



**UNIVERSIDADE FEDERAL DE MINAS GERAIS  
INSTITUTO DE GEOCIÊNCIAS  
PROGRAMA DE PÓS-GRADUAÇÃO EM  
GEOLOGIA**



## **DISSERTAÇÃO DE MESTRADO**

# **REGISTROS DE EVENTOS TAFROGÊNICOS INTERCALADOS TECTONICAMENTE NO COMPLEXO POCRANE, SE MINAS GERAIS**

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# **REGISTROS DE EVENTOS TAFROGÊNICOS INTERCALADOS TECTONICAMENTE NO COMPLEXO POCRANE, SE MINAS GERAIS**

Dissertação apresentada ao programa de Pós-graduação em Geologia do Instituto de Geociências da Universidade Federal de Minas Gerais como requisito para obtenção do título de mestre em Geologia

Área de Concentração: Geologia Regional  
Orientador: Prof. Tiago Amâncio Novo

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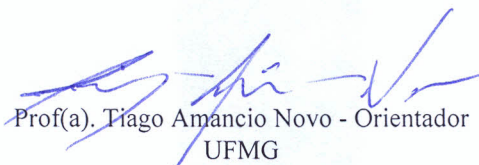
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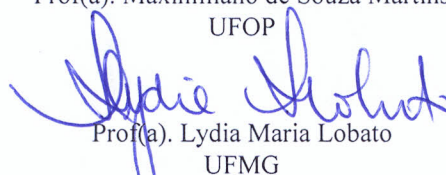
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*Às minhas avós, Ceci e Maria.*

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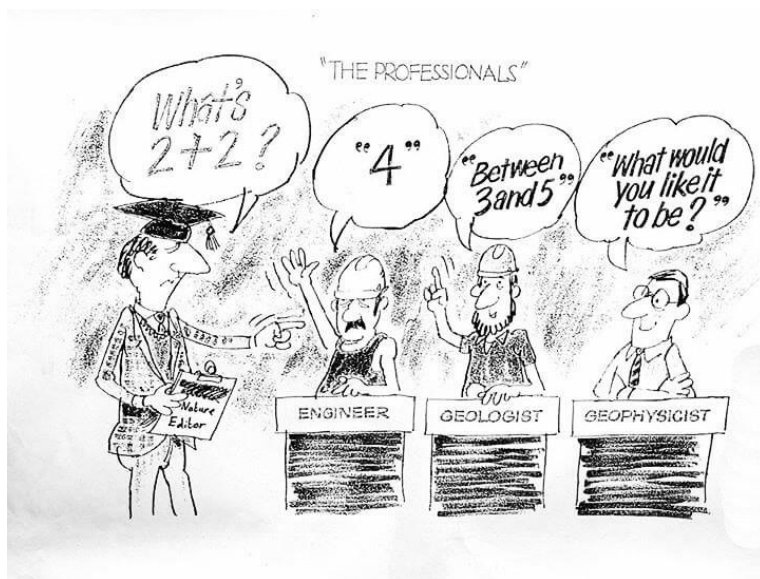
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## RESUMO

No domínio interno do Orógeno Araçuaí ocorrem rochas de natureza variada que foram fortemente retrabalhadas durante o ciclo orogênico brasileiro. Nas proximidades dos municípios de Durandé e Pocrane, localizadas no extremo leste do estado de Minas Gerais, ocorrem rochas metamáficas, metassedimentares e metaultramáficas tectonicamente intercaladas nas rochas ortognaissicas do Complexo Pocrane. Os dados geocronológicos e litoquímicos de duas lentes anfibolíticas indicam dois eventos magmáticos maficos distintos. Um caliminiano com idade ígnea balizada em  $1529 \pm 37$  Ma (U-Pb SHRIMP em zircão) com assinatura litoquímica de magmatismo intracontinental basáltico. O outro possui idade de cristalização de  $1096 \pm 20$  Ma (U-Pb SHRIMP em zircão) e representa evento Esteniano com assinatura litoquímica de magmatismo de rifte continental. O evento caliminiano (ca. 1,5 Ga) é correlato com o estágio deposicional do Espinhaço II e cronocorrelato com os diques máficos dos domínios Espinhaço-Chapada Diamantina e Curaçá enquanto que o evento Esteniano é correlato com os estagio deposicional Espinhaço III. Apresentamos também dados U-Pb de 87 grãos de zircão detrítico do Quartzito Corrego Ubá. O seu espectro de idades mostra picos em  $1176 \pm 21$  Ma (35%),  $1371 \pm 30$  Ma (18%),  $1536 \pm 22$  Ma (19%),  $1803 \pm 36$  Ma (17%) and  $1977 \pm 38$  Ma (12%), sugerindo idade máxima de deposição Eteniana (ca. 1176 Ma), porém o zircão mais novo possui idade de  $955 \pm 66$  Ma, que pode ser associada à bacia precursora do Orógeno Araçuaí-West Congo. Na região ocorrem pequenos corpos de rocha metaultramáfica encaixados em ortognaisses e metassedimentos que foram intrudidos por granitos. O levantamento geofísico realizado no Corpo Metaultramáfico Vista Alegre mostrou, ao invés de um único corpo contínuo e profundo, três porções distintas interpretadas como “mega boudins” alinhados segundo a foliação regional. A intrusão deste corpo está relacionada com intenso estiramento crustal e integra um dos vários episódios de magmatismo anorogenico de idade meso e neoproterozoica relatados no sudeste brasileiro. A análise microscópica indicou ao menos dois eventos metamórficos ocorridos depois da sua intrusão. O primeiro evento pode ser correlacionado com o estágio colisional e o segundo com o evento pós-colisional do Orógeno Araçuaí-Oeste Congo. Portanto os objetos de estudo deste trabalho representam indícios de eventos tafrogênicos que atestam as várias tentativas de fragmentação sem sucesso do paleocontinente São Francisco-Congo.

*Palavras-chave: Eventos tafrogênicos, Complexo Pocrane, Orógeno Araçuaí-Oeste Congo*



## ABSTRACT

The internal domain of the Araçuaí-West Congo orogen comprises many varieties of rocks which were strongly reworked during the Brasiliano orogenic cycle. In the vicinity of Pocrane and Durandé cities, western Minas Gerais, occurs metamafic, metasedimentary and meta-ultramafic rocks tectonically interlayered in the Rhyacian Pocrane complex. The geochronological and lithochemical study of two amphibolite lenses indicate two distinct magmatic events. The oldest, Calymnian event, with magmatic crystallization age at  $1529 \pm 37$  Ma (U-Pb SHRIMP) and lithochemical signature of basaltic magmatism related to continental intraplate settings. The other event has zircon magmatic crystallization age at  $1096 \pm 20$  Ma (U-Pb SHRIMP) and represents a Stenian event with lithochemical signature similar to mature magmatism of continental rift setting. The Calymnian event (ca. 1.5 Ga) correlates to the Espinhaço II basin stage and mafic dikes of the northern Espinhaço - Chapada Diamantina and Curaçá domains, while the Stenian episode (ca. 1.1 Ga) correlates to the Espinhaço III basin stage. We also present U-Pb data for 87 detrital zircon grains from a quartzite lens, the Córrego Ubá quartzite. Its age spectrum shows main peaks at  $1176 \pm 21$  Ma (35%),  $1371 \pm 30$  Ma (18%),  $1536 \pm 22$  Ma (19%),  $1803 \pm 36$  Ma (17%) and  $1977 \pm 38$  Ma (12%), suggesting a Stenian (ca. 1176 Ma) maximum depositional age (although only one zircon with low discordance shows an age of  $955 \pm 66$  Ma) which can be associated with the Early Tonian precursor basin of Araçuaí-West Congo orogen. In the region occur several small northeast-trending bodies hosting orthogneiss basement and metasedimentary package which are intruded by granites. The geophysical survey performed in the Vista Alegre meta-ultramafic body indicates three relative shallow meta-ultramafic portions, instead of one deep continuous body, interpreted as mega boudins aligned parallel to the regional foliation. These meta-ultramafic rocks are related to continuous crustal thinning, and integrate many other Meso and Neoproterozoic anorogenic magmatism events reported in southeast Brazil. The microscopic analyses show almost 2 distinct metamorphic events after emplacement. The first one seems to be related with collisional stage and the last one represents the thermal event during post-collisional event of the Araçuaí-West Congo orogen. Therefore, all the objects studied in this work testify the several unsuccessful fragmentation attempts that affected the long-lived São Francisco-Congo palaeocontinent.

*Keywords: Taphrogenic events, Pocrane complex, Araçuaí-West Congo orogen*

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## CONSIDERAÇÕES INICIAIS

O volume aqui apresentado consiste nos resultados dos trabalhos desenvolvidos durante o curso de mestrado do aluno Tobias M. R. Fonte Boa matriculado no programa de pós-graduação do Instituto de Geociências da Universidade Federal de Minas Gerais. Tais trabalhos foram realizados no período de março de 2015 a maio de 2017 com bolsa financiada pela Petrobras. Os trabalhos de campo e despesas laboratoriais foram custeados pelos contratos UFMG-Petrobrás (Programa PRH-PB238), UFMG-CODEMIG (Projeto Triângulo Mineiro), auxílio à pesquisa do CNPq (processo 470001/2011-9 “O Complexo Pocrane no contexto das unidades do embasamento do Orógeno Araçuaí: idade e caracterização”), CPRM-UFMG do PROGRAMA GEOLOGIA DO BRASIL e pelo Laboratório de Geotectônica do CPMTCC-UFMG.

A principal motivação desta pesquisa surgiu do mapeamento geológico desenvolvido durante o trabalho final de graduação do aluno realizado na região de Durandé, extremo leste do estado de Minas Gerais (Fig. 1) (Deluca and Fonte Boa 2014). Uma das questões mais intrigantes foi a natureza das rochas metassedimentares que afloram na região.

Tais rochas foram fortemente retrabalhadas durante a orogenia brasiliana e muitas vezes são dispostas como lascas tectônicas justapostas às rochas do embasamento. Nos projetos de mapeamento regionais elas são majoritariamente classificadas como Grupo Andrelândia, que compreende sedimentos de margem passiva (Paciullo *et al.* 2000). Porém, geotectonicamente estão inseridas dentro do domínio interno do Orógeno Araçuaí onde predominam as rochas do arco magmático Rio Doce. Portanto seriam estas representantes de margem passiva ou ativa?

Outra questão levantada diz respeito aos corpos metaultramáficos que frequentemente aparecem inseridos nas unidades metassedimentares. Seriam estes corpos intrusivos ou pertenceriam a embasamento justaposto tectonicamente às rochas de Arco? Se intrusivos, qual seu significado?

Desta forma os trabalhos apresentados nesta dissertação tiveram como principal objetivo a **caracterização e entendimento do significado geotectônico das rochas metaultramáficas, metamáficas e metassedimentares fortemente tectonizadas junto ao embasamento do Orógeno Araçuaí**. A dissertação encontra-se estruturada na forma de 3 capítulos:

(1) Guia metodológico do levantamento geofísico terrestre,

(2) Artigo 1 - ***VISTA ALEGRE META-ULTRAMAFIC BODY: A KEY TOWARDS TECTONO-METAMORPHIC EVOLUTION OF THE ARAÇUAÍ OROGEN HIGH-GRADE CORE,***

(3) Artigo 2 - ***RECORDS OF MESOPROTEROZOIC TAPHROGENIC EVENTS IN THE EASTERN BASEMENT OF THE ARAÇUAÍ OROGEN, SOUTHEAST BRAZIL.***

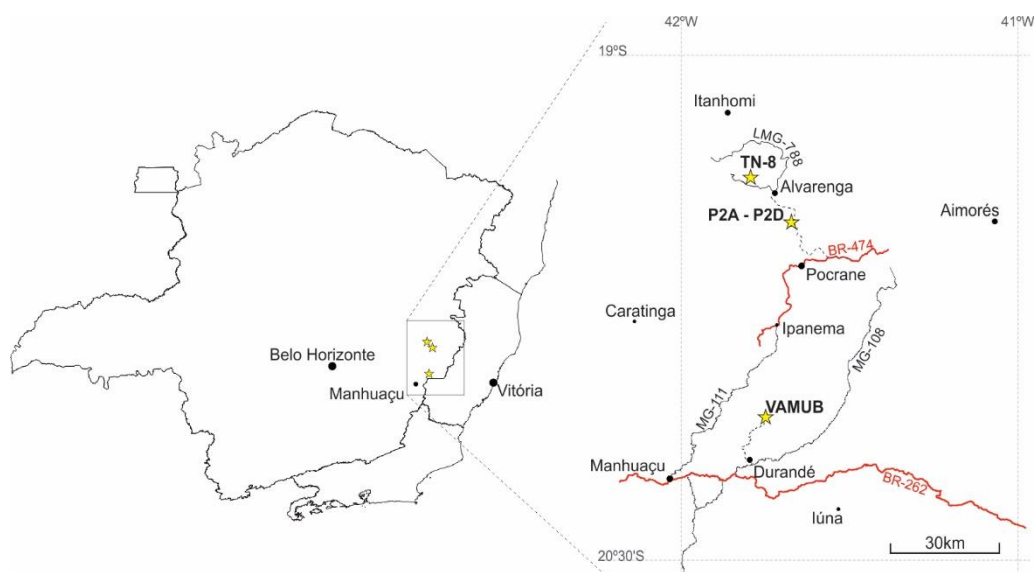


Figura 1 – Localização dos trabalhos desenvolvidos durante o mestrado. VAMUB, corpo metaultramáfico Vista Alegre que é alvo de estudo dos capítulos 1 e 2; TN-8, P2A e P2D, localização das amostras estudadas e reportadas no Capítulo 3.

O capítulo 1 consiste no Guia metodológico do levantamento geofísico terrestre. Apesar de estarem apresentadas dentro do capítulo 2, as etapas de planejamento, aquisição e processamento dos dados do levantamento geofísico terrestre carecem de detalhamento que não cabe junto ao corpo do capítulo 2. Portanto, elas estão apresentadas a parte no capítulo 1.

O capítulo 2 aborda o principal tema desenvolvido durante o curso de mestrado: **as rochas metaultramáficas das proximidades do município de Durandé**; que resultou no artigo 1. Nele são apresentados e discutidos os dados de campo, aspectos geofísicos, petrográficos e de química mineral do Corpo Metaultramáfico Vista Alegre (**VAMUB** – Fig. 1). Esta etapa do trabalho teve o apoio imprescindível do Laboratório de Inclusões Fluidas e Metalogênese do CDTN/CNEN e da Companhia de Desenvolvimento Econômico de Minas Gerais (CODEMIG) que disponibilizaram os equipamentos de geofísica, além da importante

parceria com o Serviço Geológico do Brasil (CPRM) que auxiliou no tratamento dos dados levantados. O resumo deste trabalho foi previamente apresentado no *Primer Simposio de Tectónica Sudamericana* realizado em novembro de 2016 na cidade de Santiago do Chile. A íntegra do artigo, “*Vista Alegre meta-ultramafic body, southeast Brazil: a geotectonic key towards orogenic evolution*”, será submetida, em julho, em um volume especial do ***Journal of South American Earth Sciences*** dedicado aos trabalhos mais relevantes do simpósio.

O capítulo 3 trata do artigo que primeiramente foi desenvolvido durante a disciplina “*Estudos Supervisionados*” e teve o seu resumo apresentado no 48º Congresso Brasileiro de Geologia realizado em Porto Alegre, Rio Grande do Sul. Em julho a versão final do artigo, “*Records of Mesoproterozoic taphrogenic events in the eastern basement of the Araçuaí orogen, southeast Brazil*”, foi aceito no periódico ***Brazilian Journal of Geology***. Nele são apresentados e discutidos dados de geocronologia U-Pb (LA-ICP-MS e SHRIMP) e litoquímica realizados em lentes anfibolíticas (**P2A** e **TN-8A/B**) e intercalações quartzíticas (**P2D** – Fig. 1) do Complexo Pocrane. Apesar de inéditos, os dados discutidos neste artigo foram cedidos de trabalhos anteriores com a colaboração do CNPq, CAPES, CODEMIG e CPRM.

## Capítulo 1: GUIA METODOLÓGICO DO LEVANTAMENTO GEOFÍSICO TERRESTRE

### 1. INTRODUÇÃO

Este capítulo tem como objetivo apresentar de maneira detalhada a metodologia utilizada no levantamento geofísico terrestre que se encontra brevemente descrita no capítulo 2. A metodologia foi aplicada na região da Fazenda Vista Alegre onde ocorre o então denominado Corpo Metaultramáfico Vista Alegre (**VAMUB** – *Vista Alegre metaultramafic body*). Este localiza-se aproximadamente a 20 km, na direção norte, da sede municipal de Durandé, Minas Gerais, e é representado por blocos e matacões de esteatito dispersos nas encostas de morros, e próximos ao vale do Rio José Pedro (Fig. 1).

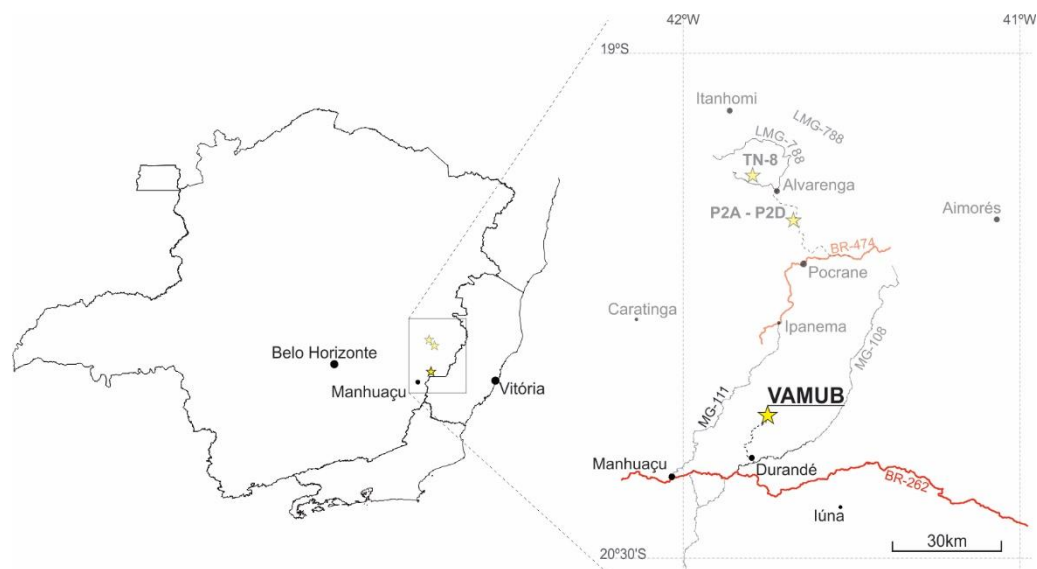


Figura 1 – Localização do corpo metaultramáfico Vista Alegre (VAMUB – Vista Alegre meta-ultramafic body).

Como também descrito no capítulo 2, o principal objetivo do levantamento foi auxiliar na delimitação do corpo meta-ultramáfico uma vez que ele não aflora. Esta fase de trabalho foi dividida em três etapas: **Planejamento**, **Aquisição** e **Processamento dos dados**.

### 2. PLANEJAMENTO

Previamente foi feita uma campanha de trabalho de campo para que fossem estipulados os alvos, objetivos e escala do levantamento. Após a avaliação da viabilidade e eficácia do levantamento perante os objetivos do trabalho, o conjunto de blocos e matacões próximos ao Rio José Pedro (212.474E, 7.777.740N, UTM24S, WGS84) foram determinados

como alvos mais promissores. A escala de trabalho estipulada foi de aproximadamente 1:5.000 numa área que abrangesse o maior numero de blocos possível.

Vários fatores foram avaliados para estipular a disposição das estações de coleta dos dados geofísicos (Fig. 1). Dentre eles estão as características geológicas, geomorfológicas e antrópicas como: disposição dos blocos metaultramáficos, *trend* estrutural, contatos geológicos, padrão de drenagem, alinhamento de serras, disposição da vegetação, cercas, postes, antenas, estradas e construções de uma forma geral. A partir dos dados coletados em campo e imagens de satélite, inferiu-se que, se o corpo fosse contínuo, possuiria dimensão aproximada de 100m x 800m alinhado segundo o *trend* geológico (NE).

Portanto, para o levantamento foi determinada uma malha de estações disposta na forma de perfis espaçados em 50m e incremento de 20m entre as estações dentro de cada perfil (Fig. 2). Por questões de simplificar a rotina do levantamento, os perfis foram alinhados à declinação magnética local ( $23^{\circ} 19'W$  - NOAA, 2016), pois esta coincidia aproximadamente com a direção perpendicular às estruturas geológicas e alinhamento dos blocos de rocha metaultramáfica.

Os levantamentos magnetométrico e cintilométrico seriam realizados simultaneamente, porém com alternância de equipamento nas estações. Primeiro seria feita a coleta dos dados de posicionamento e leitura radiométrica e, logo após o deslocamento do cintilômetro, seriam feitas as leituras do campo magnético como ilustrado na Figura 2.



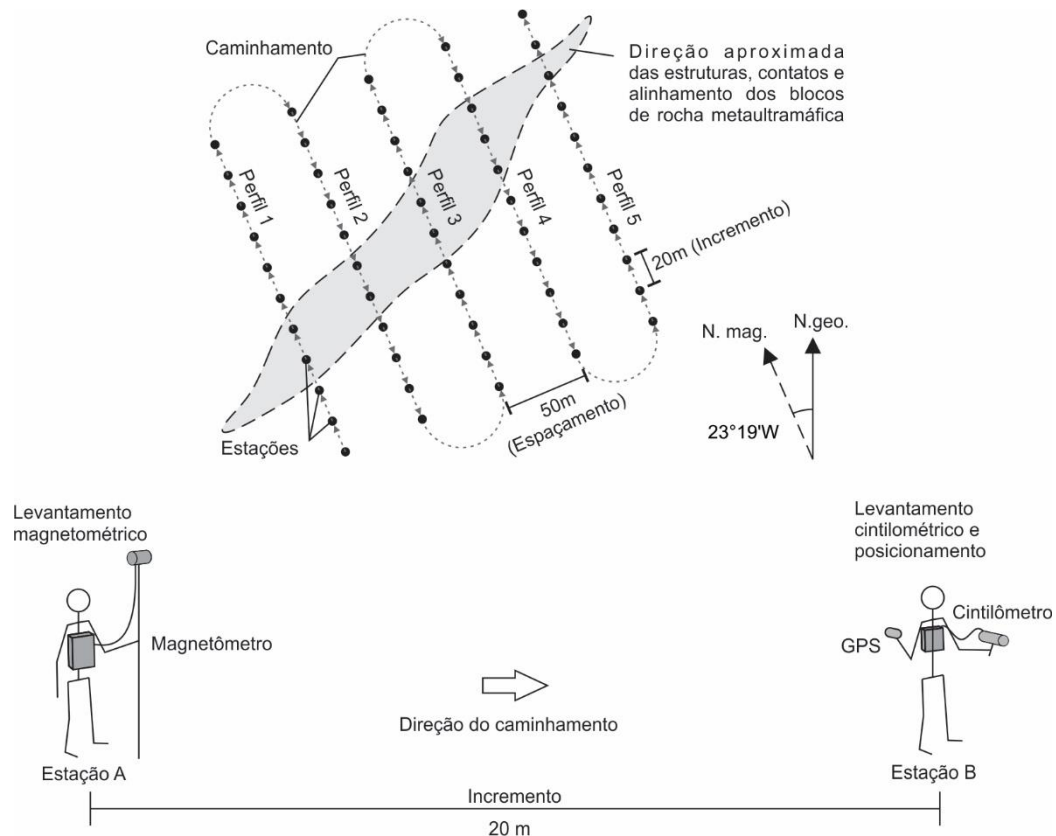


Figura 2 – Malha teórica da disposição das estações de coleta de dados geofísicos mostrando a relação entre as estruturas geológicas, declinação magnética e direção dos perfis; também é apresentada uma ilustração da rotina de coletas de dados geofísicos planejada para a etapa de levantamento.

### 3. AQUISIÇÃO DOS DADOS

O levantamento foi realizado durante cinco dias (15 – 19 de abril de 2016) e os dados de posicionamento foram coletados com a ajuda de GPS Garmin® modelo GPSMAP 64s com precisão de ~5m.

#### 3.1. Levantamento magnetométrico

Para o levantamento magnetométrico foram utilizados dois magnetômetros GEM Systems GSM-19 (precessão de prótons) disponibilizados pela CODEMIG (Fig. 3D). Um dos aparelhos foi usado como estação móvel (Fig. 3A) e o outro como estação base (Fig. 3B) para correção da variação diurna.

Alguns dos cuidados tidos durante todo o levantamento foram a verificação do porte de algum material metálico pelos operadores, presença de cerca ou objeto metálico nos arredores (mínimo 15m de distância), consistência nas leituras (variação menor que 0,3 nT em repetidas leituras no mesmo ponto) ou algum tipo alteração dos valores causada pela eficiência do aparelho. Apesar da capacidade de armazenamento dos dados em memória

interna, todos eles foram anotados em uma planilha como prevenção para possíveis erros de armazenamento ou perda de banco de dados. Para o levantamento magnético foram seguidas duas rotinas, uma diária e uma rotina de leitura ponto a ponto.

#### Rotina diária:

1. Montagem dos equipamentos,
2. Ajustes dos parâmetros dos magnetômetros como: data, hora, intervalo de leitura, nome do arquivo a ser coletado,
3. Sincronização temporal dos magnetômetros base e móvel,
4. Instalação da estação base (Fig. 3B),
5. Testes de leitura para verificação de ruído e possíveis erros de armazenagem,
6. Levantamento propriamente dito (Fig. 3A),
7. Desmonte e armazenagem dos equipamentos.

#### Rotina de leitura ponto à ponto:

1. Verificação da posição: coordenadas do GPS,
2. Posicionamento do equipamento em relação ao campo magnético terrestre local,
3. Leituras consecutivas e observação da consistência dos dados,
4. Anotação do valor de campo magnético total e posicionamento,
5. Deslocamento para a próxima estação.

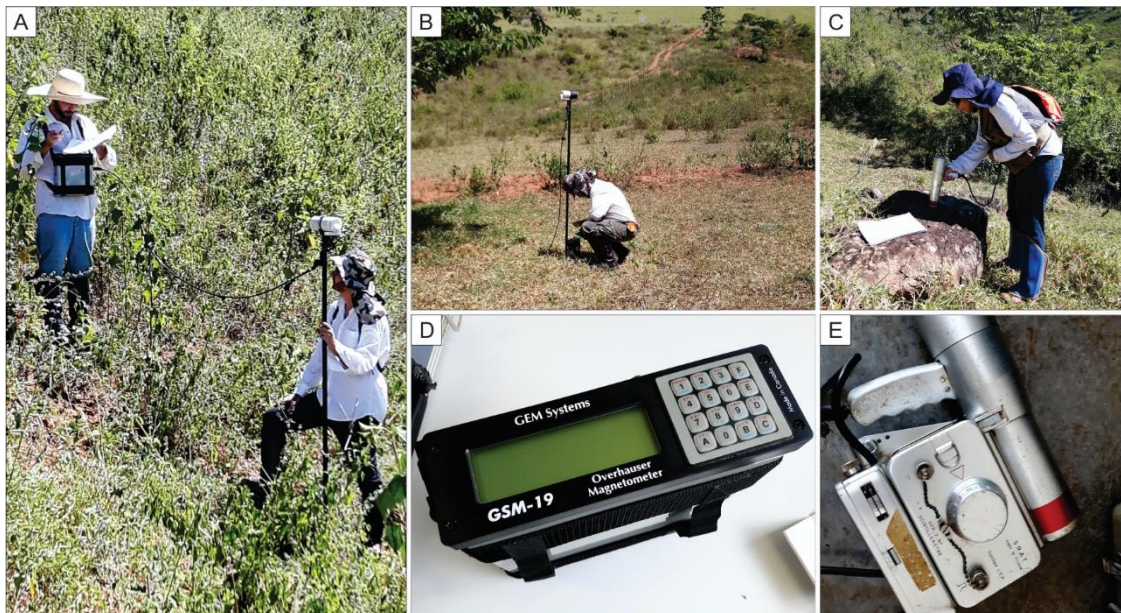


Figura 3 – Imagens da etapa de levantamento. A) Estação móvel do levantamento magnetométrico; B) Estação base do levantamento magnetométrico; C) Levantamento Cintilométrico D) Magnetômetro GSM-19 (precessão de prótons); E) Cintilômetro Système C.E.A SPP-2-NF.

Durante o levantamento a atividade solar foi monitorada através dos dados disponibilizados pela NOAA (National Oceanic And Atmospheric Administration). Geralmente ela é expressa na forma de um índice denominado índice K (K-index) que é uma

representação logarítmica da amplitude da mudança magnética solar de maior intensidade em um intervalo de três horas. Os valores de K podem variar de 0 a 9. Valores abaixo de 4 são considerados moderados e indicam baixa atividade solar, os iguais a 4 indicam atividade solar normal e quando maiores que 4 os valores indicam atividade solar intensa. Como observado na Fig. 4, não foi observada nenhuma atividade solar anômala nos períodos do levantamento.

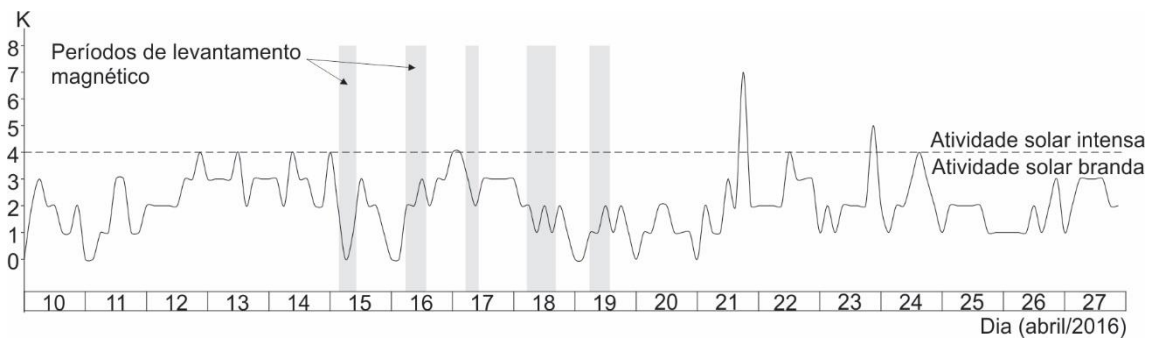


Fig. 4 - Diagrama mostrando a atividade solar (K-index) para as médias latitudes no intervalo entre os dias 10 e 27 de abril de 2016, as barras em cinza marcam os períodos de levantamento magnético terrestre realizados neste trabalho.

A estação base foi posicionada na área central do levantamento e foi programada para fazer leituras a cada 15 min. Todas as leituras, tanto da estação base quanto da estação móvel, foram realizadas há uma altura aproximada de 2 metros da superfície (Fig. 3A e 3B).

### 3.2. Levantamento cintilométrico

Para o levantamento cintilométrico foi utilizado um cintilômetro System C.E.A SPP-2-NF disponibilizado pelo Laboratório de Inclusões Fluidas e Metalogênese do CDTN/CNEN (Fig 3E). As leituras foram obtidas o mais próximo possível do solo/rocha (Fig. 3C) e foi destinado para cada leitura ao menos dez segundos de observação para estipular o melhor valor que representasse a radiação no local. Devido à alta taxa de variação dos valores no tempo (~15 cps/s), buscou-se estipular um valor intermediário que melhor representasse a radiação em cada estação. Para o levantamento cintilométrico também foram seguidas duas rotinas.

Rotina diária do levantamento cintilométrico:

1. Acionamento do equipamento,
2. Verificação do estado da bateria,
3. Regulagem do intervalo dos valores de leitura esperados,
4. Levantamento propriamente dito
5. Desligamento e armazenagem do equipamento,

Rotina de leitura ponto a ponto:

1. Posicionamento do equipamento em contato com o solo e/ou rocha,
2. Observação da taxa de variação dos valores cintilométricos no tempo,
3. Determinação do valor médio de contagem por segundo (cps),
4. Anotação dos valores de contagem radiométrica total por segundo e posicionamento,
5. Deslocamento para a próxima estação de leitura.

### 3.3. Eficiência do levantamento geofísico terrestre

As condições do terreno, tipo de equipamento, número de assistentes e condições climáticas são fatores que influenciaram muito na eficiência do levantamento e foram levados em consideração no planejamento logístico. A região do corpo metaultramáfico Vista Alegre possui terreno bastante acidentado o que dificulta no deslocamento. Contudo, a ausência de grandes corpos d'água e a vegetação, principalmente composta de campo de pastagem, facilitou bastante na rotina de levantamento. Como já foi dito anteriormente esta etapa foi realizada em 5 dias, porém o total de horas efetivas foi aproximadamente de 31 horas. Ao todo foram realizadas 380 estações de leitura o que leva a uma eficiência de aproximadamente uma estação a cada 5 minutos incluindo o deslocamento entre elas.

### 3.4. Processamento preliminar

Ao final de cada dia de trabalho os dados coletados eram compilados para a realização do processamento preliminar que consistiu em:

1. Transferência das leituras dos magnetômetros, estação base e móvel, para o computador para processamento e correção da variação diurna. O *software* previamente utilizado foi o GEMLinkW 3.0 da Gem Systems Inc. disponibilizado junto ao magnetômetro.
2. Integração dos dados magnetométricos, cintilométricos e de posicionamento (GPS) em planilhas *\*.xls*.
3. Plotagem prévia dos dados integrados em ambiente GIS para observação de possíveis erros durante o levantamento e planejamento dos próximos dias de trabalho.
4. Observação na consistência dos dados coletados para detecção de algum tipo de interferência externa como tempestades magnéticas ou erros de leitura e armazenagem.

## 4. PROCESSAMENTO DOS DADOS

Após o levantamento os dados foram organizados em planilhas para que pudessem ser sincronizados e processados. Foi empregado o *software* OASIS MONTAJ da empresa GEOSOFT, no qual as planilhas previamente organizadas são diretamente importadas e convertidas para formato de GDBs compatíveis com o programa.

#### 4.1. Dados magnetométricos

Para atender aos objetivos propostos, os dados magnéticos coletados no campo passaram por rotina de correções como, correção da variação diurna e remoção do IGRF (International Geomagnetic Reference Field). Alguns procedimentos aplicados a dados magnéticos como correção topográfica não foram feitos, pois foram considerados como irrelevantes para os resultados finais.

##### 4.1.1 Correção da Variação Diurna

Ainda na etapa de levantamento, na fase de pré-processamento, os dados magnéticos passaram pela correção da variação diurna realizada pelo *software* GEMLinkW 3.0. Porém a partir de uma prévia observação dos perfis magnetométricos foi possível identificar anomalias que não eram consistentes com os dados reais obtidos em campo. Tais anomalias foram atribuídas a erros de interpolação durante a etapa de correção diurna feita pelo *software*. Portanto os dados foram recorrigidos manualmente ponto a ponto segundo a premissa de que a correção do valor medido em uma determinada estação é feita pela soma ou subtração do valor da variação registrado pela estação base (Luiz and Silva 1995). O valor é somado se o campo magnético na estação base diminuiu em relação a um *datum* ou é subtraído se o valor aumenta. Ou seja, o fator correção é positivo se os valores medidos na estação base são menores que o *datum* e negativo quando maiores (Fig. 5).

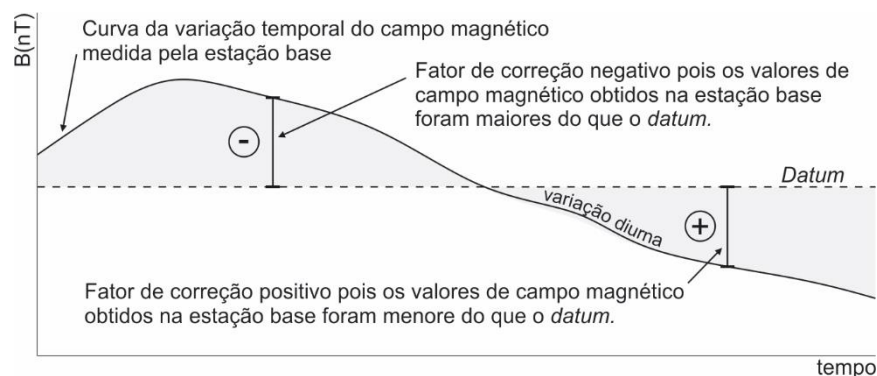


Figura 5 – Diagrama mostrando a metodologia utilizada na correção da variação diurna dos dados magnéticos.

##### 4.1.2 Remoção do IGRF

A remoção do Campo Geomagnético Internacional de Referência (IGRF) foi feita ponto a ponto a partir dos dados calculados pela NOAA. Os valores de IGRF para cada ponto foram obtidos pela 12ª geração (IGRF 12 – Thébault *et al.* 2015) à uma altitude de 500m para as datas de 15 a 19 de abril de 2016. O campo magnético anômalo ( $B_{cma}$ ) para cada um dos

pontos amostrados foi obtido pela subtração, ao campo total ( $B_t$ ), do valor do IGRF calculado para o ponto:  $\mathbf{B}_{(TMA)} = \mathbf{B}_{(TOTAL)} - \mathbf{IGRF}$ .

#### 4.2. *Processamento dos dados Cintilométricos*

Devido ao tipo de equipamento e tempo destinado ao levantamento cintilométrico, não foi possível realizar nenhum tipo de correção aos dados. Portanto estes foram diretamente integrados nas planilhas finais do banco de dados.

#### 4.3. *Interpolação e geração dos “grids”*

Para a geração dos *grids* foram utilizadas as rotinas do Oasis Montaj de *minimum curvature* (*RANGRID*). Este método foi utilizado para ambos os tipos de dados, magnetométricos e cintilométricos. Os mapas foram elaborados a partir de *grids* regulares, interpolados em malha quadrada, com células de dimensões de 12,5 m x 12,5 m que correspondem a ¼ do espaçamento entre as linhas de perfil (50m).

Observações: Os resultados, discussões e conclusões desta etapa de trabalho estão apresentados no capítulo 2 deste volume.

## Capítulo 2 – Artigo 1

### **VISTA ALEGRE META-ULTRAMAFIC BODY: A KEY TOWARDS TECTONO-METAMORPHIC EVOLUTION OF THE ARAÇUAÍ OROGEN HIGH-GRADE CORE**

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## **ASBTRACT**

The Vista Alegre Meta-Ultramafic body is part of a cluster of meta-ultramafic occurrences located in the internal tectonic domain of the Araçuaí-West Congo orogen in southeast Brazil. They consist of several small northeast-trending bodies hosting by orthogneiss basement and metasedimentary package tectonized and intruded by granites during Brasiliano orogenic cycle. To improve the existent models of the tectono-metamorphic evolution of the Araçuaí Orogen high-grade metamorphic core we performed geophysical and detailed mineralogical study of the meta-ultramafic body and its host rocks. The magnetic response indicates three relative shallow portions instead one deep continue meta-ultramafic body. These portions are interpreted as mega boudins aligned parallel to the regional foliation. The petrographic and mineral chemistry studies indicate a high-grade progressive metamorphic path followed by a retrograde process. The metamorphic peak must have reached granulite facies condition related with collisional stage of the Araçuaí-West Congo orogen, and the posterior stabilization, in greenschist facies condition, represents a metamorphic retrogression related with the thermal event during post-collisional stage.

*Keywords: Meta-ultramafic body; high-grade metamorphic core; Araçuaí orogen.*

## 1. INTRODUCTION

The Vista Alegre Meta-Ultramafic body (VAMUB) is part of a cluster of meta-mafic/ultramafic occurrences located in the Araçuaí-West Congo orogen high-grade metamorphic core (Fig. 1). These occurrences were defined by Angeli *et al.* (2001) as Ipanema Layered Mafic-Ultramafic Complex and was interpreted as part of an anorogenic magmatism related to extensional event occurred in paleocontinente São Francisco/Congo during Mesoproterozoic.

The high-grade core of the Araçuaí-West Congo orogen is a tectono-metamorphic domain which includes granites and gneiss complexes formed under amphibolite-granulite grade conditions during the Brasiliano orogeny (Cunningham *et al.* 1998, Alkmim *et al.* 2006). This orogeny was an important regional tectono-metamorphic event resulted of the collision between São Francisco and Congo craton during the Neoproterozoic. In the studied area it is mainly represented by the development of a system of NNE-trending dextral strike-slip shear zones and production of an enormous volume of pre-, sin- and post-collisional granitoids.

This paper will focus on investigating the small buried Vista Alegre meta-ultramafic body (VAMUB) and its host rock in order to characterize the regional tectono-metamorphic evolution. Here we report results of a geophysical and detailed mineralogical study with special regard to (i) magnetometric response of the meta-ultramafic body and its host rocks; and (ii) mineralogical nature and petrological significance of the essential and spinel phases. Thereby the intention here is to add new data and improve the existent models of the tectono-metamorphic evolution of the Araçuaí Orogen high-grade metamorphic core.



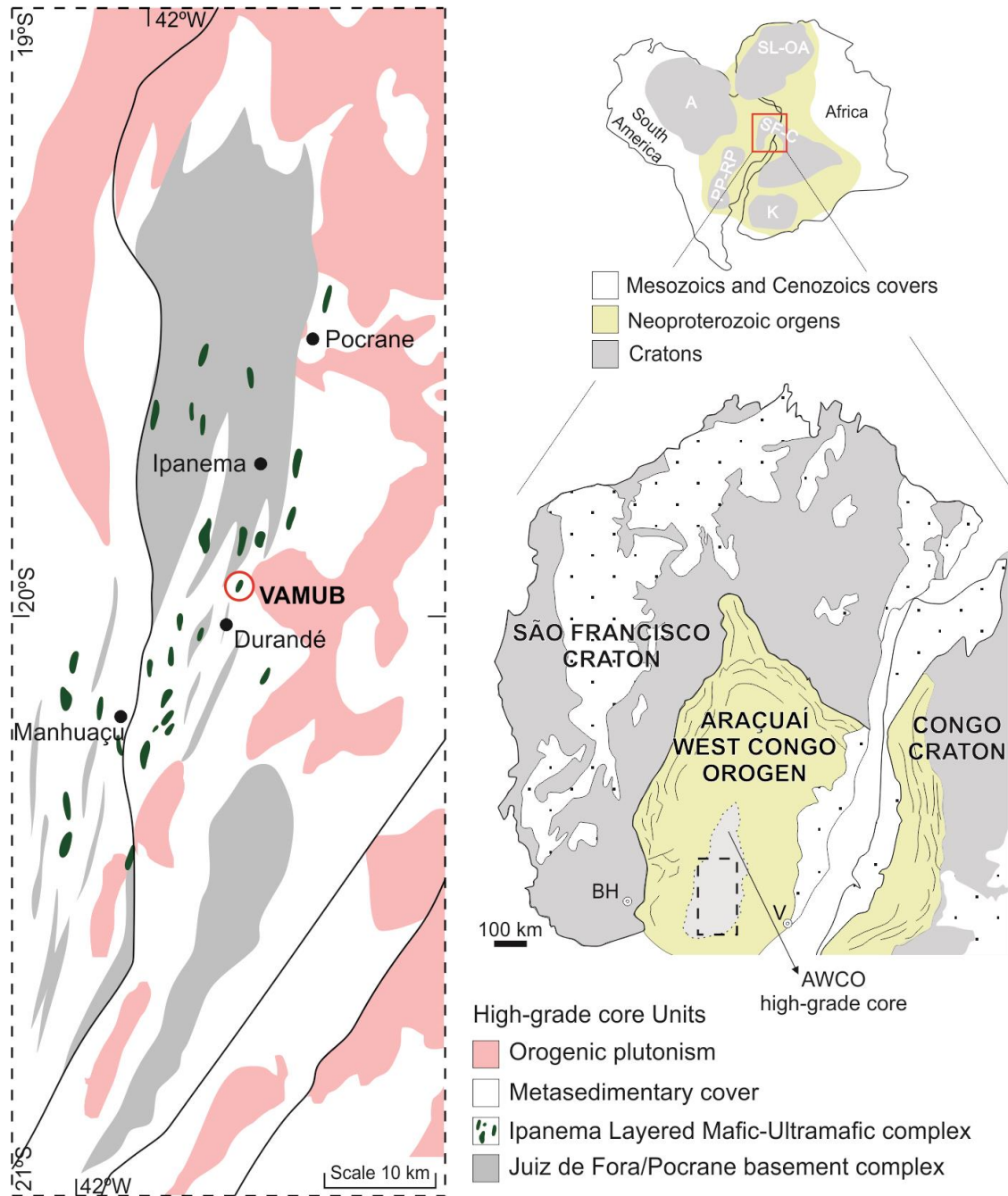


Figure 1 – Simplified geological map of the Araçuaí West Congo orogen high-grade core.

## 2. GEOLOGICAL SETTING: VAMUB DISTRICT

The area selected for study is located 20 km north from the town of Durandé (Minas Gerais state, southeastern Brazil) more specifically in the Vista Alegre farm, next to the José Pedro River where occurs the Vista Alegre Meta-ultramafic Body (VAMUB). The local geology comprises a tectonic association of basement complex, metasedimentary cover including the meta-ultramafic bodies and granitoids (Fig. 2).

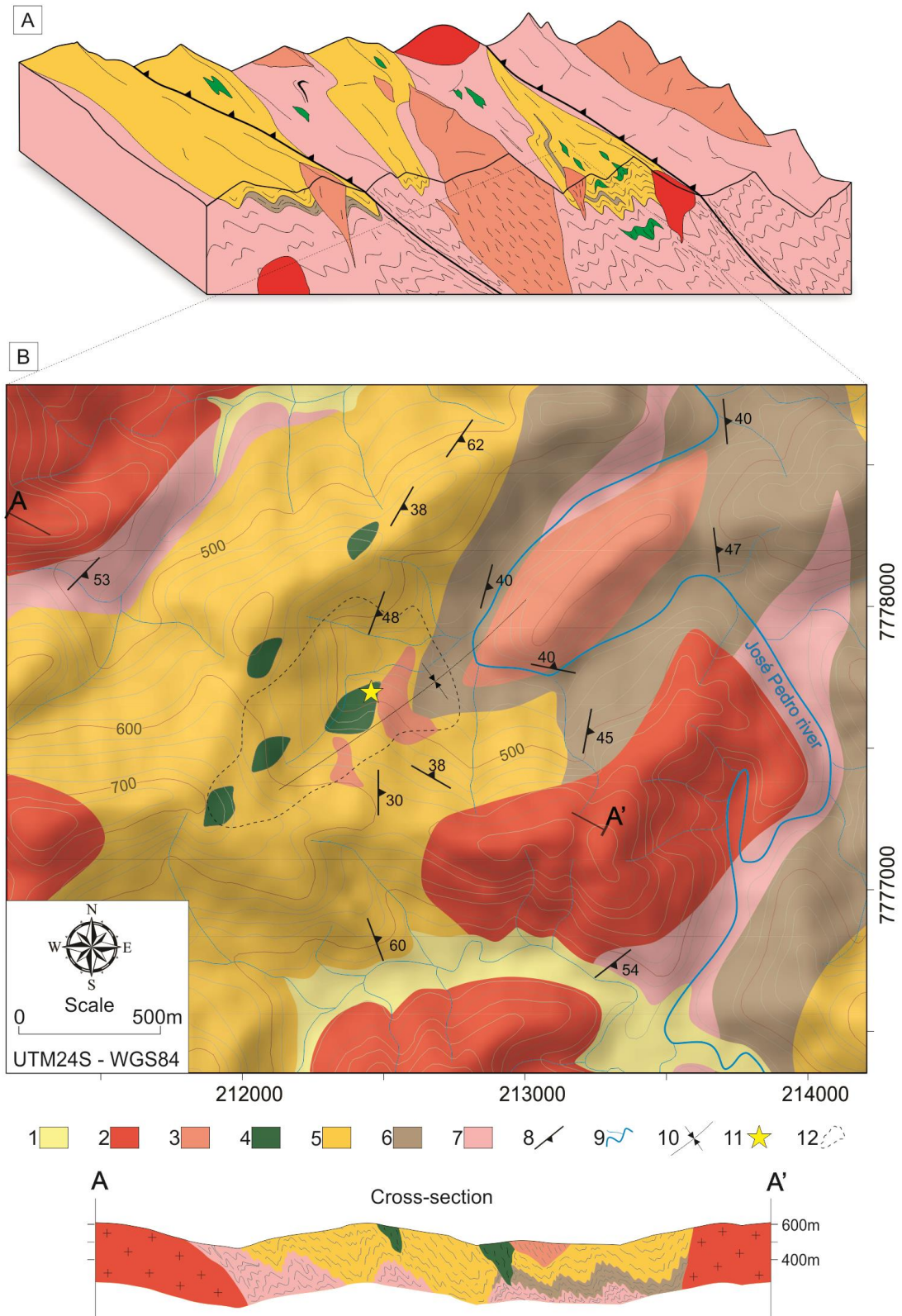


Figure 2 – A) Block Diagram showing the regional context of the study area; B) Geologic map of the study area, Durandé region, eastern Minas Gerais State. 1, Alluvial deposits; 2, Post-tectonic granitoid; 3, Sin-collisional granitoid; 4, Vista Alegre meta-ultramafic body; 5, Quartzite; 6, Mica schist; 7, Basement - migmatitic orthogneisses; 8, foliation; 9, drainage; 10, synclinal; 11, samples used for microanalysis; 12, geophysical ground survey limit area.

### 2.1 Basement

The basement is basically composed of migmatized orthogneiss with interlayered amphibolite lenses. Petrographic studies characterize fine- to medium-grained gneiss with granoblastic texture. The rock shows porphyroclasts of plagioclase as well as of orthopyroxene in a recrystallized matrix of quartz, plagioclase, clinopyroxene and  $\pm$  garnet. Hornblende and biotite typically appear replacing pyroxene and garnet. Locally the rock exhibits augen gneissic structure, mylonitic foliation and quartz ribbons with chessboard subgrains.

### 2.2 Metasedimentary cover

The metasedimentary unit involves paragneiss, schist that grades into quartzite. These rocks are characterized by quartz, biotite, garnet, hornblende, plagioclase, k-feldspar,  $\pm$  kyanite and  $\pm$  sillimanite. The paragneiss exhibit porphyroblast of garnet, kyanite and sillimanite in medium- to a fine-grained granoblastic quartz-biotite rich foliated matrix with porphyroclasts of plagioclase. Quartz displays polygonized to interlobate textures.

### 2.3 Intrusives

There are two facies of granitoids: one facies exhibit tectonic foliation and other the tectonism is absence. The sin-collisional granitoid intrudes the basement complex and metasedimentary unit. It is characterized by medium-grained granoblastic muscovite-biotite granite which is common the presence of garnet and porphyroclasts of k-feldspar. The post-collisional granitoid is coarse-grained and intrudes all units described before. It occurs as batholiths and next to the contact with foliated rocks it forms small sills parallel to foliation.

### 2.4 Structural geology

Regionally the basement and metasedimentary cover portray lenticular tectonic slices limited by mylonitic zones which the deformation decreases from border to the slices nuclei (Fig. 2A). The studied area is located in the internal portion of these slices where the basement and sedimentary cover configure folds with plunging axis in the NE-SW direction (Fig. 2) which is parallel to regional foliation ( $S_n$ ). The foliated granitoids are emplaced in folds axial surface and form elongated bodies aligned parallel to regional foliation.

## 3. VISTA ALEGRE META-ULTRAMAFIC BODY

The Vista Alegre meta-ultramafic body manifests as colluvionar boulders and blocks disperse in the hillside next to the José Pedro River (Fig. 3A). The main lithotype of the

VAMUB is a light grayish yellow colored rock with some greenish spots (Fig. 3 B). It comprises chlorite-talc schist with olivine porphyroclasts and tremolite porphyroblasts. Its modal composition is characterized by 40%-60% of olivine, 35%-45% of talc, 10%-20% of tremolite and approximately 3% of chlorite. Opaque and carbonates occur as accessory minerals.

In thin section, the **Olivine** very often appears as porphyroclasts vastly replaced by talc and chlorite (Fig. 3C). **Talc** occurs as a strongly foliated matrix and also filling veins associated with chlorite and carbonate (Fig. 3E). **Chlorite** locally substitutes olivine edges and cores forming gulfs always associated with opaques (Fig. 3 D and 3F). There are two distinct **chlorite phases** based on its interference color. One chlorite phase (Chlorite1) has low pleochroism and anomalous brown interference color which show intra-crystalline deformation. The other chlorite phase (Chlorite2) exhibit berlin blue anomalous interference color and it has no sign of deformation process. When associated, the blue chlorite displays a crystalline rim which surrounds the brown chlorite (Fig. 3F). **Opaque minerals** occur disseminated through the rock or as poikiloblastic grains associated with chlorite and seldom with tremolite and olivine. Radial fibrous porphyroblasts of **tremolite** overprint all other mineral phases (Fig. 3C, 3E and 3F).

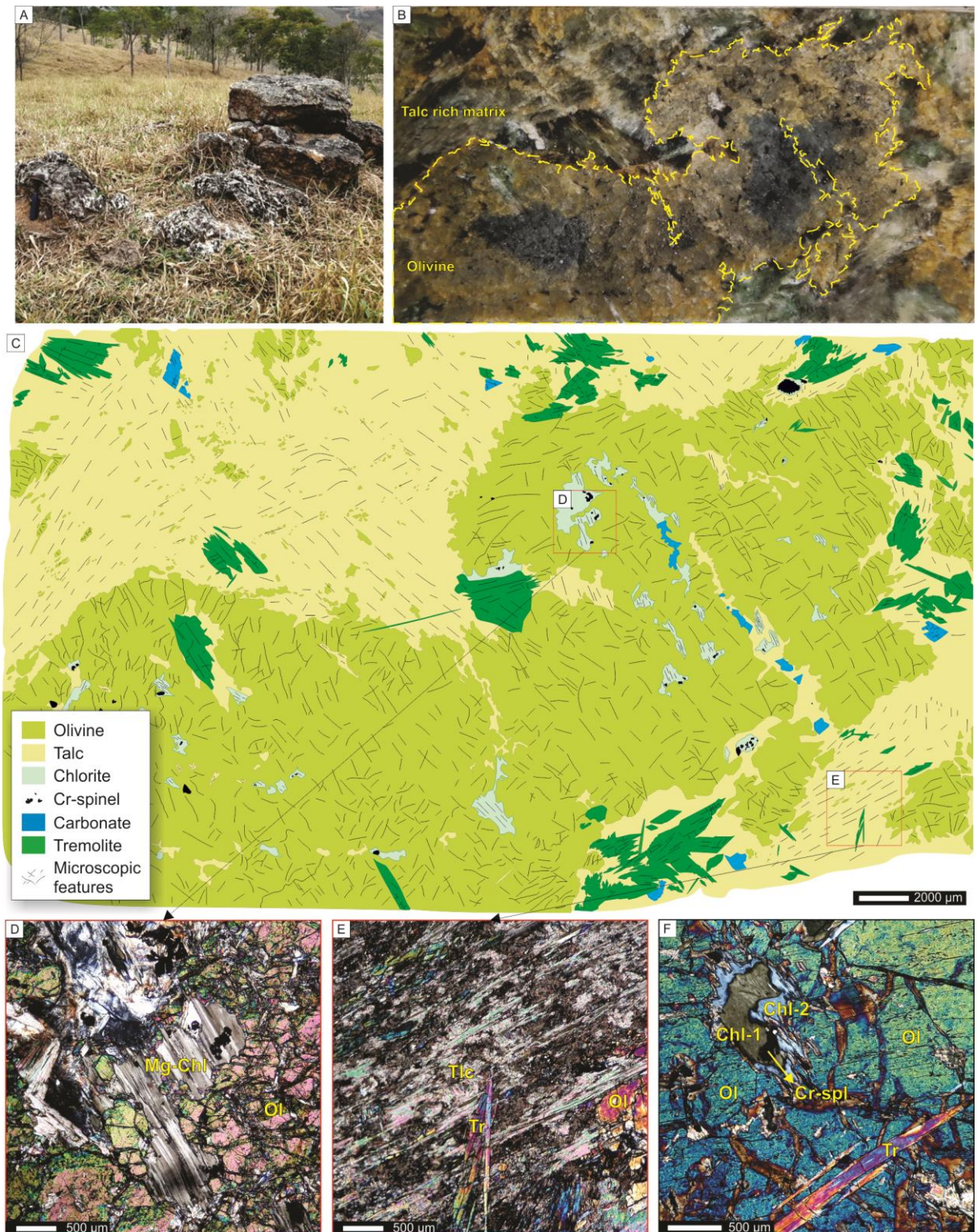


Figure 3: Microscopic features of Vista Alegre meta-ultramafic body: A) Occurrence of meta-ultramafic blocks and boulders in VAMUB; B) Macroscopic feature showing the olivine crystals in a talc-rich matrix; C) Microscopic map representing the microscopic features of the VAMUB; D) Photomicrography showing a gulf of chlorite grain displaying undulatory extinction; E) Photomicrography showing the strongly foliated matrix of talc overprinted by tremolite porphyroblasts; F) Photomicrography showing zoned chlorite grains associated with Cr-spinel grains.

## 4. ANALYTICAL PROCEDURES

### 4.1. Geophysical ground survey

The survey was composed of lines spaced by 50 m, with 20 m between stations. A total of 380 stations arranged in 19 profiles were executed. The azimuth is parallel to the local magnetic declination ( $23^{\circ}19'W$  – NOAA 2016) because it is approximately coincident with the perpendicular direction to the geological structures. The survey was conducted during five days (15 to 19, April 2016). The stations positions were measured with the Garmin® GPSMAP 64s GPS (precision ~5 m). The magnetic data was measured with two GEM Systems GSM-19 magnetometers (proton precession), one for the line acquisition and the other for the base station for diurnal variation correction. These equipments were provided by CODEMIG for this work. The solar activity was monitored with the NOAA data, which any kind of noise or interference was observed. The base station was positioned in the central part of the survey area and programmed to make measurements with 15 min time interval. All measurements (base and mobile stations) were conducted with 2 m height in reference to the ground and manually recorded. The QA/QC and basic data processing were conducted in the Geosoft Oasis Montaj software. For the magnetic data, the diurnal and IGRF (International Geomagnetic Reference Field) corrections were applied. The IGRF correction was executed with the 2016 Geosoft Oasis Montaj database. Next, Total Magnetic Anomaly (TMA) (Fig. 4A), derivatives (x, y and z directions) and Analytical Signal Amplitude (ASA) maps (Fig. 4B) were gridded using the Minimum Curvature available in Geosoft Oasis Montaj, with regular grids, square mesh and 12.5 x 12.5 cm cell size (1/4 of line spacing).

### 4.2. Microanalyses

The microanalyses were performed with an electron microprobe JEOL JXA-8230 at the Microanalysis Laboratory of the Universidade Federal de Ouro Preto. The electron beam was set at 15 kV, 20 nA, 2-5  $\mu\text{m}$  and the common matrix ZAF corrections were applied. Counting times on the peaks/background were 10/5 s for all elements (Na, Si, Al, Mg, Fe, Cr, Ti, Ca, Ni, K, Mn). The standards of the major element set-up are present in table 1 and 2. Olivine, Cr-spinel, talc, amphibole and chlorite were analyzed along transgranular profiles. The mineral formulas were calculated based on 4 oxygens for olivine and cr-spinel, 22 for talc, 23 for amphibole and 28 for chlorite crystals. The total iron content obtained by the microprobe was considered as FeO, except for oxide analysis which was measured as  $\text{Fe}_2\text{O}_3$ . The  $\text{Fe}_2\text{O}_3$  and FeO contents in spine grains were obtained by two steps. First, the total  $\text{Fe}_2\text{O}_3$

contents were transformed in FeO by multiplication for 0,8998. Second, the cationic proportion was estimated according to Dropp (1987). Chemical maps and backscattered electron (BSE) image of cr-spinel were also obtained by the microprobe in order to illustrate the mineral zonation. Operating conditions were 15-kV acceleration, 20-nA beam current, and 20-ms dwell time per spot (stage mode). All the elements considered here (Al, Fe, Cr) were analyzed by wavelength dispersion spectroscopy (WDS). Maps show quantitative element distributions.

*Table 1 - Overview of the major element set-up for olivine, talc, chlorite and tremolite analysis.*

<b>Elements</b>	<b>Crystal</b>	<b>Standard</b>
Na <sub>2</sub> O	TAPH	Anorthoclase
F	TAPH	CaF <sub>2</sub>
SiO <sub>2</sub>	TAP	Quartz
Al <sub>2</sub> O <sub>3</sub>	TAP	Corundum
MgO	TAP	Olivine
TiO <sub>2</sub>	LIFH	Ilmenite
<b>FeO</b>	LIFH	Magnetite
CaO	PETJ	Cr-Augite
NiO	LIF	Glass_Rhyolitic_Corning_Glass_IR-X
Cr <sub>2</sub> O <sub>3</sub>	LIF	Chromite
K <sub>2</sub> O	PETL	Microcline
MnO	LIFL	Ilmenite

*Table 2 - Overview of the major element set-up for spinel analysis.*

<b>Elements</b>	<b>Crystal</b>	<b>Standard</b>
Na <sub>2</sub> O	TAPH	Anorthoclase
SiO <sub>2</sub>	TAP	Quartz
Al <sub>2</sub> O <sub>3</sub>	TAP	Corundum
MgO	TAP	Olivine
TiO <sub>2</sub>	LIFH	Ilmenite
<b>Fe<sub>2</sub>O<sub>3</sub></b>	LIFH	Magnetite
CaO	PETJ	Cr-Augite
NiO	LIF	Glass_Rhyolitic_Corning_Glass_IR-X
Cr <sub>2</sub> O <sub>3</sub>	LIF	Chromite
MnO	LIFL	Ilmenite

## 5. GEOPHYSICAL ASPECTS

The geophysical maps are presented in figure 4. The ASA map presents a large magnetic anomaly in the central part of the area and many smaller circular anomalies in the vicinity (Fig. 4B). These features could be associated with portions of the Vista Alegre meta-

ultramafic body (VAMUB). Seeking to better understand this relation, further data processing was conducted. For the magnetic data, the Radial Average Power Spectrum (RAPS) and the Magnetization Vector Inversion (MVI) techniques were applied.

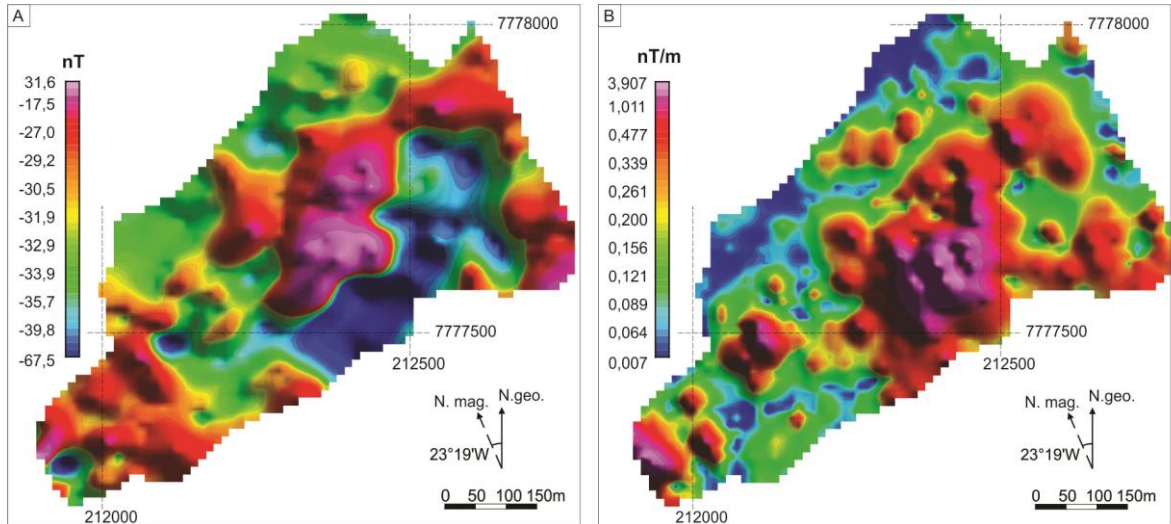


Figure 4 – Geophysical maps: A) Total Magnetic Anomaly (TMA) map; B) Analytical Signal Amplitude (ASA) map.

The RAPS is presented in figure 5. With this technique, the wavenumber (or frequency) content of the magnetic data can be associated with the depth values intervals of the magnetic sources (Spector and Grant 1970). The Nyquist wavenumber is presented in the figure, which corresponds to 25 cycles/km. This value separates the data from the aliased measurements. The shallow magnetic sources present average top depths about 25 m and the deeper sources about 40 m.

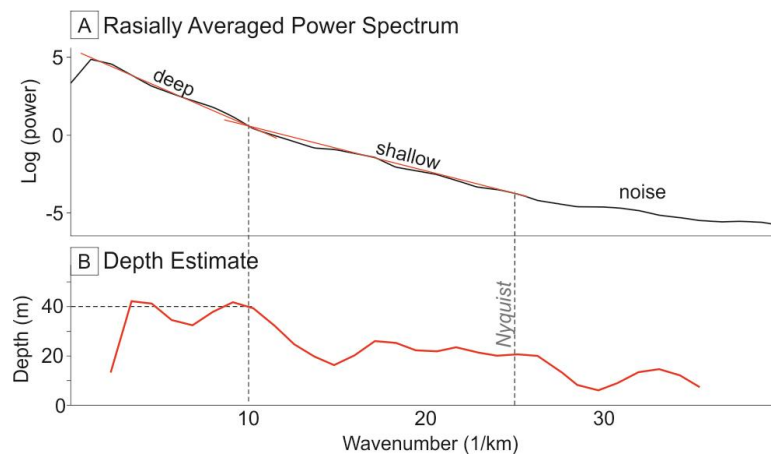


Figure 5 - Radial Average Power Spectrum (RAPS) from magnetic data.

The MVI technique was conducted with the VOXI package for the Geosoft Oasis Montaj and the algorithm is described in Ellis (2015). This algorithm solves the inverse



magnetic problem considering the total magnetization vector properties (intensity and direction). The results are composed by the 3D magnetic susceptibility distribution of the underground and the magnetization vector for each cell of the discretized magnetic model. The results provide the geometrical information about the magnetic sources. This geometrical information could be translated to structural information of the lithologies associated with the magnetic sources. Figure 6 presents the MVI results for the area. The magnetic anomaly in the central part of the area is related to a large magnetic body (magnetic susceptibility  $> 0.003$  SI), with dimensions about 230 m depth and 270 m to NE direction.

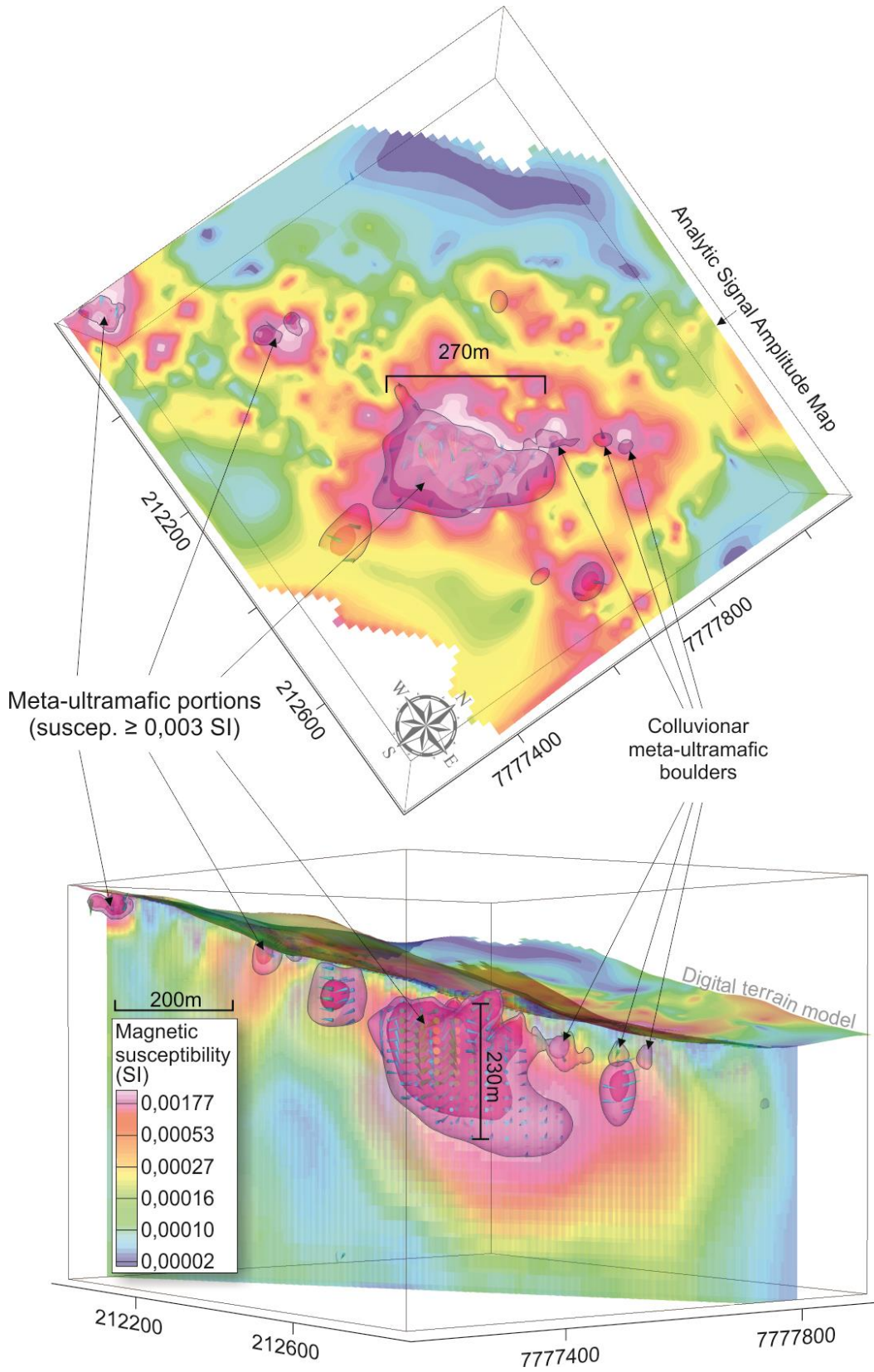


Figure 6 – Diagrams of Magnetization Vector Inversion (MVI).

### 5.1. Geophysical aspects discussion

Generally, the mineral content of the meta-ultramafic rocks are associated with high magnetic susceptibility materials, which magnetite concentration is an important aspect to be associated with the effectiveness of the magnetic method when applied to differentiate this lithology. In the studied area, the host rocks are mainly composed by granites, schist and quartzite, which present minerals with relatively low magnetic susceptibility when compared to ultramafic minerals. Therefore, ASA anomalies could be a good indicator to the location of contact zones with the meta-ultramafic rocks. However, because of the irregular geometries of these anomalies, the interpretation only with this products are limited and frequently qualitative (Telford *et al.* 1990).

This is where the geophysical modeling becomes an important interpretation tool. The MVI technique was applied seeking to solve the geometry and structural information of the meta-ultramafic body in the area. Unlike expected the results indicated that the VAMUB are composed by three shallow portions instead a deep continue one. The portions are aligned to the regional foliation and could have a few hundreds of meters of top depth and lateral extension ~230 m. The shallow magnetic anomalies (~ 25 m) determined by the RAPS analysis could be associated with the meta-ultramafic colluvionar blocks. This material is in the slope and valleys of the hill, which agrees with the shallow magnetic anomalies locations.

## 6. MINERAL CHEMISTRY ASPECTS

Six samples were collected from Vista Alegre meta-ultramafic body for petrographic analysis, of which two were selected for microanalysis. The porphyroclasts of **olivine** exhibit homogeneous MgO (47,04 - 48,28%) and FeO<sub>2</sub> (11,29 - 12,34%) content, with variable NiO (0,42 – 0,13%) and low MnO (down to 0,06%). Based on the Mg/(Fe<sup>2+</sup>+Mg) content it is classified as **chrysolite** with high forsterite compound (Fo<sub>87-88</sub>). Some crystals show cores with relatively high Fo compound (range < 1%) and minor NiO content. The **talca** have a homogeneous chemical composition and substantially compounds the foliated matrix. The results of the granoblastic **chlorite** crystals microanalyses corroborate the different crystalline phases observed in thin sections by distinct interference color. The zoned chlorite shows cores relatively enriched in Al, Fe and Cr and depleted in Mg and Si content (Fig. 7G, 7H and 7I). The chemical compositions of these cores are very similar to the deformed grains thus it might denote two distinct crystalline phases. The Radial fibrous porphyroblasts of amphibole has mainly **tremolite** composition (Leake *et al.* 1997) with subordinate magnesiohornblende.

Despite this chemical variation, the texture and crystal relations indicate that it represent only one mineral phase. The opaque minerals are characterized by high contents of  $\text{Cr}_2\text{O}_3$  (49,88 - 58,37%) ,  $\text{FeO}$  (28,7 - 29,56%) and  $\text{Fe}_2\text{O}_3$  (8,48 - 21,46%); and very low of  $\text{Al}_2\text{O}_3$  (4,24 - 0,64%) and  $\text{MgO}$  (1,65 - 2,42%). In the oxide end-member diagram (Stevens, 1944) they plot in the **Cr-spinel** field and form a trend towards chromite vertex (Fig. 7). The compositional maps and backscattered electron (BSE) images show an interesting subtle chemical zonation. The rims are relatively depleted in Al and Fe, and enriched in Cr (Fig. 7). The Cr-number ( $\text{Cr}\# = \text{Cr}/(\text{Cr}+\text{Al}) = [0,89 - 0,98]$ ,  $\text{Fe}\# = \text{Fe}^{2+}/(\text{Mg} + \text{Fe}^{2+}) = [0,78 - 0,86]$  and  $\text{Mg}\# (\text{Mg}/(\text{Mg}+\text{Fe}^{2+})) = [0,12 - 0,22]$  made it possible to classified them as **ferrichromite** or “ferritchromite”.

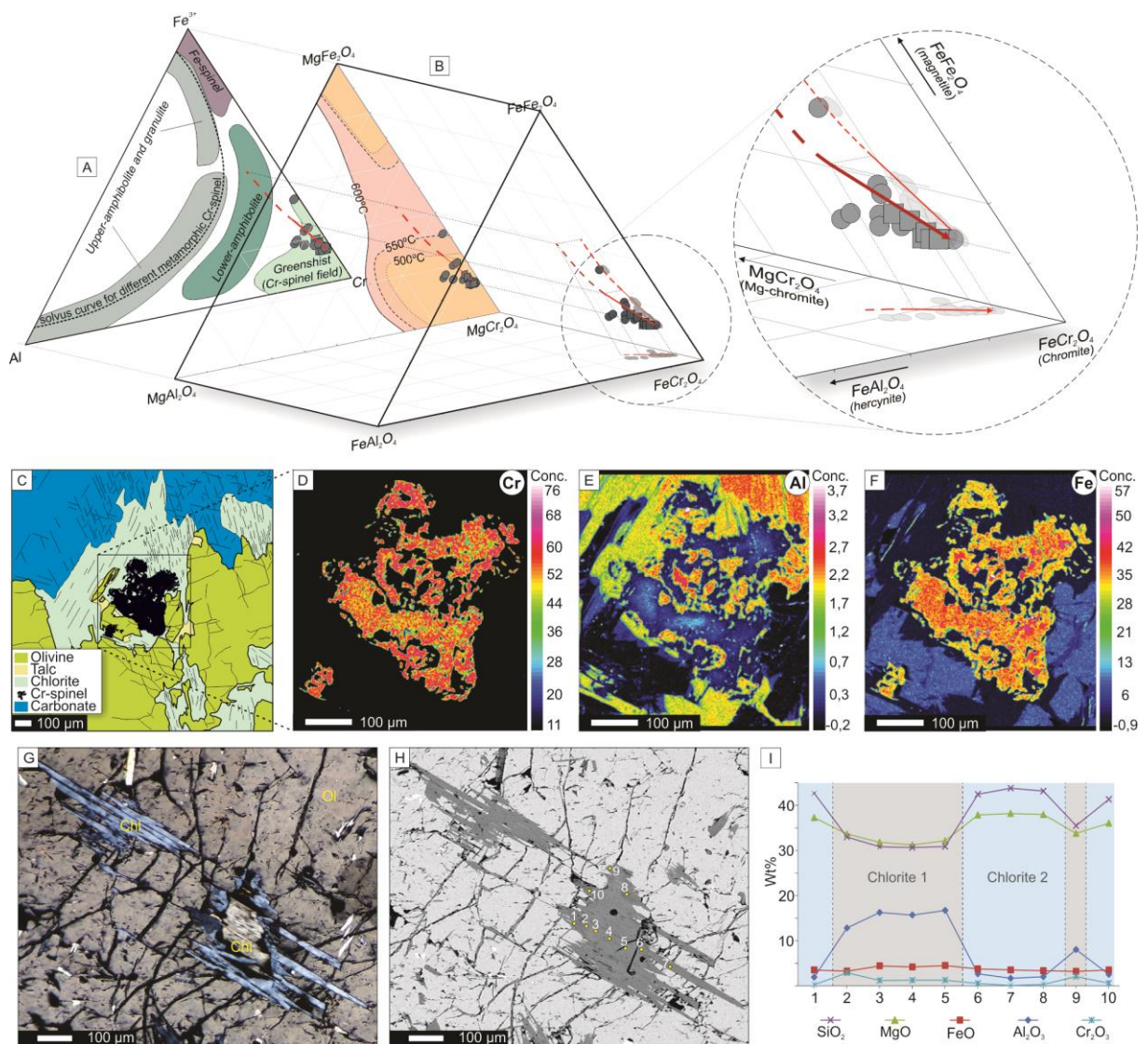


Figure 7 - A) Spinel compositions from the VAMUB based on the trivalent cations  $\text{Fe}^{3+}$ -Cr-Al. Compositional fields from different metamorphic facies after Evans and Frost (1975) and De Freitas Saita and Streider (1996); B) Spinel compositions plotted in oxide end-member diagram (Stevens 1944) and Stability limits of spinels defined for chromite and magnetite. Modified after (Sack and Ghiorso 1991; Barnes 2000) ; C) Microscopic

map representing the mineralogical association involved in spinel metamorphic transformation; D) Chromium compositional map from region limited in C; E) Aluminium compositional map from region limited in C; F) Iron compositional map from region limited in C. G) Photomicrography showing zoned chlorite grains; H) Backscattered electron image of the same chlorites grains showed in E; I) Compositional profiles of the analyzed points in the zoned chlorite grain marked in F.

### 6.1. Petrography and mineral chemistry aspects discussion

There are no petrographic evidences of the VAMUB igneous photolith. All igneous evidences, as cumulatic texture or chromitite layers, seem to be obliterated by metamorphic, metasomatic/hydrothermal and deformational processes. Therefore olivine porphyroclasts and zoned relicts of spinel were interpreted as high grade metamorphic phases which remain a progressive metamorphic peak until high-amphibolite-granulite facies condition. Representing a posterior process, the lepdoblastic talc-rich matrix, granoblastic chlorites (1 and 2) and tremolite porphyroblasts indicate a subsequent metamorphic retrogression until low amphibolite-green schist facies condition. In this retrograde step the presence of talc englobing the olivine relicts are evidence of a vast but incomplete hydration suffered by olivine. Concomitantly, chlorite was formed by metamorphic reaction between olivine and/or talc and Al from spinel. Prior studies have noted that, generally, during metamorphism spinel tends to lose Al content relative to Cr to form chlorite or amphibole, increasing the Cr# (Barnes and Roeder 2001). The new spinel formed by this retrogressive metamorphic reaction is known as ferrichromite. It is a type of chromite alteration found in many ultramafic rocks commonly associated with Mg-chlorite (Bliss and McLean 1975, Evans and Frost 1975, Barra *et al.* 1998). Strong evidence of it can be observed in the chemical zonation of Cr-spinel grains illustrated by the Figure 7. It is clear that Al content decreases and the Cr content increases from the core to the margin. The fact of Cr-spinel compositions display a trend directing to chromite or Cr vertex is another evidence for metamorphic reaction (Fig. 7B). Compared with the Cr-Al-Fe<sup>3+</sup> compositions of spinel from different metamorphic facies (Fig. 7A), as well as with spinel stability limits (Fig. 7B), the cr-spinels from VAMUB plot in the field of upper greenschist facies conduction, at temperatures ranging from 500 to 550°C. Porphyroblasts of tremolite and rims of second generation of chlorite (Chlorite 2) overprints all the precursor phases which presumably correspond to the final retrogressive metamorphic path when temperature operated without deformation.

The presence of carbonates in hydrated ultramafic rocks is very common. Its origin is very controversial but is often associated with CO<sub>2</sub> bearing fluids percolation (Schandl and Naldrett 1992; Hansen *et al.* 2005). Carbonate is restricted to high permeability zones, as fractures and veins, and seems to be present during all VAMUB alteration stages as

hydrothermal products. Interestingly, the most significant chemical difference from the other mineral groups is the presence of Calcium in the undeformed porphyroblasts. Thus, the presence of carbonate from previously alteration could be related with the source of Ca to form tremolite.

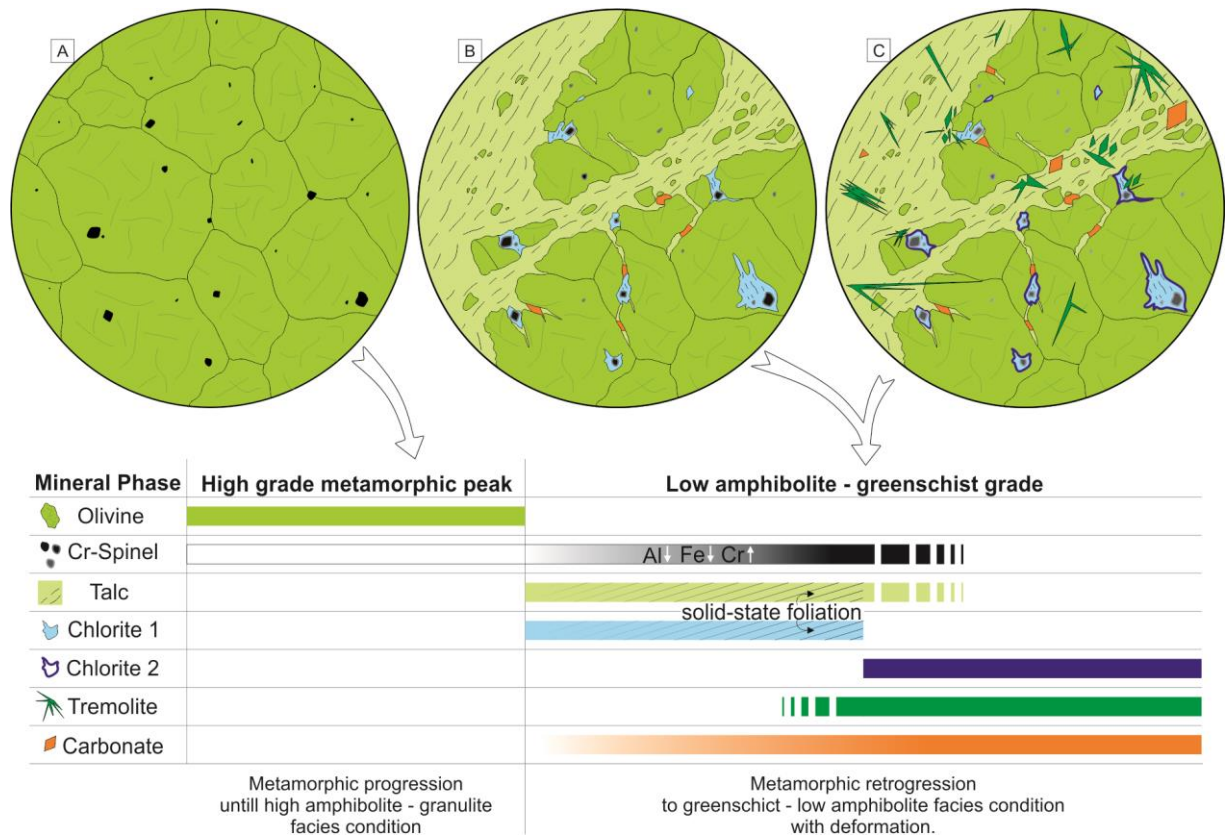


Figure 8 – Diagram representing the petrological evolution of VAMUB. A) High-grade metamorphic peak; B) Metamorphic retrogression with solid-state deformation; C) Final metamorphic retrogression stage without deformation.

## 7. TECTONO-METAMORPHIC EVOLUTION OF VAMUB DISTRICT

The petrographic and mineral chemistry studies of the meta-ultramafic rock indicate a high-grade progressive metamorphic path followed by a retrograde process. The metamorphic peak must have reached granulite facies condition. Indications of similar metamorphic evolution are found in basement and metasedimentary cover, previously described in section 3. In the basement, the high-grade conditions are represented by mineral paragenese: orthopyroxene, quartz, plagioclase and  $\pm$  garnet. In the metasedimentary cover it is represented by plagioclase, quartz, garnet,  $\pm$  silimanite and  $\pm$  kyanite.

The metamorphic retrogression is found as mineral paragenese of low amphibolite-green schist facies condition. It affected the basement, metasedimentary cover and foliated

granitoid facie. It is mainly found as oriented biotite and hornblende which replace orthopyroxene and garnet.

The tectonism seems to be present in all metamorphic paths. The ultramafic portions defined in the magnetic survey corroborates with the strong deformational process which forms big boudins parallel to the regional foliation. It is supported by mylonitic foliation, quartz ribbons with chessboard subgrains mostly observed in basement and metasedimentary cover and granoblastic and lepidoblastic texture of its substituted mineral phases.

## 8. CONCLUSIONS

This paper has investigated a small buried meta-ultramafic body and its host-rock from geophysical, petrographic and mineral chemistry aspects. The Vista Alegre meta-ultramafic body is intrusive in basement and metasedimentary cover. The magnetic data indicates three relative shallow body portions instead one deep continuous body. This spatial configuration is result of tectonic process which forms big “*boudins*” parallel to the regional foliation. The petrographic and mineral chemistry studies characterize a metamorphic path which represents the tectonic evolution of the Araçuaí-West Congo orogen high-grade core. The rocks of the VAMUB district passed through progressive metamorphic event which reaches granulite grade and posterior stabilization in greenschist facies condition by metamorphic retrogression. Angeli *et al.* (2001) and Costa *et al.* (1998) reported the same metamorphic path for nearby rocks. Geophysical and microscopic data showed a strong tectonism associated with the metamorphic evolution. The petrological and field relationships with the foliated granitoid corroborate the idea of orogenic correlated process during collisional stage of the AWCO (Pedrosa-Soares *et al.* 2011, Melo *et al.* 2017). Furthermore, due to the geological context, the undeformed granite has strong correlation with the late orogenic plutonism during the AWCO post-collisional stage (Campos *et al.* 2004).

## 9. ACKNOWLEDGMENTS

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### Capítulo 3 – Artigo 2

## RECORDS OF MESOPROTEROZOIC TAPHROGENIC EVENTS IN THE EASTERN BASEMENT OF THE ARAÇUAÍ OROGEN, SOUTHEAST BRAZIL

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### ABSTRACT

The history of palaeocontinents alternates long fragmentation to drift periods with relatively short agglutination intervals. One of the products of a Rhyacian-Orosirian orogeny was a palaeocontinent that brought together the basement of the Araçuaí-West Congo orogen (AWCO) with regions now located in the São Francisco and Congo cratons. From ca. 2 Ga to ca. 0.7 Ga, this large region of the São Francisco-Congo palaeocontinent was spared of orogenic events, but underwent at least five taphrogenic events recorded by anorogenic magmatism and/or sedimentation. The taphrogenic events are well documented in the AWCO proximal portions and neighboring cratonic regions, but lack evidence in the AWCO high-grade core. Our studies on amphibolites intercalated in the Rhyacian Pocrane complex, basement of the Rio Doce magmatic arc, allowed to the recognition of two Mesoproterozoic taphrogenic episodes. The oldest, a Calymmian episode, is recorded by amphibolites with a zircon magmatic crystallization age at  $1529 \pm 37$  Ma (U-Pb SHRIMP), and lithochemical signature of basaltic magmatism related to continental intraplate settings. Another set of amphibolite bodies records the youngest taphrogenic episode, a Stenian event, with a zircon magmatic crystallization age at  $1096 \pm 20$  Ma (U-Pb SHRIMP), and lithochemical signature similar to mature magmatism of continental rift setting. The Calymmian episode (ca. 1.5 Ga) correlates to the Espinhaço II basin stage and mafic dikes of the northern Espinhaço - Chapada Diamantina and Curaçá domains, while the Stenian episode (ca. 1.1 Ga) correlates to the Espinhaço III basin stage. We also present U-Pb data for 87 detrital zircon grains from a quartzite lens intercalated in the Pocrane complex, the Córrego Ubá quartzite. Its age spectrum shows main peaks at  $1176 \pm 21$  Ma (35%),  $1371 \pm 30$  Ma (18%),  $1536 \pm 22$  Ma (19%),  $1803 \pm 36$  Ma (17%) and  $1977 \pm 38$  Ma (12%), suggesting a Stenian (ca. 1176 Ma) maximum depositional age (although only one zircon with low discordance shows an age of  $955 \pm 66$  Ma). Comparing with data from the western sector of the Araçuaí orogen and São Francisco craton, it is noteworthy that no igneous zircon from the three samples yielded an age older than early Orosirian (~2.05 Ga), showing age spectra essentially limited in the range of ca. 1 – 2 Ga; i.e., younger than the Late Rhyacian orogeny that amalgamated the basement, and older than the main anorogenic event (930-870 Ma) associated with the Early Tonian precursor basin of AWCO. All together, these continental taphrogenic events testify the several unsuccessful fragmentation attempts that affected the long-lived São Francisco-Congo palaeocontinent, which remained preserved from a complete break-up associated with ocean spreading from the Early Orosirian to the Atlantic opening in Cretaceous time.

*Keywords: Taphrogenic Events; São Francisco-Congo palaeocontinent; Araçuaí-West Congo orogen*



## 1. INTRODUCTION

The history of palaeocontinents includes short compressive orogenic processes, intercalated with large taphrogenic phases marked by fragmentation and drift (Nance *et al.* 1988, Murphy and Nance 1992, Rogers and Santosh 2004). In this context, a new-formed continent becomes a refractory cap that hinders heat release from the Earth's mantle. The heat transmission is associated magmas, that tends to settle beneath rift systems. The reconstruction of the rifting events is easily detected and characterized when it comes from undeformed domains. However, reconstruction becomes much more complex in orogenetic reworked cores, where rocks associated with taphrogenic events are intensely deformed. A fundamental tool for the analysis of tectonized magmatism and/or sedimentation is U-Pb dating on zircon grains. Besides the magmatic and metamorphic age, the analyses of the zircon age spectra of sedimentary deposits may reflect the tectonic setting of the basin, providing important hints for tectonic and palaeogeographic interpretations (Cawood *et al.* 2012).

The study area, located in the Araçuaí orogen, southeastern Brazil (Fig. 1), records a series of events related to the amalgamation of the São Francisco-Congo palaeocontinent in the Rhyacian-Orosirian boundary (Noce *et al.* 2007), as well as the evolution of the Araçuaí orogen in Neoproterozoic time (Pedrosa-Soares *et al.* 2001, 2008; Alkmim *et al.* 2006). It lacks evidence that the region had experienced orogenic events from the Orosirian to the Ediacaran. Conversely, during that long period the region between the São Francisco and Congo cratons records at least five major taphrogenic events that ultimately led to the development of the precursor basin system of the Araçuaí orogen (Pedrosa-Soares and Alkmim 2011, Chemale *et al.* 2012, Guadagnim *et al.* 2015, Tupinambá *et al.* 2007). Although these anorogenic events are well documented in the proximal zone of the Araçuaí orogen and in the São Francisco craton, no solid evidence from them were previously found in the high-grade core of the Araçuaí orogen.

This paper focuses on metamafic rocks (amphibolites) and the Córrego Ubá quartzite, spatially associated with the Rhyacian Pocrane complex, located in the high-grade core of the Araçuaí orogen (Fig. 1). Our field, petrographic, lithochemical and geochronological (zircon U-Pb SHRIMP and LA-ICP-MS) studies provide evidence of two distinct Mesoproterozoic taphrogenic events on the Rhyacian basement of the Araçuaí orogen high-grade core. Based on a thorough compilation of the literature, we correlate these data with the main unsuccessful

taphrogenic events that affected the São Francisco-Congo palaeocontinent before the evolution of the Araçuaí orogen.

## **2. GEOLOGICAL SETTING**

The Neoproterozoic Araçuaí orogen together with its counterpart located in Africa, the West Congo belt, evolved during the Brasiliano cycle, one of the tectonic cycles that led to West Gondwana amalgamation.

The focused area covers part of the basement of the high-grade core of the Araçuaí orogen (Fig. 1), where the Ediacaran Rio Doce magmatic arc is an outstanding feature and metamorphic peaks ranges from the amphibolite to granulite facies (Novo *et al.* 2010; Tedeschi *et al.* 2015; Gonçalves *et al.* 2015).

The basement includes gneissic-migmatitic complexes in the amphibolite (e.g., the Pocrane complex; Novo 2013) to granulite facies (e.g., the Juiz de Fora complex; Noce *et al.* 2007). Those complexes formed in response to convergence related to an orogenic Rhyacian-Orosirian event that amalgamated the São Francisco-Congo palaeocontinent (Noce *et al.* 2007; Heilbron *et al.* 2010; Silva *et al.* 2016). After the basement consolidation, the region seems to have experienced a long period without any event of compressive nature (Pedrosa-Soares *et al.* 2001, 2008, 2011; Pedrosa-Soares and Alkmim 2011), until the onset of the Brasiliano orogeny in the Early Ediacaran (Novo *et al.* 2010; Pedrosa-Soares *et al.* 2011; Tedeschi *et al.* 2015).

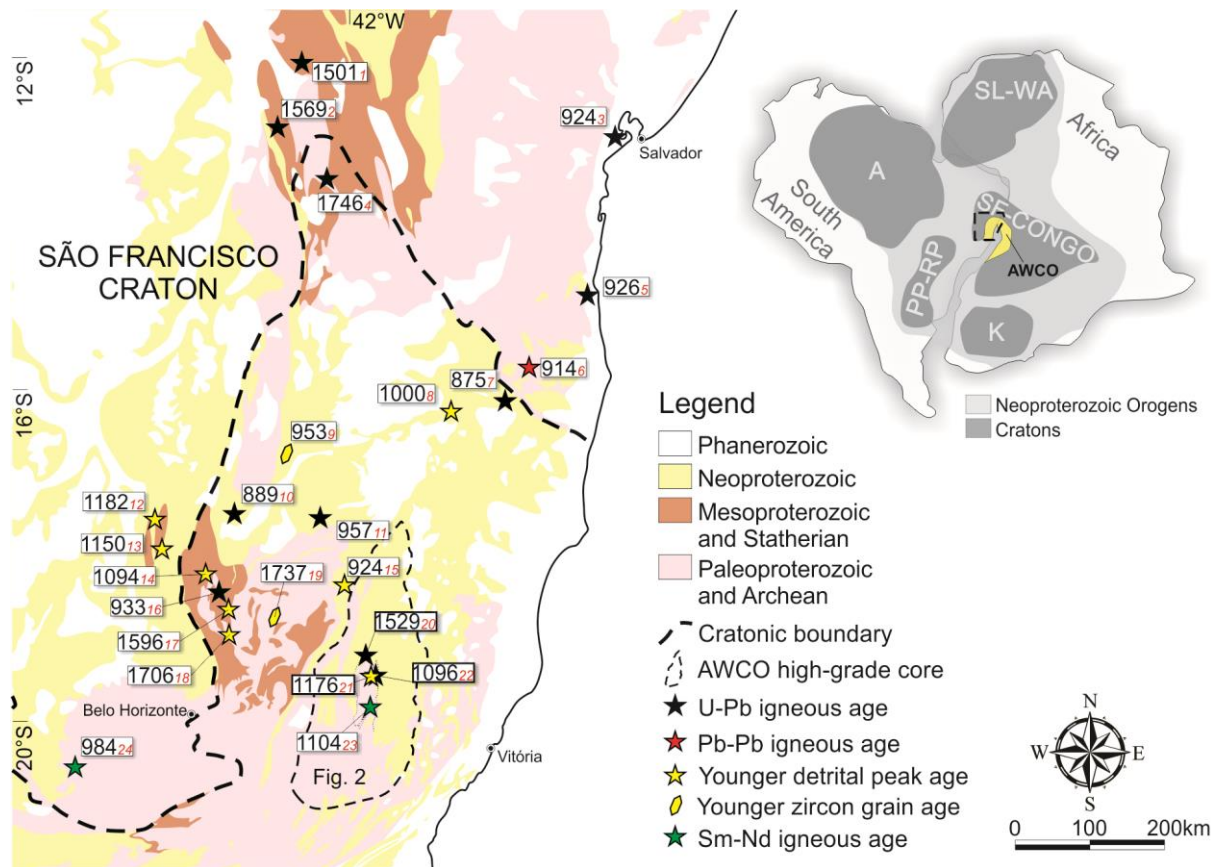


Figure 1: Tectonic situation of the São Francisco Craton and the neighbor orogens. Ages shown in the map are from: 1) *Silveira et al. 2013*; 2) *Danderfer et al. 2009*; 3) *Evans et al. 2015*; 4) *Lobato et al. 2015*; 5) *Evans et al. 2015*; 6) *Menezes et al. 2012*; 7) *Silva et al. 2002*; 8) *Gonçalves-Dias et al. 2016*; 9) *Kuchenbecker et al. 2015b*; 10) *Souza 2016*; 11) *Castro et al. 2015*; 12) *Dussin 2016*; 13) *Kuchenbecker et al. 2015a*; 14) *Chemale et al. 2012*; 15) *Peixoto et al. 2015*; 16) *Dussin & Chemale 2012*; 17) *Silveira 2016*; 18) *Rolim et al. 2016*; 19) *Barrote 2016*; 20) *This Work*; 21) *This Work*; 22) *This Work*; 23) *Angeli et al. 2004*; 24) *Chaves 2001*;

### 2.1. Pocrane Complex

The Pocrane Complex is mainly composed of TTG orthogneiss with migmatitic portions. *Stricto sensu* amphibolite lenses (Fig. 2) usually occur interlayered in this gneiss (*Silva et al. 1987*; *Novo 2013*), as sills or tectonic slices. Previously reports on these metamafic rocks (*Paes 1999*, *Silva et al. 2002*) points out the variability of its genesis. In the available geological maps (*Tuller 2000*; *Féboli and Paes 2000*; *Oliveira 2000*) lenses and layers of ultramafic and metasedimentary rocks (e.g. calcissilicatic rock, mica schist, paragneiss, quartzites, marble and paraconglomerate) were described as intercalations in the Pocrane complex orthogneiss. The structural pattern of the metasedimentary layers, delineates a large fold with a plunging axis in the NNE-SSW direction and hinge concavity facing SSW. At first, the available geological data suggests that the lithological set (orthogneiss, metamafic and metasedimentary layers) should be a bundle of interpolations of igneous and sedimentary origins, simultaneously folded as a deformed and metamorphosed volcano-sedimentary

sequence. However, the new data present in this paper refutes this theory (of one single volcano-sedimentary association), showing that at least part of the metamafic rocks and the sedimentary strata is younger than the orthogneiss.

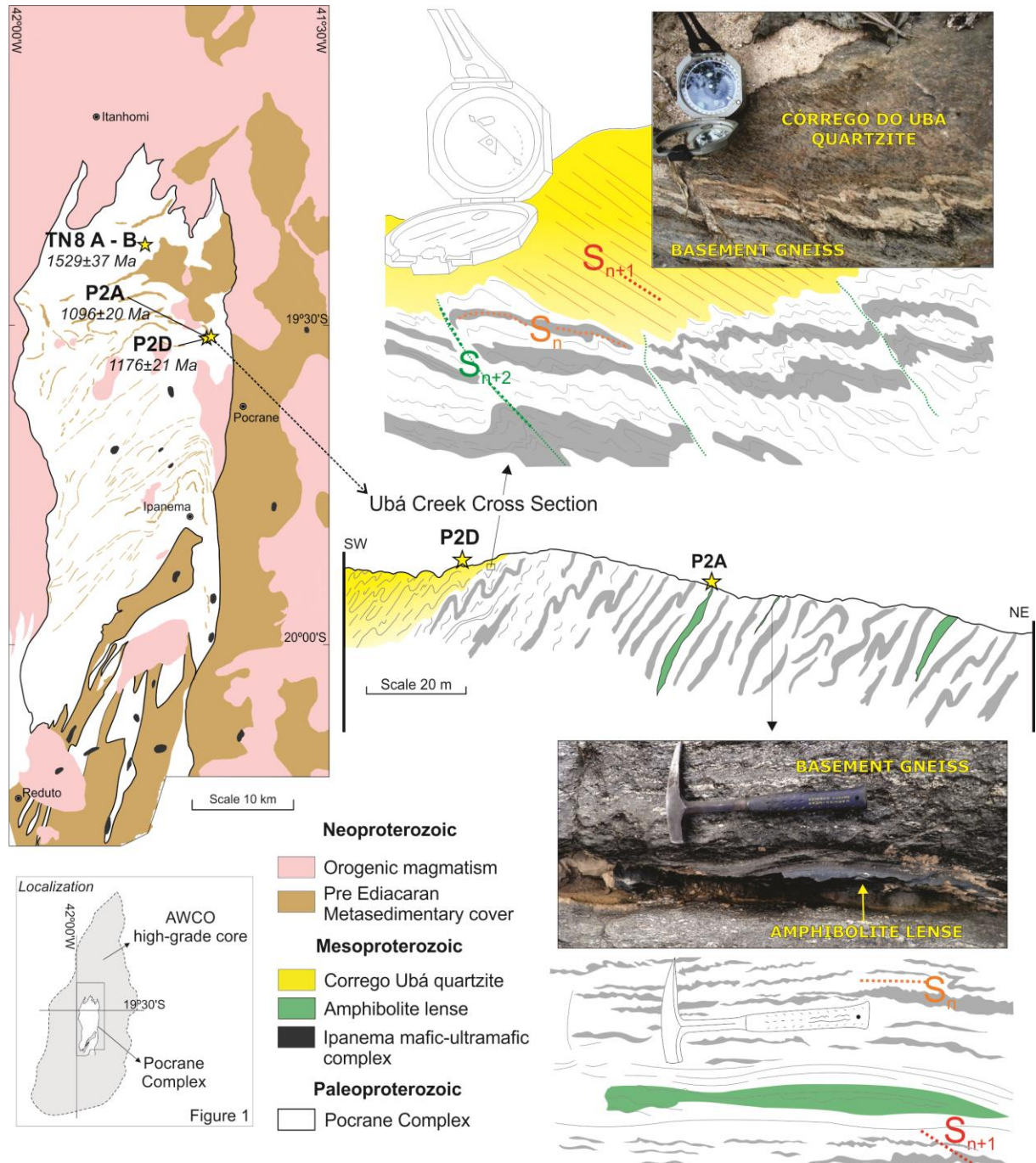


Figure 2 - Geological map of the Pocrane Complex and the Córrego Ubá Cross Section showing the field aspects of the Córrego Ubá quartzite and amphibolite lenses. Yellow star marks the sample site location.

## 2.2. Córrego Ubá quartzite

The Córrego Ubá quartzite occurs as a tectonic slice interlayered in the Pocrane Complex gneiss (Ubá Creek Cross Section in Fig. 2). It is a fine-grained and recrystallized

quartzite, that shows three foliation sets, which the main one ( $S_n$ ) is marked by biotite and muscovite, north-south trend and moderate deep to east. Near tectonic contacts the foliation develops a mylonitic texture. The biotite enrichment confers a strongly folded and crenulated gneiss banding that marks  $S_{n+1}$ . A brittle deformation crosscut all the previous structures materializing  $S_{n+2}$ . The quartzite is mainly composed by quartz with granoblastic polygonal texture and accessory biotite, muscovite, plagioclase, titanite and zircon.

### 2.3. Amphibolites lenses

The amphibolites we focus outcrop as thick lenses (Fig. 2) with low lateral continuity (not more than six meters) interlayered with the Pocrane Complex gneiss. They show fine-grained and compact aspect, but foliation is visible with a magnifying glass and in thin section, or in partially weathered outcrops. The amphibolite consists of hornblende, plagioclase, biotite, quartz, chlorite, apatite, titanite, zircon and opaque minerals (Fig. 3). Biotite and chlorite are formed by hornblende alteration. Biotite may be more abundant than hornblende. The foliation ( $S_n$ ) of amphibolites is anastomosed, developed from a progressive deformational phase. Sometimes late ductile shear zones obliterate the foliation. Amphibole crystals and biotite palettes materialize the foliation, and the stretched amphibole crystals commonly form ocellar porphyroclasts, showing pressure shadows and recrystallization tails. Quartz and plagioclase occur as stretched crystals, parallel to the foliation, and may display dynamic recrystallization with subgrains individualization.

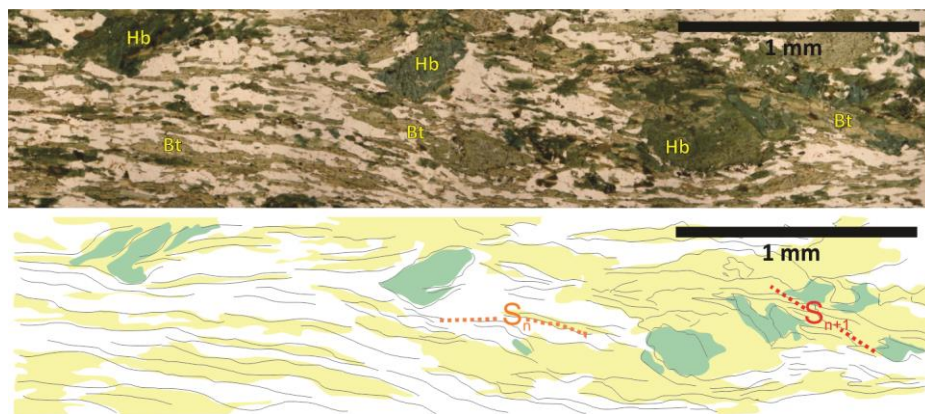


Figure 3: Amphibolite microscopic aspects:  $S_n$  and  $S_{n+1}$  foliation outlined by hornblende and biotite, which envelops hornblende porphyroclast.

### 3. AMPHIBOLITE LITHOCHEMISTRY

#### 3.1. Analytical procedures

The whole-rock lithochemical analyses were conducted on three samples from distinct amphibolite lenses: TN-8A, TN-8B and P2A (Fig. 2). Sample powders were analyzed by Geosol Laboratories in Belo Horizonte/Brazil. Major and trace element contents were determined using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OS/MS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS), respectively. Detection limits are 0.01% for oxides and 0.1 ppm for most trace elements, reaching values up to 0.01 ppm for Heavy Rare Earth Elements (HREE), such as Tb, Tm and Lu. The lithochemical analyses are available in the Supplementary data file labeled as Lithochemical\_Data.

#### 3.2. Results

Whole-rock chemical analyses were performed for major and trace elements of three samples of amphibolite lenses. Although the data are not sufficient for a statistical analysis, the analytical results provide a preliminary approach.

Classification diagrams for the magmatic protoliths of amphibolites indicate tholeiitic gabbro and sub-alkaline compositions, (Fig. 4A, 4B). The Rare Earth Elements (REE) patterns distribution show that samples TN8A and TN8B are markedly different from sample P2A (Fig. 4C). Sample P2A is low fractionated and very little depleted in LREE [(La/Yb)<sub>N</sub>=0.63], meanwhile Samples TN8A and B are, on the whole, enriched in REE [(La/Yb)<sub>N</sub>=2.91–7.39]; they show remarkable fractionation, with enrichment of LREE in relation to HREE.

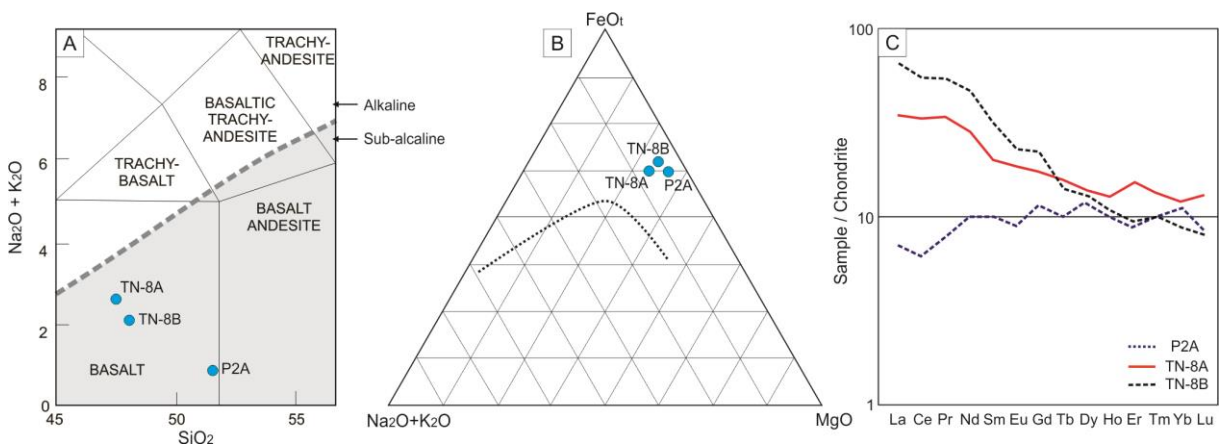


Figure 4: Classification of amphibolite samples in the diagrams: A) TAS (Wilson, 1989 and Xinhua et al. 2000) and alkaline and sub-alkaline diagram (Irvine and Baragar 1971, In Rollinson 1993; B) AFM diagram (Jensen, 1976); C) Chondrite-normalized REE patterns (Taylor and McLennan 1985) in comparison to some general

*patterns - Normalized to Morb-N (Hofmann 1988), Continental Crust and Superior Crust (Weaver and Tarney 1984) and Ocean Island Basalt (OIB; Sun, 1982);*

The lithochemistry presented here reflects the differences amphibolites under study. Despite their field and petrographic similarities, their ages are different, as shown below.

#### **4. GEOCHRONOLOGY**

Two samples of amphibolites lenses were prepared and analyzed for U–Pb isotopes in the CPGeo, São Paulo University, Brazil, by using the Sensitive High Resolution Ion Microprobe (SHRIMP IIe) equipment. One sample from Córrego Ubá quartzite were prepared and analyzed for U–Pb isotopes by using the Laser Ablasion Multicollector Inductively Coupled Plasma Mass Spectrometry (LAMC-ICP-MS) equipment in the CPGeo, São Paulo University, Brazil.

##### *4.1. Material and Methods*

About 20 to 40 kg of each rock sample, as for quartzite and amphibolite, were prepared for analyses in laboratories of the São Paulo University, Brazil. Zircon grains were separated using conventional methods (crushing, grinding, gravimetric and magnetic-Frantz isodynamic separator) and handpicked under binocular microscope. For geochronological analysis of the magmatic rocks and their metamorphic equivalents, we selected zircon crystals from the least magnetic fractions. After mounted in epoxy disks and polished to expose grain centers, backscattered electron (BSE) and cathodoluminescence (CL) images revealed morphological features and internal structures of zircon grains. No analytical spot was performed on grain areas with inclusions, fractures and/or metamict features. Temora (417 Ma; Black *et al.* 2003) standard zircon was used in SHRIMP and M127 (Klotzli *et al.* 2009) and Plešovice (Sláma *et al.* 2008) standard zircons were used in LA-MC-ICP-MS analytical routines. In this study, the spot size in SHRIMP analyzes had 30  $\mu\text{m}$  and 25  $\mu\text{m}$  in LA-MCICP-MS. Data reduction used the SQUID software (Ludwig, 2003) for the SHRIMP data, and Glitter software (Van Achterbergh *et al.* 2001), and the Excel sheet developed by Ludwig (2003) for the LA-MC-ICPMS data. Data evaluation for each spot took into account the common Pb contents, errors of isotopic ratios, percentages of discordance and Th/U ratios. From the selected spots, only those with discordance lesser than 10% were used to age calculations and plotted in histograms and Concordia diagrams. The Concordia diagram and histograms were obtained with the software Isoplot/Ex (Ludwig, 2003).

Only zircon crystals from the least magnetic fractions were selected from samples P2A and TN-08A (amphibolite lenses that occur interlayered in the Pocrane Complex orthogneiss). For the Córrego Ubá quartzite a number up to 120 detrital grains were randomly picked. Grains were mounted in epoxy disks and polished to expose their centers. Morphological features and internal structures of zircon grains were revealed by backscattered electron (BSE) and cathodoluminescence (CL) images. U–Pb (SHRIMP and LA-MC-ICP-MS) analysis were performed on zircon crystals recovered from the amphibolite lenses (samples P2A and TN-08) in order to obtain igneous crystallization and metamorphic ages. Analysis on detrital zircon grains from sample P2D (Córrego Ubá quartzite) were performed by using U–Pb (LA-MC-ICP-MS) in order to determine maximum depositional ages and sedimentary provenance. The new U-Pb analyses are available in the Supplementary data file labeled as U\_Pb\_data.

#### 4.2. U–Pb SHRIMP results for the amphibolite lenses (samples TN-08A and P2A)

Two amphibolite lenses were collected for geochronological U-Pb analyses: TN-8A (UTM24S: 206564E/7856556S WGS84) and P2A (UTM24S: 219363E/7841825S WGS84) (Fig. 2).

*Sample TN-08A:* amphibolite occurring as a decimeter-thick lens, interposed in the Pocrane Complex orthogneiss. It features as a fine-grained and massive rock, being composed of hornblende and plagioclase, quartz, biotite, apatite, titanite and zircon as accessory minerals. Amphibole and biotite mark the regional foliation (Sn). Twenty four zircon grains from sample TN8A were analyzed by U-Pb SHRIMP. Cathodoluminescence images show two different families of zircon grains (Fig. 5). The first one was formed by 2:1 and 3:1 ratio crystals, with preserved igneous features (e.g., 6.1 and 3.1 grains). The second family shows a prismatic proportion of 2:1 grains, with incipient to advanced metamict processes (e.g., 4.1 and 11.1 grains). Grains of the two families present a thin metamorphic overgrowth with high luminescence, which could not be dated due to the small length of its metamorphic edge. Fifteen spots with better analytical consistency result in an upper intercept age of  $1529 \pm 37$  Ma (MSWD = 0.25), interpreted as igneous crystallization age of TN-8A amphibolite igneous protolith (Fig. 5C). The amphibolite metamorphic age was calculated using the data from five spots with good analytical consistency, which resulted in a concordant age of  $627 \pm 20$  Ma (MSWD = 1.6; Fig. 5A). The magmatic crystallization age and metamorphic age presented here for the TN-8A amphibolite are equal (considering the analytical errors) to the values obtained in another amphibolite lens in the nearby area (Bananal site) by Silva *et al.* (2002).



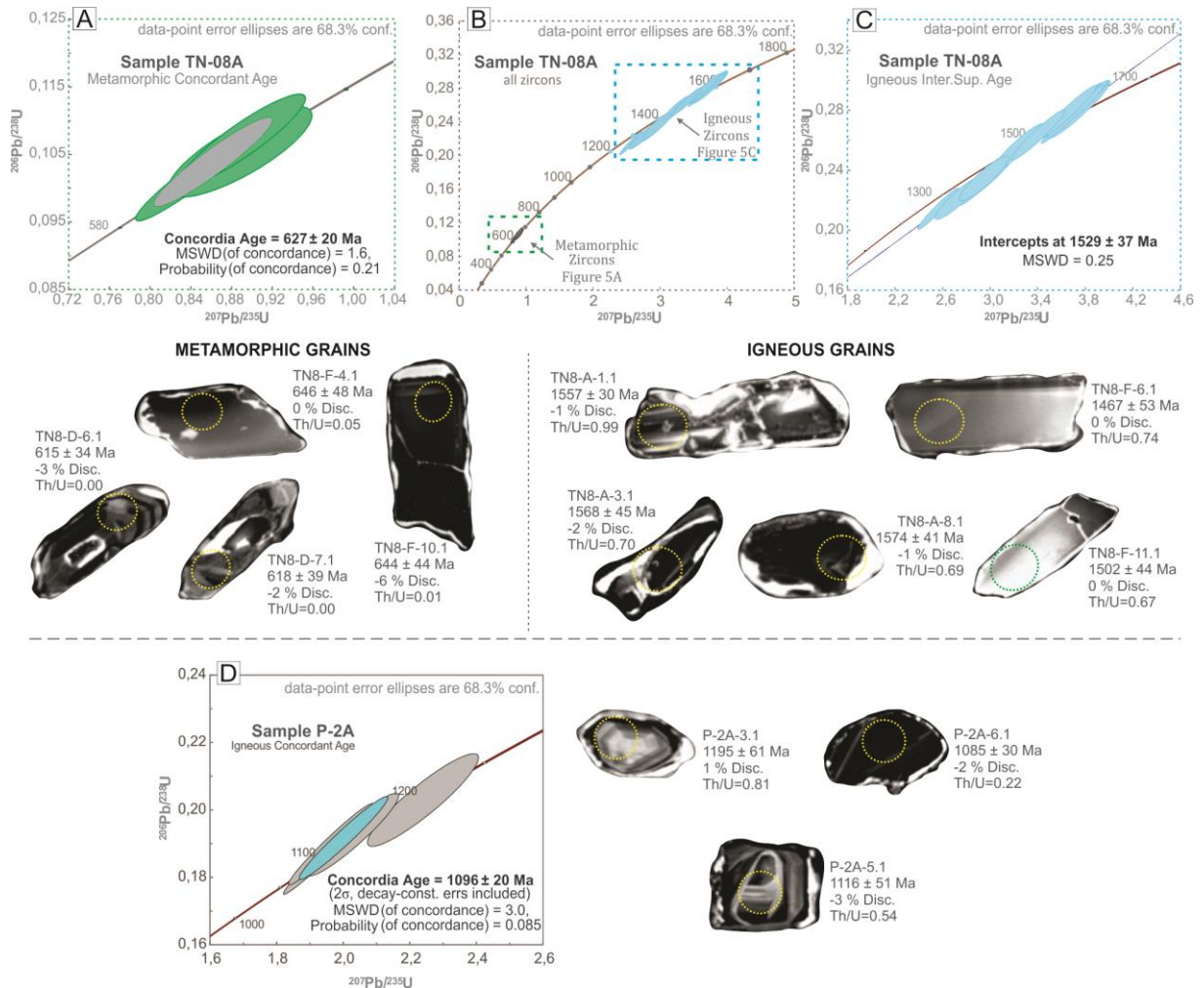


Figure 5: Ages of sample TN-08A and P-2A; A) Crystallization age of amphibolite magmatic protolith (TN-08A), given by the upper intercept Wetherill diagram, and cathodoluminescence images of analyzed grains; B) All zircons concordia diagram of sample TN-08A; C) Metamorphic concordant age and cathodoluminescence images of analyzed grains (spot size =  $30 \mu\text{m}$ ) from sample TN-08A; D) Concordia age for igneous crystallization of P2A amphibolite protolith, and cathodoluminescence images of analyzed grain (spot size =  $30 \mu\text{m}$ ).

*Sample P2A*: meter thick boudin of amphibolite interleaved in the Pocrane Complex orthogneiss. It features a fine-grained and massive rock, but with quite a distinct foliation. It consists of amphibole, plagioclase and quartz; apatite, titanite and zircon are accessory minerals. For the P2A sample, eight zircon grains were analyzed with U-Pb SHRIMP. Cathodoluminescence images show zircon grains composed of equidimensional prisms, with a high luminescence metamorphic overgrowth, which cannot be analyzed due to their small size (Fig. 5D). The U and Th contents of the analyzed spots are compatible with magmatic rocks. Four measures with good analytical consistency were selected for the construction of the Wetherill diagram, which provides the concordant age of  $1096 \pm 20$  Ma (MSWD = 3), considering the time of igneous crystallization of the amphibolite protolith (Fig. 5D). The sample also features four inherited zircon grains, which indicate Rhyacian, Statherian and

Calymmian inheritance. The Rhyacian heritage relates to the Pocrane Complex, host rock of the P2A amphibolite. Statherian heritage relates to magmatism associated with the Juiz de Fora Complex (Duarte *et al.* 2003 Heilbron *et al.* 2010). Calymmian heritage relates to the mafic magmatism represented by amphibolites co-genetic to sample TN-8 (this paper) and Bananal (Silva *et al.* 2002).

#### 4.3. Detrital zircon U–Pb data

The 90 analyzed grains from sample P2D (219.592E/7.841.790N, UTM24S WGS84) – Córrego Ubá quartzite – are prismatic, short to elongated, generally showing rounded terminations and a maximum length of 300  $\mu\text{m}$ . Some grains are pyramidal with a rounded core (Fig. 6). After data reduction, 87 spots could be used for age calculations. Representing 35% of analyzed zircon grains, the statistic peak around  $1176 \pm 21$  Ma encompasses the youngest grains of the sample (Fig. 7), which represents a younger component of the source, thus constraining the maximum depositional age of the Córrego Ubá quartzite. Furthermore, the youngest concordant grain dated show an age of  $995 \pm 66$  Ma. This youngest and most important population includes rounded grains and some euhedral to subhedral crystals with well-rounded shapes (examples shown in Fig. 6). Other significant sources of the P2A quartzite are indicated by age peaks at  $1371 \pm 30$  Ma (18%) and  $1536 \pm 22$  Ma (19%). Minor Paleoproterozoic ages point to sources around 1803 Ma and 1977 Ma (Fig. 8). It worth mention the complete absence of Ediacaran to Ordovician sources and the lack of ages older than Orosirian period.


Group 1			Group 2			Group 3			Group 4			Group 5		
1176 ± 21			1371 ± 30			1536 ± 22			1803 ± 36			1977 ± 38		
P2D-20			P2D-5			P2D-76			P2D-80			P2D-25		
1222	0	0,53	1286 ± 42	2	0,99	1512 ± 41	0	0,59	1751 ± 46	0	1,28	1972 ± 36	3	0,60
P2D-19			P2D-39			P2D-18			P2D-75			P2D-37		
1092 ± 70	0	0,56	1382 ± 50	0	0,38	1525 ± 35	1	0,40	1795 ± 53	1	0,85	2054 ± 32	0	0,83
P2D-6			P2D-9			P2D-24			P2D-29			P2D-53		
1151 ± 53	4	0,32	1390 ± 40	0	0,88	1559 ± 40	1	0,33	1819 ± 48	-1	0,70	2055 ± 55	0	1,24
P2D-15			P2D-8			P2D-32			N° CL image 					
1197 ± 49	1	0,35	1434 ± 36	3	0,18	1569 ± 40	0	0,33				Age (Ma)	Dis. (%)	$\frac{^{232}\text{Th}}{^{238}\text{U}}$

Figure 6: Cathodoluminescence (CL) images of representative zircon grains from the *Córrego Ubá* quartzite (sample P2D).

## 5. DISCUSSIONS

The history of the continental drift alternates long fragmentation periods with short agglutination intervals (Nance *et al.* 1988 Murphy and Nance 1992). Hence, one of the products of Rhyacian-Orosirian Orogeny would have been a paleocontinent that brought together inherited parts of the São Francisco and Congo cratons and the Araçuaí-West Congo Orogen basement (Atlantica paleocontinent; Rogers 1996, Rogers and Santosh 2004). Afterward, over a period of about 1.5 Ga (interval between the Rhyacian and Ediacaran orogenies), this paleocontinent region was spared of orogenic events with compressive nature. However, on the other hand, it experienced several taphrogenic episodes revealed by magmatism and sedimentation periods (Pedrosa-Soares and Alkmim 2011). The new data presented in this study characterize the *Córrego Ubá* Quartzite and amphibolite lenses as evidence of taphrogenic events tectonically interlayered in the Pocrane complex. These signs improve the knowledge about the Calymmian and Stenian episodes as unsuccessful fragmentation attempts of São Francisco-Congo paleocontinent now described in the metamorphic, highly deformed orogenic core.

The Calymmian distensive event marks one of the oldest taphrogenic episodes ever recorded in the region of Araçuaí-West Congo Orogen (the oldest is the Statherian event). Despite being regarded as part of the Espinhaço-Chapada Diamantina System (Danderfer *et al.* 2009; Babinski *et al.* 1994, 2012; Chemale-Júnior *et al.* 2012; Silveira *et al.* 2013; Guadagnin *et al.* 2016), there is only one reference to this event in the Araçuaí Orogen metamorphic core (U-Pb age by Silva *et al.* 2002). The new data from this paper displays a tholeiitic composition amphibolite with crystallization age at  $1529 \pm 37$  Ma. Its REE pattern is similar to the basic magmatism related to continental rifting or continental plateau basalt. These features suggest that this amphibolite sample represents basic magmatism related to continental rift during the Calymmian times. Reports of this approximately 1.5 Ga distensive event are common in São Francisco-Congo Craton region (Medium Espinhaço from Chemale *et al.* 2012 and Event 2 from Pedrosa-Soares and Alkmim 2011) as well as around the globe (Bingen *et al.* 2005; Bingen *et al.* 2008; Zhao *et al.* 2004; Ernst *et al.* 2000; Ernst *et al.* 2008; Wingate *et al.* 2009). The discovery of ca. 1.5 Ga intrusion in the reworked Araçuaí Orogen terrain is a major step to a more complete barcode record in the São Francisco-Congo Palecontinent, which can be used in future paleo-continental reconstructions.

The Stenian episode is well portrayed in several studies and thereby records a wide extension event (Tack *et al.* 2001; Tupinambá *et al.* 2007; Vicat and Pouclet 1995; Silveira *et al.* 2013). The sample P2A amphibolite from this work presents crystallization age of  $1096 \pm 20$  Ma and a tholeiitic gabbro composition. REE pattern correlated with advanced stage of magmatism relating to a continental rift, which confirms the tectonic environment discriminant graphics, with plots in the continental intraplate basalt fields. These features suggest that the P2A amphibolite represents basic magmatism related to a Stenian continental rift. Castro *et al.* (2015) portrait similar U-Pb ages for amphibolites lenses that occurs in the neighborhood region. Angeli *et al.* (2004) described ultramafic rocks associated with this rift system, supporting the idea of continuous crustal thinning in the region during Stenian times. Therefore, considering this mafic-ultramafic sequence, intrusive into the continental crust, the geodynamic setting should be related to specific stages in the evolution of the São Francisco-Congo Craton.

The Córrego Ubá quartzite represents the basin formed during the abovementioned Stenian event, partially preserved in the Araçuaí-West Congo orogen metamorphic core. The U-Pb geochronology study of the Córrego Ubá quartzite provide important hints for its

geotectonic and palaeogeographic interpretations. The results indicate that great part of the sedimentary supply should have come from secondary sources, located both in the São Francisco and Congo cratonic counterparts. The oldest intervals reveals contribution from Rhyacian to Stenian sources and the absence of pre 2.05 Ga zircon grains discard São Francisco and Congo cratons basement complexes. Also requires a younger source with no inheritance, which may correspond mainly to Juiz de Fora and Pocrane basement complexes from Araçuaí-West Congo orogen (Novo, 2013; Teixeira *et al.* 2000, Silva *et al.* 2002, Barbosa and Sabaté 2004, Noce *et al.* 2007). Correspondingly, the source of this interval could also be associated to rift related granites (e.g. Borrachudos Suite). The Statherian to Cambrian peaks indicate reworked sources from the Bomba Formation and Middle Espinhaço Supergroup (Danderfer *et al.* 2009, Pedrosa-Soares and Alkmim 2011, Chemale *et al.* 2012, Guadagnin *et al.* 2016). Statistical analyses point out a maximum age of deposition for the psamitic sediment limited by  $1176 \pm 21$  Ma. However, the youngest concordant grain dated show an age of  $995 \pm 66$  Ma, suggesting at the Tonian-Stenian limit.

Figure 8 shows a comparison of the detrital zircon age spectra of the Córrego Ubá quartzite with plausible primary and secondary sources from the São Francisco-Congo craton neighboring areas. Regardless of the lack of data from the Upper Espinhaço (0,9 to 1,2 Ga; Chemale *et al.* 2012), those units show significant similitude with Córrego Ubá quartzite spectra. Despite some differences, like the relative abundance of Archean zircon grains in the continental rift stages units of the Upper Espinhaço, the Córrego Ubá quartzite age spectra features great similarity to the age spectra of those units (Fig. 7 and 8A). The Córrego Ubá quartzite has no Cryogenian or Ediacaran zircons, but, instead, shows patterns that are more similar to a rift arrangement. The Córrego Ubá quartzite is then not correlative with other sedimentary successions of the Araçuaí orogen metamorphic core (e.g. Rio Doce Group and Nova Venécia Complex - Vieira 2007, Gradim *et al.* 2014). However, instead, probably represents a chronostratigraphic equivalent of the Upper Espinhaço Basin (Chemale *et al.* 2012), an extension of the passive margin sediments that formed in an intraplate setting.

Surprisingly, comparing with data from the western sector of the Araçuaí orogen and São Francisco craton, it is noteworthy that no igneous zircon from the three samples yielded an age older than early Orosirian (~2.05 Ga) showing age spectra essentially limited in the range of ca. 1 – 2 Ga; *i.e.*, younger than the Late Rhyacian orogeny that amalgamated the basement, and older than the main anorogenic event (930-870 Ma) associated with the Early Tonian precursor basin of AWCO. Therefore, it is possible to suggest that the Córrego Ubá

quartzite could represent a restrict basin, confined in a juvenile basement like the Pocrane and Juiz de Fora complexes.

During early Mesoproterozoic to late Neoproterozoic the development of a continental rift sequence and the continued thinning of the lithosphere eventually led to plate separation and creation of a true oceanic crust (Santo Antônio do Gramma Suit; Queiroga *et al.* 2006, 2007, Fig. 8B), extending to ca. 660 Ma. This basin evolved from a continental rift system surrounded by the São Francisco-Congo Paleocontinent, to an inland-sea basin (a gulf) partially floored by ocean crust (Pedrosa-Soares *et al.* 2011; Alkmim *et al.* 2006; Queiroga *et al.* 2007; Peixoto *et al.* 2015). In the Ediacaran Period, the pre-collisional Rio Doce magmatic arc marked the onset of a subduction-related convergent stage followed by regional deformation and metamorphism in the collisional stage, that provide intense tectonism, basin inversion and obduction of oceanic crust slices (Queiroga *et al.* 2006, 2007; Tupinamba *et al.* 2007, Fig. 8C and 8D).

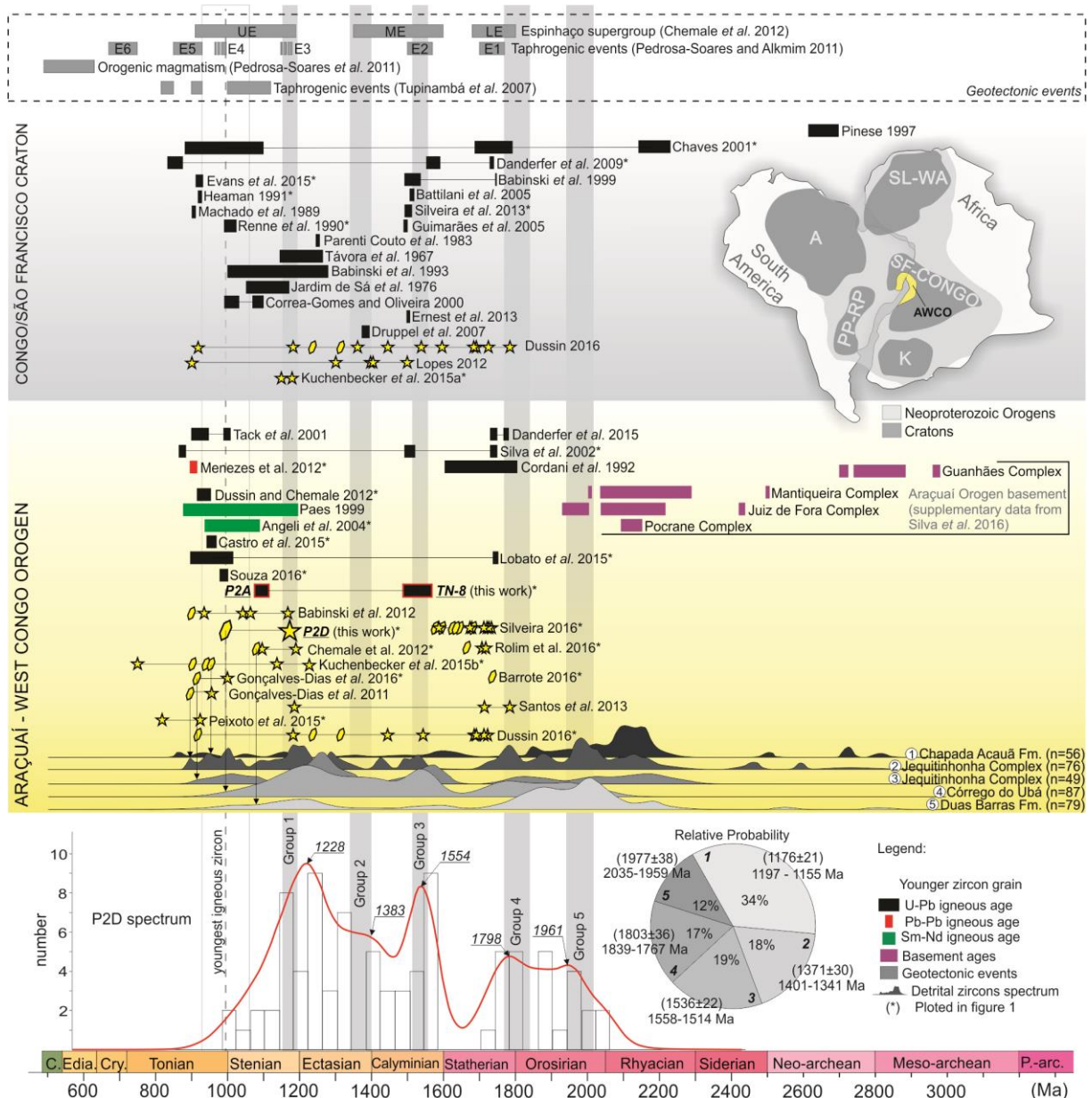


Figure 7 - Ages of main extensional events in the São Francisco-Congo craton and Araçuaí and West Congo orogen. References: 1) Kuchenbecker *et al.* 2015a; 2) Gonçalves-Dias *et al.* 2011; 3) Gonçalves-Dias *et al.* 2016; 4) This work; 5) Chemale *et al.* 2012; Mantiqueira, Juiz de Fora and Pocrane complexes data from Silva *et al.* 2016.

From a global tectonic standpoint, the Córrego Ubá quartzite and the mafic intrusives of the Pocrane complex might be correlated to the extensional processes that led to the fragmentation of a supercontinent (Atlantica). It also could marks the dismembering of the São Francisco-Congo paleocontinent, which was later amalgamated with other blocks in the Gondwana Supercontinent during the Brasiliano/Pan-African Orogeny (Tedeschi *et al.* 2015; Gonçalves *et al.* 2015; Pedrosa-Soares *et al.* 1998, 2007; Alkmim *et al.* 2006, 2007; Brito Neves *et al.* 2001; Tack *et al.* 2001; Vicat and Pouclet 1995).

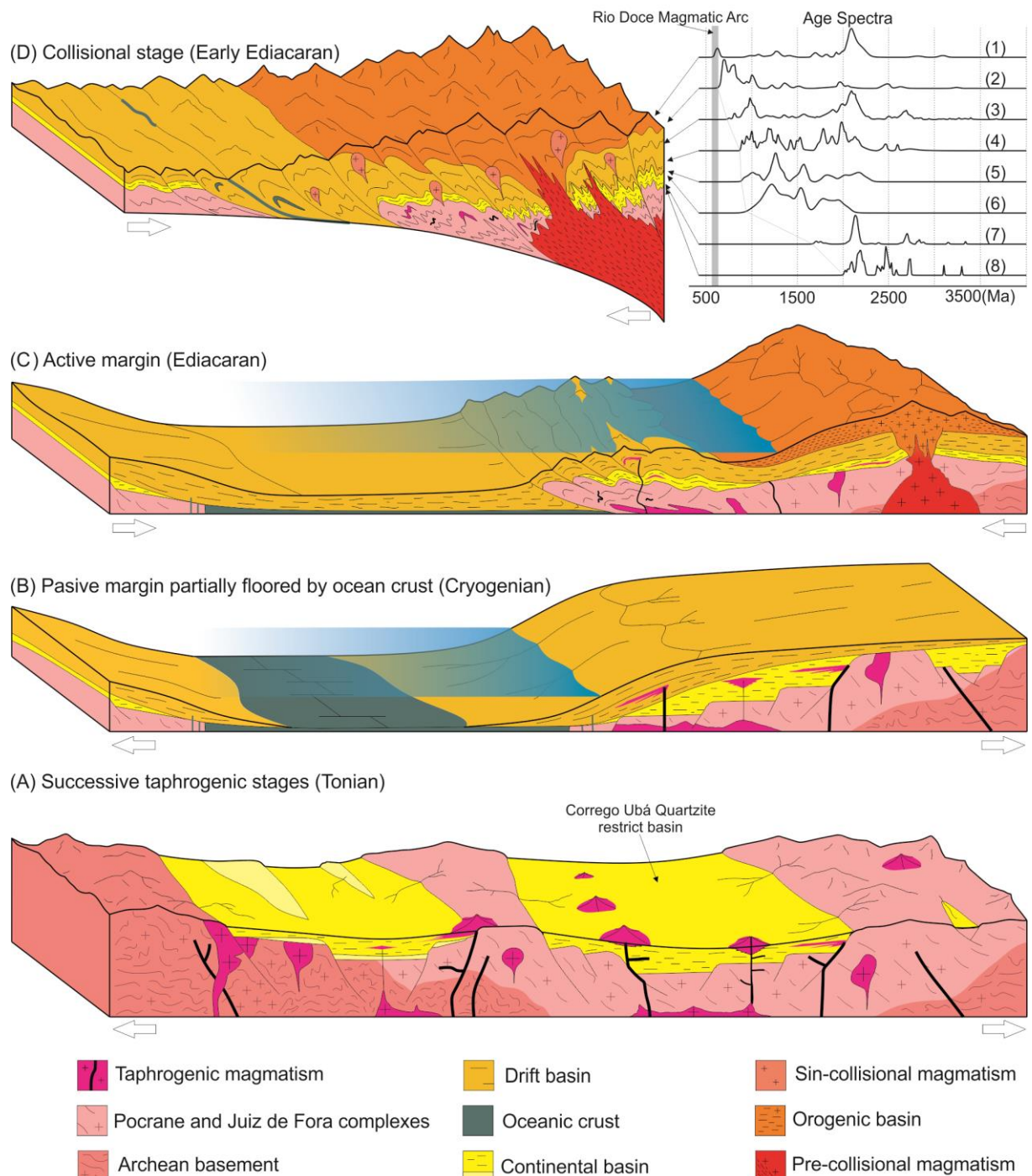


Figure 8: Tectonic model for the Mesoproterozoic-Neoproterozoic taphrogenic events and Ediacaran orogenic event in the Rio Doce Arc region, Araçuaí Orogen. (1) João Pinto Formation (Rio Doce Group), Novo 2013; (2) Palmital do Sul Formation (Rio Doce Group), Novo 2013; (3) Macaúbas Group, Kuchenbecker et al. 2015b; (4) Jequitinhonha Complex, Gonçalves-Dias et al. 2011; (5) Jequitinhonha Complex, Gonçalves-Dias et al. 2016; (6) This Work; (7) São João da Chapada Formation, Chemale et al. 2012; (8) Bandeirinhas Formation, Chemale et al. 2012.

## 6. CONCLUSION

The mafic intrusions from southeastern Brazil characterize important regional geological events in the São Francisco-Congo craton and its surrounding Neoproterozoic



mobile belts. The amphibolite lenses are interpreted as mafic intrusions, related to the Calymmian and Stenian rifting stages. They might also correlate to the extensional events that led to the break-up and dispersion of a Paleoproterozoic supercontinent, and thus relate to the mafic dike swarms and other intrusions throughout the São Francisco-Congo paleocontinent and surrounding areas (Fig. 1, 7 and 8A). The intrusions infer continued lithospheric thinning with associated volcanism. The amphibolite lenses thus provide a benchmark for the onset of the Calymmian and Stenian continental rifting in this area, and set an important marker for the registration of Atlantica breakup and dispersion processes in South America.

The Córrego Ubá quartzite show detrital zircon U-Pb age spectra indicating sources limited in the range of ca. 1 – 2 Ga, with complete absence of Cryogenian-Ediacaran peak, excluding sources related to the Brasiliano cycle. Therefore, it cannot be associated to other metasediments units of the Araçuaí orogen metamorphic core, like Rio Doce Group. Additionally the detrital zircon age spectra of the Córrego Ubá quartzite display great similarity to continental rift related units. Thus, it represents one of the several unsuccessful fragmentation attempts of São Francisco-Congo paleocontinent, deposited in a restrict basin, probably during Stenian times. It can be associated with the Tonian extensional tectonism at the São Francisco-Congo Craton area. This is the first time that such kind of basin is described in Araçuaí-West Congo orogen reworked metamorphic core.

All together, these continental taphrogenic events testify the several unsuccessful fragmentation attempts that affected the long-lived São Francisco-Congo palaeocontinent, which remained preserved from a complete break-up associated with ocean spreading from the Early Orosirian to the Atlantic opening in Cretaceous time.

## **7. ACKNOWLEDGMENTS**

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## CONSIDERAÇÕES FINAIS

Localizada no domínio interno do Orógeno Araçuaí, a região estudada abrange rochas de natureza distinta que foram retrabalhadas durante a orogenia brasileira. Dentre elas estão rochas metamáficas, metaultramáficas, metassedimentares e granitoides diversos que geralmente aparecem como lascas tectônicas intercaladas com o embasamento gnáissico. O principal objetivo deste trabalho foi a caracterização e a interpretação geotectônica destas rochas nas proximidades dos municípios de Pocrane e Durandé.

Os estudos mostraram que, apesar de serem genericamente denominados, ora de Grupo Andrelândia ora de Grupo Rio Doce, existe uma complexidade geológica muito grande na natureza e continuidade espacial dos pacotes e unidades metassedimentares. Como apresentado no Capítulo 3, os dados geocronológicos de níveis quartzíticos intercaladas no Complexo Pocrane apontam para sedimentos de uma bacia continental do tipo rifte peculiarmente restrita. Esta pertenceria aos vários ciclos de bacia do tipo rifte do paleocontinente São Francisco-Congo ocorridos entre os períodos Estateriano e Toniano. Estes são bastante descritos nas porções mais externas do Orógeno Araçuaí, como por exemplo, Supergrupo Espinhaço. Porém esta é a primeira vez que este sistema de bacias é documentado nos seus domínios internos do Orógeno Araçuaí.

As lentes anfibolíticas também documentadas no Capítulo 3 representam intrusões máficas ligadas aos eventos magmatismo anorogênico do paleocontinente São Francisco-Congo. Os dados apontam dois eventos ígneos distintos, um de idade caliminiana que é cronocorrelato com os diques máfico do Sistema Espinhaço-Cahpada Diamantina; o outro retrata o magmatismo máfico Esteniano. Por mais que não se tenha feito estudos geocronológicos no corpo metaultramáfico Vista Alegre (ver Capítulo 2), este também representa um dos eventos extensionais ocorridos no paleocontinente São Francisco-Congo.

Juntas, as rochas estudadas neste trabalho atestam os vários eventos tafrogênicos ocorridos no paleocontinente São Francisco-Congo como representado no bloco diagrama abaixo. No ponto de vista geotectônico global estas rochas representam os processos que levariam a fragmentação de um supercontinente (*e.g.* Atlântica, Columbia).

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**ANEXOS**

N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
3	16	212596	7777599	15/04/2016	08:55:22	23519,8	95	23512,62	23512,51	23540,0	-27,38	-27,49
4	16	212593	7777630	15/04/2016	09:10:27	23510,8	80	23494,64	23503,59	23540,0	-45,36	-36,41
6	16	212586	7777650	15/04/2016	09:16:47	23509,9	85	23493,82	23502,69	23540,0	-46,18	-37,31
7	16	212576	7777667	15/04/2016	09:20:47	23504,1	80	23482,22	23496,35	23540,0	-57,78	-43,65
8	16	212573	7777683	15/04/2016	09:23:17	23507,2	85	23487,30	23499,06	23540,0	-52,70	-40,94
9	16	212565	7777706	15/04/2016	09:26:07	23508,7	90	23490,32	23500,18	23540,1	-49,78	-39,92
10	16	212554	7777726	15/04/2016	09:28:52	23509,5	90	23492,08	23500,68	23540,1	-48,02	-39,42
11	16	212548	7777744	15/04/2016	09:31:17	23511,6	90	23504,22	23502,71	23540,1	-35,88	-37,39
12	16	212537	7777761	15/04/2016	09:34:02	23513,4	75	23498,76	23504,68	23540,1	-41,34	-35,42
14	16	212522	7777786	15/04/2016	09:46:07	23506,5	60	23485,98	23498,44	23540,1	-54,12	-41,66
15	16	212514	7777809	15/04/2016	09:52:47	23502,3	40	23476,66	23493,23	23540,1	-63,44	-46,87
16	16	212495	7777834	15/04/2016	10:15:52	23527,7	35	23518,40	23515,02	23540,1	-21,70	-25,08
17	16	212496	7777852	15/04/2016	10:41:47	23531,1	65	23525,24	23513,26	23540,1	-14,86	-26,84
18	16	212494	7777872	15/04/2016	10:43:37	23530,8	75	23524,50	23512,21	23540,1	-15,60	-27,89
19	16	212486	7777891	15/04/2016	10:45:37	23528,2	65	23518,32	23508,97	23540,1	-21,78	-31,13
20	16	212481	7777913	15/04/2016	10:47:52	23526,9	75	23515,86	23507,27	23540,1	-24,24	-32,83
21	16	212471	7777927	15/04/2016	10:49:27	23528,1	80	23517,28	23508,09	23540,1	-22,82	-32,01
22	16	212465	7777939	15/04/2016	10:59:22	23529,4	80	23517,70	23506,98	23540,1	-22,40	-33,12
23	16	212448	7777957	15/04/2016	11:03:07	23529,3	80	23516,60	23506,60	23540,1	-23,50	-33,51
24	16	212437	7777982	15/04/2016	11:07:47	23526,3	80	23510,68	23503,31	23540,1	-29,42	-36,79
25	16	212422	7778009	15/04/2016	11:18:17	23529,8	85	23516,60	23505,52	23540,1	-23,50	-34,58
26	15	212379	7778006	15/04/2016	11:32:47	23531,9	85	23508,88	23504,77	23540,1	-31,22	-35,33
27	15	212389	7777978	15/04/2016	11:35:52	23532,2	80	23517,48	23504,98	23540,1	-22,62	-35,12
29	15	212399	7777953	15/04/2016	11:42:12	23534,7	80	23522,38	23507,24	23540,1	-17,72	-32,86
30	15	212407	7777936	15/04/2016	11:44:42	23535,9	75	23524,86	23508,40	23540,1	-15,24	-31,70
31	15	212417	7777928	15/04/2016	11:49:07	23536,2	80	23525,44	23508,19	23540,1	-14,66	-31,91
34	15	212426	7777908	15/04/2016	11:54:37	23536,5	80	23525,08	23507,84	23540,1	-15,02	-32,26
35	15	212427	7777899	15/04/2016	11:58:27	23537,4	65	23526,88	23508,26	23540,1	-13,22	-31,85
36	15	212446	7777874	15/04/2016	12:03:07	23533,8	90	23518,56	23504,15	23540,1	-21,54	-35,95
37	15	212451	7777845	15/04/2016	12:08:22	23539,7	75	23530,46	23509,71	23540,1	-9,64	-30,39
38	15	212455	7777828	15/04/2016	12:10:52	23541,5	55	23534,04	23571,84	23540,0	-5,96	-28,80
39	15	212464	7777807	15/04/2016	12:12:52	23543,6	55	23537,26	23513,16	23540,0	-2,74	-26,84
41	11	212400	7777457	16/04/2016	08:16:47	23496	95	23460,08	23485,04	23539,7	-79,62	-54,66
42	11	212387	7777479	16/04/2016	08:20:47	23496,1	95	23458,14	23485,06	23539,7	-81,56	-54,64
43	11	212375	7777496	16/04/2016	08:23:17	23490,8	95	23445,54	23479,75	23539,7	-94,16	-59,95
44	11	212368	7777514	16/04/2016	08:25:02	23492,6	95	23448,18	23481,57	23539,7	-91,52	-58,13
46	11	212364	7777531	16/04/2016	08:27:57	23504	90	23468,92	23492,93	23539,7	-70,78	-46,77
47	11	212356	7777551	16/04/2016	08:30:07	23534,2	85	23536,36	23523,06	23539,7	-3,34	-16,64
48	11	212347	7777569	16/04/2016	08:32:42	23555,5	75	23579,94	23543,85	23539,8	40,14	4,05
49	11	212336	7777590	16/04/2016	08:35:37	23557,1	90	23582,10	23544,81	23539,8	42,30	5,01
50	11	212329	7777610	16/04/2016	08:37:52	23532,1	80	23532,22	23519,40	23539,8	-7,58	-20,40
51	11	212321	7777625	16/04/2016	08:40:37	23548,7	75	23564,30	23535,33	23539,8	24,50	-4,47
52	11	212308	7777641	16/04/2016	08:43:07	23529,5	80	23525,92	23515,62	23539,8	-13,88	-24,18
53	11	212304	7777657	16/04/2016	08:46:07	23524	80	23514,04	23509,92	23539,8	-25,76	-29,88
54	11	212300	7777676	16/04/2016	08:48:42	23524,4	85	23514,86	23510,79	23539,8	-24,94	-29,01
55	11	212294	7777699	16/04/2016	08:50:22	23523,4	75	23512,88	23510,08	23539,8	-26,92	-29,72
56	11	212290	7777718	16/04/2016	08:52:22	23520,6	70	23508,10	23507,56	23539,8	-31,70	-32,24
57	11	212275	7777739	16/04/2016	08:53:47	23521,9	75	23510,84	23509,17	23539,8	-28,96	-30,63
58	11	212272	7777757	16/04/2016	08:55:42	23520,1	70	23507,24	23507,79	23539,8	-32,56	-32,01
59	11	212262	7777775	16/04/2016	08:58:47	23517,9	65	23503,86	23506,04	23539,8	-35,94	-33,76
60	11	212255	7777793	16/04/2016	09:00:57	23511,8	65	23491,60	23500,08	23539,9	-48,30	-39,82
62	11	212245	7777823	16/04/2016	09:09:57	23513,2	60	23495,32	23501,25	23539,9	-44,58	-38,65
63	11	212242	7777838	16/04/2016	09:13:47	23516,8	60	23502,58	23504,79	23539,9	-37,32	-35,11
64	12	212273	7777862	16/04/2016	09:21:42	23518,9	60	23503,78	23504,43	23539,9	-36,12	-35,47
65	12	212291	7777849	16/04/2016	09:25:07	23519,6	65	23504,26	23503,91	23539,9	-35,64	-35,99

N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
66	12	212294	7777829	16/04/2016	09:27:22	23524,3	60	23512,56	23507,71	23539,9	-27,34	-32,19
67	12	212298	7777809	16/04/2016	09:29:32	23519,6	60	23502,10	23502,19	23539,9	-37,80	-37,71
68	12	212302	7777787	16/04/2016	09:31:37	23521,7	70	23506,42	23503,84	23539,9	-33,48	-36,06
69	12	212311	7777772	16/04/2016	09:34:52	23528	65	23519,08	23509,71	23539,9	-20,82	-30,19
70	12	212324	7777748	16/04/2016	09:36:32	23529,5	70	23520,90	23510,85	23539,9	-19,00	-29,06
71	12	212331	7777732	16/04/2016	09:38:17	23530	75	23522,08	23511,17	23539,9	-17,82	-28,73
72	12	212338	7777719	16/04/2016	09:40:57	23538	75	23538,02	23518,71	23539,8	-1,78	-21,09
73	12	212346	7777698	16/04/2016	09:42:57	23533,7	75	23528,48	23514,14	23539,8	-11,32	-25,66
74	12	212355	7777678	16/04/2016	10:16:17	23545,2	75	23556,36	23526,12	23539,8	16,56	-13,68
75	12	212358	7777659	16/04/2016	10:17:47	23549,1	80	23559,10	23530,08	23539,8	19,30	-9,72
76	12	212366	7777641	16/04/2016	10:19:42	23547	80	23554,94	23528,06	23539,8	15,14	-11,74
77	12	212372	7777629	16/04/2016	10:21:27	23579,2	80	23619,30	23560,37	23539,8	79,50	20,57
78	12	212383	7777607	16/04/2016	10:25:22	23595,6	80	23652,10	23576,90	23539,8	112,30	37,10
79	12	212392	7777589	16/04/2016	10:27:07	23528,4	75	23517,88	23509,88	23539,8	-21,92	-29,92
80	12	212402	7777571	16/04/2016	10:30:27	23494,2	75	23453,48	23475,83	23539,8	-86,32	-63,97
81	12	212407	7777553	16/04/2016	10:32:57	23490,7	75	23443,34	23472,46	23539,8	-96,46	-67,34
82	12	212414	7777532	16/04/2016	10:35:17	23495,6	75	23453,24	23477,60	23539,8	-86,56	-62,20
83	12	212423	7777516	16/04/2016	10:37:12	23499,8	80	23461,64	23481,95	23539,8	-78,16	-57,85
84	12	212428	7777498	16/04/2016	10:39:32	23508,5	75	23478,92	23490,73	23539,8	-60,88	-49,07
85	12	212429	7777484	16/04/2016	10:41:02	23509,1	75	23480,24	23491,57	23539,8	-59,56	-48,23
86	13	212491	7777498	16/04/2016	10:50:52	23519	105	23500,92	23501,42	23539,8	-38,88	-38,38
87	13	212484	7777514	16/04/2016	10:53:02	23514,7	100	23492,46	23497,14	23539,8	-47,34	-42,67
88	13	212473	7777529	16/04/2016	10:55:42	23507,3	80	23477,68	23489,62	23539,8	-62,12	-50,18
89	13	212464	7777548	16/04/2016	10:58:07	23500,9	80	23464,86	23483,11	23539,8	-74,94	-56,69
90	13	212466	7777561	16/04/2016	11:01:37	23498,3	75	23459,52	23480,26	23539,8	-80,28	-59,54
91	13	212437	7777581	16/04/2016	11:05:07	23507,1	100	23477,14	23488,83	23539,9	-62,76	-51,08
92	13	212440	7777610	16/04/2016	11:13:22	23551,6	80	23566,16	23532,78	23539,9	26,26	-7,12
93	13	212430	7777626	16/04/2016	11:16:12	23537,6	75	23545,16	23518,75	23539,9	5,26	-21,15
94	13	212425	7777643	16/04/2016	11:18:57	23570,6	75	23603,10	23551,92	23539,9	63,20	12,02
95	13	212416	7777661	16/04/2016	11:20:32	23547,2	80	23556,40	23528,69	23539,9	16,50	-11,21
96	13	212402	7777682	16/04/2016	11:25:52	23537	75	23536,02	23518,89	23539,9	-3,88	-21,01
97	13	212400	7777701	16/04/2016	11:27:12	23543,6	75	23549,16	23525,56	23539,9	9,26	-14,34
98	13	212392	7777721	16/04/2016	14:07:52	23520,7	70	23523,32	23521,96	23539,9	-16,58	-17,94
99	13	212380	7777739	16/04/2016	14:09:32	23524,1	70	23530,12	23525,29	23539,9	-9,78	-14,62
100	13	212377	7777752	16/04/2016	14:11:27	23522,5	75	23527,00	23523,64	23539,9	-12,90	-16,27
101	13	212367	7777773	16/04/2016	14:14:12	23514,6	60	23511,22	23515,63	23539,9	-28,68	-24,27
103	13	212359	7777788	16/04/2016	14:17:27	23512,1	50	23505,28	23513,82	23539,9	-34,62	-26,08
104	13	212348	7777805	16/04/2016	14:22:37	23507,7	60	23498,38	23510,86	23539,9	-41,52	-29,04
105	13	212338	7777829	16/04/2016	14:24:42	23508,4	80	23499,72	23512,13	23540,0	-40,28	-27,87
106	13	212337	7777846	16/04/2016	14:27:27	23498,8	70	23481,56	23503,35	23540,0	-58,44	-36,66
107	13	212333	7777864	16/04/2016	14:29:07	23499,6	55	23484,14	23504,66	23540,0	-55,86	-35,34
108	13	212318	7777883	16/04/2016	14:30:57	23500,5	55	23486,92	23506,00	23540,0	-53,08	-34,01
109	13	212308	7777905	16/04/2016	14:33:07	23502,2	60	23490,30	23508,21	23540,0	-49,70	-31,79
110	13	212297	7777921	16/04/2016	14:34:47	23499,9	60	23486,78	23506,36	23540,0	-53,22	-33,64
111	13	212289	7777939	16/04/2016	14:37:42	23498,9	75	23484,78	23506,08	23540,0	-55,22	-33,92
113	14	212343	7777961	16/04/2016	14:49:37	23496,2	75	23481,48	23506,26	23540,0	-58,52	-33,74
114	14	212350	7777943	16/04/2016	14:51:27	23497,2	70	23484,34	23507,40	23540,0	-55,66	-32,60
115	14	212355	7777923	16/04/2016	14:53:12	23495,3	75	23480,54	23505,85	23540,0	-59,46	-34,15
116	14	212358	7777905	16/04/2016	14:54:37	23494,3	60	23478,52	23505,10	23540,0	-61,48	-34,90
117	14	212368	7777882	16/04/2016	14:56:42	23498,9	60	23488,76	23510,13	23540,0	-51,24	-29,87
118	14	212377	7777864	16/04/2016	15:00:57	23492,9	65	23477,70	23505,11	23540,0	-62,30	-34,89
119	14	212378	7777841	16/04/2016	15:04:17	23496	75	23484,94	23508,98	23540,0	-55,06	-31,02
120	14	212389	7777829	16/04/2016	15:09:27	23494,5	70	23483,08	23508,92	23540,0	-56,92	-31,08
121	14	212390	7777815	16/04/2016	15:14:17	23495	60	23485,06	23510,68	23540,0	-54,94	-29,32
122	14	212420	7777796	16/04/2016	15:22:42	23501	60	23498,92	23518,70	23540,0	-41,08	-21,30

N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
142	14	212420	7777774	17/04/2016	08:27:22	23544,7	65	23549,48	23524,48	23540,0	9,48	-15,52
143	14	212427	7777753	17/04/2016	08:32:37	23538,6	75	23543,18	23518,72	23540,0	3,18	-21,28
144	14	212439	7777735	17/04/2016	08:40:02	23552,4	75	23565,86	23532,72	23540,0	25,86	-7,28
145	14	212445	7777718	17/04/2016	08:44:37	23537,7	75	23536,48	23518,13	23540,0	-3,52	-21,87
146	14	212456	7777692	17/04/2016	08:48:57	23512,8	75	23486,66	23493,48	23539,9	-53,24	-46,42
147	14	212464	7777675	17/04/2016	08:51:57	23518,6	80	23498,28	23499,48	23539,9	-41,62	-40,42
148	14	212468	7777664	17/04/2016	08:54:07	23527,1	85	23515,24	23508,10	23539,9	-24,66	-31,80
149	14	212472	7777652	17/04/2016	08:57:22	23526,9	85	23514,78	23508,05	23539,9	-25,12	-31,85
150	14	212482	7777625	17/04/2016	09:01:12	23517,8	95	23495,58	23499,11	23539,9	-44,32	-40,79
151	14	212489	7777603	17/04/2016	09:04:07	23513	95	23487,98	23494,25	23539,9	-51,92	-45,65
152	14	212497	7777589	17/04/2016	09:08:22	23514,7	90	23491,40	23495,86	23539,9	-48,50	-44,04
153	14	212504	7777573	17/04/2016	09:11:12	23514,9	95	23491,82	23496,01	23539,9	-48,08	-43,89
154	15	212561	7777582	17/04/2016	09:22:52	23523,3	100	23507,68	23502,07	23540,0	-32,32	-37,93
155	15	212554	7777592	17/04/2016	09:24:22	23521,8	105	23503,52	23500,54	23540,0	-36,48	-39,46
156	15	212550	7777609	17/04/2016	09:26:12	23518,4	100	23496,82	23496,70	23540,0	-43,18	-43,30
157	15	212543	7777628	17/04/2016	09:27:52	23519,4	105	23497,78	23497,34	23540,0	-42,22	-42,66
158	15	212534	7777648	17/04/2016	09:29:12	23522,3	110	23503,54	23499,88	23540,0	-36,46	-40,12
159	15	212528	7777666	17/04/2016	09:30:42	23520,7	115	23492,30	23497,98	23540,0	-47,70	-42,02
160	15	212513	7777683	17/04/2016	09:32:17	23520,2	110	23498,46	23497,37	23540,0	-41,54	-42,63
161	15	212507	7777704	17/04/2016	09:33:42	23524,3	110	23506,68	23501,38	23540,0	-33,32	-38,62
162	15	212492	7777721	17/04/2016	09:36:07	23528,5	90	23515,04	23505,30	23540,0	-24,96	-34,70
163	15	212482	7777745	17/04/2016	09:38:42	23527,1	60	23512,10	23503,54	23540,0	-27,90	-36,46
164	15	212474	7777762	17/04/2016	09:40:22	23533,7	50	23524,40	23509,99	23540,0	-15,60	-30,01
165	17	212669	7777575	17/04/2016	10:03:07	23530,8	75	23518,54	23506,51	23540,0	-21,46	-33,49
166	17	212662	7777592	17/04/2016	10:04:22	23528,8	90	23514,60	23504,23	23540,0	-25,40	-35,77
167	17	212656	7777607	17/04/2016	10:06:07	23524,4	85	23504,84	23499,48	23540,1	-35,26	-40,62
168	17	212650	7777631	17/04/2016	10:08:52	23523,8	75	23503,50	23498,27	23540,1	-36,60	-41,83
169	17	212642	7777646	17/04/2016	10:11:17	23521,9	75	23498,86	23495,95	23540,1	-41,24	-44,15
170	17	212634	7777663	17/04/2016	10:13:37	23526,4	80	23507,84	23499,96	23540,1	-32,26	-40,14
171	17	212627	7777685	17/04/2016	10:17:57	23529,4	85	23512,70	23502,35	23540,1	-27,40	-37,75
174	17	212603	7777750	17/04/2016	10:28:27	23526,2	90	23505,38	23498,39	23540,1	-34,72	-41,71
175	17	212598	7777777	17/04/2016	10:35:42	23522,8	60	23498,58	23494,53	23540,1	-41,52	-45,57
177	17	212570	7777822	17/04/2016	10:52:17	23535,4	125	23522,80	23507,54	23540,1	-17,30	-32,56
178	17	212561	7777836	17/04/2016	10:55:07	23537	75	23526,98	23509,52	23540,1	-13,12	-30,58
179	17	212550	7777851	17/04/2016	10:56:57	23543,8	60	23540,64	23516,56	23540,2	0,44	-23,64
180	17	212542	7777872	17/04/2016	11:00:42	23543,5	80	23543,96	23516,68	23540,2	3,76	-23,52
181	17	212535	7777900	17/04/2016	11:05:27	23536,6	70	23527,16	23510,05	23540,2	-13,04	-30,15
182	17	212528	7777918	17/04/2016	11:10:02	23533,6	80	23521,20	23507,37	23540,2	-19,00	-32,83
183	17	212517	7777928	17/04/2016	11:13:32	23531,9	80	23517,82	23505,87	23540,2	-22,38	-34,33
184	18	212724	7777574	18/04/2016	07:55:07	23520,9	80	23523,82	23523,12	23540,1	-16,28	-16,98
185	18	212717	7777595	18/04/2016	07:59:12	23514,3	75	23511,56	23516,78	23540,1	-28,54	-23,32
186	18	212712	7777611	18/04/2016	08:01:22	23507,2	80	23496,44	23509,76	23540,1	-43,66	-30,34
187	18	212700	7777628	18/04/2016	08:03:02	23509,2	70	23497,44	23511,74	23540,1	-42,66	-28,36
188	18	212688	7777646	18/04/2016	08:05:12	23504,3	80	23484,60	23506,80	23540,1	-55,50	-33,30
189	18	212677	7777666	18/04/2016	08:06:32	23512,2	80	23498,32	23514,64	23540,1	-41,78	-25,46
190	18	212671	7777685	18/04/2016	08:09:02	23509,3	85	23501,66	23511,78	23540,1	-38,44	-28,32
191	18	212659	7777702	18/04/2016	08:11:57	23508,7	80	23500,38	23511,11	23540,1	-39,72	-28,99
192	18	212655	7777723	18/04/2016	08:14:37	23505,3	85	23493,52	23507,65	23540,1	-46,58	-32,45
193	18	212640	7777775	18/04/2016	08:39:42	23503,4	65	23489,80	23506,21	23540,2	-50,40	-33,99
194	18	212624	7777792	18/04/2016	08:43:22	23501,7	65	23486,32	23504,72	23540,2	-53,88	-35,48
195	18	212615	7777815	18/04/2016	08:53:07	23499,5	80	23484,06	23503,75	23540,2	-56,14	-36,45
196	18	212610	7777838	18/04/2016	08:56:47	23504,5	80	23494,00	23509,20	23540,2	-46,20	-31,00
197	18	212598	7777856	18/04/2016	09:00:27	23508,1	90	23497,24	23513,20	23540,2	-42,96	-27,00
199	19	212662	7777853	18/04/2016	09:08:32	23507,1	75	23499,10	23511,02	23540,3	-41,20	-29,28
200	19	212669	7777833	18/04/2016	09:14:12	23505,7	75	23496,32	23508,85	23540,2	-43,88	-31,35

N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
203	19	212675	7777819	18/04/2016	09:17:47	23505,8	80	23495,54	23509,18	23540,2	-44,66	-31,02
204	19	212680	7777799	18/04/2016	09:21:32	23507,9	55	23499,86	23511,83	23540,2	-40,34	-28,37
206	19	212683	7777786	18/04/2016	09:25:47	23501,6	65	23488,18	23505,95	23540,2	-52,02	-34,25
207	19	212701	7777761	18/04/2016	09:33:57	23503,2	80	23491,30	23507,75	23540,2	-48,90	-32,45
208	19	212710	7777743	18/04/2016	09:36:32	23504,1	70	23493,14	23508,53	23540,2	-47,06	-31,67
209	19	212718	7777723	18/04/2016	09:40:02	23505,6	60	23496,22	23509,84	23540,2	-43,98	-30,36
210	19	212726	7777703	18/04/2016	09:42:12	23508,1	65	23501,22	23512,21	23540,2	-38,98	-27,99
211	19	212732	7777688	18/04/2016	09:44:17	23514,9	75	23514,70	23518,81	23540,2	-25,50	-21,39
212	19	212736	7777671	18/04/2016	09:46:32	23510,5	70	23505,08	23514,37	23540,2	-35,12	-25,83
213	19	212744	7777648	18/04/2016	09:48:37	23505	60	23494,06	23508,76	23540,2	-46,14	-31,44
215	19	212752	7777629	18/04/2016	09:55:27	23513,5	60	23510,96	23516,85	23540,2	-29,24	-23,35
216	19	212758	7777606	18/04/2016	09:58:22	23516,5	55	23516,96	23519,69	23540,1	-23,14	-20,41
217	18	212595	7777892	18/04/2016	10:30:12	23508,9	75	23498,86	23513,49	23540,2	-41,34	-26,71
219	18	212582	7777908	18/04/2016	10:38:17	23507,5	85	23500,00	23511,85	23540,2	-40,20	-28,35
220	18	212583	7777919	18/04/2016	10:43:37	23506	75	23496,96	23510,19	23540,2	-43,24	-30,01
221	19	212600	7777983	18/04/2016	10:53:07	23499,6	60	23485,20	23505,30	23540,3	-55,10	-35,00
222	19	212612	7777962	18/04/2016	10:55:47	23505,2	70	23497,30	23511,35	23540,3	-43,00	-28,95
223	19	212621	7777945	18/04/2016	10:59:37	23504,1	75	23495,18	23511,02	23540,3	-45,12	-29,28
224	19	212624	7777916	18/04/2016	11:05:07	23502,5	65	23496,08	23509,55	23540,3	-44,22	-30,75
225	19	212629	7777902	18/04/2016	11:07:07	23504,4	70	23500,86	23511,44	23540,3	-39,44	-28,86
228	6	212180	7777324	18/04/2016	14:38:02	23491,6	85	23481,26	23510,05	23539,4	-58,14	-29,35
229	6	212175	7777344	18/04/2016	14:39:37	23490,1	80	23478,14	23508,56	23539,4	-61,26	-30,84
230	6	212166	7777360	18/04/2016	14:41:32	23484,9	80	23467,70	23503,43	23539,4	-71,70	-35,97
231	6	212156	7777376	18/04/2016	14:44:02	23490,4	75	23478,78	23509,10	23539,4	-60,62	-30,30
232	6	212146	7777397	18/04/2016	14:46:12	23488,8	75	23473,56	23507,51	23539,4	-65,84	-31,89
233	6	212140	7777418	18/04/2016	14:47:32	23487,9	70	23468,74	23506,57	23539,5	-70,76	-32,93
234	6	212130	7777438	18/04/2016	14:48:52	23486,9	80	23472,74	23505,52	23539,5	-66,76	-33,98
235	6	212121	7777455	18/04/2016	14:51:22	23488,3	80	23475,60	23506,91	23539,5	-63,90	-32,60
236	6	212114	7777478	18/04/2016	14:54:32	23474,2	60	23447,38	23492,70	23539,5	-92,12	-46,80
237	6	212106	7777490	18/04/2016	14:56:42	23470,1	60	23439,12	23488,51	23539,5	-100,38	-50,99
238	6	212103	7777510	18/04/2016	14:58:32	23498,3	70	23495,64	23516,73	23539,5	-43,86	-22,77
239	6	212097	7777531	18/04/2016	15:01:22	23490,2	65	23476,42	23508,54	23539,5	-63,08	-30,96
240	6	212089	7777549	18/04/2016	15:02:42	23488,7	60	23470,30	23506,96	23539,5	-69,20	-32,54
241	6	212077	7777561	18/04/2016	15:04:17	23488	60	23475,06	23506,29	23539,5	-64,44	-33,21
242	6	212072	7777582	18/04/2016	15:06:27	23487,2	60	23473,48	23505,44	23539,5	-66,02	-34,06
243	6	212062	7777601	18/04/2016	15:08:07	23487,7	55	23474,48	23505,90	23539,5	-65,02	-33,60
244	6	212055	7777619	18/04/2016	15:09:37	23488,1	50	23475,22	23506,24	23539,5	-64,28	-33,26
245	6	212048	7777635	18/04/2016	15:10:52	23487,1	50	23473,24	23505,20	23539,5	-66,26	-34,30
246	6	212038	7777653	18/04/2016	15:13:02	23486,9	50	23472,80	23504,93	23539,5	-66,70	-34,57
247	6	212036	7777670	18/04/2016	15:14:32	23485,9	50	23470,84	23503,91	23539,6	-68,76	-35,69
248	7	212080	7777690	18/04/2016	15:18:42	23486,2	55	23471,36	23504,04	23539,6	-68,24	-35,56
249	7	212085	7777673	18/04/2016	15:20:37	23486,8	50	23472,52	23504,52	23539,6	-67,08	-35,08
250	7	212090	7777658	18/04/2016	15:23:12	23487,7	50	23474,40	23505,36	23539,6	-65,20	-34,24
251	7	212098	7777638	18/04/2016	15:24:42	23487,6	60	23474,22	23505,21	23539,6	-65,38	-34,39
252	7	212108	7777616	18/04/2016	15:26:17	23489,2	55	23477,46	23506,78	23539,6	-62,14	-32,82
253	7	212116	7777600	18/04/2016	15:27:47	23489,1	55	23477,12	23506,55	23539,6	-62,48	-33,05
254	7	212122	7777582	18/04/2016	15:29:32	23492,7	55	23484,32	23510,08	23539,6	-55,28	-29,52
255	7	212129	7777570	18/04/2016	15:30:52	23493,3	55	23479,52	23510,61	23539,6	-60,08	-28,99
256	7	212138	7777546	18/04/2016	15:33:07	23487,8	55	23473,54	23504,95	23539,5	-65,96	-34,55
257	7	212144	7777526	18/04/2016	15:35:02	23489,3	55	23476,62	23506,36	23539,5	-62,88	-33,14
258	7	212152	7777510	18/04/2016	15:37:32	23486	60	23470,04	23502,91	23539,5	-69,46	-36,59
259	7	212161	7777491	18/04/2016	15:40:22	23490,9	60	23479,88	23507,63	23539,5	-59,62	-31,87
260	7	212169	7777475	18/04/2016	15:42:42	23489,6	75	23477,20	23506,11	23539,5	-62,30	-33,39
261	7	212188	7777453	18/04/2016	15:44:42	23485	75	23467,00	23501,36	23539,5	-72,50	-38,14
262	7	212187	7777434	18/04/2016	15:47:32	23487,2	70	23471,36	23503,60	23539,5	-68,14	-35,90

N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
263	7	212193	7777417	18/04/2016	15:50:57	23490,1	55	23477,24	23506,60	23539,5	-62,26	-32,90
264	7	212203	7777398	18/04/2016	16:01:02	23488,6	60	23478,12	23505,29	23539,5	-61,38	-34,21
265	7	212213	7777381	18/04/2016	16:02:27	23488,6	70	23474,26	23505,41	23539,5	-65,24	-34,09
266	7	212220	7777367	18/04/2016	16:04:12	23490,5	75	23478,00	23507,34	23539,5	-61,50	-32,16
267	8	212264	7777381	18/04/2016	16:07:02	23490,1	75	23477,28	23507,11	23539,5	-62,22	-32,39
268	8	212258	7777398	18/04/2016	16:08:32	23489,4	75	23475,86	23506,49	23539,5	-63,64	-33,01
269	8	212250	7777415	18/04/2016	16:10:17	23490,5	75	23478,02	23507,64	23539,5	-61,48	-31,86
270	8	212238	7777434	18/04/2016	16:11:37	23489,2	70	23475,32	23506,35	23539,6	-64,28	-33,25
271	8	212232	7777450	18/04/2016	16:13:27	23485,5	60	23468,02	23502,75	23539,6	-71,58	-36,85
272	8	212225	7777471	18/04/2016	16:15:57	23484,6	60	23464,12	23501,84	23539,6	-75,48	-37,76
273	8	212217	7777489	18/04/2016	16:17:12	23489,2	55	23468,44	23506,44	23539,6	-71,16	-33,16
274	8	212208	7777507	18/04/2016	16:19:22	23492,6	60	23483,20	23509,75	23539,6	-56,40	-29,85
275	8	212198	7777525	18/04/2016	16:21:42	23490,5	50	23479,08	23507,58	23539,6	-60,52	-32,02
276	8	212193	7777543	18/04/2016	16:23:07	23488,4	50	23474,80	23505,41	23539,6	-64,80	-34,19
277	8	212184	7777564	18/04/2016	16:24:22	23492,9	60	23483,76	23509,86	23539,6	-55,84	-29,74
278	8	212179	7777581	18/04/2016	16:26:32	23489,8	55	23477,60	23506,69	23539,6	-62,00	-32,91
279	8	212172	7777603	18/04/2016	16:28:02	23489,5	60	23477,08	23506,36	23539,6	-62,52	-33,24
280	8	212161	7777617	18/04/2016	16:29:07	23491	55	23480,02	23507,80	23539,6	-59,58	-31,80
281	8	212154	7777638	18/04/2016	16:30:22	23490,2	55	23470,34	23506,80	23539,6	-69,26	-32,80
282	8	212147	7777658	18/04/2016	16:31:37	23489,8	65	23476,66	23506,14	23539,6	-62,94	-33,46
283	8	212136	7777675	18/04/2016	16:32:52	23488,1	50	23473,12	23504,09	23539,6	-66,48	-35,51
284	8	212132	7777689	18/04/2016	16:34:17	23489,5	50	23475,94	23505,23	23539,7	-63,76	-34,47
285	8	212122	7777708	18/04/2016	16:35:37	23490,1	50	23476,20	23505,53	23539,7	-63,50	-34,17
286	9	212163	7777748	18/04/2016	16:40:37	23491,8	50	23478,56	23505,93	23539,7	-61,14	-33,77
287	9	212170	7777734	18/04/2016	16:42:32	23492,4	45	23479,84	23506,21	23539,7	-59,86	-33,49
288	9	212178	7777714	18/04/2016	16:43:57	23494	50	23481,98	23507,48	23539,7	-57,72	-32,22
289	9	212187	7777696	18/04/2016	16:45:02	23493,1	55	23479,52	23506,37	23539,7	-60,18	-33,33
290	9	212194	7777677	18/04/2016	16:46:12	23494,3	55	23482,68	23507,43	23539,7	-57,02	-32,27
291	9	212201	7777659	18/04/2016	16:47:07	23497,5	50	23489,06	23510,53	23539,7	-50,64	-29,17
292	9	212209	7777640	18/04/2016	16:48:12	23498,4	55	23490,82	23511,33	23539,7	-48,88	-28,37
293	9	212216	7777623	18/04/2016	16:49:07	23497,5	55	23489,06	23510,32	23539,7	-50,64	-29,38
294	9	212223	7777604	18/04/2016	16:50:02	23493,9	60	23481,70	23506,54	23539,7	-58,00	-33,16
295	9	212232	7777587	18/04/2016	16:53:07	23488,2	60	23470,38	23500,53	23539,7	-69,32	-39,17
296	9	212237	7777567	18/04/2016	16:54:17	23492	50	23477,04	23504,23	23539,7	-62,66	-35,47
297	9	212247	7777548	18/04/2016	16:55:22	23495	55	23482,92	23507,04	23539,6	-56,68	-32,56
298	9	212250	7777530	18/04/2016	16:56:47	23494,6	60	23482,12	23506,49	23539,6	-57,48	-33,11
298	1	211948	7777234	19/04/2016	08:37:17	23512,6	65	23511,22	23515,30	23539,1	-27,88	-33,80
299	1	211942	7777247	19/04/2016	08:39:17	23517,7	55	23522,48	23520,37	23539,1	-16,62	-28,73
300	1	211931	7777262	19/04/2016	08:41:27	23515,6	45	23520,14	23518,14	23539,1	-18,96	-30,96
301	1	211924	7777283	19/04/2016	08:44:52	23481	65	23451,94	23483,43	23539,2	-87,26	-65,77
302	1	211918	7777298	19/04/2016	08:46:32	23539	70	23561,00	23541,68	23539,2	21,80	-7,52
303	1	211905	7777317	19/04/2016	08:48:37	23525,1	70	23533,28	23528,17	23539,2	-5,92	-21,03
304	1	211901	7777337	19/04/2016	08:51:07	23513,6	70	23510,18	23517,02	23539,2	-29,02	-32,18
305	2	211935	7777395	19/04/2016	08:55:22	23513,1	70	23510,18	23517,19	23539,3	-29,12	-32,11
306	2	211940	7777374	19/04/2016	08:57:22	23515,3	75	23514,60	23519,73	23539,2	-24,60	-29,47
307	2	211951	7777353	19/04/2016	08:59:02	23514,9	75	23513,82	23519,61	23539,2	-25,38	-29,59
308	2	211958	7777337	19/04/2016	09:00:37	23513,8	70	23508,58	23518,60	23539,2	-30,62	-30,60
309	2	211965	7777320	19/04/2016	09:02:12	23515,2	70	23515,34	23519,98	23539,2	-23,86	-29,22
310	2	211969	7777300	19/04/2016	09:04:07	23509,4	60	23503,76	23513,91	23539,2	-35,44	-35,29
311	2	211978	7777281	19/04/2016	09:06:07	23511,6	60	23508,22	23516,00	23539,2	-30,98	-33,20
312	2	211989	7777265	19/04/2016	09:07:47	23514,9	45	23514,76	23519,15	23539,2	-24,44	-30,06
313	2	211998	7777248	19/04/2016	09:09:42	23513,5	60	23512,00	23517,62	23539,2	-27,20	-31,58
314	3	212042	7777271	19/04/2016	09:14:52	23516,3	75	23516,60	23520,06	23539,2	-22,60	-29,14
315	3	212030	7777283	19/04/2016	09:18:42	23514,1	60	23512,18	23517,69	23539,2	-27,02	-31,51
316	3	212026	7777306	19/04/2016	09:20:57	23512	70	23508,04	23515,56	23539,3	-31,26	-33,74



N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
317	3	212018	7777320	19/04/2016	09:22:37	23526,7	70	23537,42	23530,18	23539,3	-1,88	-19,12
318	3	212010	7777344	19/04/2016	09:26:57	23514,5	75	23513,04	23517,87	23539,3	-26,26	-31,43
319	3	211998	7777363	19/04/2016	09:28:47	23514,1	80	23512,12	23517,35	23539,3	-27,18	-31,95
320	3	211990	7777378	19/04/2016	09:30:12	23515,1	75	23514,14	23518,32	23539,3	-25,16	-30,98
321	3	211982	7777393	19/04/2016	09:31:37	23524,1	75	23530,18	23527,31	23539,3	-9,12	-21,99
322	3	211970	7777409	19/04/2016	09:33:47	23515	70	23507,90	23518,13	23539,3	-31,40	-31,17
323	4	212016	7777454	19/04/2016	09:38:32	23514,8	75	23513,52	23517,84	23539,4	-25,88	-31,56
324	4	212022	7777431	19/04/2016	09:41:02	23518,4	75	23520,84	23521,45	23539,4	-18,56	-27,95
325	4	212033	7777410	19/04/2016	09:42:32	23516,6	80	23517,28	23519,64	23539,4	-22,12	-29,76
326	4	212041	7777394	19/04/2016	09:45:07	23515,1	85	23514,12	23518,06	23539,3	-25,18	-31,24
327	4	212048	7777376	19/04/2016	09:47:02	23516	85	23515,94	23519,05	23539,3	-23,36	-30,25
328	4	212060	7777359	19/04/2016	09:48:42	23516,9	80	23517,84	23519,98	23539,3	-21,46	-29,32
329	4	212067	7777341	19/04/2016	09:50:17	23515	75	23513,96	23518,27	23539,3	-25,34	-31,03
330	4	212075	7777321	19/04/2016	09:52:27	23516,7	75	23517,34	23520,09	23539,3	-21,96	-29,21
332	4	212089	7777296	19/04/2016	10:00:17	23517,5	75	23513,90	23521,36	23539,3	-25,40	-27,94
333	4	212086	7777278	19/04/2016	10:02:42	23515,4	70	23514,86	23519,33	23539,3	-24,44	-29,97
334	4	212096	7777266	19/04/2016	10:04:17	23513,8	80	23510,66	23517,73	23539,3	-28,64	-31,57
335	5	212137	7777282	19/04/2016	10:09:42	23517,3	80	23516,68	23521,22	23539,3	-22,62	-28,08
336	5	212129	7777304	19/04/2016	10:12:17	23519	80	23518,94	23522,84	23539,4	-20,46	-26,56
337	5	212123	7777323	19/04/2016	10:14:27	23518,8	80	23518,50	23522,61	23539,4	-20,90	-26,79
338	5	212116	7777342	19/04/2016	10:18:12	23517,4	75	23518,76	23520,81	23539,4	-20,64	-28,59
339	5	212104	7777360	19/04/2016	10:20:02	23517,2	65	23518,36	23520,39	23539,4	-21,04	-29,01
340	5	212100	7777378	19/04/2016	10:21:37	23515,6	70	23515,12	23518,56	23539,4	-24,28	-30,84
341	5	212094	7777396	19/04/2016	10:24:42	23518,1	75	23519,26	23520,64	23539,4	-20,14	-28,76
342	5	212087	7777419	19/04/2016	10:26:42	23522,2	75	23527,42	23524,54	23539,4	-11,98	-24,86
343	5	212081	7777434	19/04/2016	10:29:22	23513,6	70	23510,26	23515,62	23539,4	-29,14	-33,78
344	5	212073	7777451	19/04/2016	10:31:02	23525,9	60	23533,72	23527,55	23539,4	-5,68	-21,85
345	5	212062	7777472	19/04/2016	10:33:22	23523,6	65	23529,16	23524,85	23539,4	-10,24	-24,55
346	5	212054	7777491	19/04/2016	10:34:52	23520,4	65	23522,80	23521,38	23539,4	-16,60	-28,03
347	5	212048	7777506	19/04/2016	10:36:22	23517,5	60	23515,96	23518,17	23539,4	-23,44	-31,23
348	5	212039	7777528	19/04/2016	10:38:17	23515,9	65	23512,78	23516,22	23539,4	-26,62	-33,18
349	5	212032	7777542	19/04/2016	10:39:42	23521,8	60	23524,62	23521,81	23539,5	-14,88	-27,69
350	5	212023	7777561	19/04/2016	10:41:07	23517,9	65	23515,70	23517,65	23539,5	-23,80	-31,85
351	5	212014	7777579	19/04/2016	10:43:47	23518,5	70	23517,08	23517,80	23539,5	-22,42	-31,70
352	9	212266	7777509	19/04/2016	10:55:12	23507,4	90	23493,72	23505,35	23539,6	-45,88	-44,25
354	9	212278	7777474	19/04/2016	10:59:57	23515,9	75	23510,86	23513,43	23539,6	-28,74	-36,17
355	9	212286	7777456	19/04/2016	11:01:57	23519,8	85	23517,52	23516,87	23539,6	-22,08	-32,73
356	9	212295	7777439	19/04/2016	11:04:07	23524	85	23525,96	23520,68	23539,6	-13,64	-28,92
357	9	212303	7777419	19/04/2016	11:05:47	23520,2	85	23517,40	23516,57	23539,6	-22,20	-33,03
358	9	212307	7777400	19/04/2016	11:09:17	23527,2	90	23531,32	23522,80	23539,6	-8,28	-26,80
359	10	212354	7777417	19/04/2016	11:13:02	23524,2	90	23524,36	23519,14	23539,6	-15,24	-30,46
360	10	212344	7777437	19/04/2016	11:15:17	23520,1	85	23509,18	23514,57	23539,6	-30,42	-35,03
361	10	212337	7777457	19/04/2016	11:16:52	23516,1	80	23507,16	23510,17	23539,7	-32,54	-39,53
362	10	212331	7777474	19/04/2016	11:18:32	23510,1	90	23495,18	23503,71	23539,7	-44,52	-45,99
363	10	212323	7777493	19/04/2016	11:21:32	23512,4	80	23498,80	23505,23	23539,7	-40,90	-44,47
364	10	212316	7777512	19/04/2016	11:23:07	23520,3	75	23513,68	23512,83	23539,7	-26,02	-36,88
365	10	212308	7777530	19/04/2016	11:24:32	23527,9	75	23528,78	23520,03	23539,7	-10,92	-29,67
366	10	212301	7777550	19/04/2016	11:26:52	23537,1	80	23547,12	23528,59	23539,7	7,42	-21,11
367	10	212293	7777566	19/04/2016	11:29:52	23535,3	80	23542,54	23526,15	23539,7	2,84	-23,55
368	10	212286	7777584	19/04/2016	11:33:57	23527,3	65	23525,68	23517,37	23539,7	-14,02	-32,33
369	10	212279	7777606	19/04/2016	11:38:52	23526,9	80	23523,72	23515,97	23539,7	-15,98	-33,73
371	10	212259	7777642	19/04/2016	11:41:27	23529,8	80	23528,62	23518,49	23539,7	-11,08	-31,21
372	10	212253	7777659	19/04/2016	11:42:32	23540,7	75	23550,48	23529,18	23539,7	10,78	-20,52
373	10	212246	7777678	19/04/2016	11:43:47	23536,8	65	23542,58	23525,05	23539,7	2,88	-24,65
374	10	212239	7777697	19/04/2016	11:45:02	23534,2	70	23536,40	23522,20	23539,8	-3,40	-27,60

N	Perfil	X	Y	Data	Hora	B (nT)	R (cps)	Bt (1)	Bt (2)	IGRF	Btma (1)	Btma (2)
375	10	212230	7777717	19/04/2016	11:46:17	23532,4	55	23533,88	23520,39	23539,8	-5,92	-29,42
376	10	212225	7777733	19/04/2016	11:47:52	23531,5	60	23531,92	23519,30	23539,8	-7,88	-30,50
377	10	212217	7777752	19/04/2016	11:49:22	23532,1	60	23533,26	23519,96	23539,8	-6,54	-29,84
378	10	212210	7777772	19/04/2016	11:50:42	23532,1	55	23533,20	23519,75	23539,8	-6,60	-30,05
379	10	212204	7777790	19/04/2016	11:53:07	23530,8	50	23530,60	23518,29	23539,8	-9,20	-31,51
380	10	212202	7777804	19/04/2016	11:54:37	23528,6	60	23526,24	23516,00	23539,8	-13,56	-33,80
<b>LEGENDA</b>												
N = estação de coleta dados												
X = coordenada UTM WGS84 zona 24S												
Y = coordenada UTM WGS84 zona 24S												
B (nT) = valor de campo magnético medido												
R (cps) = valor raio métrico												
Bt(1) = valor de campo magnético corrigido pelo GEMLinkW 3.0												
Bt(2) = valor de campo magnético corrigido manualmente												
IGRF = International Geomagnetic Reference Field												
Btma(1) = campo anomalo [Bt(1) - IGRF]												
Btma(2) = campo anomalo [Bt(2) - IGRF]												

















Anfibólio

Comment	7-c3-Anf5	7-c3-Anf6	7-c3-Anf7	7-c3-Anf8	7-c3-Anf9	7-c3-Anf10	16-c7-Clo1	16-c7-Clo2	16-c7-Clo3	16-c7-Clo4	16-c7-Clo5	16-c7-Clo6
Na2O	0,71	0,70	0,89	0,49	0,36	0,90	0,68	0,77	0,53	0,46	0,66	0,18
F	0,11	0,10	0,08	0,06	0,06	0,02	0,10	0,10	0,02	0,10	0,06	0,06
SiO2	54,75	55,10	54,54	55,90	56,55	54,01	55,47	55,00	55,85	55,61	55,77	57,91
Al2O3	3,78	3,48	4,68	2,41	1,84	4,41	3,34	3,59	2,81	2,57	3,30	1,05
MgO	22,39	22,38	22,74	22,75	23,80	22,28	22,71	22,57	22,54	22,91	22,67	23,68
TiO2	0,03	0,07	0,05	0,03	0,03	0,07	0,05	0,04	0,05	0,06	0,06	0,07
FeO	2,44	2,45	2,58	2,33	2,26	2,41	2,45	2,47	2,28	2,28	2,34	2,01
CaO	12,57	12,30	12,24	12,22	12,39	12,28	12,30	12,28	12,36	12,31	12,52	12,66
NiO	0,07	0,08	0,04	0,11	0,05	0,16	0,07	0,05	0,08	0,11	0,02	0,05
Cr2O3	0,34	0,69	0,31	0,55	0,53	0,70	0,71	0,72	0,72	0,62	0,73	0,42
K2O	0,20	0,07	0,18	0,12	0,11	0,08	0,09	0,09	0,09	0,23	0,18	0,11
MnO	0,01	0,00	0,00	0,02	0,00	0,01	0,05	0,02	0,01	0,00	0,02	0,00
Total	97,34	97,38	98,29	96,97	97,96	97,31	97,97	97,66	97,34	97,21	98,30	98,18
Na	0,19	0,19	0,24	0,13	0,10	0,24	0,18	0,21	0,14	0,12	0,18	0,05
F												
Si	7,57	7,60	7,47	7,73	7,74	7,48	7,61	7,58	7,69	7,68	7,62	7,88
Al	0,62	0,57	0,75	0,39	0,30	0,72	0,54	0,58	0,46	0,42	0,53	0,17
Mg	4,61	4,60	4,64	4,69	4,85	4,60	4,65	4,63	4,63	4,72	4,62	4,80
Ti	0,00	0,01	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,01	0,01	0,01
Fe	0,28	0,28	0,30	0,27	0,26	0,28	0,28	0,28	0,26	0,26	0,27	0,23
Ca	1,86	1,82	1,80	1,81	1,82	1,82	1,81	1,81	1,82	1,82	1,83	1,84
Ni	0,01	0,01	0,00	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,00	0,01
Cr	0,04	0,08	0,03	0,06	0,06	0,08	0,08	0,08	0,08	0,07	0,08	0,05
K	0,04	0,01	0,03	0,02	0,02	0,01	0,02	0,02	0,02	0,04	0,03	0,02
Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00

Anfibólio

Comment	16-c7-Clo7	16-c7-Clo8	16-c7-Clo9
Na2O	0,70	0,66	0,98
F	0,09	0,10	0,07
SiO2	55,15	55,51	54,12
Al2O3	3,46	3,29	4,56
MgO	22,50	22,55	21,97
TiO2	0,04	0,03	0,08
FeO	2,50	2,40	2,63
CaO	12,18	12,35	12,28
NiO	0,08	0,14	0,12
Cr2O3	0,56	0,53	0,73
K2O	0,10	0,10	0,09
MnO	0,01	0,04	0,00
Total	97,34	97,65	97,60

Na	0,19	0,18	0,26
F			
Si	7,61	7,64	7,48
Al	0,56	0,53	0,74
Mg	4,63	4,62	4,52
Ti	0,00	0,00	0,01
Fe	0,29	0,28	0,30
Ca	1,80	1,82	1,82
Ni	0,01	0,02	0,01
Cr	0,06	0,06	0,08
K	0,02	0,02	0,02
Mn	0,00	0,00	0,00



Clorita

Comment	16-cY-Clo9	16-cY-Clo1	7-c1-Clo1	7-c1-Clo2	7-c1-Clo3	7-c1-Clo4	7-c1-Clo5	7-c2-Clo2	7-c2-Clo3	7-c2-Clo4	7-c2-Clo5	7-c2-Clo6	7-c2-Clo7
Na2O	0,04	0,00	0,06	0,04	0,05	0,05	0,03	0,01	0,00	0,02	0,03	0,00	0,02
F	0,08	0,13	0,09	0,10	0,12	0,09	0,07	0,14	0,18	0,13	0,13	0,12	0,14
SiO2	35,50	41,36	32,31	32,79	32,70	32,52	32,79	41,34	42,65	32,16	31,92	31,88	32,37
Al2O3	8,03	2,55	12,49	12,80	12,37	12,49	12,52	3,29	2,63	13,84	14,40	14,81	14,49
MgO	33,81	36,07	33,15	33,57	33,52	33,27	33,08	36,93	37,46	33,03	32,60	32,80	33,07
TiO2	0,01	0,01	0,01	0,05	0,04	0,05	0,02	0,03	0,03	0,02	0,04	0,07	0,06
FeO	3,19	3,52	3,34	3,43	3,53	3,29	3,37	3,79	3,73	3,65	3,69	3,81	3,60
CaO	0,03	0,06	0,02	0,00	0,01	0,00	0,00	0,00	0,02	0,02	0,02	0,03	0,04
NiO	0,19	0,11	0,18	0,12	0,21	0,13	0,18	0,19	0,14	0,18	0,19	0,23	0,25
Cr2O3	2,08	0,59	3,42	3,25	3,27	3,20	3,42	1,39	0,65	2,78	2,39	2,55	2,18
K2O	0,06	0,03	0,08	0,07	0,02	0,08	0,12	0,01	0,02	0,03	0,02	0,02	0,02
MnO	0,03	0,02	0,00	0,02	0,02	0,02	0,00	0,00	0,01	0,00	0,03	0,06	0,04
Total	83,00	84,38	85,12	86,19	85,81	85,15	85,57	87,07	87,44	85,80	85,40	86,33	86,22
Na	0,01	0,00	0,02	0,01	0,02	0,02	0,01	0,00	0,00	0,01	0,01	0,00	0,01
F	0,08	0,13	0,09	0,10	0,12	0,09	0,07	0,14	0,18	0,13	0,13	0,12	0,14
Si	7,12	8,09	6,38	6,39	6,41	6,41	6,44	7,88	8,06	6,30	6,27	6,21	6,29
Al	1,90	0,59	2,91	2,94	2,86	2,90	2,90	0,74	0,59	3,20	3,34	3,40	3,32
Mg	10,11	10,51	9,76	9,75	9,80	9,78	9,68	10,50	10,55	9,65	9,55	9,53	9,59
Ti	0,00	0,00	0,00	0,01	0,01	0,01	0,00	0,00	0,00	0,00	0,01	0,01	0,01
Fe	0,24	0,26	0,25	0,25	0,26	0,24	0,25	0,27	0,26	0,27	0,27	0,28	0,26
Ca	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01
Ni	0,03	0,02	0,03	0,02	0,03	0,02	0,03	0,03	0,02	0,03	0,03	0,04	0,04
Cr	0,33	0,09	0,53	0,50	0,51	0,50	0,53	0,21	0,10	0,43	0,37	0,39	0,34
K	0,01	0,01	0,02	0,02	0,01	0,02	0,03	0,00	0,00	0,01	0,01	0,01	0,00
Mn	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01









Comment	Talco												
	16-c8-Tal1	16-c8-Tal2	16-c8-Tal1	16-c8-Tal2	16-c8-Tal3	16-c8-Tal4	7-c1-Tal5	7-c1-Tal6	7-cX-Tal1	7-cX-Tal2	7-cX-Tal3	7-cX-Tal4	7-cX-Tal5
Na2O	0,038	0,006	0,066	0,071	0,081	0,072	0,112	0,053	0,077	0,096	0,106	0,061	0,042
F	0,077	0,062	0,009	0,111	0,08	0,092	0,011	0,111	0,066	0,084	0,074	0,106	0,072
SiO2	63,387	63,565	59,42	59,095	57,365	55,886	61,449	62,825	62,649	62,625	62,333	62,624	62,75
Al2O3	0,13	0,17	0,302	0,153	0,165	0,577	0,153	0,074	0,254	0,284	0,314	0,134	0,162
MgO	31,194	31,262	28,945	28,602	28,372	31,055	29,976	30,379	30,497	30,832	30,551	30,449	30,441
TiO2	0,026	0,031	0,025	0,009	0,034	0,036	0,02	0,013	0,036	0	0,006	0	0,031
FeO	1,347	1,345	1,279	1,143	1,658	1,984	1,277	1,286	1,273	1,339	1,302	1,308	1,354
CaO	0,047	0,033	0,266	0,194	0,314	0,269	0,057	0,007	0,017	0,014	0,014	0,008	0,011
NiO	0,125	0,164	0,248	0,187	0,266	0,166	0,16	0,193	0,245	0,217	0,222	0,173	0,154
Cr2O3	0,108	0,09	0,149	0	0,001	0,204	0,112	0,095	0,126	0,164	0,153	0,053	0,077
K2O	0,032	0,047	0,083	0,059	0,061	0,074	0,104	0,026	0,104	0,027	0,105	0,048	0,039
MnO	0	0	0	0,003	0	0,005	0	0	0,025	0,03	0,003	0	0
Total	96,479	96,749	90,788	89,58	88,363	90,381	93,426	95,015	95,341	95,677	95,152	94,919	95,103
Na	0,009295	0,001463	0,017185	0,018693	0,021776	0,019114	0,028291	0,01315	0,019066	0,023706	0,026316	0,015157	0,010415
F	0,077	0,062	0,009	0,111	0,08	0,092	0,011	0,111	0,066	0,084	0,074	0,106	0,072
Si	7,996578	7,995722	7,979685	8,024743	7,954223	7,652126	8,005736	8,039705	8,000646	7,975914	7,981567	8,025462	8,025446
Al	0,019329	0,025203	0,047799	0,024487	0,026964	0,093113	0,023493	0,011161	0,03823	0,042629	0,047387	0,020239	0,024419
Mg	5,866561	5,862258	5,794757	5,790091	5,864747	6,338977	5,821953	5,795483	5,805994	5,853869	5,83182	5,817158	5,80394
Ti	0,002468	0,002934	0,002526	0,000919	0,003547	0,003708	0,00196	0,001252	0,003459	0	0,000578	0	0,002983
Fe	0,063937	0,063656	0,064625	0,058399	0,086499	0,102211	0,062597	0,061919	0,061167	0,064164	0,062728	0,063069	0,065156
Ca	0,006353	0,004448	0,038274	0,028226	0,04665	0,039464	0,007957	0,00096	0,002326	0,00191	0,001921	0,001098	0,001507
Ni	0,012685	0,016595	0,026791	0,020427	0,02967	0,018284	0,016768	0,019868	0,025169	0,022232	0,022867	0,017834	0,015844
Cr	0,010772	0,008951	0,01582	0	0,00011	0,022084	0,011537	0,009612	0,012722	0,016514	0,015489	0,00537	0,007786
K	0,00515	0,007542	0,01422	0,010221	0,01079	0,012926	0,017285	0,004245	0,016943	0,004387	0,017152	0,007847	0,006363
Mn	0	0	0	0,000345	0	0,00058	0	0	0,002704	0,003236	0,000325	0	0

Talco

Comment	7-c4-Tal1	7-c4-Tal2	7-c4-Tal3	7-c4-Tal4	7-c4-Tal5	7-c4-Tal6
Na2O	0,039	0,072	0,035	0,065	0,059	0,048
F	0,108	0,141	0,065	0,021	0,042	0,088
SiO2	63,24	63,023	63,209	62,381	62,588	62,25
Al2O3	0,054	0,118	0,112	0,055	0,117	0,088
MgO	30,918	30,241	30,963	30,447	30,49	30,184
TiO2	0,013	0,02	0	0,036	0,02	0,04
FeO	1,246	1,715	1,256	1,227	1,18	1,182
CaO	0,001	0,018	0	0,011	0,031	0
NiO	0,191	0,203	0,215	0,24	0,132	0,204
Cr2O3	0,008	0	0,044	0,024	0,042	0,026
K2O	0,025	0,021	0,048	0,048	0,094	0,047
MnO	0,035	0,016	0	0	0	0
Total	95,833	95,529	95,92	94,546	94,777	94,12

Na	0,009594	0,017825	0,008603	0,016205	0,014664	0,012013
F	0,108	0,141	0,065	0,021	0,042	0,088
Si	8,023398	8,047445	8,013277	8,021345	8,023325	8,035599
Al	0,008075	0,017758	0,016734	0,008335	0,017677	0,013388
Mg	5,847718	5,756568	5,85171	5,836439	5,826789	5,808503
Ti	0,001241	0,001921	0	0,003483	0,001929	0,003885
Fe	0,059479	0,082395	0,05991	0,059363	0,056914	0,057408
Ca	0,000136	0,002463	0	0,001516	0,004258	0
Ni	0,019493	0,020851	0,021926	0,024825	0,013612	0,021183
Cr	0,000802	0	0,00441	0,00244	0,004257	0,002654
K	0,004046	0,003421	0,007763	0,007874	0,015373	0,00774
Mn	0,003761	0,00173	0	0	0	0

Lythochemical analysis of amphibolite samples (major elements in % weight; trace in ppm).

<b>SAMPLE</b>	<b>P2A</b>	<b>TN-8A</b>	<b>TN-8B</b>
<b>SiO<sub>2</sub></b>	51,57	47,43	47,97
<b>TiO<sub>2</sub></b>	0,99	1,71	2,81
<b>Al<sub>2</sub>O<sub>3</sub></b>	16,04	16,6	15,61
<b>Fe<sub>2</sub>O<sub>3</sub></b>	11,8	14,31	15,43
<b>MnO</b>	0,13	0,2	0,17
<b>MgO</b>	6,06	5,83	6,59
<b>CaO</b>	11,64	10,02	7,91
<b>Na<sub>2</sub>O</b>	0,67	2,01	1,37
<b>K<sub>2</sub>O</b>	0,18	0,67	0,7
<b>P<sub>2</sub>O<sub>5</sub></b>	0,06	0,35	0,41
<b>LOI</b>	0,6	0,6	0,7
<b>Sum</b>	99,82	99,78	99,75
<b>Ni</b>	162	78	72
<b>Rb</b>	1,3	10,3	24,2
<b>Ba</b>	17	124	207
<b>Sc</b>	41	34	30
<b>Th</b>	0,2	1	2
<b>U</b>	<0.1	1,2	0,6
<b>Nb</b>	1,5	13,3	23,2
<b>Ta</b>	0,1	0,7	1,3
<b>La</b>	2,5	12,4	24,4
<b>Ce</b>	6	30,9	53,2
<b>Pr</b>	1,11	4,43	7,45
<b>Sr</b>	208,2	302,4	204,2
<b>Nd</b>	6,6	21	33,4
<b>Zr</b>	44,6	136,8	180,2
<b>Hf</b>	1,9	3,1	4,1
<b>Sm</b>	2,26	4,9	7,32
<b>Eu</b>	0,81	1,64	1,98
<b>Gd</b>	3,47	5,32	6,65
<b>Tb</b>	0,57	0,9	0,85
<b>Dy</b>	4,39	5,2	5,07
<b>Y</b>	24,2	31,2	24,6
<b>Ho</b>	0,87	1,07	0,9
<b>Er</b>	2,27	3,74	2,34
<b>Tm</b>	0,34	0,46	0,35
<b>Yb</b>	2,66	2,86	2,23
<b>Lu</b>	0,32	0,48	0,31
<b>Co</b>	45,8	48,4	47,7

Analytical data of zircons of TN-8 sample. In bold unused data to obtain igneous crystallization age. In italics data used for obtaining metamorphic age.

Grain Spot	U (ppm)	Th (ppm)	Th/U	<sup>206</sup> Pb* (ppm)	<sup>206</sup> Pb <sup>c</sup> %	Isotope ratios						Age (Ma)						% Disc.	
						<sup>207</sup> Pb*/ <sup>235</sup> U ± (%)		<sup>206</sup> Pb*/ <sup>238</sup> U ± (%)		ρ	<sup>207</sup> Pb*/ <sup>206</sup> Pb* ± (%)		<sup>206</sup> Pb/ <sup>238</sup> U ±		<sup>207</sup> Pb/ <sup>235</sup> U ±		<sup>207</sup> Pb/ <sup>206</sup> Pb ±		
TN8A-1.1	311,84	298,96	0,99	73,88	-0,0086	3,664760	4,27	0,275558	4,19		0,98	0,096457	0,79	1573	58	1564	67	1557	15
TN8A-2.1	187,77	131,55	0,72	45,30	-0,2316	3,708945	4,40	0,280520	4,24	0,96	0,095893	1,16	1598	60	1573	69	1546	22	-3
TN8A-3.1	141,40	95,90	0,70	34,36	-0,0072	3,760617	4,38	0,281979	4,19	0,96	0,096727	1,26	1605	59	1584	69	1562	24	-2
TN8A-4.1	<b>306,02</b>	<b>202,74</b>	<b>0,68</b>	<b>73,20</b>	<b>-0,4101</b>	<b>3,580865</b>	<b>4,28</b>	<b>0,277981</b>	<b>4,17</b>	<b>0,97</b>	<b>0,093429</b>	<b>0,95</b>	<b>1581</b>	<b>58</b>	<b>1545</b>	<b>66</b>	<b>1497</b>	<b>18</b>	<b>-5</b>
<i>TN8A-5.1</i>	<i>467,76</i>	<i>1,35</i>	<i>0,00</i>	<i>40,62</i>	<i>-0,0322</i>	<i>0,827344</i>	<i>4,38</i>	<i>0,100982</i>	<i>4,17</i>	<i>0,95</i>	<i>0,059421</i>	<i>1,33</i>	<i>620</i>	<i>25</i>	<i>612</i>	<i>27</i>	<i>583</i>	<i>29</i>	<i>-6</i>
TN8A-6.1	151,86	102,70	0,70	36,66	-0,2249	3,726523	4,41	0,280803	4,25	0,96	0,096251	1,20	1599	60	1577	70	1553	23	-3
TN8A-7.1	<b>76,46</b>	<b>44,10</b>	<b>0,60</b>	<b>17,78</b>	<b>0,2812</b>	<b>3,484211</b>	<b>4,84</b>	<b>0,269189</b>	<b>4,23</b>	<b>0,87</b>	<b>0,093878</b>	<b>2,34</b>	<b>1537</b>	<b>58</b>	<b>1524</b>	<b>74</b>	<b>1506</b>	<b>45</b>	<b>-2</b>
TN8A-8.1	144,31	96,45	0,69	34,70	-0,0124	3,749917	4,34	0,279594	4,19	0,96	0,097274	1,14	1593	59	1582	69	1572	21	-1
TN8A-9.1	196,10	194,53	1,02	47,67	-0,3124	3,754612	4,27	0,282864	4,18	0,98	0,096269	0,90	1610	59	1583	68	1553	17	-3
TN8A-10.1	272,65	199,83	0,76	65,45	-0,1560	3,721154	4,24	0,279313	4,17	0,98	0,096624	0,79	1592	59	1576	67	1560	15	-2
TN8A-11.1	<b>50,10</b>	<b>23,62</b>	<b>0,49</b>	<b>11,33</b>	<b>0,63</b>	<b>3,39221</b>	<b>4,99</b>	<b>0,26157</b>	<b>4,26</b>	<b>0,85</b>	<b>0,09406</b>	<b>2,56790</b>	<b>1498</b>	<b>57</b>	<b>1503</b>	<b>75</b>	<b>1509</b>	<b>49</b>	<b>1</b>
TN8A-12.1	<b>206,46</b>	<b>112,13</b>	<b>0,56</b>	<b>43,44</b>	<b>0,5436</b>	<b>3,121166</b>	<b>4,32</b>	<b>0,244524</b>	<b>4,18</b>	<b>0,97</b>	<b>0,092575</b>	<b>1,08</b>	<b>1410</b>	<b>53</b>	<b>1438</b>	<b>62</b>	<b>1479</b>	<b>21</b>	<b>5</b>
TN8D-1.1	<b>548,21</b>	<b>448,01</b>	<b>0,84</b>	<b>67,59</b>	<b>1,8169</b>	<b>1,603705</b>	<b>4,27</b>	<b>0,143272</b>	<b>4,17</b>	<b>0,98</b>	<b>0,081182</b>	<b>0,95</b>	<b>863</b>	<b>34</b>	<b>972</b>	<b>42</b>	<b>1226</b>	<b>19</b>	<b>42</b>
TN8D-2.1	<b>77,94</b>	<b>43,89</b>	<b>0,58</b>	<b>13,96</b>	<b>1,2807</b>	<b>2,503567</b>	<b>5,11</b>	<b>0,207471</b>	<b>4,23</b>	<b>0,83</b>	<b>0,087517</b>	<b>2,86</b>	<b>1215</b>	<b>47</b>	<b>1273</b>	<b>65</b>	<b>1372</b>	<b>55</b>	<b>13</b>
TN8D-3.1	<b>162,19</b>	<b>63,81</b>	<b>0,41</b>	<b>26,47</b>	<b>1,6614</b>	<b>2,274242</b>	<b>4,70</b>	<b>0,189178</b>	<b>4,26</b>	<b>0,91</b>	<b>0,087187</b>	<b>1,98</b>	<b>1117</b>	<b>44</b>	<b>1204</b>	<b>57</b>	<b>1365</b>	<b>38</b>	<b>22</b>
TN8D-4.1	<b>620,59</b>	<b>39,31</b>	<b>0,07</b>	<b>59,00</b>	<b>0,4587</b>	<b>0,998464</b>	<b>4,33</b>	<b>0,110626</b>	<b>4,17</b>	<b>0,96</b>	<b>0,065460</b>	<b>1,19</b>	<b>676</b>	<b>27</b>	<b>703</b>	<b>30</b>	<b>789</b>	<b>25</b>	<b>17</b>
TN8D-5.1	160,76	112,13	0,72	32,73	0,8827	3,005246	4,41	0,236278	4,21	0,95	0,092247	1,32	1370	52	1409	62	1472	25	8
<i>TN8D-6.1</i>	<i>506,01</i>	<i>1,86</i>	<i>0,00</i>	<i>44,23</i>	<i>-0,0626</i>	<i>0,842672</i>	<i>4,31</i>	<i>0,101740</i>	<i>4,17</i>	<i>0,97</i>	<i>0,060071</i>	<i>1,09</i>	<i>625</i>	<i>25</i>	<i>621</i>	<i>27</i>	<i>606</i>	<i>23</i>	<i>-3</i>
<i>TN8D-7.1</i>	<i>362,74</i>	<i>1,46</i>	<i>0,00</i>	<i>31,69</i>	<i>-0,0157</i>	<i>0,843290</i>	<i>4,47</i>	<i>0,101644</i>	<i>4,25</i>	<i>0,95</i>	<i>0,060172</i>	<i>1,40</i>	<i>624</i>	<i>25</i>	<i>621</i>	<i>28</i>	<i>610</i>	<i>30</i>	<i>-2</i>
TN8D-8.1	<b>186,45</b>	<b>84,73</b>	<b>0,47</b>	<b>31,48</b>	<b>1,29</b>	<b>2,33792</b>	<b>4,69</b>	<b>0,19594</b>	<b>4,32</b>	<b>0,92</b>	<b>0,08654</b>	<b>1,81647</b>	<b>1153</b>	<b>46</b>	<b>1224</b>	<b>57</b>	<b>1350</b>	<b>35</b>	<b>17</b>
TN8D-9.1	<b>621,94</b>	<b>558,55</b>	<b>0,93</b>	<b>52,36</b>	<b>1,34</b>	<b>0,87336</b>	<b>4,67</b>	<b>0,09728</b>	<b>4,17</b>	<b>0,89</b>	<b>0,06511</b>	<b>2,07101</b>	<b>598</b>	<b>24</b>	<b>637</b>	<b>30</b>	<b>778</b>	<b>44</b>	<b>30</b>
TN8D-10.1	<b>25,08</b>	<b>1,54</b>	<b>0,06</b>	<b>4,49</b>	<b>7,23</b>	<b>3,56472</b>	<b>22,45</b>	<b>0,20465</b>	<b>4,58</b>	<b>0,20</b>	<b>0,12625</b>	<b>21,94877</b>	<b>1200</b>	<b>50</b>	<b>1542</b>	<b>346</b>	<b>2048</b>	<b>388</b>	<b>71</b>
TN8D-11.1	<b>18,55</b>	<b>2,51</b>	<b>0,14</b>	<b>4,16</b>	<b>9,30</b>	<b>4,83960</b>	<b>9,31</b>	<b>0,25100</b>	<b>4,57</b>	<b>0,49</b>	<b>0,13960</b>	<b>8,02231</b>	<b>1444</b>	<b>59</b>	<b>1792</b>	<b>167</b>	<b>2225</b>	<b>140</b>	<b>54</b>
TN8F-1.1	<b>302,42</b>	<b>657,91</b>	<b>2,25</b>	<b>52,81</b>	<b>1,57</b>	<b>2,46146</b>	<b>4,58</b>	<b>0,20213</b>	<b>4,19</b>	<b>0,91</b>	<b>0,08832</b>	<b>1,83445</b>	<b>1187</b>	<b>45</b>	<b>1261</b>	<b>58</b>	<b>1389</b>	<b>36</b>	<b>17</b>
TN8F-2.1	177,56	98,25	0,57	35,46	1,0354	2,924457	4,53	0,231524	4,29	0,95	0,091610	1,45	1345	52	1388	63	1459	28	9
TN8F-3.1	529,73	380,28	0,74	97,55	0,7078	2,559554	4,39	0,214007	4,25	0,97	0,086743	1,10	1253	48	1289	57	1355	21	8
<i>TN8F-4.1</i>	<i>143,32</i>	<i>6,85</i>	<i>0,05</i>	<i>13,03</i>	<i>0,4030</i>	<i>0,888704</i>	<i>5,25</i>	<i>0,105366</i>	<i>4,22</i>	<i>0,80</i>	<i>0,061174</i>	<i>3,11</i>	<i>646</i>	<i>26</i>	<i>646</i>	<i>34</i>	<i>645</i>	<i>67</i>	<i>0</i>

<b>TN8F-5.1</b>	<b>209,02</b>	<b>63,51</b>	<b>0,31</b>	<b>31,70</b>	<b>1,98</b>	<b>1,89346</b>	<b>5,36</b>	<b>0,17394</b>	<b>4,22</b>	<b>0,79</b>	<b>0,07895</b>	<b>3,21751</b>	<b>1034</b>	<b>40</b>	<b>1079</b>	<b>58</b>	<b>1171</b>	<b>65</b>	<b>13</b>
TN8F-6.1	290,01	208,07	0,74	63,81	0,5098	3,232072	4,47	0,254697	4,18	0,94	0,092038	1,56	1466	55	1465	66	1468	30	0
TN8F-7.1	238,21	206,67	0,90	57,24	-0,1774	3,656743	4,34	0,279063	4,19	0,97	0,095039	1,13	1590	59	1562	68	1529	21	-4
<b>TN8F-8.1</b>	<b>488,38</b>	<b>298,59</b>	<b>0,63</b>	<b>65,69</b>	<b>1,78</b>	<b>1,72222</b>	<b>4,46</b>	<b>0,15566</b>	<b>4,18</b>	<b>0,94</b>	<b>0,08024</b>	<b>1,52855</b>	<b>933</b>	<b>36</b>	<b>1017</b>	<b>45</b>	<b>1203</b>	<b>31</b>	<b>29</b>
TN8F-9.1	223,23	105,34	0,49	42,76	1,4558	2,725791	4,60	0,221063	4,19	0,91	0,089426	1,85	1290	49	1336	61	1413	36	10
<i>TN8F-10.1</i>	<i>288,92</i>	<i>4,01</i>	<i>0,01</i>	<i>26,64</i>	<i>-0,0036</i>	<i>0,890757</i>	<i>4,63</i>	<i>0,107163</i>	<i>4,20</i>	<i>0,91</i>	<i>0,060286</i>	<i>1,95</i>	<i>656</i>	<i>26</i>	<i>647</i>	<i>30</i>	<i>614</i>	<i>42</i>	<i>-6</i>
TN8F-11.1	264,16	172,16	0,67	60,07	0,3426	3,402661	4,37	0,263522	4,18	0,96	0,093650	1,23	1511	56	1505	66	1501	24	0
TN8F-12.1	207,82	121,13	0,60	42,10	0,9777	2,949275	4,67	0,234595	4,25	0,91	0,091178	1,93	1361	52	1395	65	1450	37	7

Analytical data of zircons of P2A sample. In bold unused data to obtain age. In italics inherited zircon grains not used to obtain age.

Grain Spot	U (ppm)	Th (ppm)	Th/U	<sup>206</sup> Pb* (ppm)	<sup>206</sup> Pb <sup>c</sup> %	Isotope ratios					Age (Ma)					% Disc.			
						<sup>207</sup> Pb*/ <sup>235</sup> U ± (%)	<sup>206</sup> Pb*/ <sup>238</sup> U ± (%)	ρ	<sup>207</sup> Pb*/ <sup>206</sup> Pb* ± (%)	<sup>206</sup> Pb/ <sup>238</sup> U ±	<sup>207</sup> Pb/ <sup>235</sup> U ±	<sup>207</sup> Pb/ <sup>206</sup> Pb ±							
P2A-1.1	<b>221,22</b>	<b>158,85</b>	<b>0,74</b>	<b>65,02</b>	<b>-0,22</b>	<b>5,34610</b>	<b>4,32</b>	<b>0,34170</b>	<b>4,22</b>	<b>0,98</b>	<b>0,11347</b>	<b>0,93035</b>	<b>1895</b>	<b>69</b>	<b>1876</b>	<b>81</b>	<b>1856</b>	<b>17</b>	<b>-2</b>
P2A-2.1	<b>106,48</b>	<b>76,75</b>	<b>0,74</b>	<b>23,26</b>	<b>-0,52</b>	<b>3,05851</b>	<b>4,55</b>	<b>0,25415</b>	<b>4,22</b>	<b>0,93</b>	<b>0,08728</b>	<b>1,69845</b>	<b>1460</b>	<b>55</b>	<b>1422</b>	<b>65</b>	<b>1367</b>	<b>33</b>	<b>-6</b>
P2A-3.1	173,47	136,72	0,81	30,36	0,41	2,23945	4,91	0,20289	4,48	0,91	0,08006	1,99145	1191	49	1193	59	1198	40	1
P2A-4.1	<i>104,04</i>	<i>77,02</i>	<i>0,76</i>	<i>34,14</i>	<i>-0,28</i>	<i>6,51932</i>	<i>4,48</i>	<i>0,38054</i>	<i>4,22</i>	<i>0,94</i>	<i>0,12426</i>	<i>1,47259</i>	<i>2079</i>	<i>75</i>	<i>2049</i>	<i>92</i>	<i>2018</i>	<i>26</i>	<i>-3</i>
P2A-5.1	266,74	139,11	0,54	44,24	0,10	2,02899	4,48	0,19255	4,20	0,94	0,07643	1,56851	1135	44	1125	50	1106	31	-3
P2A-6.1	881,15	190,44	0,22	141,54	-0,01	1,94484	4,26	0,18679	4,19	0,98	0,07552	0,76156	1104	42	1097	47	1082	15	-2
P2A-7.1	<b>502,78</b>	<b>6,91</b>	<b>0,01</b>	<b>94,20</b>	<b>-0,25</b>	<b>2,43981</b>	<b>4,29</b>	<b>0,21810</b>	<b>4,17</b>	<b>0,97</b>	<b>0,08113</b>	<b>1,01237</b>	<b>1272</b>	<b>48</b>	<b>1254</b>	<b>54</b>	<b>1225</b>	<b>20</b>	<b>-4</b>
P2A-8.1	503,11	161,98	0,33	82,07	-0,21	1,96305	4,28	0,18982	4,18	0,97	0,07501	0,95280	1120	43	1103	47	1069	19	-5
P2A-9.1	<b>895,33</b>	<b>196,42</b>	<b>0,23</b>	<b>79,17</b>	<b>2,37</b>	<b>1,03006</b>	<b>4,72</b>	<b>0,10204</b>	<b>4,17</b>	<b>0,88</b>	<b>0,07321</b>	<b>2,19816</b>	<b>626</b>	<b>25</b>	<b>719</b>	<b>34</b>	<b>1020</b>	<b>45</b>	<b>63</b>
P2A-10.1	<b>295,59</b>	<b>130,71</b>	<b>0,46</b>	<b>59,97</b>	<b>1,13</b>	<b>3,08244</b>	<b>4,33</b>	<b>0,23570</b>	<b>4,18</b>	<b>0,97</b>	<b>0,09485</b>	<b>1,12154</b>	<b>1364</b>	<b>51</b>	<b>1428</b>	<b>62</b>	<b>1525</b>	<b>21</b>	<b>12</b>
P2A-11.1	<i>90,02</i>	<i>85,19</i>	<i>0,98</i>	<i>25,22</i>	<i>-0,06</i>	<i>4,75423</i>	<i>4,61</i>	<i>0,32410</i>	<i>4,23</i>	<i>0,92</i>	<i>0,10640</i>	<i>1,80285</i>	<i>1810</i>	<i>67</i>	<i>1777</i>	<i>82</i>	<i>1738</i>	<i>33</i>	<i>-4</i>
P2A-12.1	332,68	104,97	0,33	76,55	-0,01	3,44097	4,34	0,26724	4,18	0,96	0,09339	1,15986	1527	57	1514	66	1496	22	-2

Analytical data of zircons of P2D sample. In bold unused data to obtain the age spectra.

Spot number	Ratios							Age (Ma)						%	Disc.	f 206	Age (Ma)	±	Th	U	Pb	$\frac{^{32}\text{Th}}{^{38}\text{U}}$
	$\frac{^{207}\text{Pb}^*/^{235}\text{U}}$	±	$\frac{^{206}\text{Pb}^*/^{238}\text{U}}$	±	Rho 1	$\frac{^{207}\text{Pb}^*/^{206}\text{Pb}^*}$	±	$\frac{^{206}\text{Pb}/^{238}\text{U}}$	±	$\frac{^{207}\text{Pb}/^{235}\text{U}}$	±	$\frac{^{207}\text{Pb}/^{206}\text{Pb}}$	±						ppm	ppm	ppm	
<b>P-2D 1</b>	2,31603	3,25	0,20552	3,06	0,94	0,08173	1,09	1205	37	1217	40	1239	14	3	0,0007	1229	36	216,5	515,4	181,8	0,42	
<b>P-2D 2</b>	3,43865	4,85	0,26001	4,75	0,98	0,09592	1,02	1490	71	1513	73	1546	16	4	0,0004	1542	36	57,6	221,5	78,7	0,26	
<b>P-2D 3</b>	2,76864	3,61	0,22588	2,85	0,79	0,08890	2,22	1313	37	1347	49	1402	31	6	0,0015	1542	36	22,2	77,3	24,5	0,29	
<b>P-2D 4</b>	2,30292	3,39	0,20503	3,01	0,89	0,08146	1,56	1202	36	1213	41	1233	19	2	0,0014	1219	45	706,2	545,9	188,9	1,30	
<b>P-2D 5</b>	2,55544	2,92	0,21891	2,19	0,75	0,08467	1,92	1276	28	1288	38	1308	25	2	0,0016	1286	42	127,2	129,5	47,7	0,99	
<b>P-2D 6</b>	2,08715	4,02	0,19146	3,55	0,88	0,07906	1,88	1129	40	1145	46	1174	22	4	0,0023	1151	53	24,5	75,9	20,3	0,32	
<b>P-2D 7</b>	2,11280	4,44	0,19261	4,03	0,91	0,07956	1,87	1135	46	1153	51	1186	22	4	0,0010	1164	56	34,6	118,4	31,0	0,29	
<b>P-2D 8</b>	3,06795	2,62	0,24416	2,33	0,89	0,09113	1,21	1408	33	1425	37	1449	18	3	0,0004	1434	36	52,5	300,6	99,9	0,18	
<b>P-2D 9</b>	2,92996	2,74	0,24031	2,36	0,86	0,08843	1,39	1388	33	1390	38	1392	19	0	0,0010	1390	40	220,5	252,0	90,2	0,88	
<b>P-2D 10</b>	4,93173	8,04	0,30726	7,93	0,99	0,11641	1,29	1727	137	1808	145	1902	24	9	0,0016	1897	42	218,7	236,5	127,6	0,93	
<b>P-2D 11</b>	3,47993	3,61	0,26191	3,42	0,95	0,09636	1,13	1500	51	1523	55	1555	18	4	0,0010	1545	38	29,2	149,8	52,6	0,20	
<b>P-2D 12</b>	2,25394	4,86	0,20007	4,59	0,94	0,08171	1,60	1176	54	1198	58	1238	20	5	0,0012	1221	53	62,3	111,7	34,9	0,56	
<b>P-2D 13</b>	3,22505	13,95	0,26193	3,10	0,22	0,08930	13,6	1500	47	1463	204	1411	2	-6	0,0004	1497	82	44,4	349,6	118,7	0,13	
<b>P-2D 14</b>	2,65987	5,48	0,22405	5,31	0,97	0,08610	1,33	1303	69	1317	72	1340	18	3	0,0009	1335	47	130,2	479,7	142,9	0,27	
<b>P-2D 15</b>	2,25035	3,49	0,20340	2,91	0,83	0,08024	1,92	1194	35	1197	42	1203	23	1	0,0015	1197	49	33,2	96,0	26,7	0,35	
<b>P-2D 16</b>	1,83042	3,04	0,17566	2,29	0,75	0,07557	1,99	1043	24	1056	32	1084	22	4	0,0025	1052	39	156,0	382,1	92,8	0,41	
<b>P-2D 17</b>	2,50104	4,35	0,21877	3,78	0,87	0,08292	2,17	1275	48	1272	55	1267	27	-1	0,0060	1271	61	53,1	87,3	27,9	0,61	
<b>P-2D 18</b>	3,48319	2,28	0,26517	1,90	0,83	0,09527	1,27	1516	29	1523	35	1533	19	1	0,0007	1525	35	67,8	170,8	63,0	0,40	
<b>P-2D 19</b>	1,93246	5,23	0,18328	4,89	0,93	0,07647	1,87	1085	53	1092	57	1107	21	2	0,0024	1099	59	47,2	96,0	26,7	0,50	
<b>P-2D 20</b>	2,33403	4,80	0,20906	4,26	0,89	0,08097	2,21	1224	52	1223	59	1221	27	0	0,0026	1222	64	36,6	69,1	20,6	0,53	
<b>P-2D 21</b>	2,70704	6,37	0,22734	5,64	0,89	0,08636	2,95	1321	75	1330	85	1346	40	2	0,0032	1336	87	35,9	36,1	16,2	1,00	
<b>P-2D 22</b>	5,93130	3,06	0,34740	2,75	0,90	0,12383	1,35	1922	53	1966	60	2012	27	4	0,0002	1993	42	85,6	269,1	163,1	0,32	
<b>P-2D 23</b>	2,39589	2,43	0,21139	2,03	0,84	0,08220	1,34	1236	25	1241	30	1250	17	1	0,0007	1242	35	52,5	139,6	49,1	0,38	
<b>P-2D 24</b>	3,60256	3,99	0,27019	3,82	0,96	0,09670	1,16	1542	59	1550	62	1561	18	1	0,0005	1559	40	51,1	158,2	71,6	0,33	
<b>P-2D 25</b>	5,82112	3,11	0,34723	2,91	0,94	0,12159	1,09	1921	56	1950	61	1980	22	3	0,0010	1972	36	74,6	124,3	80,6	0,60	
<b>P-2D 26</b>	4,89706	5,00	0,33021	4,78	0,96	0,10756	1,45	1839	88	1802	90	1758	26	-5	0,0007	1768	52	29,1	72,6	39,9	0,40	

<b>P-2D 27</b>	2,71883	3,21	0,22982	2,86	0,89	0,08580	1,45	1334	38	1334	43	1334	19	0	0,0020	1334	44	63,5	59,8	26,6	1,07
<b>P-2D 28</b>	2,92064	2,75	0,24103	2,31	0,84	0,08788	1,50	1392	32	1387	38	1380	21	-1	0,0012	1386	41	31,5	90,3	35,0	0,35
<b>P-2D 29</b>	5,02582	3,44	0,32843	3,09	0,90	0,11098	1,51	1831	57	1824	63	1816	27	-1	0,0018	1819	48	24,4	34,9	20,3	0,70
<b>P-2D 30</b>	3,35308	3,63	0,26043	3,36	0,92	0,09338	1,39	1492	50	1494	54	1496	21	0	0,0015	1495	45	28,4	72,0	33,5	0,40
<b>P-2D 31</b>	3,44272	3,12	0,26249	2,68	0,86	0,09512	1,60	1503	40	1514	47	1530	24	2	0,0011	1519	46	38,2	96,9	38,2	0,40
<b>P-2D 32</b>	3,68852	2,94	0,27554	2,67	0,91	0,09709	1,24	1569	42	1569	46	1569	19	0	0,0004	1569	40	74,2	223,1	91,8	0,33
<b>P-2D 33</b>	2,36693	2,86	0,21052	2,42	0,85	0,08154	1,53	1232	30	1233	35	1235	19	0	0,0009	1233	40	68,2	138,1	44,2	0,50
<b>P-2D 34</b>	<b>5,17233</b>	<b>9,43</b>	<b>0,33668</b>	<b>7,77</b>	<b>0,82</b>	<b>0,11142</b>	<b>5,34</b>	<b>1871</b>	<b>145</b>	<b>1848</b>	<b>174</b>	<b>1823</b>	<b>97</b>	<b>-3</b>	<b>0,0017</b>	<b>1841</b>	<b>150</b>	<b>23,9</b>	<b>15,0</b>	<b>9,6</b>	<b>1,60</b>
<b>P-2D 35</b>	2,71920	3,12	0,23030	2,84	0,91	0,08563	1,30	1336	38	1334	42	1330	17	0	0,0009	1332	41	18,5	125,4	38,9	0,15
<b>P-2D 36</b>	2,66804	5,99	0,22778	5,38	0,90	0,08495	2,64	1323	71	1320	79	1314	35	-1	0,0021	1318	80	36,6	33,6	13,9	1,10
<b>P-2D 37</b>	6,57853	2,34	0,37650	2,11	0,90	0,12673	1,01	2060	43	2056	48	2053	21	0	0,0003	2054	32	190,9	230,5	145,5	0,83
<b>P-2D 38</b>	3,06030	4,58	0,25014	4,45	0,97	0,08873	1,12	1439	64	1423	65	1398	16	-3	0,0004	1404	41	163,0	318,9	120,4	0,51
<b>P-2D 39</b>	2,90497	3,65	0,23974	3,26	0,89	0,08788	1,63	1385	45	1383	50	1380	22	0	0,0012	1382	50	29,9	79,4	27,4	0,38
<b>P-2D 40</b>	4,65571	3,66	0,31241	3,37	0,92	0,10808	1,44	1753	59	1759	64	1767	25	1	0,0008	1764	47	50,1	92,8	46,0	0,54
<b>P-2D 41</b>	5,31420	2,96	0,33565	2,60	0,88	0,11483	1,42	1866	49	1871	55	1877	27	1	0,0005	1874	44	97,8	99,0	64,5	1,00
<b>P-2D 42</b>	4,74930	5,78	0,31140	4,67	0,81	0,11061	3,42	1748	82	1776	103	1810	62	3	0,0029	1783	94	31,6	38,2	22,2	0,83
<b>P-2D 43</b>	4,89538	5,78	0,32067	4,74	0,82	0,11072	3,31	1793	85	1801	104	1811	60	1	0,0025	1804	94	44,8	31,9	21,0	1,41
<b>P-2D 44</b>	2,54094	5,83	0,22224	5,03	0,86	0,08292	2,96	1294	65	1284	75	1267	37	-2	0,0031	1280	82	12,1	58,8	14,5	0,21
<b>P-2D 45</b>	2,14995	2,66	0,19942	2,13	0,80	0,07819	1,59	1172	25	1165	31	1152	18	-2	0,0004	1165	37	139,5	310,2	103,2	0,45
<b>P-2D 46</b>	2,30179	2,80	0,20507	2,28	0,81	0,08141	1,63	1203	27	1213	34	1231	20	2	0,0006	1213	40	43,8	141,3	46,9	0,31
<b>P-2D 47</b>	5,45998	3,30	0,34329	2,88	0,87	0,11535	1,61	1902	55	1894	63	1885	30	-1	0,0013	1890	50	54,3	68,6	43,4	0,80
<b>P-2D 48</b>	2,15679	4,24	0,19839	3,39	0,80	0,07885	2,55	1167	40	1167	50	1168	30	0	0,0018	1167	59	63,9	77,4	28,5	0,83
<b>P-2D 49</b>	1,95465	5,41	0,18475	4,87	0,90	0,07673	2,33	1093	53	1100	59	1114	26	2	0,0020	1104	68	75,5	59,8	22,2	1,27
<b>P-2D 50</b>	1,68812	3,68	0,16981	3,28	0,89	0,07210	1,69	1011	33	1004	37	989	17	-2	0,0010	1001	46	82,6	244,5	65,6	0,34
<b>P-2D 51</b>	4,45100	5,64	0,30822	5,48	0,97	0,10474	1,33	1732	95	1722	97	1710	23	-1	0,0011	1712	48	66,2	104,3	64,8	0,64
<b>P-2D 52</b>	2,37013	5,83	0,21107	5,43	0,93	0,08144	2,13	1235	67	1234	72	1232	26	0	0,0014	1233	69	26,5	68,7	26,9	0,39
<b>P-2D 53</b>	6,56498	3,43	0,37498	2,91	0,85	0,12698	1,82	2053	60	2055	70	2057	37	0	0,0007	2055	55	60,4	48,9	42,6	1,24
<b>P-2D 54</b>	5,93850	4,12	0,35527	3,91	0,95	0,12123	1,31	1960	77	1967	81	1974	26	1	0,0004	1973	44	55,3	189,4	116,9	0,29
<b>P-2D 55</b>	2,16693	3,95	0,20065	3,69	0,93	0,07833	1,43	1179	43	1170	46	1155	17	-2	0,0003	1163	46	22,3	267,3	89,5	0,08
<b>P-2D 56</b>	4,64295	3,75	0,31261	3,29	0,88	0,10772	1,79	1754	58	1757	66	1761	31	0	0,0008	1759	55	15,4	47,9	28,2	0,32
<b>P-2D 57</b>	3,58230	3,25	0,27256	3,00	0,92	0,09532	1,26	1554	47	1546	50	1534	19	-1	0,0004	1539	41	33,4	118,3	57,8	0,28

<b>P-2D 58</b>	5,84630	4,20	0,35228	3,77	0,90	0,12036	1,85	1945	73	1953	82	1962	36	1	0,0012	1958	59	96,9	115,4	80,0	0,85
<b>P-2D 59</b>	2,14794	5,41	0,20342	4,83	0,89	0,07658	2,45	1194	58	1164	63	1110	27	-8	0,0020	1149	71	27,7	53,6	18,9	0,52
<b>P-2D 60</b>	3,57354	4,37	0,27076	4,06	0,93	0,09572	1,61	1545	63	1544	67	1542	25	0	0,0007	1543	53	30,5	114,0	58,8	0,27
<b>P-2D 61</b>	4,82954	2,59	0,32030	2,30	0,89	0,10936	1,20	1791	41	1790	46	1789	21	0	0,0007	1789	37	178,0	83,0	70,3	2,16
<b>P-2D 62</b>	<b>4,93288</b>	<b>6,31</b>	<b>0,31771</b>	<b>4,87</b>	<b>0,77</b>	<b>0,11261</b>	<b>4,02</b>	<b>1779</b>	<b>87</b>	<b>1808</b>	<b>114</b>	<b>1842</b>	<b>74</b>	<b>3</b>	<b>0,0013</b>	<b>1811</b>	<b>110</b>	<b>6,1</b>	<b>9,5</b>	<b>5,7</b>	<b>0,64</b>
<b>P-2D 63</b>	4,67546	4,03	0,31262	3,56	0,88	0,10847	1,87	1754	62	1763	71	1774	33	1	0,0012	1768	58	82,1	56,3	41,0	1,47
<b>P-2D 64</b>	2,62481	4,75	0,22364	4,42	0,93	0,08512	1,75	1301	57	1308	62	1318	23	1	0,0022	1313	57	102,3	73,9	33,9	1,39
<b>P-2D 65</b>	1,93294	5,29	0,18483	4,58	0,86	0,07585	2,66	1093	50	1093	58	1091	29	0	0,0022	1092	70	31,0	55,3	19,2	0,56
<b>P-2D 66</b>	2,13990	5,82	0,19724	4,81	0,83	0,07869	3,27	1160	56	1162	68	1164	38	0	0,0031	1162	80	14,2	44,4	15,5	0,32
<b>P-2D 67</b>	2,34276	3,93	0,20840	3,36	0,86	0,08153	2,03	1220	41	1225	48	1234	25	1	0,0013	1227	55	36,8	73,8	28,8	0,50
<b>P-2D 68</b>	3,58297	1,87	0,27016	1,55	0,83	0,09619	1,05	1542	24	1546	29	1551	16	1	0,0004	1547	29	72,0	262,1	125,1	0,28
<b>P-2D 69</b>	6,19497	5,70	0,36503	4,93	0,86	0,12309	2,86	2006	99	2004	114	2001	57	0	0,0014	2003	87	17,3	11,6	9,8	1,51
<b>P-2D 70</b>	2,36512	5,90	0,21095	5,34	0,90	0,08132	2,52	1234	66	1232	73	1229	31	0	0,0008	1231	76	18,1	43,7	17,8	0,42
<b>P-2D 71</b>	2,69138	4,69	0,23106	4,37	0,93	0,08448	1,71	1340	59	1326	62	1304	22	-3	0,0007	1314	57	51,4	132,1	50,9	0,39
<b>P-2D 72</b>	2,13668	10,33	0,19568	4	0,98	0,07919	1,97	1152	117	1161	120	1177	23	2	0,0038	1174	72	122,1	233,3	61,6	0,53
<b>P-2D 73</b>	2,35119	5,55	0,20865	4,42	0,80	0,08173	3,36	1222	54	1228	68	1239	42	1	0,0020	1228	79	19,5	27,3	9,6	0,72
<b>P-2D 74</b>	3,71360	3,99	0,28159	3,78	0,95	0,09565	1,28	1599	60	1574	63	1541	20	-4	0,0004	1551	45	55,7	255,0	100,8	0,22
<b>P-2D 75</b>	4,84178	3,29	0,31871	2,71	0,83	0,11018	1,86	1783	48	1792	59	1802	33	1	0,0012	1795	53	38,4	45,7	25,1	0,85
<b>P-2D 76</b>	3,43238	2,62	0,26435	2,15	0,82	0,09417	1,50	1512	32	1512	40	1512	23	0	0,0009	1512	41	72,1	123,3	53,0	0,59
<b>P-2D 77</b>	5,58509	3,17	0,33729	3,03	0,96	0,12009	0,92	1874	57	1914	61	1958	18	4	0,0004	1950	31	243,5	179,6	114,9	1,37
<b>P-2D 78</b>	5,40112	4,55	0,35032	3,84	0,84	0,11182	2,44	1936	74	1885	86	1829	45	-6	0,0023	1864	73	25,7	35,8	17,3	0,72
<b>P-2D 79</b>	3,72752	2,82	0,27784	2,37	0,84	0,09730	1,52	1580	37	1577	44	1573	24	0	0,0013	1576	43	33,1	76,5	32,6	0,44
<b>P-2D 80</b>	4,61513	2,80	0,31280	2,27	0,81	0,10701	1,64	1754	40	1752	49	1749	29	0	0,0015	1751	46	89,0	70,0	40,4	1,28
<b>P-2D 81</b>	2,35619	5,17	0,21206	4,87	0,94	0,08058	1,73	1240	60	1229	64	1211	21	-2	0,0007	1219	58	201,6	320,2	107,2	0,63
<b>P-2D 82</b>	2,96770	5,74	0,23279	5,36	0,93	0,09246	2,06	1349	72	1399	80	1477	30	9	0,0025	1445	65	10,8	56,3	22,4	0,19
<b>P-2D 83</b>	3,22163	8,61	0,25483	8,51	0,99	0,09169	1,31	1463	125	1462	126	1461	19	0	0,0030	1461	49	129,8	299,1	94,1	0,44
<b>P-2D 84</b>	3,06025	2,57	0,24445	2,15	0,84	0,09079	1,41	1410	30	1423	37	1442	20	2	0,0018	1426	38	89,7	268,7	96,6	0,34
<b>P-2D 85</b>	1,97675	2,91	0,18671	2,38	0,82	0,07678	1,68	1104	26	1108	32	1116	19	1	0,0010	1108	39	21,2	140,0	40,1	0,15
<b>P-2D 86</b>	1,64161	6,69	0,16398	6,39	0,95	0,07261	2,00	979	63	986	66	1003	20	2	0,0016	995	66	144,8	255,1	63,9	0,57
<b>P-2D 87</b>	2,81051	7,46	0,23047	7,16	0,96	0,08845	2,12	1337	96	1358	101	1392	29	4	0,0012	1383	72	37,5	73,1	28,9	0,52
<b>P-2D 88</b>	5,81363	5,04	0,36215	4,46	0,88	0,11643	2,36	1992	89	1948	98	1902	45	-5	0,0030	1924	75	178,3	211,0	106,9	0,85



<b>P-2D 89</b>	5,22634	3,14	0,32724	2,83	0,90	0,11583	1,37	1825	52	1857	58	1893	26	4	0,0007	1878	43	62,3	96,9	58,5	0,65
<b>P-2D 90</b>	<b>1,94655</b>	<b>15,75</b>	<b>0,18310</b>	<b>14,4</b>	<b>0,91</b>	<b>0,07710</b>	<b>6,47</b>	<b>1084</b>	<b>156</b>	<b>1097</b>	<b>173</b>	<b>1124</b>	<b>73</b>	<b>4</b>	<b>0,0024</b>	<b>1106</b>	<b>190</b>	<b>7,1</b>	<b>24,7</b>	<b>7,9</b>	<b>0,29</b>