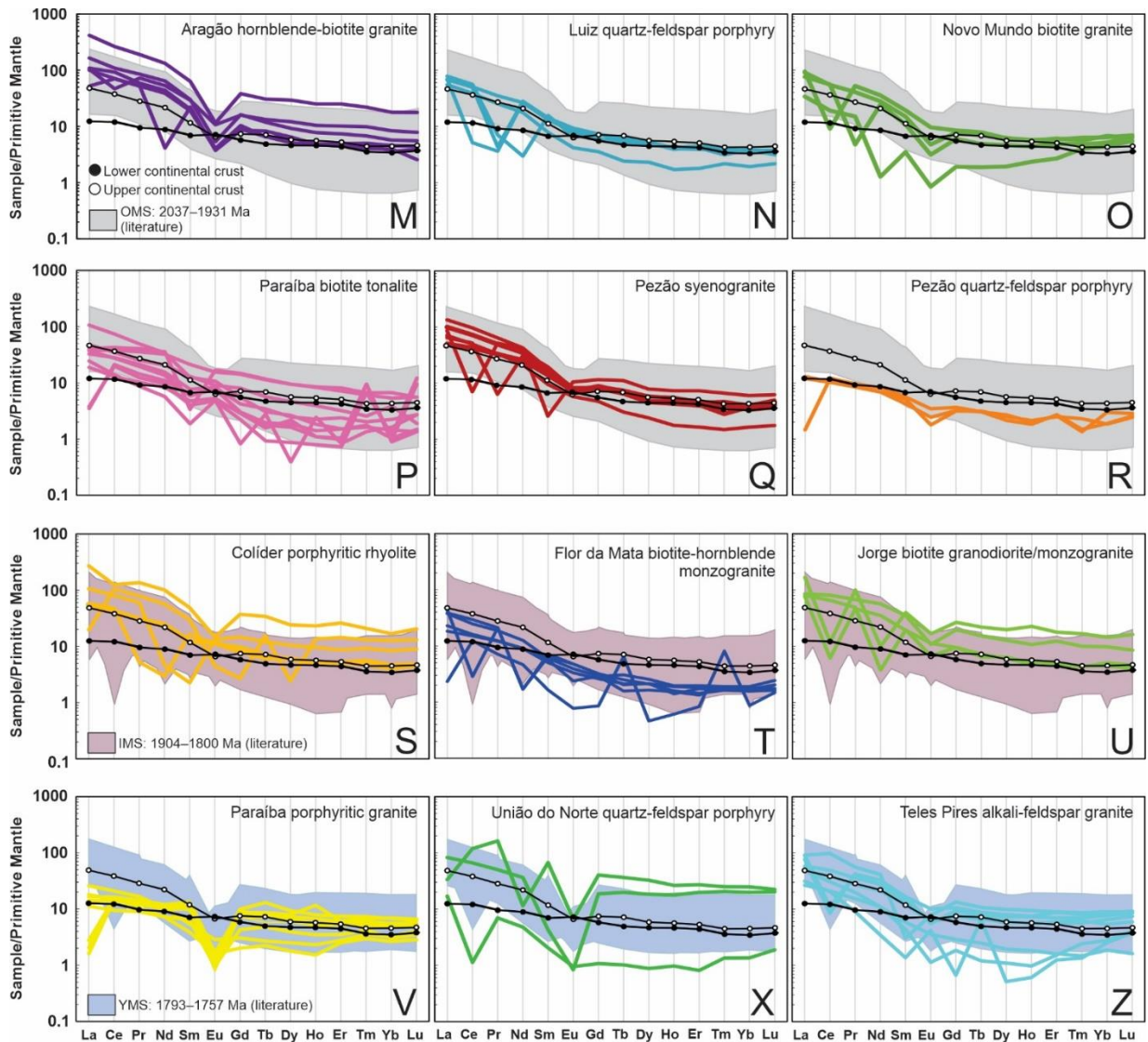


Figure 12. (cont.)

5. Discussion

5.1 Constraints on the timing of local igneous activity

The age data presented herein increase the number of dated granitic and volcanic rocks across the eastern AFMP, from the União do Norte region to the vicinities of the Pezão Au-Cu

vein-type prospect (Fig. 2). Furthermore, this study, for the first time, constrains the ages of the Flor da Mata granite (1887 ± 11 Ma), the undifferentiated granite (1788 ± 14 Ma), and the Pezão quartz-feldspar porphyry (1943 ± 11 Ma; Fig. 2). These three new ages place them into the Peixoto de Azevedo Domain. In relation to the magmatic pulses previously established in subsection 5.3 (Geochemistry), the Pezão quartz-feldspar porphyry is classified as part of the OMS, whereas the Flor da Mata and Undifferentiated granites as part of the IMS and YMS, respectively.

Additionally, the crystallization age of the Flor da Mata granite (1887 ± 11 Ma) precludes its correlation with the Novo Mundo granite and older granitic plutons with ages of ca. 1.96 Ga as presented in Ramos (2011). Moreover, on the basis of the new U–Pb geochronology results on the undifferentiated granite (1788 ± 14 Ma; Fig. 2; Fig. 8G, H), its temporal correlation either with the União do Norte granodiorite or Matupá intrusive suite as suggested by Assis (2011) is also ruled out. It is also noticeable that two well-constrained magmatic pulses in the Pezão Au-Cu prospect are defined by an older syenogranite (1987 ± 4 Ma; Trevisan, 2015), and a younger porphyry (1943 ± 11 Ma; Fig. 7G, H) intrusive into the former rock type, as previously indicated by field cross-cutting relationships (Trevisan, 2015). We find our new weighted average zircon $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1962 ± 9 Ma for the Aragão granite supersedes the discordant age of 1931 ± 12 Ma (MSWD = 5.4) presented by Miguel Jr. (2011). Therefore, this conclusion indicates that there is a gap in the geological record in this region between 1943 ± 11 Ma (Pezão quartz-feldspar porphyry; this study) and 1904 ± 5 Ma (X1 biotite granodiorite; Assis, 2015).

Furthermore, $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average crystallization ages interpreted for the Novo Mundo granite (2013 ± 33 Ma), Pé Quente intrusive suite (1984 ± 16 Ma), Aragão granite (1964 ± 9 Ma), Matupá intrusive suite (1866 ± 10 Ma), Colíder group (1834 ± 16 Ma), Paraíba quartz-feldspar porphyry (1793 ± 9 Ma), X1 quartz-feldspar porphyry (1781 ± 7 Ma), União do Norte porphyry (1779 ± 10 Ma), and Teles Pires suite (1778 ± 8 Ma) confirm or overlap within uncertainties previously published data (Table 2). It is also noteworthy that the weighted average ages obtained in this study for the Pé Quente suite and Colíder group represent, as far as we are aware, the oldest interpreted crystallization ages recorded for these units across the eastern AFMP (Table 5), whereas for the Novo Mundo granite the same assumption cannot be made due to the provisional age obtained from a limited number of zircons available on the analyzed sample.

5.2 Constraints on the geochemistry of local igneous activity

5.2.1 Magma formation processes and evolution

On the K₂O vs. SiO₂ diagram (Le Maitre *et al.*, 1989; Fig. 10F), samples plotting within the low-K field have a signature typical of mafic oceanic crust or where the continental crust is thin (Peccerillo and Taylor, 1976), which is represented by only one sample of the OMS (e.g. Paraíba biotite tonalite). Rocks with medium- and high-K can, among different possibilities, develop on increasingly thicker continental crust (Hildreth and Moorbath, 1988), which can possibly be the case of a majority of the samples investigated in this study, and from the compiled literature. Additionally, the K₂O vs. SiO₂ diagram (Le Maitre *et al.*, 1989; Fig. 10F), the Modified Alkali Index plot (Frost *et al.*, 2001; Fig. 10G) and Th vs. Co diagram (Hastie *et al.*, 2007; Fig. 10H), jointly indicate that most samples are not strongly affected by potassic alteration, except for the Pezão quartz-feldspar porphyry samples displaced from the remaining dataset on all diagrams (LOI > 3%; Fig. 4M; Table 4; Figs. 10 and 11), and, thus, suggest that the high-K calc-alkalic and shoshonitic signatures correspond to an authentic primary composition. The Th vs. Co (Fig. 10H) plot also correctly re-classify the Pezão quartz-feldspar porphyry as belonging to the same magmatic family as the Pezão syenogranite.

The Aluminum Saturation Index (ASI index; Fig. 10I) indicates that the dominant metaluminous signature of OMS and IMS samples is consistent with most of them showing an affinity with I-type granites (Fig. 10D), along with the mineralogy of these rocks including feldspars, amphibole, and biotite with occasional influence of hydrothermal minerals such as muscovite (Table 4). In turn, the predominant peralkaline signature of YMS samples is in agreement with the dominant A-type nature of these rocks and/or with highly fractionated I-type granites (Frost *et al.*, 2001; Fig. 10D). Moreover, based on the Fe-index diagram (Fig. 10J), OMS samples overall plot as ferroan to magnesian, whereas IMS and YMS rocks plot predominately into the ferroan field. According to Frost *et al.* (2001), ferroan rocks have either undergone extensive fractional crystallization of olivine-pyroxene and minor magnetite from H₂O-poor magmas, or have formed by minor melting of H₂O-poor crustal rocks, while magnesian melts have segregated from restite or cumulus with magnetite or garnet (Ellis, 1986), which suppressed iron enrichment.

On Harker diagrams, the IMS samples (e.g. Flor da Mata granite and Jorge granodiorite-monzogranite) are usually aligned in a continuous silica trend (Fig. 11A-H). This is indicative, along with similar field and petrography features (Table 4), that they might be comagmatic

rocks. This conclusion is further constrained by the overlapping zircon crystallization ages obtained for the Flor da Mata granite (1887 ± 11 Ma; Fig. 8C) and Jorge granodiorite-monzogranite (1866 ± 10 Ma; Fig. 8F). The YMS samples (e.g. Paraíba porphyritic granite, União do Norte porphyry, and Teles Pires alkali-feldspar granite) are, however, A-type, peralkaline granites with high P_2O_5 , TiO_2 , Nb, Th, and clustered in a very short range of high SiO_2 values (Fig. 11A-O), indicating that they are H_2O -poor, low-percentage melts of crustal rocks (Whalen *et al.*, 1987). These rocks also show overlapping zircon crystallization ages (Paraíba porphyritic granite: 1793 ± 9 Ma, Fig. 9I; União do Norte porphyry: 1779 ± 10 Ma, Fig. 9C; and Teles Pires alkali-feldspar granite: 1778 ± 8 Ma, Fig. 8L).

The Harker diagrams also show that the rocks analyzed in this study overall show single linear trends, regardless the age group, that are typical of fractional crystallization in which the differentiation composition remains relatively constant (Martin, 1987). Exceptions to this are the Na_2O (Fig. 11C), K_2O (Fig. 11E), Ba (Fig. 11I), Zr (Fig. 11M), and Hf (Fig. 11O), which the results return scattered or display more complex linear trends, thus indicating to be the result of fractional crystallization in which the composition evolves during the fractionation process (Martin, 1987).

Negative P and Ti anomalies in the spidergrams (Fig. 12A-L) point out to the fractionation of accessory phases such as apatite and titanite, respectively (Table 4), which along with negative Sr anomalies indicate an increase of the arc maturity (Brown *et al.*, 1984). Predominately negative anomalies of Ba (Fig. 12A-L), a fluid mobile element, is likely a result of the overprinting of igneous minerals by hydrothermal K-feldspar and mica (e.g. muscovite; biotite; Table 4), instead of reflecting primary magmatic processes (Guice *et al.*, 2018) regardless the age of the samples.

5.2.2 Potential magma sources

In some OMS and IMS samples, the Sr/Y vs. Y plot (Defant and Drummond, 1990) can help identify melts that have segregated from garnet-rich restites. The remaining samples from both age groups segregated from plagioclase-rich cumulates or restites, as did all YMS samples (Fig. 11P). The $(La/Yb)_N$ vs. Yb_N plot (Defant and Drummond, 1990) indicates fractionation of a garnet-rich residue within distinct age intervals (Fig. 11Q), whereas the Dy/Yb vs. SiO_2 plot (Davidson *et al.*, 2007) suggest predominately fractionation of amphibole + plagioclase-rich residual melts in a major number of samples from all age groups (Fig. 11R).

The variations of the Eu, Sr, and Rb anomalies can shed more light on the understanding of crystal fractionation process and compositions of residual melts (Fig. 12A–L).

The $\sum\text{LREE}/\sum\text{HREE}$ (median values in Table 6) fractionation appears to change from more to less steep from OMS to IMS age samples followed by slightly flatter YMS rocks. Moreover, the slope of the REE profiles, measured by $(\text{La}/\text{Yb})_{\text{N}}$ (median values in Table 6; Fig. 12M–Z), can add more information about the occurrence of particular mineral phases (e.g. plagioclase; garnet; amphibole) in the residue from which the rocks were derived (Loucks, 2014). Overall, steeper REE profiles are diagnostic of more garnet and/or hornblende fractionation compared to less steepened patterns characteristic of plagioclase fractionation (Loucks, 2014). OMS rocks from this study have steeper sloping REE patterns than IMS samples followed by YMS rocks (Fig. 12M–Z). This geochemical behavior is consistent with a source where garnet and/or amphibole were present in the residue or cumulates that generated OMS rocks, whereas YMS samples indicate that the residual minerals within their magma sources probably were plagioclase-rich and free of garnet and hornblende. The IMS samples may have been derived from a source represented by a mixture of more than one mineral phase in the residue.

Furthermore, the HREE patterns can also add information on different residues on the magma sources. Residues formed in deep sources are enriched in garnet and/or amphibole (Hanson, 1978; Martin *et al.*, 1983; Hildreth and Moorbath, 1988) and present flat to concave up HREE patterns, a weak to absent or even positive Eu anomalies (Petford and Atherton, 1996; Loucks, 2014), whereas melts that originated from shallower or H_2O -poor sources, perhaps in thinner or drier crust within the plagioclase stability field tend to have strong negative Eu and Sr anomalies and smaller La/Yb and Sr/Y ratios (Petford and Atherton, 1996; Loucks, 2014). Hence, it is possible to identify that the magmas sources of OMS and IMS rocks were likely rich in garnet and/or amphibole, while YMS samples segregated from restites or cumulates rich in plagioclase under lower pressure or less hydrous conditions (Fig. 12M–Z; Loucks, 2014).

From the characteristics and geochemical evidence presented above, two main magma compositional types are identified: (1) OMS and part of the IMS magmas formed from sources related to melting or fractional crystallization under simultaneous high pressures and degrees of magmatic differentiation and/or source enrichment in residual garnet; and (2) part of the IMS and all YMS magmas derived from sources with residual plagioclase, associated with lower pressures and low H_2O activity. In summary, fractional crystallization, formation under different pressure conditions (thick continental crust vs. thinner crust) and different H_2O activity

were probably the main processes that resulted in the formation of these magmas (Hanson, 1989; Petford and Atherton, 1996; Bendaoud *et al.*, 2008; Laurent *et al.*, 2014; Loucks, 2014).

5.2.3 Tectonic implications

Rocks with a calc-alkalic signature generally develop on thicker continental crust above subducting lithosphere, and transition to a thinner continental crust affected by asthenospheric upwelling (Miyashiro, 1974), whereas plutons with a calcic signature tend to lie on the oceanward portion of batholithic belts (Moore, 1959; Bateman and Dodge, 1970). The Modified Alkali Index plot (Fig. 10G) and the Th vs. Co diagram (Fig. 10H), show that overall, regardless of age, samples from this study developed predominately on continental crust experiencing or not asthenospheric upwelling.

The negative Nb-Ta anomalies along with positive Pb anomalies are considered to indicate that melts formed in an arc environment dominated by subduction processes or to indicate assimilation of such crustal protoliths (Hofmann, 1997; Arculus *et al.*, 1999; Rudnick and Gao, 2003; Hawkesworth and Kemp, 2006; Moyen and Martin, 2012). In this context, part of the samples of this study are likely to have formed in subduction-related environments (Fig. 12A–L).

On the discrimination diagrams proposed by Pearce *et al.* (1984), the majority of OMS and IMS rocks have formed within a compressional tectonic setting (e.g. magmatic arc), while most YMS samples, and a few of the OMS and IMS samples, mark a transition from a compressional to an extensional tectonic setting (e.g. post-collisional to within plate; Fig. 13A, B). Additionally, in the tectonic discriminant diagram of Schandl and Gorton (2002), samples predominantly plot within the active continental margin granites field, with a few plotting into the within plate volcanic zones field (Fig. 13C).

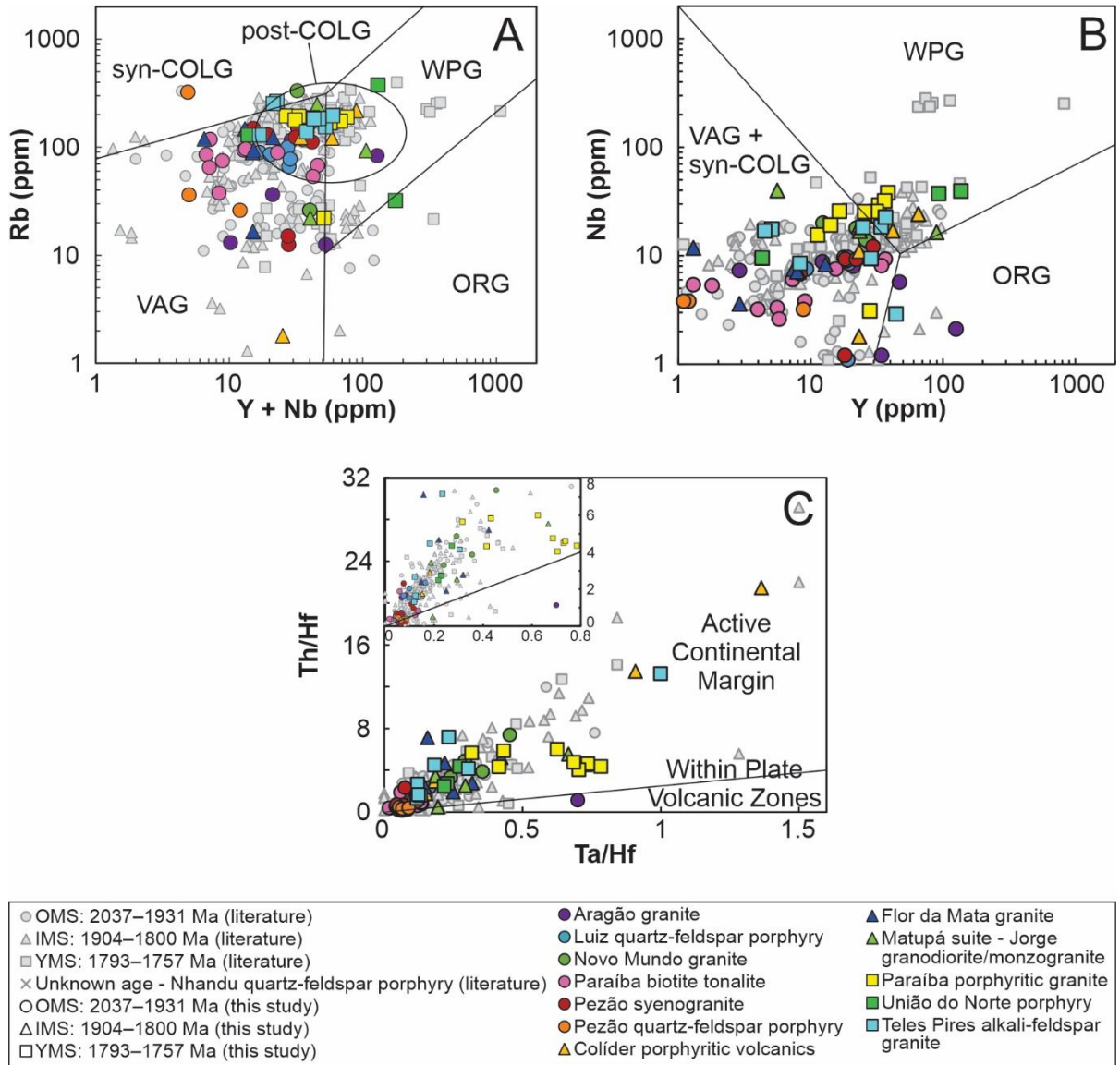


Figure 13. Tectonic discrimination diagrams: (A) Rb vs. Y+Nb; (B) Nb vs. Y (Pearce *et al.*, 1984; syn-COLG: syn-collision granites; VAG: volcanic arc granites; WPG: within plate granites; ORG: ocean ridge granites; post-COLG: post-collision granites); (C) Th/Hf vs. Ta/Hf (Schandl and Gorton, 2002). Inset in (C) represents a zoom where the data are concentrated. In all diagrams, new data in colors and published data as gray symbols.

5.3 Reassessed stratigraphy and novel geological framework for the eastern portion of the AFMP

In light of the new data generated in this study, coupled with the existing data from the literature, it is possible to redefine the stratigraphy and propose a novel geological framework for this region.

The stratigraphy is divided into five main domains (Basement, Colíder group, Teles Pires suite, unconstrained units, and cover sequences) following in part the stratigraphic proposal of [Alves et al. \(2020\)](#). The Basement comprises the OMS and part of the IMS rocks, while the four remaining domains, except for the unconstrained units, comprise part of the IMS and all YMS rocks. [Figure 14](#) and [Table 7](#) show the new geological map and a summary of the geology in this region, respectively. The temporal evolution of the magmatic activity, which took place in a time span of 280 Myr during the Orosirian and Statherian (2037-1757 Ma; [Fig. 3](#)), and mineralizing events, are presented in [Figure 15](#).

5.3.1 Basement

5.3.1.1 Gavião gneiss

The Gavião gneiss (2816 ± 4 Ma, [Paes de Barros, 2007](#); 2825 ± 9 Ma, [Alves et al., 2020](#)) represents the only well-documented Archean crustal fragment preserved within the eastern sector of the AFMP ([Fig. 14; Table 7](#)). An additional, suggested Archean age of 2669 ± 5 Ma was obtained by [Moreira \(2019\)](#) for a biotite gneiss defined by [Trevisan \(2015\)](#) in the Paraíba prospect. The fact that these ages could represent inherited ages derived from reworking of an Archean crust can, however, not be ruled out. The same scenario is observed in the Tapajós Mineral Province, where the Maloquinha suite has crystallization ages at ca. 1870–1860 Ma, and inherited zircons with dates of ca. 2714 Ma, 2679 Ma, and 2634 Ma ([Bizzinella et al., 1980](#)).

5.3.1.2 Peixoto de Azevedo Domain

The Peixoto de Azevedo Domain is divided into one complex (Cuiú-Cuiú) and four intrusive suites (Pé Quente, Nhandu, Guarantã do Norte, and Matupá) following the stratigraphic proposal of [Alves et al. \(2020\)](#).

The Cuiú-Cuiú complex consists of gneisses, volcanoclastic, and deformed/metamorphosed plutonic-volcanic rocks ([Fig. 14; Table 7](#)). It comprises the Gringo granitoids, Monzogranite, Naiuram granodiorites and dacites, Volcanoclastic Unit, Cuiú-Cuiú granites, Basement granitoids, Cuiú-Cuiú gneisses, Alto Alegre gneiss, Hornblende-quartz diorites, and Nova Guarita gneiss. The biotite tonalite of the Paraíba prospect and the Novo

Mundo granite, which were investigated in this study, are also interpreted to belong to this complex (Fig. 2; Table 2).

The Pé Quente intrusive suite consists of locally deformed syenogranites, monzogranites, granodiorites, monzonites, and quartz-feldspar porphyries (Fig. 14; Table 7). It comprises the monzogranite of the Porteira prospect, and foliated biotite tonalite. Additionally, it was possible to include three units investigated in this study into the suite: the syenogranite of the Pezão prospect, the monzonite of the Pé Quente prospect, and the quartz-feldspar porphyry of the Luiz prospect (Fig. 2; Table 2).

The Nhandu intrusive suite consists of monzogranites, syenogranites, and quartz-feldspar porphyries (Fig. 14; Table 7). It comprises the Nhandu syeno/monzogranites, and two units studied in this work, the Aragão granite and the quartz-feldspar porphyry of the Pezão prospect (Fig. 2; Table 2).

The Guarantã do Norte intrusive suite consists of tonalites and granodiorites (Table 7). It comprises the biotite granodiorite of the X1 prospect and the biotite tonalite of the Pé Quente prospect (Fig. 2; Table 2). This suite is not identified in Figure 13 due to the fact that these rocks were observed in drill cores.

The Matupá Intrusive suite consists of granodiorites, monzogranites, tonalites, monzonites, and monzodiorites (Fig. 14; Table 7). It comprises the Matupá granitoids and the União do Norte granodiorite. The Flor da Mata monzogranite, dated for the first time in this study, is also included in the suite (Fig. 2; Table 2).

In terms of geochemistry, the Peixoto de Azevedo Domain rocks are overall classified as moderately to strongly evolved, oxidized, calc-alkalic to alkali-calcic, low- to high-K, magnesian to ferroan, metaluminous to slightly peralkaline and peraluminous, I-type magmas formed within a compressional tectonic setting (e.g. volcanic arc) transitioning towards an extensional tectonic setting with the formation of post-collisional and/or within-plate A-type magmas. Meanwhile, the volcanoclastic rocks, according to lithogeochemical analyses on feldspathic-wake and lithic-sandstone by Assis (2011), indicate that the main source of the fragments may have been intermediate volcanic rocks probably deposited in an active back-arc foreland basin.

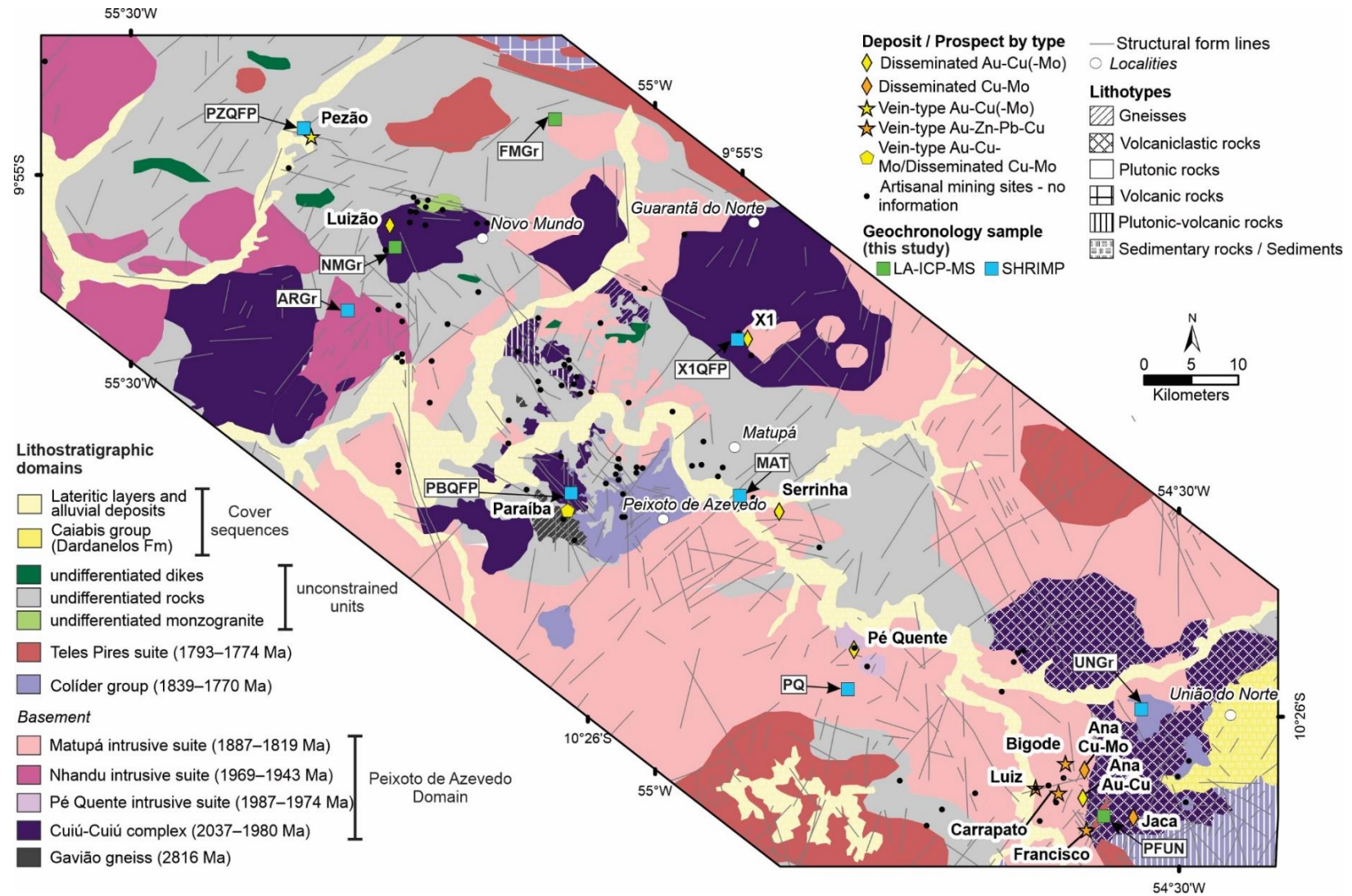


Figure 14. New geological map proposed in this study for the eastern portion of the Alta Floresta Mineral Province (Modified from Miguel Jr, 2011; Assis *et al.*, 2017).

Table 7. Summary of the new proposed geological framework of the eastern AFMP.

Magmatic sequence	Domain		Unit	Age (Ma)	Description	Geotectonic context
	Cover sequences		Lateritic layers and alluvial deposits	Cenozoic	-	-
			Caiabis group (Dardanelos Fm.)	1987–1377	Quartzite, conglomerate, arenite, and claystone	-
	unconstrained rocks		undifferentiated dikes	-	Basalt, diorite, gabbro, andesite, dacite, monzogabbro, and monzodiorite	-
			undifferentiated units	-	-	-
			undifferentiated monzogranite	-	monzogranite	-
	YMS	Teles Pires suite		1793–1774	Alkali-feldspar granite, granite, monzonite, and quartz-feldspar porphyry	
	IMS	Colíder group		1839–1770	Monzogranite, monzonite, granophyry, alkali-feldspar granite, quartz-feldspar porphyry, rhyolite, rhyodacite, dacite, andesite, trachyte, pyroclastic (tuff and ignimbrite), epiclastic, and volcanoclastic	Crustal extension Slab-rollback
				Matupá intrusive suite	1887–1819	Granodiorite, monzogranite, tonalite, monzonite, and monzodiorite
			Guarantã do Norte intrusive suite	1904–1901	Tonalite and granodiorite	
OMS	Basement	Peixoto de Azevedo Domain	Nhandu intrusive suite	1969–1943	Monzogranite, syenogranite, and quartz-feldspar porphyry	Crustal extension Slab-rollback
			Pé Quente intrusive suite	1987–1974	Locally deformed syenogranite, monzogranite, granodiorite, tonalite, monzonite, and quartz-feldspar porphyry	
			Cuiú-Cuiú complex	2037–1980	Gneiss, volcanoclastic, and deformed/metamorphosed monzogranite, granodiorite, dacite, granite, diorite, and tonalite	Crustal thickening Low-angle subduction
			Gavião gneiss	2825–2816	Granitic-tonalitic gneiss	

Accretionary orogen

Accretionary orogen

5.3.2 Colíder group

This group consists of plutono-volcanic rocks of acidic to intermediate composition represented by monzogranites, monzonite, granophyries, alkali-feldspar granites, quartz-feldspar porphyries, rhyolites, rhyodacites, dacites, andesites, trachytes, pyroclastic (tuffs and ignimbrites), and volcanoclastics (Fig. 14; Table 7). It comprises the Colíder plutonic-volcanic rocks, Peixoto granite, X1 quartz-feldspar porphyry, and Braço Sul tuffs. Also incorporated to this group of rocks is the undifferentiated alkali-feldspar granite dated for the first time in this study (Fig. 2; Table 2). The volcanic rocks are moderately to strongly evolved, metaluminous to peraluminous, calc-alkalic to alkali-calcic, whereas the plutonic rocks are classified as peralkaline to peraluminous, calc-alkalic to alkali, ferroan, high-K to shoshonitic, I- to A-type magmas. Collectively, these rocks mark the transition from a compressional tectonic setting to an extensional environment (e.g. post-collisional to within-plate).

5.3.3 Teles Pires suite

This suite consists of granites, monzonites, and quartz-feldspar porphyries (Fig. 14; Table 7). It comprises the Teles Pires granites and União do Norte quartz-feldspar porphyry along with one more unit investigated in this work, the porphyritic granite of the Paraíba prospect (Fig. 2; Table 2). The rocks of the suite are classified as strongly evolved, peralkaline to metaluminous and slightly peraluminous, calc-alkalic to alkali-calcic, medium to high-K, ferroan, A-type magmas formed in an extensional tectonic setting (e.g. post-collisional to within-plate).

5.3.4 Unconstrained units

For the areas not well document in the literature with reduced or absent lithological, geochemical, and/or geochronological information the term unconstrained units has been kept for the sake of simplicity (Fig. 14; Table 7). It comprises the undifferentiated monzogranite adjacent in the Novo Mundo region, the undifferentiated rocks with no geological information to the moment, and the undifferentiated dikes (Fig. 2; Table 2).

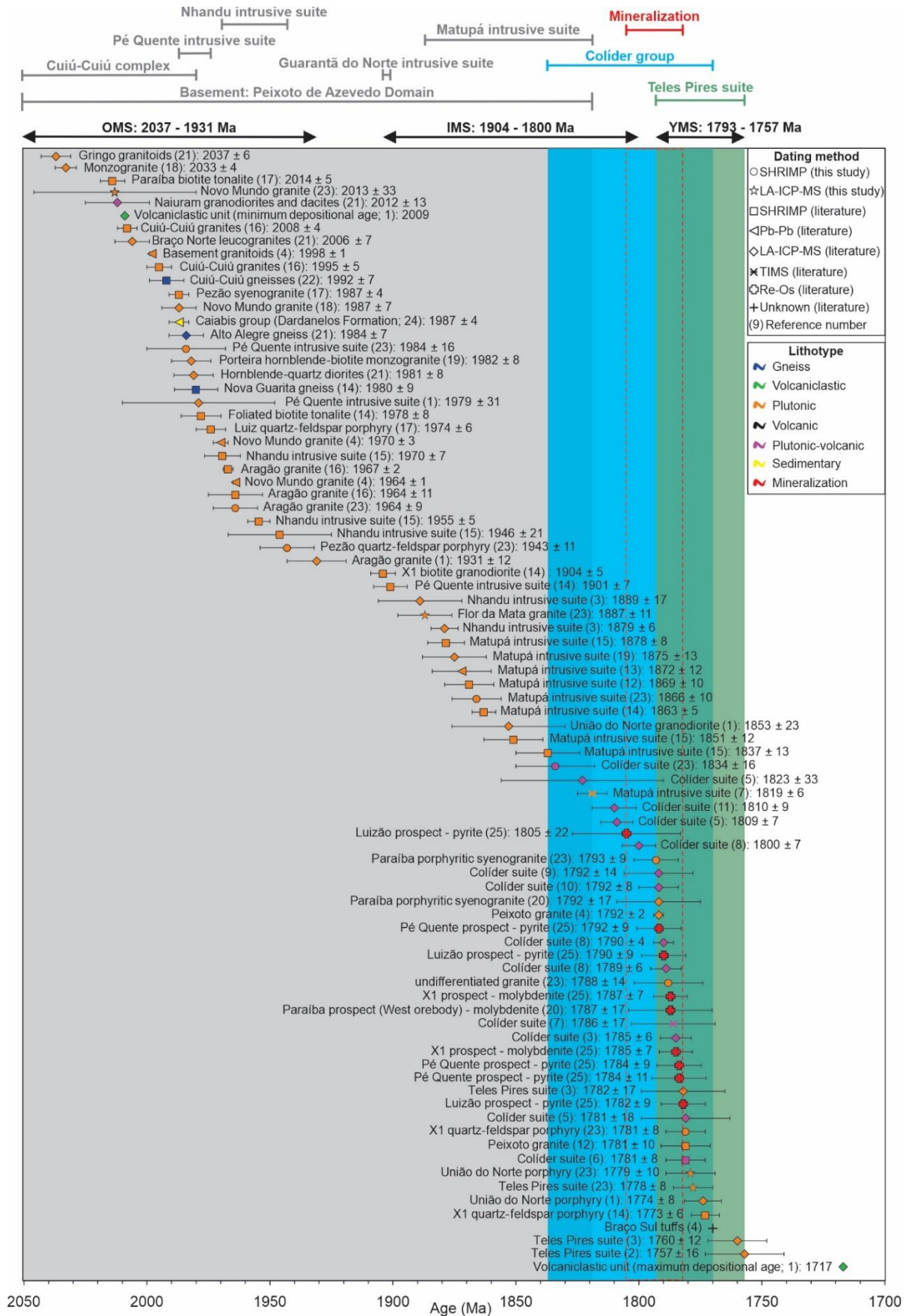


Figure 15. Temporal evolution of magmatic activity and mineralizing event in the eastern portion of the Alta Floresta Mineral Province. Key to parenthesized reference: (1) Miguel Jr

(2011); (2) Santos *et al.* (2000); (3) Silva and Abram (2008); (4) Paes de Barros (2007); (5) Duarte *et al.* (2019); (6) Pimentel (2001); (7) JICA/MMAJ (2001, 2002); (8) Almeida (2017); (9) Silva *et al.* (2018); (10) Alves *et al.* (2013); (11) Santos *et al.* (2019); (12) Silva *et al.* (2014); (13) Moura (1998); (14) Assis (2015); (15) Rocha (2016); (16) Dezula *et al.* (2018); (17) Trevisan (2015); (18) Da Costa Testa (2018); (19) Oliveira (2017); (20) Trevisan *et al.* (in prep.); (21) Quispe (2016); (22) Souza *et al.* (2005); (23) This study; (24) Leite and Saes (2003); (25) Assis *et al.* (2017).

5.3.5 Cover sequences

These sequences comprise the Caiabis group (Dardanelos Formation) in the União do Norte region, and the lateritic layers of concretions and alluvial deposits along the rivers across the eastern portion of the AFMP (Fig. 14; Table 7).

5.4 Geodynamic evolution of the eastern portion of the AFMP: tectonic switches

The new results presented in this paper integrated with published data, show evidence that the eastern portion of the AFMP was formed in an Andean-type orogenic system (accretionary orogen) characterized by a complex geologic evolution represented by the interplay between magmatic, metamorphic, and sedimentary processes. We here consider the concept of tectonic mode switches presented by Collins (2002; see section 1) as a feasible explanation for the complex geological overprinting relationships and associated mineral endowment observed in this region (Fig. 14).

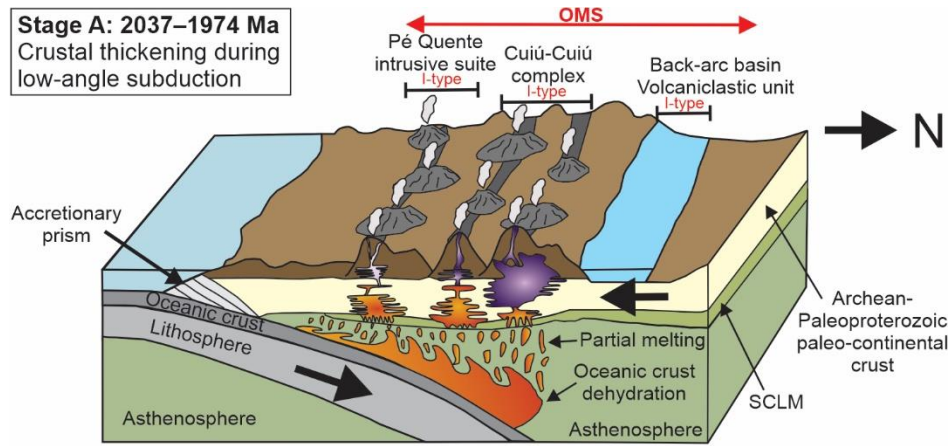
In the following, a new model for the geodynamic evolution of this region in the time interval of ca. 2.03–1.75 Ga is described in four stages in the context of the tectonic switching model (Fig. 16). In all stages, a deep, east–west oriented and north dipping ocean-continent subduction zone identified in the southern Amazonian Craton in previous studies based on multidisciplinary data (Juliani *et al.*, 2014; Carneiro *et al.*, 2019; Fernandes and Juliani, 2019) is assumed to be situated to the south in the Caiabis and Dardanelos basins region (where the subduction trench is possibly located). North of it, a single magmatically active continental margin was located within the Alta Floresta Mineral Province limits along with adjacent areas, including the rocks under and to the north-northeast of the Alto Tapajós basin. These previous studies, in particular Carneiro *et al.* (2019), also point to a system of shallower NW–SE and NE–SW major brittle faults in the southern Amazonian Craton, which are associated with the

intrusion and fissure extrusion of tardi- to predominantly post-orogenic A-type felsic plutonic-volcanic rocks. The undifferentiated rocks (Fig. 14) are not considered in the geodynamic model due to the lack of key information (see section 5.3).

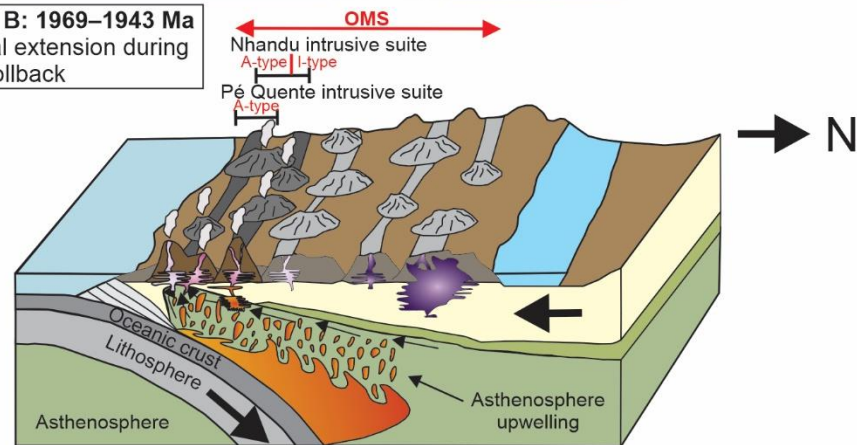
Stage A: Crustal thickening during low-angle subduction at 2.03 to 1.97 Ga

The subduction of the oceanic crust starts in very low angles beneath the continent resulting in dehydration of the oceanic crust and partial melting of the subducting slab. These processes cause metasomatism and partial melting of the mantle wedge, and generation of basaltic magmas (Zhou and Li, 2000). These newly formed mafic magmas rise through the lithosphere, and stall in the stiff, uppermost subcontinental-lithospheric mantle (SCLM) or mafic lower crust near Moho. As batches of mantle-derived basaltic magmas accumulate in lower-crustal MASH (melting-assimilation-storage-homogenization; Hildreth and Moorbath, 1988) zones (i.e. regions where magmas evolve and interact with the preexisting crust), felsic magmas are generated, which migrate to higher crustal levels (Hildreth and Moorbath, 1988; Annen *et al.*, 2006), and may eventually lead to release of magmatic fluid and ore formation (Zhou and Li, 2000). This model could explain the generation of the tonalitic-granodioritic gneisses and deformed granitic rocks of the Cuiú-Cuiú Complex along with the I-type granitoids of the Pé Quente intrusive suite in the OMS (Peixoto de Azevedo Domain; Figs. 14 and 16). The formation of metamorphic and deformed granitic rocks of the Cuiú-Cuiú complex is a result of the contractional deformation in the upper plate (Gutscher *et al.*, 2000). At the end of stage A, the formation of small back-arc basin began in the União do Norte region (Figs. 14 and 16) according to the $^{207}\text{Pb}/^{206}\text{Pb}$ maximum depositional ages of ca. 1.97 Ga reported by Leite and Saes (2003) from youngest detrital zircons in basal conglomerates. Assimilation and reworking of preexisting Archean–Paleoproterozoic continental crust is indicated by the negative $\epsilon\text{Nd}_{(1.98-1.97 \text{ Ga})}$ values (-3.36 to -0.96; Assis, 2005), and inherited zircon grains with Paleoproterozoic affinity identified in this study (see section 4.2) for both the Cuiú-Cuiú complex and Pé Quente suite rocks along with Archean–Paleoproterozoic whole-rock $\text{Nd } T_{\text{DM}}$ ages (2.51–2.41 Ga; Assis, 2015) reported for the monzonite of the Pé Quente Au-Cu prospect (Fig. 14).

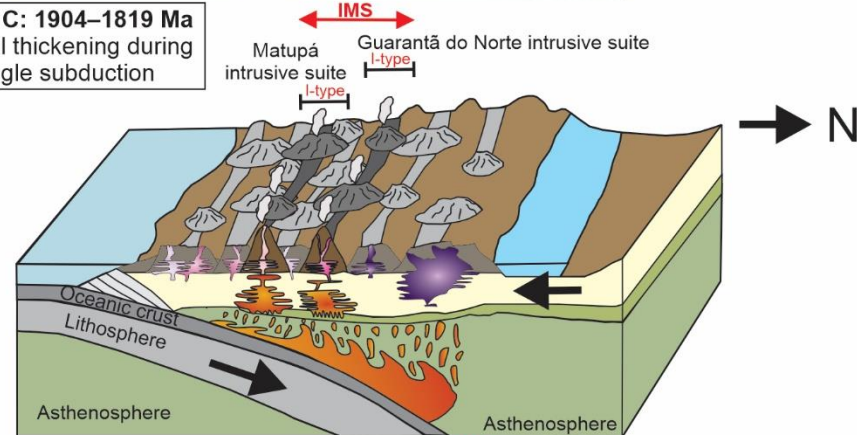
Stage A: 2037–1974 Ma
Crustal thickening during low-angle subduction



Stage B: 1969–1943 Ma
Crustal extension during slab-rollback



Stage C: 1904–1819 Ma
Crustal thickening during low-angle subduction



Stage D: 1839–1770 Ma
Crustal extension during slab-rollback

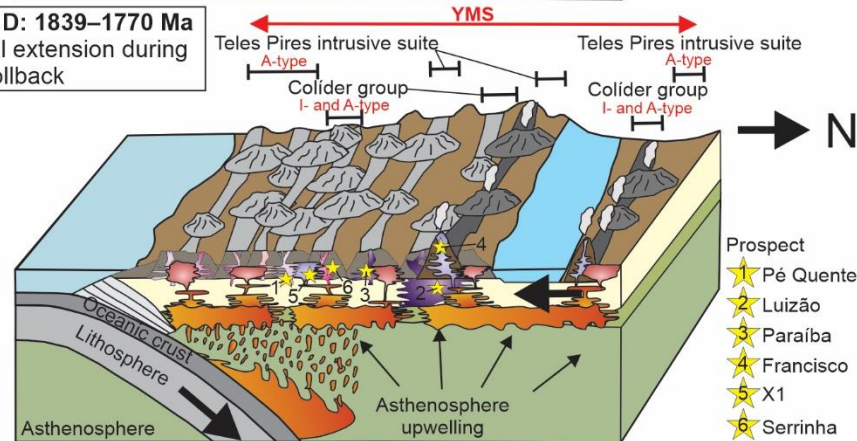


Figure 16. Four-dimensional schematic illustration (not to scale) of the conceptual model for the geodynamic evolution of the eastern portion of the AFMP in four stages. The model involves continuous subduction, beneath a single continental margin, combined with alternating subduction angle of the oceanic plate relative to the overriding plate. Note that angle of subduction is steeper in stage D than in stage B. SCLM = subcontinental lithospheric mantle.

Stage B: Crustal extension during slab-rollback at 1.97 to 1.94 Ga

After a ca. 60 Myr-long period dominated by compression and shallow subduction, the eastern portion of the AFMP is interpreted to have switched to a setting dominated by extension between 1.97 and 1.94 Ga in which the subducting oceanic slab progressively rolled back and sank with a steeper angle (Collins, 2002). The first batches of magma generated in this transitional tectonic environment would still form by melting of metasomatized mantle wedge resulting in melts that upon differentiation generate the I-type granitic rocks of the Nhandu intrusive suite in the OMS (Peixoto de Azevedo Domain; Figs. 14 and 16). Simultaneously and continuing until ca. 1.94 Ga, the slab dip became steeper as a result of the slab-rollback, causing back-arc crustal extension. The rift region facilitated asthenosphere upwelling (Collins, 2002), which triggered decompression-melting of metasomatized SCLM and predominantly lower continental crust. As a result, anorogenic felsic magmatism was produced (Harris *et al.*, 1986; Liégeois *et al.*, 1998), such as the A-type plutonic rocks belonging to both the Pé Quente and Nhandu intrusive suites in the OMS (Peixoto de Azevedo Domain; Figs. 14 and 16). Assimilation and reworking of preexisting Paleoproterozoic continental crust is indicated by the inherited ages reported by Trevisan (2015), Rocha (2016), Dezula *et al.* (2018), and in this study (see section 4.2) for both the Pé Quente and Nhandu suites.

Stage C: Crustal thickening during low-angle subduction at 1.90 to 1.81 Ga

Following the ca. 30 Myr-period of extension caused by slab-rollback, the tectonic mode switched and a contractional regime was again prevalent in the region. A shallowing of the oceanic slab between 1.90 and 1.81 Ga was likely the main mechanism behind magma production and crustal thickening during the following ca. 85 Myr. Similar processes described as responsible for the generation of the rocks in stage A are assumed, during this stage, as triggers for the formation of the Guarantã do Norte and Matupá intrusive suites in the IMS (Peixoto de Azevedo Domain; Figs. 14 and 16). Negative $\epsilon\text{Nd}_{(1.90-1.86 \text{ Ga})}$ values (-5.13 to -2.08; Assis, 2015), and inherited zircon grains with Paleoproterozoic affinity identified in this study (see section 4.2) for both the Guarantã do Norte and Matupá suites, along with Archean–

Paleoproterozoic whole-rock Nd T_{DM} ages (2.51–2.41 Ga; Assis, 2015) reported for the tonalite of the Pé Quente Au-Cu prospect (Guarantã do Norte suite), collectively point to assimilation and reworking of preexisting Archean–Paleoproterozoic continental crust.

Stage D: Crustal extension during slab-rollback at 1.83 to 1.75 Ga

The last stage of geodynamic evolution of the region was marked by a gradual switching from a contractional regime to an extensional period of ca. 80 Myr caused by progressive steepening of the oceanic slab dip compelled by slab-rollback. Similar processes as responsible for the generation of rocks in stage B are assumed to be responsible for the formation of the I-type rocks of Colíder group, followed by the generation of the A-type plutonic rocks of the Teles Pires intrusive suite in the rift stage (Figs. 14 and 16). The latter stage is interpreted to be mainly caused by crustal extension in the back-arc. The Colíder group is part of the IMS and YMS, while the Teles Pires suite belongs to the IMS. Similarly to stages A through C, this stage presents evidences for assimilation and reworking of preexisting continental crust, such as inherited zircon grains with Paleoproterozoic affinity identified in this study (see section 4.2), and negative $\epsilon Nd_{(1.77 \text{ Ga})}$ values (-2.84 to -1.38; Assis, 2015) reported for both the Colíder group and Teles Pires suite. In addition, the generation of the Colíder and, less likely, the Teles Pires rocks is interpreted in previous works (Xavier *et al.*, 2013; Assis *et al.*, 2017; Trevisan *et al.*, in prep) as spatially, temporally, and genetically associated with the formation of part of the Au-Cu(-Mo) and Cu-Mo deposits and prospects in this region. These interpretations are based on Re–Os mineralization ages at ca. 1.78 Ga on molybdenite and pyrite reported for the Pé Quente, Luizão, X1 (Assis *et al.*, 2017), and Paraíba (Trevisan *et al.*, in prep) prospects/deposits (Fig. 14). In this scenario, melts formed in the age interval between 1.83 and 1.75 Ga eventually lead to release of metal-bearing magmatic fluids and ore formation, and are thus considered, at the moment, as potentially fertile for the formation of the magmatic-hydrothermal mineralizations in the YMS and part of the IMS.

5.5 Implications for the evolution of the southern Amazonian Craton

Different studies (Bettencourt *et al.*, 2016; Assis *et al.*, 2017; Duarte *et al.*, 2019; Santos *et al.*, 2019) have pointed out that the eastern portion of the AFMP is located between the limits of the Rondônia-Juruena and Tapajós-Parima tectonic provinces (Fig. 1A–B). Therefore, in the following, we discuss in detail possible correlations between the eastern AFMP and adjacent regions in the southern Amazonian Craton. These regions include, to the west, the Western

Amazonia Igneous Belt (Rizzotto *et al.*, 2019b) within the Rondônia-Juruena province, and, to the east-north-northeast, the older neighboring Tapajós Mineral Province within the Tapajós Domain (Fig. 1B–C). The Tapajós Mineral Province is separated from the eastern AFMP by overlying rocks of the Colíder group, Teles Pires suite, and Alto Tapajós basin (Fig. 1C).

From a lithological and geochemical perspective, it is noteworthy that the 2.03–1.81 Ga rocks belonging to the Peixoto de Azevedo Domain (OMS and part of the IMS), and the ca. 1.79–1.78 Ga Teles Pires suite (YMS) share broad lithological and geochemical similarities with the rocks occurring across the adjacent Tapajós Mineral Province between 2.08 and 1.87 Ga. The Iriri group (1.89–1.87 Ga), Ingarana intrusive suite (1.88–1.87 Ga), and Maloquinha intrusive suite (1.87–1.86 Ga) of the Tapajós Mineral Province have no, so far identified, corresponding plutonic and volcanic rocks in the eastern AFMP. This is also true for the Colíder group with respect to the Tapajós Mineral Province. A complete dataset of the lithological and geochemical characteristics across the eastern portion of the AFMP and the Tapajós Mineral Province is provided on Table 8.

In the geochronological context, the zircon crystallization ages and inherited ages reported in the compiled literature, together with the new ages generated in this study, are well correlated with older rocks from the Tapajós Mineral Province and/or younger rocks belonging to the Western Amazonia Igneous Belt (Fig. 17). In terms of metamorphism, metamorphic peak conditions (high amphibolite facies) that affected migmatitic gneisses from the Cuiú-Cuiú complex may have occurred approximately between 2.01 and 1.99 Ga across the eastern AFMP (Alves *et al.*, 2020). Geochronological and petrological studies demonstrated metamorphic peak ages at ca. 1.79–1.75 Ga for the Nova Monte Verde Complex within the Western Amazonia Igneous Belt (Rizzotto *et al.*, 2019a; Fig. 17C). The metamorphic rocks of this complex are interpreted as partial melts of pre-existing crust related preferentially to the Tapajós-Parima province, and the metamorphic ages are considered to be coeval to the Juruena supersuite, Colíder group, and Teles Pires suite (Rizzotto *et al.*, 2019a). Additionally, age determinations of mineralization events on deposits and prospects across the eastern AFMP (Figs. 14 and 15) show Re–Os dates of molybdenite and pyrite from the Pé Quente, Luizão, X1 (Assis *et al.*, 2017), and Paraíba (Trevisan *et al.*, in prep) prospects at ca. 1.78 Ga (Figs. 15 and 17B), whereas a Re–Os date of molybdenite from one mineralized sample from the Juruena prospect in the northwestern sector of the province (Juruena supersuite) gives an age of ca. 1.80 Ga (Serrato, 2014; Fig. 17C). In the Tapajós Mineral Province, a Pb–Pb pyrite date at ca. 1.85 Ga is reported for the Ouro Roxo gold deposit (Veloso *et al.*, 2013), whereas Ar–Ar ages determined on alunite samples are ca. 1.87–1.86 Ga (Juliani *et al.*, 2005; Giuliani *et al.*, 2014;

Fig. 17D). The mineralization ages in the AFMP are interpreted as coeval to the Colíder group, Paranaíta suite (Juruena supersuite), and, less likely, to the Teles Pires suite (Xavier *et al.*, 2013; Assis *et al.*, 2017; Trevisan *et al.*, in prep). In the Tapajós Mineral Province, the mineralizing event is temporally connected to the ca. 1.89–1.87 Ga Parauari intrusive suite, and the ca. 1.88–1.86 Ga Uatumã event (Juliani *et al.*, 2014). A complete dataset of crystallization, metamorphic, and mineralization ages across the eastern portion of the AFMP and adjacent areas is provided in Figure 17 and Table 8.

In terms of tectonic evolution, the geodynamic model proposed in this study (see section 5.4) converges to a great extent with the ideas outlined in multidisciplinary studies published in the last decade from the Tapajós Mineral Province and São Félix do Xingu region (see section 2.2; Fernandes *et al.*, 2011; Juliani *et al.*, 2014; Carneiro *et al.*, 2018; Fernandes and Juliani, 2019; Cassini *et al.*, 2020). Moreover, the continental rift setting proposed by Rizzotto *et al.* (2019b) for the Western Amazonia Igneous Belt is here interpreted as the westward continuation to the transition from a contractional to an extensional setting, represented in the eastern portion of the AFMP between 1.83 and 1.75 Ga by the stages C and D (see section 5.4).

From a metallogenic perspective, the majority of deposits or prospects in the Alta Floresta and Tapajós mineral provinces have been classified as porphyry- and epithermal-style systems, and are closely linked to magmatic-hydrothermal systems active during the Orosirian–Statherian (Juliani *et al.*, 2002, 2005; Bettencourt *et al.*, 2016; Assis *et al.*, 2017; Trevisan *et al.*, in prep). The correlations in geochemistry, geochronology, and tectonic evolution between the two mineral provinces discussed above is significant as it suggests similar geological processes playing a critical role in the production of metals deposition in both regions. Although the ore-forming processes were not active at the same time in both provinces, as indicated by the Re–Os, Pb–Pb, and Ar–Ar dates, the results of this study suggest that the two mineral provinces are equally prospective for precious and base metals mineralization. Their lack of resources is suspected to be due to under-exploration rather than geological endowment.

Collectively, the geological similarities between the Peixoto de Azevedo Domain and the Tapajós Mineral Province reinforces the geological correspondence between these areas inferred in prior studies (Santos *et al.*, 2004; Rizzotto *et al.*, 2019a,b; Alves *et al.*, 2020). However, through an integrated assessment and discussion presented here, we suggest that the

Table 8. Lithogeochemical and geochronological correlation between the lithostratigraphic units of the eastern AFMP and Tapajós Mineral Province (Tapajós Domain).

EASTERN ALTA FLORESTA MINERAL PROVINCE		
Geochemical characteristics This study and literature	Lithostratigraphic unit (Age)	
	Alves <i>et al.</i> (2020) and this study	This study (highlighted in bold) and literature
TAPAJÓS-PARIMA PROVINCE		
Peixoto de Azevedo Domain - 2.81 to 1.85 Ga		
Oxidized, calc-alkalic to alkali-calcic, low- to high-K, magnesian to ferroan, metaluminous to peraluminous, I-type to locally A-type rocks; Feldspathic-sandstone, feldspathic-wacke, lithic-sandstone, and conglomerate rocks (Volcaniclastic unit)	Cuiú-Cuiú Complex	Gavião granitic-tonalitic gneiss (2.81 Ga)
		Gringo granitoids (2.03 Ga)
		Monzogranite (2.03 Ga)
		Naiuram granodiorites and dacites (2.01 Ga)
		Paraíba biotite tonalite (2.01 Ga)
		Novo Mundo granite (2.01-1.96 Ga)
		Volcaniclastic Unit (2.0-1.71 Ga)
		Cuiú-Cuiú granites (2.0-1.99 Ga)
		Basement granitoids and Cuiú-Cuiú gneisses (1.99-1.97 Ga)
	Alto Alegre granodioritic gneiss (1.98 Ga)	
	Honblende-quartz diorites (1.98 Ga)	
	Nova Guarita monzogranitic gneiss (1.98 Ga)	
Pé Quente intrusive suite	Pezão syenogranite (1.98 Ga) Porteira hornblende-biotite monzogranite (1.98 Ga) Pé Quente prospect - monzonite (1.98 Ga) Foliated biotite tonalite (1.97 Ga) Luiz quartz-feldspar porphyry (1.97 Ga)	
Nhandu intrusive suite	Nhandu granitoids (1.96-1.95 Ga) Aragão granite (1.96 Ga) Pezão quartz-feldspar porphyry (1.94 Ga)	
Guarantã do Norte intrusive suite	X1 biotite granodiorite (1.90 Ga) Pé Quente prospect - biotite tonalite (1.90 Ga)	
Matupá intrusive suite	Flor da Mata monzogranite (1.88 Ga) Matupá granitoids (1.87-1.81 Ga) União do Norte granodiorite (1.85 Ga)	

TAPAJÓS MINERAL PROVINCE (TAPAJÓS DOMAIN)	
Lithostratigraphic unit (Age)	Geochemical characteristics
Santos <i>et al.</i> (2004); Juliani <i>et al.</i> (2014); Cassini <i>et al.</i> (2019); and references therein	
TAPAJÓS-PARIMA PROVINCE	
Basement - 2.87 to 1.99 Ga	
Jacareacanga group (2.87-2.09 Ga)	Pelitic and mafic schists, and quartzites (Jacareacanga group); Quartz arenite, quartz oligomitic conglomerate and arkose (Castelo dos Sonhos Formation); Calc-alkalic tonalites, granodiorites, and quartz dioritic to granodioritic gneisses, locally migmatitic (Cuiú-Cuiú Complex)
Castelo dos Sonhos Formation (2.08 Ga)	
Cuiú-Cuiú Complex (2.04-1.99 Ga)	
Plutonic and volcanic units - 2.0 -1.78 Ga	
Vila Riozinho Formation (2.00 Ga) and Jamanxim suite (2.00-1.98 Ga)	Calc-alkalic, high-K to shoshonitic basaltic-andesite, trachyte, and rhyolite (Vila Riozinho Formation); Monzogranite (Jamanxim suite)
São Jorge Old Granite (1.98 Ga), Creporizão intrusive suite (1.98-1.95 Ga), and Undifferentiated rhyolites (1.97 Ga)	Monzogranite (São Jorge Old Granite); Calc-alkalic, high-K monzo-syenogranite, granodiorite and tonalite (Creporizão intrusive suite)
Tropas suite (1.90-1.88) and Parauari intrusive suite (1.89-1.87 Ga)	Calc-alkalic, medium-K tonalites and granodiorites (Tropas suite); Calc-alkalic, high-K granodiorites, granites, and quartz monzonites (Parauari intrusive suite)

GAP ?		
Colider group - 1.83 to 1.78 Ga		
Metaluminous to peraluminous, calc-alkalic rhyolites, rhyodacites, dacites, andesites, and trachytes (Colider volcanic rocks). Peralkaline to peraluminous, calc-alkalic to alkalic, ferroan, high-K to shoshonitic, I-type granites (Granites and quartz-feldspar porphyry)	Colider group	Colider plutonic-volcanic rocks (1.83-1.78 Ga) Peixoto granite (1.79-1.78 Ga) X1 quartz-feldspar porphyry (1.78 Ga) Undifferentiated alkali-feldspar granite (1.78 Ga) Braço Sul tuffs (~1.78 Ga)
Teles Pires suite - 1.79 to 1.75 Ga		
Metaluminous to peraluminous, calc-alkalic to alkali-calcic, medium to high-K, ferroan, A-type granites.	Teles Pires suite	Paraíba porphyritic granite (1.79 Ga) Teles Pires granites (1.78-1.75 Ga) União do Norte quartz-feldspar porphyry (1.78 Ga)
Unconstrained units		
Metaluminous to peraluminous, calc-alkalic, magnesian to ferroan, I-type granites (Undifferentiated monzogranite); Basalt-diorite-gabbro and andesite-dacite dikes (Undifferentiated dikes)	-	Undifferentiated monzogranite Undifferentiated units Undifferentiated dikes
Cover sequences		
Quartzites, conglomerates, arenites, and calystones (Caiabis group)	Caiabis group - Dardanelos Formation	Caiabis group - Dadarnelos Formation (1.97-1.38 Ga)
	Lateritic and alluvial deposits	Lateritic and alluvial deposits (Cenozoic age)

Iriri Group (1.89-1.87 Ga), Ingarana intrusive suite (1.88-1.87 Ga), and Maloquinha intrusive suite (1.87-1.86 Ga)	Acidic volcanic and pyroclastic rocks (Iriri); Calc-alkalic, high-K gabbros, monzogabbros, and anorthosites (Ingarana Intrusive suite); Metaluminous A-type granites (Maloquinha)
Plutonic and volcanic units - 2.0 -1.78 Ga	
GAP ?	
	
Porquinho granite (1.78 Ga)	Metaluminous to peralkaline, A-type granite

Tapajós Domain of the Tapajós-Parima tectonic province extends to the southwest under the Colíder group, Teles Pires intrusive suite, and Alto Tapajós basin (Fig. 1B–C). Therefore, the limits of the Tapajós-Parima and Rondônia-Juruena tectonic provinces should be revised. This conclusion thus brings important constraints for the tectonic provinces of the Amazonian Craton, which makes the eastern portion of the AFMP a key area for understanding part of the evolution of the south of the craton, and constrains the limits of the Alta Floresta and Tapajós mineral provinces, with direct implications for exploration of precious- and base metals in both of these areas.

We interpret the eastern portion of the AFMP as part of and correlated eastward with the Tapajós Domain, recording the overprinting of Statherian rocks belonging to the Western Amazonia Igneous Belt (Fig. 1 and 15–17). Evidence supporting this interpretation comprises: (i) inherited zircon grains in all dated samples in this study as old as 2092 ± 47 Ma, overlapping within uncertainties the igneous crystallization ages in the Tapajós Domain (Fig. 17), thus indicating assimilation of crust and/or SCLM underlying the AFMP; (ii) the occurrence of a belt of rocks belonging to the Colíder group and Teles Pires suite between the Tapajós Domain and the eastern portion of the AFMP (Fig. 1C); (iii) the observed field crosscutting intrusive relationships (Fig. 14); and (iv) the lithological, geochemical, geochronological, geodynamic, and metallogenic correlations of the eastern portion of the AFMP with both the Tapajós Domain and Western Amazonia Igneous Belt as discussed above (Tables 7 and 8).

5.6 Links on a global scale

Long-lived magmatism during the Paleoproterozoic is documented in the 1.96–1.75 Ga Cordilleran-type Svecofennian orogen in the Fennoscandian Shield (Gáal and Gorbatshev, 1987; Beunk and Page, 2001; Hermansson *et al.*, 2007; Petersson *et al.*, 2015). This orogen consists of several meta-igneous provinces that generally young progressively to the south and west (Park, 1985; Gáal and Gorbatshev, 1987; Stephens and Weihed, 2020), outwards from an Archean and Early Proterozoic nucleus in the north-eastern part of the shield (Hermansson *et al.*, 2007; Stephens and Weihed, 2020). Particularly the western portion of the orogen, the Forsmark area, shows a broadly similar geological framework to the eastern portion of the AFMP. According to Hermansson *et al.* (2008), the Forsmark area is situated between two major Paleoproterozoic tectonic domains that show contrasting histories with respect to timing, ductile deformation, and metamorphism. Geological features common to both the adjacent

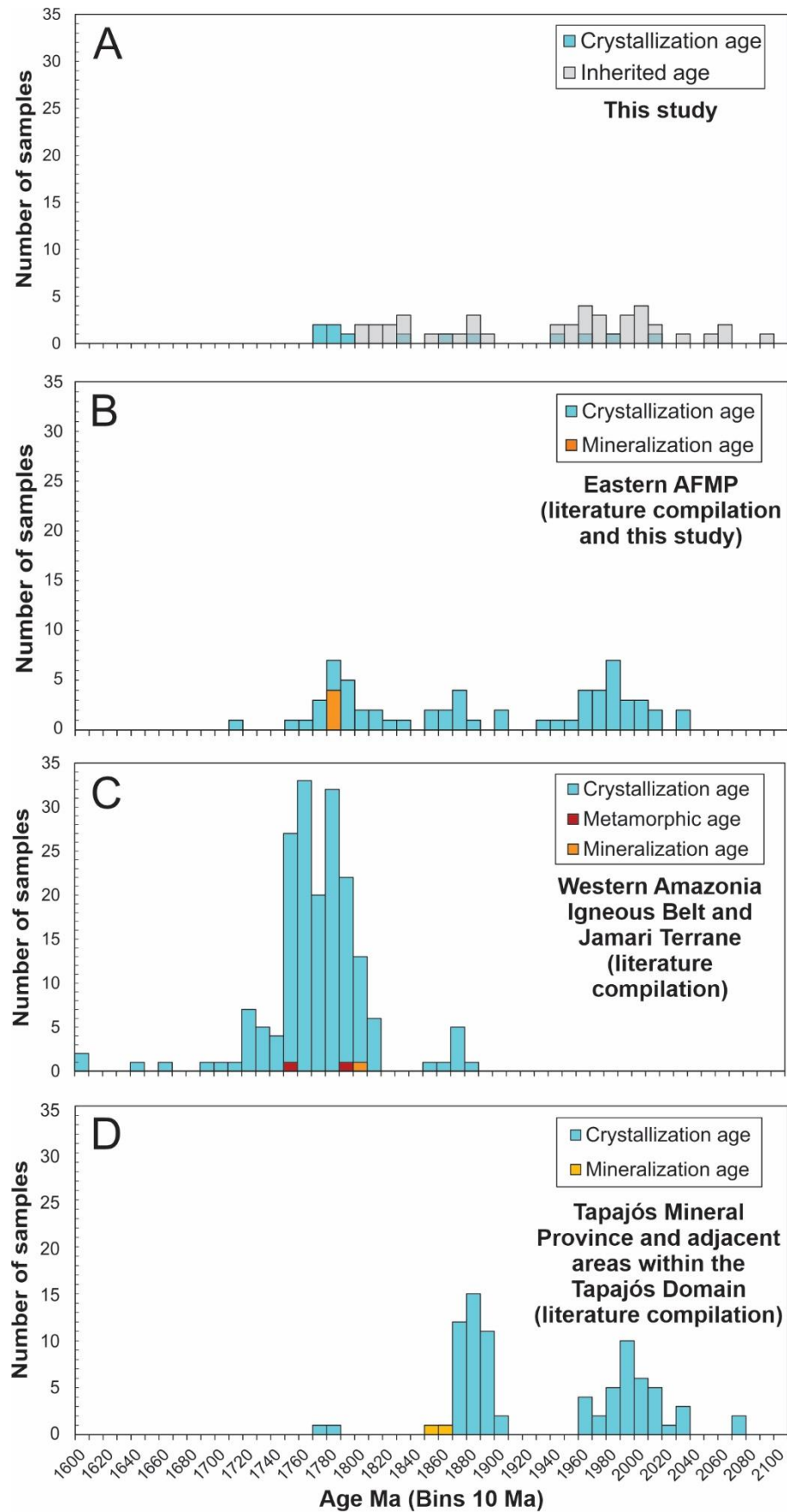


Figure 17. Histograms of crystallization, inherited, metamorphic (zircon), and mineralization (sulfides) ages of: (A) This study area; (B) Eastern portion of the AFMP; (C) Western

Amazonia Igneous Belt and Jamari Terrane; (D) Tapajós Mineral Province and adjacent areas within the Tapajós Domain.

domains are found at Forsmark. Field relationships, petrographic, geochemical, and geochronological data indicate the presence of two calc-alkalic igneous suites represented by the ca. 1.89–1.87 Ga plutons with ultramafic to intermediate, granitic, tonalitic, and granodioritic compositions, and the ca. 1.86–1.85 Ga dike-like bodies and minor intrusions with granitic, granodioritic, and tonalitic compositions. A tectonic model that makes use of alternating slab hinge retreat and advance along a single active continental margin to produce migrating cycles of extension, magmatism, and compression in the back-arc region, is favored to explain the tectonic evolution of the Forsmark area ([Hermansson *et al.*, 2008](#)). This model resembles what has been described as tectonic switching in the younger, accretionary orogenic systems of eastern Australia (Paleozoic Lachlan orogen) and New Zealand ([Hermansson *et al.*, 2008](#)). The main difference when comparing the Svecofennian orogen with the eastern portion of the AFMP is that gold occurrences in the Svecofennian orogen (e.g. southern Finland) are classified as orogenic gold and considered to be formed in a tectonic contractional period (slab advance) characterized by dextral transpression, thus providing a favorable setting for gold mineralization ([Saalman *et al.*, 2009](#)).

Other well documented examples of Paleoproterozoic orogens worldwide with, to a certain extent, a geologic framework similar to the eastern portion of the AFMP include: the ca. 2.0–1.8 Ga Trans-Hudson Orogen ([Hoffman, 1988](#); [Lewry and Collerson, 1990](#); [Maxeiner *et al.*, 2005](#); [Corrigan *et al.*, 2009](#)), and the ca. 2.02–1.85 Ga Wopmay orogen ([Buchan *et al.*, 2010](#); [Ootes *et al.*, 2020](#)), both within the Canadian Shield; the ca. 1.89–1.83 Ga Penokean orogen within the Lake Superior region ([Van Schmus, 1980](#); [Sims *et al.*, 1989](#); [Schulz and Cannon, 2007](#); [Moleski *et al.*, 2019](#); [Holm *et al.*, 2020](#)); the ca. 2.05–1.70 Ga Nagssugtoqidian orogen in western Greenland ([Kalsbeek and Nutman, 1996](#); [Connelly *et al.*, 2000](#); [Van Gool *et al.*, 2002](#)); the ca. 2.08–1.95 Ga Glenburgh Terrane within the West Australian Craton ([Occhipinti *et al.*, 2004](#); [Pilet *et al.*, 2005](#); [Johnson *et al.*, 2011, 2013](#); [Slezak and Spandler, 2020](#)); and, the ca. 2.31–2.06 Ga Birimian terrane within the West African Craton ([Petersson *et al.*, 2016](#)).

In this context, we contend that the southern Amazonian craton, along with other Paleoproterozoic orogens worldwide, experienced tectonic processes similar to Phanerozoic ones ([Cawood *et al.*, 2006](#); [Betts *et al.*, 2016](#); [Hawkesworth *et al.*, 2017, 2019](#); [Cawood and Hawkesworth, 2019](#); [Brown *et al.*, 2020](#)). Our observations and data across the

Paleoproterozoic eastern portion of the AFMP show geochemical, tectonic, and mineralization evidence supporting a scenario that resembles the Phanerozoic Earth (e.g. Andes), including: (i) subduction-related assemblages (e.g. calc-alkalic plutonic-volcanic rocks) with trace element signatures similar to Phanerozoic arc rocks; (ii) subduction-zone setting represented by an accretionary orogen with tectonic switching; and (iii) disseminated and vein-type Au-Cu-Mo, Cu-Mo, and Au-Zn-Pb-Cu prospects classified as porphyry- and epithermal-style systems that resemble Phanerozoic ones (Sillitoe, 2010). Additionally, according to Betts *et al.* (2016), some differences described in the literature between Proterozoic and modern tectonic systems are related to the resolution of geochronology data and difficulties in reading the rock record, especially in terranes that preserve mid-crustal levels. Those authors contend that, on the modern Earth, tectonic switches enhance mineral endowment. We envisage a similar scenario regarding tectonics and mineralization not only for the eastern portion of the AFMP, but also for other mineral provinces in the southern Amazonian craton. Finally, our results suggest that some parts (e.g. marginal portions) of the Columbia (Rogers and Santosh, 2002) supercontinent (2.1–1.7 Ga; Cawood and Hawkesworth, 2015), which has Amazonia as one of its components, were amalgamated in modern accretionary style, in accordance with Cycle II of Brown and Johnson (2018).

6. Conclusions

The combination of new results and observations gathered in this study with pre-existing data from the literature on the plutonic and volcanic rocks of the eastern portion of the AFMP indicate long-lived magmatism in the southern of the Amazonian Craton between 2037 and 1757 Ma (280 Myr). This region formed through tectonic switching represented by alternating periods of crustal thickening during low-angle subduction and crustal extension during slab-rollback at a single active convergent margin of an accretionary orogen. The last stage of the geodynamic evolution, from 1.83 to 1.75 Ga (crustal extension), is interpreted as spatially, temporally, and genetically associated with the metal endowment across the AFMP represented by disseminated and vein-type Au-Cu-Mo, Cu-Mo, and Au-Zn-Pb-Cu porphyry- and epithermal-style mineralization. This study interprets the eastern portion of the AFMP as part of the ca. 2.03–1.86 Ga Tapajós Domain, in particular the Tapajós Mineral Province, and recording the overprinting by ca. 1.85–1.74 Ga rocks belonging to the Western Amazonia Igneous Belt. The geological similarities between the eastern portion of the AFMP and the Tapajós Mineral Province highlight the potential of both areas, as well as other Precambrian

cratonic areas worldwide, for precious- and base-metal mineralization (e.g. porphyry and epithermal deposits), and indicate that their lack of identified resources is a result of under-exploration rather than geological endowment. Well documented, long-lived Paleoproterozoic orogens worldwide with, to varying degrees, a geologic framework similar to the eastern portion of the AFMP include the Svecofennian (Fennoscandian Shield), Trans-Hudson, Wopmay (Canadian Shield), Penokean (Lake Superior region), Nagssugtoqidian (West Greenland) orogens, and the Glenburgh (West Australian Craton) and Birimian (West African Craton) terranes. Rock associations, geochemical signatures, tectonic settings, and mineralization types indicate that, not only the eastern portion of the AFMP, but the southern Amazonian craton along with other Proterozoic orogens worldwide, are somewhat similar to Phanerozoic tectonic systems (e.g. Andes), and that marginal portions of the Columbia supercontinent (e.g. Amazonia) were amalgamated through modern-style accretionary processes.

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Declaration of competing interest

The authors declare no competing interests.

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Supplementary Material

Detailed methods. A detailed account of the methods involved in this contribution.

Figures

Figure SM1. Geological map of the eastern Alta Floresta Mineral Province with the geochronological data from the literature.

Figure SM2. Geological map of the eastern Alta Floresta Mineral Province with the samples investigated in this study.

Tables

Table SM1. Investigated samples presented in the results of this study.

Table SM2. Results of zircon SHRIMP U-Pb analysis from this study.

Table SM3. Results of zircon LA-ICP-MS U-Pb analysis from this study.

Table SM4. SHRIMP standards data.

Table SM5. LA-ICP-MS standards data.

Table SM6. Whole-rock major, minor, and trace elements geochemistry results.

Methodology

Geochronology:

Samples preparation

Approximately 2-5 kg of rock was crushed, grinded, sieved, and panned to obtain a heavy mineral concentrate at the Institute of Geosciences, University of Campinas, Brazil. After panning, zircon grains from samples VGT-02, VGT-15, PBQFP, UNGR, MAT, PQ, X1, and PEZ were concentrated via magnetic Frantz (isodynamic magnetic separator) and density (LST heavy liquid) separation. Around 100-200 zircon grains from each sample were handpicked, and mounted in three epoxy resin mounts (2.5 cm diameter) with the standards CUYZ (SHRIMP II $^{238}\text{U}/^{206}\text{Pb}$ age of 568.55 Ma; A. Kennedy, Personal Communication, 2019), OGC1 (TIMS $^{206}\text{Pb}/^{207}\text{Pb}$ age of 3465 ± 0.6 Ma; [Stern et al., 2009](#)), TEMORA 2 (ID-TIMS $^{238}\text{U}/^{206}\text{Pb}$ age of 416.8 ± 0.33 Ma; [Black et al., 2014](#)) and NIST-610 glass ([Jochum et al., 2011](#)). The epoxy mounts containing the zircon grains were then polished with diamond film polishing mats (polished up to 1 μm) to half of mean grain thickness. After polishing mounts were imaged using transmitted and reflected light microscopy. The previously described procedures were conducted at the School of Earth Sciences, The University of Western Australia (UWA), Perth, Australia. Subsequently, the mounts were cleaned using an ultrasonic bath with petroleum/ethanol spirits, followed by a soap solution, rinsed with deionized water, and, finally, Au-coated (40 μm). Further imaging was taken using secondary electron (SE), back scatter (BSE) and cathodoluminescence (CL) methodologies to identify internal growth patterns, fractures, and inclusions in order to facilitate the spot emplacement, using a Vega 3 Tescan Scanning Electron Microscope (SEM-EDS) at the Centre for Microscopy, Characterisation and Analysis (CMCA), UWA. Imaging parameters include: accelerated voltage of 15 – 20 kV, working distance of 15 mm, and beam intensity of 1.5 – 1.6 nA. After imaging, the mounts were cleaned using an ultrasonic bath with petroleum/ethanol spirits, followed by a soap solution, and finally, rinsed with deionized water. After cleaning mounts were oven dried at 60°C at the John de Laeter (JdL) Centre for Isotope Research of Curtin University, Perth, Australia. The polished surface of the mounts was then coated evaporatively with high-purity gold to a thickness of about 40 μm at the JdL Centre following the protocol described by [Wingate and Lu \(2017\)](#).

Zircon grains from samples VJ-52, VJ-49, VJ-4 and VJ-30 were concentrated via magnetic separation (Frantz isodynamic magnetic separator) followed by hand picking (up to 100 grains from each sample). Grains were mounted in epoxy resin disk and polished until

attain quasi-central sections at the Institute of Geosciences, University of Campinas, Brazil. At the State Key Laboratory of Ore Deposit Geochemistry (SKLOG), Institute of Geochemistry, Chinese Academy of Sciences (Guiyang), China, the mounts were imaged with transmitted and reflected light using conventional microscope. After C-coating, further imaging was taken using secondary electron (SE), back scatter (BSE) and cathodoluminescence (CL) imaging modes to look for internal growth patterns, fractures, and inclusions in order to facilitate the spot emplacement, were performed using a JSM-7800F Scanning Electron Microscope (SEM-EDS).

Zircon U-Pb: Sensitive High-Resolution Ion Microprobe (SHRIMP)

Analyses of selected zircon grains were conducted using the SHRIMP II B at the JdL Centre for Isotope Research, Curtin University, Perth, Australia. Details of instrument operating conditions are described in [Kennedy and De Laeter \(1994\)](#), and [De Laeter and Kennedy \(1998\)](#). Analytical conditions are described in detail in [Compston *et al.* \(1984\)](#), [Claoué-Long *et al.* \(1995\)](#), [Williams \(1998\)](#), and [Wingate and Kirkland \(2014\)](#). Raw U-Pb data was reduced with program Excel add-in SQUID version 2.5 ([Ludwig, 2009](#)) and plotted with ISOPLOT© 3 ([Ludwig, 2003](#)). Common Pb correction was based on the ^{204}Pb measured. Uncertainties given for individual analyses are at 2σ level. U-Pb ages were calculated from concordant to near concordant analysis (discordance between -10% and +10%). Additionally, analysis with U concentrations over 1000 ppm were also rejected. Measured data are presented in Supplementary Table SM2. The dates obtained on OGC1, TEMORA 2, and CUYZ standards within uncertainty were warranted (Supplementary Table SM4).

Zircon U-Pb: Laser ablation inductively coupled mass spectrometry (LA-ICP-MS)

Analyses of selected grains were conducted using an Agilent 7700x ICP-MS coupled with a 193-nm ArF Excimer Laser Ablation system (GeoLasPro). All analyses were undertaken using a 32 μm laser spot diameter, 5 Hz laser repetition rate, and a laser fluence of 7 J/cm². Helium was used as carrier gas to efficiently transport the ablated aerosol to the ICP-MS. Analysis involved 15s of background measurement (gas blank) and 60s of ablation. Raw U-Pb data was reduced with ICMPSDataCal software ([Liu *et al.*, 2010a,b](#)) and plotted with ISOPLOT© 3 ([Ludwig, 2003](#)). Zircon 91500 (TIMS U-Pb age of 1065 Ma; [Wiedenbeck *et al.*, 1995](#)) was used as external standard for U-Pb dating, and was analyzed twice every 8 analyses. Preferred U-Th-Pb isotopic ratios used for 91500 are from [Wiedenbeck *et al.* \(1995\)](#). Zircon reference material GJ-1 (TIMS $^{207}\text{Pb}/^{206}\text{Pb}$ age of 608.5 ± 0.4 Ma; [Jackson *et al.*, 2004](#)) was analyzed as unknown to check the analytical accuracy. No common Pb calibration was needed

during the data reduction and processing since the counts per second (cps) of ^{204}Pb in the sample and standard were too low to be calculated (< 10 cps). The total lead concentration in the zircon was externally calibrated against the glass standard NIST 610 (Jochum *et al.*, 2011) with Si as an internal standard (Hu *et al.*, 2011). Uncertainties given for individual analyses are at 2σ level. U-Pb ages were only calculated within the discordance interval between -10% and +10%. Additionally, analysis that comprise U concentrations over 1000 ppm were also rejected. The complete results are presented in Supplementary Table SM3. The dates obtained on 91500 and GJ-1 standards within uncertainty were warranted (Supplementary Table SM5).

Geochemistry

Whole rock geochemical analyses for major, minor, and trace elements were conducted on 70 samples devoid of veins of the major units of the eastern portion of the Alta Floresta Mineral Province. Although efforts were made to select sample with low degree of alteration, all rocks have been altered to hydrothermal minerals to different degrees as indicated by the petrography and high loss on ignition (LOI) in some samples ($> 3\%$), which may have affected alkali contents and other fluid-mobile elements. Thirty-seven samples were collected from outcrops, and thirty-three from diamond drill cores. All analyses were conducted at the ALS Minerals Global Group laboratory, Canada. Analysis consisted of lithium borate fusion Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) for major element oxides, aqua regia digestion ICP-AES for base metals, and lithium borate fusion Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) for minor and trace elements. Results were corrected for spectral inter-element interferences and oxide concentration was calculated from determined elemental concentration. LOI was determined by firing the rock powder at 1000°C and calculating the weight difference before and after the firing. In order to maintain data quality, various standards and unknowns were run between analysis). All data were processed and interpreted using MS ExcelTM. The complete results are presented in Supplementary Table SM6.

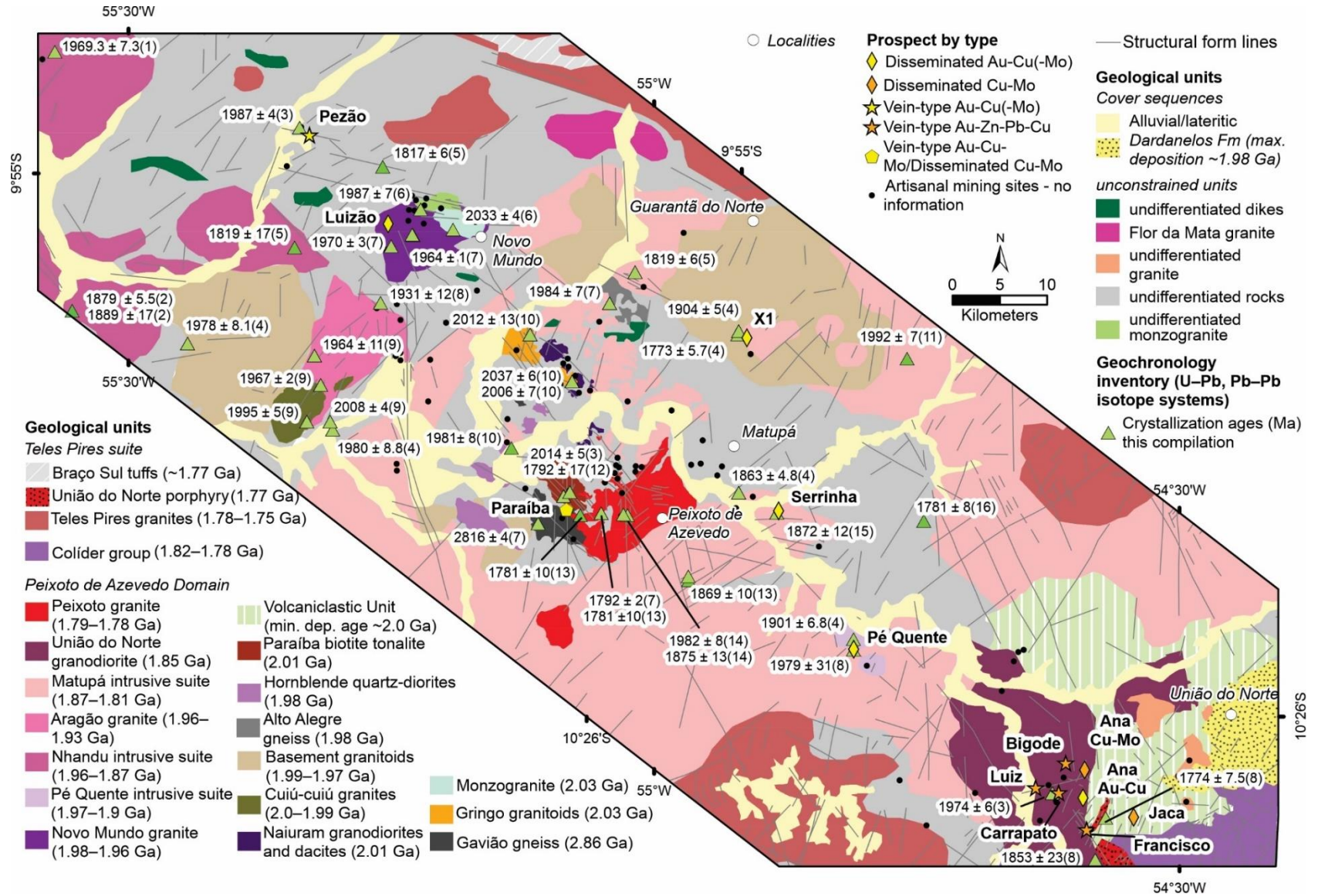


Figure SM1. Geological map of the eastern Alta Floresta Mineral Province with the geochronological data from the literature.

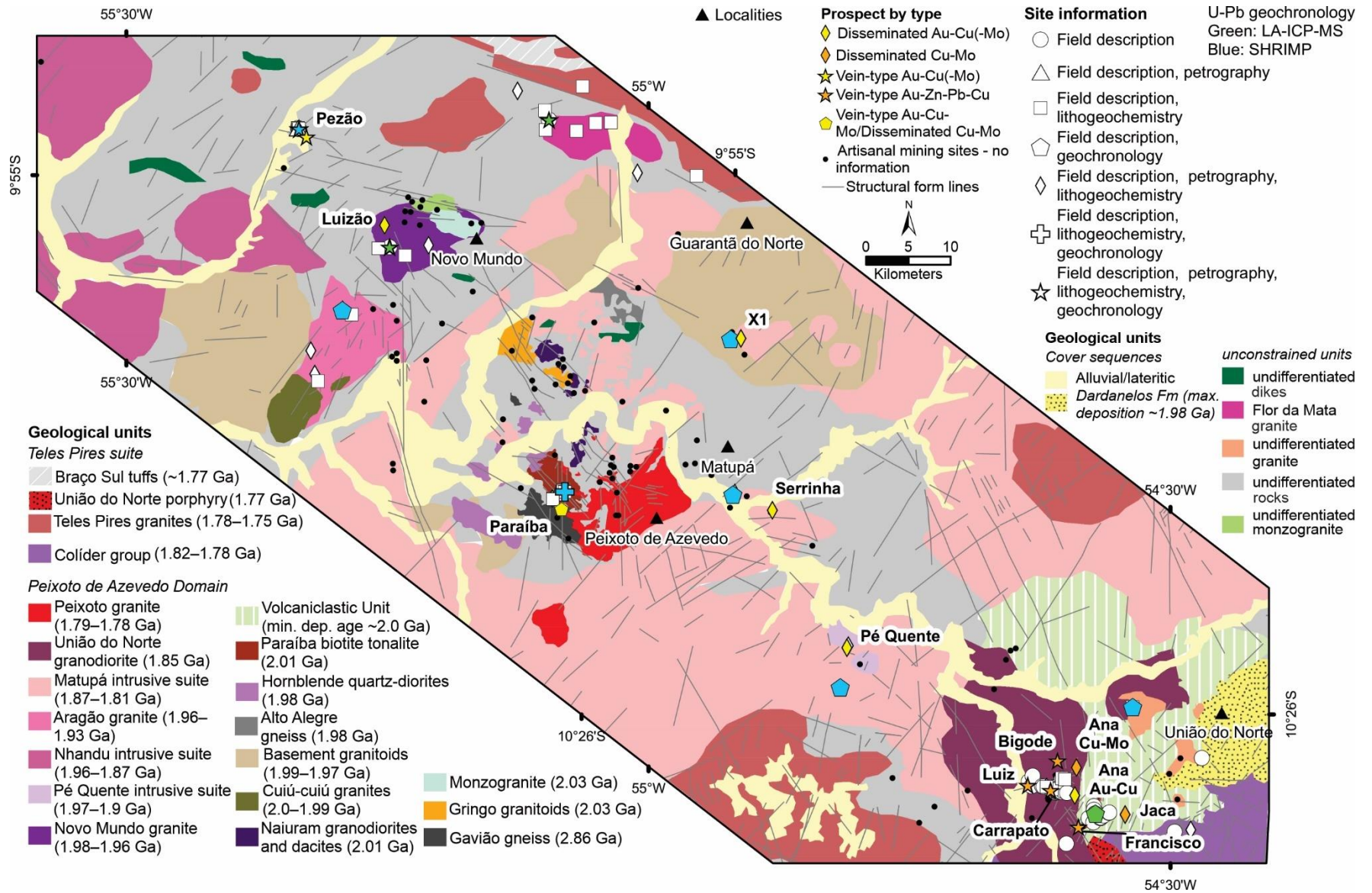


Figure SM2. Geological map of the eastern Alta Floresta Mineral Province with the samples investigated in this study.

Table SM1. Investigated samples presented in the results of this study.

Unit: lithotype	Sample	Coordinates (WSG 84)		Field hand specimen description	Petrography	Lithogeochemistry	Geochronology
		Latitude	Longitude				
Honeycomb weathering	VJ-1	-10.453	-54.579	x			
Contact of the sedimentary cover (Dardanelos Formation-Caiabis group) and the União do Norte granodiorite	VJ-3	-10.475	-54.469	x			
Silica and alunite intercalation	VJ-4	-10.545	-54.496	x			
Undifferentiated granite: porphyritic alkali-feldspar granite	UNGr-2 (VJ-2)	-10.426	-54.536	x	x		
Undifferentiated granite: porphyritic alkali-feldspar granite	UNGr (VGT-21)	-10.426	-54.536	x			x (SHRIMP)
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-5 (VJ-5)	-10.544	-54.48	x	x	x	
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-54 (VJ-54)	-10.82	-55.43	x			
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-55 (VJ-55)	-10.825	-55.398	x	x	x	
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-14 (VGT-14)	-10.827	-55.408	x		x	
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL (VGT-15)	-10.825	-55.398	x			x (SHRIMP)
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-16 (VGT-16)	-10.85	-55.418	x		x	
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-17 (VGT-17)	-10.82	-55.43	x		x	
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-29 (VGT-29)	-10.589	-54.386	x		x	
Colíder suite: porphyritic volcanic rock (dacite, andesite, rhyolite)	COL-16B (VGT-16B)	-10.85	-55.418	x	x		
União do Norte porphyry: quartz-feldspar porphyry	PFUN-6 (VJ-6)	-10.494	-54.603	x		x	
União do Norte porphyry: quartz-feldspar porphyry	PFUN-7 (VJ-7)	-10.494	-54.603	x		x	
União do Norte porphyry: quartz-feldspar porphyry	PFUN-11 (VJ-11)	-10.495	-54.601	x		x	
União do Norte porphyry: quartz-feldspar porphyry	PFUN-27 (VJ-27)	-10.536	-54.573	x			
União do Norte porphyry: quartz-feldspar porphyry	PFUN-29 (VJ-29)	-10.524	-54.573	x			
União do Norte porphyry: quartz-feldspar porphyry	PFUN-30 (VJ-30)	-10.528	-54.572	x			x (LA-ICP-MS)
União do Norte porphyry: quartz-feldspar porphyry	PFUN-31 (VJ-31)	-10.521	-54.573	x			

União do Norte porphyry: quartz-feldspar porphyry	PFUN-26 (VGT-26)	-10.528	-54.572	x			
soil profile (Pica Pau artisanal mining site)	VJ-8	-10.499	-54.602	x			
soil profile (Davi artisanal mining site)	VJ-9	-10.506	-54.603	x			
União do Norte granodiorite	VJ-10	-10.507	-54.604	x			
União do Norte granodiorite	VJ-12	-10.507	-54.609	x			
União do Norte granodiorite	VJ-20	-10.506	-54.608	x			
União do Norte granodiorite	VJ-36	-10.492	-54.631	x			
União do Norte granodiorite	VGT-25	-10.557	-54.599	x			
soil profile (Ana artisanal mining site)	VJ-13	-10.506	-54.61	x			
soil profile (Ana artisanal mining site)	VJ-14	-10.503	-54.612	x			
soil profile (Ana artisanal mining site)	VJ-15	-10.503	-54.612	x			
soil profile (Ana artisanal mining site)	VJ-16	-10.504	-54.612	x			
soil profile (Ana artisanal mining site)	VJ-17	-10.507	-54.608	x			
soil profile (Ana artisanal mining site)	VJ-18	-10.507	-54.608	x			
soil profile (Ana artisanal mining site)	VJ-19	-9.871	-54.89	x			
soil profile (Ana artisanal mining site)	VJ-21	-10.508	-54.609	x			
soil profile (Ana artisanal mining site)	VJ-22	-10.508	-54.61	x			
Volcaniclastic unit	VJ-23	-10.527	-54.558	x			
Volcaniclastic unit	VJ-24	-10.529	-54.563	x			
Volcaniclastic unit	VJ-25	-10.532	-54.567	x			
Volcaniclastic unit	VJ-26	-10.532	-54.566	x			
Volcaniclastic unit	VJ-28	-10.532	-54.578	x			
soil profile (Luiz prospect)	VJ-32	-10.001	-54.716	x			
Luiz prospect: biotite granodiorite	VJ-33	-10.497	-54.635	x			
Luiz prospect: quartz-feldspar porphyry	LZQFP-1 (Ana 028-43.70)	-10.504	-54.613	x	x	x	
Luiz prospect: quartz-feldspar porphyry	LZQFP-2 (MOC 004-61.00)	-10.502	-54.618	x	x		
Luiz prospect: quartz-feldspar porphyry	LZQFP-3 (MOC 004-60.13)	-10.502	-54.618	x	x	x	
Luiz prospect: quartz-feldspar porphyry	LZQFP-4 (Ana 028-40.42)	-10.504	-54.613	x	x	x	
Luiz prospect: quartz-feldspar porphyry	LZQFP-5 (Ana 028-110.4)	-10.504	-54.613	x		x	
Luiz prospect: quartz-feldspar porphyry	LZQFP-6 (Ana 028-35)	-10.504	-54.613	x		x	
soil profile (Carrapato prospect)	VJ-34	-10.502	-54.622	x			

soil profile (Carrapato prospect)	VJ-35	-10.502	-54.612	x			
Pé Quente suite: quartz-monzonite	PQ-37 (VJ-37)	-10.367	-54.808	x	x	x	
Pé Quente suite: quartz-monzonite	PQ (VGT-30)	-10.402	-54.816	x			x (SHRIMP)
Paraíba prospect: quartz-pyrite-magnetite-biotite-muscovite vein	VJ-38	-10.221	-55.083	x			
Paraíba prospect: biotite tonalite	PBH-1 (PB-20-05: 38.20)	-10.222	-55.083	x		x	
Paraíba prospect: biotite tonalite	PBH-2 (PB-20-25)	-10.222	-55.083	x		x	
Paraíba prospect: biotite tonalite	PBH-3 (PB-20-26)	-10.222	-55.083	x		x	
Paraíba prospect: biotite tonalite	PBH-4 (PB-20-24)	-10.222	-55.083	x		x	
Paraíba prospect: biotite tonalite	PBH-5 (PAX-PAB-084 : 19.5 to 19.83 m)	-10.227	-55.091	x		x	
Paraíba prospect: biotite tonalite	PBH-6 (PAX-PAB-DH063 : A1 - 71 m)	-10.218	-55.082	x		x	
Paraíba prospect: biotite tonalite	PBH-7 (PAX-PAB-DH063 : A2 - 107.37 m)	-10.218	-55.082	x		x	
Paraíba prospect: biotite tonalite	PBH-8 (PAX-PAB-DH063 : A3 - 145.45 m)	-10.218	-55.082	x		x	
Paraíba prospect: biotite tonalite	PBH-9 (PAX-PAB-DH061 : A1 - 185.70 m)	-10.219	-55.081	x		x	
Paraíba prospect: biotite tonalite	PBH-10 (PAX-PAB-DH061 : A2 - 207.17 m)	-10.219	-55.081	x		x	
Paraíba prospect: biotite tonalite	PBH-11 (PAX-PAB-DH097 : A1 - 30.70 m)	-10.219	-55.082	x		x	
Paraíba prospect: biotite tonalite	PBH-12 (PAX-PAB-DH097 : A2 - 43.84 m)	-10.219	-55.082	x		x	
Paraíba prospect: porphyritic granite	PBQFP-39 (VJ-39)	-10.226	-55.092	x	x	x	
Paraíba prospect: porphyritic granite	PBQFP (PB-56-65 : 937.50 m)	-10.22	-55.08	x		x	x (SHRIMP)
Paraíba prospect: porphyritic granite	PBQFP-1 (PB-56-66 : 938.20 m)	-10.22	-55.08	x		x	
Paraíba prospect: porphyritic granite	PBQFP-2 (PB-84-1: 7 to 7.28 m)	-10.227	-55.091	x		x	
Paraíba prospect: porphyritic granite	PBQFP-3 (PB-84-3: 11.17 to 11.39 m)	-10.227	-55.091	x		x	
Paraíba prospect: porphyritic granite	PBQFP-4 (PB-84-19 : 54.12 to 54.39 m)	-10.227	-55.091	x		x	
Paraíba prospect: porphyritic granite	PBQFP-5 (PB-84-24: 86.58 to 86.78 m)	-10.227	-55.091	x		x	
Paraíba prospect: porphyritic granite	PBQFP-6 (PB-84-33 : 168.16 to 168.46 m)	-10.227	-55.091	x		x	
Paraíba prospect: porphyritic granite	PBQFP-7 (PB-84-36 : 197.47 to 197.68 m)	-10.227	-55.091	x		x	
Paraíba prospect: porphyritic granite	PBQFP-8 (PB-84-1)	-10.227	-55.091	x	x		
Paraíba prospect: porphyritic granite	PBQFP-9 (PB-84-3)	-10.227	-55.091	x	x		
Paraíba prospect: porphyritic granite	PBQFP-10 (PB-84-33)	-10.227	-55.091	x	x		
Teles Pires suite: alkali-feldspar granite	TPS (VJ-40)	-9.857	-54.881	x	x	x	x (LA-ICP-MS)
Teles Pires suite: alkali-feldspar granite	TPS-1 (VJ-41)	-9.812	-54.89	x		x	

Teles Pires suite: alkali-feldspar granite	TPS-2 (VJ-42)	-9.828	-54.912	x	x	x	
Teles Pires suite: alkali-feldspar granite	TPS-3 (VJ-43)	-9.828	-54.914	x	x	x	
Teles Pires suite: alkali-feldspar granite	TPS-9 (VGT-9)	-9.831	-55.062	x		x	
Teles Pires suite: alkali-feldspar granite	TPS-18 (VGT-18)	-9.857	-54.881	x			
Teles Pires suite: alkali-feldspar granite	TPS-19 (VGT-19)	-9.871	-54.89	x		x	
Teles Pires suite: alkali-feldspar granite	TPS-20 (VGT-20)	-9.917	-54.953	x		x	
Teles Pires suite: alkali-feldspar granite	TPS-32 (VGT-32)	-10.001	-54.716	x		x	
Aragão granite: hornblende-biotite granite	ARGr-44 (VJ-44)	-10.107	-55.319	x	x	x	
Aragão granite: hornblende-biotite granite	ARGr-45 (VJ-45)	-10.085	-55.323	x	x	x	
Aragão granite: hornblende-biotite granite	ARGr-46 (VJ-46)	-10.045	-55.293	x	x	x	
Aragão granite: hornblende-biotite granite	ARGr-1 (VGT-1)	-10.113	-55.284	x		x	
Aragão granite: hornblende-biotite granite	ARGr (VGT-2)	-10.046	-55.293	x			x (SHRIMP)
Aragão granite: hornblende-biotite granite	ARGr-3 (VGT-3)	-10.05	-55.284	x		x	
Matupá suite: biotite granodiorite/monzogranite (Jorge quarry)	MAT-47 (VJ-47)	-10.221	-54.917	x	x	x	
Matupá suite: biotite granodiorite/monzogranite (Jorge quarry)	MAT-Doc.9 (P1.1)	-10.222	-54.919	x			x (SHRIMP)
Matupá suite: biotite granodiorite/monzogranite (Jorge quarry)	VGT-31	-10.466	-55.194	x		x	
Novo Mundo granite: biotite granite	NMGr (VJ-49)	-9.985	-55.248	x	X	x	x (LA-ICP-MS)
Novo Mundo granite: biotite granite	NMGr-1 (VJ-50)	-9.984	-55.21	x	X	x	
Novo Mundo granite: biotite granite	NMGr-4 (VGT-04)	-9.985	-55.248	x			
Novo Mundo granite: biotite granite	NMGr-5 (VGT-05)	-9.993	-55.233	x		x	
Novo Mundo granite: biotite granite	NMGr-12 (VGT-12)	-9.986	-55.258	x		x	
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-1 (VJ-51)	-9.836	-55.125	x	x	x	
Flor da Mata granite: biotite-hornblende monzogranite	FMGr (VJ-52)	-9.863	-55.095	x	x	x	x (LA-ICP-MS)
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-2 (VJ-53)	-9.914	-55.01	x	x	x	
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-6 (VGT-6)	-9.873	-55.098	x		x	
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-7 (VGT-7)	-9.863	-55.095	x			
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-8 (VGT-8)	-9.854	-55.099	x		x	
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-10 (VGT-10)	-9.866	-55.05	x		x	

Flor da Mata granite: biotite-hornblende monzogranite	FMGr-11 (VGT-11)	-9.874	-55.068	x		x	
Flor da Mata granite: biotite-hornblende monzogranite	FMGr-13 (VGT-13)	-9.866	-55.035	x		x	
X1 prospect: quartz-feldspar porphyry	X1QFP (VJ-56)	-10.073	-54.921	x			x (SHRIMP)
Granito antigo União do Norte (unidade ainda indefinida)	VGT-22	-10.492	-54.631	x			
Ana prospect: quartz-feldspar porphyry	PFUN-23 (VGT-23)	-10.494	-54.603	x			
granite (União do Norte region - unconstrained unit)	VGT-24	-10.508	-54.599	x			
Jaca prospect: quartz-feldspar porphyry (?)	VGT-27	-10.531	-54.566	x			
Jaca prospect: quartz-feldspar porphyry (?)	VGT-28	-10.527	-54.558	x			
Pezão prospect: syenogranite	PZH-1 (AD001-49.17)	-9.871	-390	x		x	
Pezão prospect: syenogranite	PZH-2 (AD-FD-01 : A1-171.00 m)	-8.871	-390	x			
Pezão prospect: syenogranite	PZH-3 (AD-FD-01 : A2-173.70 m)	-7.871	-390	x		x	
Pezão prospect: syenogranite	PZH-4 (AD-FD-01 : A3-174.40 m)	-6.871	-390	x		x	
Pezão prospect: syenogranite	PZH-5 (AD-FD-01 : A4-175.60 m)	-5.871	-390	x		x	
Pezão prospect: syenogranite	PZH-6 (AD-FD-01 : A5-177.65 m)	-4.871	-390	x		x	
Pezão prospect: syenogranite	PZH-7 (AD-FD-01 : A6-178.40 m)	-3.871	-390	x		x	
Pezão prospect: syenogranite	PZH-8 (AD-FD-01 : A7-181.20 m)	-2.871	-390	x		x	
Pezão prospect: quartz-feldspar porphyry	PZQFP-1 (AD-FD-02 (2) - 25.80 m)	-9.872	-55.334	x		x	
Pezão prospect: quartz-feldspar porphyry	PZQFP (AD-FD-02 : A1-25.85 m)	-9.872	-55.334	x	x	x	x (SHRIMP)
Pezão prospect: quartz-feldspar porphyry	PZQFP-2 (AD-FD-02 : A2-25.90 m)	-9.872	-55.334	x			
Pezão prospect: quartz-feldspar porphyry	PZQFP-3 (AD-FD-02 : A3-25.95 m)	-9.872	-55.334	x			
Pezão prospect: quartz-feldspar porphyry	PZQFP-4 (AD-FD-02 : A4-26.00 m)	-9.872	-55.334	x			
Pezão prospect: quartz-feldspar porphyry	PZQFP-5 (AD-FD-02 : A5-28.90 m)	-9.872	-55.334	x		x	
Pezão prospect: quartz-feldspar porphyry	PZQFP-6 (AD-FD-02 : A6-29.10 m)	-9.872	-55.334	x			

Table SM2. Results of zircon SHRIMP U-Pb analysis from this study.

Spot Name	Comment	²⁰⁶ Pb/ ²⁰⁶ Pb	1σ ±%	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ ±%	²⁰⁸ Pb/ ²⁰⁶ Pb	1σ ±%	²⁰⁶ Pb/ ²³⁵ U	1σ ±%	4-corr % ²⁰⁶ Pb _{bc}	ppm U	ppm Th	²³² Th/ ²³⁵ U	1σ ±%	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb Age	± absolute	(1) ²⁰⁶ Pb/ ²³⁵ U Age	± absolute	% DI s.	(1) ²⁰⁶ Pb/ ²³⁸ U*	1σ ±%	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb*	1σ ±%	(1) ²⁰⁶ Pb/ ²³⁸ U*	1σ ±%	err corr		
Sample ARGr - Aragão hornblende-biotite granite																												
ARGr-5		2.4E-05	100	0.12	0.98	0.18	1.31	0.57	2.27	0.04	61.11	37.83	0.64	0.40	1951	18	1906	22	3	2.91	1.33	0.12	1.02	5.68	1.68	0.34	1.33	0.79
ARGr-10		2.0E-04	21.32	0.12	0.60	0.19	0.79	0.80	3.37	0.31	110.82	70.80	0.66	0.27	1956	14	1862	18	6	2.99	1.11	0.12	0.78	5.54	1.36	0.33	1.11	0.82
ARGr-9		5.1E-05	40.83	0.12	0.57	0.21	0.72	0.79	1.93	0.08	117.39	83.66	0.74	0.25	1957	11	1899	18	3	2.92	1.09	0.12	0.62	5.67	1.26	0.34	1.09	0.87
ARGr-13		2.9E-05	70.71	0.12	0.75	0.22	0.93	0.58	1.75	0.04	104.48	78.41	0.78	0.30	1960	14	1899	19	4	2.92	1.16	0.12	0.79	5.68	1.40	0.34	1.16	0.83
ARGr-3		6.7E-05	33.33	0.12	0.55	0.18	0.72	0.80	3.10	0.10	136.58	82.60	0.62	1.46	1962	11	1923	18	2	2.88	1.07	0.12	0.60	5.77	1.23	0.35	1.07	0.87
ARGr-16.1		-5.1E-05	50	0.12	0.71	0.18	0.95	0.75	2.23	-0.08	75.96	46.38	0.63	0.31	1966	14	1926	20	2	2.87	1.18	0.12	0.76	5.79	1.40	0.35	1.18	0.84
ARGr-11		-2.0E-05	50	0.12	0.86	0.19	0.58	0.74	1.83	-0.03	201.56	128.91	0.66	0.20	1968	15	1900	16	4	2.92	0.99	0.12	0.86	5.71	1.32	0.34	0.99	0.76
ARGr-4		8.9E-06	100	0.12	0.60	0.21	0.74	0.69	1.82	0.01	129.29	93.23	0.74	0.25	1968	11	1902	26	4	2.91	1.56	0.12	0.60	5.71	1.68	0.34	1.56	0.93
ARGr-12		8.3E-05	50	0.12	0.91	0.30	2.19	0.74	4.64	0.13	50.89	51.43	1.04	0.58	1968	18	1845	21	7	3.02	1.34	0.12	1.03	5.52	1.69	0.33	1.34	0.79
ARGr-8		3.4E-04	31.45	0.13	1.10	0.13	1.72	0.94	0.98	0.51	153.70	64.55	0.43	0.00	1975	29	1855	14	7	3.00	0.86	0.12	1.64	5.57	1.85	0.33	0.86	0.46
Rejected ARGr-7.2	Pb-loss	-2.2E-13	9999	0.11	0.79	0.16	1.06	0.64	1.82	0.00	76.72	42.58	0.57	0.51	1784	14	1769	18	1	3.17	1.18	0.11	0.79	4.75	1.42	0.32	1.18	0.83
ARGr-7	Pb-loss	1.8E-04	44.73	0.11	1.21	0.32	2.43	0.69	2.16	0.28	30.84	32.42	1.09	0.43	1785	29	1681	23	7	3.36	1.54	0.11	1.58	4.48	2.21	0.30	1.54	0.70
ARGr-2	Pb-loss	1.5E-04	44.72	0.12	1.09	0.21	2.30	0.42	1.43	0.23	79.91	56.04	0.72	1.73	1915	24	1873	22	3	2.97	1.33	0.12	1.34	5.45	1.89	0.34	1.33	0.70
ARGr-6	Pb-loss	1.8E-05	100	0.12	0.85	0.27	0.96	0.70	2.15	0.03	58.98	55.28	0.97	0.34	1934	16	1926	21	0	2.87	1.28	0.12	0.87	5.69	1.55	0.35	1.28	0.83
ARGr-14.1	inherited	1.2E-05	100	0.12	0.68	0.19	0.89	0.66	1.56	0.02	89.90	59.35	0.68	0.29	1979	12	1869	18	6	2.97	1.14	0.12	0.69	5.64	1.33	0.34	1.14	0.85
ARGr-15.1	inherited	-5.3E-05	37.80	0.12	0.54	0.10	0.95	0.70	2.18	-0.08	139.57	47.90	0.35	0.28	1982	10	1922	17	3	2.88	1.05	0.12	0.58	5.83	1.20	0.35	1.05	0.87
ARGr-1	large positive discordance (LPD)	2.4E-03	13.50	0.17	1.14	0.31	1.37	0.70	1.03	3.55	143.95	89.51	0.64	0.00	2241	59			25	3.21	0.98	0.14	3.44	6.07	3.57	0.31	0.98	0.27
Sample COL - Colider porphyritic rhyolite																												
COL-15		4.0E-05	100	0.11	1.35	0.30	1.43	0.60	5.15	0.06	40.69	41.87	1.06	0.52	1828	26	1775	25	3	3.15	1.60	0.11	1.44	4.88	2.15	0.32	1.60	0.74
COL-7		1.3E-04	44.72	0.11	1.03	0.48	0.92	0.67	0.82	0.20	40.89	66.35	1.68	0.35	1829	23	1757	22	4	3.19	1.40	0.11	1.27	4.83	1.89	0.31	1.40	0.74
COL-12		9.3E-05	57.74	0.11	1.13	0.29	1.21	0.68	2.14	0.14	34.25	33.28	1.00	0.73	1830	24	1791	23	2	3.12	1.48	0.11	1.31	4.94	1.98	0.32	1.48	0.75
COL-6		7.4E-05	57.74	0.11	1.01	0.39	0.98	0.68	2.56	0.12	44.72	59.23	1.37	0.35	1830	21	1768	21	4	3.17	1.37	0.11	1.14	4.87	1.79	0.32	1.37	0.77
COL-10		-4.3E-13	9999	0.11	1.09	0.28	1.19	0.67	0.86	0.00	37.91	37.76	1.03	0.71	1836	20	1808	23	2	3.09	1.44	0.11	1.09	5.01	1.80	0.32	1.44	0.80
COL-1		-9.8E-14	9999	0.11	0.90	0.24	1.03	0.67	2.58	0.00	56.42	45.92	0.84	0.34	1839	16	1787	20	3	3.13	1.28	0.11	0.90	4.95	1.57	0.32	1.28	0.82
COL-8		-1.3E-04	57.74	0.11	1.34	0.36	1.31	0.69	1.71	-0.20	24.48	30.08	1.27	0.47	1841	29	1818	26	1	3.07	1.66	0.11	1.59	5.06	2.30	0.33	1.66	0.72
Rejected COL-5	U-gain	1.1E-04	57.74	0.11	1.26	0.50	1.09	0.66	2.42	0.18	28.74	49.43	1.78	0.42	1764	28	171	24	-1	3.14	1.57	0.11	1.52	4.73	2.19	0.32	1.57	0.72
COL-13	Pb-loss	1.5E-04	44.72	0.11	1.11	0.40	1.05	0.66	2.45	0.23	36.50	48.87	1.38	0.38	1767	26	1747	22	1	3.21	1.45	0.11	1.41	4.64	2.02	0.31	1.45	0.72
COL-11	Pb-loss	1.3E-04	57.74	0.11	1.34	0.29	1.42	0.67	1.06	0.20	24.58	23.95	1.01	0.83	1778	30	1759	26	1	3.19	1.66	0.11	1.66	4.70	2.35	0.31	1.66	0.71
COL-3	Pb-loss	2.0E-04	40.83	0.11	1.17	0.22	1.39	0.68	2.06	0.31	31.29	23.96	0.79	0.45	1782	29	1767	23	1	3.17	1.51	0.11	1.57	4.74	2.18	0.32	1.51	0.69

COL-2	Pb-loss	5.8E-05	50	0.11	0.7 7	0.26	0.8 7	0.75	2.3 8	0.09	67.10	59.48	0.92	0.3 0	1811	16	1798	19	1	3.11	1.2 1	0.11	0.8 6	4.91	1.4 8	0.32	1.2 1	0.82
COL-9	Pb-loss	6.6E-05	44.7 2	0.11	0.7 4	0.36	0.7 4	0.66	2.8 1	0.10	80.79	97.91	1.25	0.2 6	1812	15	1770	18	3	3.16	1.1 6	0.11	0.8 3	4.83	1.4 3	0.32	1.1 6	0.81
COL-14	Pb-loss	8.9E-05	50	0.11	0.9 5	0.20	1.1 9	0.69	2.4 0	0.14	46.41	31.72	0.71	0.3 8	1813	20	1776	32	2	3.15	2.0 5	0.11	1.1 1	4.84	2.3 3	0.32	2.0 5	0.88
COL-4	inherited	-1.2E-04	50	0.11	1.1 1	0.41	1.0 4	0.64	0.9 7	-0.18	38.15	52.39	1.42	0.3 8	1854	23	1802	23	3	3.10	1.4 5	0.11	1.3 0	5.04	1.9 4	0.32	1.4 5	0.75

Sample PBQFP - Paraba porphyritic granite

PBQFP-13.1		2.3E-05	70.7 1	0.11	1.1 4	0.17	0.9 3	0.72	3.5 4	0.04	104.2 0	58.64	0.58	1.2 7	1782	21	1686	16	6	3.35	1.0 8	0.11	1.1 6	4.49	1.5 9	0.30	1.0 8	0.68
PBQFP-7.1		1.1E-04	23.5 7	0.11	0.5 1	0.27	0.6 1	0.73	2.5 6	0.18	187.3 8	169.8 5	0.94	0.3 8	1789	11	1752	15	2	3.20	0.9 6	0.11	0.6 2	4.71	1.1 4	0.31	0.9 6	0.84
PBQFP-14.1		6.9E-05	28.8 7	0.11	0.5 0	0.18	0.7 2	0.68	2.6 8	0.11	218.0 0	130.3 3	0.62	1.9 6	1790	10	1720	14	4	3.27	0.9 4	0.11	0.5 6	4.62	1.0 9	0.31	0.9 4	0.86
PBQFP-18.1		1.7E-05	57.7 4	0.11	0.5 0	0.28	0.5 4	0.68	2.5 0	0.03	223.9 2	222.8 2	1.03	0.7 5	1793	9	1723	14	4	3.26	0.9 4	0.11	0.5 1	4.63	1.0 7	0.31	0.9 4	0.88
PBQFP-15.1		-1.5E-05	70.7 1	0.11	0.5 6	0.20	0.7 0	0.70	1.6 6	-0.02	168.7 7	112.3 6	0.69	0.4 3	1794	10	1740	15	3	3.23	0.9 8	0.11	0.5 7	4.69	1.1 3	0.31	0.9 8	0.86
PBQFP-8.1		7.1E-05	28.8 7	0.11	0.5 0	0.16	1.1 9	0.72	2.5 9	0.11	193.7 8	102.0 6	0.54	0.5 5	1800	10	1714	14	5	3.28	0.9 5	0.11	0.5 7	4.62	1.1 0	0.30	0.9 5	0.86
Rejected																												
PBQFP-4.1	LPD	2.2E-05	57.7 4	0.10	0.5 8	0.13	1.3 4	0.31	4.0 5	0.04	360.4 9	75.13	0.22	2.5 6	1612	11	654	7	62	9.36	1.1 5	0.10	0.6 0	1.46	1.3 0	0.11	1.1 5	0.88
PBQFP-6.1	LPD	2.0E-05	57.7 4	0.10	0.5 5	0.11	1.4 2	0.31	2.3 2	0.03	401.3 1	86.40	0.22	0.6 6	1672	11	851	9	52	7.08	1.1 0	0.10	0.5 7	2.00	1.2 4	0.14	1.1 0	0.89
PBQFP-3.1	LPD	-4.3E-06	100	0.11	0.4 3	0.28	1.1 4	0.55	2.5 4	-0.01	336.2 1	249.8 3	0.77	0.6 8	1721	8	1225	24	32	4.78	2.1 9	0.11	0.4 4	3.04	2.2 4	0.21	2.1 9	0.98
PBQFP-12.1	Pb-loss	1.1E-04	25	0.11	0.6 3	0.34	1.6 8	0.70	2.9 5	0.18	146.8 5	169.1 6	1.19	1.3 9	1760	13	1699	15	4	3.32	1.0 3	0.11	0.7 3	4.48	1.2 7	0.30	1.0 3	0.81
PBQFP-16.1	LPD	-4.7E-06	100	0.11	0.4 4	0.28	0.4 8	0.49	0.9 5	-0.01	371.1 1	334.9 9	0.93	0.1 6	1761	8	1352	11	26	4.28	0.8 7	0.11	0.4 5	3.47	0.9 8	0.23	0.8 7	0.89
PBQFP-11.1	LPD	1.3E-04	18.2 6	0.11	0.4 3	0.23	0.5 1	0.68	0.9 9	0.21	310.5 1	206.3 8	0.69	0.6 3	1784	10	1326	23	28	4.38	1.8 9	0.11	0.5 4	3.43	1.9 6	0.23	1.8 9	0.96
PBQFP-10.1	LPD	1.8E-05	57.7 4	0.11	0.5 0	0.26	1.0 4	0.61	1.7 4	0.03	237.7 4	196.0 4	0.85	0.9 3	1789	9	1595	13	12	3.56	0.9 3	0.11	0.5 2	4.23	1.0 6	0.28	0.9 3	0.87
PBQFP-1.1	LPD	1.1E-05	100	0.11	0.7 1	0.22	4.5 4	0.36	2.5 1	0.02	190.8 1	95.85	0.52	3.7 5	1794	13	1279	11	32	4.56	0.9 6	0.11	0.7 3	3.32	1.2 1	0.22	0.9 6	0.80
PBQFP-9.1	LPD	7.2E-05	44.7 2	0.11	0.7 8	0.38	0.7 5	0.28	1.5 2	0.11	244.1 8	207.5 7	0.88	1.4 4	1805	16	1256	18	33	4.65	1.6 1	0.11	0.8 8	3.27	1.8 3	0.22	1.6 1	0.88
PBQFP-5.1	inherited	2.7E-06	100	0.11	0.5 5	0.15	0.4 7	0.72	2.6 5	0.00	442.0 1	230.3 8	0.54	0.5 1	1809	10	1763	13	3	3.18	0.8 6	0.11	0.5 5	4.80	1.0 2	0.31	0.8 6	0.84
PBQFP-17.1	inherited	1.2E-05	100	0.11	0.7 1	0.18	1.8 9	0.67	1.5 7	0.02	110.0 3	66.19	0.62	1.1 9	1814	13	1688	16	8	3.34	1.0 7	0.11	0.7 2	4.58	1.2 9	0.30	1.0 7	0.83
PBQFP-2.1	inherited	7.7E-05	70.7 1	0.11	1.2 6	0.39	1.2 0	0.50	2.3 1	0.12	50.82	67.60	1.37	0.4 1	1823	26	1753	22	4	3.20	1.4 3	0.11	1.4 3	4.80	2.0 2	0.31	1.4 3	0.71

Sample UNGr - Undifferentiated porphyritic alkali-feldspar granite

UNGr-1.1		-6.2E-05	100	0.11	2.7 4	0.42	1.5 0	0.50	2.6 5	-0.10	39.56	57.26	1.50	0.5 1	1769	52	1752	26	1	3.20	1.7 1	0.11	2.8 3	4.66	3.3 0	0.31	1.7 1	0.52
UNGr-14.1		8.7E-05	35.3 6	0.11	0.6 7	0.21	0.8 1	0.72	2.3 2	0.14	109.3 2	77.91	0.74	0.2 7	1783	14	1756	16	2	3.19	1.0 6	0.11	0.7 8	4.71	1.3 2	0.31	1.0 6	0.81
UNGr-12.1		-6.1E-13	999 9	0.11	1.3 1	0.27	1.4 4	0.73	3.5 4	0.00	28.78	26.03	0.93	0.4 8	1785	24	17515	24	4	3.28	1.6 0	0.11	1.3 1	4.58	2.0 7	0.30	1.6 0	0.77
UNGr-10.1		1.9E-04	37.8 0	0.11	1.7 2	0.27	1.1 8	0.71	1.9 3	0.30	44.87	41.29	0.95	0.4 0	1787	36	1744	21	3	3.22	1.3 9	0.11	1.9 9	4.68	2.4 3	0.31	1.3 9	0.57
UNGr-15.1		-9.4E-13	999 9	0.11	1.1 4	0.35	1.1 3	0.63	2.1 9	0.00	48.39	59.47	1.27	0.4 0	1789	21	1819	22	-2	3.07	1.4 0	0.11	1.1 4	4.91	1.8 1	0.33	1.4 0	0.78
UNGr-16.1		-1.3E-13	999 9	0.11	1.0 5	0.26	1.1 8	0.68	2.2 6	0.00	47.81	42.64	0.92	0.3 9	1790	19	1798	21	0	3.11	1.3 5	0.11	1.0 5	4.85	1.7 1	0.32	1.3 5	0.79
UNGr-13.1		2.6E-05	57.7 4	0.11	0.6 1	0.24	0.7 0	0.73	2.4 3	0.04	136.5 0	113.5 9	0.86	0.2 4	1791	12	1737	15	3	3.23	1.0 2	0.11	0.6 4	4.67	1.2 0	0.31	1.0 2	0.85
UNGr-7.1		-4.4E-05	100	0.11	1.3 7	0.25	1.5 3	0.57	1.6 6	-0.07	37.76	32.78	0.90	0.4 8	1795	27	1758	24	2	3.19	1.5 4	0.11	1.4 7	4.74	2.1 3	0.31	1.5 4	0.72
Rejected																												
UNGr-17.1	U-gain	2.1E-04	44.7 3	0.11	1.3 2	0.53	1.8 4	0.72	1.6 4	0.33	28.50	52.17	1.89	0.4 4	1729	33	1770	25	-3	3.16	1.6 3	0.11	1.8 2	4.61	2.4 4	0.32	1.6 3	0.67
UNGr-5.1	U-gain	2.2E-04	35.3 6	0.11	1.0 8	0.37	1.0 5	0.63	2.2 0	0.35	51.72	63.75	1.27	0.6 5	1734	28	1759	21	-2	3.19	1.3 5	0.11	1.5 0	4.59	2.0 2	0.31	1.3 5	0.67
UNGr-6.1	U-gain	2.4E-04	35.3 6	0.11	1.1 2	0.56	0.9 4	0.71	2.5 5	0.37	43.37	83.17	1.98	0.3 7	1741	29	1799	22	-4	3.11	1.4 2	0.11	1.5 8	4.73	2.1 3	0.32	1.4 2	0.67

UNGR-11.1	U-gain	4.7E-05	100	0.11	1.3 9	0.25	1.5 8	0.44	2.8 2	0.07	60.51	53.15	0.91	0.4 7	1759	28	1799	34	-3	3.11	2.1 4	0.11	1.5 2	4.77	2.6 3	0.32	2.1 4	0.82
UNGR-2.1	Pb-loss?	1.8E-04	33.3 4	0.11	0.9 3	0.29	0.9 9	0.75	2.9 1	0.29	57.57	57.28	1.03	0.3 4	1761	22	1733	19	2	3.24	1.2 8	0.11	1.2 3	4.58	1.7 7	0.31	1.2 8	0.72
UNGR-4.1	Pb-loss?	9.5E-05	70.7 1	0.11	1.4 3	0.53	1.2 2	0.53	3.0 7	0.15	45.24	81.17	1.85	1.3 1	1762	31	1746	36	1	3.22	2.3 8	0.11	1.6 8	4.62	2.9 1	0.31	2.3 8	0.82
UNGR-3.2	LPD	1.8E-04	23.5 7	0.11	1.3 1	0.26	0.7 4	0.46	3.6 4	0.29	261.5 3	225.1 3	0.89	0.5 1	1798	26	1640	14	10	3.45	0.9 8	0.11	1.4 5	4.39	1.7 5	0.29	0.9 8	0.56
UNGR-18.1	inherited	-4.6E-05	70.7 1	0.11	0.9 8	0.43	0.9 0	0.74	1.5 8	-0.07	55.62	83.04	1.54	0.3 4	1806	19	1813	21	0	3.08	1.3 2	0.11	1.0 5	4.95	1.6 9	0.32	1.3 2	0.78
UNGR-9.1	inherited	-2.8E-05	100	0.11	1.0 8	0.30	1.8 1	0.63	3.0 5	-0.04	51.93	53.53	1.06	0.3 8	1813	21	1715	30	6	3.28	2.0 0	0.11	1.1 3	4.66	2.3 0	0.30	2.0 0	0.87
UNGR-8.1	inherited	-6.9E-05	70.7 1	0.11	1.1 9	0.29	1.2 7	0.65	2.5 0	-0.11	40.43	40.47	1.03	0.4 3	1821	24	1807	23	1	3.09	1.4 7	0.11	1.3 2	4.97	1.9 8	0.32	1.4 7	0.74
UNGR-3.1	inherited	-4.8E-05	100	0.11	1.4 1	0.44	1.3 1	0.41	2.5 5	-0.07	63.24	95.90	1.57	1.0 4	1831	28	1784	23	3	3.14	1.4 7	0.11	1.5 2	4.92	2.1 1	0.32	1.4 7	0.69
Sample X1QFP - X1 quartz-feldspar porphyry																												
X1-20		3.9E-06	100	0.11	0.6 9	0.29	0.4 3	0.56	2.0 0	0.01	697.4 2	693.7 2	1.03	0.1 7	1773	13	1741	13	2	3.23	0.8 7	0.11	0.6 9	4.63	1.1 1	0.31	0.8 7	0.79
X1-8		1.5E-05	70.7 1	0.11	0.5 6	0.31	0.5 8	0.54	2.0 2	0.02	385.0 2	399.3 2	1.07	0.2 1	1777	10	1719	14	4	3.27	0.9 4	0.11	0.5 8	4.58	1.1 0	0.31	0.9 4	0.85
X1-16		1.6E-05	50	0.11	0.4 0	0.28	0.7 1	0.60	1.8 7	0.02	627.8 9	592.7 9	0.98	0.1 7	1778	8	1759	20	1	3.19	1.2 7	0.11	0.4 2	4.71	1.3 4	0.31	1.2 7	0.95
X1-15		1.5E-05	57.7 4	0.11	0.4 6	0.21	0.5 6	0.54	2.4 6	0.02	555.2 9	384.5 3	0.72	0.1 9	1781	9	1767	14	1	3.17	0.8 9	0.11	0.4 7	4.73	1.0 1	0.32	0.8 9	0.88
X1-5		6.6E-05	30.1 5	0.11	0.5 1	0.31	0.5 3	0.53	2.8 5	0.10	439.8 9	444.3 3	1.04	0.1 9	1783	10	1755	14	2	3.20	0.9 2	0.11	0.5 7	4.70	1.0 8	0.31	0.9 2	0.85
X1-14		-1.5E-05	44.7 2	0.11	0.3 6	0.25	0.4 0	0.56	2.1 0	-0.02	902.3 4	755.9 4	0.87	0.1 6	1787	7	1778	16	1	3.15	1.0 1	0.11	0.3 6	4.78	1.0 8	0.32	1.0 1	0.94
Rejected																												
X1-1	LPD	8.2E-05	33.3 3	0.11	0.6 3	0.19	0.7 8	0.40	3.5 5	0.13	373.4 3	431.6 3	1.19	1.0 2	1738	13	1310	11	27	4.44	0.9 3	0.11	0.7 3	3.30	1.1 8	0.23	0.9 3	0.79
X1-3	Pb-loss	4.9E-04	19	0.11	0.7 5	0.31	0.7 9	0.49	3.5 4	0.77	205.4 2	194.2 9	0.98	1.6 6	1739	27	1599	33	9	3.55	2.3 1	0.11	1.4 5	4.13	2.7 3	0.28	2.3 1	0.85
X1-13	Pb-loss	2.3E-05	50	0.11	0.4 9	0.22	0.5 8	0.58	1.6 0	0.04	466.5 1	355.6 2	0.79	0.2 0	1758	9	1744	14	1	3.22	0.9 1	0.11	0.5 1	4.60	1.0 5	0.31	0.9 1	0.87
X1-11	Pb-loss	1.8E-05	44.7 2	0.11	0.3 9	0.26	0.4 3	0.51	2.8 2	0.03	846.3 7	731.3 8	0.89	0.1 6	1770	7	1645	20	8	3.44	1.3 5	0.11	0.4 0	4.34	1.4 1	0.29	1.3 5	0.96
X1-7	LPD	1.2E-04	23.4 3	0.11	0.9 2	0.30	1.2 3	0.52	1.6 5	0.18	451.4 2	566.2 3	1.30	1.4 2	1776	18	1615	13	10	3.51	0.9 2	0.11	0.9 9	4.26	1.3 5	0.28	0.9 2	0.68
X1-17	U > 1000 ppm	5.7E-06	57.7 4	0.11	0.2 9	0.33	0.9 6	0.53	1.8 9	0.01	1448. 85	1632. 16	1.16	0.8 6	1779	5	1759	13	1	3.19	0.8 2	0.11	0.2 9	4.70	0.8 7	0.31	0.8 2	0.94
X1-19	U > 1000 ppm	-6.6E-15	999 9	0.11	0.2 4	0.43	0.2 2	0.57	2.3 7	0.00	1980. 93	2874. 83	1.50	0.4 3	1780	4	1817	13	-2	3.07	0.8 1	0.11	0.2 4	4.89	0.8 5	0.33	0.8 1	0.96
X1-12	U > 1000 ppm	6.3E-06	44.7 2	0.11	0.3 7	0.39	0.2 3	0.56	2.3 0	0.01	2067. 96	2702. 62	1.35	0.1 2	1782	7	1794	15	-1	3.12	0.9 4	0.11	0.3 8	4.82	1.0 2	0.32	0.9 4	0.93
X1-18	U > 1000 ppm	3.6E-06	70.7 1	0.11	0.2 8	0.37	0.2 7	0.57	2.7 2	0.01	1378. 27	1722. 57	1.29	0.1 3	1786	5	1794	13	-1	3.12	0.8 4	0.11	0.2 8	4.83	0.8 9	0.32	0.8 4	0.95
X1-10	U > 1000 ppm	-1.2E-06	100	0.11	0.2 3	0.45	0.7 3	0.60	2.3 5	0.00	2082. 54	3150. 36	1.56	0.4 1	1786	4	1825	17	-3	3.06	1.0 4	0.11	0.2 3	4.93	1.0 6	0.33	1.0 4	0.98
X1-6	LPD	4.2E-04	15.2 2	0.12	0.5 8	0.26	0.6 6	0.48	0.4 3	0.65	356.1 4	315.0 4	0.91	0.5 3	1789	18	1496	13	18	3.83	0.9 5	0.11	1.0 0	3.94	1.3 8	0.26	0.9 5	0.69
X1-9	Pb-loss	-7.8E-06	100	0.11	0.5 8	0.24	2.0 6	0.54	1.7 6	-0.01	371.9 5	307.0 8	0.85	1.6 4	1795	11	1737	15	4	3.23	0.9 5	0.11	0.5 8	4.68	1.1 2	0.31	0.9 5	0.85
X1-4	inherited	2.1E-21	999 9	0.11	0.5 8	0.21	0.7 2	0.56	1.7 1	0.00	294.9 6	207.5 6	0.73	0.2 4	1831	11	1802	15	2	3.10	0.9 7	0.11	0.5 8	4.98	1.1 3	0.32	0.9 7	0.86
X1-2	inherited	1.2E-04	37.8 0	0.12	0.8 4	0.29	0.9 2	0.53	3.6 5	0.18	146.3 2	186.0 6	1.31	1.0 2	1870	18	1739	17	8	3.23	1.1 2	0.11	0.9 9	4.88	1.5 0	0.31	1.1 2	0.75
X1-2.1	inherited	2.9E-05	50	0.12	0.5 4	0.29	0.5 9	0.53	0.8 7	0.05	409.1 9	391.7 5	0.99	0.2 1	1880	10	1765	15	7	3.17	0.9 4	0.12	0.5 7	5.00	1.1 0	0.32	0.9 4	0.85
Sample MAT - Jorge biotite granodiorite/monzogranite																												
MAT-7		8.1E-05	50	0.11	0.9 0	0.72	0.7 2	0.58	2.1 1	0.12	126.3 9	308.3 0	2.52	0.3 0	1859	19	1828	19	2	3.05	1.2 1	0.11	1.0 3	5.14	1.5 9	0.33	1.2 1	0.76
MAT-17		3.8E-05	57.7 4	0.11	0.7 1	0.38	0.6 9	0.68	2.0 2	0.06	183.5 6	243.3 2	1.37	0.4 5	1859	14	1852	18	0	3.00	1.0 9	0.11	0.7 6	5.22	1.3 3	0.33	1.0 9	0.82
MAT-10		1.6E-04	37.8 0	0.12	0.9 7	0.51	0.8 6	0.55	3.3 4	0.25	114.4 0	184.0 1	1.66	0.3 3	1860	22	1745	19	7	3.22	1.2 4	0.11	1.2 3	4.88	1.7 5	0.31	1.2 4	0.71
MAT-12		1.9E-04	44.7 3	0.12	1.2 2	0.56	1.0 6	0.59	2.7 3	0.29	70.54	133.9 5	1.96	0.4 1	1862	29	1846	24	1	3.02	1.4 8	0.11	1.6 0	5.20	2.1 8	0.33	1.4 8	0.68

MAT-2		1.8E-04	26.7 3	0.12	0.7 2	0.37	1.3 5	0.60	3.1 1	0.27	196.3 5	223.8 2	1.18	0.8 1	1863	17	1732	28	8	3.24	1.8 5	0.11	0.9 3	4.84	2.0 7	0.31	1.8 5	0.89
MAT-16		5.9E-05	70.7 1	0.11	1.7 0	0.56	1.9 5	0.61	1.8 9	0.09	85.61	163.7 5	1.98	1.4 3	1866	32	1845	22	1	3.02	1.3 9	0.11	1.7 8	5.21	2.2 6	0.33	1.3 9	0.61
MAT-8		-1.5E-05	100	0.11	0.7 8	0.38	1.1 8	0.58	3.1 0	-0.02	171.8 3	213.5 5	1.28	1.1 4	1867	14	1777	30	6	3.15	1.9 3	0.11	0.8 0	5.00	2.0 9	0.32	1.9 3	0.92
MAT-19		1.2E-05	100	0.11	0.7 1	0.44	0.6 6	0.64	1.4 8	0.02	217.3 6	327.5 7	1.56	0.4 8	1867	13	1802	17	4	3.10	1.0 8	0.11	0.7 2	5.08	1.3 0	0.32	1.0 8	0.83
MAT-3		9.1E-05	44.7 2	0.12	0.8 5	0.40	0.8 2	0.61	2.1 5	0.14	130.3 8	175.6 3	1.39	0.3 1	1868	18	1839	19	2	3.03	1.1 9	0.11	0.9 9	5.20	1.5 4	0.33	1.1 9	0.77
MAT-13		6.8E-05	57.7 4	0.12	0.9 6	0.47	0.8 8	0.60	2.6 3	0.10	108.0 3	168.0 7	1.61	0.3 3	1868	19	1787	20	5	3.13	1.2 5	0.11	1.0 7	5.03	1.6 5	0.32	1.2 5	0.76
MAT-15		1.7E-05	100	0.11	0.8 4	0.48	0.7 6	0.64	0.6 6	0.03	140.4 3	226.7 5	1.67	0.6 2	1870	16	1844	19	2	3.02	1.1 8	0.11	0.8 6	5.22	1.4 6	0.33	1.1 8	0.81
MAT-4		-5.1E-05	57.7 4	0.11	1.5 2	0.66	0.6 7	0.63	1.2 0	-0.08	140.9 2	311.2 2	2.28	0.2 9	1874	28	1866	19	0	2.98	1.1 7	0.11	1.5 5	5.31	1.9 4	0.34	1.1 7	0.60
MAT-11		-2.8E-05	100	0.11	1.0 6	0.71	1.4 2	0.60	0.8 2	-0.04	91.18	223.3 0	2.53	0.7 5	1876	20	1844	21	2	3.02	1.3 4	0.11	1.1 1	5.24	1.7 4	0.33	1.3 4	0.77
MAT-5		1.0E-32	100	0.11	1.1 8	0.62	0.9 8	0.64	1.9 8	0.00	69.96	149.5 0	2.21	0.4 0	1878	21	1865	24	1	2.98	1.4 7	0.11	1.1 8	5.31	1.8 9	0.34	1.4 7	0.78
Rejected																												
MAT-6	U-gain	1.4E-04	50	0.11	1.1 9	0.62	0.9 8	0.62	2.3 8	0.21	71.09	147.8 6	2.15	0.4 0	1835	27	1858	36	-1	2.99	2.2 6	0.11	1.4 6	5.16	2.6 9	0.33	2.2 6	0.84
MAT-1	inherited	4.3E-05	57.7 4	0.12	0.7 6	0.27	0.8 5	0.61	1.5 0	0.07	167.3 3	151.6 5	0.94	0.3 0	1882	15	1853	18	2	3.00	1.1 1	0.12	0.8 2	5.29	1.3 8	0.33	1.1 1	0.80
MAT-9	large error associated with 7/6 age	-1.3E-04	70.7 2	0.11	3.1 2	0.39	1.5 5	0.61	3.5 8	-0.19	39.82	51.83	1.34	0.5 6	1885	58	1836	29	3	3.03	1.8 3	0.12	3.2 4	5.24	3.7 2	0.33	1.8 3	0.49
MAT-14	inherited	2.3E-05	100	0.12	0.9 7	0.35	0.9 8	0.64	2.2 0	0.04	106.3 7	124.5 4	1.21	0.3 6	1889	18	1838	21	3	3.03	1.2 8	0.12	1.0 1	5.26	1.6 3	0.33	1.2 8	0.79
MAT-18	inherited	-2.1E-05	100	0.12	0.9 1	0.59	0.7 7	0.60	1.4 9	-0.03	132.2 2	264.3 8	2.07	0.3 1	1896	17	1874	20	1	2.96	1.2 2	0.12	0.9 4	5.40	1.5 4	0.34	1.2 2	0.79
MAT-20	inherited	-1.9E-04	44.7 3	0.12	1.2 4	0.46	1.1 3	0.59	1.8 2	-0.29	74.61	116.1 3	1.61	0.4 3	1942	28	1818	24	7	3.07	1.5 0	0.12	1.5 4	5.35	2.1 5	0.33	1.5 0	0.70
Sample PQ - Pé Quente quartz-monzonite																												
PQ-6		-4.6E-05	100	0.12	2.1 4	0.20	1.7 5	0.68	2.1 7	-0.07	51.83	34.55	0.69	0.5 8	1963	39	1984	29	-1	2.77	1.7 0	0.12	2.1 9	5.99	2.7 7	0.36	1.7 0	0.61
PQ-15		4.8E-05	100	0.12	1.3 6	0.19	2.9 2	0.68	2.8 2	0.07	51.09	33.76	0.68	0.5 8	1964	26	1919	29	3	2.88	1.7 2	0.12	1.4 7	5.76	2.2 6	0.35	1.7 2	0.76
PQ-14		8.2E-05	70.7 1	0.12	1.2 5	0.30	1.3 8	0.67	1.0 3	0.13	61.54	62.08	1.04	0.4 9	1976	25	1975	27	0	2.79	1.5 9	0.12	1.4 2	6.00	2.1 3	0.36	1.5 9	0.75
PQ-16		-5.8E-05	70.7 1	0.12	1.0 6	0.20	2.3 0	0.71	2.1 5	-0.09	80.62	54.25	0.70	0.4 6	1977	20	1959	24	1	2.82	1.4 3	0.12	1.1 4	5.94	1.8 3	0.36	1.4 3	0.78
PQ-4		2.0E-13	999 9	0.12	1.2 4	0.19	1.6 1	0.72	2.5 4	0.00	57.30	37.95	0.68	0.5 4	1981	22	1963	27	1	2.81	1.6 1	0.12	1.2 4	5.97	2.0 3	0.36	1.6 1	0.79
PQ-3		-4.9E-05	100	0.12	1.3 7	0.39	1.3 6	0.67	1.9 2	-0.07	50.30	66.53	1.37	0.5 2	1989	26	1988	29	0	2.77	1.7 2	0.12	1.4 6	6.09	2.2 5	0.36	1.7 2	0.76
PQ-5		-6.4E-05	70.7 1	0.12	1.1 2	0.20	1.4 6	0.69	2.3 1	-0.10	72.95	48.76	0.69	0.4 8	1991	22	1983	25	0	2.78	1.4 7	0.12	1.2 1	6.07	1.9 1	0.36	1.4 7	0.77
PQ-8		-3.5E-05	100	0.12	1.1 6	0.23	1.4 0	0.70	2.1 8	-0.05	68.24	54.93	0.83	0.4 8	1996	22	1966	26	2	2.80	1.5 2	0.12	1.2 2	6.03	1.9 5	0.36	1.5 2	0.78
PQ-11		-4.3E-05	100	0.12	1.2 8	0.22	1.5 9	0.75	2.3 6	-0.06	49.93	37.20	0.77	0.5 4	1998	24	1914	28	5	2.89	1.6 9	0.12	1.3 5	5.85	2.1 6	0.35	1.6 9	0.78
Rejected																												
PQ-19	Pb-loss	2.0E-04	44.7 3	0.12	1.2 4	0.29	1.3 5	0.69	3.4 7	0.30	58.86	58.47	1.03	0.4 8	1923	29	1885	26	2	2.94	1.5 8	0.12	1.6 2	5.52	2.2 7	0.34	1.5 8	0.70
PQ-9	U-gain	4.4E-05	100	0.12	1.3 2	0.20	1.7 0	0.69	1.6 9	0.07	52.51	36.97	0.73	0.5 6	1931	26	1990	29	-4	2.77	1.6 7	0.12	1.4 2	5.90	2.1 9	0.36	1.6 7	0.76
PQ-12	Pb-loss	5.7E-05	70.7 1	0.12	1.0 6	0.18	1.4 2	0.68	2.0 2	0.09	82.36	48.82	0.61	0.4 6	1947	21	1924	24	1	2.88	1.4 2	0.12	1.1 6	5.72	1.8 3	0.35	1.4 2	0.77
PQ-2	U-gain	1.0E-32	100	0.12	1.1 5	0.18	1.5 5	0.69	2.4 7	0.00	69.80	43.89	0.65	0.8 2	1957	21	1987	26	-2	2.77	1.5 1	0.12	1.1 5	5.98	1.9 0	0.36	1.5 1	0.80
PQ-17	Pb-loss?	-1.1E-05	100	0.12	0.6 7	0.15	0.9 6	0.73	1.8 9	-0.02	191.1 2	99.79	0.54	0.3 1	1963	12	1908	18	3	2.90	1.0 9	0.12	0.6 8	5.72	1.2 8	0.34	1.0 9	0.85
PQ-10	inherited	1.0E-32	100	0.12	1.2 5	0.19	1.6 5	0.75	2.3 6	0.00	52.66	34.03	0.67	0.5 5	2002	22	1916	27	5	2.89	1.6 4	0.12	1.2 5	5.88	2.0 6	0.35	1.6 4	0.79
PQ-1	inherited	1.3E-04	70.7 2	0.12	1.5 9	0.32	1.7 2	0.71	2.4 6	0.20	35.85	39.75	1.15	0.6 3	2003	34	1965	34	2	2.81	1.9 9	0.12	1.9 1	6.05	2.7 6	0.36	1.9 9	0.72
PQ-20	inherited	2.2E-05	100	0.12	0.9 2	0.20	2.1 0	0.65	2.6 5	0.03	112.8 8	78.84	0.72	0.3 9	2005	17	1871	21	8	2.97	1.2 7	0.12	0.9 5	5.73	1.5 9	0.34	1.2 7	0.80

PQ-13	inherited	-2.9E-05	100	0.12	1.0 5	0.32	1.1 2	0.73	2.7 4	-0.04	76.76	86.09	1.16	0.6 8	2011	19	1913	24	6	2.89	1.4 4	0.12	1.0 9	5.89	1.8 1	0.35	1.4 4	0.80
PQ-7	inherited	5.0E-05	100	0.12	1.3 8	0.32	1.4 8	0.76	2.5 4	0.08	41.30	46.85	1.17	0.5 4	2016	26	1890	29	7	2.93	1.7 9	0.12	1.4 9	5.83	2.3 3	0.34	1.7 9	0.77
PQ-18	inherited	-5.7E-05	100	0.12	1.4 7	0.31	1.6 1	0.77	1.2 7	-0.09	37.09	40.37	1.12	0.5 8	2031	28	1871	31	9	2.97	1.9 0	0.13	1.5 8	5.81	2.4 7	0.34	1.9 0	0.77
Sample PQZFP - Pezão quartz-feldspar porphyry																												
PEZ-13		9.3E-05	57.7 4	0.12	1.1 0	0.22	1.3 4	0.61	0.8 6	0.14	57.01	42.30	0.77	0.4 4	1932	23	1917	37	1	2.89	2.2 2	0.12	1.2 7	5.65	2.5 6	0.35	2.2 2	0.87
PEZ-16		5.8E-05	57.7 4	0.12	0.8 7	0.29	1.0 5	0.61	2.6 5	0.09	87.16	83.99	1.00	1.7 6	1936	17	1885	34	3	2.94	2.1 1	0.12	0.9 6	5.56	2.3 1	0.34	2.1 1	0.91
PEZ-15		1.2E-04	44.7 2	0.12	0.9 6	0.40	0.9 4	0.66	2.1 5	0.18	69.01	96.39	1.44	0.9 0	1936	21	1920	36	1	2.88	2.1 6	0.12	1.1 5	5.68	2.4 5	0.35	2.1 6	0.88
PEZ-1		4.8E-05	57.7 4	0.12	0.7 9	0.33	0.8 4	0.63	1.8 3	0.07	108.0 3	120.2 7	1.15	0.3 0	1936	15	1973	35	-2	2.79	2.0 8	0.12	0.8 5	5.86	2.2 5	0.36	2.0 8	0.92
PEZ-8		1.6E-04	44.7 2	0.12	1.1 2	0.60	0.9 6	0.59	2.5 3	0.24	57.94	121.7 2	2.17	0.3 8	1945	25	1911	47	2	2.90	2.8 1	0.12	1.4 0	5.67	3.1 4	0.35	2.8 1	0.90
PEZ-17		7.5E-05	57.7 4	0.12	0.9 4	0.29	1.0 9	0.61	1.9 1	0.11	73.31	72.48	1.02	0.3 7	1946	20	1936	36	1	2.85	2.1 6	0.12	1.1 1	5.76	2.4 3	0.35	2.1 6	0.89
PEZ-23		1.8E-05	100	0.12	0.8 4	0.27	0.9 5	0.63	0.7 5	0.03	94.69	89.24	0.97	0.3 3	1947	16	1903	41	3	2.91	2.4 7	0.12	0.8 7	5.65	2.6 2	0.34	2.4 7	0.94
PEZ-4		8.6E-05	57.7 4	0.12	1.0 6	0.24	1.2 6	0.61	2.5 1	0.13	60.11	48.30	0.83	0.4 2	1948	22	1906	36	3	2.91	2.2 1	0.12	1.2 1	5.67	2.5 1	0.34	2.2 1	0.88
PEZ-18		6.0E-05	57.7 4	0.12	0.8 9	0.32	0.9 4	0.61	1.9 6	0.09	97.36	104.6 2	1.11	0.3 3	1949	17	1985	42	-2	2.77	2.4 7	0.12	0.9 8	5.94	2.6 6	0.36	2.4 7	0.93
PEZ-19		-8.0E-05	57.7 4	0.12	1.0 3	0.17	1.4 1	0.52	2.4 8	-0.12	94.02	54.88	0.60	1.3 2	1949	20	1897	35	3	2.92	2.1 5	0.12	1.1 4	5.64	2.4 3	0.34	2.1 5	0.88
PEZ-22		5.8E-05	70.7 1	0.12	1.0 5	0.34	1.1 0	0.63	1.7 0	0.09	59.20	68.33	1.19	0.3 9	1950	21	1898	36	3	2.92	2.2 1	0.12	1.1 5	5.64	2.4 9	0.34	2.2 1	0.89
Rejected																												
PEZ-10	U-gain	6.8E-05	70.7 1	0.11	1.2 0	0.16	1.6 3	0.58	2.2 9	0.10	58.01	32.71	0.58	1.1 9	1849	24	1880	37	-2	2.95	2.2 6	0.11	1.3 4	5.28	2.6 2	0.34	2.2 6	0.86
PEZ-2	U-gain	9.3E-05	50	0.11	0.9 7	0.07	1.9 7	0.63	0.7 6	0.14	71.37	16.36	0.24	0.5 3	1849	20	1900	44	-3	2.92	2.6 6	0.11	1.1 3	5.34	2.8 9	0.34	2.6 6	0.92
PEZ-12	U-gain	2.4E-05	100	0.12	1.6 0	0.17	1.3 2	0.65	0.7 7	0.04	82.83	49.24	0.61	0.4 1	1883	29	1906	36	-1	2.91	2.1 6	0.12	1.6 3	5.46	2.7 0	0.34	2.1 6	0.80
PEZ-21	Pb-loss	1.4E-05	70.7 1	0.12	0.5 2	0.21	0.6 5	0.55	2.2 0	0.02	264.1 7	186.4 2	0.73	0.2 1	1884	10	1778	39	6	3.15	2.4 8	0.12	0.5 4	5.05	2.5 4	0.32	2.4 8	0.98
PEZ-11	U-gain	1.1E-13	999 9	0.12	0.9 5	0.19	1.2 3	0.63	0.7 5	0.00	99.09	64.34	0.67	0.3 9	1893	17	1893	35	0	2.93	2.1 4	0.12	0.9 5	5.45	2.3 5	0.34	2.1 4	0.91
PEZ-14	U-gain	-2.1E-05	100	0.12	0.9 2	0.10	1.5 9	0.61	2.2 6	-0.03	84.02	29.16	0.36	0.4 4	1896	17	1951	48	-3	2.83	2.8 8	0.12	0.9 5	5.65	3.0 3	0.35	2.8 8	0.95
PEZ-20	U-gain	1.0E-04	57.7 4	0.12	1.1 6	0.24	2.5 5	0.74	0.9 7	0.16	51.76	41.49	0.83	1.2 3	1907	25	2069	41	-10	2.64	2.3 1	0.12	1.3 6	6.09	2.6 9	0.38	2.3 1	0.86
PEZ-5	inherited	8.2E-06	100	0.12	0.5 7	0.24	0.6 8	0.60	2.1 0	0.01	220.7 9	181.3 6	0.85	0.2 3	1955	10	1922	35	2	2.88	2.1 2	0.12	0.5 8	5.74	2.2 0	0.35	2.1 2	0.97
PEZ-6	inherited	1.3E-13	999 9	0.12	1.0 3	0.32	1.0 9	0.60	0.8 9	0.00	67.62	72.54	1.11	0.3 8	1958	18	1938	43	1	2.85	2.5 7	0.12	1.0 3	5.81	2.7 7	0.35	2.5 7	0.93
PEZ-7	inherited	-2.3E-05	100	0.12	0.9 6	0.34	1.0 0	0.61	0.8 3	-0.04	73.32	82.61	1.16	0.6 7	1962	18	1953	43	1	2.83	2.5 5	0.12	0.9 9	5.87	2.7 4	0.35	2.5 5	0.93
PEZ-24	inherited	-2.5E-05	100	0.12	0.9 9	0.30	1.0 6	0.62	1.9 6	-0.04	72.37	74.66	1.07	0.7 5	1962	18	1965	37	0	2.81	2.1 6	0.12	1.0 2	5.91	2.3 9	0.36	2.1 6	0.90
PEZ-3	inherited	4.8E-05	100	0.12	1.3 7	0.35	1.4 1	0.61	2.3 5	0.07	37.20	44.89	1.25	0.5 0	1966	26	1936	40	2	2.86	2.4 0	0.12	1.4 8	5.83	2.8 2	0.35	2.4 0	0.85
PEZ-2.2	inherited	7.1E-05	57.7 4	0.12	0.9 5	0.30	1.0 4	0.59	2.4 3	0.11	72.48	74.81	1.07	0.3 6	1970	19	1908	35	4	2.90	2.1 5	0.12	1.0 6	5.74	2.4 0	0.34	2.1 5	0.90
PEZ-9	inherited	2.1E-13	999 9	0.12	1.2 5	0.33	1.3 5	0.59	3.5 0	0.00	45.18	50.22	1.15	0.9 2	2001	22	1888	38	7	2.94	2.3 2	0.12	1.2 5	5.77	2.6 3	0.34	2.3 2	0.88

Errors are 1-sigma; Pb_c and Pb_r indicate the common and radiogenic portions, respectively.

(1) % of common ²⁰⁶Pb is measured ²⁰⁶Pb, estimated from ²⁰⁴Pb assuming a present-day Stacey and Kramers (1975) model for terrestrial Pb-isotope composition.

Table SM3. Results of zircon LA-ICP-MS U-Pb analysis from this study.

Spot name	Comment	4-corr % ²⁰⁶ Pb _c	ppm U	ppm Th	²³² Th/ ²³⁸ U	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb*	2σ ± abs	(1) ²⁰⁶ Pb/ ²³⁸ U*	2σ ± abs	rho	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb Age	2σ err ±	(1) ²⁰⁶ Pb/ ²³⁸ U Age	2σ err ±	Concordance %
Sample FMGr - Flor da Mata biotite-hornblende monzogranite															
FMGr-01		0.00	93.10	60.53	0.65	0.12	0.00	0.35	0.01	0.64	1913	47	1939	33	99%
FMGr-03		0.02	63.64	31.21	0.49	0.11	0.00	0.34	0.01	0.59	1877	48	1871	27	99%
FMGr-04		0.85	147.06	129.15	0.88	0.12	0.00	0.34	0.01	0.72	1883	41	1891	34	99%
FMGr-05		1.80	139.46	126.79	0.91	0.12	0.00	0.33	0.01	0.88	1895	44	1849	49	98%
FMGr-06		0.70	99.82	70.03	0.70	0.12	0.00	0.33	0.01	0.73	1906	43	1851	34	98%
FMGr-07		0.16	156.34	183.66	1.17	0.11	0.00	0.33	0.01	0.67	1872	45	1822	26	98%
FMGr-08		0.00	95.93	70.34	0.73	0.11	0.00	0.36	0.01	0.64	1880	50	2005	34	96%
FMGr-9		0.19	92.36	53.18	0.58	0.11	0.00	0.35	0.01	0.66	1876	47	1948	33	98%
FMGr-10		0.78	128.75	143.68	1.12	0.12	0.00	0.32	0.01	0.61	1894	45	1793	26	97%
FMGr-11		0.70	150.94	115.37	0.76	0.11	0.00	0.34	0.02	0.87	1869	40	1877	74	99%
FMGr-12		0.86	139.83	88.39	0.63	0.11	0.00	0.36	0.01	0.54	1872	43	1967	25	97%
FMGr-16		0.00	660.43	507.13	0.77	0.11	0.00	0.39	0.01	0.66	1874	66	2115	43	94%
FMGr-17		0.28	116.35	86.74	0.75	0.12	0.00	0.34	0.01	0.79	1880	41	1880	37	99%
FMGr-19		0.37	166.06	176.22	1.06	0.12	0.00	0.37	0.01	0.85	1884	41	2045	56	96%
FMGr-20		1.83	172.40	99.09	0.57	0.12	0.00	0.39	0.01	0.61	1881	39	2101	32	94%
FMGr-21		0.65	180.43	216.10	1.20	0.12	0.00	0.31	0.01	0.58	1924	61	1734	40	95%
FMGr-23		0.00	127.03	98.14	0.77	0.12	0.00	0.34	0.01	0.78	1909	42	1870	43	99%
Rejected															
FMGr-15	U > 1000 ppm	0.91	1653.12	161.21	0.10	0.16	0.00	0.46	0.01	0.95	2468	44	2446	65	99%
FMGr-02	inherited	0.03	83.37	140.66	1.69	0.13	0.00	0.40	0.01	0.69	2056	50	2189	33	96%
FMGr-13	inherited	0.23	37.55	35.83	0.95	0.12	0.00	0.38	0.01	0.59	1995	45	2097	31	97%
FMGr-14	inherited	1.98	86.18	71.17	0.83	0.13	0.00	0.34	0.01	0.41	2062	69	1908	24	96%
FMGr-18	inherited	2.73	209.90	135.21	0.64	0.12	0.00	0.36	0.01	0.89	2067	47	1960	52	99%
FMGr-22	inherited	1.67	199.40	260.03	1.30	0.12	0.00	0.36	0.01	0.76	1977	40	1969	41	99%
FMGr-24	inherited	0.82	32.79	50.32	1.53	0.12	0.01	0.36	0.01	0.38	1967	85	2000	33	98%
Sample NMGr - Novo Mundo biotite granite															
NMGr-01		5.39	376.45	350.80	0.93	0.12	0.00	0.36	0.01	0.57	1984	48	1993	28	99%
NMGr-03		0.00	40.28	45.23	1.12	0.12	0.01	0.34	0.01	0.70	2024	93	1869	59	96%
NMGr-08		1.43	206.20	193.88	0.94	0.13	0.00	0.37	0.01	0.65	2044	52	2018	37	99%
Rejected															
NMGr-02	high discordance	17.72	1094.84	625.77	0.57	0.14	0.00	0.12	0.01	1.10	2203	42	754	40	52%

NMGr-04	U > 1000 ppm	0.78	1018.99	755.44	0.74	0.12	0.00	0.36	0.01	0.76	2000	37	2003	36	99%
NMGr-05	high discordance	17.87	773.43	358.26	0.46	0.15	0.00	0.16	0.01	1.13	2350	44	966	51	57%
NMGr-06	high discordance	11.54	597.08	420.95	0.71	0.13	0.00	0.28	0.01	0.68	2087	57	1606	33	87%
NMGr-07	high discordance	90.52	869.32	485.87	0.56	0.26	0.02	0.16	0.02	1.48	3242	100	947	102	33%
NMGr-09	inherited	5.01	676.84	618.82	0.91	0.13	0.00	0.31	0.01	0.86	2092	47	1760	33	91%
NMGr-10	high discordance	35.83	646.64	601.60	0.93	0.18	0.03	0.23	0.01	0.37	2663	245	1322	63	63%

Sample TPS - Teles Pires alkali-feldspar granite

TPS-01		0.00	194.35	208.87	1.07	0.11	0.00	0.32	0.01	0.62	1800	49	1787	32	99%
TPS-04		0.73	146.67	147.03	1.00	0.11	0.00	0.34	0.01	0.60	1779	12	1877	25	97%
TPS-05		0.00	73.01	69.16	0.95	0.11	0.00	0.33	0.01	0.66	1765	47	1855	36	97%
TPS-06		0.00	136.42	202.18	1.48	0.11	0.00	0.32	0.01	0.62	1774	54	1767	36	99%
TPS-07		0.00	162.90	154.75	0.95	0.11	0.00	0.31	0.01	0.53	1761	56	1735	25	99%
TPS-08		0.00	124.19	141.21	1.14	0.11	0.00	0.33	0.01	0.67	1787	66	1820	37	99%
TPS-09		1.38	185.75	193.88	1.04	0.11	0.00	0.34	0.01	0.64	1776	54	1865	35	97%
TPS-11		0.00	89.89	114.57	1.27	0.11	0.00	0.33	0.01	0.60	1776	56	1823	31	98%
TPS-13		0.00	71.50	74.17	1.04	0.11	0.00	0.33	0.01	0.53	1792	63	1831	33	99%
TPS-14		0.89	90.32	108.28	1.20	0.11	0.00	0.33	0.00	0.41	1766	63	1862	21	97%
TPS-15		1.29	149.58	165.74	1.11	0.11	0.00	0.32	0.01	0.73	1773	48	1793	34	99%
TPS-16		1.45	122.95	145.33	1.18	0.11	0.00	0.31	0.01	0.62	1777	51	1755	27	99%
TPS-17		0.00	92.47	85.90	0.93	0.11	0.00	0.33	0.01	0.59	1766	55	1821	30	98%
TPS-18		0.00	167.13	153.15	0.92	0.11	0.00	0.32	0.01	0.71	1795	44	1809	32	99%
TPS-19		0.20	80.27	104.73	1.30	0.11	0.00	0.32	0.01	0.57	1794	50	1786	27	99%
TPS-20		0.00	139.27	118.78	0.85	0.11	0.00	0.32	0.01	0.73	1767	42	1778	39	99%
TPS-21		0.00	107.67	130.00	1.21	0.11	0.00	0.32	0.01	0.67	1783	50	1787	33	99%
TPS-22		0.26	148.80	151.93	1.02	0.11	0.00	0.33	0.01	0.65	1761	44	1833	29	98%
Rejected															
TPS-02	Pb loss	1.43	234.35	322.50	1.38	0.11	0.00	0.27	0.01	0.87	1780	58	1536	63	93%
TPS-03	inherited	1.56	140.09	144.32	1.03	0.12	0.01	0.30	0.01	0.44	1948	46	1708	37	93%
TPS-10	inherited	2.91	143.52	129.61	0.90	0.12	0.00	0.32	0.01	0.40	1995	63	1806	26	94%
TPS-12	Pb loss	0.00	121.34	108.81	0.90	0.11	0.01	0.28	0.01	0.62	1784	84	1587	61	94%
TPS-23	Pb loss	0.00	88.76	128.98	1.45	0.11	0.00	0.25	0.01	0.71	1788	67	1441	35	90%
TPS-24	large negative discordance	3.46	143.55	194.67	1.36	0.12	0.01	0.22	0.01	1.22	1962	75	1266	52	79%

Sample PFUN - União do Norte quartz-feldspar porphyry

PFUN-02		0.00	175.90	91.45	0.52	0.11	0.00	0.32	0.01	0.56	1788	51	1792	29	99%
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PFUN-05		0.89	141.52	84.41	0.60	0.11	0.00	0.32	0.01	0.66	1774	48	1778	33	99%
PFUN-06		0.00	118.92	71.89	0.60	0.11	0.00	0.31	0.01	0.72	1810	92	1759	37	98%
PFUN-07		1.29	110.62	61.83	0.56	0.11	0.00	0.32	0.01	0.63	1776	53	1777	34	99%
PFUN-10		0.00	187.05	96.63	0.52	0.11	0.00	0.32	0.01	0.69	1795	54	1776	37	99%
PFUN-12		0.52	241.80	125.24	0.52	0.11	0.00	0.31	0.01	0.72	1769	43	1757	33	99%
PFUN-16		0.80	122.27	75.16	0.61	0.11	0.00	0.32	0.01	0.72	1806	61	1767	46	99%
PFUN-17		0.30	261.68	124.34	0.48	0.11	0.00	0.31	0.01	0.54	1759	55	1764	30	99%
PFUN-20		1.37	222.99	111.08	0.50	0.11	0.00	0.32	0.01	0.64	1772	47	1772	29	99%
PFUN-21		0.47	274.72	128.68	0.47	0.11	0.00	0.31	0.01	0.61	1754	52	1753	33	99%
Rejected															
PFUN-01	inherited	1.86	93.73	42.78	0.46	0.12	0.01	0.35	0.01	0.20	1991	161	1918	32	98%
PFUN-03	Pb loss?	0.00	153.96	120.91	0.79	0.11	0.00	0.31	0.01	0.75	1773	68	1731	54	98%
PFUN-04	Pb loss	0.00	192.93	100.31	0.52	0.11	0.00	0.31	0.01	0.68	1781	14	1727	35	98%
PFUN-08	inherited	0.59	270.68	154.35	0.57	0.11	0.00	0.33	0.01	0.59	1835	62	1835	32	99%
PFUN-09	inherited	0.00	116.93	67.15	0.57	0.11	0.01	0.31	0.01	0.56	1861	85	1727	35	96%
PFUN-11	Pb gain	0.52	190.66	83.34	0.44	0.11	0.00	0.33	0.01	0.57	1769	45	1850	27	97%
PFUN-13	error	n/a	n/a	n/a		0.00	0.00	0.77	0.00	n/a	n/a	n/a	3681	2	-100%
PFUN-14	Pb gain	0.00	195.36	151.48	0.78	0.11	0.00	0.33	0.01	0.62	1758	49	1836	33	98%
PFUN-15	Pb gain	1.99	162.65	90.66	0.56	0.11	0.00	0.33	0.01	0.59	1794	51	1837	30	98%
PFUN-18	Pb gain	1.31	145.90	92.67	0.64	0.11	0.00	0.33	0.01	0.50	1776	57	1818	31	98%
PFUN-19	Pb loss	0.00	113.68	62.41	0.55	0.11	0.00	0.29	0.01	0.63	1829	80	1662	45	95%
PFUN-22	large negative discordance	6.38	286.23	156.51	0.55	0.13	0.00	0.21	0.01	0.56	2069	67	1207	34	74%
PFUN-23	error	n/a	n/a	n/a		0.20	0.13	0.00	0.00	n/a	2824	1295	0	n/a	n/a
PFUN-24	error	n/a	n/a	n/a		0.09	0.11	0.05	0.29	n/a	1400	1366	313	1796	-100%

Errors are 1-sigma; Pb_c and Pb^{*} indicate the common and radiogenic portions, respectively.

(1) Common Pb corrected using measured ²⁰⁴Pb.

Table SM4. SHRIMP standards data.

Spot Name	²⁰⁴ Pb/ ²⁰⁶ Pb	1σ ±%	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ ±%	²⁰⁸ Pb/ ²⁰⁶ Pb	1σ ±%	²⁰⁶ Pb/ ²³ U	1σ ±%	4-corr % ²⁰⁶ Pb	ppm U	ppm Th	²³² Th/ ²³ U	1σ ±%	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb Age	1σ ± absolute	(1) ²⁰⁶ Pb/ ²³ U Age	1σ ± absolute	% Discordance	(1) ²⁰⁶ Pb/ ²³⁸ U*	1σ ±%	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb*	1σ ±%	(1) ²⁰⁷ Pb/ ²³⁵ U*	1σ ±%	(1) ²⁰⁶ Pb/ ²³⁸ U*	1σ ±%	err corr
Mount 1 - Session 1 - Samples ARGr and COL																											
Standard OGC1: ²⁰⁷ Pb/ ²⁰⁶ Pb weighted average age: 3468 ± 3.7 Ma (MSWD = 1.51; 2σ)																											
OGC.1.1	3.0E-05	35	0.30	0.29	0.22	0.50	1.28	0.40	0.04	155	128	0.85	0.22	3461	5	3374	27	3	1.45	1.00	0.30	0.30	28.28	1.10	0.69	1.00	0.96
OGC.1.2	3.6E-05	29	0.30	0.26	0.21	0.40	1.37	2.40	0.04	184	142	0.80	0.21	3466	4	3384	27	3	1.45	1.00	0.30	0.30	28.47	1.00	0.69	1.00	0.97
OGC.2.1	2.4E-05	41	0.30	0.30	0.14	0.60	1.46	1.80	0.03	129	68	0.54	0.26	3475	5	3372	28	4	1.46	1.10	0.30	0.30	28.51	1.10	0.69	1.10	0.96
OGC.3.1	2.5E-06	100	0.30	0.24	0.19	0.40	1.47	2.50	0.00	204	146	0.74	0.19	3469	4	3352	26	4	1.47	1.00	0.30	0.20	28.18	1.00	0.68	1.00	0.97
OGC.4.1	-9.3E-06	58	0.30	0.26	0.23	0.40	1.25	1.70	-0.01	203	179	0.91	0.20	3472	4	3389	27	3	1.45	1.00	0.30	0.30	28.63	1.00	0.69	1.00	0.97
Standard TEMORA 2: ²³⁸ U/ ²⁰⁶ Pb weighted average age: 408.9 ± 2.9 Ma (MSWD = 0.95; 2σ)																											
TEM.1.1	1.8E-05	100	0.06	1.12	0.08	1.60	0.13	1.50	0.03	321	75	0.24	2.25	467	27	409	4	13	15.27	1.00	0.06	1.20	0.51	1.50	0.07	1.00	0.62
TEM.2.1	-1.6E-05	100	0.06	1.06	0.15	1.10	0.13	2.20	-0.03	421	420	0.50	0.30	434	25	412	4	5	15.15	0.90	0.06	1.10	0.51	1.50	0.07	0.90	0.64
TEM.3.1	1.2E-05	100	0.06	0.93	0.10	1.90	0.13	1.90	0.02	481	150	0.32	0.40	417	22	412	4	1	15.17	0.90	0.06	1.00	0.50	1.40	0.07	0.90	0.68
TEM.4.1	-9.3E-05	58	0.05	1.51	0.17	1.50	0.14	1.80	-0.17	162	85	0.54	0.23	443	45	410	4	8	15.23	1.00	0.06	2.00	0.50	2.30	0.07	1.00	0.45
TEM.5.1	-2.8E-05	58	0.06	0.81	0.18	2.10	0.10	1.20	-0.05	913	533	0.60	1.76	468	20	401	4	15	15.59	1.10	0.06	0.90	0.50	1.40	0.06	1.10	0.78
TEM.6.1	6.7E-05	38	0.05	0.83	0.14	0.90	0.14	1.80	0.12	561	246	0.45	0.14	350	25	411	4	-18	15.20	0.90	0.05	1.10	0.49	1.40	0.07	0.90	0.64
TEM.7.1	1.1E-04	35	0.06	1.01	0.14	2.20	0.14	1.70	0.20	360	159	0.46	0.17	367	34	406	4	-11	15.37	0.90	0.05	1.50	0.48	1.80	0.07	0.90	0.53
Mount 1 - Session 2 - Samples PBQFP and UNGr																											
Standard OGC1: ²⁰⁷ Pb/ ²⁰⁶ Pb weighted average age: 3465 ± 4.9 Ma (MSWD = 1.67; 2σ)																											
OGC.4.1	1.0E-05	58	0.30	0.84	0.21	1.90	1.54	2.60	0.01	156	126	0.83	1.69	3467	13	3460	36	0	1.41	1.30	0.30	0.84	29.33	1.60	0.71	1.30	0.85
OGC.5.1	2.2E-05	38	0.30	0.27	0.12	0.60	1.23	4.20	0.03	218	100	0.47	0.23	3465	4	3274	30	7	1.51	1.20	0.30	0.27	27.29	1.20	0.66	1.20	0.97
OGC.6.1	-2.3E-05	35	0.30	0.25	0.22	0.40	1.58	2.50	-0.03	193	157	0.84	0.46	3472	4	3414	25	2	1.43	1.00	0.30	0.26	28.91	1.00	0.70	1.00	0.97
OGC.7.1	4.4E-06	100	0.30	0.32	0.11	0.70	1.10	1.50	0.01	235	103	0.45	0.27	3458	5	3410	26	2	1.43	1.00	0.30	0.32	28.61	1.00	0.70	1.00	0.95
Standard TEMORA 2: ²³⁸ U/ ²⁰⁶ Pb weighted average age: 414 ± 16 Ma (MSWD = 11.17; 2σ)																											
TEM.2.2	-1.3E-04	58	0.06	1.75	0.14	3.00	0.32	0.39	-0.23	343	168	0.51	0.23	521	55	387	5	26	16.15	1.30	0.06	2.50	0.49	2.80	0.06	1.30	0.47
TEM.3.2	1.1E-05	100	0.06	1.56	0.10	1.10	0.60	0.58	0.02	531	170	0.33	0.17	437	35	416	3	5	15.00	0.80	0.06	1.59	0.51	1.80	0.07	0.80	0.47
TEM.5.2	8.7E-06	100	0.06	0.80	0.19	0.80	0.78	1.49	0.02	707	422	0.62	0.56	444	18	412	3	7	15.14	0.80	0.06	0.83	0.51	1.20	0.07	0.80	0.71
TEM.8.1	5.5E-05	41	0.05	0.84	0.15	0.90	0.70	3.60	0.10	624	294	0.49	0.88	376	24	414	3	-10	15.08	0.80	0.05	1.05	0.49	1.30	0.07	0.80	0.62
TEM.9.1	1.5E-04	45	0.06	1.46	0.15	1.60	0.23	0.85	0.27	207	92	0.46	0.24	396	53	430	4	-9	14.48	1.00	0.05	2.35	0.52	2.50	0.07	1.00	0.38
Mount 2 - Session 3 - Sample X1QFP																											
Standard OGC1: ²⁰⁷ Pb/ ²⁰⁶ Pb weighted average age: 3459 ± 6.3 Ma (MSWD = 0.51; 2σ)																											
OGC.1	1.4E-05	71	0.30	0.39	0.28	0.59	1.28	2.50	0.02	146	150	1.06	0.29	3456	6	3477	30	-1	1.40	1.10	0.30	0.39	29.31	1.20	0.72	1.10	0.94
OGC.2	1.3E-05	100	0.30	0.54	0.17	1.00	1.20	2.50	0.02	8250	50	0.63	0.43	3452	8	3310	34	5	1.49	1.30	0.30	0.55	27.44	1.40	0.67	1.30	0.92
OGC.3	1.2E-05	71	0.30	0.36	0.30	0.52	1.30	1.20	0.01	199	221	1.15	0.27	3464	6	3476	29	0	1.40	1.10	0.30	0.36	29.44	1.10	0.71	1.10	0.95
OGC-4	3.0E-05	71	0.30	0.57	0.18	1.02	1.34	0.80	0.04	8054	54	0.70	0.46	3464	9	3495	38	-1	1.39	1.40	0.30	0.58	29.66	1.50	0.72	1.40	0.93
OGC-5	3.7E-05	58	0.30	0.53	0.21	3.92	1.27	2.80	0.04	100	80	0.83	2.01	3457	8	3446	35	0	1.42	1.30	0.30	0.53	28.98	1.40	0.71	1.30	0.93

Standard TEMORA 2: $^{238}\text{U}/^{206}\text{Pb}$ weighted average age: 423 ± 8.8 Ma (MSWD = 2.9; 2σ)

TEM.1	1.7E-04	35	0.05	1.24	0.18	$\frac{1.2}{1}$	0.12	$\frac{2.3}{0}$	0.30	$\frac{54}{9}$	$\frac{31}{2}$	0.59	$\frac{0.1}{9}$	298	48	414	4	-40	15.09	$\frac{0.9}{0}$	0.05	$\frac{2.1}{0}$	0.48	$\frac{2.3}{0}$	0.07	$\frac{0.9}{0}$	0.39
TEM.2	5.3E-05	71	0.06	1.38	0.17	$\frac{1.3}{9}$	0.12	$\frac{2.4}{0}$	0.10	$\frac{45}{6}$	$\frac{24}{7}$	0.56	$\frac{0.2}{1}$	426	38	429	5	-1	14.54	$\frac{1.1}{0}$	0.06	$\frac{1.7}{0}$	0.52	$\frac{2.1}{0}$	0.07	$\frac{1.1}{0}$	0.55
TEM.3	5.8E-05	100	0.06	2.07	0.17	$\frac{2.0}{8}$	0.13	$\frac{1.9}{0}$	0.11	$\frac{22}{6}$	$\frac{12}{1}$	0.55	$\frac{0.3}{0}$	409	59	439	8	-7	14.21	$\frac{1.8}{0}$	0.05	$\frac{2.6}{2}$	0.53	$\frac{3.2}{0}$	0.07	$\frac{1.8}{0}$	0.57
TEM.4	4.4E-05	100	0.06	1.78	0.17	$\frac{1.7}{9}$	0.12	$\frac{1.6}{0}$	0.08	$\frac{30}{4}$	$\frac{15}{8}$	0.54	$\frac{0.4}{4}$	412	48	426	6	-4	14.63	$\frac{1.4}{0}$	0.06	$\frac{2.1}{5}$	0.52	$\frac{2.6}{0}$	0.07	$\frac{1.4}{0}$	0.55
TEM.4.2	-1.0E-04	71	0.06	1.90	0.19	$\frac{1.8}{5}$	0.12	$\frac{1.5}{0}$	-0.18	$\frac{26}{4}$	$\frac{15}{7}$	0.61	$\frac{0.2}{7}$	543	56	421	4	23	14.83	$\frac{1.0}{0}$	0.06	$\frac{2.5}{6}$	0.54	$\frac{2.8}{0}$	0.07	$\frac{1.0}{0}$	0.37
TEM.6	n/a	100	0.06	2.10	0.16	$\frac{2.1}{7}$	0.11	$\frac{4.7}{0}$	0.00	$\frac{38}{9}$	$\frac{20}{3}$	0.54	$\frac{0.3}{1}$	443	47	432	7	3	14.43	$\frac{1.6}{0}$	0.06	$\frac{2.1}{0}$	0.53	$\frac{2.7}{0}$	0.07	$\frac{1.6}{0}$	0.61

Mount 2 - Session 4 - Samples MAT and PQ

Standard OGC1: $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age: 3463 ± 5.7 Ma (MSWD = 0.17; 2σ)

OGC.6	-2.20E-05	58	0.2977	0.4	0.16	0.7	1.305	2.4	-0.03	$\frac{15}{1}$	89	0.61	0.6	3460	6	3398	30	2	1.44	1.1	0.298	0.4	28.51	1.2	0.69	1.1	0.94
OGC.7	2.10E-05	58	0.2992	0.4	0.22	0.6	1.37	1.7	0.02	$\frac{15}{3}$	$\frac{12}{4}$	0.84	0.3	3465	6	3420	30	2	1.43	1.1	0.299	0.4	28.85	1.2	0.70	1.1	0.95
OGC.8	-1.30E-05	71	0.299	0.4	0.25	0.6	1.308	1.7	-0.02	$\frac{18}{8}$	$\frac{17}{8}$	0.98	0.3	3466	6	3393	29	3	1.44	1.1	0.299	0.4	28.57	1.2	0.69	1.1	0.94
OGC.9	3.20E-05	58	0.2989	0.5	0.27	0.7	13.08	2.5	0.04	$\frac{12}{1}$	$\frac{12}{3}$	1.05	0.4	3463	8	3396	34	2	1.44	1.3	0.299	0.5	28.55	1.4	0.69	1.3	0.93
OGC.10	2.20E-05	58	0.2987	0.4	0.14	0.8	1.33	1.6	0.03	$\frac{17}{6}$	92	0.54	0.3	3462	6	3349	30	4	1.47	1.1	0.298	0.4	28.03	1.2	0.68	1.1	0.94

Standard TEMORA 2: $^{238}\text{U}/^{206}\text{Pb}$ weighted average age: 412 ± 8 Ma (MSWD = 3.2; 2σ)

TEM.7	3.6E-04	41	0.06	2.10	0.15	$\frac{2.2}{0}$	0.12	$\frac{2.6}{0}$	0.67	$\frac{20}{3}$	95	0.48	$\frac{0.5}{7}$	215	114	417	4	-97	14.95	$\frac{1.1}{0}$	0.05	$\frac{4.9}{0}$	0.47	$\frac{5.0}{0}$	0.07	$\frac{1.1}{0}$	0.22
TEM.8	-5.9E-05	100	0.06	2.10	0.19	$\frac{2.0}{0}$	0.12	$\frac{1.9}{0}$	-0.11	$\frac{20}{7}$	$\frac{12}{0}$	0.60	$\frac{0.2}{9}$	455	56	400	4	12	15.61	$\frac{1.1}{0}$	0.06	$\frac{2.5}{0}$	0.50	$\frac{2.8}{0}$	0.06	$\frac{1.1}{0}$	0.38
TEM.9	2.5E-04	41	0.06	1.70	0.16	$\frac{1.8}{0}$	0.12	$\frac{2.5}{0}$	0.45	$\frac{32}{0}$	$\frac{18}{0}$	0.58	$\frac{0.2}{6}$	278	78	417	4	-52	14.97	$\frac{1.0}{0}$	0.05	$\frac{3.4}{0}$	0.48	$\frac{3.6}{0}$	0.07	$\frac{1.0}{0}$	0.28
TEM.10	1.3E-04	58	0.06	1.80	0.17	$\frac{1.8}{0}$	0.12	$\frac{1.4}{0}$	0.24	$\frac{30}{6}$	$\frac{16}{3}$	0.55	$\frac{0.2}{6}$	342	63	410	4	-21	15.24	$\frac{1.0}{0}$	0.05	$\frac{2.8}{0}$	0.48	$\frac{3.0}{0}$	0.07	$\frac{1.0}{0}$	0.34
TEM.11	n/a	n/a	0.06	1.50	0.17	$\frac{1.5}{0}$	0.13	$\frac{1.9}{0}$	0.00	$\frac{41}{9}$	$\frac{22}{2}$	0.55	$\frac{0.4}{3}$	466	34	407	5	13	15.35	$\frac{1.3}{0}$	0.06	$\frac{1.5}{0}$	0.51	$\frac{2.0}{0}$	0.07	$\frac{1.3}{0}$	0.64
TEM.12	5.2E-05	100	0.06	1.90	0.21	$\frac{1.8}{0}$	0.13	$\frac{2.0}{0}$	0.09	$\frac{26}{4}$	$\frac{17}{7}$	0.69	$\frac{0.2}{8}$	428	53	414	4	3	15.08	$\frac{1.0}{0}$	0.06	$\frac{2.4}{0}$	0.51	$\frac{2.6}{0}$	0.07	$\frac{1.0}{0}$	0.40

Mount 3 - Session 5 - Samples PZQFP and PBQFP

Standard OGC1: $^{207}\text{Pb}/^{206}\text{Pb}$ weighted average age: 3461 ± 5.4 Ma (MSWD = 1.13; 2σ)

OGC.1.1	1.6E-05	58	0.30	0.34	0.28	$\frac{0.5}{0}$	1.26	$\frac{2.2}{0}$	0.02	$\frac{16}{3}$	$\frac{16}{8}$	1.06	$\frac{0.2}{5}$	3461	5	3395	53	2	1.44	$\frac{2.0}{0}$	0.30	$\frac{0.3}{0}$	28.50	$\frac{2.0}{0}$	0.69	$\frac{2.0}{0}$	0.99
OGC.2.1	4.1E-05	38	0.30	0.36	0.13	$\frac{1.2}{0}$	1.23	$\frac{2.5}{0}$	0.05	$\frac{14}{9}$	70	0.49	$\frac{0.3}{0}$	3461	6	3402	54	2	1.44	$\frac{2.0}{0}$	0.30	$\frac{0.4}{0}$	28.58	$\frac{2.1}{0}$	0.70	$\frac{2.0}{0}$	0.98
OGC.3.1	2.9E-05	45	0.30	0.36	0.24	$\frac{0.6}{0}$	1.23	$\frac{2.4}{0}$	0.03	$\frac{15}{4}$	$\frac{13}{6}$	0.91	$\frac{0.5}{3}$	3454	6	3428	54	1	1.42	$\frac{2.0}{0}$	0.30	$\frac{0.4}{0}$	28.73	$\frac{2.1}{0}$	0.70	$\frac{2.0}{0}$	0.98
OGC.8.1	-9.9E-06	71	0.30	0.33	0.21	$\frac{0.6}{0}$	1.23	$\frac{2.2}{0}$	-0.01	$\frac{18}{4}$	$\frac{14}{4}$	0.81	$\frac{0.2}{6}$	3468	5	3434	59	1	1.42	$\frac{2.2}{0}$	0.30	$\frac{0.3}{0}$	29.06	$\frac{2.2}{0}$	0.70	$\frac{2.2}{0}$	0.99

Standard TEMORA 2: $^{238}\text{U}/^{206}\text{Pb}$ weighted average age: 408 ± 7 Ma (MSWD = 0.74; 2σ)

TEM.1.1	n/a	n/a	0.05	1.91	0.17	$\frac{1.9}{0}$	0.12	$\frac{2.0}{0}$	0.00	$\frac{18}{7}$	96	0.53	$\frac{0.2}{7}$	365	43	408	8	-12	15.31	$\frac{2.0}{0}$	0.05	$\frac{1.9}{0}$	0.48	$\frac{2.8}{0}$	0.07	$\frac{2.0}{0}$	0.72
TEM.2.1	-2.6E-04	45	0.06	1.98	0.17	$\frac{2.0}{0}$	0.12	$\frac{2.7}{0}$	-0.46	$\frac{16}{9}$	83	0.51	$\frac{0.2}{8}$	581	73	410	8	30	15.23	$\frac{2.0}{0}$	0.06	$\frac{3.4}{0}$	0.54	$\frac{3.9}{0}$	0.07	$\frac{2.0}{0}$	0.51
TEM.3.1	2.4E-04	45	0.06	1.84	0.18	$\frac{1.8}{0}$	0.12	$\frac{2.3}{0}$	0.43	$\frac{18}{6}$	$\frac{10}{8}$	0.60	$\frac{0.2}{6}$	319	81	406	9	-28	15.39	$\frac{2.2}{0}$	0.05	$\frac{3.5}{0}$	0.47	$\frac{4.2}{0}$	0.07	$\frac{2.2}{0}$	0.53
TEM.4.1	-3.9E-05	100	0.06	1.67	0.18	$\frac{1.7}{0}$	0.12	$\frac{2.1}{0}$	-0.07	$\frac{22}{7}$	$\frac{12}{4}$	0.57	$\frac{0.2}{4}$	493	43	403	9	19	15.51	$\frac{2.2}{0}$	0.06	$\frac{1.9}{0}$	0.51	$\frac{2.9}{0}$	0.06	$\frac{2.2}{0}$	0.75
TEM.8.2	n/a	100	0.05	1.42	0.14	$\frac{1.5}{0}$	0.11	$\frac{2.7}{0}$	0.00	$\frac{41}{8}$	$\frac{18}{4}$	0.46	$\frac{0.3}{2}$	345	32	399	9	-16	15.65	$\frac{2.3}{0}$	0.05	$\frac{1.4}{0}$	0.47	$\frac{2.7}{0}$	0.06	$\frac{2.3}{0}$	0.85
TEM.6.2	-1.50E-05	100	0.06	1	0.113	1.3	1.11	$\frac{2.3}{0}$	-0.03	$\frac{71}{8}$	$\frac{25}{1}$	0.36	0.3	467	24	421	9	10	14.83	2.1	0.06	$\frac{1.1}{0}$	0.52	$\frac{2.4}{0}$	0.07	2.1	0.89

Errors are 1-sigma; Pb_c and Pb_r indicate the common and radiogenic portions, respectively.

(1) % of common ^{206}Pb is measured ^{206}Pb , estimated from ^{204}Pb assuming a present-day Stacey and Kramers (1975) model for terrestrial Pb-isotope composition.

Table SM5. LA-ICP-MS standards data.

Spot name	4-corr % ²⁰⁶ Pb _c	ppm U	ppm Th	²³² Th/ ²³⁸ U	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb*	2σ ± abs	(1) ²⁰⁶ Pb/ ²³⁸ U*	2σ ± abs	rho	(1) ²⁰⁷ Pb/ ²⁰⁶ Pb Age	2σ err ±	(1) ²⁰⁶ Pb/ ²³⁸ U Age	2σ err ±	Concordance %
Mount 1 - Sample NMGr														
Standard 91500														
91500.5	0	74.5	26.5	2.87	0.08	0.00	0.18	0.00	0.39	1102	107	1051	20	98
91500.6	0.67	72.1	25.4	2.89	0.07	0.00	0.18	0.00	0.40	1028	92	1074	18	98
91500.7	0	70.9	24.3	2.95	0.08	0.00	0.18	0.00	0.49	1069	80	1058	21	99
91500.16	1.92	72.5	25.4	2.86	0.08	0.00	1.18	0.00	0.49	1070	83	1059	22	99
91500.17	0	72.5	25	2.90	0.07	0.00	0.18	0.00	0.47	1061	83	1065	21	99
91500.39	0.48	70.8	24.6	2.88	0.08	0.00	0.18	0.00	0.40	1081	87	1075	19	99
91500.40	0	72.8	25.3	2.88	0.07	0.00	0.18	0.00	0.38	1050	74	1050	15	99
Standard GJ-1														
GJ.18	0.84	453	8.11	56.18	0.06	0.00	0.10	0.00	0.47	733	80	585	11	97
GJ.38	0.99	462	8.33	55.82	0.06	0.00	0.10	0.00	0.48	618	79	608	12	99
Mount 2 - Sample FMGr														
Standard 91500														
91500.5	0.20	79.60	27.80	2.89	0.08	0.00	0.18	0.00	0.48	1083	72	1055	17	99
91500.6	1.33	78.00	27.30	2.88	0.07	0.00	0.18	0.00	0.48	1047	78	1070	17	99
91500.2	1.04	85.20	29.00	2.93	0.07	0.00	0.18	0.00	0.50	1013	75	1069	19	98
91500.18	0.28	75.80	26.80	2.84	0.08	0.00	0.18	0.00	0.49	1117	76	1056	20	98
91500.27	0.64	75.60	26.30	2.89	0.08	0.00	0.18	0.00	0.49	1133	61	1068	15	99
91500.28	0.00	76.20	26.60	2.89	0.08	0.00	0.18	0.00	0.41	1102	71	1063	15	98
91500.29	0.62	76.80	26.90	2.88	0.07	0.00	0.18	0.00	0.56	1031	57	1062	17	98
91500.39	0.70	80.00	27.90	2.90	0.07	0.00	0.18	0.00	0.46	1054	67	1061	15	99
91500.40	0.00	80.00	28.20	2.87	0.08	0.00	0.18	0.00	0.44	1076	67	1064	16	99
Standard GJ-1														
GJ.7	0.61	478	8.57	56.01	0.06	0.00	0.10	0.00	0.60	591	59	600	9	99
GJ.16	0.16	474	8.53	55.54	0.06	0.00	0.10	0.00	0.51	569	63	600	9	99
GJ.38	0.87	480	8.63	56.33	0.06	0.00	0.10	0.00	0.55	598	56	606	9	99
Mount 3 - Sample TPS														
Standard 91500														
91500.5	0.00	67.6	23.30	2.88	0.07	0.00	0.18	0.00	0.44	1054	95	1064	24	99
91500.6	0.00	68.7	23.70	2.88	0.08	0.00	0.18	0.00	0.52	1080	100	1061	25	99
91500.7	1.48	68.5	23.60	2.88	0.08	0.00	0.18	0.00	0.46	1133	82	1061	22	99
91500.2	0.00	67.3	23.20	2.88	0.08	0.00	0.18	0.00	0.46	1080	99	1072	22	99
91500.2	1.78	67.5	23.30	2.87	0.07	0.00	0.18	0.00	0.43	1050	94	1053	20	99

91500.3	0.36	67.4	23.30	2.89	0.07	0.00	0.18	0.00	0.51	1052	87	1059	22	99
91500.3	0.07	67.9	23.60	2.86	0.08	0.00	0.18	0.00	0.52	1080	84	1065	22	99
91500.3	0.89	67.1	23.30	2.88	0.07	0.00	0.18	0.00	0.44	1056	95	1056	20	99
91500.4	0.00	65.3	22.80	2.88	0.08	0.00	0.18	0.00	0.50	1102	83	1062	20	98
91500.4	1.73	65.8	23.00	2.88	0.07	0.00	0.18	0.00	0.45	1028	84	1063	19	98
Standard GJ-1														
GJ.18	0.00	468	8.50	54.89	0.06	0.00	0.10	0.00	0.56	546	72	620	12	97
GJ.42	1.00	452	8.16	55.75	0.06	0.00	0.10	0.00	0.60	589	69	608	11	99

Mount 4 - Sample PFUN

Standard 91500														
91500.5	1.60	75	26.30	2.92	0.08	0.00	0.18	0.00	0.44	1081	106	1065	24	99
91500.6	0.60	82	29.50	2.84	0.07	0.00	0.18	0.00	0.40	1050	107	1054	22	99
91500.7	0.00	78	27.70	2.89	0.07	0.00	0.18	0.00	0.34	1065	111	1069	20	99
91500.2	0.00	78	27.20	2.93	0.07	0.00	0.18	0.00	0.41	1039	104	1058	20	99
91500.2	0.75	82	29.30	2.84	0.08	0.00	0.18	0.00	0.44	1100	95	1067	21	99
91500.3	0.00	78	27.30	2.89	0.07	0.00	0.18	0.00	0.38	1055	113	1056	23	99
91500.3	0.99	82	28.80	2.88	0.08	0.00	0.18	0.00	0.35	1077	118	1067	22	99
91500.3	0.00	83	29.20	2.88	0.07	0.00	0.18	0.00	0.37	1065	117	1065	23	99
91500.4	1.24	77	26.80	2.87	0.07	0.00	0.18	0.00	0.42	1065	111	1066	24	99
91500.4	0.48	77	26.70	2.90	0.07	0.00	0.18	0.00	0.38	1066	130	1059	26	99
Standard GJ-1														
GJ.18	0.00	470	8.29	57.80	0.06	0.00	0.10	0.00	0.53	606	76	606	11	99
GJ.38	0.00	488	8.53	57.03	0.06	0.00	0.10	0.00	0.61	576	79	607	16	98

Errors are 1-sigma; Pb_c and Pb^{*} indicate the common and radiogenic portions, respectively.

(1) Common Pb corrected using measured ²⁰⁴Pb.

Table SM6. Whole-rock major, minor, and trace elements geochemistry results.

Geological Unit	Novo Mundo biotite granite				Flor da Mata biotite-hornblende monzogranite								Aragão hornblende-biotite granite						
Sample code	NMGr-49(2)	NMGr-50(2)	NMGr-05	NMGr-12A	FMGr-51(2)	FMGr-52(2)	FMGr-53(2)	FMGr-06A	FMGr-08A	FMGr-10	FMGr-11	FMGr-13A	ARGr-44(2)	ARGr-44(5)	ARGr-45(2)	ARGr-46(2)	ARGr-46(5)	ARGr-01	ARGr-03A
Major and minor elements																			
SiO ₂	74.20	77.00	74.80	79.30	69.60	70.80	72.60	70.10	71.80	78.20	72.50	75.30	74.00	75.70	70.70	76.70	75.20	77.10	75.90
TiO ₂	0.19	0.21	0.16	0.07	0.30	0.22	0.14	0.24	0.24	0.04	0.16	0.10	0.28	0.15	0.53	0.21	0.19	0.16	0.23
Al ₂ O ₃	12.25	12.65	13.15	12.35	15.30	14.10	13.85	14.60	14.60	12.60	14.40	13.45	13.90	12.25	14.30	12.60	11.95	11.75	12.20
Fe ₂ O ₃	1.55	1.65	1.22	0.54	2.90	1.89	1.42	2.34	2.32	0.79	1.72	1.14	1.50	1.89	2.87	2.10	1.81	1.59	1.99
MnO	0.07	0.04	0.03	0.01	0.06	0.05	0.04	0.05	0.05	0.01	0.04	0.03	0.08	0.03	0.08	0.04	0.03	0.03	0.04
MgO	0.24	0.27	0.18	0.09	1.19	0.65	0.29	0.89	0.95	0.04	0.50	0.23	0.24	0.05	0.37	0.12	0.08	0.05	0.13
CaO	0.79	0.68	0.67	0.16	2.47	1.39	1.24	2.24	2.25	0.45	1.69	0.92	0.43	0.04	0.74	0.52	0.47	0.15	0.58
Na ₂ O	3.70	3.55	3.46	3.80	4.50	4.44	4.44	4.21	4.16	3.59	4.17	4.26	5.53	5.94	3.97	3.12	3.09	3.50	3.21
K ₂ O	4.72	5.20	5.11	4.54	3.74	3.94	4.08	3.37	3.71	5.06	3.86	4.14	4.03	1.94	5.93	5.70	5.36	5.12	5.42
P ₂ O ₅	0.04	0.03	0.03	0.01	0.13	0.08	0.04	0.10	0.10	<0.01	0.06	0.02	0.04	0.03	0.08	0.03	0.02	0.01	0.02
LOI	0.44	0.48	0.55	0.37	0.88	0.95	0.62	0.79	0.64	0.28	0.61	0.39	0.39	0.21	0.36	0.26	0.21	0.17	0.29
Total	98.19	101.76	99.45	101.24	99.17	99.17	99.17	99.14	101.04	101.06	99.93	100.07	99.72	99.72	99.72	99.72	99.72	99.64	100.04
Trace elements																			
Ba	426.00	488.00	766.00	24.70	1100.00	1220.00	1080.00	1300.00	1395.00	33.60	1435.00	608.00	303.00	17.40	828.00	313.00	271.00	67.50	309.00
Y	22.10	27.70	26.20	12.40	7.40	7.40	12.90	7.70	8.10	2.90	7.90	10.30	126.00	12.30	25.10	21.10	20.90	46.90	34.30
Sc	18.00	17.00	13.00	14.00	18.00	16.00	15.00	13.00	13.00	12.00	13.00	13.00	19.00	12.00	19.00	17.00	13.00	13.00	16.00
Zr	164.00	182.00	154.00	72.00	122.00	114.00	71.00	113.00	100.00	72.00	107.00	77.00	1020.00	42.00	621.00	319.00	235.00	326.00	343.00
Be	0.42	0.46	0.21	0.71	0.88	0.88	0.68	0.52	0.39	0.13	0.42	0.62	0.51	0.19	0.18	0.14	0.09	0.08	0.25
V	8.00	7.00	6.00	<5	41.00	27.00	11.00	33.00	37.00	7.00	19.00	8.00	<5	<5	9.00	<5	<5	<5	<5
Cr	8.21	8.37	8.24	6.31	25.60	20.40	13.75	16.90	19.60	16.95	14.85	13.55	6.78	5.93	7.16	7.99	9.55	6.17	8.07
Co	1.01	1.20	0.81	0.09	4.90	2.71	1.73	4.84	4.62	0.40	3.06	1.00	0.26	0.23	1.25	0.75	0.61	0.18	0.83
Ni	1.66	1.81	1.27	0.72	8.69	4.65	2.47	8.12	8.31	1.61	4.69	2.17	1.41	1.28	1.57	1.60	1.50	1.59	2.43
Cd	0.02	0.01	0.07	0.01	0.01	0.08	0.03	0.01	0.02	0.00	0.01	0.01	0.03	0.00	0.02	0.04	0.02	0.01	0.07
Cu	2.63	1.19	1.03	0.48	2.29	3.38	6.04	6.71	4.35	1.01	2.10	0.96	1.28	1.35	3.34	2.35	1.97	0.90	1.98

Au	0.20	0.30	0.90	0.30	1.00	0.40	0.40	0.70	0.40	0.30	0.30	0.70	0.30	0.20	0.40	0.20	0.40	<0.1	0.40
Li	8.00	3.40	6.20	1.10	13.80	11.30	8.90	14.00	12.20	2.10	14.20	9.10	1.30	4.40	15.70	10.30	9.60	0.60	17.80
Zn	35.20	27.40	22.40	5.10	33.20	47.70	26.30	38.50	24.90	6.50	29.20	13.10	39.60	17.80	60.60	49.10	41.00	25.60	64.50
Ga	20.50	17.80	17.80	19.80	19.40	20.50	19.40	19.70	20.50	17.50	17.60	18.90	20.70	21.10	19.20	17.10	15.20	20.50	19.60
Rb	206.00	169.50	206.00	331.00	88.80	115.00	123.00	89.00	93.80	119.00	106.50	147.00	83.00	36.30	99.10	115.50	103.00	120.50	118.00
Nb	17.90	13.20	14.00	19.90	7.50	7.10	8.30	8.00	7.10	3.60	7.10	11.80	20.10	8.80	14.30	8.00	7.30	5.70	10.20
Mo	0.29	0.23	0.28	0.16	0.28	0.35	1.17	0.22	0.24	0.32	0.28	0.29	0.23	0.32	0.35	0.29	0.72	0.20	0.49
Sn	2.00	2.00	2.00	3.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	3.00	2.00	2.00	1.00	1.00	2.00	2.00
Sb	0.02	0.03	0.07	0.02	0.05	0.15	0.04	0.03	0.03	0.02	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02
Cs	1.69	1.32	4.13	6.79	0.37	0.81	0.52	0.51	0.44	0.52	0.59	0.92	0.40	0.16	0.62	0.90	0.70	0.23	0.93
Hf	4.80	5.00	4.50	3.30	3.40	3.20	2.20	3.40	3.20	3.20	3.20	2.60	21.20	1.00	13.50	7.80	5.90	7.70	8.90
Ta	1.40	1.20	1.60	1.50	0.50	0.40	0.70	0.70	0.70	0.50	0.80	1.10	1.50	0.70	0.70	0.40	0.50	0.50	0.60
W	<0.5	<0.5	1.50	1.10	<0.5	<0.5	<0.5	0.60	0.60	0.70	0.80	0.80	1.10	0.70	1.50	0.80	0.80	0.70	1.20
Pb	11.80	4.61	9.58	4.54	7.29	28.90	10.70	5.79	7.42	10.90	7.90	15.80	7.54	5.29	17.60	17.05	17.05	9.29	17.15
Bi	0.03	0.03	0.10	0.11	0.03	0.10	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.03	0.02	0.00	0.03
Th	23.40	16.55	17.40	24.30	8.14	9.26	6.10	8.45	15.00	22.80	6.12	13.55	13.50	1.14	8.98	10.60	9.95	5.64	13.75
U	3.39	2.07	4.74	2.29	1.95	2.44	1.64	1.77	4.13	3.72	1.82	3.88	0.81	0.23	0.98	1.02	1.38	0.47	1.53
Sr	75.80	80.90	111.50	11.60	652.00	368.00	422.00	694.00	678.00	45.20	562.00	251.00	46.60	6.70	94.70	38.30	34.70	16.30	35.50
K	19591.5 1	21583.8 6	21210. 30	18844.3 7	15523.7 8	16353.9 3	16935.0 3	13988.0 0	15399.2 6	21002. 76	16021. 87	17184.0 8	16727.4 9	8052.44	24613.9 1	23659.2 4	22247.9 8	21251. 80	22497.0 3
Ti	1138.75	1258.62	958.95	419.54	1798.02	1318.55	839.08	1438.42	1438.42	239.74	958.95	599.34	1678.16	899.01	3176.51	1258.62	1138.75	958.95	1378.49
P	87.27	65.46	65.46	21.82	283.64	174.55	87.27	218.18	218.18	#VALUE!	130.91	43.64	87.27	65.46	174.55	65.46	43.64	21.82	43.64
La	51.90	61.90	64.70	23.20	26.60	33.30	15.70	29.50	29.80	10.60	25.80	12.60	286.00	36.00	82.30	74.80	68.70	71.00	113.00
Ce	98.10	96.40	106.00	33.60	52.20	58.50	28.50	56.20	50.10	21.90	43.80	26.70	467.00	124.50	196.00	164.00	126.50	83.00	193.50
Pr	10.30	11.15	14.40	4.01	5.85	6.37	3.41	6.22	5.79	1.97	5.16	3.35	52.30	14.30	19.00	16.20	14.35	19.95	23.40
Nd	32.80	37.60	47.90	10.70	20.30	23.20	12.20	21.60	20.30	6.30	17.00	12.30	179.50	50.60	67.90	59.30	52.50	72.00	87.00
Sm	4.76	6.57	8.05	1.53	2.88	3.16	2.24	3.61	3.19	0.73	2.68	2.51	28.10	9.79	10.60	8.98	8.04	13.00	13.30
Eu	0.52	0.79	1.06	0.14	0.80	0.71	0.56	0.90	0.80	0.13	0.66	0.40	1.94	0.63	1.68	0.68	0.66	1.08	0.90
Gd	3.51	4.56	4.99	1.12	1.91	1.93	1.55	1.80	1.91	0.51	1.73	1.72	22.80	5.12	7.84	6.20	5.33	9.45	9.65
Tb	0.52	0.74	0.84	0.20	0.22	0.21	0.23	0.26	0.27	0.07	0.17	0.33	3.29	0.89	0.98	0.70	0.71	1.43	1.28
Dy	3.37	4.55	4.49	1.40	1.58	1.37	1.57	1.49	1.55	0.34	1.21	1.88	21.60	4.77	5.33	4.74	3.76	8.95	6.79

Ho	0.71	0.89	0.93	0.38	0.23	0.26	0.31	0.24	0.26	0.10	0.25	0.32	4.10	0.76	0.98	0.79	0.77	1.71	1.27
Er	2.33	2.90	2.79	1.27	0.83	0.76	0.88	0.75	0.69	0.40	0.64	0.94	12.00	2.23	2.89	2.36	2.18	4.86	3.54
Tm	0.35	0.41	0.46	0.29	0.12	0.10	0.13	0.13	0.12	0.06	0.14	0.14	1.62	0.30	0.41	0.37	0.36	0.73	0.50
Yb	2.51	3.03	3.11	2.16	0.85	0.69	0.83	0.60	0.77	0.43	0.89	0.93	8.79	1.95	2.79	2.25	1.77	4.12	2.81
Lu	0.48	0.46	0.51	0.40	0.12	0.10	0.15	0.15	0.12	0.11	0.13	0.18	1.31	0.19	0.48	0.33	0.29	0.58	0.41

Table SM6. (cont.)

Geological Unit	Jorge biotite granodiorite/monzogranite					Paraíba biotite tonalite										
Sample code	MAT-47(2)	MAT-47(5)	MAT-47(8)	MAT-47(11)	MAT-31A	PBH-PB-20-05:38.20	PBH-PB-20-25	PBH-PB-20-26	PBH-PB-20-24	PBH-PAXPAB-084-19.5-19.83	PBH-PAB63-107.37	PBH-PAB63-145.45	PBH-PAB61-185.70	PBH-PAB61-207.17	PBH-PAB97-30.70	PBH-PAB97-43.84

Major and minor elements																
SiO ₂	69.10	68.30	70.20	62.30	69.20	66.60	69.50	66.20	65.80	65.30	60.00	63.30	62.80	59.80	71.70	68.80
TiO ₂	0.46	0.49	0.50	0.92	0.41	0.74	0.44	0.62	0.49	0.86	1.03	0.58	0.64	0.97	0.36	0.61
Al ₂ O ₃	13.85	14.50	14.85	15.65	15.00	15.25	16.05	15.60	15.65	15.25	14.60	15.75	15.80	17.25	13.95	14.00
Fe ₂ O ₃	3.22	3.24	3.60	5.65	2.55	4.75	2.44	5.28	3.45	6.91	8.94	4.98	5.66	6.40	2.89	4.02
MnO	0.06	0.06	0.07	0.14	0.08	0.07	0.04	0.12	0.09	0.11	0.14	0.12	0.10	0.09	0.03	0.05
MgO	1.01	0.97	1.07	2.02	0.51	2.42	1.38	1.76	1.54	1.47	2.86	1.90	2.17	1.83	0.81	0.95
CaO	2.32	2.46	2.46	3.29	1.08	3.60	2.82	3.32	3.48	3.86	4.82	4.49	4.71	3.98	3.45	2.95
Na ₂ O	3.48	3.45	3.48	4.24	4.53	3.63	4.25	4.23	3.88	3.74	3.53	3.87	3.89	4.36	3.96	3.44
K ₂ O	4.45	4.39	4.64	3.42	5.26	2.10	2.67	2.23	2.03	1.84	2.40	2.95	2.41	2.90	1.27	2.84
P ₂ O ₅	0.18	0.18	0.19	0.30	0.10	0.02	0.10	0.28	0.18	0.25	0.34	0.18	0.20	0.28	0.16	0.19
LOI	0.77	0.49	0.67	0.63	0.32	1.83	2.00	1.57	1.46	1.47	0.65	0.73	0.60	1.14	0.50	0.39
Total	98.90	98.53	101.73	98.56	99.27	101.01	101.69	101.21	98.05	101.06	99.56	99.16	99.25	99.34	99.23	98.68

Trace elements																
Ba	925.00	977.00	941.00	533.00	1970.00	1225.00	1160.00	971.00	1005.00	505.00	1680.00	2320.00	1720.00	2530.00	809.00	3430.00
Y	23.50	23.40	24.40	50.60	89.20	1.30	4.00	9.10	5.60	15.50	38.60	36.60	34.30	7.30	5.80	10.80
Sc	20.00	20.00	19.00	24.00	14.00	15.00	15.00	16.00	15.00	21.00	28.00	31.00	24.00	12.00	11.00	13.00
Zr	262.00	277.00	258.00	451.00	431.00	83.00	362.00	222.00	246.00	314.00	253.00	164.00	162.00	310.00	191.00	298.00

Be	0.34	0.25	0.30	0.39	0.23	0.25	0.22	0.28	0.18	0.29	0.25	0.25	0.18	0.30	0.12	0.10
V	41.00	41.00	42.00	71.00	18.00	54.00	53.00	111.00	63.00	54.00	146.00	71.00	101.00	100.00	34.00	37.00
Cr	23.00	24.10	26.60	37.80	10.40	23.80	13.90	22.60	13.90	21.90	72.90	20.70	37.70	24.80	13.50	10.20
Co	6.58	6.71	7.28	14.25	1.78	12.55	4.98	9.37	8.95	11.85	12.70	7.95	10.55	12.50	4.86	5.87
Ni	11.80	12.05	12.80	24.90	1.72	19.10	4.80	8.38	7.00	7.66	24.40	9.90	14.05	13.15	2.46	3.32
Cd	0.02	0.02	0.03	0.04	0.03	0.01	0.01	0.02	0.03	0.04	0.04	0.03	0.04	0.01	0.01	0.01
Cu	15.00	15.40	15.30	23.40	2.09	38.20	4.90	25.20	9.56	21.50	11.40	17.75	24.00	45.30	9.64	8.37
Au	0.50	0.20	0.50	0.70	0.50	3.20	3.60	2.30	1.40	1.10	0.80	1.80	1.00	1.20	0.70	0.40
Li	32.90	38.20	33.50	92.10	11.10	18.20	12.20	14.90	11.60	12.40	21.50	9.60	14.40	23.50	7.20	9.40
Zn	58.50	63.20	63.10	130.00	62.90	71.20	86.80	85.90	57.80	130.00	71.40	39.90	49.80	72.40	33.80	43.80
Ga	20.60	20.90	20.90	27.50	19.70	18.90	21.00	22.20	19.70	23.60	23.70	21.10	20.30	24.60	18.40	18.90
Rb	202.00	199.00	202.00	248.00	92.70	85.20	117.50	93.20	74.30	88.90	63.60	67.60	53.10	95.40	37.70	64.90
Nb	16.80	19.20	18.00	39.90	16.40	5.40	3.20	3.80	3.30	7.50	11.40	9.30	8.10	6.00	2.60	5.30
Mo	0.28	0.27	0.37	0.35	0.40	0.25	0.19	0.23	0.21	4.99	0.26	0.29	0.29	0.30	0.30	0.31
Sn	2.00	3.00	2.00	5.00	3.00	1.00	7.00	5.00	1.00	4.00	3.00	3.00	3.00	3.00	1.00	2.00
Sb	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.02	0.02	0.01	0.02	0.02
Cs	3.43	4.22	3.77	6.93	0.57	1.89	2.26	2.15	1.71	2.10	1.29	1.79	2.90	2.15	1.07	1.46
Hf	6.70	7.00	6.60	11.60	10.50	2.00	8.80	5.10	5.90	7.40	6.20	4.40	4.50	7.10	4.70	7.40
Ta	1.30	1.30	1.30	3.40	1.00	0.30	0.20	0.30	0.10	0.90	0.70	0.60	0.60	0.30	0.20	0.40
W	<0.5	<0.5	<0.5	<0.5	0.50	<0.5	11.00	2.90	<0.5	<0.5	0.80	0.90	0.70	3.10	0.90	2.40
Pb	10.10	7.84	10.05	8.60	8.70	3.17	3.45	7.19	6.48	3.31	2.60	3.81	3.17	3.41	1.79	2.83
Bi	0.04	0.04	0.06	0.36	0.02	0.12	1.84	0.41	0.07	0.08	0.03	0.05	0.03	7.85	0.07	0.05
Th	30.40	24.10	35.30	29.40	8.32	3.24	3.21	9.06	2.33	4.04	4.06	3.46	3.79	3.77	2.71	3.94
U	4.12	3.92	3.81	6.69	1.31	0.25	1.21	1.25	1.07	1.39	0.92	0.90	0.91	1.23	0.55	1.10
Sr	226.00	242.00	229.00	246.00	250.0 0	620.00	452.00	499.00	521.00	307.00	529.00	572.00	674.00	638.00	606.00	628.00
K	18470. 81	18221. 76	19259. 45	14195. 54	21832. 91	8716.56	11082.48	9256.16	8426.01	7637.37	9961.78	12244.69	10003.29	12037.15	5271.44	11788.11
Ti	2756.9 7	2936.7 7	2996.7 1	5513.9 4	2457. 30	4435.13	2637.10	3715.92	2936.77	5154.34	6173.22	3476.18	3835.78	5813.61	2157.63	3655.98
P	392.73	392.73	414.55	654.55	218.1 8	43.64	218.18	610.91	392.73	545.46	741.83	392.73	436.37	610.91	349.09	414.55
La	52.30	55.10	71.30	58.80	114.5 0	16.80	20.60	72.70	12.90	32.50	39.80	28.10	26.30	25.50	20.40	22.40
Ce	110.00	116.00	147.00	143.50	201.0 0	24.70	35.10	131.00	22.90	62.00	103.00	75.50	66.60	48.80	37.40	49.90

Pr	12.80	13.55	16.30	18.70	27.60	2.39	3.38	13.55	2.80	6.93	14.10	11.20	9.84	5.35	3.96	5.86
Nd	47.60	50.10	60.10	76.60	103.50	7.70	13.10	46.20	11.20	27.80	57.90	48.20	43.60	18.30	14.90	21.00
Sm	8.05	8.67	9.70	15.60	17.65	0.83	1.78	5.54	2.11	5.77	10.75	10.05	9.42	2.60	2.08	3.41
Eu	1.09	1.13	1.17	1.81	2.80	0.82	0.80	1.08	0.89	1.51	2.14	2.08	2.06	1.29	1.03	1.04
Gd	5.64	5.66	6.47	11.70	15.85	0.49	1.32	3.27	1.70	4.79	8.57	8.80	8.46	1.80	1.77	2.51
Tb	0.70	0.78	0.75	1.65	2.36	0.03	0.10	0.33	0.17	0.61	1.26	1.26	1.22	0.21	0.19	0.37
Dy	4.71	4.47	4.92	9.36	14.05	0.29	0.64	1.94	1.06	3.41	7.48	6.96	6.96	1.36	1.02	1.82
Ho	0.82	0.78	0.89	1.76	3.07	0.04	0.13	0.30	0.18	0.64	1.41	1.39	1.36	0.23	0.18	0.37
Er	2.31	2.40	2.46	5.09	8.52	0.04	0.35	0.73	0.47	1.54	4.03	3.89	3.42	0.72	0.50	1.14
Tm	0.32	0.33	0.30	0.74	1.24	0.01	0.05	0.12	0.07	0.19	0.63	0.49	0.45	0.13	0.07	0.15
Yb	2.05	2.21	2.08	4.82	7.10	0.08	0.57	0.71	0.47	1.09	3.67	3.29	2.64	0.51	0.44	1.10
Lu	0.34	0.30	0.30	0.63	1.02	0.02	0.09	0.10	0.07	0.14	0.45	0.41	0.41	0.11	0.10	0.20

Table SM6. (cont.)

Geological Unit	Pezão syenogranite							Teles Pires alkali-feldspar granite								União do Norte quartz-feldspar porphyry		
Sample code	PZH-AD001-49.17	PZH-AD001-173.70	PZH-AD001-174.40	PZH-AD001-175.60	PZH-AD001-177.65	PZH-AD001-178.40	PZH-AD001-181.20	TPS-40(2)	TPS-41(5)	TPS-42(2)	TPS-43(2)	TPS-09	TPS-19	TPS-20	TPS-32A	PFUN-06(1)	PFUN-07(2)	PFUN-11(1)

Major and minor elements																		
SiO₂	69.00	67.70	71.10	68.40	72.20	66.30	66.50	75.10	79.20	77.20	75.30	74.00	76.00	73.60	78.70	76.10	77.70	74.60
TiO₂	0.33	0.42	0.31	0.41	0.32	0.42	0.42	0.25	0.27	0.15	0.28	0.10	0.25	0.27	0.09	0.11	0.11	0.11
Al₂O₃	14.30	15.40	13.05	15.00	13.50	16.30	16.10	12.40	10.50	12.50	12.75	13.90	12.00	12.90	12.35	11.85	12.40	11.55
Fe₂O₃	1.89	2.43	1.56	2.38	1.52	2.56	2.60	2.03	1.71	1.44	1.84	1.16	1.72	1.85	1.08	1.87	2.00	2.53
MnO	0.08	0.07	0.06	0.09	0.06	0.08	0.07	0.03	0.06	0.01	0.02	0.05	0.03	0.04	0.01	0.02	0.01	0.05
MgO	0.89	0.79	0.56	1.05	0.58	0.93	1.01	0.21	0.31	0.12	0.19	0.42	0.14	0.33	0.05	0.07	0.34	0.11
CaO	0.83	1.26	0.81	1.12	0.62	1.13	1.17	0.21	0.50	0.03	0.03	0.84	0.12	0.80	0.39	0.17	0.04	0.44
Na₂O	3.74	4.17	1.94	3.52	2.32	4.15	4.16	3.95	2.36	4.16	3.52	4.39	3.95	4.02	3.68	3.37	0.13	3.68
K₂O	5.33	5.02	7.34	5.83	6.77	5.75	5.37	5.11	5.63	4.92	6.01	4.42	4.85	4.78	4.69	4.99	3.78	4.70
P₂O₅	0.08	0.09	0.03	0.10	0.05	0.10	0.10	0.02	0.03	0.01	0.03	0.04	0.02	0.06	0.01	0.01	0.01	0.01
LOI	1.60	1.20	1.29	1.79	1.09	1.57	1.47	0.47	0.47	0.26	0.33	2.42	0.36	0.36	0.22	0.69	1.77	0.28

Total	98.22	98.72	98.22	99.85	99.19	99.48	99.17	99.31	100.5 7	100.5 4	99.97	101.8 8	99.45	99.08	101.2 7	99.25	98.29	98.06
Trace elements																		
Ba	1280.00	1380.00	1465.00	1345.00	1415.00	1570.00	1660.00	172.5 0	771.0 0	108.0 0	316.0 0	938.0 0	121.0 0	606.0 0	20.60	158.00	504.00	7.60
Y	18.90	18.30	23.10	18.20	8.30	22.10	29.70	34.20	28.60	5.10	36.90	8.30	44.30	24.80	4.50	136.50	4.30	92.80
Sc	14.00	12.00	7.00	17.00	7.00	13.00	10.00	16.00	13.00	14.00	14.00	12.00	15.00	13.00	13.00	16.00	15.00	15.00
Zr	366.00	243.00	295.00	339.00	349.00	403.00	342.00	424.0 0	233.0 0	270.0 0	385.0 0	71.00	391.0 0	218.0 0	130.0 0	363.00	75.00	359.00
Be	0.21	0.26	0.22	0.33	0.15	0.24	0.31	1.03	0.08	0.26	0.43	0.66	0.71	1.02	0.32	2.41	0.16	0.96
V	21.00	24.00	17.00	25.00	16.00	29.00	29.00	9.00	10.00	<5	<5	8.00	<5	12.00	<5	<5	18.00	<5
Cr	8.94	8.93	12.05	9.09	11.05	7.38	11.25	9.89	37.50	11.30	6.84	12.40	13.50	13.30	8.62	0.75	1.60	0.16
Co	1.75	2.63	1.34	3.12	2.59	2.61	3.02	0.64	2.23	0.39	0.84	1.27	0.39	1.86	0.46	0.51	0.43	0.64
Ni	1.79	2.09	1.67	2.29	1.58	1.86	2.40	1.87	4.59	1.36	1.65	2.27	1.93	1.92	1.13	1.88	1.30	2.69
Cd	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	1.07	0.00	0.01	0.03	0.02	0.09	0.00	0.09	0.01	0.05
Cu	0.89	3.65	1.03	1.16	1.33	2.70	2.29	1.69	2.56	2.06	2.98	3.75	1.28	1.74	0.67	14.90	9.60	3.46
Au	0.30	0.30	0.10	0.90	1.70	0.20	<0.1	0.10	1.30	0.40	0.30	0.40	1.70	2.40	1.50	3.20	0.50	3.80
Li	9.50	13.00	7.90	15.10	7.60	12.50	17.40	3.30	1.90	4.00	6.60	11.50	2.70	10.40	1.10	2.41	0.16	0.96
Zn	19.50	39.90	16.40	29.00	12.10	30.60	35.30	29.00	210.0 0	43.40	31.00	23.20	55.70	38.20	4.80	72.80	4.90	66.50
Ga	17.50	17.80	13.70	18.20	14.80	18.90	18.40	20.10	10.50	22.60	19.60	18.40	22.20	21.00	19.40	24.80	16.90	22.80
Rb	120.50	105.00	148.00	129.50	148.00	122.50	111.00	154.0 0	138.5 0	265.0 0	195.0 0	128.5 0	183.0 0	182.0 0	252.0 0	320.00	128.50	374.00
Nb	9.00	9.30	9.50	10.20	6.80	9.20	12.10	18.40	9.40	17.60	22.70	8.50	20.90	18.20	16.80	39.40	9.50	37.30
Mo	0.32	0.35	0.45	0.36	0.42	0.31	0.44	0.63	1.35	0.48	0.27	0.33	1.63	6.77	0.35	4.06	10.95	2.94
Sn	2.00	1.00	1.00	1.00	1.00	2.00	2.00	3.00	1.00	2.00	3.00	1.00	3.00	3.00	1.00	11.00	4.00	6.00
Sb	0.02	0.03	0.02	0.03	0.02	0.02	0.03	0.02	0.16	0.02	0.02	0.08	0.03	0.05	0.02	0.21	0.15	0.11
Cs	0.76	1.20	1.09	0.77	0.48	0.64	0.84	0.32	0.51	0.91	0.59	0.79	0.64	0.93	0.90	1.54	1.67	2.65
Hf	8.90	6.00	7.50	8.00	8.80	9.30	8.60	11.00	5.30	9.10	10.50	2.30	11.30	6.60	6.00	13.10	3.30	12.90
Ta	0.60	0.50	0.80	0.60	0.40	0.60	1.00	1.30	0.70	1.10	1.50	0.70	1.40	1.20	1.40	3.00	0.90	2.80
W	1.30	1.20	1.30	1.90	3.60	1.40	0.80	1.00	1.60	0.90	1.40	0.60	1.10	1.30	1.20	5.40	11.60	2.40
Pb	1.03	2.04	5.30	3.99	1.03	1.14	1.79	4.57	76.40	10.10	5.80	13.05	22.60	26.80	10.35	24.60	6.62	35.60
Bi	0.02	0.05	0.01	0.03	0.06	0.02	0.02	0.05	0.07	0.09	0.07	0.04	0.12	0.09	0.03	0.75	1.60	0.16
Th	5.09	10.50	8.88	18.55	6.24	10.40	8.27	14.45	8.40	24.30	19.85	9.54	18.65	29.50	43.00	35.80	14.40	32.00

U	0.91	0.96	2.31	3.09	0.54	0.96	0.88	2.86	1.18	3.38	4.57	1.83	4.36	15.40	19.30	10.40	1.42	10.90
Sr	162.50	199.00	127.50	165.00	131.50	203.00	223.00	110.57	82.45	167.72	57.89	17.19	83.87	53.83	46.14	24.80	21.10	10.50
K	22123.46	20836.73	30466.45	24198.83	28100.53	23866.77	22289.49	21210.30	23368.68	20421.66	24945.97	1834.628	2013.110	1984.055	1946.699	20712.21	15689.81	19508.49
Ti	1977.83	2517.23	1857.96	2457.30	1917.89	2517.23	2517.23	1498.35	1618.22	899.01	1678.16	599.34	1498.35	1618.22	539.41	659.28	659.28	659.28
P	174.55	196.37	65.46	218.18	109.09	218.18	218.18	43.64	65.46	21.82	65.46	87.27	43.64	130.91	21.82	21.82	21.82	21.82
La	34.50	68.40	44.40	92.20	48.60	69.60	58.80	39.90	33.00	33.30	52.80	18.30	62.40	62.30	21.50	203.00	11.70	56.70
Ce	74.90	128.50	92.10	171.50	88.10	129.00	120.50	87.30	69.00	54.50	105.00	37.40	174.00	109.50	36.40	211.00	20.00	117.50
Pr	9.10	13.65	10.75	17.70	9.23	13.60	14.25	9.86	7.50	5.05	11.65	4.24	15.40	11.00	2.05	44.80	1.92	13.85
Nd	34.60	47.30	41.40	57.70	29.10	49.40	56.10	37.30	28.50	14.90	44.20	14.90	56.00	36.90	4.70	150.50	6.50	49.40
Sm	6.02	7.27	7.40	7.96	4.23	8.66	10.15	7.28	5.38	1.94	7.40	2.61	10.35	6.01	0.61	29.80	0.91	10.90
Eu	1.22	1.24	1.21	1.40	0.97	1.34	1.76	0.93	0.99	0.19	1.07	0.60	1.30	0.98	0.07	1.11	0.16	0.14
Gd	4.82	4.91	5.39	4.96	2.82	5.18	6.86	5.61	4.43	1.10	6.03	1.72	7.99	4.54	0.40	24.00	0.64	11.15
Tb	0.71	0.73	0.78	0.71	0.33	0.81	1.02	0.81	0.71	0.13	0.95	0.27	1.16	0.76	0.07	3.94	0.11	2.14
Dy	3.40	3.47	4.26	3.33	1.77	4.31	5.77	5.40	4.56	0.81	5.87	1.43	7.30	4.20	0.38	24.00	0.65	13.50
Ho	0.71	0.78	0.91	0.74	0.29	0.90	1.20	1.02	0.90	0.16	1.23	0.30	1.55	0.94	0.10	4.32	0.16	2.92
Er	1.93	1.99	2.26	2.02	0.79	2.16	3.05	3.35	2.87	0.73	4.02	0.77	4.28	2.74	0.60	13.00	0.39	9.53
Tm	0.30	0.21	0.33	0.29	0.11	0.35	0.49	0.52	0.46	0.18	0.60	0.11	0.64	0.42	0.10	1.85	0.10	1.52
Yb	1.93	1.86	2.00	1.63	0.81	1.99	2.96	3.80	2.64	1.37	4.24	0.92	4.42	3.20	1.25	12.25	0.67	9.82
Lu	0.30	0.34	0.29	0.27	0.13	0.37	0.46	0.63	0.44	0.30	0.68	0.12	0.64	0.55	0.28	1.66	0.14	1.50

Table SM6. (cont.)

Geological Unit	Paraíba porphyritic granite								
Sample code	PBQFP-39(1)	PBQFP-PB-56(65)-937.50	PBQFP-PB-56(66)-938.20	PBQFP-PB-84(01)-7-7.28	PBQFP-PB-84(03)-11.17-11.39	PBQFP-PB-84-19-54.12-54.39	PBQFP-PB-84(24)-86.58-86.78	PBQFP-PB-84(33)-168.16-168.46	PBQFP-PB-84(36)-197.47-197.68
Major and minor elements									
SiO ₂	77.10	76.20	76.40	78.30	79.70	77.80	78.70	77.40	78.30
TiO ₂	0.06	0.10	0.10	0.05	0.05	0.07	0.05	0.05	0.05
Al ₂ O ₃	12.85	12.70	12.75	12.70	12.05	13.15	12.55	12.75	11.75
Fe ₂ O ₃	0.71	1.11	1.28	0.74	0.70	0.69	0.61	0.60	0.65

MnO	<0.01	0.04	0.04	<0.01	0.01	0.01	0.02	0.01	0.01
MgO	0.07	0.25	0.17	0.05	0.08	0.10	0.08	0.06	0.04
CaO	0.33	0.81	0.74	0.17	0.31	0.51	0.47	0.48	0.36
Na ₂ O	3.69	3.70	3.76	3.36	3.51	4.06	3.87	3.86	2.98
K ₂ O	4.94	4.84	4.76	5.56	4.96	4.94	4.77	4.90	5.43
P ₂ O ₅	0.01	0.02	0.01	0.01	0.02	0.01	<0.01	0.01	0.01
LOI	0.49	1.02	0.85	0.60	0.47	0.64	0.53	0.48	0.61
Total	100.25	100.79	100.86	101.54	101.86	101.98	101.65	100.60	100.19
Trace elements									
Ba	29.60	79.80	84.30	55.80	57.00	41.90	18.20	28.50	50.10
Y	16.50	11.30	14.20	32.90	28.10	38.30	36.30	31.30	25.70
Sc	15.00	15.00	16.00	15.00	15.00	17.00	20.00	15.00	15.00
Zr	54.00	87.00	84.00	58.00	57.00	59.00	67.00	60.00	69.00
Be	0.08	0.46	0.39	0.08	0.35	0.66	0.32	0.40	0.40
V	<5	6.00	6.00	<5	<5	<5	<5	<5	<5
Cr	4.43	5.46	7.34	5.10	7.45	7.20	7.49	7.29	7.82
Co	0.14	0.77	0.45	0.56	0.67	1.04	0.55	1.31	1.58
Ni	1.02	1.41	2.78	0.91	1.05	0.90	1.44	0.91	1.52
Cd	0.00	0.08	0.02	0.02	0.01	0.02	0.01	0.00	0.33
Cu	3.13	201.00	100.50	39.90	16.30	32.00	13.05	15.30	31.40
Au	0.70	16.10	5.80	0.80	1.10	2.10	0.60	1.30	2.00
Li	0.10	2.10	1.90	0.10	0.40	0.60	0.50	0.50	0.30
Zn	3.30	49.60	23.80	13.60	14.50	13.10	15.70	8.80	34.60
Ga	18.00	17.90	18.90	18.60	19.40	20.10	19.30	18.70	17.10
Rb	186.50	194.00	193.00	196.50	177.50	189.00	174.00	167.50	202.00
Nb	25.70	15.50	19.10	29.20	30.10	38.10	31.90	25.60	25.40
Mo	9.03	0.84	1.03	1.07	15.65	39.10	15.75	0.50	2.79
Sn	1.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	3.00
Sb	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.02

Cs	0.53	1.17	1.15	0.57	0.50	0.72	0.38	0.49	0.71
Hf	3.20	3.80	3.70	3.70	3.70	3.80	4.40	3.50	4.10
Ta	2.00	1.20	1.60	2.90	2.70	2.80	3.10	2.40	1.70
W	4.30	4.20	3.20	5.20	3.60	3.40	3.10	2.60	6.70
Pb	9.50	12.80	15.55	11.40	11.95	16.60	18.45	17.25	13.70
Bi	0.32	0.32	1.30	0.83	0.13	0.39	0.95	0.37	0.29
Th	19.20	21.50	21.60	16.15	16.70	17.05	17.80	16.65	17.75
U	5.93	6.82	8.26	9.91	12.00	14.15	13.10	11.10	9.00
Sr	13.80	48.70	50.10	18.70	16.80	20.20	13.60	16.00	20.60
K	20504.67	20089.60	19757.54	23078.13	20587.69	20504.67	19799.04	20338.64	22538.54
Ti	359.60	599.34	599.34	299.67	299.67	419.54	299.67	299.67	299.67
P	21.82	43.64	21.82	21.82	43.64	21.82	#VALUE!	21.82	21.82
La	7.70	12.30	17.80	11.40	9.70	10.10	10.90	10.40	10.60
Ce	16.80	26.60	37.10	29.10	24.70	26.40	27.20	26.60	26.00
Pr	2.47	2.86	4.06	3.96	3.36	3.60	3.74	3.45	3.50
Nd	9.80	9.80	14.10	16.20	13.30	15.60	15.90	15.00	14.50
Sm	2.85	1.72	2.39	5.09	4.54	5.55	5.36	4.48	4.12
Eu	0.16	0.27	0.48	0.28	0.24	0.22	0.22	0.18	0.13
Gd	2.55	1.20	1.82	5.33	4.41	5.90	5.15	4.61	4.03
Tb	0.52	0.24	0.29	0.90	0.77	1.04	0.93	0.82	0.62
Dy	2.89	1.32	1.85	5.37	4.95	6.90	5.88	5.17	4.29
Ho	0.57	0.25	0.38	1.01	0.88	1.29	1.09	0.84	0.80
Er	1.69	1.02	1.33	2.86	2.50	3.56	2.94	2.84	2.47
Tm	0.31	0.22	0.26	0.44	0.38	0.54	0.50	0.41	0.37
Yb	1.51	1.30	1.60	2.73	2.36	3.33	3.04	2.52	2.46
Lu	0.26	0.21	0.30	0.41	0.36	0.46	0.49	0.39	0.35

Table SM6. (cont.)

Geological Unit	Pezão quartz-feldspar porphyry			Luiz quartz-feldspar porphyry					Colíder porphyritic volcanics				
Sample code	PZQFP-AD-FD-02(2)-25.8	PZQFP-AD002-25.85	PZQFP-AD002-28.9	LZQFP-MOC004-60.13-61.1	LZQFP-ANA028-40-42.05	LZQFP-ANA028-110.4	LZQFP-ANA028-35	LZQFP-ANA028-43.7	COL-05(2)	COL-55(2)	COL-14A	COL-16A	COL-29A
Major and minor elements													
SiO ₂	54.90	57.30	56.20	73.80	69.70	72.40	68.30	71.80	74.20	66.50	61.30	66.20	76.90
TiO ₂	0.36	0.35	0.31	0.29	0.45	0.30	0.56	0.47	0.30	0.56	0.89	0.78	0.21
Al ₂ O ₃	19.50	19.80	17.00	13.25	14.30	12.85	14.55	14.00	12.70	14.85	15.55	14.10	11.50
Fe ₂ O ₃	3.51	3.72	3.69	2.21	2.61	1.67	3.57	2.54	2.30	4.38	7.08	5.00	1.93
MnO	0.45	0.47	1.09	0.08	0.04	0.03	0.08	0.05	0.08	0.09	0.08	0.11	0.06
MgO	2.72	2.50	3.24	0.61	0.90	0.52	0.88	0.88	0.52	0.79	2.45	0.97	0.11
CaO	2.51	2.14	4.36	1.34	0.92	0.65	3.31	1.33	0.81	2.33	3.39	1.91	0.32
Na ₂ O	0.08	0.08	0.06	4.75	4.28	4.19	4.42	4.82	2.29	4.34	3.44	3.95	3.40
K ₂ O	7.13	6.93	5.98	4.02	4.45	4.69	3.09	3.47	5.53	4.28	2.92	4.89	5.04
P ₂ O ₅	0.11	0.11	0.10	0.07	0.11	0.04	0.17	0.11	0.02	0.08	0.27	0.32	0.01
LOI	6.94	6.23	9.10	0.77	1.18	0.72	0.96	1.18	1.82	0.79	2.16	1.88	0.39
Total	98.21	99.72	101.19	101.19	98.94	98.06	99.89	100.65	100.57	98.99	99.66	100.32	99.91
Trace elements													
Ba	788.00	816.00	566.00	1645.00	1795.00	1590.00	1495.00	1550.00	561.00	1800.00	633.00	1720.00	251.00
Y	10.20	10.10	8.80	9.30	17.90	19.10	19.50	19.00	206.00	23.30	23.20	41.70	65.20
Sc	16.00	10.00	8.00	16.00	19.00	18.00	20.00	19.00	16.00	22.00	25.00	19.00	14.00
Zr	136.00	166.00	117.00	192.00	269.00	231.00	250.00	273.00	325.00	242.00	208.00	418.00	348.00
Be	0.33	0.43	0.52	0.46	0.87	0.42	0.55	0.62	2.23	0.43	0.63	0.98	2.60
V	44.00	47.00	31.00	22.00	22.00	11.00	31.00	23.00	6.00	47.00	138.00	37.00	<5
Cr	1.72	1.94	1.86	18.45	18.20	14.95	18.70	16.05	11.65	21.20	20.70	16.10	15.45
Co	0.54	1.67	0.41	2.89	1.98	1.12	2.45	2.08	1.19	4.92	16.10	6.73	0.52
Ni	1.61	2.18	1.93	2.82	1.97	1.59	1.91	1.70	2.93	5.61	11.45	3.02	1.93
Cd	0.01	0.01	0.03	3.32	0.07	0.03	0.05	0.07	0.04	0.03	0.04	0.05	0.06
Cu	6.87	7.56	2.08	14.85	1.56	3.76	2.20	4.45	5.67	8.74	68.80	3.02	1.35

Au	17.10	96.90	17.00	6.40	15.20	5.20	16.10	8.50	1.30	0.90	1.10	0.10	5.60
Li	5.30	8.00	8.60	11.10	24.60	12.50	18.60	23.20	8.20	7.30	26.20	7.60	2.00
Zn	15.70	21.40	33.70	598.00	59.60	41.70	66.10	54.80	27.70	74.20	75.30	82.90	52.50
Ga	30.20	27.90	21.60	17.00	19.40	16.80	20.90	19.90	18.30	15.60	19.20	23.10	19.60
Rb	306.00	321.00	260.00	89.00	98.90	85.30	66.00	77.30	191.50	10.80	123.00	121.50	218.00
Nb	3.80	3.80	3.20	7.50	9.60	10.10	8.50	9.60	23.30	10.80	11.00	17.00	24.20
Mo	0.04	0.06	0.06	0.69	0.62	0.74	2.84	0.60	0.88	0.44	0.30	0.91	1.53
Sn	3.00	3.00	2.00	1.00	1.00	1.00	1.00	1.00	3.00	2.00	3.00	3.00	4.00
Sb	0.03	0.02	0.03	0.15	0.26	0.08	0.72	0.32	0.14	0.13	0.06	0.11	0.08
Cs	2.07	2.01	1.68	0.65	1.24	1.06	0.71	1.16	1.29	0.61	3.85	1.48	1.66
Hf	3.70	4.60	3.40	4.90	6.70	6.10	6.10	6.60	8.80	5.80	5.30	10.10	10.10
Ta	0.20	0.30	0.30	0.80	0.50	0.60	0.60	0.50	1.60	0.70	0.80	1.00	1.50
W	4.20	5.60	5.80	<0.5	0.80	0.70	1.20	1.10	1.90	1.50	1.20	1.50	1.30
Pb	1.02	1.94	1.45	409.00	5.26	8.07	5.54	3.60	2.55	9.36	4.71	14.95	18.10
Bi	0.13	0.30	0.16	1.62	0.06	0.09	0.07	0.10	0.07	0.08	0.03	0.62	0.12
Th	1.74	1.49	1.37	11.50	11.15	12.45	9.33	10.95	25.70	8.38	9.34	14.80	23.60
U	0.72	0.77	0.69	2.37	2.23	2.48	1.96	2.27	6.18	1.66	3.36	3.66	5.80
Sr	7.20	7.40	9.70	240.00	241.00	142.50	423.00	284.00	38.10	370.00	475.00	289.00	44.30
K	29594.80	28764.65	24821.44	16685.99	18470.81	19466.99	12825.80	14403.08	22953.6 1	17765.1 8	12120. 17	20297. 13	20919. 75
Ti	2157.63	2097.69	1857.96	1738.09	2697.04	1798.02	3356.31	2816.90	1798.02	3356.31	5334.1 4	4674.8 6	1258.6 2
P	240.00	240.00	218.18	152.73	240.00	87.27	370.91	240.00	43.64	174.55	589.10	698.19	21.82
La	8.20	8.90	10.00	37.90	46.20	53.60	47.00	47.30	186.00	37.90	39.80	72.60	103.50
Ce	18.20	18.50	21.60	68.70	89.70	99.20	87.80	90.10	222.00	73.40	85.60	143.00	185.50
Pr	2.33	2.43	2.64	6.98	9.68	10.95	10.20	10.00	37.60	8.42	10.45	16.60	21.80
Nd	9.30	9.30	11.00	23.90	35.80	40.00	37.90	37.00	136.50	32.60	40.00	60.30	76.40
Sm	2.26	1.88	2.48	3.47	5.83	6.93	6.28	5.85	21.70	5.51	7.37	10.00	13.25
Eu	0.30	0.41	0.58	0.70	1.35	1.11	1.56	1.41	2.45	1.94	1.88	2.23	0.75
Gd	1.88	1.92	2.19	2.11	3.57	4.41	4.37	4.29	22.10	4.90	5.83	8.68	10.60
Tb	0.34	0.33	0.33	0.26	0.56	0.56	0.65	0.67	3.07	0.68	0.78	1.30	1.67
Dy	1.85	1.98	1.58	1.70	3.59	3.82	3.66	3.73	17.75	4.45	4.30	7.73	10.80

Ho	0.35	0.33	0.30	0.28	0.66	0.69	0.66	0.64	3.79	0.82	0.82	1.57	2.22
Er	1.02	1.24	1.03	0.86	1.88	2.15	1.98	2.10	12.05	2.46	2.45	4.15	6.94
Tm	0.17	0.10	0.11	0.16	0.27	0.27	0.23	0.31	1.55	0.40	0.34	0.68	0.97
Yb	0.91	1.48	0.93	0.95	1.92	1.84	1.90	1.73	8.30	2.25	1.97	4.14	6.26
Lu	0.18	0.21	0.19	0.16	0.23	0.28	0.26	0.24	1.51	0.35	0.33	0.66	0.97

APPENDIX B: Manuscript 2 - Assessments of copper and gold prospectivity in the Paleoproterozoic Alta Floresta Mineral Province, southern Amazonian Craton: magma fertility indicators from whole-rock and zircon geochemistry (in prep)

Assessments of copper and gold prospectivity in the Paleoproterozoic Alta Floresta Mineral Province, southern Amazonian Craton: magma fertility indicators from whole-rock and zircon geochemistry

Veronica G. Trevisan¹, Robert R. Loucks²; Steffen G. Hagemann^{2,3}; Gonzalo J. Henríquez²; Andreas Petersson^{3,4}; Anthony I. S. Kemp^{2,3}; Roberto P. Xavier¹

¹Institute of Geosciences, University of Campinas, São Paulo, Brazil

²Centre for Exploration Targeting, School of Earth Sciences, The University of Western Australia, Crawley, Australia

³School of Earth Sciences, The University of Western Australia, Crawley, Australia

⁴Swedish Museum of Natural History, Stockholm, Sweden

Abstract

Magmas having a high oxidation state, a high-water content and a high degree of fractionation are necessary to form Cu-rich deposits, whereas an enriched metal source and redox gradients in the mantle are first-order controls to generate Au-rich deposits. In both cases, favorable geodynamic conditions also represent key factors controlling the localization of regions endowed with metals. Different proxies, such as geochemical signatures of whole-rock (e.g. high Sr/Y, V/Sc, (Eu/Eu*)/Yb, Sr/Zr, Ba/Zr, Nb/Y and Th/Yb) as well as elemental ratios in zircon (e.g. Eu/Eu*, $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$, and $10^3 \times (\text{Ce}/\text{Nd})/\text{Y}$) are commonly used to trace these magmatic conditions. Here, the geochemical characteristics of whole-rock samples and zircon grains collected from different igneous geological units from the eastern portion of the Alta Floresta Mineral Province, located in the southern Amazonian Craton, were determined in order to evaluate their potential as tracers for Cu and Au mineralization in this region. Our results show that whole-rock geochemistry represents an exploration tool with some limitations, i.e. not fully reliable, to access Cu- and/or Au-prospectivity in search for buried deposits in this area because the hydrothermal alteration obliterates the primary minerals and initial geochemical signatures of the investigated rocks. Our zircon chemical analyses, however, are considered effective to identify geological units potentially prospective for Au and Cu in this portion of the province. The Colíder group and, to a lesser extent, the Matupá and Teles Pires suites are the geological units highlighted as prospective for Cu and/or Au based on the zircon compositions. These three units have high water content represented by zircon $\text{Eu}/\text{Eu}^* > 0.3$, $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb} > 1$ and $10^3 \times (\text{Ce}/\text{Nd})/\text{Y} > 1$, and high oxidation state characterized by zircon

relative oxygen fugacity (ΔFMQ) in the range 0 to +3. The integration of whole-rock and zircon geochemistry with geochronology information is particularly useful to track the tectonic stress regime (e.g. compressive versus non-compressive) over time in the studied region. The periods of crustal extension or relaxation during slab-rollback are the most favorable for Cu and Au metallogeny, in particular the period from ca. 1.83-1.77 Ga. This scenario is encouraging and can help guide current and future exploration for Cu and Au (e.g. porphyry- and epithermal-style deposits) in southern Amazonian Craton and other Proterozoic cratonic, underexplored areas worldwide.

Introduction

Magmatic fertility or the ore-forming potential of a mineral system is directly related to the oxidation state, water content and metal budget of the melts as well as the tectonic stress regime (Richards, 2011; Loucks, 2014; Lu *et al.*, 2016). Fertile igneous suites are defined as the causative intrusions leading to ore-formation (e.g., porphyry- and epithermal-type mineralization), whereas infertile suites refer to magmatic rocks that are absent of mineralization at any grade (Lu *et al.*, 2016).

Studies during the last three decades have shown that copper-fertile magmatic-hydrothermal systems (e.g. porphyry deposits) are generally associated with calc-alkaline magmas characterized by whole-rock compositions that display high Sr/Y (≥ 35), V/Sc (≥ 10), (Eu/Eu*)/Yb_N (≥ 2) and Sr/Zr (Thiéblemont *et al.*, 1997; Richards, 2011; Loucks, 2012a, 2014), whereas gold-fertile magmatic-hydrothermal systems are related to high-K calc-alkaline and alkaline magmas identified by whole-rock signatures presenting high Ba/Zr, Nb/Y and Th/Yb (Ryskamp *et al.*, 2008; Loucks, 2012b).

Other studies (Ballard *et al.*, 2002; Muñoz *et al.*, 2012; Dilles *et al.*, 2015; Lu *et al.*, 2016; Loucks *et al.*, 2020) have suggested that the fertility of magmas can also be tracked from *in-situ* zircon chemical analyses. Lu *et al.* (2016) highlighted that the best zircon indicators of potential magmatic fertility for porphyry Cu deposits are Eu/Eu* (> 0.3), $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ (> 1) and (Ce/Nd)/Y (> 0.01). However, there is no study published so far that has used *in-situ* zircon geochemistry in the investigation of Au-ore-forming magmas. Additionally, the majority of the works have investigated Phanerozoic examples of Cu-rich deposits using whole-rock and/or zircon geochemistry (Ballard *et al.*, 2002; Muñoz *et al.*, 2012; Dilles *et al.*, 2015; Lu *et al.*, 2016; Baatar *et al.*, 2020; Wells *et al.*, 2020), except for one study (Lu *et al.*, 2019) that

examined zircon grains from Archean granitic rocks in the Yilgarn Craton (Australia) in order to evaluate their potential as magma fertility indicators.

The present study applies the most recent advances in the understanding of magma fertility indicators to the emerging, poorly known and under-covered Alta Floresta Mineral Province (AFMP), which is located in the southern Amazonian Craton. This work also represents the first study to systematically examine whole-rock samples and zircon grains from igneous rocks as potential Cu-Au metallogenic fertility indicators of Paleoproterozoic magmatic-hydrothermal systems, and to investigate zircon compositions as a tool to characterize gold-ore-related magmas. This study focuses on felsic-to-mafic igneous rocks from the eastern portion of the AFMP using whole-rock geochemistry and *in-situ* zircon chemical analyses to assess their potential for Cu and Au prospectivity and to host porphyry- and epithermal-style mineralization. Furthermore, the new data and observations provide constraints on the implications of our findings for metals exploration in this portion of the province.

Geological and geodynamic setting

The Alta Floresta Mineral Province

The AFMP covers an area of approximately 500 km long by 100 km wide and lies in the southern Amazonian Craton between the ca. 2.03–1.88 Ga Tapajós-Parima and ca. 1.82–1.54 Ga Rondônia-Juruena tectonic provinces (Santos *et al.*, 2000; Fig. 1A). The Tapajós-Parima province consists of arc-type sequences that vary in composition from tonalite to granite, volcanoclastic units, porphyry intrusions and, to a lesser extent, gneisses and back-arc sedimentary rocks. This province is divided into four distinctive domains from north to south (Parima, Uaimiri, Tapajós, and Peixoto de Azevedo) separated from each other by three Phanerozoic sedimentary basins (Solimões, Amazon, and Alto Tapajós/Cachimbo; Santos *et al.*, 2004; Santos *et al.*, 2006; Fig. 1B). The Rondônia-Juruena province comprises calc-alkaline arc-type granitoids and volcano-sedimentary sequences (Santos *et al.*, 2006).

The main lithostratigraphic units within the area of the AFMP include (Rizzotto *et al.*, 2019b; Fig. 1C): the 2.8–1.86 Ga Peixoto de Azevedo Domain, the 1.85 Ga São Marcelo-Cabeça group (Silva and Abram 2008), the 1.81–1.75 Ga Juruena supersuite, the 1.81–1.76 Ga Nova Monte Verde Complex, the 1.81–1.76 Ga Colíder group, the 1.79–1.75 Ga Teles Pires suite, the 1.76–1.74 Ga Roosevelt group, the 1.98–1.37 Ga Caiabis group, and the ca. 0.30 Ga Alto

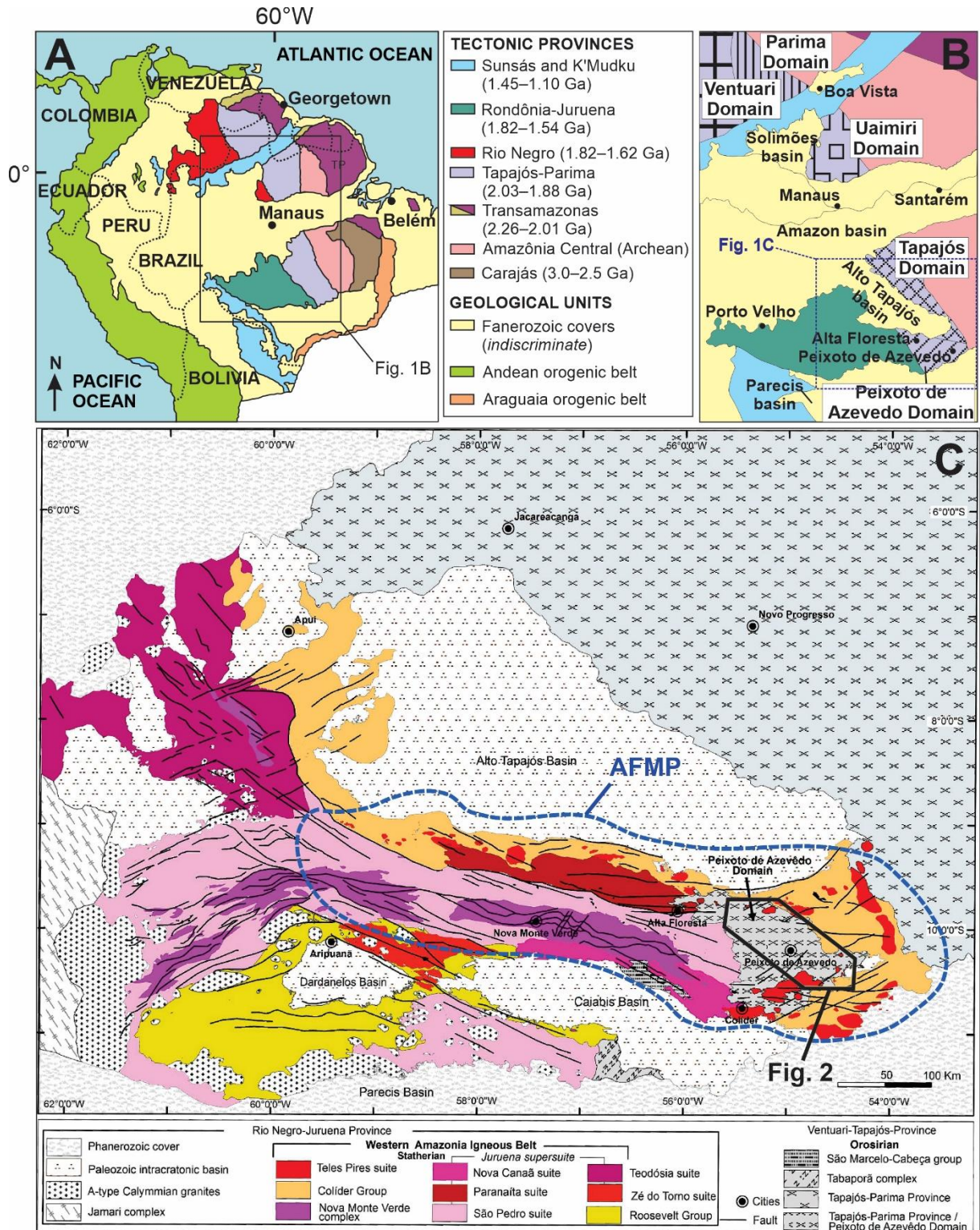


Figure 1. (A) Tectonic provinces of the Amazonian craton (Santos *et al.*, 2000); (B) Location of the four domains of the Tapajós-Parima tectonic province (modified from Santos *et al.*, 2004); (C) Simplified geological map of the southwestern Amazonian Craton, showing part of the Tapajós-Parima province, Western Amazonia Igneous Belt, and the location of the Alta Floresta Mineral Province (AFMP; modified from Rizzotto *et al.*, 2019b).

Tapajós basin. The Peixoto de Azevedo Domain and the São Marcelo-Cabeça group are part of the Tapajós Domain within the Tapajós-Parima tectonic province (Fig. 1A–B), while the Juruena Supersuite, Roosevelt, and Caibis groups belong to the context of the Rondônia-Juruena tectonic province (Fig. 1A–B). Additionally, the Roosevelt group, Juruena supersuite, Nova Monte Verde Complex, Colíder group, and Teles Pires intrusive suite are collectively denominated Western Amazonia Igneous Belt (Rizzotto *et al.*, 2019a,b). A summary of these lithostratigraphic units is presented in Table 1.

Varied tectonic interpretations have been proposed on the basis of interdisciplinary studies in the AFMP, which is separated from the Tapajós Mineral Province (within the Tapajós Domain) to the north by the Alto Tapajós basin (Rizzotto *et al.*, 2019a) and bounded to the south by the Caiabis basin (Paes de Barros, 2007; Fig. 1C). Some authors propose a succession of continental (Duarte *et al.*, 2019; Scandolaro *et al.*, 2017; Alves *et al.*, 2020) or island (De Assis *et al.*, 2017) arcs accreted to the southwestern margin of the Archean Amazonia Central tectonic province (Fig. 1A). In contrast, others (Neder *et al.*, 2002; Barros *et al.*, 2009; Rizzotto *et al.*, 2019a,b), propose an intraplate extensional environment (or continental rift setting) for the generation of part of the rocks of the southern Amazonian Craton. More recently, Trevisan *et al.* (under review) propose an E-W-oriented accretionary orogen with tectonic switching that alternated between low-angle subduction and slab-rollback.

The Eastern Alta Floresta Mineral Province

The geological framework of the eastern AFMP is separated into five main domains according to new proposals by Trevisan *et al.* (under review) into: (i) 2.86–1.81 Ga Basement, subdivided into the Gavião gneiss and Peixoto de Azevedo Domain; (ii) 1.83–1.77 Ga Colíder group; (iii) 1.79–1.77 Ga Teles Pires suite; (iv) unconstrained rocks; and (v) 1.98–1.37 Ga and Cenozoic sedimentary cover sequences (Fig. 2). The unconstrained rocks represent poorly documented areas with reduced or no lithological, geochemical, and/or geochronological information. A detailed outline of the geology along the eastern portion of the AFMP is presented in Table 2.

This portion of the province has historically been an important gold-producing region in Brazil (~ 4 Moz from 1990 to 1999; Paes de Barros, 2007) for containing along its E-W to NW-SE extension over a hundred placer and medium- to high-grade and low tonnage (< 0.2 Moz) primary gold deposits, occurrences, and prospects, mostly exploited by artisanal prospectors (Fig. 2). Recent studies have indicated the polymetallic potential of the AFMP with

Table 1. Summary of the main lithostratigraphic units identified at the Alta Floresta Mineral Province (Trevisan *et al.*, under review).

Tectonic Province	Domain	Lithostratigraphic Unit		Age (Ga)	Description	Reference
-	-	Alto Tapajós basin (or Cachimbo graben)		Silurian-Devonian	sandstones, siltstones, arkoses, conglomerates, and claystones	Juliani <i>et al.</i> (2014); Toczeck <i>et al.</i> (2019); Alves <i>et al.</i> (2020)
Rondônia-Juruena	Western Amazonia Igneous Belt	Caiabis group (Dardanelos Formation)		1.98–1.37	clastic sediments	Leite and Saes (2003); Alves <i>et al.</i> (2020)
		Roosevelt group		1.76–1.74	mudstone interdigitated with chert, manganiferous siltstone, BIFs, tuffs, ignimbrites, volcanoclastic conglomerates, dacites, and rhyolites	
		Teles Pires suite		1.79–1.75	granitic rocks	
		Colíder group		1.81–1.76	pyroclastic and effusive volcanic rocks with rhyolitic, dacitic, and, to a lesser extent, andesitic and basaltic composition	
		Nova Monte Verde complex		1.81–1.76	granulitic-migmatitic gneissic rocks	
		Juruena supersuite	Zé do Torno suite	1.81–1.75	granitic rocks	Rizzotto <i>et al.</i> (2019b)
			Teodósia suite			
			Nova Canaã suite			
			São Pedro suite			
Tapajós-Parima	Tapajós Domain	São Marcelo-Cabeça group		1.85	granites, monzogranites, granodiorites, diorites, syenites, rhyolites, rhyodacites, metapelites, metaconglomerates, metagreywackes, metacherts, schists, and quartzites	Silva and Abram (2008)
		Peixoto de Azevedo Domain	Matupá intrusive suite	1.88–1.86	non-metamorphosed granitic rocks	Rizzotto <i>et al.</i> (2019b); Alves <i>et al.</i> (2020)
			Guarantã do Norte intrusive suite	1.90–1.89		
			Nhandu intrusive suite	1.97–1.95		
			Pé Quente intrusive suite	1.99–1.97		
			Cuiú Cuiú complex	2.04–1.98	tonalitic-granodioritic gneisses, amphibolite, and deformed, metamorphosed granitic rocks	

prospects and deposits that may be grouped into three main types (Trevisan *et al.*, 2017; De Assis *et al.*, 2017): (1) disseminated and vein-type intrusion-hosted Au-Cu-Mo; (2) disseminated Cu-Mo-Au; and, (3) vein-type Au-Zn-Pb-Cu. A summary of their main characteristics is presented in Table 3.

The broad spatial association of these mineralizing systems with granitic units, their occurrence in the same district, hydrothermal alteration types and zoning, and stable isotope data, have collectively led several authors to envisage such deposits and prospects as magmatic-hydrothermal systems (Moura *et al.*, 2006; Bettencourt *et al.*, 2016; De Assis *et al.*, 2017). In addition, some of these mineralizations have been envisaged as equivalent to porphyry-type and low- to intermediate-sulfidation-type epithermal systems (Moura *et al.*, 2006; De Assis *et al.*, 2017), similar to those identified in the Tapajós Mineral Province, located north-northeastern of the Alta Floresta Province (Juliani *et al.*, 2002, 2005; Bettencourt *et al.*, 2016).

Methods

This study employed whole-rock geochemistry and *in-situ* zircon chemical analyses.

Samples

Seventy samples from drill-cores and outcrops were analyzed for whole-rock geochemistry, whereas eight samples were analyzed for *in-situ* zircon geochemistry (Table 4; Fig. 2; Appendix Fig. A1). Hand-specimen and thin-section petrographic descriptions of these samples are presented in Trevisan *et al.* (under review). Those authors also provided U–Pb zircon ages for these eight samples investigated in the present study. Owing to the presence of overprinting alteration assemblages and veins, all samples selected for whole-rock geochemical analyses were considered to have undergone some degree of alteration. The new whole-rock geochemical data from this study were combined with pre-existing published chemical data (whole-rock major, minor, and trace elements) from Paleoproterozoic rocks in the eastern AFMP (n = 310).

Whole-rock geochemistry

All analyses were conducted at the ALS Minerals Global Group laboratory, Canada. Analyses consisted of lithium borate fusion Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) for major-element oxides, aqua regia digestion ICP-AES for base metals, and lithium borate fusion Inductively Coupled Plasma – Mass Spectrometry (ICP-MS)

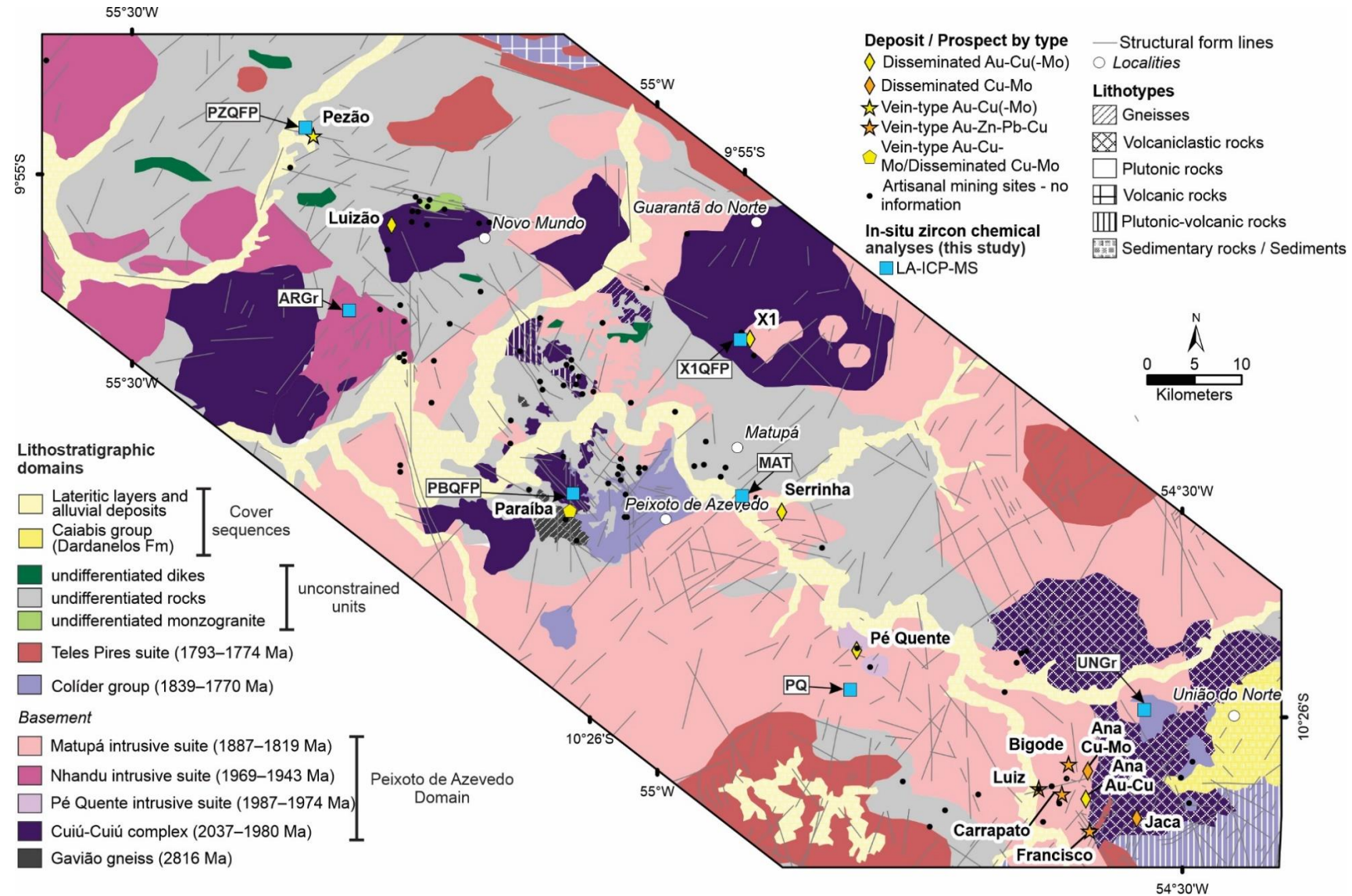


Figure 2. Geological map of the eastern portion of the AFMP (modified from Miguel Jr, 2011 and Assis *et al.*, 2017; Trevisan *et al.*, under review).

Table 2. Summary of the new proposed geological framework of the eastern AFMP (Trevisan *et al.*, under review).

Domain	Unit	Age (Ma)	Description	Geotectonic context	
Cover sequences	Lateritic layers and alluvial deposits	Cenozoic	-	-	
	Caiabis group (Dardanelos Fm.)	1987–1377	Quartzite, conglomerate, arenite, and claystone	-	
unconstrained rocks	undifferentiated dikes	-	Basalt, diorite, gabbro, andesite, dacite, monzogabbro, and monzodiorite	-	
	undifferentiated units	-	-	-	
	undifferentiated monzogranite	-	monzogranite	-	
Teles Pires suite		1793–1774	Alkali-feldspar granite, granite, monzonite, and quartz-feldspar porphyry	Crustal extension Slab-rollback	
Colíder group		1839–1770	Monzogranite, monzonite, granophyry, alkali-feldspar granite, quartz-feldspar porphyry, rhyolite, rhyodacite, dacite, andesite, trachyte, pyroclastic (tuff and ignimbrite), epiclastic, and volcanoclastic		
Basement	Peixoto de Azevedo Domain	Matupá intrusive suite	1887–1819	Granodiorite, monzogranite, tonalite, monzonite, and monzodiorite	Crustal thickening Low-angle subduction
		Guarantã do Norte intrusive suite	1904–1901	Tonalite and granodiorite	
		Nhandu intrusive suite	1969–1943	Monzogranite, syenogranite, and quartz-feldspar porphyry	Crustal extension Slab-rollback
		Pé Quente intrusive suite	1987–1974	Locally deformed syenogranite, monzogranite, granodiorite, tonalite, monzonite, and quartz-feldspar porphyry	Crustal thickening Low-angle subduction
		Cuiú-Cuiú complex	2037–1980	Gneiss, volcanoclastic, and deformed/metamorphosed monzogranite, granodiorite, dacite, granite, diorite, and tonalite	
	Gavião gneiss	2825–2816	Granitic-tonalitic gneiss		

Accretionary orogen

Accretionary orogen

Table 3. Summary of the major prospects and deposits of the eastern portion for the Alta Floresta Mineral Province (Trevisan *et al.*, under review).

Prospect / Deposit		Pé Quente	Luizão	Dionísio	Basílio	Serrinha	Pezão	Ana	Bigode	Francisco	Luiz	Jaca
Geological unit		Pé Quente and Guarantã do Norte intrusive suites	Cuiú-Cuiú complex	Cuiú-Cuiú complex	Cuiú-Cuiú complex	Matupá intrusive suite	Pé Quente and Nhandu intrusive suites	Cuiú-Cuiú complex (?) and Pé Quente intrusive suite (?)	Matupá intrusive suite	Cuiú-Cuiú complex	Pé Quente intrusive suite	Colíder group (?)
Host Rock		Leucomonzonite, quartz diorite, (quartz-) monzodiorite, monzogranite, albitite, biotite tonalite and aplitic granodiorite	Syenogranite, monzonite and (biotite-) hornblende syenogranite to tonalite	Hornblende monzogranite to tonalite	Biotite-hornblende granodiorite to tonalite	Equigranular to porphyritic biotite granite to monzogranite (Matupá Intrusive suite)	Syenogranite and quartz-feldspar porphyry	Quartz-feldspar porphyry	Biotite-hornblende granodiorite.	Feldspathic-wake and volcaniclastic lithic-sandstone, besides quartz-feldspar porphyry	Biotite granodiorite and quartz-feldspar porphyry	Quartz-feldspar porphyry
Host rock age (Ma)		1979 ±31Ma (monzonite) and 1901 ± 6.8 Ma (leucomonzonite)	1970 ± 3 Ma (monzogranite) and 1964 ± 1Ma (syenogranite)	-	-	1872 ±12 (monzogranite)	1987 ±4 (syenogranite)	-	1853 ±23 Ma (granodiorite)		1974 ± 6 Ma (quartz-feldspar porphyry)	-
Alteration mineralogy	Proximal	Alb, Kf, Qtz, Hem, Ser, Py	Ser, Chl, Qtz, Py	Ser, Chl, Qtz, Py, Cpy	Ser, Chl, Qtz, Py, Cpy	Ser, Chl, Kf, Qtz, Py	Qtz, Chl, Ser, Py, Cpy	Ser, Qtz, Alb, Bt, Py, Cpy, Mo	Qtz, Ser, Py, Sph, Gn, Cpy	Qtz, Ser, Py, Sph, Gn, Cpy	Ser, Qtz, Chl, Py, Cpy, Sph, Gn	Ser, Bt, Chl, Qtz, Py, Cpy, Mo
	Intermediate	Qtz, Cal, Ser	Alb, Qtz, Kf, Hem	Kf, Hem, Qtz, Cal, Chl	Kf, Hem, Qtz, Cal	Cal	Kf, Qtz, Cal, Qtz	Kf, Qtz, Hem	Kf, Hem, Qtz, Kln	Kf, Hem, Qtz, Kln	Kf, Qtz, Hem	Chl, Ep, Qtz
	Distal	Ep, Czo, Chl, Ser, Kf, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz, Ser	Ep, Czo, Chl, Cal, Qtz	Alb, Kf, Qtz	Kf, Qtz, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Ep, Czo, Chl, Cal, Qtz	Qtz
Mineralization style		Disseminate	Disseminate	Disseminate / vein-type	Disseminate / vein-type	Disseminate	Vein-type	Disseminate	Disseminate	Disseminate / vein-type	Vein-type	Disseminate / vein-type
Ore minerals		Py, Cpy, Gn, Bi-tellurides	Py, Cpy, Sph, Gn	Py, Cpy, Bn, Sph, Cv, Gn	Py, Cpy, Gn, Sph, Bi-tellurides, Hessite	Py, Cpy, Sph, Po, Cbn, Gn	Py, Cpy, Gn, Sph, Bi-tellurides, Hessite, Cv	Py, Cpy, Mo	Py, Sph, Gn, Cpy	Py, Sph, Gn, Dg, Cpy, Bn, Po, Cct	Py, Sph, Gn, Cpy, Brt, Bi-tellurides	Py, Cpy, Mo, Sph, Gn, Cv

Mineralization age (Ma)	1787 ± 5 (pyrite NTIMS Re-Os)	1787 ± 6 (pyrite NTIMS Re-Os)	-	-	-	-	-	-	1779 ± 6 and 1777 ± 6 (sericite ⁴⁰ Ar- ³⁹ Ar)	-	-
Geochemical associations	Au, Cu, Bi, Te, Pb	Au, Cu, Ag, Te	Au,Cu, Pb, Zn	Au, Cu, Pb, Zn, Bi, Te	Au, Cu, Zn, Pb	Au, Cu, Zn, Pb	Cu, Mo	Au, Ag, Zn, Pb	Au, Ag, Zn, Pb, Cd	Au, Zn, Pb, Cu	Cu, Mo
Fluid regime	Coexistence of two-phase aqueous fluids and aqueous-carbonic fluids.	Coexistence of saline aqueous fluids (33,6-37% eq. NaCl) with moderate temperature (Tht= 200 to 280°C) and low salinity aqueous fluids (2,5-15% eq. NaCl) and Tht = 61-185°C.	-	-	Coexistence of high saline aqueous fluids (45-57% eq. NaCl and Tht: 375 to 480 °C) and low salinity aqueous-carbonic fluids (2-11,89% eq. NaCl and Tht = 220-360 °C).	Coexistence of two-phase aqueous and monophasic fluids.	-	-	Low to moderate aqueous fluids (>24% eq. NaCl) with variable filling degree of the vapor phase (10-70%).	Coexistence of two-phase aqueous and monophasic fluids.	-
References	Miguel Júnior (2011); Assis (2011, 2015); Stabile Júnior (2012); Assis <i>et al.</i> (2017)	Assis (2006); Paes de Barros (2007); Assis <i>et al.</i> (2017)	Trevisan (2012)	Trevisan (2012)	Moura <i>et al.</i> (2006)	Trevisan (2015)	Matos <i>et al.</i> (2018)	Assis (2008)	Assis (2008, 2011, 2015)	Trevisan (2015)	Novo (2015)

Abbreviations: Alb-albite, Kf-potassium feldspar, Qtz-quartz, Hem-hematite, Ser-sericite, Chl-chlorite, Bt-biotite, Cal-calcite, Kln-Kaolinite, Czo-clinozoisite, Py-pyrite, Bn-bornite, Cpy-chalcopyrite, Gn-galena, Sph-sphalerite, Cv-covellite, Po-pyrrhotite, Cbn-cubanite, Mo-molybdenite, Dg-digenite, Cct-chalcocite.

for minor and trace elements. Results were corrected for spectral inter-element interferences, and oxide concentration was calculated from determined elemental concentration. Loss on ignition (LOI) was determined by firing the rock powder at 1000 °C and calculating the weight difference before and after the firing. In order to maintain data quality, various standards and unknowns were run between analysis. All data were processed and interpreted using Excel. Complete results of the whole-rock geochemistry analyses are reported in [Appendix Table A1](#). New and published analyses were screened with the following criteria: analyses yielding a SiO₂ content greater than 80 wt.% and/or low Zr values (< 70 ppm) were discarded as unlikely to represent primary igneous compositions. Published analyses done by wet-chemical, acid-digestion methods, without prior fusion with Li-borate, do not completely dissolve refractory minerals (e.g. zircon, barite, monazite, sphene, chromite, gahnite, garnet, ilmenite, rutile, cassiterite, magnetite), REE and other high-field strength elements ([Act-Labs, 2016](#)), so analyses entailing total-fusion and/or XRF were selected.

In-situ zircon chemical analyses

Zircon grains selected for *in-situ* chemical analyses were imaged using transmitted and reflected light microscopy at the School of Earth Sciences, The University Western Australia (UWA), Perth, Australia. Further imaging was taken using secondary electron (SE), back-scattered electron (BSE) and cathodoluminescence (CL) imaging methodologies using a Vega 3 Tescan Scanning Electron Microscope (SEM-EDS) at the Centre for Microscopy, Characterization and Analysis (CMCA), UWA. Imaging parameters include: accelerated voltage of 15–20 kV, working distance of 15 mm, and beam intensity of 1.5–1.6 nA. LA-ICP-MS analyses were performed at the School of Earth Sciences, UWA, using an X-series II quadrupole ICP-MS attached to an Analyte G2 Excimer laser system (193 nm wavelength) with a standard dual volume cell. The He carrier gas was set at 0.9 l/min (MFC1= 0.6 l/min and MFC2= 0.4 l/min) and was mixed with a nebulizer flow of argon (0.7 l/min) in a glass mixing bulb. A steady flow of ~5 ml/min N₂ was added in order to enhance sensitivity and reduce oxide production before being introduced into the plasma. The mass spectrometer was tuned to maximum sensitivity at plasma conditions of Th/U ~ 1 in a NIST610 glass, and the production of molecular oxide species was monitored by maintaining a low ThO⁺/Th⁺ ratio ~0.25%. The laser ablation repetition rate was 10 Hz, with a laser fluence of 5J/cm². A spot size of 25 or 35 micrometers was used for the unknowns and 35 and 40 micrometer spot sizes were used for standard reference material NIST610 and NIST612, respectively. The dwell time for each

Table 4. Investigated whole-rock and zircon samples presented in the results of this study.

Sample code	Latitude	Longitude	Geological domain	Geological unit	Rock type	Age (Ma)*
<i>Whole-rock geochemistry</i>						
NMGr-49(2)	-9.99	-55.25	Basement - Peixoto de Azevedo Domain	Cuiú-Cuiú Complex	Biotite granite	2013 ± 33
NMGr-50(2)	-9.98	-55.21				
NMGr-05	-9.99	-55.23				
NMGr-12A	-9.99	-55.26				
FMGr-51(2)	-9.84	-55.13		Matupá intrusive suite	Biotite-hornblende monzogranite	1887 ± 11
FMGr-52(2)	-9.86	-55.10				
FMGr-53(2)	-9.91	-55.01				
FMGr-06A	-9.87	-55.10				
FMGr-08A	-9.85	-55.10				
FMGr-10	-9.87	-55.05				
FMGr-11	-9.87	-55.07				
FMGr-13A	-9.87	-55.04				
ARGr-44(2)	-10.11	-55.32		Nhandu intrusive suite	Hornblende-biotite granite	-
ARGr-44(5)	-10.11	-55.32				
ARGr-45(2)	-10.09	-55.32				
ARGr-46(2)	-10.05	-55.29				
ARGr-46(5)	-10.05	-55.29				
ARGr-01	-10.11	-55.28				
ARGr-03A	-10.05	-55.28				
MAT-47(2)	-10.22	-54.92		Matupá intrusive suite	Biotite granodiorite/monzogranite	-
MAT-47(5)	-10.22	-54.92				
MAT-47(8)	-10.22	-54.92				
MAT-47(11)	-10.22	-54.92				
MAT-31A	-10.47	-55.19				
PBH-PB-20-05:38.20	-10.22	-55.08		Cuiú-Cuiú Complex	Biotite tonalite	2014 ± 5
PBH-PB-20-25	-10.22	-55.08				

PBQFP-PB-84(01)-7-7.28	-10.23	-55.09				
PBQFP-PB-84(03)-11.17-11.39	-10.23	-55.09				
PBQFP-PB-84-19-54.12-54.39	-10.23	-55.09				
PBQFP-PB-84(24)-86.58-86.78	-10.23	-55.09				
PBQFP-PB-84(33)-168.16-168.46	-10.23	-55.09				
PBQFP-PB-84(36)-197.47-197.68	-10.23	-55.09				
PZQFP-AD-FD-02(2)-25.8	-9.87	-55.33				
PZQFP-AD002-25.85	-9.87	-55.33		Nhandu intrusive suite	Quartz-feldspar porphyry	-
PZQFP-AD002-28.9	-9.87	-55.33				
LZQFP-MOC004-60.13-61.1	-10.50	-54.62	Basement - Peixoto de Azevedo Domain			
LZQFP-ANA028-40-42.05	-10.50	-54.61				
LZQFP-ANA028-110.4	-10.50	-54.61		Pé Quente intrusive suite	Quartz-feldspar porphyry	1974 ± 6
LZQFP-ANA028-35	-10.50	-54.61				
LZQFP-ANA028-43.7	-10.50	-54.61				
COL-05(2)	-10.54	-54.48				
COL-55(2)	-10.83	-55.40				
COL-14A	-10.83	-55.41		Colíder group	Andesite, dacite, rhyolite	-
COL-16A	-10.85	-55.42				
COL-29A	-10.59	-54.39				
<i>In-situ zircon chemical analyses</i>						
ARGr	-10.05	-55.29	Basement - Peixoto de Azevedo Domain	Nhandu intrusive suite	Hornblende-biotite granite	1964 ± 9
UNGr	-10.43	-54.54			Porphyritic alkali-feldspar granite	1788 ± 14
COL	-10.83	-55.40		Colíder group	Porphyritic rhyolite	1834 ± 16
PBQFP	-10.22	-55.08		Teles Pires suite	Porphyritic granite	1793 ± 9
PQ	-10.41	-54.82			Quartz-monzonite	1984 ± 16
MAT	-10.22	-54.92	Basement - Peixoto de Azevedo Domain	Pé Quente intrusive suite		
X1	-10.07	-54.92		Matupá intrusive suite	Biotite granodiorite/monzogranite	1866 ± 10
PZQFP	-9.87	-55.33		Colíder group	Quartz-feldspar porphyry	1781 ± 7
			Basement - Peixoto de Azevedo Domain	Nhandu intrusive suite	Quartz-feldspar porphyry	1943 ± 11

* Ages reported in Trevisan *et al.* (under review)

element was set at 20ms. A 30 seconds background was collected prior to each analysis. Element concentrations were reduced with the Iolite software package (Hellstrom *et al.*, 2008) using bracketing analysis of NIST610 as an external standard with the reference concentrations taken from Jochum *et al.* (2011). SiO₂ (31.57 wt.%) was used as the internal standard value for each analyzed grain and NIST612 was analyzed and used as a secondary standard. Reduced data were plotted and interpreted using Excel. Zircon analyses containing La or Pr > 2 ppm and/or P > 800 ppm are contaminated by apatite nano-inclusions in the analyzed spot (Lu *et al.*, 2016), and therefore were deleted. Data were screened for contamination by mineral inclusions the parameters given in Lu *et al.* (2016). Complete results of the *in-situ* zircon chemical analyses are reported in Appendix Table A2.

Results

Whole-rock geochemistry

A compilation of new and pre-existing published data from the eastern portion of the Alta Floresta Mineral Province was plotted on distinct classification diagrams (Figure 3; Table 5). Plutonic rocks classified using mobile major elements in the R1-R2 chemical variation diagram (De La Roche *et al.*, 1980) range from gabbro to granite (Fig. 3A). Immobile-trace-element plots (Winchester and Floyd, 1977; Fig. 3B) indicate compositional ranges from granodiorite through monzonite (equivalent to basalt to trachyandesite).

On the basis of K/Rb ratios (Blevin, 2004), rocks of the different geological units plot mostly within the range of the moderately evolved granitoids, except for some samples in the strongly evolved and unevolved fields (Fig. 3C). Also, most rocks show similarities with unfractionated M-, I- and S-type granites along with A-Type granites in the FeO/MgO vs. Zr+Nb+Ce+Y diagram (Whalen *et al.*, 1987; Fig. 3D), whereas some plot within the fractionated granites field. See Whalen *et al.* (1987) for S-I-A-M classification of granitic rocks.

The samples generally fit into the subalkaline field, but a few plot within the alkaline field (Irvine and Baragar, 1971; Fig. 3E). The majority of the rocks fall between the high-K calc-alkaline to shoshonite series fields, whereas some plot in the medium-K calc-alkaline series field (Le Maitre *et al.*, 1989; Fig. 3F).

In the Modified Alkali-Lime Index (MALI index; Frost *et al.*, 2001), the distinct geological units are classified as calcic to alkalic. However, rocks fall predominately between the calc-alkalic and alkali-calcic fields (Fig. 3G). In the Th vs. Co discrimination diagram (Hastie *et al.*, 2007), which involve elements of low solubility in hydrothermal fluids

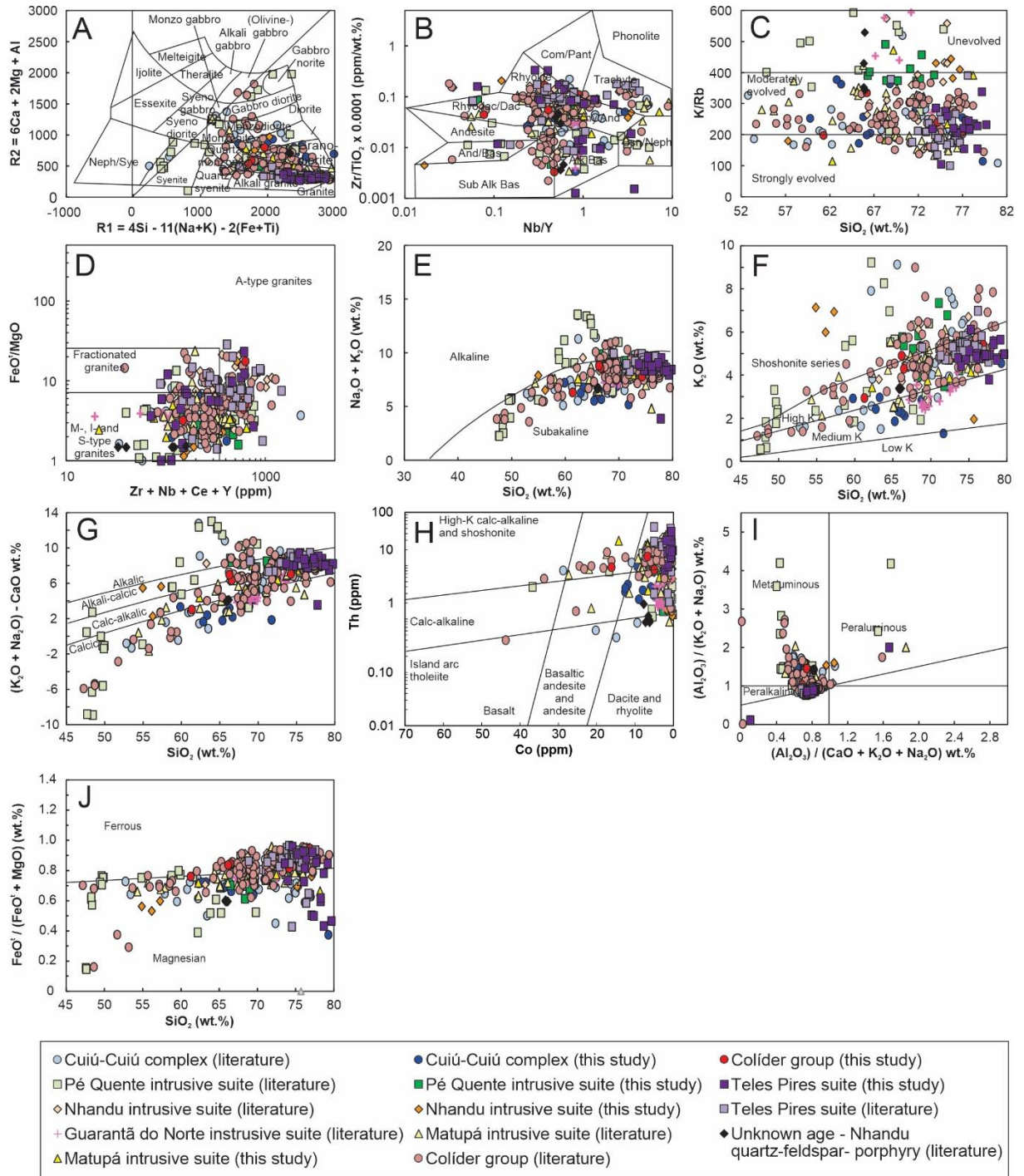


Figure 3. Geochemical classification diagrams showing new whole-rock data in dark colors and published data in pale colors: (A) R1-R2 chemical variation diagram (De La Roche *et al.*, 1980); (B) Plutonic and volcanic rocks classified by Zr/Ti vs. Nb/Y (Winchester and Floyd, 1977); (C) K/Rb vs. SiO₂ (Blevin, 2004); (D) FeO^t/MgO vs. Zr+Nb+Ce+Y (Whalen *et al.*, 1987); (E) (K₂O + Na₂O) vs. SiO₂ (Irvine and Baragar, 1971); (F) K₂O vs. SiO₂ (Le Maitre *et al.*, 1989); (G) Modified Alkali-Lime Index (MALI index; Frost *et al.*, 2001); (H) Aluminum-saturation index (Frost *et al.*, 2001); (I) (FeO)^t/(FeO^t+MgO) vs. SiO₂ (Frost *et al.*, 2001).

Table 5. Summary of whole-rock major, minor, and trace elements geochemistry results (median values).

Geological unit	Number of samples	Major, minor (wt.%) and trace (ppm) elements															
		SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI	Total	Ba	Rb	Sr	Nb
Cuiú-Cuiú complex (literature)	35	72.38	0.23	14.45	1.81	0.20	0.67	0.96	3.33	4.74	0.23	1.20	100.15	530.95	121.00	88.00	13.40
Cuiú-Cuiú complex (this study)	14	67.70	0.60	15.25	3.83	0.35	1.43	3.39	3.84	2.76	0.20	0.67	99.86	242.50	79.75	281.75	6.75
Pé Quente intrusive suite (literature)	34	63.05	0.54	15.90	2.60	0.23	0.99	2.67	4.34	3.17	0.20	1.50	100.45	758.00	42.50	325.70	5.70
Pé Quente intrusive suite (this study)	12	69.35	0.42	14.30	2.41	0.70	0.88	1.13	4.17	5.27	0.24	1.25	100.09	755.50	93.95	163.75	9.10
Nhandu intrusive suite (literature)	22	71.96	0.30	13.60	2.99	0.40	0.40	0.72	3.56	5.43	0.30	0.65	101.16	372.50	118.70	44.50	10.85
Nhandu intrusive suite (this study)	9	75.20	0.23	12.60	1.99	0.40	0.50	0.52	3.21	5.42	0.20	0.29	100.44	271.00	36.30	16.30	3.80
Guarantã do Norte intrusive suite (literature)	18	70.54	0.22	15.37	1.91	0.50	0.52	2.73	4.60	3.11	0.15	0.85	100.68	582.00	33.10	473.50	4.95
Matupá intrusive suite (literature)	52	70.39	0.43	14.59	2.97	0.50	0.94	1.93	3.42	4.63	0.24	0.80	100.76	649.00	147.30	218.50	13.35
Matupá intrusive suite (this study)	10	70.70	0.35	14.45	2.44	0.45	0.73	2.03	4.21	4.27	0.18	0.62	100.46	365.00	106.40	248.50	10.05
Colíder group (literature)	112	71.50	0.43	14.20	2.77	0.45	0.52	1.20	3.55	4.79	0.20	1.18	100.83	340.00	137.50	81.85	13.15
Colíder group (this study)	5	66.50	0.56	14.10	4.38	0.80	0.79	1.91	3.44	4.89	0.27	1.82	100.86	251.00	123.00	44.30	17.00
Teles Pires suite (literature)	31	74.76	0.21	12.95	1.69	0.50	0.24	0.47	3.81	5.18	0.30	0.70	100.78	196.00	193.40	-	22.40
Teles Pires suite (this study)	20	77.15	0.27	12.53	1.36	0.20	0.34	0.40	3.70	4.91	0.10	0.49	101.28	56.40	182.50	17.94	18.75
Unknown age - Nhandu quartz-feldspar porphyry (literature)	5	65.97	0.296	15.97	2.67	0.63	1.78	2.77	3.39	3.37	0.14	3.57	100.552	444	65.4	141	2.94

Geological unit	Number of samples	Major, minor (wt.%) and trace (ppm) elements															
		Zr	Th	Hf	U	Y	Sc	Be	V	Cr	Co	Ni	Cd	Cu	Au	Li	Zn
Cuiú-Cuiú complex (literature)	35	143.70	15.90	4.50	2.40	12.10	4.10	2.02	15.00	20.40	2.40	7.50	0.08	5.50	-	19.26	22.10
Cuiú-Cuiú complex (this study)	14	173.00	3.87	4.90	1.24	10.75	15.00	0.25	37.00	13.70	5.43	5.90	0.24	9.60	1.05	10.60	41.85
Pé Quente intrusive suite (literature)	34	90.40	4.05	3.71	1.40	13.90	4.00	2.00	28.35	16.98	4.00	4.70	0.40	5.37	1.55	3.98	40.85
Pé Quente intrusive suite (this study)	12	271.00	8.58	7.10	2.10	18.95	13.50	0.32	22.50	12.00	2.60	1.89	0.65	2.25	1.70	12.75	37.60
Nhandu intrusive suite (literature)	22	282.55	9.15	7.50	1.50	18.15	4.00	2.00	16.50	0.30	1.60	1.60	0.15	3.60	-	-	50.00
Nhandu intrusive suite (this study)	9	166.00	1.74	5.90	0.77	12.30	13.00	0.43	44.00	6.17	0.54	1.60	0.41	1.98	0.40	5.30	33.70
Guarantã do Norte intrusive suite (literature)	18	77.30	4.15	2.45	0.85	5.70	2.00	3.00	20.50	-	2.80	1.20	-	2.25	2.40	-	28.50

Matupá intrusive suite (literature)	52	152.50	14.95	4.65	3.29	22.30	5.98	2.37	23.00	15.50	5.60	10.35	0.60	8.95	1.60	21.30	38.00
Matupá intrusive suite (this study)	10	99.50	10.94	3.20	3.80	8.00	13.00	0.39	28.00	18.28	4.11	6.50	0.25	3.63	0.45	13.00	27.75
Colíder group (literature)	112	194.10	16.05	5.87	3.76	38.30	4.50	2.90	17.00	2.20	3.30	2.20	0.35	4.00	6.40	-	21.00
Colíder group (this study)	5	325.00	14.80	5.30	3.66	26.00	19.00	0.98	42.00	15.45	4.92	3.20	0.44	5.67	1.10	7.60	74.20
Teles Pires suite (literature)	31	232.00	24.00	9.40	5.30	38.30	3.00	4.00	12.00	0.60	1.05	1.10	0.20	3.60	-	-	34.00
Teles Pires suite (this study)	20	73.00	18.23	3.95	6.38	28.35	15.00	0.56	8.00	7.40	0.64	1.51	0.31	3.61	1.30	1.25	23.50
Unknown age - Nhandu quartz-feldspar porphyry (literature)	5	93.1	0.97	3.26	0.36	5.5	3.79	1.15	37.4	15.6	6.5	8.56	0.1	1.33	-	23.5	37.3

Geological unit	Number of samples	Major, minor (wt.%), trace and Rare Earth (ppm) elements															
		Ga	Mo	Sn	Sb	Cs	Ta	W	Pb	Bi	La	Ce	Pr	Nd	Sm	Eu	Gd
Cuiú-Cuiú complex (literature)	35	18.60	0.60	2.00	0.10	1.30	1.00	0.56	15.90	0.10	35.68	67.37	6.52	24.20	4.10	0.67	3.16
Cuiú-Cuiú complex (this study)	14	19.30	0.29	2.50	0.23	2.00	0.50	1.50	3.63	0.46	25.90	49.35	5.61	24.40	3.11	1.30	2.89
Pé Quente intrusive suite (literature)	34	16.95	0.20	1.50	0.15	0.55	0.50	0.90	4.83	0.20	17.30	24.80	4.22	16.30	3.12	0.81	2.64
Pé Quente intrusive suite (this study)	12	17.65	0.45	1.00	0.26	0.81	0.60	1.20	3.80	0.40	47.95	88.90	9.17	37.45	6.24	1.29	4.62
Nhandu intrusive suite (literature)	22	15.55	0.30	2.00	-	0.80	0.60	0.40	16.80	-	58.20	106.75	12.48	37.95	6.51	0.81	5.34
Nhandu intrusive suite (this study)	9	17.10	0.40	2.00	0.21	0.90	0.50	1.10	7.54	0.31	68.70	124.50	14.35	52.50	8.98	0.66	5.33
Guarantã do Norte intrusive suite (literature)	18	18.55	0.20	-	-	0.40	0.35	-	4.95	0.10	16.45	32.65	3.70	13.30	2.21	0.54	1.43
Matupá intrusive suite (literature)	52	15.90	0.39	1.63	0.37	2.90	1.25	0.33	14.10	0.19	36.90	71.25	7.49	34.50	6.10	1.01	4.70
Matupá intrusive suite (this study)	10	18.25	0.29	1.00	0.24	0.58	0.90	0.70	7.63	0.31	28.20	27.60	5.82	12.25	3.04	0.80	1.91
Colíder group (literature)	112	18.10	2.10	2.20	0.50	1.31	1.11	1.35	16.45	0.40	44.90	80.30	12.22	39.05	6.45	1.29	6.17
Colíder group (this study)	5	19.20	0.88	3.00	0.17	1.48	1.00	1.50	9.36	0.62	39.80	143.00	16.60	32.60	7.37	1.94	5.83
Teles Pires suite (literature)	31	18.70	1.10	4.00	0.10	0.80	1.60	0.85	14.45	0.30	48.00	89.10	18.43	35.80	6.50	0.69	5.76
Teles Pires suite (this study)	20	18.80	1.67	2.00	0.21	0.72	1.55	2.85	13.60	0.46	18.05	28.15	4.10	15.25	4.30	0.28	4.49
Unknown age - Nhandu quartz-feldspar porphyry (literature)	5	19	-	0.5	0.43	1.56	0.14	2.27	1.99	-	7.9	14.2	2.2	8.78	1.79	0.5	1.44

Geological unit	Number of samples	Rare Earth Elements (ppm) and selected element ratios													
		Tb	Dy	Ho	Er	Tm	Yb	Lu	Sr/Y	(Eu/Eu*)/Yb	V/Sc	Sr/Zr	Ba/Zr	Nb/Y	Th/Yb
Cuiú-Cuiú complex (literature)	35	0.53	2.90	0.52	1.73	0.28	2.12	0.31	15.86	0.87	7.07	0.63	4.03	0.82	8.65

Cuiú-Cuiú complex (this study)	14	0.35	1.88	0.39	1.21	0.38	1.50	0.41	17.64	3.11	2.57	1.00	1.28	0.56	5.31
Pé Quente intrusive suite (literature)	34	0.44	2.15	0.44	1.24	0.36	1.45	0.47	18.30	1.68	6.33	2.31	5.08	0.56	3.96
Pé Quente intrusive suite (this study)	12	0.69	3.63	0.70	2.05	0.28	1.88	0.28	8.83	1.35	1.75	0.58	3.81	0.46	4.68
Nhandu intrusive suite (literature)	22	0.82	4.44	0.74	2.61	0.32	2.68	0.37	2.45	0.46	0.00	0.14	1.28	0.49	4.06
Nhandu intrusive suite (this study)	9	0.71	4.74	0.77	2.23	0.36	1.95	0.29	1.10	0.42	3.88	0.10	1.15	0.38	1.47
Guarantã do Norte instrusive suite (literature)	18	0.19	1.17	0.18	0.52	0.37	0.62	0.38	63.54	4.69	8.00	6.08	6.75	0.89	5.95
Matupá intrusive suite (literature)	52	0.70	3.91	0.79	2.30	0.33	1.94	0.31	8.94	0.87	6.00	1.03	3.81	0.66	7.46
Matupá intrusive suite (this study)	10	0.52	1.73	0.32	0.91	0.23	0.91	0.17	38.32	2.56	1.87	2.07	1.03	0.89	8.46
Colíder group (literature)	112	1.10	5.58	1.26	3.59	0.56	3.52	0.58	3.56	0.70	5.42	0.59	1.70	0.41	4.50
Colíder group (this study)	5	1.30	4.45	1.57	4.15	0.68	4.14	0.66	1.59	1.35	2.04	0.15	0.72	0.41	3.72
Teles Pires suite (literature)	31	1.91	6.72	2.43	4.17	1.07	4.49	0.69	2.12	0.23	3.00	0.44	0.92	0.62	4.00
Teles Pires suite (this study)	20	0.77	4.76	0.89	2.79	0.42	2.58	0.40	0.72	0.45	0.56	0.24	0.69	0.88	6.84
Unknown age - Nhandu quartz-feldspar porphyry (literature)	5	0.19	1.50	0.18	0.51	0.80	0.45	0.70	26.31	6.44	9.82	1.20	4.77	0.56	2.16

(i.e. immobile trace elements), samples are classified as calc-alkaline to high-K calc-alkaline and shoshonite (Fig. 3H). Evaluation of the Aluminum Saturation Index (ASI index) shows that the majority of the rocks are metaluminous and others peralkaline (Fig. 3I). Moreover, based on the Fe-index diagram (Frost *et al.*, 2001), rocks are predominately ferroan and, to a lesser extent, magnesian (Fig. 3J).

All investigated rocks in NMORB normalized (Sun and McDonough, 1989) REE diagrams are more enriched in light rare-earth elements (LREE) than in heavy rare-earth elements (HREE) regardless of the geological unit (Figs. 4A-N). The LREE show steep patterns regardless of geological unit, whereas for the HREE, samples show predominantly flat to slightly concave upwards pattern (Figs. 4A-M), except for the Nhandu quartz-feldspar porphyry with Tm and Lu positive anomalies (Fig. 4N), which may represent analytical error.

The majority of the geological units show negative Eu anomalies (Figs. 4A-N), except for the Cuiú-Cuiú complex (Figs. 4A-B), Matupá intrusive suite (Figs. 4H-I), and Colíder group (Figs. 4J-K) which have negative to positive Eu anomalies. Most units also show at least one sample with no Eu anomaly. The Eu anomalies $(Eu/Eu^*)_N$ values (where $Eu_N/Eu_N^* = 2 * Eu_N / (Sm_N + Gd_N)$) vary from 0.09 to 9.09.

Variation in the concentration of trace elements measured in whole-rock has been a relatively useful tool to distinguish prospective intrusive bodies from those that are unrelated to copper and/or gold mineralization, for example, in porphyry systems (Thiéblemont *et al.*, 1997; Loucks, 2012a, 2012b, 2014). The discriminants of magmatic copper fertility include the ratios Sr/Y, $(Eu/Eu^*)/Yb$, V/Sc and Sr/Zr; while indicators of magmatic gold fertility include Ba/Zr, Nb/Y and Th/Yb. Variations of these copper-fertility indicator ratios can be explained in terms of the oxidation state, water content, degree of fractionation of magmas and/or tectonic stress regime (e.g. compressive *versus* non-compressive; Loucks, 2012a). Variations among indicators of magmatic gold fertility mainly represent variation in degrees of partial melting of the mantle source (Loucks, 2012b).

Figure 5 shows the relationship of each of these ratios mostly with wt.% SiO₂. The Sr/Y shows high to low fractionation values that range between 0.02 and 349 (Fig. 5A; median values in Table 5), with most of the “adakite-like” values > 20 occurring in most geological units and, to a lesser extent, in the Nhandu and Teles Pires suites (Fig. 5B). The $(Eu/Eu^*)/Yb$ varies from 0.002 to 41, with the highest values associated with the Cuiú-Cuiú complex and Pé Quente and Guarantã do Norte suites (Fig. 5C; median values in Table 5). The V/Sc in the studied rocks ranges between 0.24 and 79, with Colíder group and Matupá suite presenting the highest values

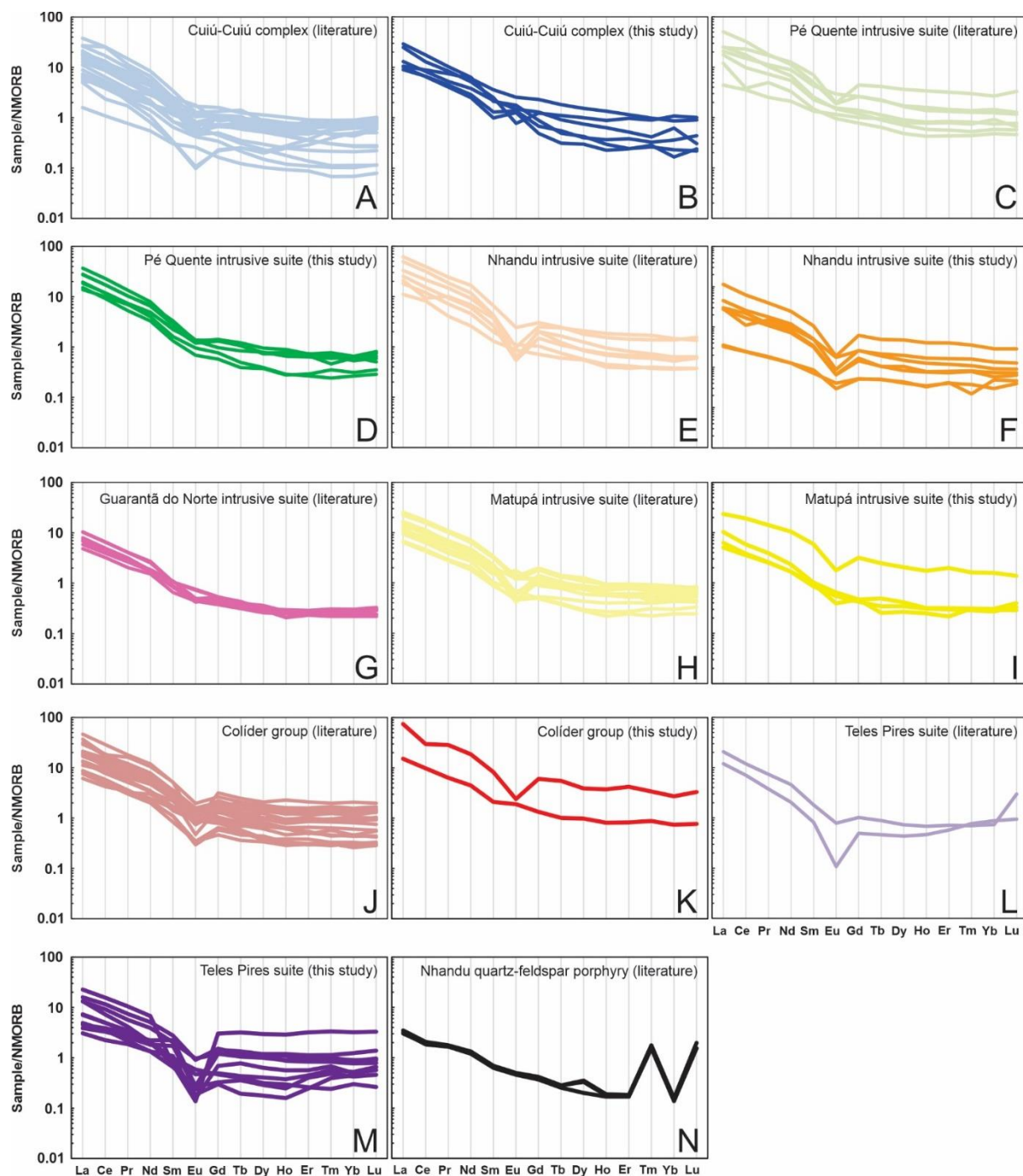


Figure 4. (A-N) Whole-rock REE plots by geological unit. New data in dark colors and published data in pale colors. All samples and reference reservoirs normalized with respect to NMORB as defined by [Sun and McDonough \(1989\)](#).

([Fig. 5D](#); median values in [Table 5](#)). The Sr/Zr varies from 0.04 to 678, with the highest values related to the Matupá suite ([Fig. 5E](#); median values in [Table 5](#)). The Ba/Zr ranges between 0.02 and 234, with Guarantã do Norte, Pé Quente and Matupá suites and Colíder group presenting the highest values ([Fig. 5F](#); median values in [Table 5](#)). The Nb/Y ranges between 0.02 and 11,

with part of the Colíder group, Cuiú-Cuiú complex, Teles Pires and Pé Quente suites showing the highest values (Fig. 5G; median values in Table 5). The Th/Yb ranges between 0.01 and 53, with Matupá and Teles Pires suites presenting the highest values (Fig. 5H; median values in Table 5).

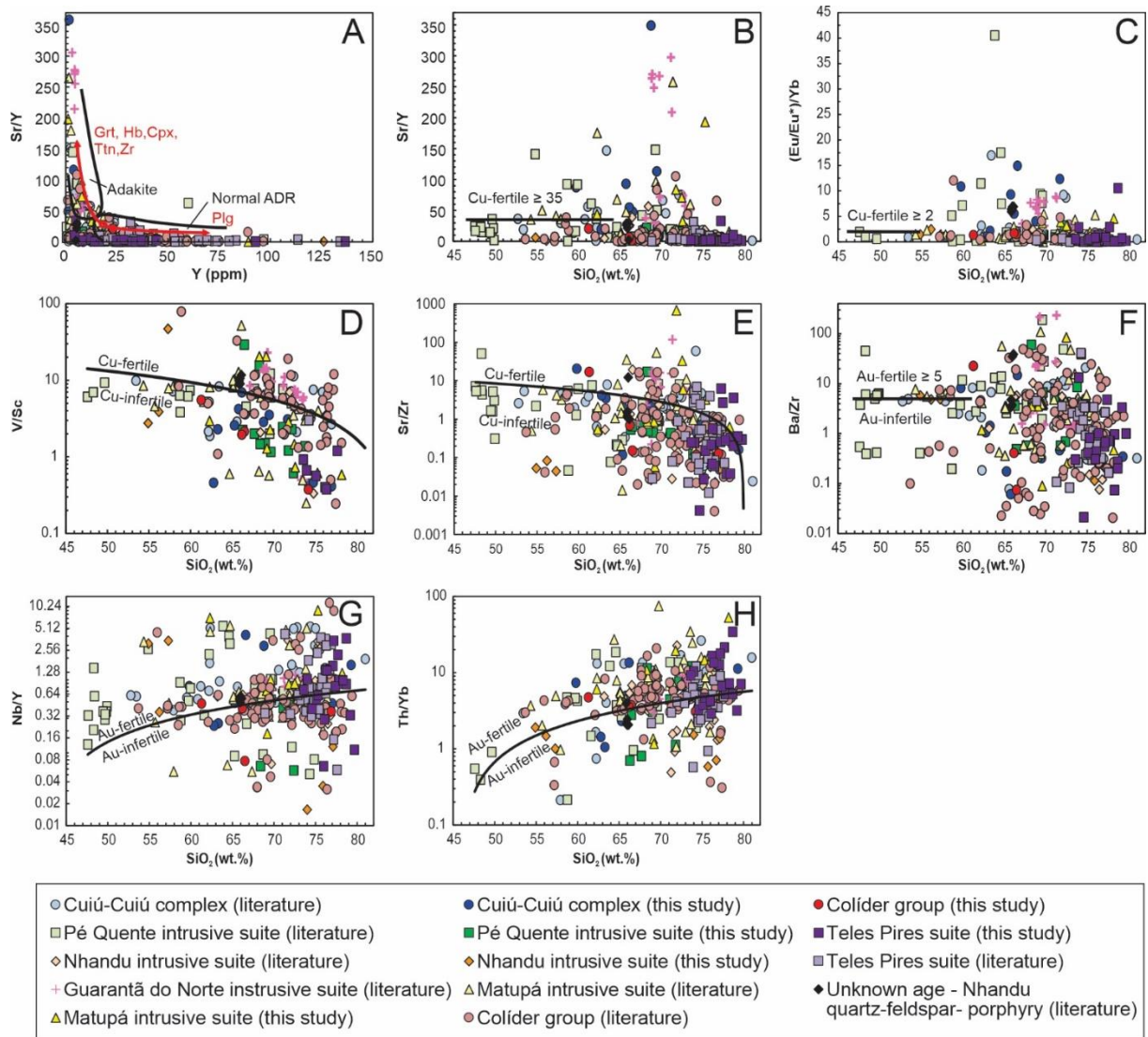


Figure 5. Whole-rock indicators of magmatic copper and gold fertility showing new data in dark colors and published data in pale colors: (A) Sr/Y vs. Y (Defant and Drummond, 1990) showing fields for adakite and ordinary arc andesite-dacite-rhyolite (ADR) magmas of Castillo *et al.* (1999). Differentiation paths resulting from fractionation of various minerals are from Richards and Kerrich (2007); (B) Sr/Y vs. SiO_2 (Richards and Kerrich, 2007); (C) $(\text{Eu}/\text{Eu}^*)/\text{Yb}$ vs. SiO_2 (Lu *et al.*, 2016); (D) V/Sc vs. SiO_2 (Loucks, 2014); (E) Sr/Zr vs. SiO_2 (Loucks, 2012a); (F) Ba/Zr vs. SiO_2 ; (G) Nb/Y vs. SiO_2 ; (H) Th/Yb vs. SiO_2 . Diagrams (F), (G) and (H) are from

Loucks (2012b). Abbreviations: Grt = garnet; Cpx = clinopyroxene; Hb = hornblende; Plg = plagioclase; Ttn = titanite.

Zircon morphology and internal textures

Zircon grains from the Pé Quente suite are prismatic, clear to light brown, and locally medium brown. They range from 134 to 294 μm long with a length to width ratio between 3.42 and 3.55. Grains have fractures and mineral inclusions. CL (cathodoluminescence) images show oscillatory zoning and, occasionally, sector zoning (Fig. 6).

Nhandu suite zircon grains are clear to light brown, prismatic, and with abundant mineral inclusions and fractures. They range in length from 81–269 μm with a length to width ratio of 1.24–2.66. CL images show five different internal patterns: oscillatory rim surrounding core with sector zoning; recrystallized core or dark, featureless core; oscillatory or sector zoning across the entire grain; brighter core with oscillatory zoning overgrown by a fine, dark rim; recrystallized core surrounded by featureless rim; and featureless grains (Fig. 6).

Zircon grains from the Matupá suite are light to medium brown and prismatic. They range in size from 107–227 μm with a length to width ratio between 2.35 and 3.8. CL images show varied internal structures: a core with oscillatory zoning overgrown by dark, fine rim; faint to well-developed oscillatory zoning; and dark, featureless core surrounded by rim with oscillatory zoning. Most grains have fractures and mineral inclusions (Fig. 6).

Colíder group zircon grains are prismatic, clear to dark brown, commonly with mineral inclusions and fractures. They range in size between 78 and 240 μm with a length to width ratio from 1.03 to 3.16. CL images show different internal textures: featureless grains; sector zoning; faint to well-developed oscillatory zoning; and, recrystallized core overgrown by a featureless rim (Fig. 6).

Zircon grains from the Teles Pires suite are medium to dark brown, prismatic, densely fractured and contained few mineral inclusions. They range in size from 71–241 μm with a length to width ratio between 1.51 and 3.04. CL images show: faint oscillatory zoning; some featureless grains; and some having a fine, dark rim surrounding brighter featureless core (Fig. 6).

Zircon geochemistry

The *in-situ* zircon chemical analyses are available for fewer samples (Table 6) of fewer geological units than the whole-rock geochemistry shown in Figures 3 to 5. The REE patterns of magmatic zircons (free of contamination by foreign mineral inclusions) from five geological

units are presented in [Figure 7](#). All units are characterized by positive Ce anomalies and depletion of LREE relative to HREE. The Pé Quente and Nhandu intrusive suite and the Colíder group have conspicuous to minimal negative or even absent Eu anomalies, whereas the Matupá and Teles Pires suite have small to minimal negative Eu anomalies.

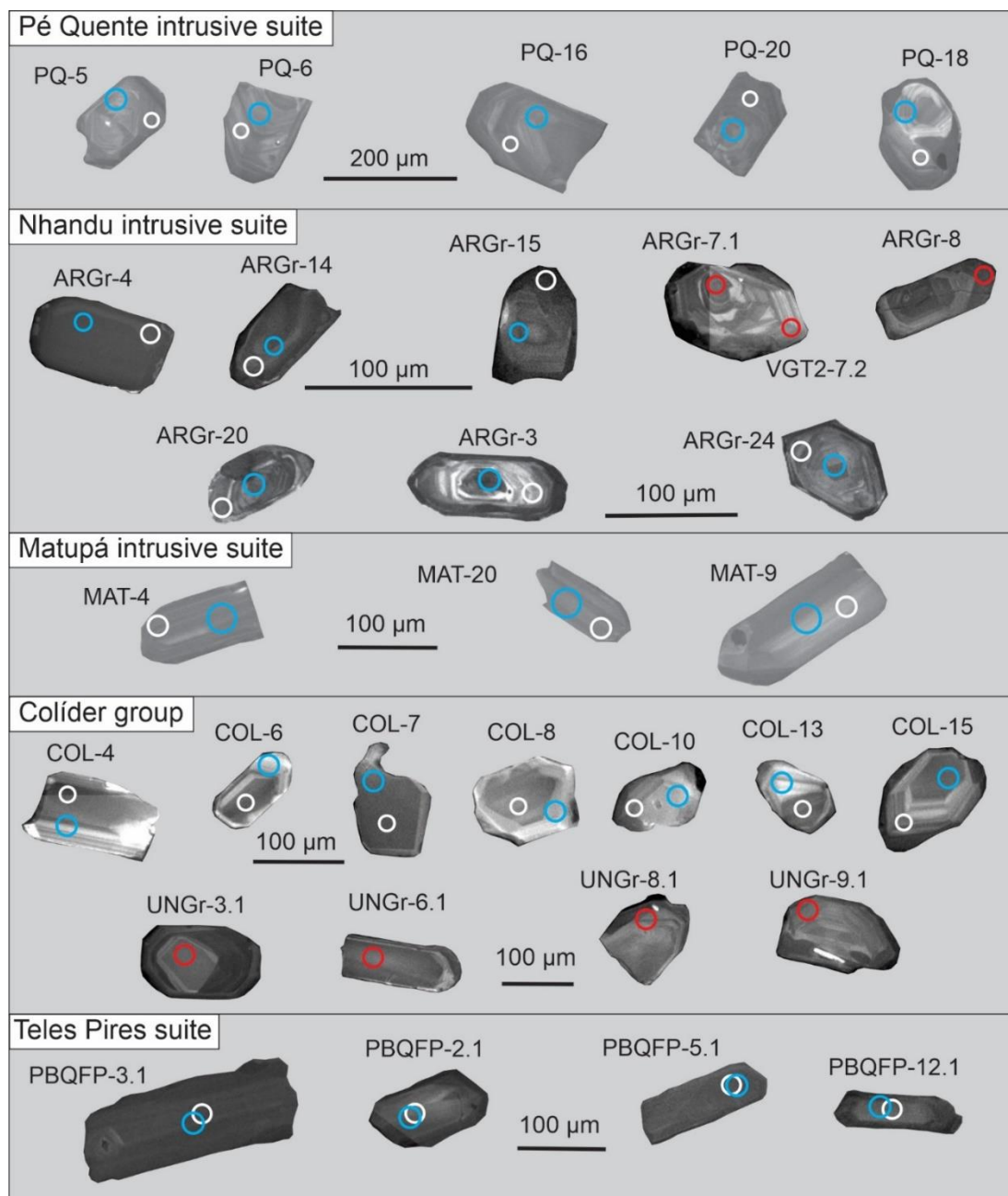


Figure 6. Cathodoluminescence images of zircon grains with individual SHRIMP ($^{207}\text{Pb}/^{206}\text{Pb}$ -dates; [Appendix Table A2](#)) and LA-ICP-MS trace elements spots location. LA-ICP-MS spot (25-35 μm) in blue and SHRIMP spot (20 μm) in white. Spots in red color represent analyses of SHRIMP and LA-ICP-MS performed in the same location.

Table 6. Summary of *in-situ* zircon chemical analyses (median values).

Geological unit	Number of samples	Trace and Rare Earth Elements (ppm)														
		P	Ca	Sc	Ti (49)	Cu	Rb	Sr	Y	Nb	Ba	La	Ce	Pr	Nd	Sm
Teles Pires suite	4	235	-	206	9.35	1.88	0.59	0.59	1485	3.93	0.42	0.59	57.85	1.13	10.65	12.75
Colíder group	11	365	-	186	29.70	-	0.56	0.22	1030	1.02	0.13	0.04	29.40	0.23	3.70	5.82
Nhandu intrusive suite	9	278	-	122	10.70	-	1.01	0.17	788	2.04	0.20	0.05	34.60	0.17	2.86	5.12
Matupá intrusive suite	3	413	-	161	13.30	-	-	0.33	1270	2.51	0.33	1.32	33.80	0.77	8.50	10.50
Pé Quente intrusive suite	5	338	-	109	11.00	-	-	0.19	796	2.97	0.06	0.02	16.56	0.09	1.95	4.09
Geological unit	Number of samples	Trace and Rare Earth Elements (ppm)														
		Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Pb (206)	Pb (207)	Th (232)	U (238)
Teles Pires suite	4	4.98	48.95	13.29	150.30	50.75	222.00	45.15	376.00	75.05	9465	0.68	254.30	31.70	249.50	196.50
Colíder group	11	2.42	28.70	8.30	98.00	35.30	157.30	30.60	254.00	51.00	8090	0.34	52.20	6.39	39.90	37.60
Nhandu intrusive suite	9	0.93	21.20	6.57	76.40	27.00	123.00	24.10	215.00	45.60	9170	0.65	120.70	16.06	52.90	77.00
Matupá intrusive suite	3	1.99	38.70	11.10	129.00	44.00	194.00	38.10	330.00	62.10	9420	0.95	160.00	20.70	215.20	110.10
Pé Quente intrusive suite	5	0.47	19.60	6.11	76.20	28.10	128.90	26.60	234.40	46.40	8910	0.77	94.20	12.97	44.70	59.90

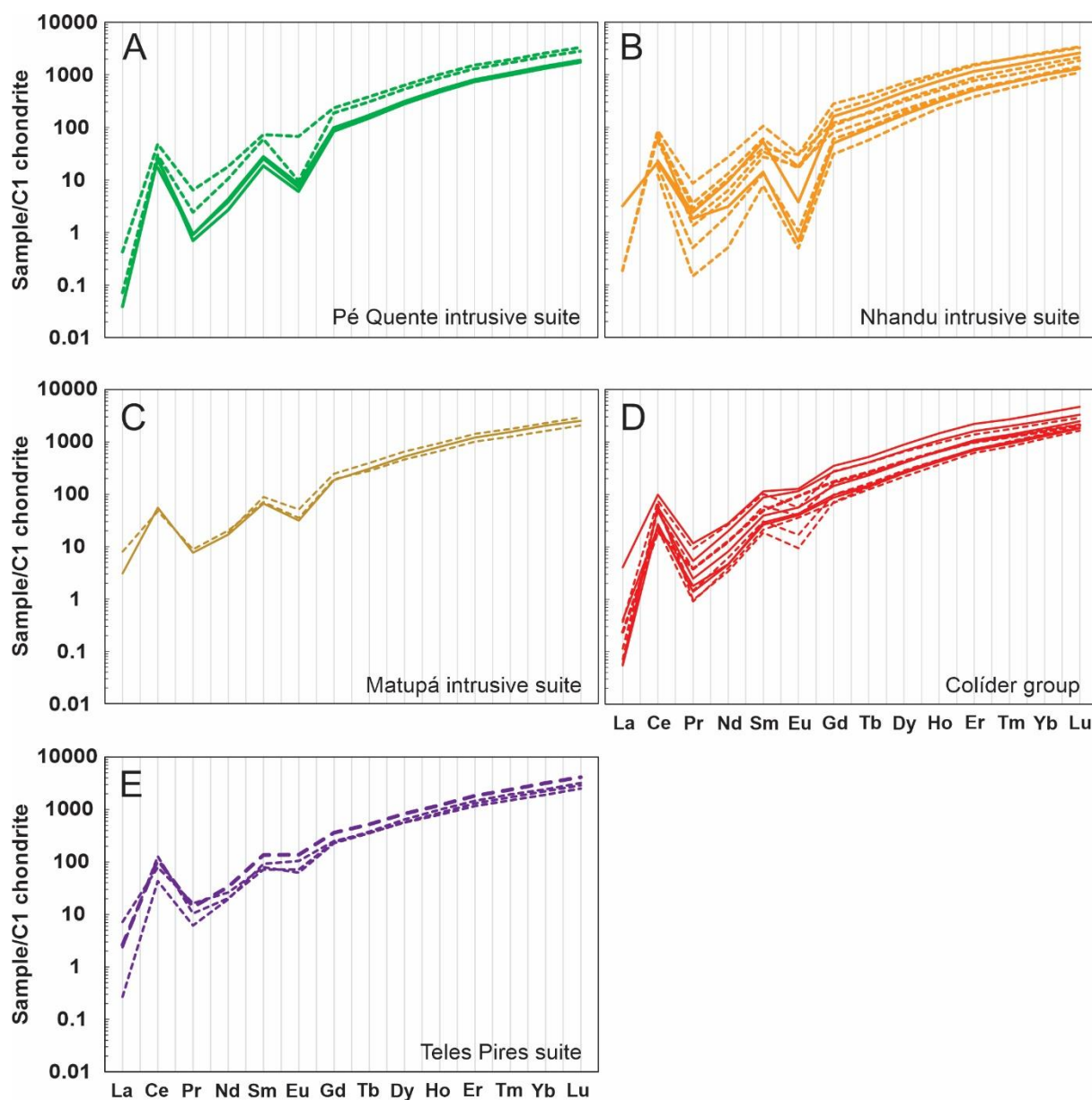


Figure 7. (A-E) Zircon REE profiles by geological unit. Dashed curves represent inherited grains or slightly discordant (see [Appendix Table A2](#) for comments for each grain). All samples normalized with respect to C1 chondrite as defined by [Sun and McDonough \(1989\)](#).

The temperature of zircon crystallization was calculated using the Ti-in-zircon thermometer of [Ferry and Watson \(2007\)](#) revised by [Loucks *et al.* \(2020\)](#) with corrections for pressure and reduced activity of TiO_2 and SiO_2 in rutile- and quartz-undersaturated melts. The temperatures range between 796°C and 1140°C, with the Nhandu suite and Colíder group zircon grains yielding the lowest and highest values, respectively ([Fig. 8](#)).

The oxygen fugacity ($\log f_{\text{O}_2}$) and relative oxygen fugacity (ΔFMQ) of the Pé Quente, Nhandu, Matupá and Teles Pires suites, and Colíder group, were calculated after [Loucks *et al.*](#)

(2020). Oxygen fugacity generally decreases with decreasing temperature, except for the Colíder group and Teles Pires suite with a degree of scatter (Fig. 9A-E). The Pé Quente and Matupá suites cluster around the FMQ (fayalite-magnetite-quartz) buffer, whereas the Colíder group and Nhandu and Teles Pires suites plot below the FMQ buffer, in between the FMQ and NNO (nickel metal-nickel oxide) buffers and/or above the NNO buffer (Fig. 9A-E). The Nhandu and Teles Pires suites have the lower and higher ΔFMQ values, respectively (Fig. 9F).

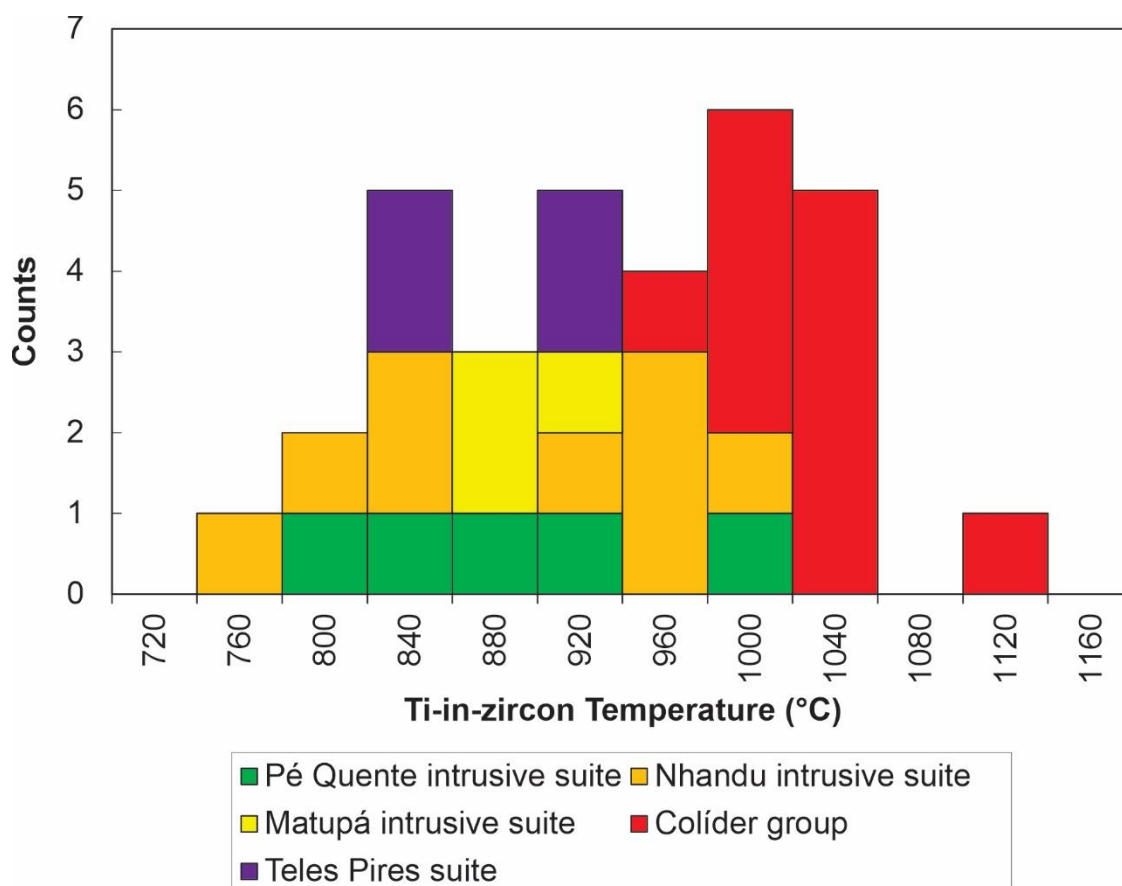


Figure 8. Crystallization temperature of zircon grains. Temperatures were calculated using the Ti-in-zircon thermometer (Loucks *et al.*, 2020), assuming an activity in the melt for $a\text{SiO}_2 = 1$ and $a\text{TiO}_2 = 0.5$.

In the same way as whole-rock chemical analyses, variation in the concentration of trace elements measured in zircons has been used as a relatively useful tool to discriminate prospective intrusive bodies from those that are unrelated to copper and/or gold mineralization, for example, in porphyry systems (Ballard *et al.*, 2002; Belousova *et al.*, 2002; Muñoz *et al.*, 2012; Dilles *et al.*, 2015; Lu *et al.*, 2016; Loader *et al.*, 2017). Some of these are represented by the $\text{Ce}/\sqrt{(\text{UxTi})}$ indicator of magmatic oxidation state (Loucks *et al.*, 2020), and the

(Eu/Eu*)/Yb_N and (Ce/Nd)/Y indicators of magmatic hydration state (Lu *et al.*, 2016). Variations of these ratios can also be explained in terms of degree of fractionation of magmas and/or tectonic stress regime (e.g. compressive *versus* non-compressive).

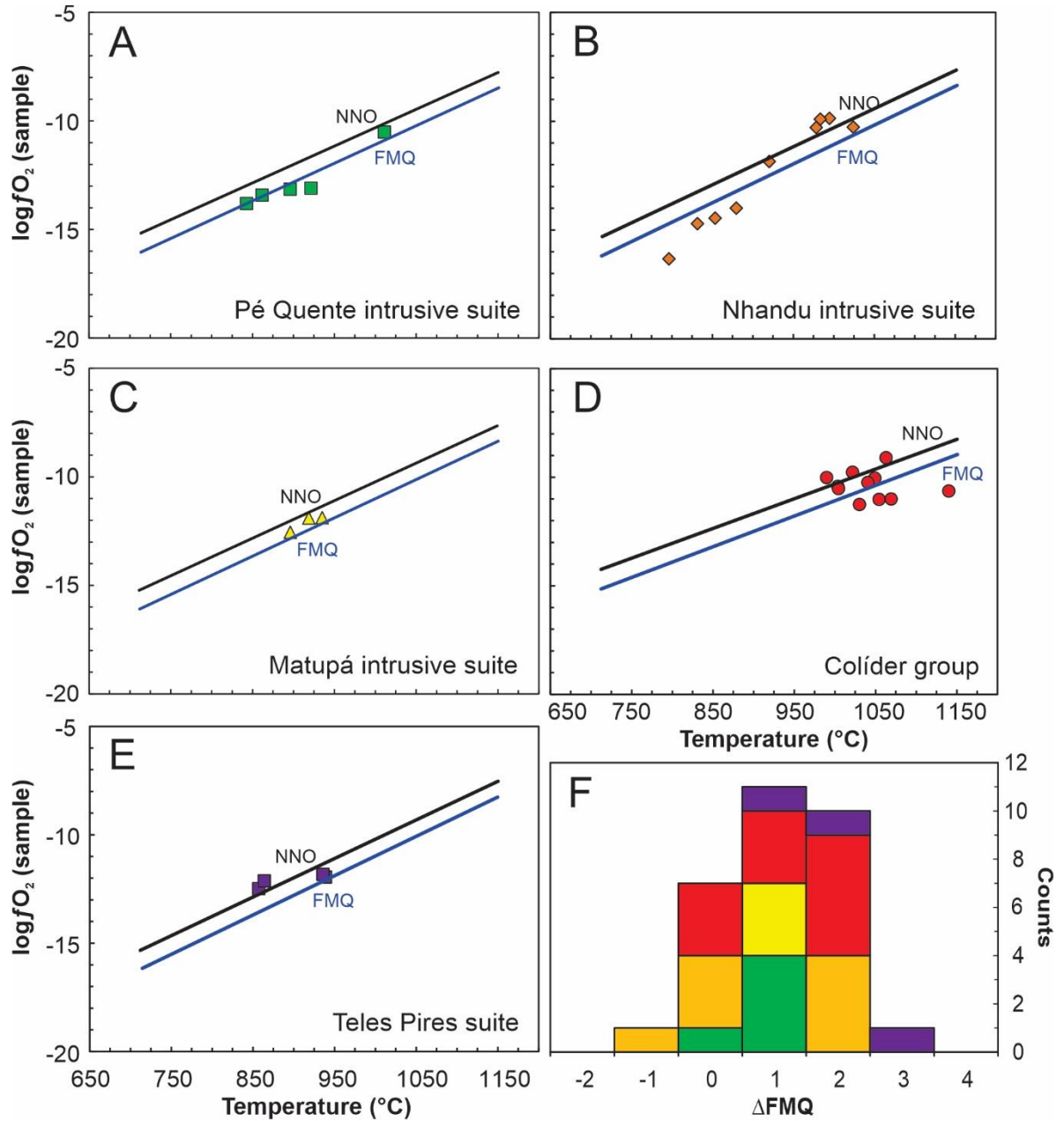


Figure 9. (A-E) Zircon oxybarometer for igneous suites after Loucks *et al.* (2020) versus Ti-in-zircon temperature (Ferry and Watson, 2007 revised by Loucks *et al.*, 2020). Blue curve represents the FMQ buffer (fayalite-magnetite-quartz; after O'Neill, 1987) and black curve the NNO buffer (nickel metal-nickel oxide; after Pownceby and O'Neill, 1994). (F) Histogram of relative oxygen fugacity (ΔFMQ). See Figure 8 for legend of colors.

Zircon $Ce/\sqrt{(UxTi)}$ was recently proposed as a proxy for magma oxidation state (Loucks *et al.*, 2020a). The $Ce/\sqrt{(UxTi)}$ values varies from 0.26 to 1.75, with the lowest values associated with the Nhandu suite and Colíder group and the highest values related to the Teles Pires suite (Fig. 10a; Table 6). This also suggests that the Nhandu and Colíder are less oxidized than the Teles Pires.

Zircon $(Eu/Eu^*)/Yb_N$ is a proxy for melt hydration state (Lu *et al.*, 2016). This ratio ranges between 0.21 and 8.11, with the Nhandu suite and Colíder group showing the lowest and highest values, respectively (Fig. 10a; Table 6), and implying that the first is less hydrous than the last one. Similarly, the $(Ce/Nd)/Y$ ratio is also used as a proxy for the hydration state of the melt (Lu *et al.*, 2016). The $(Ce/Nd)/Y$ varies from 1.46 to 66, with the lowest values associated with the Matupá and Teles Pires suites, whereas the Colíder group and Nhandu suite present the highest values (Fig. 10b; Table 6), indicating that the last two geological units are more hydrous than the first ones.

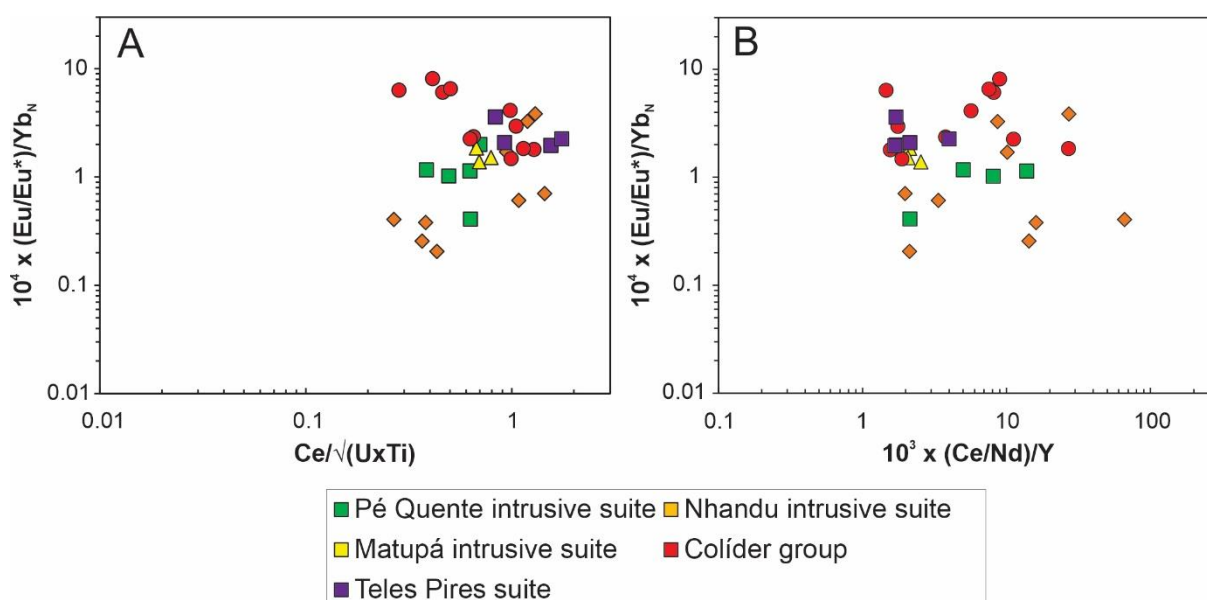


Figure 10. Compositions of zircon grains from the eastern portion of the Alta Floresta Mineral Province. The N subscript indicates values normalized to chondritic values (Sun and McDonough, 1989).

Discussion

Whole-rock geochemistry assessment

Rare-earth-element patterns have been used to assess Cu prospectivity of arc magmas and provide insights into magma fertility (Loucks, 2012a). Whereas Cu-ore-forming magmas may display normalized REE patterns sloping steeply downward from La with a minimum around

Ho and Er and a rise to Yb and Lu, with no significant negative europium anomaly ($\text{Eu}/\text{Eu}^* \sim 1$) and resembling a “Nike swoosh” shape (or listric-shaped curves) in the HREE, those magmas with a Cu-infertile character are characterized by less steeply REE profiles, a conspicuous negative Eu anomaly and relatively flat HREE patterns (Loucks, 2012a). High pressure and high magmatic water content retard and diminish plagioclase production and enhance production of hornblende, clinopyroxene and/or garnet. Suppressed plagioclase prevents a substantial negative Eu anomaly in the REE profiles, whereas hornblende and/or garnet are the only minerals among the major igneous rock-forming minerals capable of imposing a strong depletion of HREE, and hornblende is the only one that produces an upward concavity in the HREE, with a minimum around Ho-Er, and a flat pattern in the HREE (Loucks, 2012a). Overall, the combination of these features related to the REE patterns suggest a Cu-fertile signature for about half of the investigated geological units (e.g. Cuiú-Cuiú complex, Pé Quente and Guarantã do Norte suites, and Colíder group), whereas the remaining units are interpreted as unprospective for Cu mineralization (Fig. 4).

Elevated whole-rock Sr/Y (≥ 35), $(\text{Eu}/\text{Eu}^*)/\text{Yb}$ (≥ 2), V/Sc (≥ 10) and Sr/Zr ratios are indicators of elevated water content in the magma, which is favorable, for example, for the genesis of porphyry Cu mineralization (Richards, 2011; Chiaradia *et al.*, 2012; Richards *et al.*, 2012; Loucks, 2014). Trapping of typical calc-alkaline arc magmas at deep- to mid-crustal levels rather than in sub-volcanic magma chambers leads to relatively high-pressure fractional crystallization dominated by amphibole ($\pm$ garnet for deep crustal settings), with suppression of plagioclase fractionation (Loucks, 2014). This fractionation process eventually generates intermediate to felsic calc-alkaline residual liquids with distinctive Cu-fertile geochemical compositions, relative to typical, Cu-infertile arc magmas (Rohrlach and Loucks, 2005; Loucks, 2014). The whole-rock geochemical data for the geological units investigated in this work show about 25% and 23% of the samples having $\text{Sr}/\text{Y} \geq 35$ (Fig. 5A-B) and $(\text{Eu}/\text{Eu}^*)/\text{Yb} \geq 2$ (Fig. 5C), respectively, 15% of the analyzed rocks with $\text{V}/\text{Sc} \geq 10$ (Fig. 5D) and approximately a third of the samples plotting above the cutoff line for Sr/Zr (i.e. the Cu-fertile field; Fig. 5E). Overall, these features suggest a Cu-infertile metallogeny signature for most of the geological units of the eastern portion of the AFMP.

Although Sr/Y is the most sensitive lithophile-element indicator of magmatic Cu fertility, it is also the most susceptible to being rendered useless by plagioclase-destructive hydrothermal alteration (e.g. potassic and phyllic alterations) and weathering, which nearly always leaches the liberated Sr, thereby lowering the whole-rock Sr/Y into the range of Cu-infertile magmas (Loucks, 2014). Therefore, samples to be assessed for Cu prospectivity using

Sr/Y and (Eu/Eu*)/Yb should have predominantly fresh plagioclase with still-visible twinning and/or LOI < 3% owing to the mobility of Sr during alteration (Loucks, 2014). Eu is less mobile than Sr during hydrothermal alteration and weathering, so the whole-rock ratio (Eu/Eu*)/Yb seems to be more resistant than Sr/Y to destruction by mild hydrothermal alteration (Loucks, 2012a). Given the ubiquity of hydrothermal alteration in the rocks investigated in this work, the Sr/Y and (Eu/Eu*)/Yb whole-rock ratios are not fully reliable to assess Cu prospectivity in the eastern portion of the AFMP and, therefore, another approach to Cu magmatic fertility assessment must be considered for this region.

An alternative to circumvent the alteration effect on the rocks studied in this work is to use plots of elements such as Y and Zr having high-ionic charge, low aqueous solubility and low mobility in mildly altered rocks (e.g. propylitic alteration and other alteration in which chlorite and carbonates are stable). Both elements have low values in copper-ore-forming arc magmas (Wells *et al.*, 2020). The main sink for Zr is zircon, which tends to advance in the crystallization sequence as the melt's H₂O content increases, because the H₂O depresses the crystallization temperatures of most other minerals more than zircon (Naney, 1983; Watson and Harrison, 1983). Of the common major minerals in arc rocks, the most effective sink for yttrium and HREE (e.g. Yb) is hornblende. Garnet and zircon often play a modest, late role. Hornblende advances in the mineral-saturation sequence and crystallizes more profusely as the depth (pressure) and/or H₂O content of the magma increase (Naney, 1983). In this context, a whole-rock Y (≤ 18 ppm) *versus* Zr (≤ 180 ppm) plot can be effective in discriminating mildly-altered Cu-fertile from infertile granitoid arc magmas (Wells *et al.*, 2020). The whole-rock geochemical data for the geological units investigated in this work show about 44% and 55% of the samples having Y ≤ 18 ppm and Zr ≤ 180 ppm, respectively (Fig. 11). Overall, these features suggest a Cu-fertile metallogeny signature for approximately half of the geological units of the eastern portion of the AFMP studied here.

A recent work (Henríquez *et al.* 2018) has shown that unmineralised mid-Miocene Patagonian adakites in south Chile (i.e., rocks with SiO₂ $\geq$ 56 wt.%, Al₂O₃ $\geq$ 15 wt.%, Na₂O $\geq$ 3 wt.%, Sr/Y $\geq$ 20 wt.%, La/Yb $\geq$ 20, Y $\leq$ 10 ppm, Yb $\leq$ 1 ppm; Richards and Kerrich, 2007; Castillo, 2012) have the same (Eu/Eu*)/Yb and Sr/Y values than Andean giant porphyry copper deposits. According to the authors, the distinctive chemical features that identify adakitic magmas reflect deep entrapment and high-pressure magmatic differentiation of arc magmas during tectonic compression. For that reason, they argue that real adakites or “adakite-like” magma signature track tectonic compressive stress and do not track Cu-fertility directly.

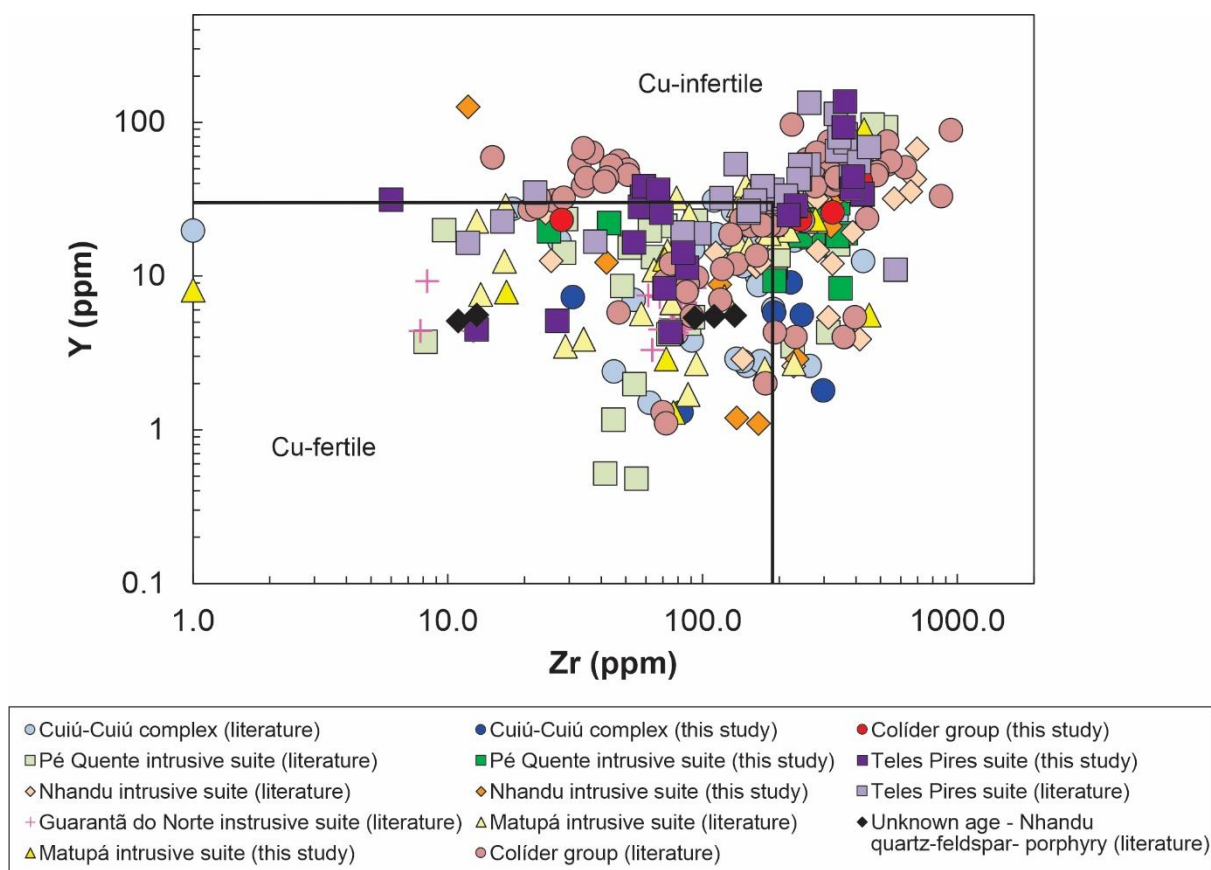


Figure 11. Whole-rock Y versus Zr fertility plot showing new data in dark colors and published data in pale colors. The “Cu-fertile” box is from [Wells *et al.* \(2020\)](#).

The compressive, orogenic tectonic stress is in agreement with the tectonic evolution proposed by [Trevisan *et al.* \(under review\)](#) for the eastern portion of the AFMP, which is represented by an accretionary orogen having alternating periods of low-angle subduction and slab-rollback. This argument is also reinforced by the distribution of Sr/Y and (Eu/Eu*)/Yb over time in this sector of the province. [Figures 12](#) shows that the orogenic pulses represented by peaks in the Sr/Y and (Eu/Eu*)/Yb ratios coincide with the periods of crustal thickening during low-angle subduction (stages A and C) proposed by [Trevisan *et al.* \(under review\)](#).

Low-potassium tholeiitic to high-potassium calc-alkalic arc magmas that exsolve a gold-ore-forming hydrothermal fluid are distinguished from infertile ordinary arc magmas by higher contents of lithophile elements that partition strongly into melt relative to residues during partial melting of mantle peridotite ([Loucks, 2012b](#)). According to this author, high values of the whole-rock element ratios Ba/Zr (≥ 5), Nb/Y and Th/Yb are useful to discriminate unaltered or little-altered samples of gold-ore-forming magmas associated with different types of magmatic-hydrothermal gold-rich ore deposits (e.g. porphyry, high-sulfidation to low-sulfidation epithermal, Tintina- and Carlin-types) from unmineralized magmas across the low-

to high-silica range (Loucks, 2012b). The fact that Au-fertile magmas are compositionally distinctive across the entire SiO₂ range implies that gold fertility is a primary property of parental mafic magmas, acquired by partial melting of compositionally distinctive source materials, in contrast to copper fertility indicators, which diverge from a common type of parent magma (Figs. 5B-C), which means that copper fertility is an emergent property acquired by distinctive processes of magmatic differentiation from the same types of mafic parental magmas that produce Cu-infertile igneous suites (Loucks, 2012b).

The whole-rock geochemical data for the geological units investigated in this work show about 28% of the samples having Ba/Zr $\geq$ 5 (Fig. 5F), and approximately 62% and about half of the samples plotting above the cutoff line for Nb/Y (Fig. 5G) and Th/Yb (i.e. the Au-fertile field; Fig. 5H), respectively. Overall, these features suggest an Au-fertile metallogenic signature for most of the geological units of the eastern portion of the AFMP, particularly if considering the Nb/Y values (Fig. 5G). According to Loucks (2012b), because both Nb and Y are relatively insoluble in subducting-slab-derived metamorphic fluids and are conserved in the ore-forming intrusion during mild to moderate-intensity hydrothermal alteration and weathering, the Nb/Y ratio is the most robust and least ambiguous in petrogenetic meaning of the three magmatic Au-fertility indicators. Additionally, mineralization related to potassic-alkaline magmatism in arc terrains includes a large portion of the world's giant gold deposits (Sillitoe, 2002). Thus, the high-K calc-alkaline to shoshonitic signatures of the majority of the studied geological units (Figs. 3F-H) reinforce the Au-prospectivity potential of this portion of the province.

The pattern of element enrichments that distinguishes gold-productive from gold-infertile arc magmas mirrors the chemical distinction between sub-arc lithospheric mantle and asthenospheric upper mantle (Loucks, 2012b). This author presents geochemical evidence that gold-ore-forming arc magmas are derived by partial melting of lithospheric mantle to a greater degree than ordinary, gold infertile arc magmas. Figure 13A compares abundances of incompatible elements in basalts from unmineralised arc segments with abundances in unaltered basalts that are nearest in distance and age to major gold deposits. Various conclusions about the origin of gold-ore-forming magmas can be drawn from Figure 13A,

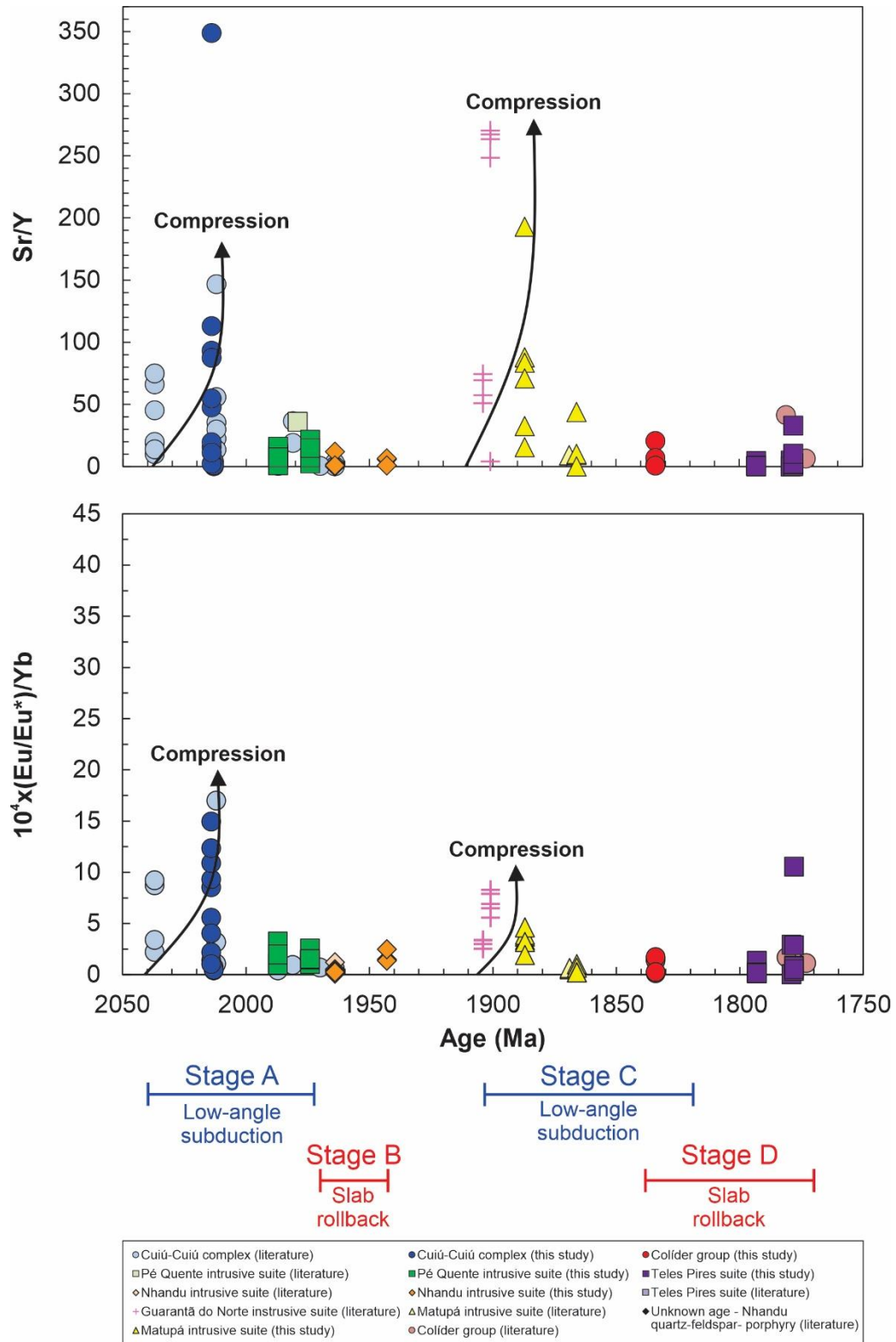


Figure 12. Changes over time in the tectonic stress regime across the eastern portion of the Alta Floresta Mineral Province. The whole-rock Sr/Y and (Eu/Eu*)/Yb ratios rise during episodes of lithospheric shortening, i.e. compressive tectonic stress (Loucks, 2012a). Timing of crustal thickening during flat or low-angle subduction (stages A and C) and crustal extension or relaxation during slab-rollback (stages B and D) from Trevisan *et al.* (under review).

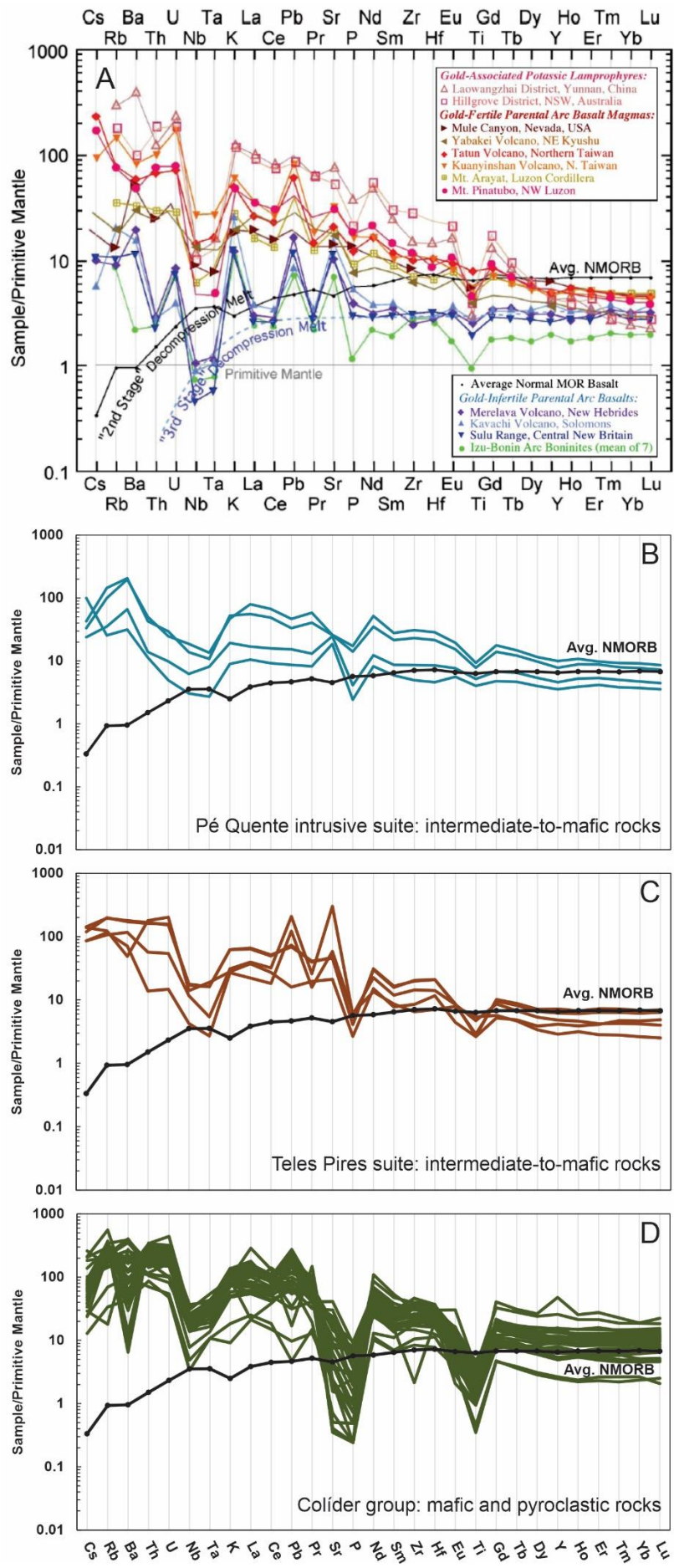


Figure 13. Whole-rock lithophile-element abundances in (A) gold-ore forming mafic magmas and their differentiation products and gold-infertile arc basalts (Loucks, 2012b) and (B-D) in intermediate-to-mafic samples analyzed in this study. Average NMORB curve from Hofmann (1988).

according to Loucks (2012b): (i) spikes of water-soluble LILE's have greater amplitude, but no height, in gold-unproductive magmas that represent higher degrees of partial melting and more refractory, depleted mantle sources. Therefore, gold-ore-productive magmas are not products of unusually high degree of mantle fluxing by slab-derived fluids, and thus gold is not supplied mainly by slab-derived fluids; (ii) element patterns in the interval Y to Lu are as flat in gold-fertile basaltic magmas as in the parental basalts of barren magma series. The flatness implies that residual garnet has no perceptible role in the melting regime, thus ruling out perceptible contributions by partial melts of subducted material in the eclogite facies; and, (iii) abundances of highly incompatible HFSE's (Th, Nb, Ta, La, Ce) are substantially higher above the NMORB reference line in parental basalts of gold-ore-productive magma series than in basaltic parents of barren arc magmas series. The unmodified average mantle residue left from extraction of average NMORB cannot be the source of a further melt increment that is more enriched in incompatible elements than NMORB. Therefore, relatively high concentrations of strongly incompatible HFSE's in parental magmas of gold-re-productive suites imply that their source includes mantle that is relatively undepleted or refertilised (Tassara *et al.*, 2017), whereas the gold-infertile arc magmas have HFSE abundances implying high-percentage melting and/or derivation from depleted mantle left after NMORB extraction. Additionally, experiments on meta-basaltic and metapelitic eclogites show that Nb and Ta, in particular, have negligible solubilities in slab-derived metamorphic fluids (Ayers, 1998; Johnson and Plank, 1999), so such fluids cannot be the agents of that refertilisation. A garnet signature is missing from the flat HREE patterns of basaltic melts parental to gold-productive derivatives, so slab melts cannot be the agents of mantle refertilisation (Loucks, 2012b).

Lithophile trace-element composition of intermediate to mafic magmas available for three of the eight geological units investigated in this work (i.e. Pé Quente and Teles Pires suites, and Colíder group) are represented in Figures 13B-D. Some of the features mentioned above are observed in the Pé Quente and Teles Pires intermediate to mafic rocks, but not in the Colíder group rocks. This suggests that the mafic to intermediate investigated rocks from the Pé Quente and Teles Pires suites could represent the mafic melts parental to potential gold-productive magmas.

Over the geological record, the shallower part of the uppermost asthenospheric mantle has become very depleted in highly incompatible elements such as Cs, Rb, Ba, Th and Nb during formation of continental crust and again during extraction of normal mid-ocean-ridge basalts (Niu, 2004; Workman and Hart, 2005). However, in the lithospheric mantle, that depletion has been partially to completely reversed over the eons by addition of veins and dikes that formed when relatively low-temperature, low-percentage partial melts of the deep asthenospheric mantle froze in transit through the cooler lithospheric mantle, i.e. the lithospheric mantle has been refertilized by these veins and dikes of low-percentage mantle melts. Later, when the enriched mantle is heated or hydrated or de-compressed, these metasomatic veins and dykes are selectively re-melted, producing Au-rich, high-K mafic melts enriched in Ba, Nb, Th and U (Ryskamp *et al.*, 2008; Loucks, 2012b).

Tectonic settings conducive to lithospheric partial melting by heating include (i) highly compressive geodynamic situations that thicken the lithospheric mantle and depress its base, and possible cause it to drip off into hotter asthenospheric mantle; and, (ii) settings wherein the lithospheric mantle is underplated by upwelling hot asthenospheric mantle, as above slab windows or slab-peel-away regions (Loucks, 2012b) or perhaps above mantle plumes (Tassara *et al.*, 2017). Partial melting of lithospheric mantle in response to exceptional hydration, which lowers the solidus temperature, is favoured in regions of flat-slab subduction, which thins the asthenospheric mantle wedge and juxtaposes the dehydrating slab near to the over-riding lithosphere. Partial melting by decompression of veined and otherwise enriched lithospheric mantle occurs in regions of crustal extension such as pull-apart basins, metamorphic core complex, etc., where diapirism of the lithospheric mantle is favoured (Loucks, 2012b). Additionally, the degree to which lithospheric mantle has been refertilised is represented by the elemental-ratio discriminants of gold-fertile arc magmas mentioned above (Ba/Zr, Nb/Y and Th/Yb; Loucks, 2012b; Figs. 5F-H).

The compressive geodynamic context is in agreement with the tectonic evolution proposed by Trevisan *et al.* (under review) for the eastern portion of the AFMP, which is represented by an accretionary orogen with alternating periods of low-angle subduction and slab-rollback, and thus favorable for the formation of gold-fertile magmas. The potential for the geological units investigated in this work to be gold-prospective has been particularly suggested by the high Nb/Y values of the analyzed rocks (Fig 5G). Figure 14 shows that the intervals of

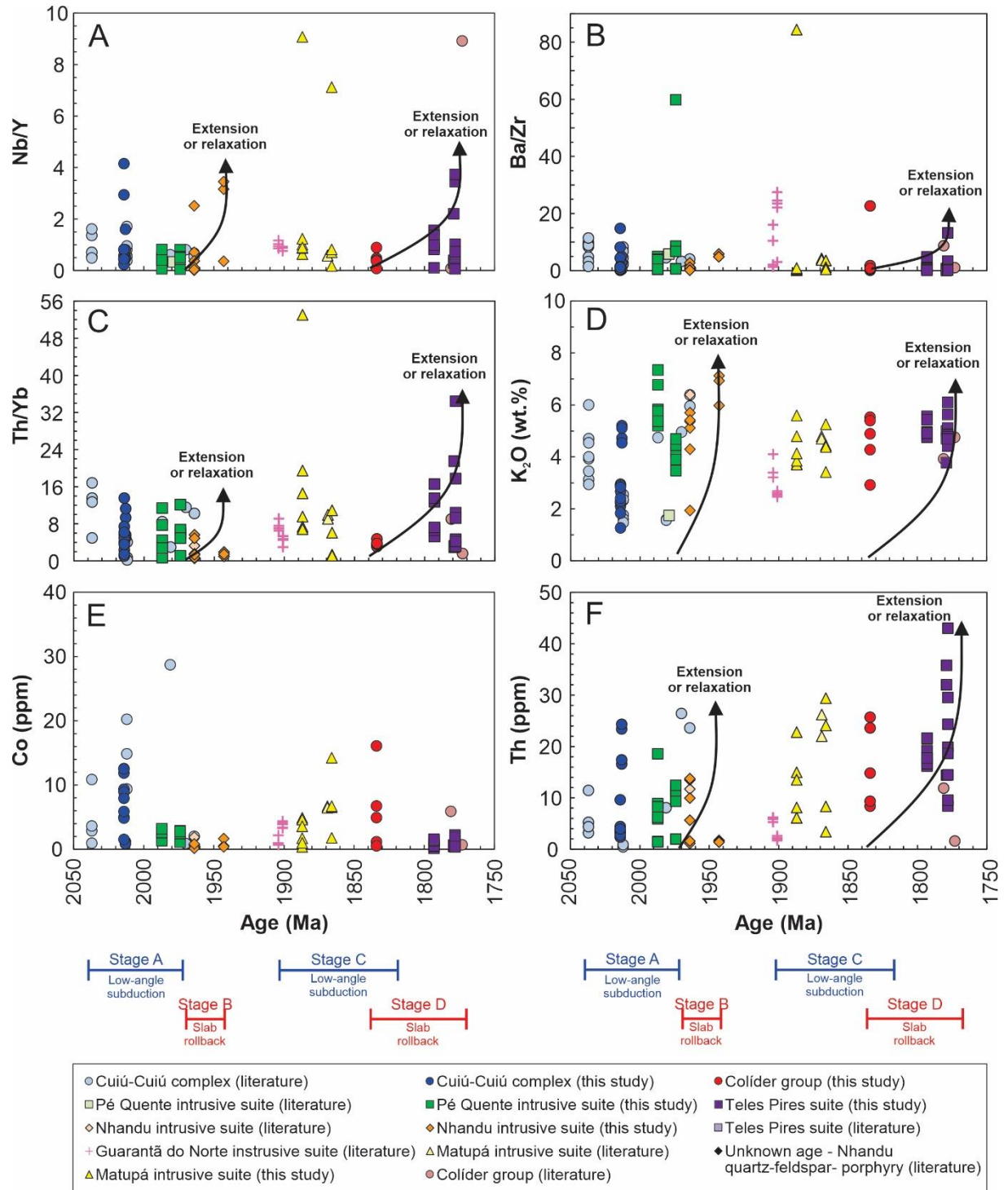


Figure 14. Changes over time in the tectonic stress regime across the eastern portion of the Alta Floresta Mineral Province. The whole-rock Nb/Y, Ba/Zr and Th/Yb ratios and K₂O, Co and Th values, i.e. Au-fertility potential, rise during episodes of lithospheric extension or relaxation, i.e. non-compressive tectonic stress. Timing of crustal thickening during low-angle subduction (stages A and C) and crustal extension or relaxation during slab-rollback (stages B and D) from Trevisan *et al.* (under review).

occurrence of gold-rich magmas, represented by peaks in the Nb/Y (Fig. 14A) and, to a lesser extent, in the Ba/Zr (Fig. 14B) and Th/Yb (Fig. 14C) ratios and K₂O (Fig. 14D), Co (Fig. 14E) and Th (Fig. 14F) contents, coincide with the periods of crustal extension or relaxation during slab-rollback (stages B and D) proposed by Trevisan *et al.* (under review).

Furthermore, from the whole-rock geochemistry it is possible to argue that: (i) Au-rich magmas in the eastern portion of the AFMP developed during periods of low-angle subduction (stage A and C of Trevisan *et al.*, under review), which underthrust the already existing Paleoproterozoic-Archean lithospheric mantle that had been refertilized at some point by veins and dikes of low-percentage mantle melts (e.g. high-K melts/magmas); (ii) during slab-rollback (stage B and D of Trevisan *et al.*, under review), the asthenospheric mantle upwelling heated the hydrated, refertilized lithospheric mantle, causing selective re-melting of veins and dikes and facilitated the ascent of the gold-ore-forming magmas into the upper crust; and, (iii) the potential presence of Cu-rich systems slightly older or contemporaneous to Au-rich systems in this portion of the province, as indicated by molybdenite and pyrite Re-Os dates at ca. 1.79-1.78 Ga (De Assis *et al.*, 2017; Trevisan *et al.*, *in prep*), can be explained by the switching from low-angle subduction during stage C to slab-rollback during stage D. This implies that the transition from crustal thickening during low-angle subduction, which is favorable for the generation of Cu- and Au-rich arc magmas, to crustal extension during slab-rollback, propitious for the rise and emplacement of these fertile magmas in the upper crust, is a major geodynamic factor controlling copper and gold mineralization in the eastern portion of the AFMP.

In the following section, we evaluate the composition of zircon grains from part of the geological units investigated by whole-rock geochemistry in order to provide further constraints on the assessment of Cu and Au prospectivity in the eastern portion of the AFMP.

Zircon geochemistry assessment

Distinctive zircon morphology and *in-situ* elemental compositions can also be used to distinguish between Cu-prospective versus non-prospective magmas. Following Lu *et al.* (2016) and Corfu *et al.* (2018), it is considered that needle-shaped, strongly zoned zircons precipitate from rapidly cooling, high-level magmas that are generally associated with Cu-non-fertile systems. Conversely, equant, stubby zircon crystals with unzoned cores and zoned rims are thought to have grown in slowly cooling, deep-seated magmas chambers that are known to feed Cu-fertile intrusions. Zircon morphology supports a Cu-non-fertile character for the Teles Pires suites and a Cu-fertile character for the Colíder group and, to a lesser extent, Matupá, Nhandu e Pé Quente suites (Fig. 6).

REE profiles also provide insights into copper magma fertility. Whereas zircons from both Cu-fertile and non-fertile magmas may display distinctively positive Ce anomalies as well as a notable depletion of LREE compared to HREE, those from fertile magmas lack significant negative Eu anomalies (Lu *et al.*, 2016). According to these authors, a strong negative Eu anomaly ($\text{Eu}/\text{Eu}^* < 0.3$) is a common feature of non-fertile suites, as it reflects strong prior plagioclase crystallization from a relatively dry host magma, whereas Eu/Eu^* closer to unity or > 0.3 or 0.4 is related to the fractionation of garnet and hornblende from hydrous melts (Ballard *et al.*, 2002; Muñoz *et al.*, 2012; Loucks, 2014; Dilles *et al.*, 2015; Lu *et al.*, 2016). Our zircons from the Pé Quente and Nhandu suites generally show $\text{Eu}/\text{Eu}^* < 0.3$, whereas those from the Matupá and Teles Pires suites and Colíder group have $\text{Eu}/\text{Eu}^* > 0.3$, suggesting that the last three geological units have a Cu-prospective signature (Fig. 7; Table 6).

Other ratios measured in zircon that work as proxies for magma water content are the $10^3 \times (\text{Ce}/\text{Nd})/\text{Y}$ and $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ (Lu *et al.*, 2016). Early garnet and hornblende crystallization depletes Y and Yb in the residual melt (Chiaradia *et al.*, 2012; Lu *et al.*, 2016). Therefore, higher $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ and $10^3 \times (\text{Ce}/\text{Nd})/\text{Y}$ are expected in zircon grains from Cu-fertile magmas (e.g., porphyry copper deposits) than in zircons from non-mineralized intrusive bodies with lower water content. Ratios of $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb} > 1$ and $10^3 \times (\text{Ce}/\text{Nd})/\text{Y} > 1$ have been documented by Henríquez *et al.* (2019) in zircon from different porphyry copper deposits of Phanerozoic age (i.e. Cu-fertile magmas). Zircon grains from the majority of geological units investigated in this study have both $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ and $10^3 \times (\text{Ce}/\text{Nd})/\text{Y} > 1$, except for a few samples belonging to the Pé Quente and Nhandu suites (Fig. 10), and match the Cu-fertile igneous suites field of Henríquez *et al.* (2019). This implies that they have high dissolved water in the parent melt. Figure 15 shows an increase of $10^3 \times (\text{Ce}/\text{Nd})/\text{Y}$ (Fig. 15A) and $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ (Fig. 15B) values (i.e. water content in the melt increases) as the geological units become younger, with a peak of maximum hydration associated with the Colíder group over a time span of crustal extension or relaxation during slab-rollback. Therefore, the Colíder group represents the most prospective geological unit for Cu in the eastern portion of the AFMP.

Another critically important factor for arc magma fertility is the redox-dependent sulfur-carrying capacity (Field *et al.*, 2005; Loucks, 2014; Richards, 2014), which increases in andesitic-rhyolitic magmas with oxidation state as determined in experimental studies (Botcharnikov *et al.*, 2011). At the usual redox state of porphyry Cu magmas (FMQ +1 to +2;

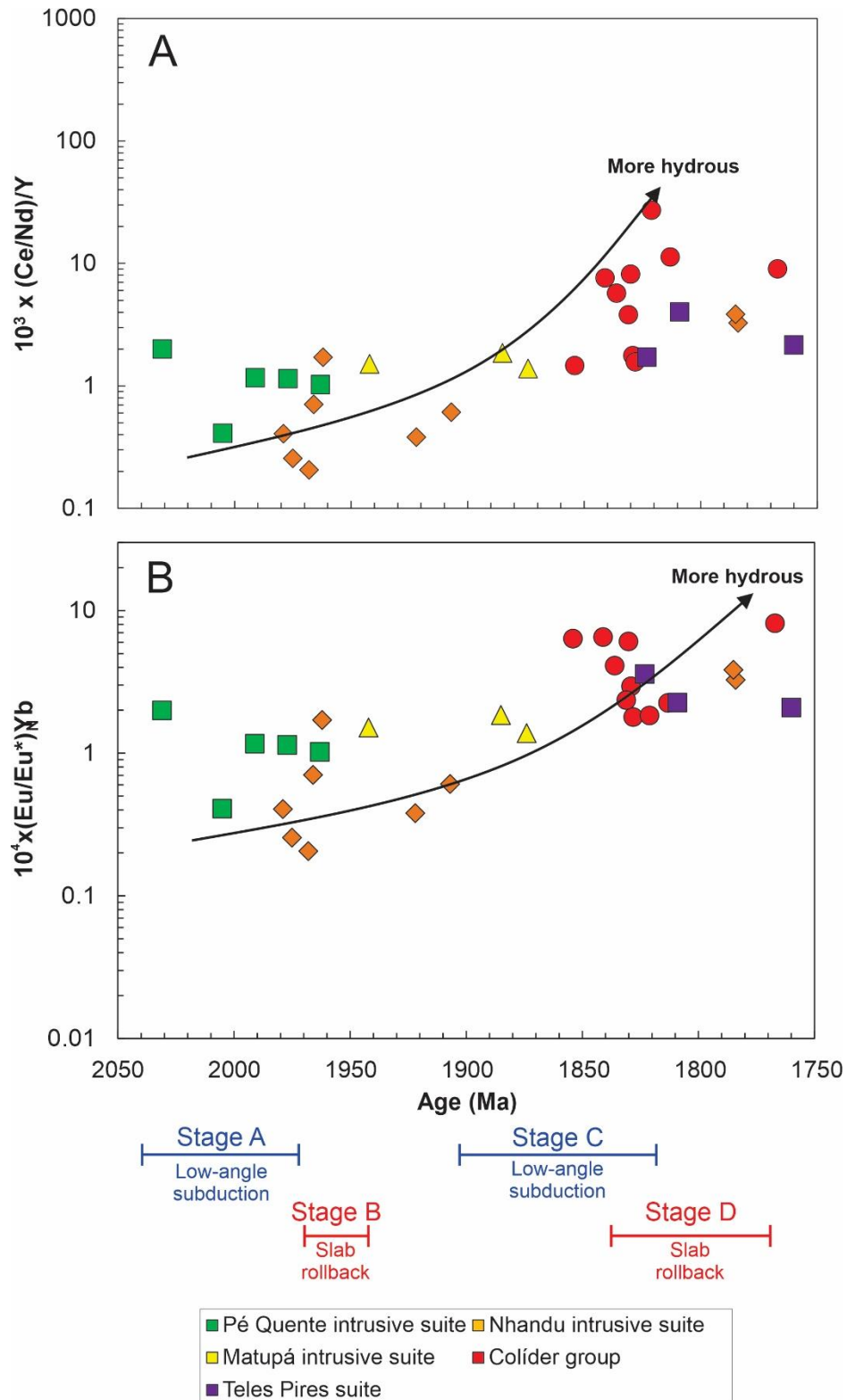


Figure 15. Changes over time in the tectonic stress regime across the eastern portion of the Alta Floresta Mineral Province. The $10^3 \times (\text{Ce/Nd})/\text{Y}$ and $10^4 \times (\text{Eu/Eu}^*)\text{Yb}_N$ ratios, i.e. zircon indicators of melt hydration state, rise as the geological units become younger. Timing of crustal thickening during low-angle subduction (stages A and C) and crustal extension or relaxation during slab-rollback (stages B and D) from [Trevisan *et al.* \(under review\)](#).

Richards, 2014), 90 to 99% of S is dissolved in the melt as sulfate (Field *et al.*, 2005). Thus, the magmatic oxidation state is an important fertility indicator (Ballard *et al.*, 2002; Richards, 2014; Dilles *et al.*, 2015). Values of oxygen fugacity (fO_2) less than FMQ +2 has been reported for Cu-infertile suites of Phanerozoic age, whereas Cu-fertile suites show oxygen fugacity values greater than FMQ +2 (Lu *et al.*, 2016). Figure 9 shows that the Matupá and Teles Pires suites have values of $\log fO_2$ plotting above the FMQ and/or NNO buffers, whereas values of $\log fO_2$ for the Pé Quente and Nhandu suites and Colíder group plot below and above the FMQ and NNO buffers. Our results suggest that the investigated geological units correlates mostly with moderate to reduced oxidation state suites. Figure 16A shows that peaks in the $\log fO_2$, which represent an increase in the oxygen fugacity, coincide with the periods of crustal extension or relaxation during slab-rollback (stages B and D) proposed by Trevisan *et al.* (under review). Therefore, these periods are considered to be more prospective in terms of oxidation when compared to the periods of crustal thickening during low-angle subduction in the eastern portion of the AFMP. Additionally, part of the relative oxygen fugacity (ΔFMQ) values in the range FMQ +0 to +1 for the Pé Quente, Nhandu suite and Colíder group (Fig. 16B) are in the ΔFMQ range of maximum Au solubility (i.e. transport capability) in silicate melts according to Tassara *et al.* (2020), and also overlap the periods of crustal extension or relaxation during slab-rollback. This reinforces the prospectivity potential, at least for gold metallogenesis, during the two periods of crustal extension. According to Tassara *et al.* (2020), in addition to an enriched metal source and favourable geodynamic conditions, redox gradients (i.e. the difference of oxygen fugacity between the ascending melts and the surrounding) in the mantle, which promote oxidation of the infiltrating melt leading to optimal Au solubility conditions and boost the potential of the melt to scavenge gold during ascent throughout the sub-continental lithospheric mantle, may exert a first-order control on the global-scale localization of crustal provinces endowed with gold deposits.

Other parameter using trace elements in zircon that corresponds to a proxy for magma oxidation state is the oxybarometer $Ce\sqrt{UxTi}$ proposed by Loucks *et al.* (2020). This novel oxybarometer for determining the relative oxygen fugacity (ΔFMQ) of a magma as zircon crystallised was calibrated using ratios of the elements Ce, U and Ti in zircon, without explicit determination of the ionic charge of any them, and without independent determination of crystallization temperature or pressure or parental melt composition (Loucks *et al.*, 2020). It has been demonstrated that this new zircon oxybarometer defines a rising trend in oxygen fugacity between pre-ore stage and Cu-ore-related intrusions (Henríquez *et al.*, 2019). Our results show higher $Ce\sqrt{UxTi}$ values for the Nhandu and TelesPires suites and Colíder group

(Fig. 10). Figure 17 also shows a slightly increase in the $Ce\sqrt{(UxTi)}$ values over the periods of crustal extension or relaxation during slab-rollback.

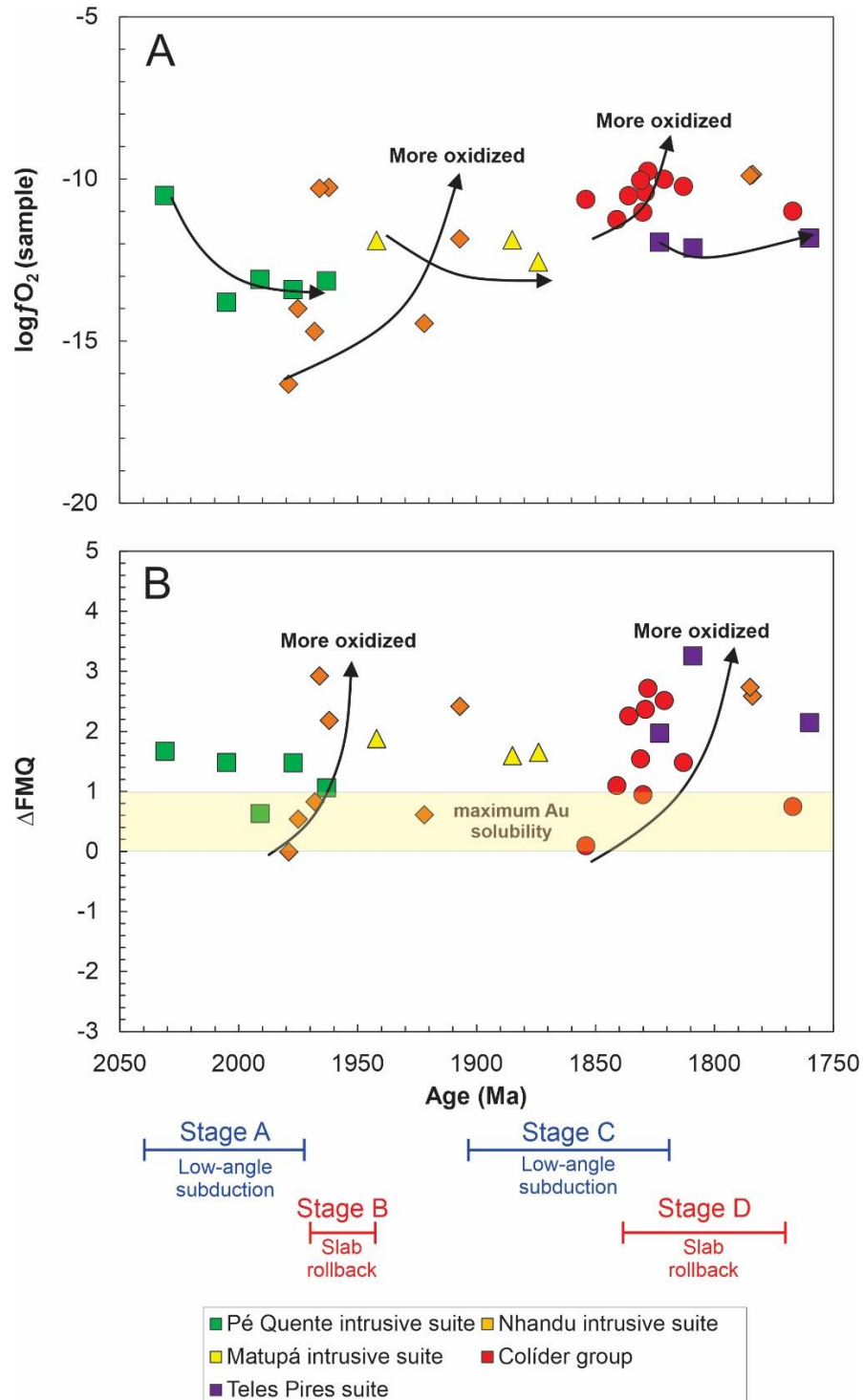


Figure 16. Changes over time in the tectonic stress regime across the eastern portion of the Alta Floresta Mineral Province. The fO_2 and ΔFMQ , i.e. magmatic oxidation state, rise during episodes of lithospheric extension or relaxation, i.e. non-compressive tectonic stress. Timing of crustal thickening during low-angle subduction (stages A and C) and crustal extension or

relaxation during slab-rollback (stages B and D) from [Trevisan *et al.* \(under review\)](#). The Δ FMQ range of maximum Au solubility at 2 Kbar in sulfur-bearing basaltic to andesitic silicate melts is from [Botcharnikov *et al.* \(2011\)](#).

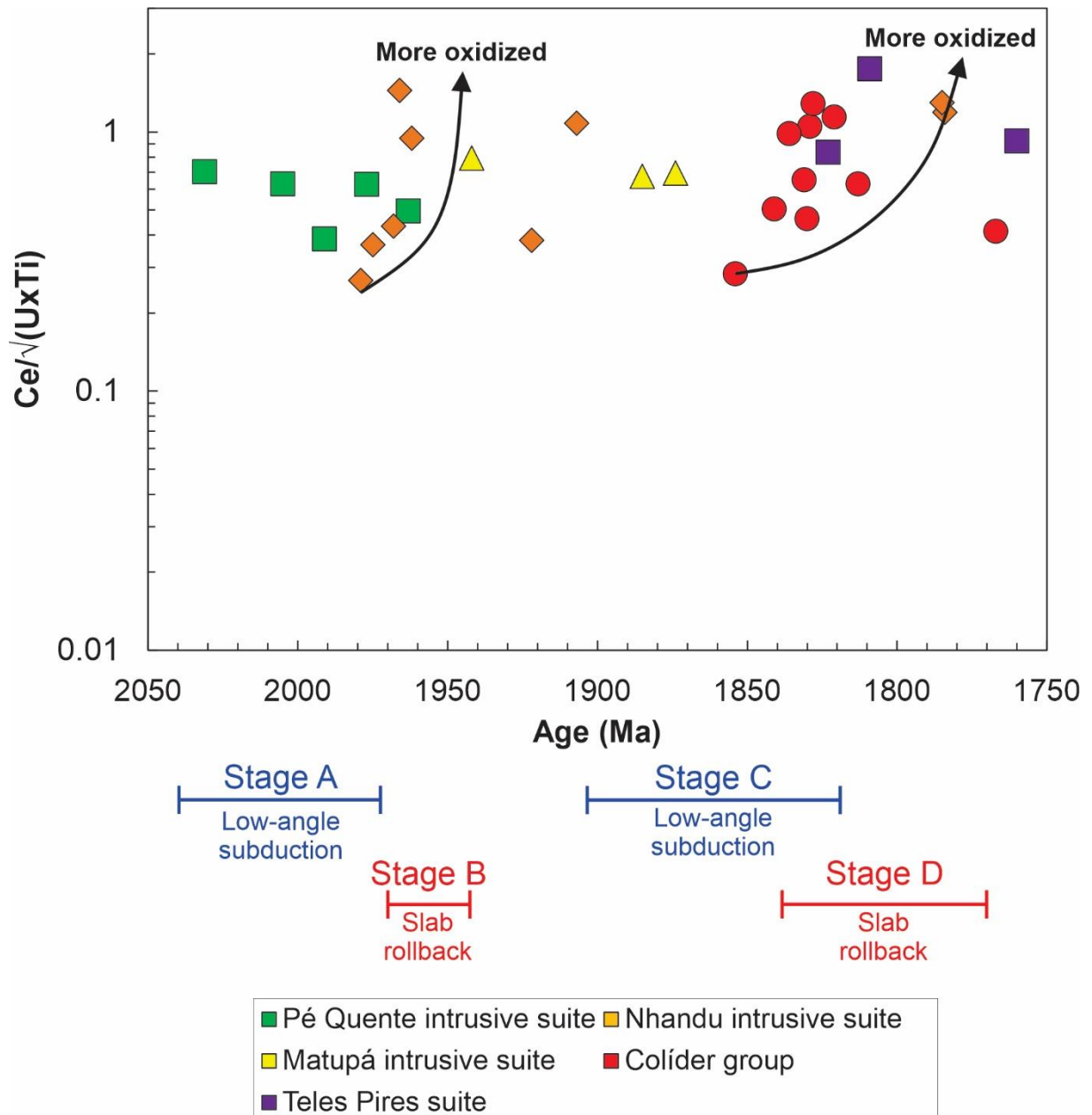


Figure 17. Changes over time in the tectonic stress regime across the eastern portion of the Alta Floresta Mineral Province. The zircon $\text{Ce}/(\text{UxTi})$ ratio, an indicator of magmatic oxidation state ([Loucks *et al.*, 2020](#)), rises during episodes of lithospheric extension or relaxation, i.e. non-compressive tectonic stress. Timing of crustal thickening during low-angle subduction

(stages A and C) and crustal extension or relaxation during slab-rollback (stages B and D) from Trevisan *et al.* (under review).

A combination of the $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ and $\text{Ce}\sqrt{(\text{UxTi})}$ parameters in a single plot allows the simultaneous evaluation of the hydration and oxidation state of the magmas. Figure 10A shows positive correlations of zircon $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ with $\text{Ce}\sqrt{(\text{UxTi})}$ for the Pé Quente and Nhandu suite, whereas negative correlations are observed for the Matupá and Teles Pires suites and Colíder group. According to Loucks *et al.* (2018), the negative slopes represent oxidation of the melt while hydrothermal fluid was exsolving (i.e. losing water from the melt in response to decreasing lithostatic load) and gravitationally segregating during decompression of ascending magmas. The segregation of exsolving fluid from its parent melt causes concurrent oxidation of the residual melt because the departing hydrothermal fluid selectively removes reduced species from the melt (e.g., S^{4+} relative to S^{6+} , Fe^{2+} relative to Fe^{3+} , and H_2 relative to H_2O), leaving the residual melt relatively enriched in the oxidized species (Loucks *et al.*, 2018). The rise in the residual melt's oxidation state is transmitted to zircon, which prefers Ce^{4+} to Ce^{3+} and U^{4+} to U^{5+} , so the ratio $\text{Ce}\sqrt{(\text{UxTi})}$ rises in zircon growing from increasing oxidized melt (Loucks *et al.*, 2018). This implies that the zircon grains from the Matupá and Teles Pires suites and Colíder group were crystallizing from fluid-saturated melts, which should be an indicator of magmatic Cu and/or Au metallogenic fertility for reasons explained above. Therefore, the zircon grains from these three geological units could be tracking Cu- and/or Au-ore-forming intrusions in the eastern portion of the AFMP, whereas the zircon grains from the Pé Quente and Nhandu suites may represent pre-fertile stages of magmatic differentiation. Positive and negative trending arrays have also been documented in pre-fertile and ore-forming intrusions, respectively, in the El Teniente porphyry copper deposit and other porphyry-copper bearing intrusive complexes around the world (R. Loucks, Personal Communication, 2020).

Implications for exploration in the eastern portion of the AFMP

Exploration for Cu and Au deposits in green field or covered terranes can be improved by applying whole-rock and zircon fertility indicators, which could fingerprint apparently fertile intrusions associated with hidden mineralization (Loucks, 2014; Lu *et al.*, 2016). Major, minor and trace elements bivariate plots, spidergrams and REE profiles show that the igneous suites analyzed in this study show variable whole-rock and zircon geochemical content over time, which reflects changes in the oxidation state, water content, degree of fractionation of magmas

and/or tectonic stress regime. This scenario implies, therefore, in different potentials for copper and gold prospectivity among the distinct geological units across the eastern portion of the AFMP.

Whole-rock REE profiles and the Y versus Zr bivariate plot indicate that about half of the investigated geological units have a Cu-fertile metallogenic signature. According to the REE profiles, the Cu prospective units include the Cuiú-Cuiú complex, Pé Quente and Guarantã do Norte suites and Colíder group (Fig. 4), whereas following the Y (≤ 18 ppm) and Zr (≤ 180 ppm) contents all units have samples plotting in the Cu-fertile field (Fig. 11). The Sr/Y (≥ 35), (Eu/Eu*)/Yb (≥ 2), V/Sc (≥ 10) and Sr/Zr plots also show that all units have samples plotting above the cutoff values and/or curves (Fig. 5). Additionally, rises in the Sr/Y ratio values do track tectonic compressive periods of the geodynamic evolution rather than Cu-prospectivity directly in the eastern portion of the AFMP (Fig. 12) as also observed by [Henríquez et al. \(2018\)](#) in the unmineralised mid-Miocene Patagonian adakites in southern Chile. Therefore, whole-rock geochemistry fertility indicators are not considered robust tools for assessing Cu prospectivity in the eastern portion of the AFMP. The same scenario is observed for the assessment of Au prospectivity in this region. Although among the three elemental ratios commonly used to identify Au-fertile magmas (Ba/Zr, Nb/Y and Th/Yb), the Nb/Y ratio seems to be the most robust and least ambiguous, all geological units investigated in this work have samples plotting in the Au-fertile field, i.e. above the Nb/Y cutoff curve (Fig. 5G).

The assessment for Cu and, to a lesser extent, Au prospectivity, using zircon geochemistry, however, shows a more promising picture for the eastern portion of the AFMP. Because zircon can survive intense hydrothermal alteration, weathering, metamorphism and long-distance detrital transport, it can be used as a more robust Cu ([Lu et al., 2016](#)) and Au fertility indicator. Previous works have indicated that zircon chemistry is an effective prospectivity tool in Phanerozoic ([Ballard et al., 2002](#); [Dilles et al., 2015](#); [Lu et al., 2016](#)) and Archean ([Lu et al., 2019](#)) terranes. The results of this study confirm similar potential for prospectivity analysis in Proterozoic terranes with Cu- and/or Au-rich magmatic-hydrothermal deposits and affected by hydrothermal alteration, weathering and metamorphism, such as the eastern portion of the AFMP.

Collectively, the zircon REE profiles (Fig. 57) and different elemental ratios ($10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$; $(\text{Ce}/\text{Nd})/\text{Y}$; and $\text{Ce}/(\text{U}+\text{Ti})$; Fig. 10), as well as the oxygen fugacity ($\log f\text{O}_2$) and relative oxygen fugacity (ΔFMQ) calculations (Fig. 9), suggest that the Colíder group is the most prospectivity geological unit for Cu in the eastern portion of the AFMP and, to a lesser extent, the Matupá and Teles Pires suite. In terms of Au-prospectivity, the Pé Quente

and Nhandu suites and the Colíder group may be potentially Au-fertile owing that their ΔFMQ values in the range FMQ +0 to +1 are in the ΔFMQ range for maximum Au solubility in silicate melts (Fig. 16) according to Tassara *et al.* (2020). There is no published study to the moment that has used zircon as fertility indicator for Au-rich magmatic-hydrothermal systems. Additionally, as shown in the $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb}$ vs. $\text{Ce}/(\text{U}+\text{Ti})$ plot (Fig. 10A), the analyzed zircon grains from the Colíder group and Matupá and Teles Pires suites are likely to be derived from Cu- and/or Au-ore-forming intrusions, whereas the analyzed zircon grains from the Pé Quente and Nhandu suites could be tracking pre-fertile stages of magmatic differentiation of these two geological units.

Finally, both the whole-rock and zircon geochemistry results suggest that the two periods of crustal extension or relaxation during slab-rollback (stages B and D of Trevisan *et al.*, under review) are the most prospective for Cu and Au in the eastern portion of the AFMP, in particular the period from ca. 1.83-1.77 Ga.

Conclusions

This work documents the first study to systematically examine whole-rock and zircon chemical analyses from granitic rocks in the eastern portion of the Alta Floresta Mineral Province, southern Amazonian Craton, as potential metallogenic fertility/prospectivity indicators of Paleoproterozoic Cu- and Au-rich magmatic hydrothermal systems. The conclusions can be summarized as follows:

- The whole-rock geochemistry represents an exploration tool with some limitations, i.e. not fully reliable, to access Cu- and/or Au-prospectivity in search for buried deposits in the eastern portion of the AFMP due to the strong hydrothermal alteration that affect the rocks across the province.
- Zircon chemical analyses can be used as an efficient exploration tool to identify geological units potentially fertility for copper and/or gold in this region.
- The integration of whole-rock and zircon geochemistry with geochronology information is particularly useful to track the tectonic stress regime (e.g. compressive versus non-compressive) over time in the studied region.
- The zircon geochemistry suggests that the Colíder group and, to a lesser extent, the Matupá and Teles Pires suites are the geological units prospective for Cu and/or Au in the eastern portion of the AFMP.

- The zircon geochemistry suggests that the Colíder group and, to a lesser extent, the Matupá and Teles Pires suites are the geological units prospective for Cu and/or Au in the eastern portion of the AFMP.
- The zircon grains from these three geological units present high-water content represented by $\text{Eu}/\text{Eu}^* > 0.3$, $10^4 \times (\text{Eu}/\text{Eu}^*)/\text{Yb} > 1$ and $10^3 \times (\text{Ce}/\text{Nd})/\text{Y} > 1$, and high oxidation state characterized by FMQ in the range 0 to +3.
- The periods of crustal extension or relaxation during slab-rollback are the most favorable for copper and gold metallogeny in the eastern portion of the AFMP, in particular the period from ca. 1.83-1.77 Ga.
- The identification of potentially prospective hydrous and oxidized magmas for Cu and/or Au mineralization across the eastern portion of the AFMP is encouraging and can help guide current and future exploration for Cu and Au (e.g. porphyry- and epithermal-style deposits) in southern Amazonian Craton.

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Appendix

Figure A1. Geological map of the eastern Alta Floresta Mineral Province with the samples investigated in this study.

Tables

Table A1. Whole-rock major, minor and trace elements geochemistry results.

Table A2. *In-situ* zircon chemical results.

Table A1. Whole-rock major, minor, and trace elements geochemistry results.

Geological Unit	Cuiú-Cuiú complex														
Sample code	NMGr-49(2)	NMGr-50(2)	NMGr-05	NMGr-12A	PBH-PB-20-05:38.20	PBH-PB-20-25	PBH-PB-20-26	PBH-PB-20-24	PBH-PAXPAB-084-19.5-19.83	PBH-PAB63-107.37	PBH-PAB63-145.45	PBH-PAB61-185.70	PBH-PAB61-207.17	PBH-PAB97-30.70	PBH-PAB97-43.84
Major and minor elements															
SiO ₂	74.20	77.00	74.80	79.30	66.60	69.50	66.20	65.80	65.30	60.00	63.30	62.80	59.80	71.70	68.80
TiO ₂	0.19	0.21	0.16	0.07	0.74	0.44	0.62	0.49	0.86	1.03	0.58	0.64	0.97	0.36	0.61
Al ₂ O ₃	12.25	12.65	13.15	12.35	15.25	16.05	15.60	15.65	15.25	14.60	15.75	15.80	17.25	13.95	14.00
Fe ₂ O ₃	1.55	1.65	1.22	0.54	4.75	2.44	5.28	3.45	6.91	8.94	4.98	5.66	6.40	2.89	4.02
MnO	0.07	0.04	0.03	0.01	0.07	0.04	0.12	0.09	0.11	0.14	0.12	0.10	0.09	0.03	0.05
MgO	0.24	0.27	0.18	0.09	2.42	1.38	1.76	1.54	1.47	2.86	1.90	2.17	1.83	0.81	0.95
CaO	0.79	0.68	0.67	0.16	3.60	2.82	3.32	3.48	3.86	4.82	4.49	4.71	3.98	3.45	2.95
Na ₂ O	3.70	3.55	3.46	3.80	3.63	4.25	4.23	3.88	3.74	3.53	3.87	3.89	4.36	3.96	3.44
K ₂ O	4.72	5.20	5.11	4.54	2.10	2.67	2.23	2.03	1.84	2.40	2.95	2.41	2.90	1.27	2.84
P ₂ O ₅	0.04	0.03	0.03	0.01	0.02	0.10	0.28	0.18	0.25	0.34	0.18	0.20	0.28	0.16	0.19
LOI	0.44	0.48	0.55	0.37	1.83	2.00	1.57	1.46	1.47	0.65	0.73	0.60	1.14	0.50	0.39
Total	98.19	101.76	99.45	101.24	101.01	101.69	101.21	98.05	101.06	99.56	99.16	99.25	99.34	99.23	98.68
Trace elements															
Ba	426.00	488.00	766.00	24.70	1225.00	1160.00	971.00	1005.00	505.00	1680.00	2320.00	1720.00	2530.00	809.00	3430.00
Y	22.10	27.70	26.20	12.40	1.30	4.00	9.10	5.60	15.50	38.60	36.60	34.30	7.30	5.80	10.80
Sc	18.00	17.00	13.00	14.00	15.00	15.00	16.00	15.00	21.00	28.00	31.00	24.00	12.00	11.00	13.00
Zr	164.00	182.00	154.00	72.00	83.00	362.00	222.00	246.00	314.00	253.00	164.00	162.00	310.00	191.00	298.00
Be	0.42	0.46	0.21	0.71	0.25	0.22	0.28	0.18	0.29	0.25	0.25	0.18	0.30	0.12	0.10
V	8.00	7.00	6.00	<5	54.00	53.00	111.00	63.00	54.00	146.00	71.00	101.00	100.00	34.00	37.00
Cr	8.21	8.37	8.24	6.31	23.80	13.90	22.60	13.90	21.90	72.90	20.70	37.70	24.80	13.50	10.20
Co	1.01	1.20	0.81	0.09	12.55	4.98	9.37	8.95	11.85	12.70	7.95	10.55	12.50	4.86	5.87
Ni	1.66	1.81	1.27	0.72	19.10	4.80	8.38	7.00	7.66	24.40	9.90	14.05	13.15	2.46	3.32
Cd	0.02	0.01	0.07	0.01	0.01	0.01	0.02	0.03	0.04	0.04	0.03	0.04	0.01	0.01	0.01
Cu	2.63	1.19	1.03	0.48	38.20	4.90	25.20	9.56	21.50	11.40	17.75	24.00	45.30	9.64	8.37

Au	0.20	0.30	0.90	0.30	3.20	3.60	2.30	1.40	1.10	0.80	1.80	1.00	1.20	0.70	0.40
Li	8.00	3.40	6.20	1.10	18.20	12.20	14.90	11.60	12.40	21.50	9.60	14.40	23.50	7.20	9.40
Zn	35.20	27.40	22.40	5.10	71.20	86.80	85.90	57.80	130.00	71.40	39.90	49.80	72.40	33.80	43.80
Ga	20.50	17.80	17.80	19.80	18.90	21.00	22.20	19.70	23.60	23.70	21.10	20.30	24.60	18.40	18.90
Rb	206.00	169.50	206.00	331.00	85.20	117.50	93.20	74.30	88.90	63.60	67.60	53.10	95.40	37.70	64.90
Nb	17.90	13.20	14.00	19.90	5.40	3.20	3.80	3.30	7.50	11.40	9.30	8.10	6.00	2.60	5.30
Mo	0.29	0.23	0.28	0.16	0.25	0.19	0.23	0.21	4.99	0.26	0.29	0.29	0.30	0.30	0.31
Sn	2.00	2.00	2.00	3.00	1.00	7.00	5.00	1.00	4.00	3.00	3.00	3.00	3.00	1.00	2.00
Sb	0.02	0.03	0.07	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.02	0.02	0.01	0.02	0.02
Cs	1.69	1.32	4.13	6.79	1.89	2.26	2.15	1.71	2.10	1.29	1.79	2.90	2.15	1.07	1.46
Hf	4.80	5.00	4.50	3.30	2.00	8.80	5.10	5.90	7.40	6.20	4.40	4.50	7.10	4.70	7.40
Ta	1.40	1.20	1.60	1.50	0.30	0.20	0.30	0.10	0.90	0.70	0.60	0.60	0.30	0.20	0.40
W	<0.5	<0.5	1.50	1.10	<0.5	11.00	2.90	<0.5	<0.5	0.80	0.90	0.70	3.10	0.90	2.40
Pb	11.80	4.61	9.58	4.54	3.17	3.45	7.19	6.48	3.31	2.60	3.81	3.17	3.41	1.79	2.83
Bi	0.03	0.03	0.10	0.11	0.12	1.84	0.41	0.07	0.08	0.03	0.05	0.03	7.85	0.07	0.05
Th	23.40	16.55	17.40	24.30	3.24	3.21	9.06	2.33	4.04	4.06	3.46	3.79	3.77	2.71	3.94
U	3.39	2.07	4.74	2.29	0.25	1.21	1.25	1.07	1.39	0.92	0.90	0.91	1.23	0.55	1.10
Sr	75.80	80.90	111.50	11.60	620.00	452.00	499.00	521.00	307.00	529.00	572.00	674.00	638.00	606.00	628.00
K	19591.51	21583.86	21210.30	18844.37	8716.56	11082.48	9256.16	8426.01	7637.37	9961.78	12244.69	10003.29	12037.15	5271.44	11788.11
Ti	1138.75	1258.62	958.95	419.54	4435.13	2637.10	3715.92	2936.77	5154.34	6173.22	3476.18	3835.78	5813.61	2157.63	3655.98
P	87.27	65.46	65.46	21.82	43.64	218.18	610.91	392.73	545.46	741.83	392.73	436.37	610.91	349.09	414.55
La	51.90	61.90	64.70	23.20	16.80	20.60	72.70	12.90	32.50	39.80	28.10	26.30	25.50	20.40	22.40
Ce	98.10	96.40	106.00	33.60	24.70	35.10	131.00	22.90	62.00	103.00	75.50	66.60	48.80	37.40	49.90
Pr	10.30	11.15	14.40	4.01	2.39	3.38	13.55	2.80	6.93	14.10	11.20	9.84	5.35	3.96	5.86
Nd	32.80	37.60	47.90	10.70	7.70	13.10	46.20	11.20	27.80	57.90	48.20	43.60	18.30	14.90	21.00
Sm	4.76	6.57	8.05	1.53	0.83	1.78	5.54	2.11	5.77	10.75	10.05	9.42	2.60	2.08	3.41
Eu	0.52	0.79	1.06	0.14	0.82	0.80	1.08	0.89	1.51	2.14	2.08	2.06	1.29	1.03	1.04
Gd	3.51	4.56	4.99	1.12	0.49	1.32	3.27	1.70	4.79	8.57	8.80	8.46	1.80	1.77	2.51
Tb	0.52	0.74	0.84	0.20	0.03	0.10	0.33	0.17	0.61	1.26	1.26	1.22	0.21	0.19	0.37

Dy	3.37	4.55	4.49	1.40	0.29	0.64	1.94	1.06	3.41	7.48	6.96	6.96	1.36	1.02	1.82
Ho	0.71	0.89	0.93	0.38	0.04	0.13	0.30	0.18	0.64	1.41	1.39	1.36	0.23	0.18	0.37
Er	2.33	2.90	2.79	1.27	0.04	0.35	0.73	0.47	1.54	4.03	3.89	3.42	0.72	0.50	1.14
Tm	0.35	0.41	0.46	0.29	0.01	0.05	0.12	0.07	0.19	0.63	0.49	0.45	0.13	0.07	0.15
Yb	2.51	3.03	3.11	2.16	0.08	0.57	0.71	0.47	1.09	3.67	3.29	2.64	0.51	0.44	1.10
Lu	0.48	0.46	0.51	0.40	0.02	0.09	0.10	0.07	0.14	0.45	0.41	0.41	0.11	0.10	0.20

Geological Unit	Pé Quente suite											
Sample code	PZH-AD001-49.17	PZH-AD001-173.70	PZH-AD001-174.40	PZH-AD001-175.60	PZH-AD001-177.65	PZH-AD001-178.40	PZH-AD001-181.20	LZQFP-MOC004-60.13-61.1	LZQFP-ANA028-40-42.05	LZQFP-ANA028-110.4	LZQFP-ANA028-35	LZQFP-ANA028-43.7
Major and minor elements												
SiO ₂	69.00	67.70	71.10	68.40	72.20	66.30	66.50	73.80	69.70	72.40	68.30	71.80
TiO ₂	0.33	0.42	0.31	0.41	0.32	0.42	0.42	0.29	0.45	0.30	0.56	0.47
Al ₂ O ₃	14.30	15.40	13.05	15.00	13.50	16.30	16.10	13.25	14.30	12.85	14.55	14.00
Fe ₂ O ₃	1.89	2.43	1.56	2.38	1.52	2.56	2.60	2.21	2.61	1.67	3.57	2.54
MnO	0.08	0.07	0.06	0.09	0.06	0.08	0.07	0.08	0.04	0.03	0.08	0.05
MgO	0.89	0.79	0.56	1.05	0.58	0.93	1.01	0.61	0.90	0.52	0.88	0.88
CaO	0.83	1.26	0.81	1.12	0.62	1.13	1.17	1.34	0.92	0.65	3.31	1.33
Na ₂ O	3.74	4.17	1.94	3.52	2.32	4.15	4.16	4.75	4.28	4.19	4.42	4.82
K ₂ O	5.33	5.02	7.34	5.83	6.77	5.75	5.37	4.02	4.45	4.69	3.09	3.47
P ₂ O ₅	0.08	0.09	0.03	0.10	0.05	0.10	0.10	0.07	0.11	0.04	0.17	0.11
LOI	1.60	1.20	1.29	1.79	1.09	1.57	1.47	0.77	1.18	0.72	0.96	1.18
Total	98.22	98.72	98.22	99.85	99.19	99.48	99.17	101.19	98.94	98.06	99.89	100.65
Trace elements												
Ba	1280.00	1380.00	1465.00	1345.00	1415.00	1570.00	1660.00	1645.00	1795.00	1590.00	1495.00	1550.00
Y	18.90	18.30	23.10	18.20	8.30	22.10	29.70	9.30	17.90	19.10	19.50	19.00
Sc	14.00	12.00	7.00	17.00	7.00	13.00	10.00	16.00	19.00	18.00	20.00	19.00
Zr	366.00	243.00	295.00	339.00	349.00	403.00	342.00	192.00	269.00	231.00	250.00	273.00
Be	0.21	0.26	0.22	0.33	0.15	0.24	0.31	0.46	0.87	0.42	0.55	0.62

V	21.00	24.00	17.00	25.00	16.00	29.00	29.00	22.00	22.00	11.00	31.00	23.00
Cr	8.94	8.93	12.05	9.09	11.05	7.38	11.25	18.45	18.20	14.95	18.70	16.05
Co	1.75	2.63	1.34	3.12	2.59	2.61	3.02	2.89	1.98	1.12	2.45	2.08
Ni	1.79	2.09	1.67	2.29	1.58	1.86	2.40	2.82	1.97	1.59	1.91	1.70
Cd	0.01	0.01	0.01	0.01	0.00	0.01	0.01	3.32	0.07	0.03	0.05	0.07
Cu	0.89	3.65	1.03	1.16	1.33	2.70	2.29	14.85	1.56	3.76	2.20	4.45
Au	0.30	0.30	0.10	0.90	1.70	0.20	<0.1	6.40	15.20	5.20	16.10	8.50
Li	9.50	13.00	7.90	15.10	7.60	12.50	17.40	11.10	24.60	12.50	18.60	23.20
Zn	19.50	39.90	16.40	29.00	12.10	30.60	35.30	598.00	59.60	41.70	66.10	54.80
Ga	17.50	17.80	13.70	18.20	14.80	18.90	18.40	17.00	19.40	16.80	20.90	19.90
Rb	120.50	105.00	148.00	129.50	148.00	122.50	111.00	89.00	98.90	85.30	66.00	77.30
Nb	9.00	9.30	9.50	10.20	6.80	9.20	12.10	7.50	9.60	10.10	8.50	9.60
Mo	0.32	0.35	0.45	0.36	0.42	0.31	0.44	0.69	0.62	0.74	2.84	0.60
Sn	2.00	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00
Sb	0.02	0.03	0.02	0.03	0.02	0.02	0.03	0.15	0.26	0.08	0.72	0.32
Cs	0.76	1.20	1.09	0.77	0.48	0.64	0.84	0.65	1.24	1.06	0.71	1.16
Hf	8.90	6.00	7.50	8.00	8.80	9.30	8.60	4.90	6.70	6.10	6.10	6.60
Ta	0.60	0.50	0.80	0.60	0.40	0.60	1.00	0.80	0.50	0.60	0.60	0.50
W	1.30	1.20	1.30	1.90	3.60	1.40	0.80	<0.5	0.80	0.70	1.20	1.10
Pb	1.03	2.04	5.30	3.99	1.03	1.14	1.79	409.00	5.26	8.07	5.54	3.60
Bi	0.02	0.05	0.01	0.03	0.06	0.02	0.02	1.62	0.06	0.09	0.07	0.10
Th	5.09	10.50	8.88	18.55	6.24	10.40	8.27	11.50	11.15	12.45	9.33	10.95
U	0.91	0.96	2.31	3.09	0.54	0.96	0.88	2.37	2.23	2.48	1.96	2.27
Sr	162.50	199.00	127.50	165.00	131.50	203.00	223.00	240.00	241.00	142.50	423.00	284.00
K	22123.46	20836.73	30466.45	24198.83	28100.53	23866.77	22289.49	16685.99	18470.81	19466.99	12825.80	14403.08
Ti	1977.83	2517.23	1857.96	2457.30	1917.89	2517.23	2517.23	1738.09	2697.04	1798.02	3356.31	2816.90
P	174.55	196.37	65.46	218.18	109.09	218.18	218.18	152.73	240.00	87.27	370.91	240.00
La	34.50	68.40	44.40	92.20	48.60	69.60	58.80	37.90	46.20	53.60	47.00	47.30
Ce	74.90	128.50	92.10	171.50	88.10	129.00	120.50	68.70	89.70	99.20	87.80	90.10

Pr	9.10	13.65	10.75	17.70	9.23	13.60	14.25	6.98	9.68	10.95	10.20	10.00
Nd	34.60	47.30	41.40	57.70	29.10	49.40	56.10	23.90	35.80	40.00	37.90	37.00
Sm	6.02	7.27	7.40	7.96	4.23	8.66	10.15	3.47	5.83	6.93	6.28	5.85
Eu	1.22	1.24	1.21	1.40	0.97	1.34	1.76	0.70	1.35	1.11	1.56	1.41
Gd	4.82	4.91	5.39	4.96	2.82	5.18	6.86	2.11	3.57	4.41	4.37	4.29
Tb	0.71	0.73	0.78	0.71	0.33	0.81	1.02	0.26	0.56	0.56	0.65	0.67
Dy	3.40	3.47	4.26	3.33	1.77	4.31	5.77	1.70	3.59	3.82	3.66	3.73
Ho	0.71	0.78	0.91	0.74	0.29	0.90	1.20	0.28	0.66	0.69	0.66	0.64
Er	1.93	1.99	2.26	2.02	0.79	2.16	3.05	0.86	1.88	2.15	1.98	2.10
Tm	0.30	0.21	0.33	0.29	0.11	0.35	0.49	0.16	0.27	0.27	0.23	0.31
Yb	1.93	1.86	2.00	1.63	0.81	1.99	2.96	0.95	1.92	1.84	1.90	1.73
Lu	0.30	0.34	0.29	0.27	0.13	0.37	0.46	0.16	0.23	0.28	0.26	0.24

Geological Unit	Nhandu intrusive suite									
Sample code	ARGr-44(2)	ARGr-44(5)	ARGr-45(2)	ARGr-46(2)	ARGr-46(5)	ARGr-01	ARGr-03A	PZQFP-AD-FD-02(2)-25.8	PZQFP-AD002-25.85	PZQFP-AD002-28.9
Major and minor elements										
SiO₂	74.00	75.70	70.70	76.70	75.20	77.10	75.90	54.90	57.30	56.20
TiO₂	0.28	0.15	0.53	0.21	0.19	0.16	0.23	0.36	0.35	0.31
Al₂O₃	13.90	12.25	14.30	12.60	11.95	11.75	12.20	19.50	19.80	17.00
Fe₂O₃	1.50	1.89	2.87	2.10	1.81	1.59	1.99	3.51	3.72	3.69
MnO	0.08	0.03	0.08	0.04	0.03	0.03	0.04	0.45	0.47	1.09
MgO	0.24	0.05	0.37	0.12	0.08	0.05	0.13	2.72	2.50	3.24
CaO	0.43	0.04	0.74	0.52	0.47	0.15	0.58	2.51	2.14	4.36
Na₂O	5.53	5.94	3.97	3.12	3.09	3.50	3.21	0.08	0.08	0.06
K₂O	4.03	1.94	5.93	5.70	5.36	5.12	5.42	7.13	6.93	5.98
P₂O₅	0.04	0.03	0.08	0.03	0.02	0.01	0.02	0.11	0.11	0.10
LOI	0.39	0.21	0.36	0.26	0.21	0.17	0.29	6.94	6.23	9.10
Total	99.72	99.72	99.72	99.72	99.72	99.64	100.04	98.21	99.72	101.19

Trace elements										
Ba	303.00	17.40	828.00	313.00	271.00	67.50	309.00	788.00	816.00	566.00
Y	126.00	12.30	25.10	21.10	20.90	46.90	34.30	10.20	10.10	8.80
Sc	19.00	12.00	19.00	17.00	13.00	13.00	16.00	16.00	10.00	8.00
Zr	1020.00	42.00	621.00	319.00	235.00	326.00	343.00	136.00	166.00	117.00
Be	0.51	0.19	0.18	0.14	0.09	0.08	0.25	0.33	0.43	0.52
V	<5	<5	9.00	<5	<5	<5	<5	44.00	47.00	31.00
Cr	6.78	5.93	7.16	7.99	9.55	6.17	8.07	1.72	1.94	1.86
Co	0.26	0.23	1.25	0.75	0.61	0.18	0.83	0.54	1.67	0.41
Ni	1.41	1.28	1.57	1.60	1.50	1.59	2.43	1.61	2.18	1.93
Cd	0.03	0.00	0.02	0.04	0.02	0.01	0.07	0.01	0.01	0.03
Cu	1.28	1.35	3.34	2.35	1.97	0.90	1.98	6.87	7.56	2.08
Au	0.30	0.20	0.40	0.20	0.40	<0.1	0.40	17.10	96.90	17.00
Li	1.30	4.40	15.70	10.30	9.60	0.60	17.80	5.30	8.00	8.60
Zn	39.60	17.80	60.60	49.10	41.00	25.60	64.50	15.70	21.40	33.70
Ga	20.70	21.10	19.20	17.10	15.20	20.50	19.60	30.20	27.90	21.60
Rb	83.00	36.30	99.10	115.50	103.00	120.50	118.00	306.00	321.00	260.00
Nb	20.10	8.80	14.30	8.00	7.30	5.70	10.20	3.80	3.80	3.20
Mo	0.23	0.32	0.35	0.29	0.72	0.20	0.49	0.04	0.06	0.06
Sn	3.00	2.00	2.00	1.00	1.00	2.00	2.00	3.00	3.00	2.00
Sb	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.03
Cs	0.40	0.16	0.62	0.90	0.70	0.23	0.93	2.07	2.01	1.68
Hf	21.20	1.00	13.50	7.80	5.90	7.70	8.90	3.70	4.60	3.40
Ta	1.50	0.70	0.70	0.40	0.50	0.50	0.60	0.20	0.30	0.30
W	1.10	0.70	1.50	0.80	0.80	0.70	1.20	4.20	5.60	5.80
Pb	7.54	5.29	17.60	17.05	17.05	9.29	17.15	1.02	1.94	1.45
Bi	0.01	0.01	0.02	0.03	0.02	0.00	0.03	0.13	0.30	0.16
Th	13.50	1.14	8.98	10.60	9.95	5.64	13.75	1.74	1.49	1.37
U	0.81	0.23	0.98	1.02	1.38	0.47	1.53	0.72	0.77	0.69

Sr	46.60	6.70	94.70	38.30	34.70	16.30	35.50	7.20	7.40	9.70
K	16727.49	8052.44	24613.91	23659.24	22247.98	21251.80	22497.03	29594.80	28764.65	24821.44
Ti	1678.16	899.01	3176.51	1258.62	1138.75	958.95	1378.49	2157.63	2097.69	1857.96
P	87.27	65.46	174.55	65.46	43.64	21.82	43.64	240.00	240.00	218.18
La	286.00	36.00	82.30	74.80	68.70	71.00	113.00	8.20	8.90	10.00
Ce	467.00	124.50	196.00	164.00	126.50	83.00	193.50	18.20	18.50	21.60
Pr	52.30	14.30	19.00	16.20	14.35	19.95	23.40	2.33	2.43	2.64
Nd	179.50	50.60	67.90	59.30	52.50	72.00	87.00	9.30	9.30	11.00
Sm	28.10	9.79	10.60	8.98	8.04	13.00	13.30	2.26	1.88	2.48
Eu	1.94	0.63	1.68	0.68	0.66	1.08	0.90	0.30	0.41	0.58
Gd	22.80	5.12	7.84	6.20	5.33	9.45	9.65	1.88	1.92	2.19
Tb	3.29	0.89	0.98	0.70	0.71	1.43	1.28	0.34	0.33	0.33
Dy	21.60	4.77	5.33	4.74	3.76	8.95	6.79	1.85	1.98	1.58
Ho	4.10	0.76	0.98	0.79	0.77	1.71	1.27	0.35	0.33	0.30
Er	12.00	2.23	2.89	2.36	2.18	4.86	3.54	1.02	1.24	1.03
Tm	1.62	0.30	0.41	0.37	0.36	0.73	0.50	0.17	0.10	0.11
Yb	8.79	1.95	2.79	2.25	1.77	4.12	2.81	0.91	1.48	0.93
Lu	1.31	0.19	0.48	0.33	0.29	0.58	0.41	0.18	0.21	0.19

Geological Unit	Matupá intrusive suite												
Sample code	FMGr-51(2)	FMGr-52(2)	FMGr-53(2)	FMGr-06A	FMGr-08A	FMGr-10	FMGr-11	FMGr-13A	MAT-47(2)	MAT-47(5)	MAT-47(8)	MAT-47(11)	MAT-31A
Major and minor elements													
SiO₂	69.60	70.80	72.60	70.10	71.80	78.20	72.50	75.30	69.10	68.30	70.20	62.30	69.20
TiO₂	0.30	0.22	0.14	0.24	0.24	0.04	0.16	0.10	0.46	0.49	0.50	0.92	0.41
Al₂O₃	15.30	14.10	13.85	14.60	14.60	12.60	14.40	13.45	13.85	14.50	14.85	15.65	15.00
Fe₂O₃	2.90	1.89	1.42	2.34	2.32	0.79	1.72	1.14	3.22	3.24	3.60	5.65	2.55
MnO	0.06	0.05	0.04	0.05	0.05	0.01	0.04	0.03	0.06	0.06	0.07	0.14	0.08
MgO	1.19	0.65	0.29	0.89	0.95	0.04	0.50	0.23	1.01	0.97	1.07	2.02	0.51

CaO	2.47	1.39	1.24	2.24	2.25	0.45	1.69	0.92	2.32	2.46	2.46	3.29	1.08
Na₂O	4.50	4.44	4.44	4.21	4.16	3.59	4.17	4.26	3.48	3.45	3.48	4.24	4.53
K₂O	3.74	3.94	4.08	3.37	3.71	5.06	3.86	4.14	4.45	4.39	4.64	3.42	5.26
P₂O₅	0.13	0.08	0.04	0.10	0.10	<0.01	0.06	0.02	0.18	0.18	0.19	0.30	0.10
LOI	0.88	0.95	0.62	0.79	0.64	0.28	0.61	0.39	0.77	0.49	0.67	0.63	0.32
Total	99.17	99.17	99.17	99.14	101.04	101.06	99.93	100.07	98.90	98.53	101.73	98.56	99.27
Trace elements													
Ba	1100.00	1220.00	1080.00	1300.00	1395.00	33.60	1435.00	608.00	925.00	977.00	941.00	533.00	1970.00
Y	7.40	7.40	12.90	7.70	8.10	2.90	7.90	10.30	23.50	23.40	24.40	50.60	89.20
Sc	18.00	16.00	15.00	13.00	13.00	12.00	13.00	13.00	20.00	20.00	19.00	24.00	14.00
Zr	122.00	114.00	71.00	113.00	100.00	72.00	107.00	77.00	262.00	277.00	258.00	451.00	431.00
Be	0.88	0.88	0.68	0.52	0.39	0.13	0.42	0.62	0.34	0.25	0.30	0.39	0.23
V	41.00	27.00	11.00	33.00	37.00	7.00	19.00	8.00	41.00	41.00	42.00	71.00	18.00
Cr	25.60	20.40	13.75	16.90	19.60	16.95	14.85	13.55	23.00	24.10	26.60	37.80	10.40
Co	4.90	2.71	1.73	4.84	4.62	0.40	3.06	1.00	6.58	6.71	7.28	14.25	1.78
Ni	8.69	4.65	2.47	8.12	8.31	1.61	4.69	2.17	11.80	12.05	12.80	24.90	1.72
Cd	0.01	0.08	0.03	0.01	0.02	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.03
Cu	2.29	3.38	6.04	6.71	4.35	1.01	2.10	0.96	15.00	15.40	15.30	23.40	2.09
Au	1.00	0.40	0.40	0.70	0.40	0.30	0.30	0.70	0.50	0.20	0.50	0.70	0.50
Li	13.80	11.30	8.90	14.00	12.20	2.10	14.20	9.10	32.90	38.20	33.50	92.10	11.10
Zn	33.20	47.70	26.30	38.50	24.90	6.50	29.20	13.10	58.50	63.20	63.10	130.00	62.90
Ga	19.40	20.50	19.40	19.70	20.50	17.50	17.60	18.90	20.60	20.90	20.90	27.50	19.70
Rb	88.80	115.00	123.00	89.00	93.80	119.00	106.50	147.00	202.00	199.00	202.00	248.00	92.70
Nb	7.50	7.10	8.30	8.00	7.10	3.60	7.10	11.80	16.80	19.20	18.00	39.90	16.40
Mo	0.28	0.35	1.17	0.22	0.24	0.32	0.28	0.29	0.28	0.27	0.37	0.35	0.40
Sn	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	2.00	3.00	2.00	5.00	3.00
Sb	0.05	0.15	0.04	0.03	0.03	0.02	0.06	0.02	0.01	0.01	0.02	0.01	0.02
Cs	0.37	0.81	0.52	0.51	0.44	0.52	0.59	0.92	3.43	4.22	3.77	6.93	0.57
Hf	3.40	3.20	2.20	3.40	3.20	3.20	3.20	2.60	6.70	7.00	6.60	11.60	10.50

Ta	0.50	0.40	0.70	0.70	0.70	0.50	0.80	1.10	1.30	1.30	1.30	3.40	1.00
W	<0.5	<0.5	<0.5	0.60	0.60	0.70	0.80	0.80	<0.5	<0.5	<0.5	<0.5	0.50
Pb	7.29	28.90	10.70	5.79	7.42	10.90	7.90	15.80	10.10	7.84	10.05	8.60	8.70
Bi	0.03	0.10	0.01	0.02	0.02	0.01	0.02	0.01	0.04	0.04	0.06	0.36	0.02
Th	8.14	9.26	6.10	8.45	15.00	22.80	6.12	13.55	30.40	24.10	35.30	29.40	8.32
U	1.95	2.44	1.64	1.77	4.13	3.72	1.82	3.88	4.12	3.92	3.81	6.69	1.31
Sr	652.00	368.00	422.00	694.00	678.00	45.20	562.00	251.00	226.00	242.00	229.00	246.00	250.00
K	15523.78	16353.93	16935.03	13988.00	15399.26	21002.76	16021.87	17184.08	18470.81	18221.76	19259.45	14195.54	21832.91
Ti	1798.02	1318.55	839.08	1438.42	1438.42	239.74	958.95	599.34	2756.97	2936.77	2996.71	5513.94	2457.30
P	283.64	174.55	87.27	218.18	218.18	#VALOR!	130.91	43.64	392.73	392.73	414.55	654.55	218.18
La	26.60	33.30	15.70	29.50	29.80	10.60	25.80	12.60	52.30	55.10	71.30	58.80	114.50
Ce	52.20	58.50	28.50	56.20	50.10	21.90	43.80	26.70	110.00	116.00	147.00	143.50	201.00
Pr	5.85	6.37	3.41	6.22	5.79	1.97	5.16	3.35	12.80	13.55	16.30	18.70	27.60
Nd	20.30	23.20	12.20	21.60	20.30	6.30	17.00	12.30	47.60	50.10	60.10	76.60	103.50
Sm	2.88	3.16	2.24	3.61	3.19	0.73	2.68	2.51	8.05	8.67	9.70	15.60	17.65
Eu	0.80	0.71	0.56	0.90	0.80	0.13	0.66	0.40	1.09	1.13	1.17	1.81	2.80
Gd	1.91	1.93	1.55	1.80	1.91	0.51	1.73	1.72	5.64	5.66	6.47	11.70	15.85
Tb	0.22	0.21	0.23	0.26	0.27	0.07	0.17	0.33	0.70	0.78	0.75	1.65	2.36
Dy	1.58	1.37	1.57	1.49	1.55	0.34	1.21	1.88	4.71	4.47	4.92	9.36	14.05
Ho	0.23	0.26	0.31	0.24	0.26	0.10	0.25	0.32	0.82	0.78	0.89	1.76	3.07
Er	0.83	0.76	0.88	0.75	0.69	0.40	0.64	0.94	2.31	2.40	2.46	5.09	8.52
Tm	0.12	0.10	0.13	0.13	0.12	0.06	0.14	0.14	0.32	0.33	0.30	0.74	1.24
Yb	0.85	0.69	0.83	0.60	0.77	0.43	0.89	0.93	2.05	2.21	2.08	4.82	7.10
Lu	0.12	0.10	0.15	0.15	0.12	0.11	0.13	0.18	0.34	0.30	0.30	0.63	1.02

Geological Unit	Colíder group				
Sample code	COL-05(2)	COL-55(2)	COL-14A	COL-16A	COL-29A
Major and minor elements					

SiO ₂	74.20	66.50	61.30	66.20	76.90
TiO ₂	0.30	0.56	0.89	0.78	0.21
Al ₂ O ₃	12.70	14.85	15.55	14.10	11.50
Fe ₂ O ₃	2.30	4.38	7.08	5.00	1.93
MnO	0.08	0.09	0.08	0.11	0.06
MgO	0.52	0.79	2.45	0.97	0.11
CaO	0.81	2.33	3.39	1.91	0.32
Na ₂ O	2.29	4.34	3.44	3.95	3.40
K ₂ O	5.53	4.28	2.92	4.89	5.04
P ₂ O ₅	0.02	0.08	0.27	0.32	0.01
LOI	1.82	0.79	2.16	1.88	0.39
Total	100.57	98.99	99.66	100.32	99.91
Trace elements					
Ba	561.00	1800.00	633.00	1720.00	251.00
Y	206.00	23.30	23.20	41.70	65.20
Sc	16.00	22.00	25.00	19.00	14.00
Zr	325.00	242.00	208.00	418.00	348.00
Be	2.23	0.43	0.63	0.98	2.60
V	6.00	47.00	138.00	37.00	<5
Cr	11.65	21.20	20.70	16.10	15.45
Co	1.19	4.92	16.10	6.73	0.52
Ni	2.93	5.61	11.45	3.02	1.93
Cd	0.04	0.03	0.04	0.05	0.06
Cu	5.67	8.74	68.80	3.02	1.35
Au	1.30	0.90	1.10	0.10	5.60
Li	8.20	7.30	26.20	7.60	2.00
Zn	27.70	74.20	75.30	82.90	52.50
Ga	18.30	15.60	19.20	23.10	19.60
Rb	191.50	10.80	123.00	121.50	218.00

Nb	23.30	10.80	11.00	17.00	24.20
Mo	0.88	0.44	0.30	0.91	1.53
Sn	3.00	2.00	3.00	3.00	4.00
Sb	0.14	0.13	0.06	0.11	0.08
Cs	1.29	0.61	3.85	1.48	1.66
Hf	8.80	5.80	5.30	10.10	10.10
Ta	1.60	0.70	0.80	1.00	1.50
W	1.90	1.50	1.20	1.50	1.30
Pb	2.55	9.36	4.71	14.95	18.10
Bi	0.07	0.08	0.03	0.62	0.12
Th	25.70	8.38	9.34	14.80	23.60
U	6.18	1.66	3.36	3.66	5.80
Sr	38.10	370.00	475.00	289.00	44.30
K	22953.61	17765.18	12120.17	20297.13	20919.75
Ti	1798.02	3356.31	5334.14	4674.86	1258.62
P	43.64	174.55	589.10	698.19	21.82
La	186.00	37.90	39.80	72.60	103.50
Ce	222.00	73.40	85.60	143.00	185.50
Pr	37.60	8.42	10.45	16.60	21.80
Nd	136.50	32.60	40.00	60.30	76.40
Sm	21.70	5.51	7.37	10.00	13.25
Eu	2.45	1.94	1.88	2.23	0.75
Gd	22.10	4.90	5.83	8.68	10.60
Tb	3.07	0.68	0.78	1.30	1.67
Dy	17.75	4.45	4.30	7.73	10.80
Ho	3.79	0.82	0.82	1.57	2.22
Er	12.05	2.46	2.45	4.15	6.94
Tm	1.55	0.40	0.34	0.68	0.97
Yb	8.30	2.25	1.97	4.14	6.26

Lu	1.51	0.35	0.33	0.66	0.97
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Geological Unit	Teles Pires suite																			
Sample code	TPS - 40(2)	TPS - 41(5)	TPS - 42(2)	TPS - 43(2)	TP S- 09	TP S- 19	TP S- 20	TP S- 32A	PFU N- 06(1)	PFU N- 07(2)	PFU N- 11(1)	PBQ FP- 39(1)	PBQFP- PB-56(65)- 937.50	PBQFP- PB-56(66)- 938.20	PBQFP- PB-84(01)- 7-7.28	PBQFP-PB- 84(03)-11.17- 11.39	PBQFP-PB- 84-19-54.12- 54.39	PBQFP-PB- 84(24)-86.58- 86.78	PBQFP-PB- 84(33)-168.16- 168.46	PBQFP-PB- 84(36)-197.47- 197.68

Major and minor elements																				
SiO ₂	75.10	79.20	77.20	75.30	74.00	76.00	73.60	78.70	76.10	77.70	74.60	77.10	76.20	76.40	78.30	79.70	77.80	78.70	77.40	78.30
TiO ₂	0.25	0.27	0.15	0.28	0.10	0.25	0.27	0.09	0.11	0.11	0.11	0.06	0.10	0.10	0.05	0.05	0.07	0.05	0.05	0.05
Al ₂ O ₃	12.40	10.50	12.50	12.75	13.90	12.00	12.90	12.35	11.85	12.40	11.55	12.85	12.70	12.75	12.70	12.05	13.15	12.55	12.75	11.75
Fe ₂ O ₃	2.03	1.71	1.44	1.84	1.16	1.72	1.85	1.08	1.87	2.00	2.53	0.71	1.11	1.28	0.74	0.70	0.69	0.61	0.60	0.65
MnO	0.03	0.06	0.01	0.02	0.05	0.03	0.04	0.01	0.02	0.01	0.05	<0.01	0.04	0.04	<0.01	0.01	0.01	0.02	0.01	0.01
MgO	0.21	0.31	0.12	0.19	0.42	0.14	0.33	0.05	0.07	0.34	0.11	0.07	0.25	0.17	0.05	0.08	0.10	0.08	0.06	0.04
CaO	0.21	0.50	0.03	0.03	0.84	0.12	0.80	0.39	0.17	0.04	0.44	0.33	0.81	0.74	0.17	0.31	0.51	0.47	0.48	0.36
Na ₂ O	3.95	2.36	4.16	3.52	4.39	3.95	4.02	3.68	3.37	0.13	3.68	3.69	3.70	3.76	3.36	3.51	4.06	3.87	3.86	2.98
K ₂ O	5.11	5.63	4.92	6.01	4.42	4.85	4.78	4.69	4.99	3.78	4.70	4.94	4.84	4.76	5.56	4.96	4.94	4.77	4.90	5.43
P ₂ O ₅	0.02	0.03	0.01	0.03	0.04	0.02	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	<0.01	0.01	0.01
LOI	0.47	0.47	0.26	0.33	2.42	0.36	0.36	0.22	0.69	1.77	0.28	0.49	1.02	0.85	0.60	0.47	0.64	0.53	0.48	0.61
Total	99.31	100.57	100.54	99.97	101.88	99.45	99.08	101.27	99.25	98.29	98.06	100.25	100.79	100.86	101.54	101.86	101.98	101.65	100.60	100.19

Trace elements																				
Ba	172.50	771.00	108.00	316.00	938.00	121.00	606.00	20.60	158.00	504.00	7.60	29.60	79.80	84.30	55.80	57.00	41.90	18.20	28.50	50.10
Y	34.20	28.60	5.10	36.90	8.30	44.30	24.80	4.50	136.50	4.30	92.80	16.50	11.30	14.20	32.90	28.10	38.30	36.30	31.30	25.70
Sc	16.00	13.00	14.00	14.00	12.00	15.00	13.00	13.00	16.00	15.00	15.00	15.00	15.00	16.00	15.00	15.00	17.00	20.00	15.00	15.00
Zr	424.00	233.00	270.00	385.00	71.00	391.00	218.00	130.00	363.00	75.00	359.00	54.00	87.00	84.00	58.00	57.00	59.00	67.00	60.00	69.00
Be	1.03	0.08	0.26	0.43	0.66	0.71	1.02	0.32	2.41	0.16	0.96	0.08	0.46	0.39	0.08	0.35	0.66	0.32	0.40	0.40
V	9.00	10.00	<5	<5	8.00	<5	12.00	<5	<5	18.00	<5	<5	6.00	6.00	<5	<5	<5	<5	<5	<5
Cr	9.89	37.50	11.30	6.84	12.40	13.50	13.30	8.62	0.75	1.60	0.16	4.43	5.46	7.34	5.10	7.45	7.20	7.49	7.29	7.82
Co	0.64	2.23	0.39	0.84	1.27	0.39	1.86	0.46	0.51	0.43	0.64	0.14	0.77	0.45	0.56	0.67	1.04	0.55	1.31	1.58
Ni	1.87	4.59	1.36	1.65	2.27	1.93	1.92	1.13	1.88	1.30	2.69	1.02	1.41	2.78	0.91	1.05	0.90	1.44	0.91	1.52

Cd	0.01	1.07	0.00	0.01	0.03	0.02	0.09	0.00	0.09	0.01	0.05	0.00	0.08	0.02	0.02	0.01	0.02	0.01	0.00	0.33
Cu	1.69	2.56	2.06	2.98	3.75	1.28	1.74	0.67	14.90	9.60	3.46	3.13	201.00	100.50	39.90	16.30	32.00	13.05	15.30	31.40
Au	0.10	1.30	0.40	0.30	0.40	1.70	2.40	1.50	3.20	0.50	3.80	0.70	16.10	5.80	0.80	1.10	2.10	0.60	1.30	2.00
Li	3.30	1.90	4.00	6.60	11.50	2.70	10.40	1.10	2.41	0.16	0.96	0.10	2.10	1.90	0.10	0.40	0.60	0.50	0.50	0.30
Zn	29.00	210.00	43.40	31.00	23.20	55.70	38.20	4.80	72.80	4.90	66.50	3.30	49.60	23.80	13.60	14.50	13.10	15.70	8.80	34.60
Ga	20.10	10.50	22.60	19.60	18.40	22.20	21.00	19.40	24.80	16.90	22.80	18.00	17.90	18.90	18.60	19.40	20.10	19.30	18.70	17.10
Rb	154.00	138.50	265.00	195.00	128.50	183.00	182.00	252.00	320.00	128.50	374.00	186.50	194.00	193.00	196.50	177.50	189.00	174.00	167.50	202.00
Nb	18.40	9.40	17.60	22.70	8.50	20.90	18.20	16.80	39.40	9.50	37.30	25.70	15.50	19.10	29.20	30.10	38.10	31.90	25.60	25.40
Mo	0.63	1.35	0.48	0.27	0.33	1.63	6.77	0.35	4.06	10.95	2.94	9.03	0.84	1.03	1.07	15.65	39.10	15.75	0.50	2.79
Sn	3.00	1.00	2.00	3.00	1.00	3.00	3.00	1.00	11.00	4.00	6.00	1.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	3.00
Sb	0.02	0.16	0.02	0.02	0.08	0.03	0.05	0.02	0.21	0.15	0.11	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.02
Cs	0.32	0.51	0.91	0.59	0.79	0.64	0.93	0.90	1.54	1.67	2.65	0.53	1.17	1.15	0.57	0.50	0.72	0.38	0.49	0.71
Hf	11.00	5.30	9.10	10.50	2.30	11.30	6.60	6.00	13.10	3.30	12.90	3.20	3.80	3.70	3.70	3.70	3.80	4.40	3.50	4.10
Ta	1.30	0.70	1.10	1.50	0.70	1.40	1.20	1.40	3.00	0.90	2.80	2.00	1.20	1.60	2.90	2.70	2.80	3.10	2.40	1.70
W	1.00	1.60	0.90	1.40	0.60	1.10	1.30	1.20	5.40	11.60	2.40	4.30	4.20	3.20	5.20	3.60	3.40	3.10	2.60	6.70
Pb	4.57	76.40	10.10	5.80	13.05	22.60	26.80	10.35	24.60	6.62	35.60	9.50	12.80	15.55	11.40	11.95	16.60	18.45	17.25	13.70
Bi	0.05	0.07	0.09	0.07	0.04	0.12	0.09	0.03	0.75	1.60	0.16	0.32	0.32	1.30	0.83	0.13	0.39	0.95	0.37	0.29
Th	14.45	8.40	24.30	19.85	9.54	18.65	29.50	43.00	35.80	14.40	32.00	19.20	21.50	21.60	16.15	16.70	17.05	17.80	16.65	17.75
U	2.86	1.18	3.38	4.57	1.83	4.36	15.40	19.30	10.40	1.42	10.90	5.93	6.82	8.26	9.91	12.00	14.15	13.10	11.10	9.00
Sr	110.57	82.45	167.72	57.89	17.19	83.87	53.83	46.14	24.80	21.10	10.50	13.80	48.70	50.10	18.70	16.80	20.20	13.60	16.00	20.60
K	21210.30	23368.68	20421.66	24945.97	18346.28	20131.10	19840.55	19466.99	20712.21	15689.81	19508.49	20504.67	20089.60	19757.54	23078.13	20587.69	20504.67	19799.04	20338.64	22538.54
Ti	1498.35	1618.22	899.01	1678.16	599.34	1498.35	1618.22	539.41	659.28	659.28	659.28	359.60	599.34	599.34	299.67	299.67	419.54	299.67	299.67	299.67
P	43.64	65.46	21.82	65.46	87.27	43.64	130.91	21.82	21.82	21.82	21.82	21.82	43.64	21.82	21.82	43.64	21.82	#VALOR!	21.82	21.82
La	39.90	33.00	33.30	52.80	18.30	62.40	62.30	21.50	203.00	11.70	56.70	7.70	12.30	17.80	11.40	9.70	10.10	10.90	10.40	10.60
Ce	87.30	69.00	54.50	105.00	37.40	174.00	109.50	36.40	211.00	20.00	117.50	16.80	26.60	37.10	29.10	24.70	26.40	27.20	26.60	26.00
Pr	9.86	7.50	5.05	11.65	4.24	15.40	11.00	2.05	44.80	1.92	13.85	2.47	2.86	4.06	3.96	3.36	3.60	3.74	3.45	3.50
Nd	37.30	28.50	14.90	44.20	14.90	56.00	36.90	4.70	150.50	6.50	49.40	9.80	9.80	14.10	16.20	13.30	15.60	15.90	15.00	14.50
Sm	7.28	5.38	1.94	7.40	2.61	10.35	6.01	0.61	29.80	0.91	10.90	2.85	1.72	2.39	5.09	4.54	5.55	5.36	4.48	4.12

Eu	0.93	0.99	0.19	1.07	0.6 0	1.3 0	0.9 8	0.0 7	1.11	0.16	0.14	0.16	0.27	0.48	0.28	0.24	0.22	0.22	0.18	0.13
Gd	5.61	4.43	1.10	6.03	1.7 2	7.9 9	4.5 4	0.4 0	24.0 0	0.64	11.1 5	2.55	1.20	1.82	5.33	4.41	5.90	5.15	4.61	4.03
Tb	0.81	0.71	0.13	0.95	0.2 7	1.1 6	0.7 6	0.0 7	3.94	0.11	2.14	0.52	0.24	0.29	0.90	0.77	1.04	0.93	0.82	0.62
Dy	5.40	4.56	0.81	5.87	1.4 3	7.3 0	4.2 0	0.3 8	24.0 0	0.65	13.5 0	2.89	1.32	1.85	5.37	4.95	6.90	5.88	5.17	4.29
Ho	1.02	0.90	0.16	1.23	0.3 0	1.5 5	0.9 4	0.1 0	4.32	0.16	2.92	0.57	0.25	0.38	1.01	0.88	1.29	1.09	0.84	0.80
Er	3.35	2.87	0.73	4.02	0.7 7	4.2 8	2.7 4	0.6 0	13.0 0	0.39	9.53	1.69	1.02	1.33	2.86	2.50	3.56	2.94	2.84	2.47
Tm	0.52	0.46	0.18	0.60	0.1 1	0.6 4	0.4 2	0.1 0	1.85	0.10	1.52	0.31	0.22	0.26	0.44	0.38	0.54	0.50	0.41	0.37
Yb	3.80	2.64	1.37	4.24	0.9 2	4.4 2	3.2 0	1.2 5	12.2 5	0.67	9.82	1.51	1.30	1.60	2.73	2.36	3.33	3.04	2.52	2.46
Lu	0.63	0.44	0.30	0.68	0.1 2	0.6 4	0.5 5	0.2 8	1.66	0.14	1.50	0.26	0.21	0.30	0.41	0.36	0.46	0.49	0.39	0.35

Table A2. *In-situ* zircon chemical results.

Geological unit	Teles Pires suite				Colider group										
Rock type	Porphyritic granite				Poprhyritic rhyolite							Poprhyritic alkali-feldspar granite			
Sample code	PB56-3.1	PB56-2.1	PB56-5.1	PB56-12.1	VGT15-4	VGT15-6	VGT15-8	VGT15-7	VGT15-10	VGT15.13	VGT15-15	VGT21-3.1	VGT21-6.1	VGT21-8.1	VGT21-9.1
Age (Ma) from Trevisan <i>et al.</i> (under review)	1721	1823	1809	1760	1854	1830	1841	1829	1836	1767	1828	1831	1741	1821	1813
Comment	discordant	inherited	inherited	discordant	inherited					discordant		inherited	discordant		inherited
P_ppm_m31	185	175	285	462	236	319	279	213	403	334	425	446	372	372	365
Ca_ppm_m43															
Sc_ppm_m45	160	189	223.1	268	186.5	192	188.3	185.9	205	183.2	211	134.1	149.6	114	133

Ti_ppm_m49	6.1	12.5	6.5	12.2	51.4	29.7	25.1	20.7	20.8	32.8	23.6	35.2	38.6	23.2	33.2
Cu_ppm_m63			2.4	1.36											
Rb_ppm_m85	0.49			0.68							0.56				
Sr_ppm_m88	0.78	0.227	0.4	2.2		0.204	0.191	0.177	0.135		0.299	0.24	0.28		0.231
Y_ppm_m89	1956	1295	1570	1400	1046	732	674	1619	1042	612	2240	1030	1516	705	753
Nb_ppm_m93	5.2	1.07	4.79	3.06	0.493	1.02	0.87	0.97	1.22	0.94	2	1	1.22	1.98	1.6
Ba_ppm_m138	0.36	0.068	0.85	0.48		0.09		0.144	0.12		0.32	0.121	0.118	0.184	0.168
La_ppm_m139	0.62	0.064	0.56	1.71	0.056	0.0129	0.095	0.0137			0.96	0.027	0.087	0.017	
Ce_ppm_m140	67.4	26.4	78.5	48.3	11.98	16.67	14.5	34.7	29.4	13.19	60.2	28.8	46	39.4	31.9
Pr_ppm_m141	1.29	0.57	0.97	1.51	0.35	0.129	0.166	0.498	0.229	0.084	1.08	0.354	0.84	0.09	0.135
Nd_ppm_m146	15.3	8.88	9.3	12	5.84	2.08	2.12	9.06	3.7	1.79	12.8	5.5	12.02	1.54	2.81
Sm_ppm_m147	20.1	13.7	10.6	11.79	7.3	4.31	3.89	12.9	5.82	3.15	16.87	8.8	15.15	2.75	4.5
Eu_ppm_m153	7.78	5.9	4.06	3.53	5.23	2.42	2.25	6.45	3.16	2.02	7.16	2.21	3.14	0.531	0.95
Gd_ppm_m157	71.9	49.9	48	45.4	34.7	19.4	17.2	53.4	28.7	13.72	69.6	32.5	55.1	14.21	19.7
Tb_ppm_m159	18.85	12.87	13.7	12.79	9.56	5.35	5.03	14.66	8.3	4.48	18.68	8.9	14.51	4.92	5.85
Dy_ppm_m163	204.4	138.8	159	141.6	105.5	66.9	62.3	166.1	98	53.3	218.4	102	160.4	62.1	70.3
Ho_ppm_m165	65.9	43.6	54.4	47.1	36.2	24.7	22.92	58.4	36.7	20.03	79.3	35.3	52.1	23.51	25.1
Er_ppm_m167	292	186	235	209	157.3	117.2	110	257	172	98.4	354	160	222.1	114.6	114.7
Tm_ppm_m169	59.3	36.9	48	42.3	30.6	24.1	22.75	49.6	33.9	20.05	66.6	31.3	43	25.23	24.4
Yb_ppm_m173	515	309	392	360	254	214	207.1	410	292	185.9	572	273	362	227.2	220.4
Lu_ppm_m175	102	61.8	78.9	71.2	51	45.4	44.6	81.1	60.9	40.2	114.8	53.1	70.9	46.3	45.2
Hf_ppm_m179	9830	9080	10180	9100	7630	7820	7530	8140	7510	7670	8090	8320	8620	9760	8710
Ta_ppm_m181	0.689	0.323	0.939	0.665	0.2	0.314	0.261	0.281	0.341	0.242	0.531	0.372	0.363	0.64	0.528
Pb_ppm_m206	298.6	81.6	348	210	34.7	44.6	33.6	53.4	42.3	31.6	91.5	56.4	57.4	52.2	78.8
Pb_ppm_m207	36.8	10.55	43.1	26.6	4.14	5.09	4.55	6.75	5.8	4.04	11.33	7.19	6.75	6.39	9.07
Th_ppm_m232	275	93.6	254	245	32	27.9	21.4	64.5	39.9	18.71	109.6	57.3	78.9	38.4	54.9
U_ppm_m238	231.2	58.6	227	166	25.3	32	24	38.6	31.4	23	68.1	40.4	41.2	37.6	56.6

Geological unit	Nhandu intrusive suite	Matupá intrusive suite	Pé Quente intrusive suite
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Rock type	Hornblende-biotite granite						Quartz-feldspar porphyry			Biotite granodiorite/monzogranite			Quartz-monzonite				
Sample code	VG2-4	VG2-14	VG2-15	VG2-7.2	VG2-7.1	VG2-8	PEZ-24	PEZ-3	PEZ-20	TAM-9	TAM-20	TAM-4	PQ-18	PQ-20	PQ-16	PQ-6	PQ-5
Age (Ma) from Trevisan <i>et al.</i> (under review)	1968	1979	1922	1784	1785	1975	1962	1966	1907	1885	1942	1874	2031	2005	1977	1963	1991
Comment		inherited	inherited	discordant	discordant		inherited	inherited	discordant	discordant	inherited		inherited	inherited			
P_ppm_m31	297		169	259	249	227	501	469	327	320	502	413	475	389	287	266	338
Ca_ppm_m43																	
Sc_ppm_m45	118	88.7	106.7	136.3	134.3	101	141.3	133.5	122	160.7	213	159	154.5	109.3	101.5	106.7	121.1
Ti_ppm_m49	6.1	4.3	7.5	24	22.1	9.5	24	17.1	10.7	15.2	13.3	11	27.1	6.8	8.1	11	13.6
Cu_ppm_m63																	
Rb_ppm_m85						1.4	0.61										
Sr_ppm_m88		0.124	0.136		0.135	0.24	0.173	0.242	0.23	0.39		0.277	0.193	0.23			0.162
Y_ppm_m89	1175	362	524	788	569	487	891	1612	1480	1093	1520	1270	1557	1320	731	793	796
Nb_ppm_m93	2.72	3.35	2.04	0.97	0.97	3.21	1.76	1.63	2.52	1.52	3.33	2.51	1.79	3.21	3.22	2.97	2.02
Ba_ppm_m138	0.04		0.037	0.203	0.21	0.63	0.205	0.184	0.255	0.42		0.233	0.131	0.063	0.062		
La_ppm_m139						0.75		0.044	0.045	1.9		0.73	0.101	0.017		0.0092	
Ce_ppm_m140	14.19	7.51	10.83	43.2	43.5	13.2	34.6	52.6	40.1	29	35.9	33.8	29.3	18.2	16.56	15.04	10.45
Pr_ppm_m141	0.222	0.0136	0.047	0.263	0.123	0.17	0.164	0.79	0.334	0.82		0.71	0.593	0.225	0.065	0.085	0.085
Nd_ppm_m146	4.24	0.234	0.96	4.7	2.1	1.41	2.86	12.3	6	9.3	8.5	7.8	8.16	4.8	1.22	1.74	1.95
Sm_ppm_m147	7.9	1.15	1.91	5.86	4.02	2.07	5.12	15.6	8.9	10.5	13.1	9.8	10.74	8.8	2.75	3.74	4.09
Eu_ppm_m153	0.212	0.028	0.059	1.7	1.06	0.038	0.934	1.73	1	1.99	2.89	1.77	3.77	0.54	0.339	0.409	0.472
Gd_ppm_m157	31.8	6.11	11.9	24.1	15.9	9.9	21.2	55.7	40.4	38.7	49.2	37	46.5	37.3	16.8	18.9	19.6
Tb_ppm_m159	9.38	2.05	3.66	6.57	4.78	3.38	7.02	15.12	11.7	10.07	14.34	11.1	13.78	11	5.4	6.11	6.02
Dy_ppm_m163	113.4	28.7	47.3	76.4	53.4	42.3	85.5	170.4	144	113.4	161.3	129	155.4	131	68.9	75.3	76.2
Ho_ppm_m165	41.1	12.6	18.34	27	19.49	16.7	30.1	57.9	52.1	36.6	51.6	44	55	46.9	25.6	27.9	28.1
Er_ppm_m167	186	60.7	83.8	123	90.1	80.9	140.9	250.3	238	162	228.6	194	244	210	118.2	128.9	128.8
Tm_ppm_m169	36.6	13.6	17.72	24.1	18.18	17.6	29.9	49.1	49.6	31.1	43.5	38.1	47.9	41.9	24.5	26.6	26.17
Yb_ppm_m173	319	127.9	159.8	215	169.5	161	258	409	425	261	369	330	416	358	214.7	234.4	222.2

Lu_ppm_m175	63.6	27.2	32.1	45.6	35.1	32.4	52.6	80.3	84	50.7	72.6	62.1	81.3	69.1	42.7	46.4	44.5
Hf_ppm_m179	9630	11700	9170	7150	7690	10450	8030	8170	10070	8630	9420	9790	7890	9300	8910	9280	8560
Ta_ppm_m181	0.84	1.45	0.645	0.328	0.273	1.1	0.563	0.58	0.802	0.528	1.03	0.947	0.521	0.916	0.807	0.773	0.623
Pb_ppm_m206	210.5	204	120.7	59.9	51.8	147	65.1	88.7	137.9	132	160	201	68.3	140.2	95.7	94.2	60.3
Pb_ppm_m207	26.9	27.5	16.06	7.15	5.8	19.3	8.71	11.93	19.3	16.6	20.7	25.7	8.78	18.6	12.97	13	7.93
Th_ppm_m232	98.3	50.5	49.5	52.9	41.9	49	58.5	88.2	109	171	215.2	248	78.4	76	44.7	44.4	30.3
U_ppm_m238	125.6	130.4	77	40.3	37.4	97	39.9	55.3	92.6	88.1	110.1	156	45.4	86.8	61.1	59.9	38.3

Geological unit	Standard NIST612												
Sample code	G_NIST612_1	G_NIST612_2	G_NIST612_3	G_NIST612_4	G_NIST612_5	G_NIST612_6	G_NIST612_7	G_NIST612_8	G_NIST612_9	G_NIST612_10	G_NIST612_11	G_NIST612_12	G_NIST612_13
P_ppm_m31	38	71	65		57		53		54		71	80	
Ca_ppm_m43	84200	84500	83800	86700	88700	84000	87800	83300	85000	85500	82800	86900	83800
Sc_ppm_m45	40.7	41.4	39.9	41.5	41.9	41.5	42	40.7	41.1	41.1	40	41.3	40.7
Ti_ppm_m49	44.1	43	44.6	45.1	45.8	43.1	44.3	41.7	44.2	45.6	42.4	43.5	45.8
Cu_ppm_m63	36.83	38.2	35.4	37.7	37.4	37	37.9	36.8	37	38.3	36.2	36.8	36.6
Rb_ppm_m85	32.1	31.4	30.7	31	31.4	31.5	32.3	30.7	32.1	31.2	31.9	30.8	31.6
Sr_ppm_m88	78.9	78	78.3	78.6	78.4	78.3	78.7	78	78.6	78.4	78.3	78.6	78.2
Y_ppm_m89	38.16	37.79	37.9	38.1	38	37.94	38.1	37.8	38.1	38	38	38.1	37.9
Nb_ppm_m93	39.88	40.3	39.74	40.2	40.1	39.9	40.4	39.6	40.2	40	39.9	40.4	39.7
Ba_ppm_m138	40.3	40.8	38.1	39.3	39.5	39.9	41.3	38.7	39.9	39.9	39	40	39.7
La_ppm_m139	36.05	35.57	35.78	35.8	35.8	35.8	35.9	35.7	35.85	35.8	35.8	35.9	35.7
Ce_ppm_m140	38.8	38.7	38.64	38.7	38.8	38.6	38.8	38.6	38.7	38.8	38.7	38.5	39
Pr_ppm_m141	37.21	36.95	37.19	37.21	37.2	37.2	37.3	37.1	37.3	37.2	37.2	37.28	37.1
Nd_ppm_m146	37.4	36.4	34.7	35.1	36.2	35.4	36.4	35.1	35.8	36.5	36	35.5	36.5

Sm_ppm_m147	40.1	38.4	36.2	37.5	39.2	37.4	38.3	36.9	38.4	38.6	37.5	38.5	38.5
Eu_ppm_m153	36.3	35.6	33.69	35.09	34.8	34.7	35.02	34.2	35.6	35.25	34.4	35.16	35.5
Gd_ppm_m157	36.8	36.8	36.4	36.9	36.7	36.9	37	36.1	36.9	36.7	36.7	36.4	37.1
Tb_ppm_m159	36.14	35.9	35.97	36	36	36	36.1	35.9	36.05	36	36	36.2	35.8
Dy_ppm_m163	36.3	35.77	36	36.1	36	36	36	35.9	36	36	36	36.07	35.9
Ho_ppm_m165	38.2	37.8	37.96	38	38	37.9	38.2	37.8	38.1	38	38	38.06	37.9
Er_ppm_m167	38.2	38	37.69	38.4	37.9	38.2	38.1	37.1	38.5	38	37.9	37.9	38.2
Tm_ppm_m169	38.24	37.76	38	38	38	37.99	38	37.9	38	37.99	38	37.97	38.03
Yb_ppm_m173	40.5	40.6	36.8	39	39.7	38.6	39.2	37.7	39.8	39.7	38.5	39.7	39.6
Lu_ppm_m175	37.94	37.65	35.17	36.5	36.9	37.14	37.4	35.6	37.4	37.38	36.44	37.05	37.03
Hf_ppm_m179	38.8	37.8	35.6	36.4	37.2	37	38.5	35.4	37	38.1	37	36.8	37.2
Ta_ppm_m181	41.81	40.9	38.04	39.8	39.5	40.3	40.5	38.6	40.6	40.7	39.8	40.26	39.8
Pb_ppm_m206	40.5	38.8	36.9	38.3	38.9	38.4	39.2	37.6	38.4	39.2	38	39.1	38.4
Pb_ppm_m207	38.9	38.3	38.5	38.6	38.6	38.4	38.8	38.1	38.9	38.6	38.5	38.9	38.3
Th_ppm_m232	38.6	38.3	35.9	37.6	38.4	38.09	38.7	36.6	38.1	37.9	37.9	37.78	37.5
U_ppm_m238	38.1	37.86	35.81	37.46	37.8	37.6	38.1	36.3	38	37.84	36.8	37.54	37

Geological unit	Standard NIST610												
Sample code	G_NIST610_1	G_NIST610_2	G_NIST610_3	G_NIST610_4	G_NIST610_5	G_NIST610_6	G_NIST610_7	G_NIST610_8	G_NIST610_9	G_NIST610_10	G_NIST610_11	G_NIST610_12	G_NIST610_13
P_ppm_m31	390	375	343	369	402	392	411	392	432	429	450	451	454
Ca_ppm_m43	87400	82700	83500	84400	85200	84400	80900	83900	83100	84300	80600	82500	82500
Sc_ppm_m45	492	474	477	475	487	485	473	476	486	481	473	466	470
Ti_ppm_m49	528	506	514	505	522	525	491	508	518	516	499	504	510
Cu_ppm_m63	498	472	447.4	427.9	444	442	434	435	442	442	441	437	434
Rb_ppm_m85	478	446	420	425	435	428	421	420	428	426	418.6	415	425
Sr_ppm_m88	559	530	534	525	527	530	507	519	524	515	522	509	517
Y_ppm_m89	494	461	467	462	471	465	447	453	459	459	463	453	458

Nb_ppm_m93	528	502	499	499	503	491	477.1	488	489	487	490	478	492
Ba_ppm_m138	517	489	451	460	473	465	451	459	461	463	460	457	463
La_ppm_m139	477	453	455	442	451	449	431	450	443	444	446	443	444
Ce_ppm_m140	505	476	472	473	465	469	461	466	470	455	465	462	465
Pr_ppm_m141	485	459	463	455	448	450	436	449	453	439	457	445	444
Nd_ppm_m146	500	467	435	443	448	448	438	432	448	443	445	437	443
Sm_ppm_m147	524	490	453	465	467	466	457	449	467	463	459	458	463
Eu_ppm_m153	504	470	436	442	452	446	442	437	449	448	446	445	449
Gd_ppm_m157	480	450	451	445	447	436	426	434	440	435	438	437	440
Tb_ppm_m159	463	438	440	433	435	429	410.8	425	429	427	430	423	427
Dy_ppm_m163	471	450	462	436	447	437	421.6	444	450	434	448	441	441
Ho_ppm_m165	494	465	464	462	455	455	439	449	448	449	458	449	447
Er_ppm_m167	505	473	466	464	462	452	446	447	455	449	459	453	453
Tm_ppm_m169	476	452	469	455	454	452	444	450	449	451	458	450	454
Yb_ppm_m173	529	494	459	460	468	469	461	453	465	464	468	461	462
Lu_ppm_m175	506	472	439	443	457	450	441	432	444	446	448	445	448
Hf_ppm_m179	500	463	441	445	448	448	433	429	441	440	435	431	434
Ta_ppm_m181	547	512	480	485	501	493	475	474	492	488	490	486	485
Pb_ppm_m206	469	442.1	417.7	423	435	434	419	418	437	434	435	437	431
Pb_ppm_m207	449	429.1	439.3	438	435	441	420	429	438	433	443	435	436
Th_ppm_m232	509	480	461	461	470	471	461	448	467	465	463	458	463
U_ppm_m238	515	487	466	465	483	470	463	455	470	471	468	462	469

Geological unit	Standard 91500											
	Z_91500_1	Z_91500_2	Z_91500_3	Z_91500_4	Z_91500_5	Z_91500_6	Z_91500_7	Z_91500_8	Z_91500_9	Z_91500_10	Z_91500_11	Z_91500_12
Sample code												
P_ppm_m31												
Ca_ppm_m43												
Sc_ppm_m45	89.7	87.8	85.5	82.1	81.6	82.1	81.8	80.4	78.8	78.1	76.4	76.6

Ti_ppm_m49	5.9	7	6.51	5.9	6.8	5.42	5.33	6.37	4.9	5.99	5.18	6.5
Cu_ppm_m63												
Rb_ppm_m85												
Sr_ppm_m88	0.083	0.11	0.134			0.071	0.067	0.081	0.083		0.06	0.076
Y_ppm_m89	141.7	152	143.8	149.2	142.6	123.4	126.5	128.6	125.2	137.9	130.2	136.2
Nb_ppm_m93	1.19	1.18	1.012	1.067	1.011	0.945	0.965	0.922	0.955	0.954	0.967	0.949
Ba_ppm_m138		0.029	0.08									
La_ppm_m139												
Ce_ppm_m140	2.93	3.06	2.83	2.83	2.79	2.57	2.51	2.69	2.51	2.78	2.7	2.6
Pr_ppm_m141	0.0104	0.01	0.0123							0.0135		0.0116
Nd_ppm_m146	0.182	0.213	0.238	0.134	0.205	0.193	0.18	0.155	0.179	0.199	0.196	0.189
Sm_ppm_m147	0.345	0.57	0.43	0.363	0.337	0.417	0.407	0.411	0.357	0.34	0.369	0.423
Eu_ppm_m153	0.223	0.268	0.226	0.234	0.215	0.189	0.171	0.195	0.214	0.228	0.206	0.21
Gd_ppm_m157	2.08	2.42	2.1	2.4	2.15	1.88	1.95	1.92	1.87	2.19	1.94	2.15
Tb_ppm_m159	0.774	0.877	0.798	0.866	0.781	0.688	0.691	0.711	0.719	0.8	0.774	0.782
Dy_ppm_m163	11.57	12.86	11.57	11.66	11.13	9.88	10.43	10.32	9.45	10.87	10.44	11.2
Ho_ppm_m165	4.75	5.18	4.89	4.78	4.72	4.17	4.3	4.24	4.14	4.59	4.29	4.69
Er_ppm_m167	26.46	29	26.87	26.9	25.1	23.47	23.96	23.65	23.14	26.01	24.41	25.29
Tm_ppm_m169	6.73	7.28	6.6	6.51	6.41	6.06	6.13	5.99	5.94	6.44	6.23	6.33
Yb_ppm_m173	69.6	73.1	67.4	67.2	67.6	61.8	61.2	61.1	59.8	65.2	63.1	65.1
Lu_ppm_m175	14.32	15	13.76	13.96	13.88	12.65	12.83	12.68	12.42	13.32	12.66	13.27
Hf_ppm_m179	7060	6660	6450	6260	6110	6530	6490	6440	6430	5990	5900	5650
Ta_ppm_m181	0.573	0.562	0.519	0.489	0.475	0.544	0.515	0.51	0.507	0.449	0.432	0.469
Pb_ppm_m206	61.5	68.8	61.2	64.8	63.2	55.8	55.8	57.7	54	58.9	57	60.7
Pb_ppm_m207	4.97	5.49	5.37	5.07	5.18	4.33	4.7	4.62	4.42	4.91	4.83	4.9
Th_ppm_m232	29.4	33	29.85	31	30.4	25.1	25.35	26.58	25.31	29.14	27.39	29.28
U_ppm_m238	85.6	94.4	85.9	88.2	87.3	77.1	76.4	77.9	75.6	82.3	78.5	82.4

**APPENDIX C: Abstract – Event: 14th SGA Biennial Meeting (2017) – Title:
Paleoproterozoic porphyry-related Au $\pm$ Cu ($\pm$ Mo) systems in the Alta Floresta Gold
Province, southern Amazonian Craton, Brazil: the case of the X1 and Paraíba deposits**

Paleoproterozoic porphyry-related Au ± Cu (± Mo) systems in the Alta Floresta Gold Province, southern Amazonian Craton, Brazil: the case of the X1 and Paraíba deposits

Veronica Godinho Trevisan, Roberto Perez Xavier, Rosana Mara Rodrigues, Juliana Oliveira Bartolomeu, José Henrique S. N. Matos, Maria José Mesquita
Instituto de Geociências - Universidade Estadual de Campinas (UNICAMP), Campinas (SP), Brazil

Rafael Rodrigues de Assis

Instituto de Geociências e Ciências Exatas - Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Rio Claro (SP), Brazil

Abstract. The Alta Floresta Gold Province (AFGP) consists of Paleoproterozoic plutono-volcanic sequences (1.98 - 1.75 Ga) originated from a series of successive magmatic arcs that accreted to the southwestern margin of the Central Amazonian Province. The province contains a significant number of intrusion-hosted gold systems, some of which temporally and spatially associated with 1.8-1.7 Ga porphyries. Among these, X1 and Paraíba deposits are two important examples in which the Au ± Cu (± Mo) mineralizations, both disseminated or in quartz veins, are partially hosted, respectively, by ca. 1.78 Ga and ca. 1.80 Ga quartz-feldspar porphyries of tonalite and syenogranite composition. In both deposits, the gold (Ag = 5 - 30%)-bearing pyrite-chalcocopyrite-molybdenite zones are contained within phengitic muscovite-chlorite-rich zones with distal propylitic and potassic alteration with K-feldspar. Molybdenite Re-Os and pyrite Pb-Pb systematics constrain the mineralization age in the 1.78 - 1.84 Ga range, which overlaps with the host porphyry ages. Hence, the X1 and Paraíba deposits represent magmatic-hydrothermal systems that bear broad similarities to porphyry gold-rich systems, but that have formed at deeper crustal levels with a significant involvement of magmatic CO₂-rich fluids.

Keywords: Amazonian Craton, Alta Floresta Gold Province, porphyry-related systems, gold mineralization.

1 Introduction

The Alta Floresta Gold Province (AFGP) is located in the southern sector of the Amazonian Craton, between the Ventuari-Tapajós (2.0 - 1.8 Ga) and Rio Negro-Juruena (1.80 - 1.55 Ga) geochronological provinces (Tassinari & Macambira 1999) in the Mato Grosso state, Brazil. The province outlines a NW-SE to E-W-striking belt of 500 km extension and 30 km wide containing plutonic-volcanic sequences generated in continental arc settings during the Paleoproterozoic (1.95 - 1.75 Ga; Souza et al. 2005). A significant number of high grade, low tonnage (< 5 t) gold systems occur throughout the province: which on the basis of mineralization style and metallic association, are grouped into: (1) disseminated and structurally-controlled vein-type Au ± Cu (± Mo) deposits (e.g. Luizdo, Pó Quente, X1, Serrinha and Paraíba deposits); (2)

structurally-controlled vein-type Au + Zn + Pb ± Cu deposits (e.g. Francisco, Bigode and Luiz deposits); and (3) disseminated Cu + Mo ± Au deposits (e.g. Ana and Jaca deposits). These deposits are commonly hosted by relatively oxidized I-type, calc-alkaline to sub-alkaline, medium to high potassium, metaluminous to slightly peraluminous granitic intrusions of tonalite to syenogranitic compositions and quartz-feldspar porphyries representative of A₂-type post-orogenic alkaline granites of ages from 1.98 to 1.78 Ga (Pires de Barros 2007; Assis 2011, 2015).

Group (1) is by far and large the most abundant in the province and from which gold has been exploited by artisanal mining since the 1980's. These intrusion-hosted deposits have been interpreted as orogenic gold systems (Santos et al. 2001), intrusion-related gold systems (Pires de Barros 2007), or similar to gold-rich porphyry systems (Moura et al. 2006). In this work we use the porphyry-related X1 and Paraíba Au-(Cu-Mo) deposits to argue on the basis of wall-rock alteration, ore associations, fluid regimes, and U-Pb, Pb-Pb and Re-Os geochronology, that these deposits may be deep crustal level analogues of gold-rich, copper and molybdenium-poor, porphyry systems.

2 Host rocks and Hydrothermal Alteration

The X1 Au ± Cu (± Mo) deposit is hosted by an equigranular to porphyritic biotite granodiorite and a quartz-feldspar porphyry of tonalitic composition (Rodrigues 2012). The porphyry is devoid of mafic phases and contains 5-10% quartz and plagioclase phenocrysts in an aphanitic to very-fine-grained matrix composed of quartz (60-75%), plagioclase (15-30%) and K-feldspar (1-8%), with apatite, zircon and rutile as accessory phases (Fig. 1A). Its geochemical composition points to a highly evolved, calc-alkaline, high K, sub-alkaline and slightly peraluminous magma formed in within a continental arc onset. Both the biotite granodiorite and the quartz-feldspar porphyry at the X1 deposit have been variably affected by the following hydrothermal alteration types: (1) strong potassic alteration with orthoclase ± hematite, usually

distal to the mineralized zones; (2) phyllic alteration zones with coarse-grained muscovite + quartz + sulphides that partially or completely replace that potassic alteration within either the core of the granitic host as alteration halos around quartz-rich veins (3) propylitic alteration with chlorite + epidote + calcite $\pm$ apatite $\pm$ rutile $\pm$ hematite $\pm$ pyrite distal to the ore zones; (4) distal and restricted chloritic alteration; and (5) pervasive to late calcite-rich veinlets, sometimes with bladed calcite (Rodrigues 2012).

The host rocks of the Paraíba Au-(Cu-Mo) deposit include fine-grained equigranular biotite gneiss with an alkali-feldspar granitic composition, medium to coarse-grained equigranular biotite tonalite, and quartz-feldspar porphyry of syenogranitic composition (Trevisan 2015; Bartolomeu 2016). The quartz-feldspar porphyry form meter-wide dikes intrusive into the tonalite and gneiss. It consists of about 20% phenocrysts of microcline (40%), quartz (40%) and orthoclase (20%) immersed into a medium to fine-grained matrix containing microcline (35%), quartz (40%), plagioclase (20%), orthoclase (3%) and biotite (2%) (Bartolomeu 2016; Fig. 1B).

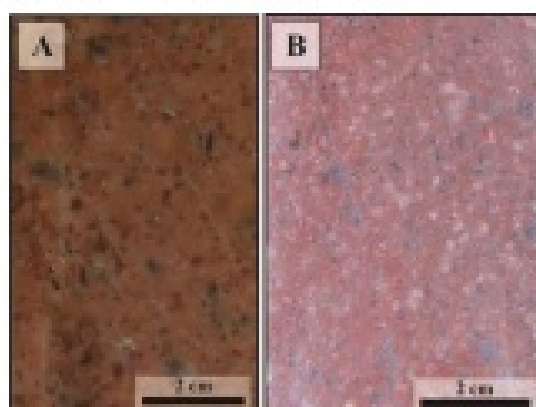


Figure 1. (A) XI quartz-feldspar porphyry with pyramidal quartz phenocrysts; (B) Paraíba quartz-feldspar porphyry with microcline, quartz and orthoclase phenocrysts immersed in a matrix affected by strong potassic alteration with K-feldspar.

Potassic alteration with K-feldspar (orthoclase + quartz + hematite $\pm$ microcline $\pm$ pyrite $\pm$ molybdenite) and propylitic alteration (epidote + clinzoisite + chlorite + carbonate $\pm$ quartz $\pm$ magnetite) predominate outwards to the mineralizing zones. Phyllic alteration zones defined by sericite and/or coarse-grained muscovite + quartz $\pm$ carbonate $\pm$ magnetite $\pm$ sulphides are proximal to the gold $\pm$ copper $\pm$ molybdenium vein zones within the tonalite and quartz-feldspar porphyry, together with more subordinate silicification represented by fronts of replacement or aggregates and quartz infill alteration exemplified by quartz veins, stockwork zones, fractures or hydrothermal breccias. Particular in shear zone hosted gold-sulphide veins, potassic alteration with biotite + quartz + magnetite + carbonate + sulfides is replaced by chloritic alteration (chlorite + quartz + carbonate $\pm$

magnetite $\pm$ rutile $\pm$ titanate $\pm$ zircon $\pm$ sulphides). Additionally, also occur late veinlets of variable composition (carbonate, quartz, quartz + carbonate, epidote, sericite and chlorite) (Trevisan 2015; Bartolomeu 2016).

3 Gold $\pm$ copper ($\pm$ molybdenium) ore zones

The gold mineralization at the XI deposit occurs mainly disseminated within the phyllic alteration zones and more subordinately confined to quartz veins. The ore paragenesis consists of pyrite $\pm$ chalcocopyrite $\pm$ molybdenite $\pm$ rutile $\pm$ hematite, and gold grades range from 0.5 to 10 g/t. Quartz veins usually exhibit a centimeter to meter-wide phyllic alteration halo and contain the same sulphide mineral assemblage, but lower gold contents (<0.2 ppm). Within the phyllic zone, chalcocopyrite and molybdenite generally fill pyrite, quartz and muscovite interstices, or occur as small inclusions within pyrite. Gold (Ag = 20–30 wt.%) appears as small inclusions (~ 20 μ m) in pyrite together with bornite (BiTe), hessite (Ag₂Te), galena, monazite, sphalerite, apatite and molybdenite (Figs. 2A–B; Rodrigues 2012).

Gold $\pm$ copper ($\pm$ molybdenium) mineralization at the Paraíba deposit mainly occurs associated with meter-wide gold lode veins controlled by a N05W / 65–70NE dextral strike-slip shear zone, as well as with a set of 5 to 20 cm wide veins. To a lesser extent, mineralization also occurs disseminated at the Paraíba deposit, particularly in the quartz-feldspar porphyry within the silicification, phyllic and potassic (with K-feldspar) alteration halos. The ore zones mainly comprise pyrite $\pm$ chalcocopyrite $\pm$ molybdenite and minor magnetite. Covellite and hematite commonly replace chalcocopyrite. Galena, sphalerite, scheelite, barite, monazite, xenotime, Bi-Te rich phases, bismuth, selenite (PbCuBiS₃), oxyallanite, hessite (Ag₂Te), stützite (Ag₁₀Te₃) and thorite occur in subordinate concentrations, often as inclusions within pyrite. Gold (Ag = 5–24 wt.%) occurs as inclusions (2–20 μ m) in pyrite and chalcocopyrite (Fig. 2C–D; Trevisan 2015; Bartolomeu 2016).



Figure 2. X1 deposit: (A) Vein and pod filled by milky-quartz within coarse-grained muscovite + quartz and massive pyrite; (B) Massive pyrite and molybdenite in a muscovite + quartz alteration in the major ore-style; Paraíba deposit: (C) Quartz vein in shear zone filled by massive pyrite + chalcocopyrite + magnetite in the major ore-style; (D) Quartz vein with massive pyrite and fine to medium-grained molybdenite.

4 Fluid regimes

Fluid inclusions in muscovite-sulphide-quartz veins from the X1 deposit are dominated by intragranular swarms or plane arrays of coexisting two-phase aqueous and three-phase $\text{H}_2\text{O}-\text{CO}_2$ inclusions at room temperature (Rodrigues 2012). The aqueous inclusions have variable salinities (2.0–26.0 wt.% eq. NaCl), very low CO_2 contents as recorded by clathrate nucleation and homogenization temperatures ranging from 126.5 to 268.4°C. The $\text{H}_2\text{O}-\text{CO}_2$ inclusions are of low salinity (6.0–9.0 wt.% eq. NaCl) and display higher homogenization temperatures (251.6 – 334.6°C). The fluid inclusions assemblages containing both types of inclusions show a wide variation in the degree of fill (0.05–0.95) which suggests heterogeneous entrapment.

Four types of inclusion fluids are recognized in the main gold-bearing quartz-sulphide vein of the Paraíba deposit: (1) two-phase aqueous inclusions; (2) multi-solid aqueous inclusions; (3) $\text{H}_2\text{O}-\text{CO}_2$ inclusions; and (4) monophasic inclusions. Type 1 inclusions have low salinity (< 10 wt.% eq. NaCl) and yield variable homogenization temperatures ranging from 79°C to 234°C. The type 2 inclusions contain an aqueous phase ($\text{H}_2\text{O}_{\text{L}}$), a water

vapour ($\text{H}_2\text{O}_{\text{V}}$) bubble and one or more solid phases, possibly daughter minerals (halite and carbonate). The inclusions containing $\text{H}_2\text{O}_{\text{L}}$ + $\text{H}_2\text{O}_{\text{V}}$ + halite yield salinities up to 40.3 wt.% NaCl eq. and homogenization temperatures ranging from 286.5°C to 362°C. The aqueous-carbonic inclusions (type 3) are the dominant type in the Paraíba mineralized vein quartz and display degree of fill in the 0.10–0.80 range. Salinity is generally low (up to 8.7 wt.% NaCl eq.) and homogenization temperatures vary from 160°C to 316°C, with higher concentrations at 285°C (Trevisan 2015). Previous microthermometry investigations (Silva & Abram 2008) have shown that type 4 inclusions consist essentially of a CO_2 -liquid phase.

5 Temporal relationships between granitic hosts and the Au ± Cu (± Mo) ore

Zircon U-Pb dating using SHRIMP IIc gave a crystallization age of 1.901 ± 13 (MSWD = 1.3) and 1.784 ± 10 Ma (MSWD = 0.54) for the biotite granodiorite and quartz-feldspar porphyry, respectively, at the X1 deposit. The X1 quartz-feldspar porphyry exhibits TDM ages of 2.18 to 2.12 Ga and $\epsilon\text{Nd}(t)$ values ranging from -1.7 to -1.39 suggesting a mixing between a metasomatized mantle and crust (Assis 2015). Re-Os age obtained in molybdenite separates yielded a weighted average model age at 1.786 ± 5 Ma (MSWD = 0.16) (Assis, 2015).

At the Paraíba deposit, zircon U-Pb dating also by SHRIMP IIc provided a crystallization age of 2.014 ± 5.1 (MSWD = 2.0; Trevisan 2015) and 1.820 ± 17 Ma (MSWD = 0.4; unpublished data) for the biotite tonalite and quartz-feldspar porphyry, respectively. The geochemical investigation of the Paraíba quartz-feldspar porphyry is still under progress. A Pb-Pb age obtained in pyrite separates provided a geochronometry independently age of 1.841 ± 22 (MSWD = 1.6; Santos 2011) for the Paraíba Au-(Cu-Mo) mineralization.

6 Conclusions

The continental arc setting attributed to the AFGP plutono-volcanic sequences, the close spatial relationship between the Au ± Cu (± Mo) mineralizations and granitic plutons, and the types and distribution of the hydrothermal alteration, collectively suggest that the X1 and Paraíba deposits may be genetically linked to the emplacement of magmatic-hydrothermal systems. This is further corroborated by the molybdenite Re-Os and pyrite Pb-Pb ages of 1.786 Ma and 1.841 Ma that remarkably overlap the crystallization ages of the porphyries at the X1 (1.784 ± 10 Ma) and Paraíba (1.820 ± 17 Ma) deposits, respectively. Similar age interval has also been obtained for other intrusion-hosted gold deposits of the province: Re-Os model ages of pyrite are in the range of 1.782 ± 8.9 to 1.790 ± 9.4 Ma for the Lúrio and of 1.792 ± 9.0 to 1.784 ± 11 Ma for the Pé Queiro deposits (Assis, 2015); Re-Os model age of 1805 ± 7 Ma in ore-related molybdenite at the Juruena gold district in the northern

sector of the province (Acevedo 2014). Nevertheless, porphyry outcrops or interception of porphyries by drill cores have not been reported so far in these cases. This age interval is further confirmed by the sericite $^{40}\text{Ar}/^{39}\text{Ar}$ ages between 1.779 ± 6.5 and 1.777 ± 6.3 Ma from the sericitic alteration halo of the Francisco gold-base metal deposit, which are in agreement to the 1.774 ± 7.5 Ma União do Norte porphyry (Assis 2015). Hence, the interval of 1.782 Ma – 1.841 Ma seems to mark an important regional gold metallogeny episode in the Alta Floresta Province. The regional felsic magmatism in the province that displays a broad temporal association with this 1.78 – 1.84 Ga gold event includes volcanics and granitic intrusions that belong to the Colider group (1.82 – 1.77 Ga), the Paranaíba (1.81 – 1.79 Ga) and Teles Pires intrusive suites (1.78 – 1.75 Ga). These units show no evidence of regional metamorphism, but have been extensively affected by regional E-W to NW-SE-striking brittle-ductile shear zones. The first two units show affinities to relatively oxidized I-type, calc-alkaline, medium to high K, metaluminous to slightly peraluminous plutonic-volcanic sequences originated in continental arc settings and that commonly contain intrusion-hosted deposits/occurrences (e.g., Juruena gold district; Acevedo 2014). The latter suite, on the other hand, represents post-orogenic to anorogenic felsic magmatism and hitherto shows no reports of hosting gold deposits. Despite the lack of consensus regarding the regional tectonic framework of the AFGP, the Colider group and Paranaíba intrusive suites have been interpreted as part of the evolution of the Juruena magmatic arc (~1815 to 1780 Ma; Silva & Abreu 2008; Duarte 2015). Within this framework, the XI and Paraíba porphyries and the accompanying Au-(Cu-Mo) mineralizations were likely emplaced either during late accretionary orogeny or post-orogenic extensional stages (Assis 2015; Duarte 2015).

At the deposit scale, ex-solution of $\text{H}_2\text{O}-\text{CO}_2$ fluids from the crystallizing porphyries may have triggered the magmatic-hydrothermal system. The CO_2 -rich nature of these magmatic fluids suggest that emplacement of the causative porphyries likely occurred at deep crustal levels, since the solubility of volatiles in magma is controlled dominantly by pressure (Lowenstein 2001). Fluid phase separation accompanied by progressive mixing with externally-derived fluids (metamorphic?) causing CO_2 dilution, cooling (400°C–350°C) and increase in the $f\text{O}_2$, may have caused the lowering of the solubility of Au and other metals.

On the basis of the geotectonic setting, combined with the geological characteristics of the mineralizations and their temporal relationship with the porphyries, we argue that the ore-forming processes at the XI and Paraíba Au-(Cu-Mo) deposits were similar to those observed in porphyry Cu $\pm$ Mo $\pm$ Au, emplaced at deeper crustal levels. In a similar scenario, paleoproterozoic Cu-Au and Cu-Mo $\pm$ Au porphyry-type mineralizations in association with sub-volcanic felsic rocks formed in continental magmatic arc settings, together with calc-alkaline volcanic rock hosting epithermal Au and base metal mineralization have also been reported in the Tapajós Gold Province in the

southern Amazonian Craton (Juliani et al. 2005).

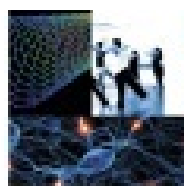
Acknowledgements

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APPENDIX D: Abstract – Event: XXV Congresso Interno de Iniciação Científica da Unicamp (2017) – Title: Análise geoquímica das rochas graníticas do setor leste da Província Aurífera de Alta Floresta, MT: caracterização de séries magmáticas e ambientes geotectônicos



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Análise geoquímica das rochas graníticas do setor leste da Província Aurífera de Alta Floresta, MT: caracterização de séries magmáticas e ambientes geotectônicos.

Tainá N. Almeida*, Maria José Mesquita, Veronica G. Trevisan, Igor C. Moreira

Resumo

A presente pesquisa consiste na construção e interpretação de um banco de dados georreferenciados de análises geoquímicas em rocha total, nos granitóides existentes na porção leste da Província Aurífera de Alta Floresta, sul do Cráton Amazônico. Os dados compilados foram refinados de diferentes trabalhos da bibliografia, resultando em 209 amostras, e foram divididos em três grupos de acordo com as idades de cristalização das rochas analisadas: (1) 1,97 a 1,93 Ga; (2) 1,93 a 1,8 Ga; e (3) 1,8 a 1,73 Ga. A partir dos dados compilados, foram construídos diagramas que indicaram tendências e assinaturas geoquímicas diferentes para cada grupo. A análise dos diagramas mostra campos muito amplos para o grupo 1, que dificultaram a interpretação; campos bem definidos para o grupo 2 que indicam relação com magmatismo de arco; e assinaturas de ambiente pós-colisional a intraplaca para o grupo 3.

Palavras-chave: Província Aurífera de Alta Floresta, granitos, geoquímica de rocha total.

Introdução

A PAAF, localizada na porção sul do Cráton Amazônico, consiste de seqüências plutono-vulcânicas com idades do Paleoproterozóico ao Mesoproterozóico. Dentro da província, o setor leste hospeda um grande número de depósitos com associação metálica representada por Au - Cu (-Mo), Au + Zn + Pb ± Cu e Cu - Mo. Ainda que seja uma província aurífera potencial, esta região carece de mapeamentos e estudos de detalhe. O objetivo deste estudo é reunir e interpretar o conhecimento geoquímico já existente sobre os granitos da área, a partir de uma melhor compreensão das séries magmáticas dessas rochas, bem como do seu ambiente geotectônico de formação, de modo a auxiliar na construção de modelos exploratórios mais robustos para os depósitos.

Resultados e Discussão

Um total de 209 amostras analisadas em 16 trabalhos prévios diferentes foram compiladas e divididas em 3 grupos de acordo com suas idades (Tabela 1) baseados nos três eventos magmáticos definidos por Assis (2015)¹.

Tabela 1. Unidades geológicas da PAAF divididas em três grupos de acordo com suas idades, modificado de Assis¹.

Grupo	Unidade Geológica
1 (1,97 a 1,93 Ga)	Granito Novo Mundo, Granito Anáglio, Granito Nhandu
2 (1,93-1,8 Ga)	Granodiorito X1, tonalito Pé Quente, Suite Intrusiva Metupá, Granodiorito Joropá, Granodiorito União do Norte
3 (1,8-1,73 Ga)	Suite Intrusiva Taléo Pires, Granito Peixoto, Pórfiro União do Norte

Com os dados separados nos três grupos, foi possível construir diagramas geoquímicos e, assim, fazer comparações entre os grupos. A Figura 1 mostra exemplo dos diagramas usados na pesquisa. O grupo 1 apresenta um trend magnésiano a ferroso, caráter variando entre cálcio-álcali e alcalino e tendência a uma assinatura de ambiente pós-colisional. O grupo 2 é fortemente magnésiano, de caráter cálcio-álcali e se insere no campo de granitos de arco magmático, com baixo teor de Y+Nb. Por fim, o grupo 3 apresenta caráter álcali-cálcico, trend predominantemente ferroso e assinatura geoquímica de ambiente pós-colisional a intraplaca, com enriquecimento em Y+Nb.

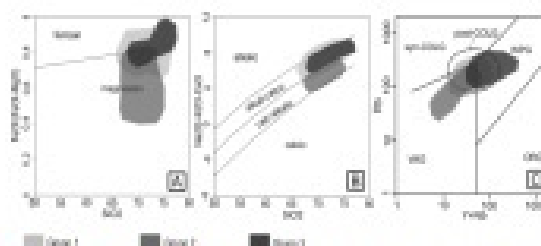


Figura 1. Diagramas geoquímicos contendo dados dos grupos 1, 2 e 3: (A) Diagrama de enriquecimento de FeO e MgO ($\text{FeO}/(\text{FeO}+\text{MgO})$ vs. SiO_2); (B) Diagrama de índice de alcalinidade ($\text{Na}_2\text{O} + \text{K}_2\text{O} - \text{CaO}$); (C) Diagrama de ambiente tectônico².

Conclusões

O grupo 1 não apresentou tendências claras, já que resultou em campos muito amplos em diagramas de elementos maiores, o que dificultou a classificação da série magmática. De acordo com os diagramas de elementos traço, porém, podem estar relacionados ao final de arcos magmáticos. O grupo 2, pertencente à série magmática cálcio-álcali, está provavelmente relacionado ao magmatismo do arco Juruena³. O grupo 3, pode ser classificado como parte da série alcalina, variando entre os cenários pós-colisional e intra-placa. É importante ressaltar que os diagramas de elementos maiores podem não apresentar alta confiabilidade, devido a alterações hidrotermais. Por fim, nota-se a necessidade de melhores estudos acerca dos grupos definidos e, talvez, uma possível redifinição dos dados.

Agradecimentos

Ao apoio financeiro do CNPq

¹ Assis R.R. 2015. *Depósitos auríferos associados ao magmatismo (Alta Floresta de Alta Floresta (MT), Cráton Amazônico: idade das mineralizações, geotectônica e fonte dos fluidos*. Tese de Doutorado, Instituto de Geociências, Universidade Estadual de Campinas, 367p.

² Frost, B.R.; Barnes, C.G.; Collins, W.J.; Arculus, R.J.; Ellis, D.J.; Frost, C.D. 2001. *A geochemical classification for granite rocks*. *Journal of Petrology*, 42:2657-2698.

³ Passero L.A. 1996. *Source and setting of granitic rocks*. *Lithos*, 39(4):128-133.

APPENDIX E: Abstract – Event: VIII Brazilian Symposium on Mineral Exploration (SIMEXMIN 2018) – Title: Fertility of Paleoproterozoic granites constrained by zircon trace element geochemistry in the Alta Floresta Gold Province, southern Amazon Craton, Brazil

Fertility of Paleoproterozoic granites constrained by zircon trace element geochemistry in the Alta Floresta Gold Province, southern Amazon Craton, Brazil

TREVISAN V.G.¹; XAVIER R.P.¹; GAO J-F.²; MATOS J.H.S.N.¹; ASSIS R.R.³

¹IG, UNICAMP; ²SKLOG, Chinese Academy of Sciences; ³IGc, USP

Porphyry deposits are economically important as they supply nearly 70, 50, and 25% of world's Cu, Mo, and Au, respectively. Although most are Mesozoic - Cenozoic, few examples from Precambrian are known, including the Paleoproterozoic Cu-Mo and Au-Cu-Mo porphyry-type deposits in the Tapajós and Alta Floresta Gold Provinces, southern Amazon Craton, suggesting that their potential in Precambrian cratons might be underexplored. Ore fertility indicators are needed by industry and can help focus exploration on prospective areas.

Zircon compositions have been recently proposed as good pathfinder for porphyry deposits. We tested the zircon fertility indicators in Paleoproterozoic (1989 to 1774 Ma) fertile and barren granites from the eastern sector of the Alta Floresta Gold Province (AFGP), and compared with those of Phanerozoic fertile and infertile and Yilgarn Archean barren suites from the literature. The zircon REE patterns of AFGP granites are similar to both Phanerozoic and Yilgarn Archean granites, with positive Ce and negative Eu anomalies, and depletion of LREE relative to HREE. The AFGP granites have lower zircon Ce/Ce* (fertile: 6.2–859; infertile: 6.1–971) and Eu/Eu* (fertile: 0.06–1.02; infertile: 0.04–0.77) than Phanerozoic fertile (Ce/Ce* = 14–3458; Eu/Eu* = 0.22–1.45) and barren suites (Ce/Ce* = 2.5–1120; Eu/Eu* = 0.002–0.31), but higher ratios than Yilgarn Archean suites (Ce/Ce* = 5–49; Eu/Eu* = 0.24–0.42), suggesting that the AFGP fertile granites are less hydrous than Phanerozoic fertile suites and more hydrous than Yilgarn Archean granites. Most AFGP fertile granites have higher Dy/Yb ratios (>0.3), defining a positive trend together with the Yilgarn Archean granites, which contrast with the negative trend for AFGP infertile and Phanerozoic fertile suites (Dy/Yb <0.3). It indicates that AFGP fertile compositional evolution was similar to Yilgarn Archean granites, whereas Phanerozoic fertile suites have a different genesis. This also suggests Yilgarn Archean granite magmas, and, to a lesser extent, AFGP fertile magmas are drier compared to Phanerozoic fertile suites. Zircon Ce/(U x Ti) ratios for AFGP granites are similar to or slightly higher than Phanerozoic fertile suites, whereas Yilgarn Archean granites are lower than both and similar to those of Phanerozoic infertile suites. This also suggests that Phanerozoic fertile and most AFGP granites are more oxidized than Yilgarn Archean granites.

The differences in zircon chemistry between Archean, Paleoproterozoic and Phanerozoic granites, suggest different processes were involved in forming magmas. We argue that AFGP Paleoproterozoic fertile granites might have been formed through lower- or infracrustal partial melting of mafic lower crust in the garnet stability field, similar to Yilgarn Archean granites, whereas Phanerozoic fertile suites were formed by intracrustal amphibole-dominated fractionation of mafic magmas. Granites formed by the former process have lower potential for porphyry mineralization due to low magmatic water contents and the lack of sulfur and metals (e.g. Cu and Mo) build-up in the melt.

APPENDIX F: Abstract – Event: VIII Brazilian Symposium on Mineral Exploration (SIMEXMIN 2018) – Title: Paleoproterozoic porphyry-related Cu-Mo and Au-base metal systems of the Alta Floresta Gold Province, southern Amazon Craton, Brazil

PALEOPROTEROZOIC PORPHYRY-RELATED Cu-Mo AND Au-BASE METAL SYSTEMS OF THE ALTA FLORESTA GOLD PROVINCE, SOUTHERN AMAZON CRATON, BRAZIL

Matos, J.H.S.N.¹; Xavier, R.P.¹; Santos, T.J.S.¹; Trevisan, V.G.¹

¹Universidade Estadual de Campinas (UNICAMP)

The Alta Floresta Gold Province (AFGP) (1.98-1.75 Ga) is located in the southern Amazon Craton and encompasses plutono-volcanic units from both the Tapajós-Parima (2,030-1,860 Ma) and Rodônia-Juruena (1,850-1,540 Ma) geotectonic provinces. Several disseminated Cu-Mo and structurally-controlled vein-type Au(-Cu) and Au-Pb-Zn(-Cu) deposits are concentrated in the União do Norte region, eastern part of the AFGP. The disseminated Cu-Mo deposit (Ana Cu-Mo) has been temporally and genetically related to a porphyry intrusion of 1,989±12 Ma, whereas the vein-type Au(-Cu) and Au-Pb-Zn(-Cu) deposits are confined along a NW-striking brittle-ductile sinistral shear zone. The shear zone consists of two ductile-brittle to brittle structural sets, D1' and D1''. D1' is marked by a vertical to sub-vertical N70W-striking mylonitic foliation continuous along strike for 4 km and width of 1-4 m. D1' hosts two types of auriferous sulfide-quartz veins (V1a and V1b) particularly in E-W inflections. V1a defines the Au+Cu deposit (Ana Au-Cu) in the D1 eastern part. V1b comprises the Au+Zn+Pb±Cu deposits in the center and western parts (Moc and Luiz deposits, respectively). D1'' structures cuts D1' and represents a set of several transcurrent faults and tension fractures with vertical dip, N20-40E and 1.5 km maximum extension. D1'' hosts Au mineralized magnetite-quartz veins (V2). Additionally, D1'' connects porphyry intrusion (Cu+Mo) with gold deposits at D1'. Open space-filling texture barren quartz veins (V3) crosscut all structures and display predominantly N60W strike with vertical dip. Hydrothermal chlorite in paragenesis with ore minerals in V1a and V1b show temperature of crystallization decreasing from east towards to the west (401–240 °C) according to the distance from the Ana Porphyry. Spatial and temporal relationships between structures indicate a single deformational event for D1' and D1'' formation. D1' was product of NE horizontal σ_1 under ductile-brittle transition, whereas D1'' developed in shallower crustal level as result of NW horizontal σ_3 . V3 represents the shallowest crustal level and a rotation of stress vectors. We suggest a stage of mineralization during 1.98 Ga, where Ana Porphyry was the source of mineralized fluids. In this case, D1'' structures worked as the main fluid pathway, whereas E-W inflections of D1' structure was the fluid traps that promoted the precipitation of Au-Cu closer and Au-base metals far from the porphyry intrusion, and V3 is the late epithermal event.

APPENDIX G: Abstract – Event: 15th SGA Biennial Meeting (2019) – Title: Geology setting and metallogensis of the Alta Floresta Province, southern Amazon Craton (Brazil)

Geology setting and metallogenes of the Alta Floresta Province, southern Amazon Craton (Brazil)

Veronica Trevisan, Roberto Xavier

Institute of Geosciences, University of Campinas, Brazil

Steffen Hagemann, Anthony Kemp, Robert Loucks

Centre for Exploration Targeting, The University of Western Australia, Australia

Jian-Feng Gao

State Key Laboratory of Ore Deposit Geochemistry, Chinese Academy of Sciences, Guiyang, China

Abstract. The Alta Floresta Province consists of Paleoproterozoic plutonic-volcanic sequences (2.01–1.75 Ga) originated from a series of successive magmatic arcs that accreted to the southwestern margin of the Central Amazon Province. The geologic framework of the eastern sector of the province is organized into: 2.8–1.97 Ga deformed metamorphic and metamorphosed granitic basement; 1.97–1.78 Ga I-type plutonic-volcanic and volcano-sedimentary sequences; 1.78–1.77 Ga post-orogenic and anorogenic plutonic-volcanic units; and Mesoproterozoic (~1.3 Ga) to Quaternary sedimentary sequences. The ore deposits are clustered into four main groups: (i) disseminated Au-Cu-Mo; (ii) structurally-controlled vein-type Au-Cu-Mo; (iii) disseminated Cu-Mo; and (iv) structurally-controlled vein-type Au-Zn-Pb-Cu. Groups (i) to (iii) are characterized by pyrite-chalcopyrite-molybdenite, whereas group (iv) consists of pyrite-sphalerite-galena-chalcopyrite-digenite. In most deposits, mineralization is contained within muscovite-chlorite-quartz-rich or silica-rich zones. The fluid regime of groups (i) and (ii) is mainly represented by CO₂-rich fluids, whereas group (iv) by two-phase aqueous fluids with heterogeneous degree of filling. Re-Os on pyrite and molybdenite and Pb-Pb on pyrite geochronology systematics constrain the mineralization age between 1.84 – 1.77 Ga. This overlaps with the ages of porphyritic granitoids, and in a regional scale with ages of the Colider and Teles Pires suites. These deposits represent magmatic-hydrothermal systems and are considered to share broad similarities with porphyry-epithermal deposits.

1 Introduction

The Alta Floresta Province (AFP) is located in the southern sector of the Amazon Craton, between the Tapejós-Parima (2.03 – 1.88 Ga) and Rondônia-Juruena (1.82 – 1.54 Ga) tectonic provinces (Santos et al. 2008) in the Mato Grosso state, Brazil. The province outlines a NW-SE to E-W-striking belt of 500 km extent and 30 km wide containing plutonic-volcanic sequences generated in continental arc to post-collisional settings during the Paleoproterozoic (2.01 – 1.75 Ga; Souza et al. 2005; Paes de Barros 2007; Assis 2015) (Fig. 1). This

province has historically been an important gold-producing region in Brazil (~4 Moz from 1990 and 1999), especially its eastern segment, where the number of mining sites totals over a hundred placer and medium to high-grade and low-tonnage (< 5t) "hard rock" gold deposits, mainly exploited by local artisanal prospectors (garimpeiros; Paes de Barros 2007). However, since the 1980's, junior companies, and more recently (2015 to today) major companies, have been exploring and discovering large-scale "hard rock" polymetallic deposits. The scarcity of outcrops, the Mesoproterozoic to Quaternary sedimentary cover over the plutonic-volcanic sequences, and poor understanding of geological controls for the mineralization have made exploration challenging in this region.

Based on the metallic association and mineralization style, the deposits are clustered into four main groups (Xavier et al. 2011; Trevisan et al. 2017): (i) disseminated Au-Cu-Mo mineralization (e.g. Luizão, Pé Quente, X1 and Serrinha deposits); (ii) structurally-controlled vein-type Au-Cu-Mo mineralization (e.g. Paraíba, Pazão, and Peteca deposits); (iii) disseminated Cu-Mo mineralization (e.g. Ana, Jaca and Paraíba deposits); and (iv) structurally-controlled vein-type Au-Zn-Pb-Cu mineralization (e.g. Francisco, Bigode, Camapato and Luit deposits).

This work provides an overview of the regional geology and main characteristics of these deposits based on host rocks, structures and vein textures, hydrothermal alteration, ore associations, fluid regime, and U-Pb, Pb-Pb and Re-Os geochronology. These deposits have been considered (Meurs et al. 2008; Xavier et al. 2011; Trevisan et al. 2017; Assis et al. 2017; Xavier et al. 2011; Trevisan et al. 2017; Assis et al. 2017) to represent magmatic-hydrothermal systems that display broad similarities to Au-Cu-Mo, Cu-Mo porphyry and Au-Zn-Pb-Cu epithermal systems.

2 Regional geology

In the eastern sector of the AFP, basement rocks of Orosirian age (2.8 – 1.97 Ga) rarely crop out and include tonalitic-to-granitic gneiss and migmatite intruded by calc-alkaline foliated and nondeformed

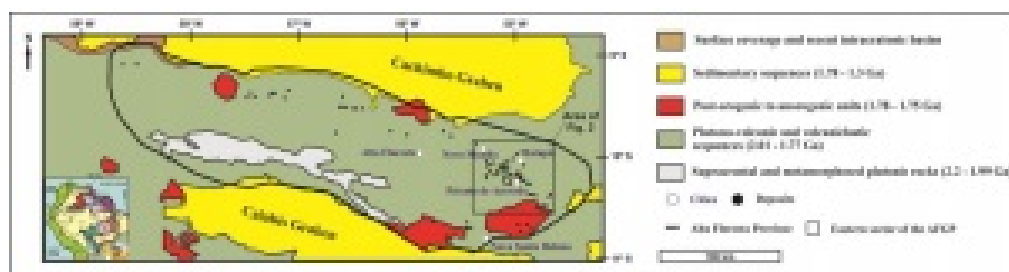


Figure 1. Simplified geological map of the AFT showing the distribution of the mineral occurrences (Modified from Paes de Barros 2007).

monzogranite to tonalite (Paes de Barros 2007; Assis et al. 2017).

The previous units are crosscut by Orosirian non-deformed I-type granitoids including the Aragão granite (1.99 – 1.93 Ga; Miguel-Jr 2011), Novo Mundo granite (Paes de Barros 2007) that varies from monzogranite (1.97 Ga) to syenogranite (1.96 Ga), Pé Quente Intrusive Suite composed of monzonite (1.97 Ga; Miguel-Jr 2011) and biotite tonalite (1.9 Ga; Assis 2015), Nhanderu granite (1.88 – 1.84 Ga; Silva and Abram 2008), Matupá Intrusive Suite (1.87 – 1.86 Ga; Moura et al. 2008), Flor da Mata granite (1.87 Ga; unpublished data), União do Norte granodiorite (1.85 Ga; Miguel-Jr 2011), undifferentiated granite (1.8 Ga; unpublished data), and Pelaxoto granite (1.79 – 1.78 Ga; Paes de Barros 2007; Silva et al. 2014). Except for the Flor da Mata, undifferentiated and Pelaxoto granites, all other units host mineralization. Collectively, these plutonic-volcanic sequences show affinities to oxidized I-type, calc-alkaline, medium to high-K, metaluminous to slightly peraluminous granites originated in continental arc settings. Also, volcanoclastic sediments represented by immature feldspathic-sandstone, feldspathic-wacke, lithic-sandstone, and conglomerate rocks from the Serra Formosa Formation overlie an unknown basement (~2.0 Ga; Miguel-Jr 2011).

These units are often crosscut by dikes and rocks that vary in composition from basalt-diorite-gabbro to andesite-dacite. According to Duarte (2015), this ~1.82 – 1.77 Ga mafic-intermediate magmatism episode may belong to the Colider suite, which also hosts mineralization.

Units listed above are intruded by post-orogenic and anorogenic felsic plutonic-volcanic units represented by the Teles Pires Intrusive suite (1.78 – 1.75 Ga; Silva and Abram 2008), which includes the União do Norte porphyry (1.77 Ga; Miguel-Jr 2011) and the Braço Sul tuffs (unknown age; Paes de Barros 2007).

Overlying all the units listed above are Mesoproterozoic rocks of the Caiabi group (Dardanelo Formation), composed of sandstone, arkose, siltstone, mudstone, volcanic greywackes and basal conglomerate (maximum ages ~1.3 Ga; Leite and Sees 2003). The Mesozoic and Cenozoic are represented by detritus-lateritic covers, whereas the Quaternary by alluvial deposits (Souza et al. 2005) (Fig. 2).

Despite the lack of consensus regarding the regional tectonic framework of the AFT, Assis (2015) correlates

the units to three tectono-magmatic events: (stage 1) 2.1 to 1.95 Ga, coeval with the Cuiú-Cuiú magmatic arc defined by the Tapajós-Parima tectonic province; (stage 2) 1.88 to 1.82 Ga, Juruena magmatic arc evolved within the Rondônia-Juruena tectonic province; and (stage 3) 1.78 to 1.75 Ga, the post-orogenic and anorogenic felsic magmatism of the Juruena magmatic arc.

3 Features of the deposits

3.1 Host rocks

The deposits in the AFT are mainly hosted by tonalitic to syeno-monzogranitic intrusions (1.98, 1.90 and 1.87 Ga), quartz-feldspar porphyries (1.98, 1.97 and 1.77 Ga), and, to a lesser degree, basement rocks (2.0 to 1.98 Ga) and volcanic/volcanoclastic sequences (2.0 Ga) (Moura et al. 2008, Paes de Barros 2007, Silva and Abram 2008, Assis et al. 2017). In some deposits, aplite and mafic to intermediate rocks of unknown ages frequently contain mineralization (e.g. Luiz and Pé Quente deposits).

3.2 Structures and vein textures

The vein-type deposits are controlled by NNE, NW and E-W-striking shear zones or faults. The veins commonly display massive to banded, open-space filling (e.g. comb, crustiform, zonal, coliform, cockade, mini geodes), recrystallization (e.g. flamboyant or feathery), platy (e.g. bladed calcite and quartz), and vuggy textures. Stockwork veins and hydrothermal breccias are also found in these deposits (Trevizan 2015).

3.3 Hydrothermal alteration and mineralization

In all deposits, the mineralization occurs within and/or enveloped by pervasive muscovite-quartz-sulfides-carbonate-magnetite (phyllic alteration), orthoclase-quartz-hematite-sulfides-microcline or biotite-quartz-magnetite-carbonate-sulfides (potassic alteration) halos or silicification represented by fronts of replacement or aggregates and quartz infill alteration (e.g. quartz veins, stockwork zones, fracture-fill, and hydrothermal breccias). However, disseminated gold mineralization associated with early pervasive albite-quartz-coarse-

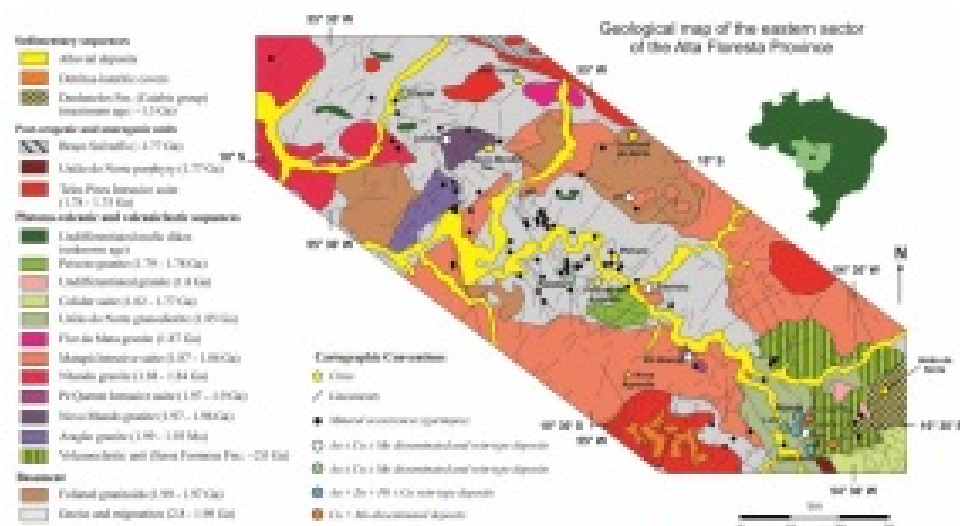


Figure 2. Geological map of the eastern sector of the Alta Floresta Province (Modified from Assis et al. 2017)

grained pyrite (sodic alteration) is also recognized at Pá Quente deposit. Outwards from the ore zones, carbonatization, silicification, potassic (K-feldspar), epidote-clinzoisite-chlorite-calcite-apatite-rutile-magnetite-hematite-pyrite assemblage (propylitic alteration) and late veinlets with variable composition (carbonate, quartz, quartz-carbonate, epidote, sericite and chlorite) are important hydrothermal alteration types, whereas kaolinite-sericite-quartz-hematite assemblage (argillic alteration) is also found in distal zones at the Francisco and Bigode deposits.

The ore paragenesis in groups (i), (ii) and (iii) consists mainly of pyrite-chalcopyrite-molybdenite-magnetite, whereas in the group (iv) is represented by pyrite-sphalerite-galena-chalcopyrite-digenite. In all groups, gold occurs as inclusions mainly in pyrite and, to a lesser extent, in galena or as free gold (Assis 2015, Trevisan 2015, Trevisan et al. 2017, Assis et al. 2017).

3.4 Fluid characteristics

Fluid inclusion studies in quartz from the ore zones of the deposits belonging to groups (i) and (ii) reveal the presence of three types of fluids: (i) two-phase aqueous with variable salinity (2.1 – 28.1 wt.% eq. NaCl) and homogenization temperature between 128.5°C and 268.4°C; (ii) aqueous-carbonic fluids of low salinity (8.1 to 8.9 wt.% eq. NaCl) and homogenization temperatures between 251.8°C and 334.6°C; and, more subordinately, (iii) high saline (33.8 to 37 wt.% eq. NaCl) aqueous fluid represented by halite-bearing fluid inclusions with homogenization temperatures between 98.9 and 211.9°C and dissolution temperature of halite between 200.2 and 280.3°C (Assis 2015, Trevisan et al. 2017). In contrast, fluid inclusions in group (iv) deposits are represented by aqueous fluids of low to moderate salinity (up to 24 wt.% eq. NaCl) and variable homogenization temperatures between 85.3° C and

373.2°C (Assis 2015; Trevisan et al. 2017).

Oxygen, deuterium, and sulfur isotope data (Assis 2015) point to a predominant contribution of magmatic water for the formation of groups (i) and (ii) deposits, whereas external fluids (meteoric) may have strongly interacted with magmatic fluids in the case of group (iv) deposits. There is no fluid inclusions or stable isotopes data available in the literature for group (iii) so far.

3.5 Timing of mineralization

The Re-Os ages obtained in pyrite and molybdenite from groups (i) and (ii) deposits yielded weighted average model ages at 1788.7 ± 3.2 Ma (MSWD = 0.98; molybdenite, X1 deposit; Assis et al. 2017), 1787 ± 6.2 Ma (MSWD = 2.2; pyrite, Lúzio deposit; Assis et al. 2017), 1787 ± 5.5 Ma (MSWD = 0.98; pyrite, Pá Quente deposit; Assis et al. 2017), and 1787 ± 17 Ma (molybdenite, Paraíba deposit; unpublished data). Conventional Pb-Pb geochronometry yielded an age of 1841 ± 22 Ma (MSWD = 1.6; Santos 2011) in pyrite from the Paraíba deposit. The Re-Os analyses in sulfides from group (iii) deposits are still under progress.

Sericite ^{40}Ar - ^{39}Ar plateau ages from the phyllic alteration halo of the Francisco deposit (group iv) yielded ages between 1779 ± 6.3 and 1777 ± 6.3 Ma (Assis 2015), very similar to the Re-Os ages obtained for groups (i) and (ii).

4 Conclusions and future work

The continental arc setting attributed to the AFP plutonic-volcanic units, the close spatial relationship between the mineralization and granitic plutons, structures and vein textures, types and distribution of the hydrothermal alteration and ore paragenesis, collectively suggest that the Au-Cu-Mo, Cu-Mo and Au-

Zn-Pb-Cu deposits may be genetically linked to the emplacement of magmatic-hydrothermal systems. This is further corroborated by the pyrite and molybdenite Re-Os and sericite ^{40}Ar - ^{39}Ar ages described above that closely overlap the crystallization ages of the quartz-feldspar porphyries at the X1 (1.78 Ga; Assis 2015) and Paraíba (1.79 Ga). A similar age interval has also been obtained for other intrusion-hosted deposits in the province: Re-Os model ages of pyrite of ~1.78 Ga for the Luizão and Pó Quente deposits; Re-Os model age of 1.8 Ga in ore-related molybdenite at the Juruena gold district (Paranaíba suite) in the northern sector of the province (Serrato 2014). Nevertheless, quartz-feldspar porphyry outcrops or interception by drill cores have not been reported so far in these cases. Hence, the interval of 1.77 to 1.84 Ga seems to mark an important regional metallogeny episode in the Alta Floresta Province. The regional felsic magmatism in the province that displays a broad temporal association with this 1.77 – 1.84 Ga event includes volcanics and granitic intrusions that belong to the Colider (1.82 – 1.77 Ga), Paranaíba (1.81 – 1.79 Ga) and Teles Pires (1.78 – 1.75 Ga) intrusive suites.

At the deposit scale, exsolution of aqueous-carbonic fluids from crystallizing quartz-feldspar porphyries in the deposits belonging to groups (i) and (ii) may have triggered the magmatic-hydrothermal system. The CO_2 -rich nature of these magmatic fluids suggest that emplacement of the causative porphyries likely occurred at deep crustal levels, since the solubility of volatiles in magma is controlled dominantly by pressure (Lowenstern 2001). Heterogeneous entrapment by fluid phase separation (immiscibility processes) accompanied by progressive mixing with externally-derived fluids (meteoric) causing CO_2 dilution and cooling may have caused the lowering of the solubility of gold and other metals. In contrast, in the case of group (iv), boiling process may have driven precipitation of metals in a shallower crustal level.

Based on the geotectonic setting, combined with the geological characteristics of the mineralization and their temporal relationship with the porphyritic rocks, we argue that ore-forming processes at the deposits from the eastern sector of the Alta Floresta Province were similar to those observed in Mesozoic-Cenozoic Au-Cu-Mo and Cu-Mo-Au porphyry systems, but emplaced at deeper crustal levels, and Au-Zn-Pb-Cu epithermal systems.

Future work will include dating of granitoids via SHRIMP U-Pb on zircon, which will potentially provide crystallization ages than can help to better constrain the magmatic framework of the eastern sector of the province. Whole-rock geochemical analyses, and Lu-Hf, trace elements and O isotopes analyses on the same zircons will be applied in order to constrain the chemistry, source/contamination, evolution and fertility potential of the magmas.

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**APPENDIX H: Abstract – Event: SEG 2019 Conference South American Metallogeny:
Sierra to Craton (2019) – Title: Whole-rock geochemistry fingerprints of
Paleoproterozoic cooper-molybdenum and gold-copper-molybdenum-ore-related
magmas in the Alta Floresta Province, Amazon Craton**

SEG 2019 - South American Metallogeny: Sierra to Craton

ID: 2355 | Submission Type: **Abstract** | Requested Presentation: **Poster** | Subject: **South American Polymetallic Deposits and Metallogeny**

Whole-rock geochemistry fingerprints of Paleoproterozoic copper-molybdenum and gold-copper-molybdenum-ore-related magmas in the Alta Floresta Province, Amazon Craton

Vernica Trevisan^{1, 2}, Robert Loucks², Steffen Hagemann², Gonzalo Henríquez², Roberto Xavier¹

¹. Institute of Geosciences, University of Campinas, Campinas, SP, Brazil, ². Centre for Exploration Targeting, The University of Western Australia, Crawley, WA, Australia

Abstract

Introduction

Porphyry deposits supply nearly 70, 50, and 25% of world's Cu, Mo, and Au, respectively. Although most are Phanerozoic, a few examples from the Precambrian are known, including the Paleoproterozoic Cu-Mo and Au-Cu-Mo porphyry-style deposits in the Alta Floresta Province (AFP) and Tapajós Gold Province, southern Amazon Craton (Brazil), suggesting that their potential in Precambrian cratons might be underexplored.

Whole-rock ratios between elements and REE profiles have been demonstrated to be an important tool in discriminating copper and gold-ore-forming intrusions from barren magmas in arc settings (Loucks 2012, 2014). Ore fertility indicators are needed by industry and can help focus exploration on prospective areas. In this context, this work tests the whole-rock magma fertility indicators in Paleoproterozoic (2.01 to 1.77 Ga) Cu-Mo and Au-Cu-Mo-ore-related granitoids from the eastern sector of the AFP and compared with those from granitoids lacking known mineralization.

Regional Geology

The AFP is located in the southern Amazon Craton, between the Tapajós-Parima (2.03-1.88 Ga) and Rondônia-Juruena (1.82-1.54 Ga) tectonic provinces (Santos *et al.* 2006) (Fig. 1A). The province outlines a NW-SE to E-W-striking belt of 500km extent and 30km wide containing plutonic-volcanic sequences generated in continental arc settings during the Paleoproterozoic (Paes de Barros 2007, Assis *et al.* 2017) (Fig. 1B). The province contains a significant number of intrusion-hosted deposits, some of which are temporally and/or spatially associated with 1.98-1.97 and 1.8-1.77 Ga porphyritic granitoids (Trevisan *et al.* 2017, Assis *et al.* 2017).

The geologic framework of the eastern sector of the province is organized into: 2.8-1.97 Ga basement represented by tonalitic-to-granitic gneiss and migmatite intruded by calc-alkaline foliated and nondeformed monzogranite to tonalite; 1.97-1.78 Ga I-type plutonic-volcanic and volcano-sedimentary sequences; 1.78-1.77 Ga post-orogenic anorogenic plutonic-volcanic; and Mesoproterozoic (~1.3 Ga; Dardanelos Formation) to Quaternary sedimentary sequences (Fig. 2).

The ore deposits are clustered into three main groups (Trevisan et al. 2017; Assis et al. 2017): (i) disseminated and vein-type Au-Cu-Mo mineralization (e.g. Paraíba, Pezão, Peteca, Luizão, Pé Quente, X1 and deposits); (ii) disseminated Cu-Mo mineralization (e.g. Ana, Jaca and Paraíba deposits); and (iii) vein-type Au-Zn-Pb-Cu mineralization (e.g. Francisco, Bigode, Carrapato and Luiz deposits).

Selected samples

The ore-related samples were chosen from representative causative intrusions from Cu-Mo (Ana, Paraíba and Colider) and Au-Cu-Mo (X1, Nhandu and Pezão) deposits. The unmineralized samples selected for comparison comprise granitoids from the eastern sector of the Alta Floresta Province, Campinorte Arc (Central Brazil), Dos Cabezas Mountains (Arizona, USA), Kongling Terrane (Yangtze Block, South China), and Serra da Barra suite (Alto Moxotó Terrane, Northeast Brazil) within the time span of 2.0 to 1.77 Ga.

Whole-rock geochemistry

REE profiles

Ore-related granitoids are represented by steeper sloping REE profiles ($\text{LaN/YbN} = 21.5\text{--}49.1$, Colider Cu-Mo deposit; $26.13\text{--}43.3$, X1 Au-Cu-Mo deposit), smaller negative Eu anomalies ($\text{Eu/Eu}^* = 0.59\text{--}0.85$, Colider Cu-Mo deposit; $0.37\text{--}0.6$, X1 Au-Cu-Mo deposit), and more pronounced depletion of HREEs. In contrast, unmineralized granitoids have less steepened sloping REE profiles ($\text{LaN/YbN} = 12.6\text{--}19.11$, União do Norte quartz-feldspar porphyry; $8.62\text{--}45.9$, Serra da Barra suite), bigger negative Eu anomalies ($\text{Eu/Eu}^* = 0.13\text{--}0.21$, União do Norte quartz-feldspar porphyry; $0.34\text{--}1.11$, Serra da Barra suite) and less pronounced depletion of HREEs.

Copper fertility indicators

In Y vs Zr (ppm) plot, Cu-Mo-related granitoids show slightly smaller Y values when compared to unmineralized granitoids.

Gold fertility indicators

In Ba/Zr vs SiO_2 wt.% plot, Au-Cu-Mo-related granitoids are represented by bigger Ba/Zr values in relation to unmineralized granitoids.

Preliminary conclusions and future work

Preliminary conclusions indicate that ore-related intrusions are represented by more hydrous magmas when compared to unmineralized granitoids as illustrated by smaller negative Eu anomalies in the REE profiles. Furthermore, the steeper REE and spoon-profile HREEs patterns from the ore-related intrusions compared to a less steepened REE and flat-shape HREEs patterns from the unmineralized granitoids may diagnostic of more hornblende and less plagioclase fractionation, but probably little garnet crystallization, from ore-related intrusions (Loucks, 2012a).

Y vs Zr discriminant plot indicate that Cu-Mo-related intrusions have slightly smaller Y contents than unmineralized granitoids, suggesting that may be effective in discriminating Cu-fertile arc igneous suites from infertile arc igneous suites due to the relatively more immobile behavior of Y mildly-altered rocks (Loucks & Ballard, 2002). Moreover, Au-Cu-Mo-related intrusions have higher Ba/Zr values in the Ba/Zr vs SiO₂ plot than most unmineralized granitoids, in agreement with Loucks (2012b) results for Phanerozoic gold-ore-forming arc magmas. These higher Ba/Zr values might possibly suggest that the lithospheric mantle had been undepleted or refertilised in relation to unmineralized magmas (Loucks, 2012).

Ongoing trace elements analyses on zircon will help to shed more light on the understanding of chemical differences between Paleoproterozoic Cu-Mo and Au-Cu-Mo-related-magmas from the Alta Floresta Province, and unmineralized magmas within the same time span.

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