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DISSERTAÇÃO DE MESTRADO

CARACTERIZAÇÃO, CONDIÇÕES DE METAMORFISMO E IMPLICAÇÕES
GEOTECTÔNICAS DOS MIGMATITOS GRANATÍFEROS DA SERRA DO
CAPARAÓ (MG)

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Orientador: Prof. Tiago Amâncio Novo

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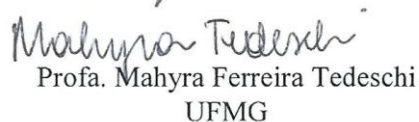
Caracterização, condições de metamorfismo e implicações geotectônicas dos migmatitos granatíferos da Serra do Caparaó (MG)


PEDRO LEONARDO NICOLAU DO CARMO ROSSI VIEIRA

Dissertação submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em GEOLOGIA, como requisito para obtenção do grau de Mestre em GEOLOGIA, área de concentração GEOLOGIA REGIONAL.

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Belo Horizonte, 27 de agosto de 2018.

A meus familiares, à minha amada e aos amigos de toda a vida.

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*“When the wind fills the sky the clouds will move aside,
And there will be a road to all our dreams
And for every day that stings
Two better days it brings, nothing is as bad as it seems!”
- Manowar, Master of the Wind*

RESUMO

Rochas metamórficas de temperatura ultra-alta (UHT) afloram na Serra do Caparaó (Sudeste do Brasil) como lascas tectônicas de ortognaisses e migmatitos pertencentes às unidades basais do Orógeno Araçuaí juntamente a migmatitos paraderivados. Esses migmatitos granatíferos são observados em intercalações tectônicas às unidades ortoderivadas, e podem ser subdivididos em hercinita-silimanita-granada migmatitos e ortopiroxênio-granada-biotita-migmatitos. Neste trabalho, conduzimos estudos petrológicos nestas rochas granatíferas com a finalidade de compreender melhor as condições metamórficas atingidas pelas partes mais profundas do Orógeno Araçuaí. Hercinita-silimanita-granada migmatitos exibem as associações mineralógicas do pico metamórfico preservadas, contendo safirina+quartzo e hercinita+quartzo estáveis, ambos diagnósticos de terranos UHT em todo o mundo. Ortopiroxênio-granada-biotita migmatitos exibem cristais de ortopiroxênio de alto Al, também característicos de rochas submetidas a condições UHT. Combinando termobarometria *Average P-T* (THERMOCALC) com modelamento de equilíbrio de fases, foram obtidas condições de pico metamórfico entre 1066-1076 °C, 7,6-7,9 kbar para os hercinita-silimanita-granada migmatitos e entre 988-1023 °C, 9.8-10.9 kbar para os ortopiroxênio-granada-biotita migmatitos, as mais altas condições de temperatura já calculadas para rochas do Orógeno Araçuaí. Dados geocronológicos U-PB LA-ICP-MS em cristais de zircão de ambas amostras forneceram idades mínimas entre 626-585 Ma para o metamorfismo, consideravelmente mais velhas que as idades de pico metamórfico obtidas por outras sequências metassedimentares em fácies granulito que afloram no núcleo cristalino do orógeno. As possíveis fontes de calor para atingir o metamorfismo UHT podem estar geodinamicamente relacionadas à subdução, associadas a processos de *magma underplating* durante o magmatismo da fase de arco ou a assimilação parcial da placa oceânica durante a exumação tectônica. Esta nova ocorrência de rochas metamórficas UHT soma-se às ainda poucas ocorrências deste tipo de terreno conhecidas mundialmente.

Palavras-chave: migmatito, metamorfismo UHT, petrologia metamórfica, Serra do Caparaó, Orógeno Araçuaí

ABSTRACT

Ultrahigh temperature (UHT) metamorphic rocks outcrops on the Caparao Range (southeastern Brazil) as tectonic slices of orthogneisses and migmatites from basement units of the Araçuaí Orogen alongside metasedimentary migmatites. These garnet-bearing migmatites are observed as tectonic intercalations into orthoderived units, and can be subdivided into hercynite-sillimanite-garnet migmatites and orthopyroxene-garnet-biotite migmatites. In this work, we conducted petrological studies on these garnet-bearing rocks in order to better comprehend the metamorphic conditions attained by the lowermost parts of the Araçuaí Orogen. Hercynite-sillimanite-garnet migmatites show preserved metamorphic peak assemblages containing stable sapphirine+quartz and hercynite+quartz, diagnostic of ultrahigh temperature (UHT) metamorphic terrains worldwide. Orthopyroxene-garnet-biotite migmatites exhibit high-Al orthopyroxene crystals, also characteristic of rocks submitted to UHT conditions. Combining Average P-T (THERMOCALC) thermobarometry with phase-equilibria modelling, metamorphic peak P-T conditions of 1066-1076 °C, 7.6-7.9 kbar are obtained for hercynite-sillimanite-garnet migmatites and 988-1023 °C, 9.8-10.9 kbar for orthopyroxene-garnet-biotite migmatites, the highest calculated for Araçuaí Orogen rocks. U-Pb LA-ICP-MS geochronology data obtained from zircon crystals from both migmatite types provided minimum metamorphic ages between 626-585 Ma, considerably older than the metamorphic peak ages obtained from other granulite-facies metasedimentary sequences outcropped in the crystalline nuclei of the orogen. The possible sources of heat for achieving UHT metamorphism may be geodynamically related to subduction, associated to magma underplating during arc related magmatism or to partial assimilation of the slab during tectonic exhumation. This newfound occurrence of UHT metamorphic rocks sums up to the yet few worldwide occurrences of this kind of terrain.

Keywords: migmatite, UHT metamorphism, metamorphic petrology, Caparao Range, Araçuaí Orogen

SUMÁRIO

1	INTRODUÇÃO	12
1.1	CONSIDERAÇÕES INICIAIS	12
1.2	JUSTIFICATIVA	12
1.3	ORGANIZAÇÃO DA DISSERTAÇÃO	13
2	GEOLOGIA REGIONAL	13
2.1	CONTEXTUALIZAÇÃO GEOTECTÔNICA	13
2.2	COMPARTIMENTAÇÃO ESTRUTURAL.....	14
2.3	CONTEXTO GEOLÓGICO REGIONAL.....	15
2.3.1	Embasamento	15
2.3.2	Megassequência Andrelândia.....	17
2.3.3	Grupo Rio Doce.....	17
2.3.4	Supersuíte G1	18
2.3.5	Supersuíte G2	18
3	ARTIGO: Ultrahigh temperature (UHT) metamorphic rocks from the Araçuaí Orogen, southeastern Brazil: tectonic implications from petrography, thermobarometry and phase-equilibria modelling.....	20
1	Introduction.....	20
2	Geological setting.....	22
2.1	Regional Geology	22
2.2	Local Geology	22
3	Materials and Methods	23
3.1	Mineral chemistry and thermobarometry.....	23
3.2	Whole-rock geochemistry and phase-equilibria modelling	24
3.3	LA-ICP-MS U-Pb geochronology	25
4	Results	26
4.1	Petrography and Mineral Chemistry.....	27
4.2	Thermobarometry	40
4.3	Phase-equilibria modelling.....	43
4.4	U-PB Geochronology.....	50
5	Discussions	56
6	Conclusions.....	65
7	Acknowledgements	65
8	References.....	66

4	RESULTADOS COMPLEMENTARES - PETROGRAFIA.....	75
4.1	Hc-Sil-Grt migmatitos.....	76
4.1.1	Spr-Hc-Sil-Grt diatexitos	78
4.1.2	Hc-Sill-Crd-Grt-Bt diatexitos	82
4.2	(Opx)-Grt-Bt Migmatitos	88
4.2.1	Grt-Bt metatexitos.....	89
4.2.2	Opx-Grt-Bt metatexitos.....	93
4.2.3	Opx-Grt-Bt diatexitos	101
4.2.4	Hc-Opx-Grt-Bt diatexitos.....	108
4.3	Opx-Cpx migmatitos.....	114
4.3.1	Cpx-Bt-Opx-Hbl metatexitos	115
4.3.2	Cpx-Opx diatexitos	118
5	CONCLUSÕES	122

1 INTRODUÇÃO

1.1 CONSIDERAÇÕES INICIAIS

Este volume consiste dos resultados do trabalho de pesquisa desenvolvido pelo discente Pedro Leonardo Nicolau do Carmo Rossi Vieira ao longo do curso de mestrado em Geologia Regional pelo Programa de Pós-Graduação em Geologia da Universidade Federal de Minas Gerais.

O trabalho foi desenvolvido no período de Março de 2016 a Junho de 2018, e foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Código de Financiamento 001, no período de Março de 2016 a Março de 2018. Trabalhos de campo e despesas laboratoriais foram custeados pelo projeto “EVOLUÇÃO DO EMBASAMENTO DO ORÓGENO ARAÇUAÍ NA REGIÃO DE MANHUAÇU A IPANEMA (MG), CARACTERIZAÇÃO ISOTÓPICA, QUÍMICA E ESTRUTURAL”, Edital MCTI/CNPq Nº 14/2014, e pelo Laboratório de Geotectônica do Centro de Pesquisa Professor Manoel Teixeira da Costa (CPMTC), coordenados pelo professor Antônio Carlos Pedrosa-Soares. As análises de microsonda eletrônica foram realizadas no e tiveram apoio do Laboratório de Microanálises do DEGEO/EM (LMIC) - Laboratório integrante da RMIC, Rede de Microscopia e Microanálises de Minas Gerais (FAPEMIG) -, coordenado pela professora Gláucia N. Queiroga.

A área de estudo se localiza na Serra do Caparaó, feição geomorfológica que se destaca na divisa dos estados de Minas Gerais e Espírito Santo, portadora do terceiro ponto mais elevado do território nacional (INDE, 2015). Nela se localiza o Parque Nacional do Caparaó, criado em 1961 por um decreto do então presidente Jânio Quadros, e a região se insere no contexto geológico do Núcleo Cristalino do Orógeno Araçuaí.

1.2 JUSTIFICATIVA

A escolha da área se deu a partir do mapeamento geológico realizado na região do Parque Nacional do Caparaó, no ano de 2015, por Barroso & Figueiredo (2015), Hoerlle & Silveira (2015), Laranjeira & Muzzi (2015) e Rosa & Amaral (2015) como parte dos Trabalhos Geológicos de Graduação (TG) apresentados pelos mesmos para obtenção do título de Bacharel em Geologia pela Universidade Federal de Minas Gerais. Estes trabalhos foram orientados pelo professor Tiago Amâncio Novo, e um aspecto de destaque foram as ocorrências mapeadas de migmatitos granatíferos diatexíticos, intercalados às litologias predominantes observadas na Serra do Caparaó - ortogneisses e migmatitos a ortopiroxênio e clinopiroxênio, de composição charnockítica e dispostos segundo um antiforame regional de direção aproximadamente NNE e vergência para W ao longo de toda a mesma (Cunningham et al., 1998). Estes granada-migmatitos ora se apresentam associados a zonas de cisalhamento, ora são encontrados ao longo da zona de charneira do antiforame. O contraste observado entre estas rochas e suas encaixantes suscitou as seguintes dúvidas:

- Em quais condições de pressão e temperatura estas rochas se formaram?
- Qual a idade de metamorfismo destas rochas?
- Teriam estas rochas alguma relação genética com os litotipos clássicos descritos como pertencentes à Suíte Caparaó/Complexo Juiz de Fora?
- Compreendidas as condições petrológicas que ocasionaram a formação destas rochas, quais suas implicações para o entendimento do Orógeno Araçuaí-Congo Ocidental?

Com o intuito de responder a estas questões, este trabalho foi desenvolvido com o principal objetivo de **realizar a caracterização do metamorfismo dos migmatitos granatíferos da Serra do Caparaó, determinando as condições de pressão e temperatura envolvidas em sua formação e suas implicações no contexto do Orógeno Araçuaí-Congo Ocidental.**

1.3 ORGANIZAÇÃO DA DISSERTAÇÃO

Esta dissertação consiste de cinco capítulos, organizados como se segue:

O *Capítulo 1 – Introdução* consiste na apresentação do trabalho e das justificativas para a realização do mesmo.

O *Capítulo 2 – Geologia Regional* apresenta a contextualização geológica e geotectônica acerca da área de estudo e do sistema orogênico onde se insere.

O *Capítulo 3 – Artigo “Ultrahigh temperature (UHT) metamorphic rocks from the Araçuaí Orogen, southeastern Brazil: tectonic implications from petrography, thermobarometry and phase-equilibria modelling”* consiste nos principais resultados obtidos ao longo deste curso de mestrado e suas interpretações, submetidos à revista *Journal of Metamorphic Geology* em Agosto de 2018. Nele são descritos dados de petrografia, termobarometria e modelamento de equilíbrio de fases que revelaram condições de metamorfismo de temperatura ultra-alta para as rochas estudadas neste trabalho. Estes dados foram apresentados de forma preliminar no 15º Simpósio de Geologia do Sudeste – GEOSUDESTE 2017, sediado na cidade de Diamantina (MG) em Outubro de 2017, na forma de apresentação oral.

O *Capítulo 4 – Resultados Complementares* apresenta dados petrográficos e termobarométricos analisados e produzidos ao longo do desenvolvimento do projeto que complementam os apresentados no artigo.

O *Capítulo 5 – Conclusões e Considerações Finais* apresenta as conclusões do trabalho, implicações e apontamentos futuros.

2 GEOLOGIA REGIONAL

2.1 CONTEXTUALIZAÇÃO GEOTECTÔNICA

A área de estudo se insere no contexto geológico da Faixa Araçuaí, definida por Almeida (1977) como a faixa de dobramentos e empurrões localizada entre o Cráton do São Francisco e a margem atlântica brasileira, e que juntamente com sua contraparte do Oeste da África (Faixa Oeste-Congolesa) constituem o Orógeno Araçuaí-Congo Ocidental. De idade Neoproterozoica-Ediacarana, este orógeno foi edificado como parte da Orogenia Brasileira-Pan-Africana durante a amalgamação do Supercontinente Gondwana. Este Orógeno constitui uma situação geotectônica extramamente singular, desenvolvendo-se entre duas massas continentais, denominadas Paleocôntinente São-Francisco e Paleocôntinente Congo, unidas por meio de uma ponte cratônica (Ponte Bahia-Gabão),

podendo ser considerado, portanto, como exemplo-tipo de um Orógeno Confinado (Pedrosa-Soares *et al.* 2001, 2003; Rogers & Santosh 2004).

Apesar de sua singularidade, no Orógeno Araçuaí são observados todos os componentes principais que caracterizam a evolução de um orógeno, desde os registros de formação de crosta oceânica e depósitos de margem passiva da bacia precursora até os componentes do arco magmático e do orógeno colisional, representando assim os registros de um ciclo orogênico completo (Pedrosa-Soares *et al.*, 2001, 2007).

2.2 COMPARTIMENTAÇÃO ESTRUTURAL

O Orógeno Araçuaí é dividido, segundo Alkmim *et al.* (2006), em dez compartimentos estruturais que se distinguem por meio de critérios associados a orientação espacial, história de nucleação e significado cinemático das estruturas observadas em cada setor.

A área de estudo se situa no setor denominado Núcleo Cristalino do Orógeno Araçuaí, situado a Leste da Zona de Cisalhamento de Abre Campo (ZCAC, Figura 1), compreendendo tanto granitóides de idade neoproterozoica, relacionados com as fases de evolução do Orógeno, quanto rochas metassedimentares e metavulcanossedimentares cronocorrelatas, que se relacionam tanto às bacias precursoras quanto as sin-orogênicas. Esta estrutura regional, que se estende por mais de 300 km, exibe direção aproximadamente N-S e constitui uma das mais marcadas descontinuidades do Orógeno Araçuaí, separa o embasamento em um domínio metamórfico predominantemente de fácies anfibólito, a Oeste, de um domínio predominantemente em fácies granulito, correspondente ao Núcleo Cristalino. Neste contexto a Zona de Cisalhamento de Abre Campo poderia constituir, segundo Cunningham *et al.* (1998), Fischel *et al.* (1998), Brueckener *et al.* (2000) e Alkmim *et al.* (2006, 2007) uma zona de sutura paleoproterozoica. Ao mesmo tempo, a presença de remanescentes ofiolíticos ao longo da estrutura na região próxima a Governador Valadares (Figura 1), pertencentes à Formação Ribeirão da Folha, são sugestivos de que a ZCAC represente a zona de sutura do Orógeno Araçuaí, desenvolvida durante o fechamento da porção oceânica da Bacia Macaúbas (Alkmim *et al.* 2006, Pedrosa-Soares *et al.* 2008). A ocorrência de plútons representativos do estágio pré-colisional apenas a Leste deste grande lineamento corrobora essa hipótese (Alkmim *et al.*, 2006). Associadas à Zona de Cisalhamento de Abre Campo, as Zonas de Cisalhamento de Manhuaçu (aproximadamente N-S) e Guaicui (aproximadamente NE-SW) justapõe lateralmente lascas do embasamento, seções do arco magmático, paragneisses e migmatitos associados, constituindo um panorama estrutural e metamórfico complexo.

A Serra do Caparaó, localizada (Figura 1) entre a Zona de Cisalhamento de Manhuaçu (ZCM), a Oeste, e a Zona de Cisalhamento de Guaicuí (ZCG), a Leste (Cunningham *et al.*, 1998), foi esculpida sobre ortogneisses do embasamento e paragneisses das coberturas metassedimentares neoproterozoicas (Söllner, 1991; Seidensticker & Wiedemann, 1992; Da Silva *et al.*, 2002; Da Silva *et al.*, 2004; Novo *et al.*, 2011), exibindo um *trend* estrutural predominantemente NNE. A macroestrutura definida pelo bandamento gnáissico ao longo da Serra representa uma lasca tectônica estruturada segundo um antiforme quilométrico, assimétrico, muito apertado, exibindo o flanco W invertido a subvertical, eixo caindo aproximadamente para NNE, vergência predominante para W e plano axial aproximadamente vertical (Cunningham *et al.*, 1998; Novo *et al.*, 2011), exibindo uma leve inflexão para NE em sua porção norte. Sua borda Oeste é marcada por zonas de cisalhamento

reversas, de alto ângulo, mergulhantes para WNW exibindo componente direcional dextral e notoriamente associadas a flancos de dobras parasíticas (Cunningham *et al.* 1998; Rosa & Amaral, 2015; Dias & Barroso, 2015). Na borda Leste também se observam zonas de cisalhamento reversas com componente direcional dextral, porém os mergulhos neste flanco são relativamente mais suaves, chegando a até 60° mergulhando para ESE (Hoerlle & Silveira, 2015).

2.3 CONTEXTO GEOLÓGICO REGIONAL

2.3.1 Embasamento

2.3.1.1 *Suíte Caparaó/Complexo Juiz de Fora*

O arcabouço geológico que sustenta a Serra é composto majoritariamente pela Suíte Caparaó (Figura 1), que constitui-se de gnaisses e migmatitos cinza-esverdeados a ortopiroxênio e clinopiroxênio, com proporções variadas de ortoclásio, hornblenda e biotita, cuja composição modal varia entre granodiorítica e gabróica, que se encontram metamorfizados em fácies granulito com reestabilização local em fácies anfíbolito (Campos Neto & Figueiredo, 1990; Seidensticker & Wiedemann, 1992; Da Silva *et al.*, 2002; Noce *et al.*, 2007). Tanto a composição quanto as idades (aproximadamente 2195 Ma, Da Silva *et al.* 2002, 2011) das rochas descritas na Suíte Caparaó permitem correlacioná-la com as litologias do Complexo Juiz de Fora, de origem ortoderivada, composição diorítica a gabronorítica e relacionada a um arco magmático de idade Riacciana afetado por metamorfismo granulítico de mesma idade (2084-2119 Ma) e, posteriormente, pela orogenia Brasileira (Da Silva *et al.* 2002, 2004, 2011; Noce *et al.*, 2007; Novo *et al.* 2011). Entretanto, a presença de gnaisses e migmatitos portadores de granada, rochas calcissilicáticas e quartzitos nos arredores da Serra do Caparaó e ao longo da mesma levaram à proposição de uma origem paraderivada às litologias da Suíte Caparaó por Barbosa & Sad (1983), Söllner (1989), Seidensticker & Wiedemann (1992), Söllner *et al.* (2000), Campos *et al.* (2004) e Söllner (2004), que consideraram os Opx-Cpx gnaisses e migmatitos como oriundos do metamorfismo em fácies granulito de rochas grauvaqueanas.

Seidensticker & Wiedemann (1992), Horn (2007), Novo *et al.* (2011) e Novo (2012) reconheceram, na Serra do Caparaó, uma clara distinção entre um domínio majoritariamente composto por rochas exibindo feições de incipiente a moderada fusão parcial, dominadas por gnaisses e metatexitos (segundo a classificação de Sawyer, 2008), e um domínio dominado por rochas com proeminentes feições anatéticas, comumente denominado de “núcleo migmatítico”, com predomínio de diatexitos. Os trabalhos de Barroso & Figueiredo (2015), Hoerlle & Silveira (2015), Laranjeira & Muzzi (2015) e Rosa & Amaral (2015) mapearam tanto o domínio predominantemente gnaissico-metatexítico quanto o domínio diatexítico (Figura 2), evidenciando as diferenças mineralógicas entre as litologias clássicas da Suíte Caparaó (SC) e os migmatitos granatíferos bem como a correlação espacial dos diatexitos (SC e granatíferos) às megaestruturas encontradas ao longo da Serra (discutido abaixo). Os dados dos mapeamentos realizados por estes autores foram reunidos e integrados ao longo deste trabalho.

Segundo Cunningham *et al.* (1998), Novo *et al.* (2011), Barroso & Figueiredo (2015), Laranjeira & Muzzi (2015) e Rosa & Amaral (2015), as unidades do embasamento que compõe a Suíte Caparaó se encontram sobrepostas às sequências metassedimentares neoproterozoicas a Oeste, pertencentes à Supersequência Andrelândia.

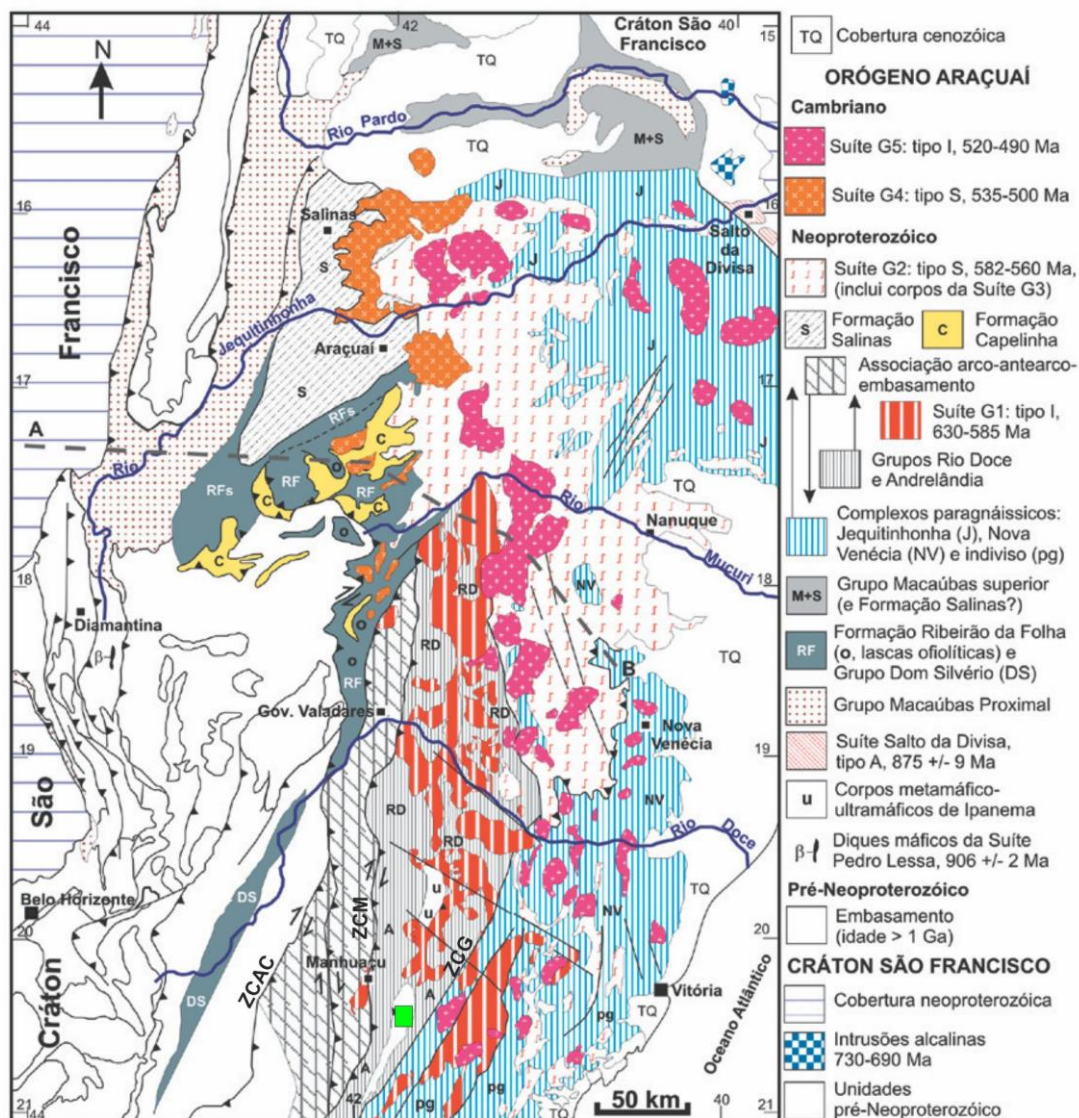


Figura 1 - Mapa geológico do Orógeno Araçuaí modificado de Pedrosa-Soares et al. (2007), sendo indicada a localização da área de estudo (retângulo verde). ZCAC – Zona de Cisalhamento de Abre Campo. ZCM – Zona de Cisalhamento de Manhuaçu. ZCG – Zona de Cisalhamento de Guaiçuí.

2.3.1.2 Complexo Pocrane

No flanco leste da Serra, as litologias pertencentes ao Complexo Pocrane (Silva *et al.*, 1987; Novo, 2013) se encontram justapostas por zonas de cisalhamento reversas sobre a Suíte Caparaó (Hoerlle & Silveira, 2015). Constituem epidoto-biotita-hornblenda-ortognaisses e, em menor proporção, migmatitos, sendo estes mais comumente metatexitos, e comumente exibem pórfiros de feldspato que, nas faixas miloníticas, formam *augens* com geometria predominantemente do tipo σ (Hoerlle & Silveira, 2015); segundo Novo (2013), são observados golfos de corrosão nos pórfiros de plagioclásio preenchidos por agregados de quartzo e feldspato da matriz, sugerindo uma origem vulcânica ou vulcanoclástica para o Complexo Pocrane. Sua composição química se situa predominantemente entre granítica e granodiorítica, apresentando termos monzo-dioríticos, gabro-dioríticos e dioríticos, o que, somado ao intervalo de idades de cristalização magmática desta unidade (entre 2,08-2,19 Ga), sugere que o Complexo Pocrane possa representar a parte vulcânica do Arco Magmático Juiz de Fora

(Novo, 2013). As litologias desta unidade na região apresentam metamorfismo marcadamente em fácies anfíbolito.

2.3.2 Megassequência Andrelândia

As sequências metassedimentares aflorantes na região são consideradas pertencentes à Megassequência Andrelândia (ou Grupo Andrelândia, Figura 1) com base em trabalhos anteriores realizados no leste de Minas Gerais (Noce et al. 2003; Horn 2007; Tupinambá *et al.*, 2007; Novo *et al.* 2010; Belém *et al.*, 2011; Novo 2012; Novo 2013). Fazendo correlações com as fácies descritas por Paciullo *et al.* (2000), Barroso & Figueiredo (2015), Hoerlle & Silveira (2015), Laranjeira & Muzzi (2015) e Rosa & Amaral (2015) descreveram a Megassequência Andrelândia na área de estudo (Figura 2) como duas sequências distintas: a Sequência Carrancas, constituída por granada-biotita gnaisses e silimanita-granada-biotita gnaisses, podendo exibir cordierita e hercinita concomitante ao desaparecimento da biotita e exibindo variados graus de anatexia, e a Sequência Serra do Turvo, correspondendo a granada-plagioclásio-biotita-muscovita xistos podendo conter estauroлита e turmalina. Estudos geocronológicos nos paragnaisses da Megassequência Andrelândia aflorantes no Orógeno Araçuaí (Belém *et al.*, 2011; Degler *et al.*, 2017) mostraram uma provável contribuição do arco magmático do Orógeno Araçuaí – o Arco Rio Doce – na sedimentação desta unidade, exibindo idades máximas de sedimentação entre 592-615 Ma. Outras fontes, incluindo o embasamento Arqueano-Paleoproterozóico e o Arco Mágmatco Rio Negro, são também identificáveis pela análise de zircões detríticos segundo Degler *et al.* (2017). A proximidade temporal com as idades do Grupo Rio Doce sugere que ambas as bacias sejam cronocorrelatas (Novo, 2013), sendo a Megassequência Andrelândia representante da sedimentação nos setores oeste e sul das regiões de antearco e arco.

2.3.3 Grupo Rio Doce

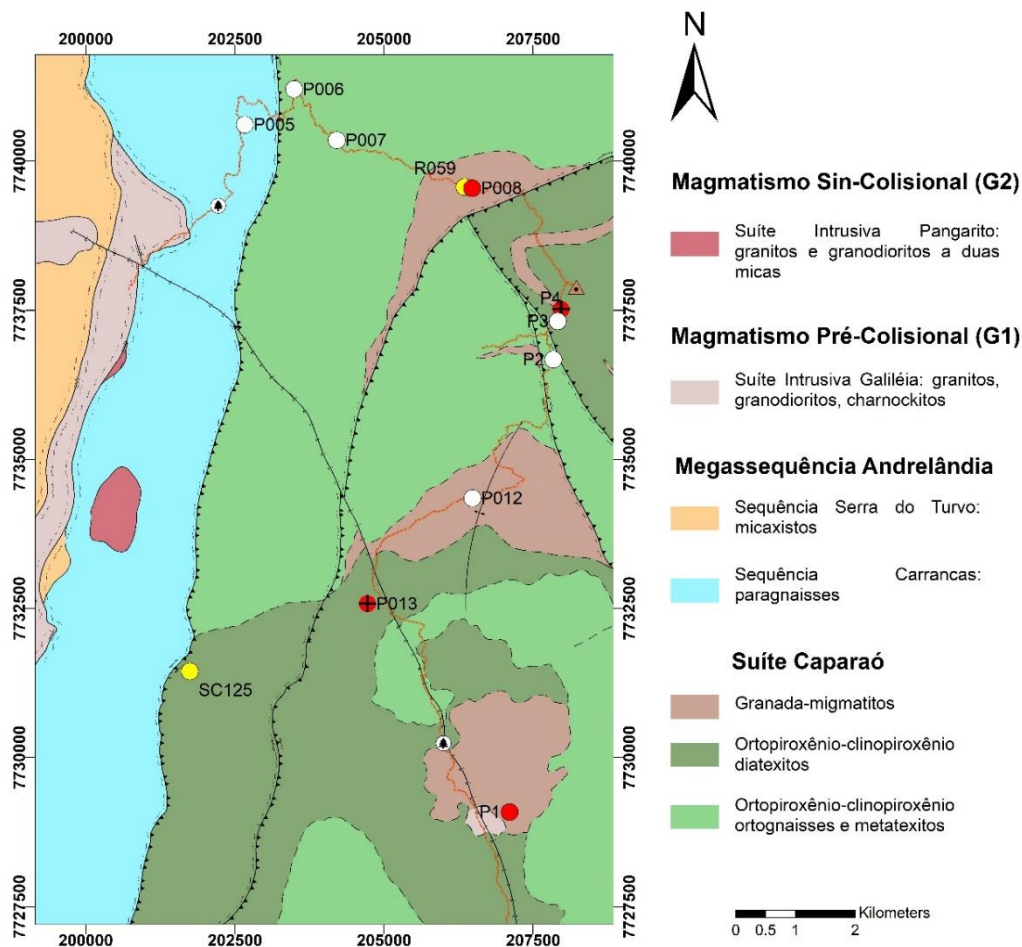
O Grupo Rio Doce (Figura 1) abarca uma sequência de gnaisses, “xistos gnáissicos”, micaxistos e quartzitos, incluindo sequências metaturbidíticas (Pedreira *et al.*, 1997), cuja gênese se associa à edificação do Arco Mágmatco do Rio Doce. Intercalações de rochas metavulcânicas e metapiroclásticas nas litologias metassedimentares conferem ao Grupo Rio Doce, considerado originalmente como uma sucessão exclusivamente paraderivada (Pedrosa-Soares, 1994), o caráter de sequência metavulcanossedimentar (Vieira *et al.*, 2004, 2006; Vieira, 2007; Novo *et al.*, 2018). “Xistos gnáissicos” ricos em feldspatos, metadacitos e meta-lapili tufos constituem os principais componentes vulcânicos e vulcanoclásticos identificados no Grupo Rio Doce (Vieira, 2007; Novo, 2013; Novo *et al.*, 2018). O metamorfismo desta unidade atinge um máximo em fácies anfíbolito alto, com migmatização incipiente a ausente (Vieira, 2007; Novo *et al.*, 2015). Tando as idades máximas de sedimentação, situadas entre 636-594 Ma., obtidas para diferentes litologias metassedimentares do Grupo Rio Doce quanto as idades de cristalização magmática dos componentes metavulcânicos associados, entre 595-584 Ma., permitem sua correlação cronológica com o Grupo Andrelândia na região do Orógeno Araçuaí (Novo *et al.*, 2018), sendo o Grupo Rio Doce representante da sedimentação nos setores leste e norte das regiões de antearco e arco. O Grupo Rio Doce ocorre em associação espacial com os plútons granitóides da Supersuíte G1 (Novo *et al.*, 2018), também relacionada à fase de arco magmático do orógeno, e aflora a NNE da área de estudo, nas proximidades da cidade de Ipanema (Novo, 2013).

2.3.4 Supersuíte G1

Os plútons granitóides representantes da raiz do Arco Magmático Rio Doce são englobados na Supersuíte G1 (Figuras 1), marcando o magmatismo tipo I da fase pré a sin-colisional do Orógeno Araçuaí (630-585 Ma – Pedrosa-Soares *et al.*, 2001; Noce *et al.*, 2007; Pedrosa-Soares *et al.*, 2008). Consistem de batólitos e *stocks* de granodioritos e tonalitos, com fácies e autólitos de dioritos e rochas mais máficas associadas, sendo observados subordinadamente termos graníticos e charnockíticos (Novo *et al.*, 2010). Comumente apresentam impressa a foliação regional, por vezes milonítica, e outras estruturas impressas pela deformação sin-colisional, embora intrusões com deformação restrita às bordas sejam também observadas (Pedrosa-Soares *et al.*, 2007). Na área de estudo a Supersuíte G1 se manifesta pela Suíte Galiléia (Figura 2), que aflora majoritariamente em justaposição lateral a litologias da Megassequência Andrelândia por meio de contatos tectônicos, segundo um *trend* predominantemente N-S, e consiste de álcali-feldspato granitos e granodioritos a biotita, sendo rara a hornblenda (Barroso & Figueiredo, 2015; Hoerlle & Silveira, 2015; Laranjeira & Muzzi, 2015; Rosa & Amaral, 2015). Ao longo da Serra do Caparaó, Rosa & Amaral (2015) identificaram um corpo de charnockito com feições predominantemente ígneas, intrudido em litologias pertencentes à Suíte Caparaó, e consideraram como pertencente à Supersuíte G1. Medina (2017) também descreveu ocorrências de charnockitos incipientemente foliados a isotrópicos a Sul da Serra, tendo-as atribuído aos termos migmatíticos da Suíte Caparaó; estes, entretanto, apresentam texturas essencialmente granoblásticas a granonematoblásticas (ver Capítulo 4), de forma que a associação mais provável dos charnockitos seja com a Supersuíte G1.

2.3.5 Supersuíte G2

A Supersuíte G2 (Figura 1) consiste majoritariamente em granitóides tipo S, representantes do estágio sin-colisional do Orógeno Araçuaí (Pedrosa-Soares *et al.*, 2001; Pedrosa-Soares *et al.*, 2008), cuja fase principal de cristalização coincide com o pico metamórfico regional observado nas sequências metassedimentares (575-560 Ma – De Campos *et al.*, 2004a; Pedrosa-Soares *et al.*, 2008; Gradim *et al.*, 2014). Predominam granitos peraluminosos a duas micas, foliados, portadores de granada, silimanita e cordierita comumente exibindo estruturação milonítica, embora batólitos com feições ígneas preservadas também sejam observados (Pedrosa-Soares *et al.*, 2006; Vauchez *et al.*, 2007). Na área de estudo a Supersuíte G2 se manifesta pela Suíte Pangarito (Figura 2), constituída por granitos e granodioritos a duas micas que ocorrem como corpos intrusivos à Megassequência Andrelândia e à Suíte Galiléia.



CONVENÇÕES CARTOGRÁFICAS

- Afloramentos amostrados para petrografia por Rosa & Amaral (2015) e Laranjeira & Muzzi
- Afloramentos amostrados para petrografia neste trabalho
- Afloramentos amostrados para petrografia, análises de química de rocha total e química mineral
- ⊕ Afloramentos amostrados para petrografia, análises de química de rocha total, química mineral e geocronologia U-Pb (LA-ICP-MS)
- Trilha principal - Parque Nacional do Caparaó
- P Portarias Parque Nacional do Caparaó
- ▲ Pico da Bandeira 2892m

CONVENÇÕES GEOLÓGICAS

- Zona de cisalhamento transcorrente
- ← Zona de cisalhamento transcorrente sinistral
- Zona de cisalhamento transcorrente destal
- ↗ Zona de cisalhamento transpressiva destal
- ↖ Zona de cisalhamento transpressiva sinistral
- ⊕ Anticlinal
- ⊖ Antiformal com caimento indicado
- ⊕ Sinclinal
- Contato definido
- Contato inferido
- ↔ Contato tectônico inferido
- ↔ Falha indiscriminada

Figura 2 - Mapa geológico da área de estudo, produzido a partir dos dados compilados de Barroso & Figueiredo (2015), Hoerlle & Silveira (2015), Laranjeira & Muzzi (2015) e Rosa & Amaral (2015), destacando os pontos de campo visitados com a finalidade de coletar amostras para petrografia, química de rocha total, química mineral (EMPA) e geocronologia U-Pb (LA-ICP-MS).

3 **ARTIGO: Ultrahigh temperature (UHT) metamorphic rocks from the Araçuaí Orogen, southeastern Brazil: tectonic implications from petrography, thermobarometry and phase-equilibria modelling.**

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Abstract:

Ultrahigh temperature (UHT) metamorphic rocks outcrops on the Caparaó Range (southeastern Brazil) as tectonic slices of orthogneisses and migmatites from basement units of the Araçuaí Orogen alongside metasedimentary migmatites. These garnet-bearing migmatites are observed as tectonic intercalations into orthoderived units, and can be subdivided into hercynite-sillimanite-garnet migmatites and orthopyroxene-garnet-biotite migmatites. In this work, we conducted petrological studies on these garnet-bearing rocks in order to better comprehend the metamorphic conditions attained by the lowermost parts of the Araçuaí Orogen. Hercynite-sillimanite-garnet migmatites show preserved metamorphic peak assemblages containing stable sapphirine+quartz and hercynite+quartz, diagnostic of ultrahigh temperature (UHT) metamorphic terrains worldwide. Orthopyroxene-garnet-biotite migmatites exhibit high-Al orthopyroxene crystals, also characteristic of rocks submitted to UHT conditions. Combining Average P-T (THERMOCALC) thermobarometry with phase-equilibria modelling, metamorphic peak P-T conditions of 1066-1076 °C, 7.6-7.9 kbar are obtained for hercynite-sillimanite-garnet migmatites and 988-1023 °C, 9.8-10.9 kbar for orthopyroxene-garnet-biotite migmatites, the highest calculated for Araçuaí Orogen rocks. U-Pb LA-ICP-MS geochronology data obtained from zircon crystals from both migmatite types provided minimum metamorphic ages between 626-585 Ma, considerably older than the metamorphic peak ages obtained from other granulite-facies metasedimentary sequences outcropped in the crystalline nuclei of the orogen. The possible sources of heat for achieving UHT metamorphism may be geodynamically related to subduction, associated to magma underplating during arc related magmatism or to partial assimilation of the slab during tectonic exhumation. This newfound occurrence of UHT metamorphic rocks sums up to the yet few worldwide occurrences of this kind of terrain.

Keywords: sapphirine+quartz, UHT metamorphism, migmatites, Caparaó Suite, Araçuaí Orogen

1 Introduction

Petrological studies conducted on ultrahigh temperature (UHT) granulite-facies terrains present several challenges to petrologists. As temperatures (≥ 900

°C) surpass most closure boundaries for cation-exchange reactions and partial melting takes place, the record of mineral assemblages and their compositions at the metamorphic peak can be completely replaced by those generated during cooling (Powel &

Holland, 2008; Moraes, Nicollet, Barbosa, Fuck & Sampaio, 2015; Kelsey & Hand, 2015), making most geothermometers and geobarometers based on direct calibrations fail to provide the conditions attained at the metamorphic peak. The relative small number of metamorphic belts where characteristic UHT assemblages are found may be explained by these retrograde processes. On other hand, finding sapphirine+quartz or hercynite+quartz assemblages doesn't necessarily means that UHT conditions were attained as elements like Fe³⁺ and Zn can substantially change the stability field for those minerals (Waters, 1991; Kelsey, 2008; Taylor-Jones & Powell, 2010), and so thermodynamic calculations involving these rocks must be made with caution. Despite the difficulties, retrieving the pressure (P) and temperature (T) conditions achieved by these rocks is an important step to comprehend the geotectonic setting at which such extreme thermal events took place.

Special attention also must be paid for geochronological studies on UHT rocks, as temperatures above 900 °C may possibly reset even zircon U-Pb geochronometers on various degrees (Cherniak & Watson, 2003; Wang et al, 2017). Multiple stances of zircon growth may also be present along an UHT metamorphic history, and as both features often provide a spreading over Concordia Diagrams (Whitehouse & Kemp, 2010; Vervoort & Kemp, 2016) caution is advised while interpreting both metamorphic and sedimentary provenance ages associated with

metasedimentary UHT metamorphic rocks.

Up to date, only scarce evidence of the occurrence of ultrahigh temperature metamorphic rocks have been registered at the Araçuaí Orogen. This orogenic belt comprises a singular geotectonic setting as a Neoproterozoic-Cambrian confined orogeny, holding registers of oceanic basin, accretionary, collisional and post-collisional phases both on its brazillian and African parts. At the Caparao Range, located on the boundary between the states of Minas Gerais and Espírito Santo (Brazil), several granulite-facies rocks outcrop, being predominatly orthopyroxene-clinopyroxene-bearing orthogneisses and migmatites which belong to the Rhyacian basement of the Araçuaí Orogen (Campos Neto & Figueiredo, 1990; Da Silva et al., 2002; Novo, Noce, Pedrosa-Soares & Batista, 2011), and tectonic slices of garnet-bearing metasedimentary rocks. This whole set is thrustured over lower-grade (high amphibolite to granulite) Neoproterozoic metasedimentary sequences and arc-related to syn-collisional granitoids.

In this work, we present a detailed metamorphic study on Caparao Range garnet-bearing rocks, providing evidences for the first record of ultrahigh temperature metamorphic rocks on the Araçuaí Orogen confirmed both by characteristic mineral assemblages (sapphirine+quartz and hercynite+quartz) and thermodynamic data. Outcrop-scale features, petrography, mineral chemistry, whole-rock geochemistry and U-Pb geochronology were analyzed in an integrative approach. For better

determining the metamorphic peak P-T conditions, thermobarometry calculations were performed using Average P-T (THERMOCALC; Powell & Holland, 1988, 1994) and phase-equilibria (thermodynamic) modelling (Theriak-Domino; De Capitani & Petrakakis, 2010). Both the petrological and geochronological data presented here provide new and important insights about the evolution of the Araçuaí Orogen and the occurrence of UHT metamorphism on confined orogens.

2 Geological setting

2.1 Regional Geology

The Caparao Range is located on the high-grade anatectic-metamorphic core of the Araçuaí Orogen (Pedrosa-Soares, Noce, Wiedemann & Pinto, 2001; Alkmim et al., 2006; Pedrosa-Soares et al., 2008) (Figure 1A). The orogen's Paleoproterozoic basement (Juiz de Fora Complex) comprises an association of granulite-facies orthogneisses and correlated migmatites predominantly of dioritic to gabbroic composition, locally with granitic, granodioritic and noritic terms (Campos Neto & Figueiredo, 1990; Da Silva et al., 2002; Noce, Pedrosa-Soares, Silva, Armstrong & Piuzana, 2007; Da Silva, Pedrosa-Soares, Armstrong & Noce, 2011; Novo, Noce, Pedrosa-Soares & Batista, 2011). The orthogneisses' banding define a large-scale antiform structure on the Caparao Range, which is thrust over Neoproterozoic metasedimentary sequences of the Andrelândia Group, representing both forearc and back-arc related paragneisses and schists

(Cunningham, Alkmim & Marshak, 1998; Novo et al. 2011; Novo, 2013; Amaral et al., 2016; Vieira, Vieira & Novo, 2017). On the surroundings of the range several granitoid plutons outcrop, related both to the pre- to syn-collisional stages of the Araçuaí Orogen. The arc magmatism is represented by granodiorites, tonalites and charnockites belonging to the G1 supersuite, formed between 630 and 585 Ma and showing an active continental margin geochemical signature (Pedrosa-Soares et al., 2011). The collisional magmatism is represented by two-mica granites, with minor monzogranites and granodiorites, often showing garnet, with ages ranging between 585-560 Ma and exhibiting a syn-collisional geochemical signature. This orogenic belt represents a singular geological context, as it evolved from the consumption of oceanic crust generated in a gulf-like basin restricted by a cratonic bridge between the São Francisco and Congo paleocontinents to a confined orogeny driven by external collisions (Pedrosa-Soares et al., 2001; Alkmim et al., 2006).

2.2 Local Geology

The map presented on Figure 1B is based on the works of Amaral et al. (2016) and Vieira et al. (2017). On the studied area, the Juiz de Fora Complex outcrops both as metatexite and diatexite units (Figure 1B). The metatexite unit is composed of ortho and clinopyroxene-bearing gneisses and patch to stromatic metatexites, with dioritic to gabbroic composition, exhibiting varied proportions of orthoclase, hornblende and biotite. The diatexite unit comprises nebulitic, schollen and schlieren diatexites with similar compositions to

those of the metatexite unit (orthopyroxene-clinopyroxene diatexites), although hornblende- and biotite-free rocks are more frequently observed. Garnet is rare on both units and usually observed as reaction rims between orthopyroxene and plagioclase.

Garnet-bearing migmatites, gneisses and granulites are observed along the range in tectonic contacts with Juiz de Fora Complex orthogneisses and migmatites, and are subdivided into two sequences (Figure 1B). Orthopyroxene-garnet-biotite-bearing migmatites comprises schlieren to schollen diatexites and subordinate patch to stromatic metatexites, with granitic to dioritic composition. The diatexites outcrop predominantly as leucosome-rich migmatite bodies associated with shear zones and the regional fold hinge zone. Orthopyroxene is present both on melanosomes and leucosomes, and hercynite is rarely observed. The hercynite-sillimanite-garnet-bearing migmatites are schollen to schlieren diatexites, often exhibiting a flow-banded structure, are predominantly granitic in composition and show ubiquitous hercynite, sillimanite and garnet as residual phases; leucosome-rich and residuum-rich terms show appreciable differences on their mineral assemblages, as will be presented ahead.

3 Materials and Methods

Four outcrops of Grt-bearing migmatites (Figure 1B) were selected for detailed characterization. Twenty-three samples were collected and prepared for petrography (P), electron microprobe analysis (EMPA), whole-rock geochemistry (WRG) and laser ablation

inductively coupled plasma mass spectrometry (LA-ICP-MS) U-Pb geochronology as indicated on Table 1. Mineral abbreviations follow the recommendations of Whitney & Evans (2010) and the nomenclature of migmatites is after Sawyer (2008).

3.1 Mineral chemistry and thermobarometry

Mineral chemistry data was obtained from seven polished thin sections (as indicated on Table 1) using a JEOL JXA-8230 electron microprobe at the Microscopy and Microanalyses Laboratory of the Universidade Federal de Ouro Preto (UFOP). The calibration of the electron beam was set to 15 kV, 20 nA, 5-10 μm spot size. The raw data was processed with common ZAF matrix corrections. Counting times on the peaks/background were 10/5s for all elements (Si, Al, Ti, Fe, Mn, Mg, Ca, Na, K, Zn, F) except for Cr and Cl (30/15 s). Analytical errors are within 0.20% and 1.06%. Minerals were characterized by analyses from cores and rims when applicable. Analytical standards are presented at Supplementary File S1. A total of 1160 spots of the following minerals were carried out: biotite (Bt), cordierite (Crd), garnet (Grt), hercynite (Hc), ilmenite (Ilm), orthoclase (Or), orthopyroxene (Opx), plagioclase (Pl), sapphirine (Spr) and sillimanite (Sil). As the electron-microprobe analyses accounted all Fe as FeO_T, the Fe³⁺ contents of minerals (when applicable) were recalculated by charge-balance and stoichiometric equations, along with structural formulae, based on the following authors: Tindle & Webb (1990) for biotite; Deer, Howie & Zussman (1992) for cordierite and

sillimanite; Perkins (2007) for garnet, pyroxene and feldspars; Droop (1987) for ilmenite; Higgins, Ribbe & Herd (1979), Grew, Halenius, Pasero & Barbier (2008) and Taylor-Jones & Powell (2010) for sapphirine; and using the Spinel End-Member Generator software by Ferracutti, Gargiulo, Ganuza, Bjerg & Castro (2015) for hercynite and magnetite. Some representative mineral compositions are presented on Supplementary File S2.

Temperature and pressure conditions for the analyzed samples were calculated by two thermobarometry methods: I) THERMOCALC Average P-T (Powell & Holland, 1994; Powell & Holland, 2008), using THERMOCALC “mode 2”, version 3.33 using database version 5.5 (Powell & Holland, 1988) and the A-X software, version 2 (Holland, 2014) for activity calculations; II) Phase-equilibria modelling combined with mineral isopleths and isomodes, using Theriak-Domino software (De Capitani & Petrakakis, 2010) with the THERMOCALC-translated database 5.5 (activated mineral solution models listed on Table 2). P-T plots for Average P-T and comparison figures on the Discussion section were made using the TriQuick software, version 1.0.0.23 (Dolivo-Dobrovolsky, 2012).

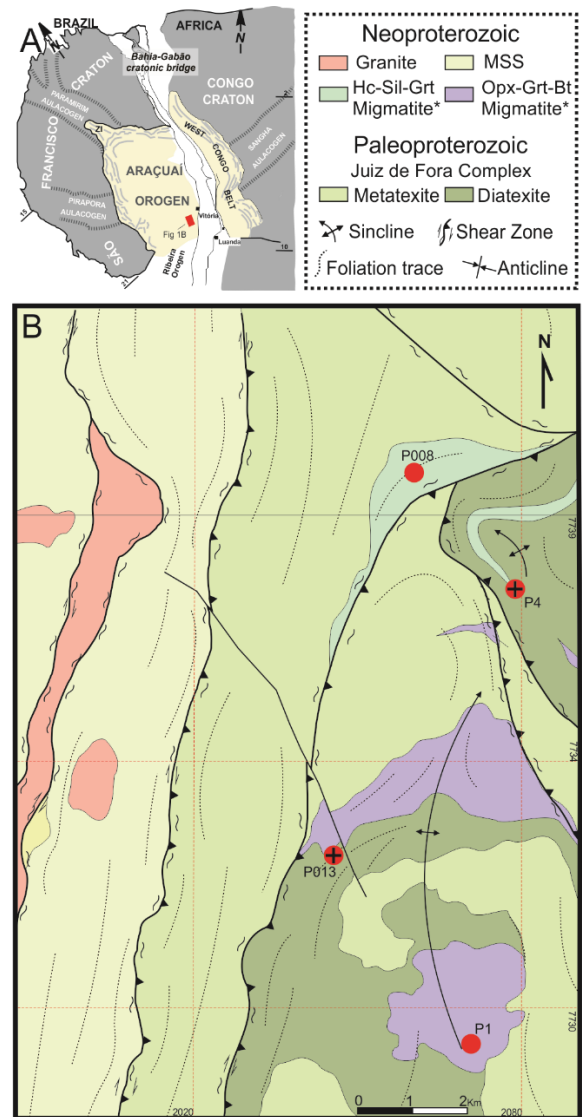


Figure 1 - A) Geotectonic setting of the studied area relative to the Araçuaí Orogen (AO); B) Geological map of the studied area modified after Amaral et al. (2016) and Vieira et al. (2017), emphasizing the locations of the selected outcrops. Orthopyroxene-garnet-biotite migmatites and hercynite-sillimanite-garnet migmatites are informal units/sequences focused and characterized in this work (see below). Red dots represent outcrops sampled for petrography, electron microprobe analysis and whole-rock geochemistry. Outcrops also sampled for LA-ICP-MS U-Pb geochronology are marked with a cross. MSS – metasedimentary sequence. *Neoproterozoic ages for both migmatite types were obtained in this work (see ahead).

3.2 Whole-rock geochemistry and phase-equilibria modelling

Seven samples (see Table 2) were taken for whole-rock geochemical analyses at the GEOX Laboratory (UFOP) and the SGS GEOSOL Labs. Analytical

procedures for each are listed on Supplementary File S1. The samples were analyzed for major elements; their compositions are presented at Supplementary File S4. Three samples (hercynite-sillimanite-cordierite-garnet-biotite diatexite, sapphirine-hercynite-sillimanite-garnet diatexite and orthopyroxene-garnet-biotite metatexite) were selected for phase-equilibria modelling in the NCKFMASHTO system using the Theriak-Domino software (De Capitani & Petrakakis, 2010), taking the THERMOCALC-translated database of Holland & Powell (1998), version 5.5. The selection of these samples, as discussed ahead, took into account the relative proportions of leucosome and residue of the migmatites in order to better approach the metamorphic history of these rocks, as discussed by Sawyer (2008) and Moraes et al. (2015). As all Fe was accounted as $\text{Fe}_2\text{O}_{3\text{T}}$ on the analyses, the total iron was converted to FeO_{T} through the formula $\text{FeO}_{\text{T}} = \text{Fe}_2\text{O}_{3\text{T}} * 0,8998$, and actual Fe^{3+} contents of the samples selected for phase-equilibria modelling was calculated by analyzing ilmenite-hematite isopleths on P-X diagrams ($X = \text{Fe}^{3+}$), as described on Section 4.4.

3.3 LA-ICP-MS U-Pb geochronology

Two samples (hercynite-sillimanite-cordierite-garnet-biotite diatexite and orthopyroxene-garnet-biotite metatexite) were selected for LA-ICP-MS U-Pb geochronology (Table 1). About 10-15 kg of rock for each sample were prepared for analyses in the Isotopic Geochemistry Laboratory of the Universidade Federal de Ouro Preto

(UFOP, Brazil). Zircon separation was performed using conventional methods (crushing, grinding, gravimetric, and magnetic-Frantz isodynamic separator). For geochronological analyses, we selected zircon crystals from the least magnetic fractions, aiming to determine metamorphic ages and possible inherited or igneous zircon populations. A final concentration of zircon crystals was obtained by density separation using bromoform. As this concentrate consisted of almost only zircon grains (>99%), the grains were randomized in an alcohol solution and then pipetted over epoxy mounts, guaranteeing minimum bias on the selection of zircon crystals for analysis. The mounts were submitted to polishing for exposing grain centers, and backscattered electron (BSE) and cathodoluminescence (CL) images were obtained for revealing morphological features and internal structures of zircon grains.

Analytical spots were performed avoiding grain areas with inclusions, fractures, and/or metamict features. U-Pb isotopic analyses were performed in the Laser Ablation Multicollector Inductively Coupled Plasma Mass Spectrometry (LA-MCICP-MS) laboratory at the Universidade Federal de Ouro Preto. BB (Santos et al., 2017), Gj-1 (Jackson, Pearson, Griffin & Belousova, 2004; Morel, Nebel, Nebel-Jacobsen, Miller & Vroon, 2008) and Plešovice (Sláma et al. 2008) standard zircons were used in LA-MC-ICP-MS analytical routines. In this study, the spot size in LA-MC-ICP-MS analysis had a diameter of 25 μm . Data reduction used the Glitter software (Van Achterbergh, Ryan, Jackson & Griffin, 2001), and the

Excel sheet developed by Ludwig (2003). Data evaluation for each spot took into account the common Pb contents, errors of isotopic ratios, the position of each analyzed spot, and the existence of inherited grains and percentage of discordance. From the selected spots, only those with

discordance less than 5% were used for age calculations and plotted in Concordia diagrams. The Concordia diagrams were obtained with the software Isoplot 4.15 (Ludwig, 2008). The U-Pb analytical results are available on Supplementary File S5.

Table 1 – Characteristics of outcrops and samples collected for this work with indication of the analytical methods carried out for the samples. A.P. – accessory phases; ¹ – P4E residuum and leucosome were analyzed as separate samples on EMPA. ² – P1 leucosome and melanosome were analyzed as separate samples for WRG. X, Y and Z – UTM northing, easting and elevation respectively (Datum SIRGAS 2000, UTM zone 23S). P – Petrography. EMPA – Electron Microprobe Analysis. WRG – Whole-rock geochemistry. LA-ICP-MS - Laser Ablation Inductively Coupled Plasma Mass Spectrometry.

Outcrop	Sample	Lithotype	X (m)	Y (m)	Z (m)	Mineral Assemblage	P	EMPA	WRG	LA-ICP-MS
P1	P1	Opx-Grt-Bt diatexite	207104	7729088	1347	Ilm+Opx+Grt+Bt+Or+Pl+Qz; A.P.: Rt, Zr, Mnz, Ap, Py, Cpy, Po	X	X	X, ²	
	P1D		207175	7729248	1352	Rt+Grt+Bt+Or+Pl+Qz; A.P.: Ilm, Zr, Mnz, Ap, Py, Cpy	X	X	X	
P4	P4E	Hc-Sil-Crd-Grt-Bt diatexite	207977	7737495	2839	Ilm+Hc+Sill+Crd+Grt+Bt+Pl+Or+Qz; A.P.: Ap, Zr, Mnz, Mag	X	X, ¹	X	X
	P010A	Hc-Opx-Grt-Bt diatexite	207970	7737514	2838	Ilm+Hc+Opx+Grt+Bt+Or+Pl+Qz; A.P.: Rt, Zr, Ap, Mnz, Py, Mag	X	X	X	
	P010B					X				
P008	P008	Spr-Hc-Sil-Grt diatexite	206475	7739546	2321	Spr+Ilm+Hc+Sill+Grt+Pl+Or+Qz; A.P.: Ap, Zr, Mnz, Mag	X	X	X	
P013	P013	Opx-Grt-Bt metatexite	204722	7732591	1847	Ilm+Opx+Grt+Bt+Or+Pl+Qz; A.P.: Ap, Zr, Mnz, Mag, Py	X	X	X	X

Table 2 – References for solution models utilized on phase-equilibria modelling.

Mineral/Phase	Solution model
Biotite, Garnet, Ilmenite, Spinel, liquid	White, Powell & Holland (2007)
Chlorite	Holland, Baker & Powell (1998)
Cordierite, Staurolite	Holland & Powell (1998)
Feldspars	Baldwin, Powell, Brown, Moraes & Fuck (2005)
White micas	Coggon & Holland (2002)
Omphacite	Hollan & Powell (2006)
Orthopyroxene	Holland, Powell & Clarke (2002)
Osumilite, Sapphirine	Kelsey, White, Holland & Powell (2004)

4 Results

Results from petrography and mineral chemistry are presented together. When applicable, mineral generations are divided based both on textural relations and mineral chemistry, and assemblages

are interpreted based on both criteria. A summary of the chemical criteria for classification of mineral generations is presented on Supplementary File S3, and representative mineral compositions for each sample are listed on Supplementary File S2.

4.1 Petrography and Mineral Chemistry

Schlieren sapphirine-sillimanite-hercynite-garnet diatexites (sample P008)

The schlieren sapphirine-sillimanite-hercynite-garnet diatexites consists, on outcrop scale, of diffuse to moderately oriented residue schliere, between 30-50% of the migmatite's observed volume, immerse in a mass of leucosome. Residue consists of a granulite composed of sapphirine (1%), ilmenite (4%), sillimanite (9%), hercynite (4%), garnet (14%), plagioclase (16%), perthitic orthoclase (23%) and quartz (29%), with apatite, zircon, rutile and magnetite as accessory phases. Sapphirine is mostly observed at the borders of hercynite crystals (Figure 2A) or in association with garnet, ilmenite or, rarely, corundum (Figure 2B), as diminute crystals with compositions close to the 7:9:3 end-member ($Al_{TOTAL} = 8.67-8.75$ apfu., $Si = 1.50-1.59$ apfu., Figure 3), showing considerable Fe^{2+} substitution for Mg ($X_{Mg} = 0.775-0.798$) and estimated Fe^{3+} contents between 0.101-0.224 (see Supplementary File S3). Hercynite crystals (48.7-58.0% Hc) are fine to medium-grained, often exhibiting magnetite exsolution lamellae, showing low Zn contents (less than 1.10% Ghn) and considerable Fe^{3+} (up to 7.20% Mag+Mfr). Garnet crystals are predominantly medium-grained, show inclusions of all other mineral phases except for sapphirine and have almost homogeneous composition (Figure 3), with minor variations from cores (Alm = 46.7-50.0%, Prp = 45.2-47.2%, Sps = 2.18-2.70%, Grs = 2.56-3.90%) to rims

(Alm = 47.6-50.3%, Pyr = 44.8-47.0%, Sps = 2.22-2.62%, Grs = 2.60-3.62%). Sillimanite crystals are prismatic, fine to medium grained and contain up to 1.2 wt.% FeO (Supplementary File S3). Biotite (less than 1 vol.%) seldom occurs as inclusions in garnet (Bt₁), showing higher Fe^{2+} contents ($X_{Mg} = 0.799-0.817$) and low TiO₂ (1.4-1.6 wt.%), or as a phase crystalized along borders and/or fractures on aluminous/mafic minerals (Bt₂), with lower Fe^{2+} ($X_{Mg} = 0.864-0.871$) and higher TiO₂ (6.06-6.26 wt.%, Figure 3). Cordierite is rarely observed and only as pinitized moats around sapphirine, hercynite or sillimanite. Matrix plagioclase has the same composition as those found as inclusions in garnet (andesine, An = 34.8-40.2%), and orthoclase crystals are predominantly perthitic, containing up to 14.3% Ab (Figure 3). Ilmenite is observed as a heterogeneous phase, showing Hem-rich lamellae (Hem = 63.7-67.4%) in a Ilm-rich matrix (Ilm = 78.4-83.4%), both with low Mn contents (Pph <0.4%; Supplementary File S3, Figure 3). Metamorphic peak assemblage is interpreted to be Spr+Ilm+Hc+Sil+Grt+Pl+Or+Qz±Crn as contacts between sapphirine and hercynite seems to have reached equilibrium (Figure 2A) and both are observed on stable contacts with quartz (Figure 2A-B). Disequilibrium textures are rarely observed, occurring as cordierite moats around hercynite or sapphirine (Figure 2A) and symplectitic intergrowths between sillimanite-cordierite (Figure 2C) or hercynite-garnet-quartz (Figure 2D), providing evidence of retrograde reactions. Garnet inclusion assemblage consists of Grt+Bt₁+Pl+Or+Sill+Qz. Leucosome's

assemblage is similar to the residue's, but it lacks sapphirine and corundum, contains up to 75% orthoclase+plagioclase+quartz, 15% garnet and less than a 10% total of biotite, ilmenite, hercynite and

sillimanite. Fine-grained orthoclase, plagioclase and quartz crystals often form fine-grained intergrowths between larger crystals, showing acute or cusped terminations indicative of crystallization from a residual melt.

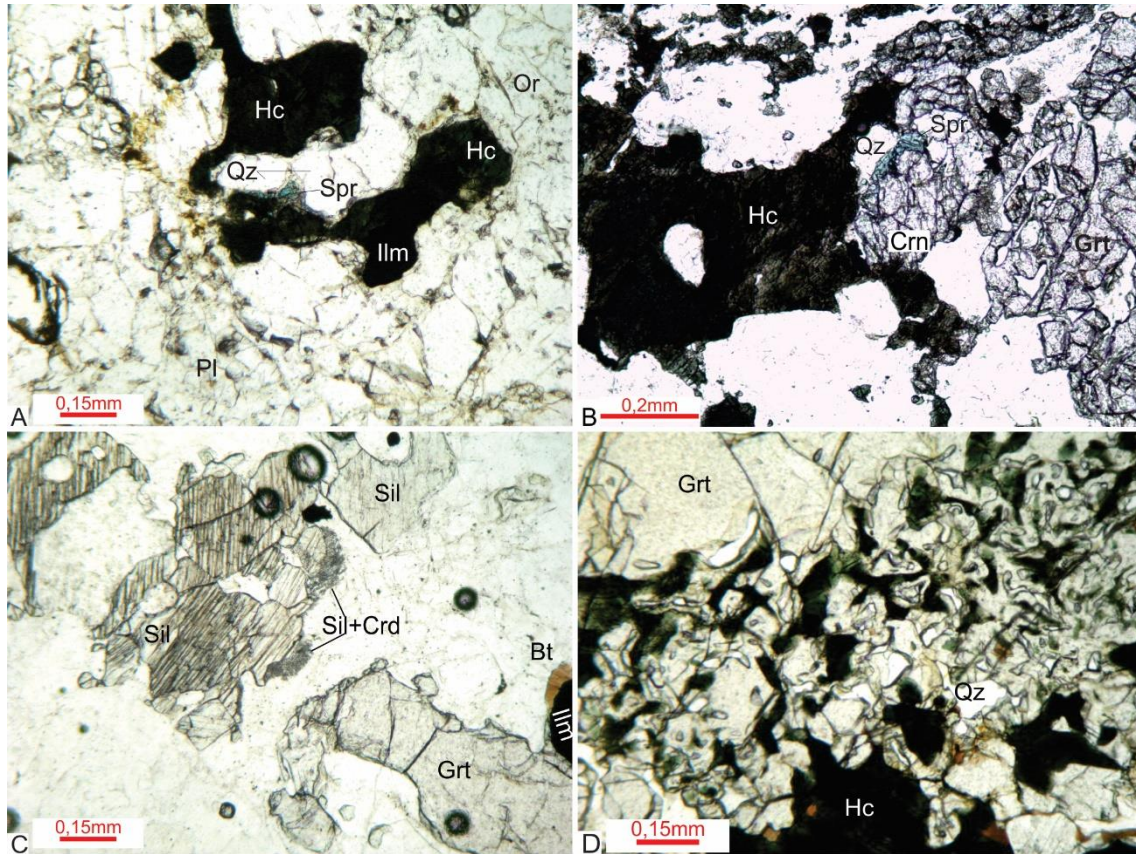


Figure 2 - Textural features of the sapphirine-hercynite-sillimanite-garnet diatexites (sample P008). A) Sapphirine (Spr) crystal formed at the border of hercynite (Hc), showing partially stable contacts with quartz (Qz) and limited alteration to pinitite; B) Sapphirine (Spr) crystal exhibiting stable contacts with quartz (Qz) and corundum (Crn), in association with garnet (Grt) and hercynite (Hc); C) Disequilibrium texture consisting of sillimanite+cordierite (Sil+Crd) symplectites at the borders of sillimanite crystal; D) Symplectitic intergrowth between garnet (Grt), quartz (Qz) and hercynite (Hc) with associated opaque minerals.

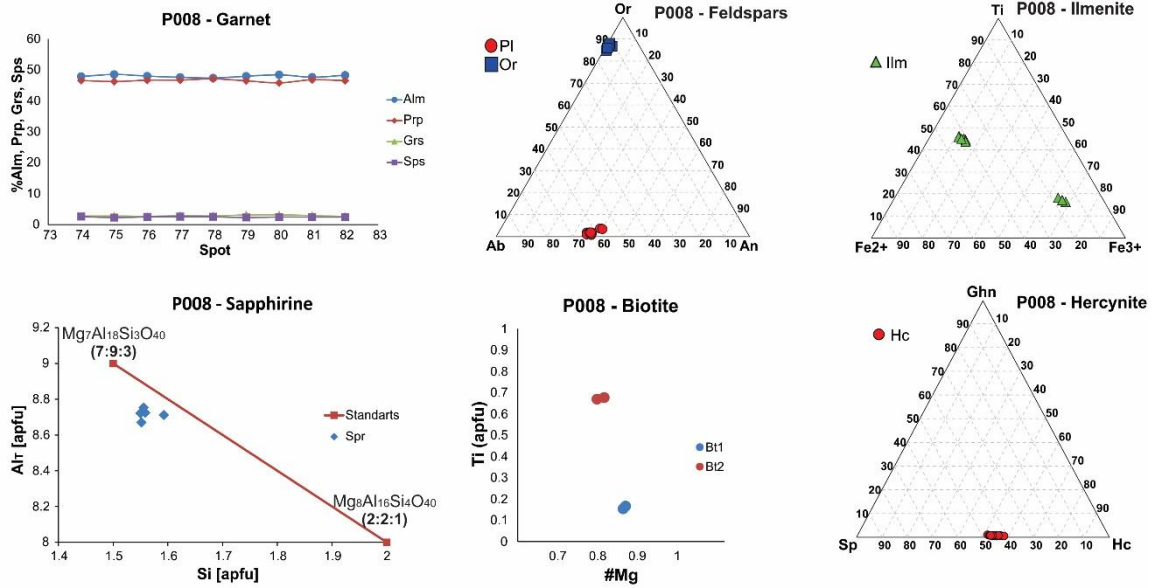


Figure 3 - Compositional plots for the main analyzed phases of sample P008. Al_T – total aluminium. $\#Mg = X_{Mg} = Mg/(Fe^{2+}+Mg)$. Classification plot of sapphirine adapted after Barbosa et al. (2017) with end-member compositions of Higgins et al. (1979) and Grew et al. (2008).

Schlieren/schollen hercynite-sillimanite-cordierite-biotite-garnet diatexites (sample P4E)

The hercynite-sillimanite-cordierite-biotite-garnet diatexites exhibit a variety of morphologies in outcrop scale, predominantly from schlieren to schollen diatexites often with a notable flux-banding; leucosome and residue occur in similar proportions on the banded zones, and “leucosome pockets” are commonly observed where schollen textures are predominant, commonly presenting garnet crystals up to 4 cm wide. Residue-melt segregation is not complete. Residuum is composed of ilmenite (5%), hercynite (6%), quartz (23%), biotite (9%), sillimanite (11%), garnet (20%) and cordierite (8%), with fine-grained orthoclase and plagioclase (18%). Leucosome is composed of medium to very coarse-grained garnet (9%), biotite (7%), fine to coarse-grained plagioclase (13%) and perthitic orthoclase (28%), fine to medium-

grained quartz (29%) and up to 14% hercynite, cordierite and sillimanite. Zircon, monazite, apatite, rutile and magnetite are present as accessory phases on both parts of the migmatite. Hercynite crystals are fine to medium-grained, occurring as inclusions in garnet (Figure 4A) or as a free phase in matrix, rarely showing stable contacts with quartz; most hercynite crystals are separated from quartz and feldspars by a retrograde pinitized cordierite moat (Figure 4B-C). Hercynite compositions contain low Zn contents (Ghn less than 1.7%), and can be divided into three generations: inclusions in leucosome’s garnet (Hc_1 , Figure 5) are more magnesian (maximum Hc ~52.0%) than those observed in the matrix (Hc_2 , maximum Hc ~60.5%, Figure 5), while in the residue both show similar compositions to the later (Hc_2 , Hc = 52.4-58.0%). Exsolution lamellae (Hc_3), composed of a Fe^{3+} -rich phase (Mag+Mfr up to 49.3%), is observed on most crystals, indicative that

metamorphic peak compositions are not preserved. Sillimanite crystals show prismatic habits, are fine to medium-grained and have high FeO_T contents (0.98-1.22 wt.%, Supplementary File S3), sometimes exhibiting cordierite moats with symplectitic intergrowths (Figure 4C). Cordierite is observed as a free phase (Crd_1), exhibiting poikiloblastic texture (Figure 4B) and showing compositions with X_{Mg} ranging from 0.840 to 0.852, as overgrowths on ilmenite or hercynite (Crd_2), showing slightly higher X_{Mg} (up to 0.866), and as a retrograde phase (Crd_3), forming moats around hercynite or sillimanite or occurring as an alteration of Crd_1 (Figure 4D), showing the lowest X_{Mg} (0.832-0.838). Garnet porphyroblasts may show inclusions of all other minerals (Figure 4B), commonly developing an internal foliation, marked by acicular sillimanite, that indicates pre to syn-kynematic crystallization, and are divided into four generations based mainly on their chemistry (Figure 5): Grt_1 are large (diameter up to 4 cm) poikiloblastic crystals, showing cores with similar Alm (47.2-49.1%) and Prp (43.5-46.1%) contents and rims compositions with slightly higher Alm (49.2-55.4%) and lower Prp (38.5-43.6%); Grt_1 and Grt_2 cores have similar Sps (max. 2.99% and 3.21%, respectively) and Grs (max. 4.90% and 4.95%) contents, but the difference between Alm (49.9-53.0) and Prp (40.4-42.8) is significantly higher on the latter, and the enrichment on Alm to the rims (51.9-56.8%) paired with Prp decrease (37.2-42.1%) is also observed; Grt_3 cores have higher Fe^{2+} (Alm up to 55.7%) and lower Ca^{2+} (Grs = 2.79-3.37%) and Mg^{2+} (Prp = 53.4-55.7%) contents than the previous, showing the

same pattern of Alm increase (54.4-58.7%) and Prp decrease (35.8-40.3%) observed on the first two generations. Grt_4 occurs as overgrowths on biotite and ilmenite, have the highest Fe^{2+} contents (Alm up to 60.3%) and similar contents of Sps (2.20-2.75%) and Grs (2.74-3.29%) to Grt_3 cores. Biotite is observed as three distinct generations (Figure 5): Bt_1 is found as inclusions in garnet crystals at the leucosome or as a free phase in the residuum's matrix, showing moderate to high TiO_2 (3.23-5.04 wt.%) and X_{Mg} (0.733-0.842), Bt_2 occurs as free lamellae in the matrix, showing high TiO_2 (4.36-5.67%) and low to moderate X_{Mg} (0.635-0.730), and Bt_3 is crystallized after garnet rims, showing low TiO_2 (1.18-2.93%) and moderate X_{Mg} values (0.721-0.784). Ilmenite crystals are predominantly fine-grained, often associated with hercynite or garnet, show low Mn (Pph up to 0.9%, Supplementary File S3) and most crystals are heterogeneous (leucosome and residue), showing Ilm-rich lamellae (49.3-88.2%) intercalated with Hem-rich ones (51.3-72.7%). Plagioclase and orthoclase crystals are fine to coarse-grained on the leucosome, often showing inclusions of ilmenite or hercynite, and fine grained on the residuum, often developing fine-grained intergrowths and filling interstitial sites between crystals, interpreted as trapped residual melt. Little variations in compositions are observed on both cases (Figure 5): plagioclase have andesine composition ($\text{An} = 32.0-40.7\%$) and orthoclase is strongly micropertitic ($\text{Ab} = 11.4-29.2\%$). Metamorphic peak assemblage is interpreted as $\text{Ilm}+\text{Hc}+\text{Sil}+\text{Crd}_1\text{-}_2+\text{Grt}+\text{Pl}+\text{Or}+\text{Qz}$. Sillimanite, biotite and opaque minerals are strongly

oriented parallel to the banding, defining a foliation.

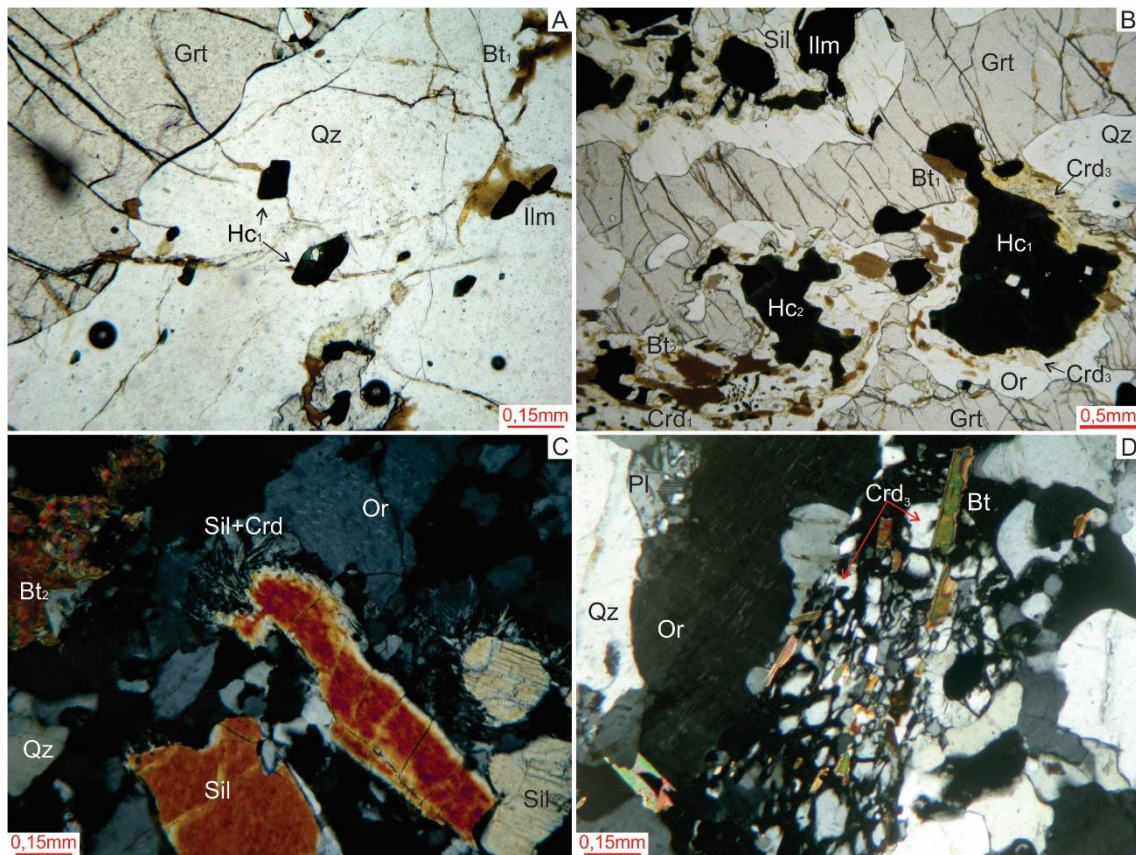


Figure 4 - Textural features of the hercynite-sillimanite-cordierite-garnet-biotite diatexites (sample P4E). A) Hercynite (Hc), ilmenite (Ilm), quartz (Qz) and biotite (Bt) inclusions in garnet (Grt), with stable contacts between hercynite and quartz; **B)** Leucosome's cm-scale garnet crystal in contact with residue assemblage Crd (poikiloblast)+Bt+Ilm+Hc+Qz showing sillimanite, ilmenite, quartz, hercynite (bordered by cordierite - Crd - moat), orthoclase and biotite inclusions; **C)** sillimanite (Sil)+cordierite (Crd) symplectites formed around sillimanite crystals; **D)** Cordierite (Crd) crystal partially altered to pinitized cordierite (Crd₃) and biotite (Bt).

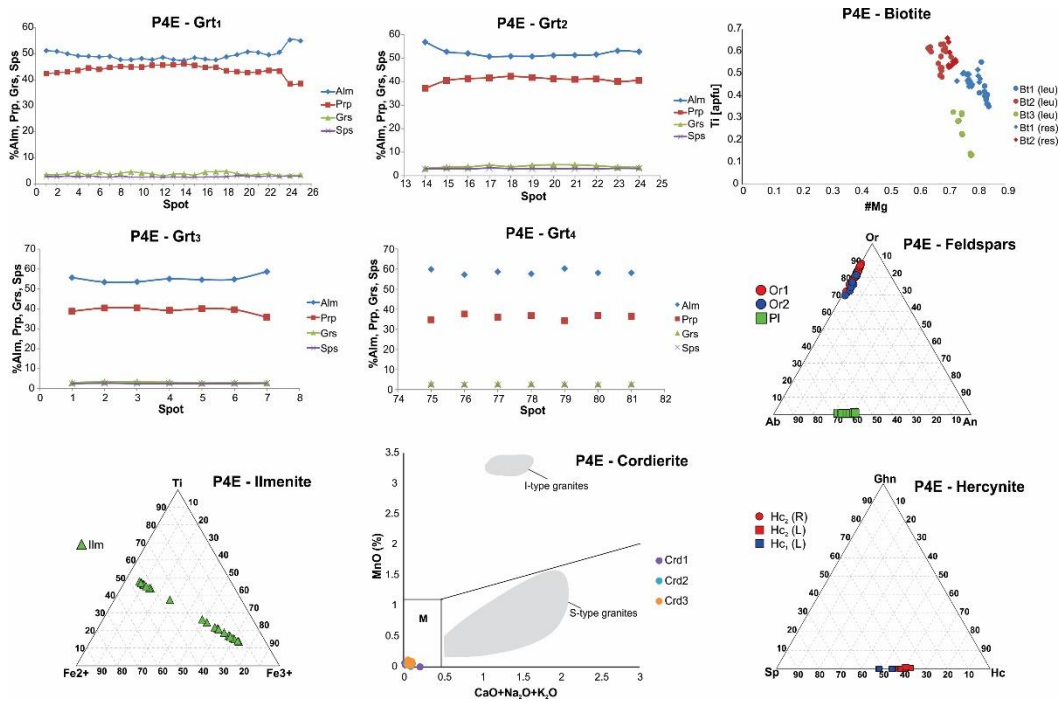


Figure 5 - Compositional plots for the main analyzed phases of sample P4E. #Mg = $X_{Mg} = Mg/(Fe^{2+}+Mg)$. M – metamorphic. R – residuum. L – leucosome. Cordierite classification diagram by Barbero & Villaseca (1992) and Villaseca & Barbero (1994).

Stromatic Opx-Grt-Bt-Metatexite, sample P013

Stromatic Opx-Grt-Bt-metatexites exhibit a well-defined banding on the paleosome, parallel to which neosome layers form connected patches, locally crosscutting the structure, defining an in situ in source morphology.

The paleosome (Figure 6A-B) consists of garnet-biotite-orthoclase-plagioclase-quartz gneiss, with ilmenite, zircon, apatite and monazite as accessory minerals. Garnet crystals are medium to coarse-grained, predominantly poikiloblastic and containing inclusions of biotite, plagioclase, quartz, ilmenite, zircon, and monazite without internal orientation. Garnet compositions show an asymmetrical distribution of the Grs component along the chemical sections (Figure 7), associated with a general decrease towards the rims (cores: 5.70-9.01%; rims: 5.45-6.34%), and an

overall hyperbolic pattern created by increase of Alm associated with decrease of Prp contents from the cores (max. Alm = 59.57%, Prp = 33.15%) to the rims (max. Alm = 62.70%, Prp = 31.44%); low Sps contents (less than 2.12%) are common for both cores and rims. The matrix is predominantly fine-grained, composed of biotite, plagioclase, orthoclase and quartz, and exhibits a foliation defined by oriented biotite and opaque minerals as well as preferentially elongated felsic minerals. Biotite belongs to 3 distinct generations (Figure 7): inclusions in garnet (Bt₁), showing the highest X_{Mg} values (0.763-0.770) and the lowest TiO₂ contents (1.89-1.99%); matrix crystals (Bt₂), showing lower X_{Mg} (0.654-0.684) and the highest observed TiO₂ (5.17-5.52%); crystals formed from the borders of garnet crystals or inside embayments on these, showing intermediate values of both X_{Mg} (0.606-0.718) and TiO₂ (4.92-5.08%).

Plagioclase observed as inclusions in Grt (Pl₁) is strongly calcic (An = 59.0-76.3%), plotting in the fields of labradorite and bytownite (Figure 7), while matrix plagioclase (Pl₂) is strictly andesine (An = 42.1-46.3%). Orthoclase is only observed in the matrix and as a single generation of relatively homogeneous composition (Or = 88.9-91.0%). Paleosome's peak metamorphic assemblage is interpreted to be Grt+Bt₂+Pl₂+Or+Qz±Ilm.

Neosome consists of fine to medium-grained leucosome (Figure 6A-D) domains interlayered with thin melanosome bands. Foliation is less developed on the neosome and it's parallel to the banding. Neosome is composed of ilmenite (3%), orthopyroxene (6%), garnet (17%), biotite (6%), plagioclase (29%), orthoclase (19%) and quartz (20%), with magnetite, apatite, zircon and rare sulphide as accessory phases. Garnet crystals show three morphological types: one medium to coarse-grained and inclusion-rich (Grt₁), containing biotite, opaques, plagioclase, orthoclase, quartz, zircon, apatite and orthopyroxene inclusions, similar to paleosome's garnets (Figure 6C, Figure 7) both in texture and in composition (cores: Alm = 58.16-59.89%, Prp = 31.56-34.52%, Grs = 5.19-7.24%) and also shows asymmetrical profiles for Grs and a general hyperbolic pattern for Alm and Prp; one with few inclusions, fine to medium-grained (Grt₂), showing mostly linear chemical profiles, and its cores shows higher Alm (60.01-61.98%) and smaller both Prp (30.28-33.04%) and Grs (5.06-5.91%) contents; and one composed of skeletal crystals (Grt₃),

showing the highest proportions of Ca²⁺ (Grs = 7.09-9.19%) and Fe²⁺ (62.44-64.31%) and the lowest of Mg²⁺ (26.17-28.62%) and Mn²⁺ (1.56-1.76%), and often associated with skeletal orthopyroxene (Figure 6D). The rims of Grt₁ and Grt₂ show similar compositions (Supplementary File S3), with a general increase of Alm and decrease of Prp on both (respectively 59.60-63.95% and 28.42-32.89%). Orthopyroxene occur both as prismatic and skeletal crystals, the last frequently associated with skeletal garnet, but no significant chemical differences are observed between these, defining a single generation with hypersthene composition (En = 55.8-57.9%) and high Al contents (between 0,189-0,232 apfu.), showing little differences from core to rim compositions (Supplementary File S3). Biotite crystals observed as inclusions in garnet are chemically divided into two generations (Figure 7): Bt₁ is associated with Grt₁, and show compositions similar to those observed on the paleosome (X_{Mg} = 0.7789-0.8339, TiO₂ = 1.92-2.34%); Bt₂ is found as inclusions in Grt₂, show lower X_{Mg} (0.7110-0.7303) and higher TiO₂ (6.22-6.35%) than Bt₁. Free biotite in the matrix belong to a single generation (Bt₃), exhibiting the lowest X_{Mg} values (0.6357-0.7032) and intermediate TiO₂ (4.57-5.75%). Plagioclase, orthoclase and quartz occur both as inclusions in garnet as in the matrix, with increasing grain size from melanosome to leucosome bands. Plagioclase inclusions in garnet and matrix plagioclase show no chemical differences (Figure 7), belonging to a single generation with andesine composition (An = 43.0-44.9%), while orthoclase inclusions

(Or₁) are slightly richer in sodium (Ab = 10.1-12.1%) than those of the matrix (Or₂, Ab = 8.3-10.4%). Ilmenite found on both the paleosome and the neosome are fine-grained and homogeneous crystals (Supplementary File S3), with

Ilm contents of 85.0-86.9% and low Mn (Pph= 0.3-0.4%). Neosome metamorphic peak assemblage is interpreted to be Opx+Grt₂+Pl+Or+Qz±Ilm.

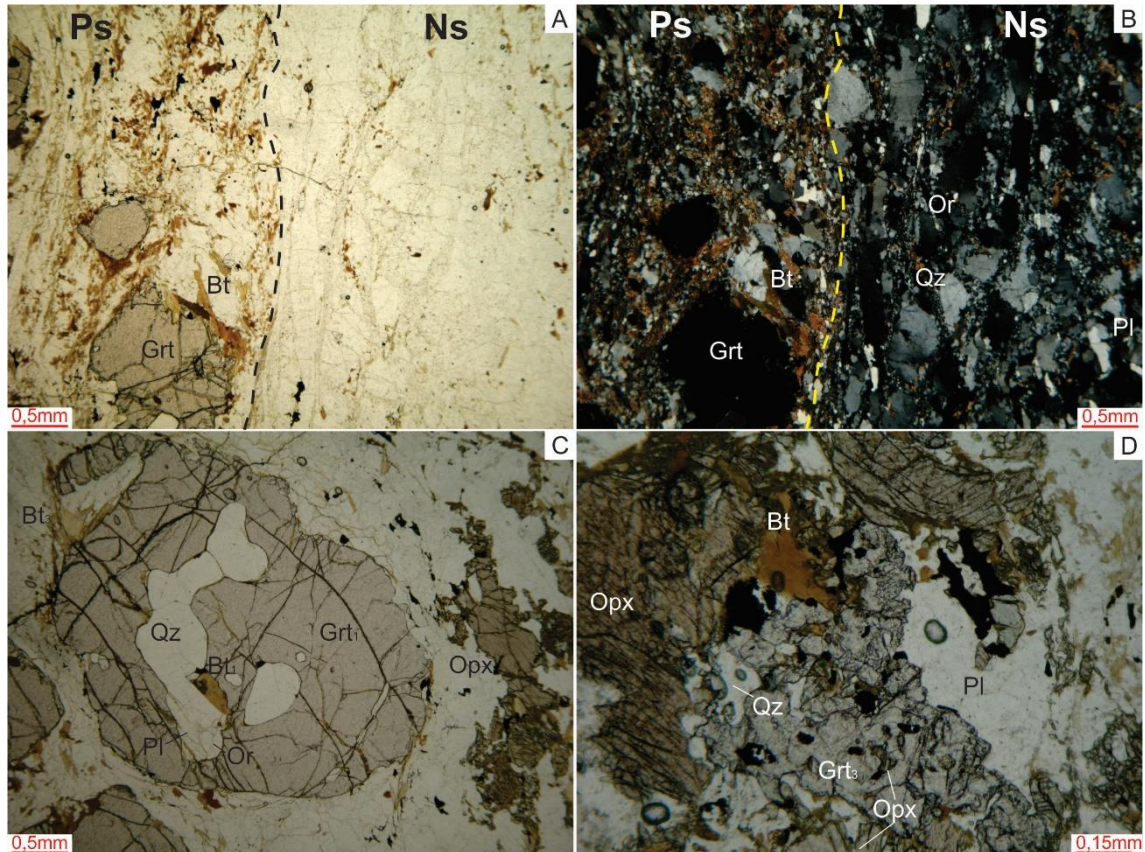


Figure 6 - Textural features of the orthopyroxene-garnet-biotite metatexites (sample P013). A-B) Boundary between paleosome (PS) and neosome (NS), with a clear grain-size increase from PS to NS; C) Biotite (Bt), quartz (Qz), plagioclase (Pl) and orthoclase (Or) inclusions in garnet (Grt) crystal associated with orthopyroxene (Opx); D) Skeletal crystals of garnet (Grt), showing quartz (Qz), biotite (Bt) and orthopyroxene (Opx) inclusions, and associated orthopyroxene.

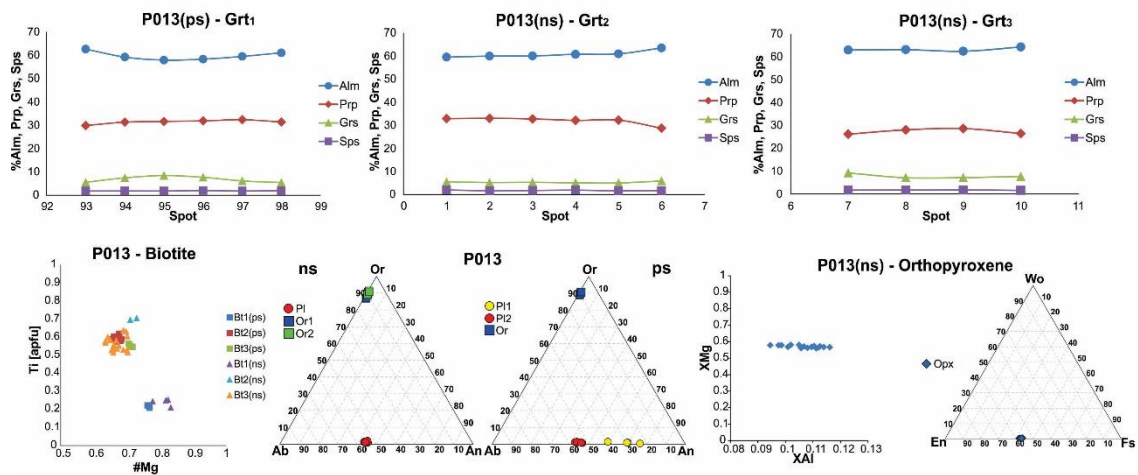


Figure 7 - Compositional plots for the main analyzed phases of sample P013. ns – neosome; ps – paleosome. #Mg = XMg = Mg/(Mg+Fe)[apfu]; XAl = Al[apfu]/2 (Pattison et al. 2003).

Schlieren Opx-Grt-Bt-Diatextite, samples P1 and P1D

Schlieren Opx-Grt-Bt diatexites exhibit an almost complete segregation between leucosome and melanosome, and no paleosome is observed. Melanosome schlieren may show random orientation or be parallel to leucosome's foliation. Melanosome is fine to medium-grained, composed of ilmenite (5%), quartz (10%), orthopyroxene (15%), garnet (20%), biotite (20%) and plagioclase (30%), with lesser amounts of orthoclase and magnetite, and accessory assemblage composed of apatite, zircon, rutile and primary sulphides (pyrite, chalcopyrite and pyrrhotite). Secondary sulphides are also observed being associated with chlorite and carbonate pseudomorphs after orthopyroxene, garnet or biotite along veins. Rare orthoclase crystals observed in the melanosome seem to have been mostly consumed by melting reactions, showing myrmekitic intergrowths with plagioclase and quartz on their borders, and show homogeneous composition (Or = 93.8-94.3%). Orthopyroxene crystals occur both as irregular, fractured, fine-grained crystals which are usually

affected by chlorite-carbonate alteration (Opx₂), showing low Al contents (0.094-0.141 apfu.), and as prismatic, fine to medium-grained crystals (Opx₁), exhibiting moderate to high Al contents (0.144-0.199 apfu.), both exhibiting hypersthene composition (En = 55.2-61.5%, Figure 9). Garnet crystals are fine to coarse-grained, usually have no internal orientation (Figure 8A) and contain inclusions of all other phases except for orthoclase; compositions are rather uniform (Figure 9, Supplementary File S3), defining a single generation with small variations from core to rims of Alm contents (cores: 59.61-63.27%; rims: 60.16-63.59%) and Prp (cores 27.5-30.64%, rims 25.93-29.79%), slightly higher variations of Grs (cores: 5.93-7.68%; rims: 6.70-8.61%) and almost no variation of Sps (less than 2.48%), although chemical profiles show two distinct patterns: hyperbolic or oscillatory. That difference seems to be tied to the exposure to the alteration process, which is more intense on the fields where the oscillatory-pattern garnets are found. Some garnet crystals exhibit sulphide inclusions in circular patterns marking growth zones (Figure

8A). Biotite crystals are predominantly fine-grained and are divided into three generations (Figure 9): Bt₁ occurs as inclusions in garnet crystals preserved from alteration processes, showing the highest TiO₂ (6.21-6.34%) and high X_{Mg} (0.690-0.698); Bt₂ occurs as a free phase in the matrix biotite, showing intermediate TiO₂ (4.69-5.54%) and lower X_{Mg} (0.644-0.670); Bt₃ have the lowest TiO₂ (3.64-5.10%) and highest X_{Mg} (0.680-0.748), and it's associated with borders of orthopyroxene and garnet crystals or as inclusions affected by fractures on those, next to alteration fronts. Plagioclase and quartz are observed as fine-grained granoblastic crystals or as veinlets of very fine-grained intergrowths that fill intergranular sites, a textural evidence of residual melt crystallization (Figure 8B). Plagioclase inclusions in garnet shows no chemical differences from matrix plagioclase, both exhibiting andesine to labradorite composition (An = 45.9-51.4%, Figure 9). Ilmenite crystals are homogeneous, with high Ilm contents (87.49-89.81%) and low Mn (less than 0.6% Pph). Metamorphic peak assemblage is interpreted as Ilm+Grt+Opx+Pl+Qz.

Leucosome is fine to coarse-grained, foliated, with modal composition between granitic and granodioritic (rarely tonalitic), composed by rutile (<1-5%), biotite (10-15%), garnet (10-15%), orthoclase (15-20%), plagioclase (15-35%) and quartz (20-40%), rare orthopyroxene (<5% when present) and accessory assemblage composed of primary sulphides (pyrite and chalcopyrite), ilmenite, zircon and monazite. When observed, alteration

processes (secondary sulphides+chlorite+carbonate) is more intense on the leucosome (Figure 8B, D), replacing all Opx for pseudomorphs with few relicts preserved. Rutile is commonly associated with biotite, occurring as inclusions, as a free phase in the matrix or in pressure shadows around garnet crystals. Biotite occurrence is similar to that observed on the melanosome, and in the leucosome it is preferably oriented defining a foliation. Garnet crystals range from fine to very coarse-grained, containing inclusions of all other minerals observed on the leucosome and, rarely, even phases not present in the matrix (like hercynite, Figure 8C), which may form an internal foliation (Figure 8D). Orthoclase and plagioclase may form subhedral crystals, fine to coarse-grained and commonly perthitic/anti-perthitic, or occur as intergrowths with quartz on very fine-grained veinlets fulfilling interstitial grain sites. Quartz may also occur as fine to coarse-grained crystals and show chessboard extinction patterns. Sample P1D represents a leucosome vein intruded on the orthopyroxene-clinopyroxene orthogneiss, showing almost no melanosome but mostly similar to the proximal leucosome (P1_L).

Separate mineral chemistry analyses were made for the proximal (P1_L) and distal (P1D) leucosome, but the results are similar (Figure 9). Garnet crystals observed in P1_L are very similar to those observed on the melanosome (cores: Alm = 60.28-62.64%, Prp = 28.30-31.04%, Sps = 1.97-2.40%, Grs = 6.17-7.46%; rims: Alm = 60.74-63.22%, Prp = 27.53-29.55%, Sps = 2.03-2.32%, Grs = 6.36-8.06%), while P1D garnets show

a relative increase in Alm (cores – 57.25-62.90%, rims – 61.66-64.52%) and Prp (cores – 28.61-35.83%, rims – 26.87-35.51%) and a considerable decrease in Grs (cores – 4.67-5.70%, rims – 4.68-5.23%); on both cases there's a single generation of Grt (Figure 9). Three generations of biotite crystals are identified in both P1_L and P1D, although in the later little differences are observed between their compositions (Figure 9): Bt₁ inclusions in Grt shows moderate to high X_{Mg} (P1_L = 0.7084-0.7134, P1D = 0.6782-0.7417) and high TiO₂ (P1_L = 6.00-6.03%, P1D = 4.42-4.91%); Bt₂ comprises both matrix biotite and

overgrowths to Grt showing stable contacts, showing smaller X_{Mg} (P1_L = 0.6458-0.7168, P1D = 0.6433-0.7154) and intermediate TiO₂ (P1_L = 4.15-5.5%, P1D = 4.07-5.19%); Bt₃ makes up for biotite crystals formed by Grt borders or embayments, with high X_{Mg} (P1_L = 0.6879-0.7792, P1D = 0.7200-0.7443) and low TiO₂ (P1_L = 2.27-3.99%, P1D = 3.98-4.81%). Orthoclase crystals on both P1_L and P1D have similar composition (Or = 86.3-90.0% and 88.0-92.6%, respectively, Figure 9), while plagioclase from P1_L is remarkably more calcic (An = 44.1-49.4%) than P1D's (An = 31.5-39.9%).

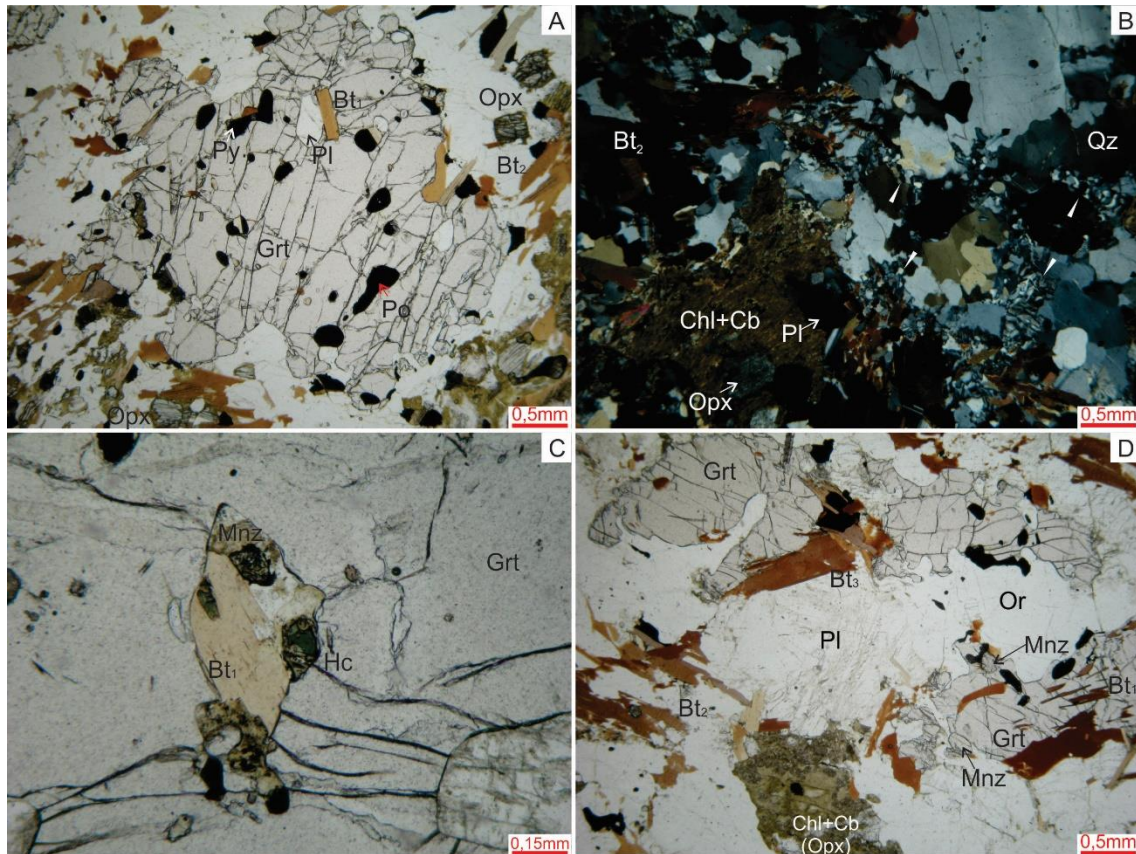


Figure 8 - Textural features of the Opx-Grt-Bt diatexites (samples P1, P1D). A) Melanosome garnet, containing inclusions of plagioclase (Pl), biotite (Bt), pyrite (Py) and pyrrhotite (Po); B) Veinlets of very fine-grained intergrowths of quartz-plagioclase (indicated by white triangles) at the boundary between a melanosome schlier and the leucosome; C) Inclusions of biotite (Bt), hercynite (Hc) and monazite (Mnz) on leucosome's garnet; D) Leucosome garnet crystals showing oriented biotite (Bt) inclusions and pseudomorph of orthopyroxene (Opx) after chlorite (Chl) and carbonate (Cb).

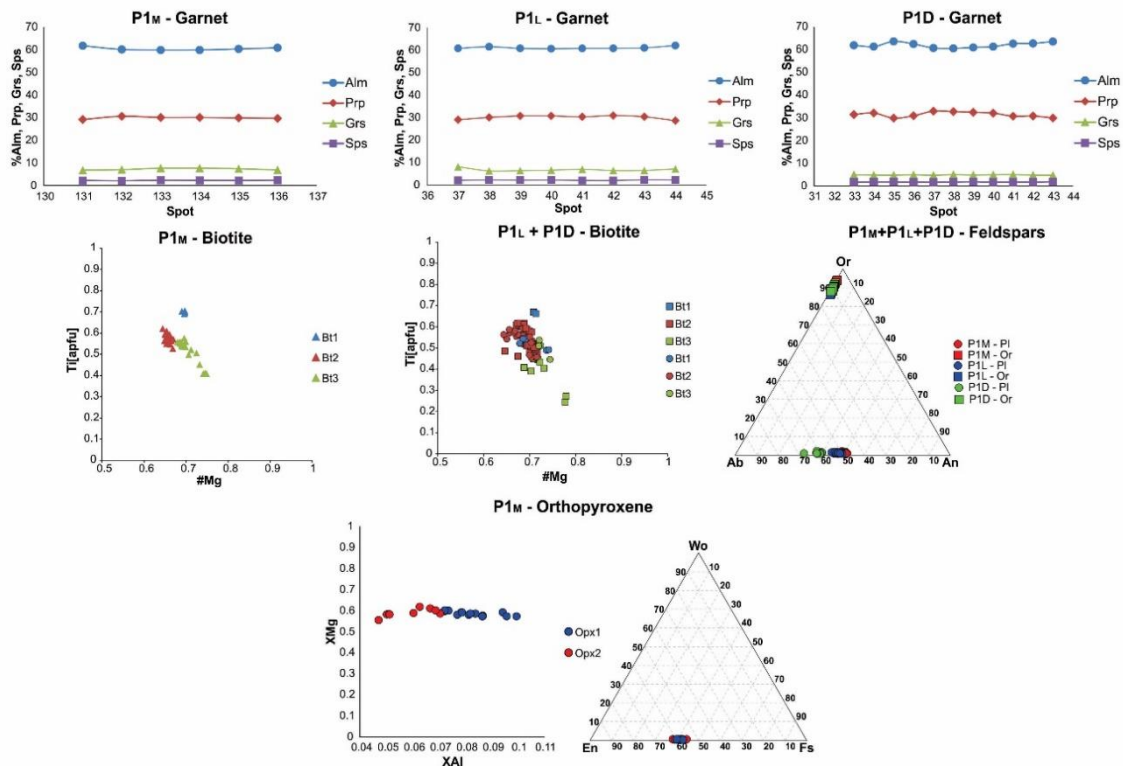


Figure 9 - Compositional plots for the main analyzed phases of samples P1 and P1D. P1_M - melanosome; P1_L - proximal leucosome. #Mg = $X_{Mg} = \text{Mg}/(\text{Mg}+\text{Fe})_{[\text{apfu}]}$; $X_{Al} = \text{Al}_{[\text{apfu}]} / 2$ (Pattison et al. 2003)

Hercynite-orthopyroxene-garnet-biotite diatexite (samples P010A, P010B)

Hercynite-orthopyroxene-garnet-biotite diatexites show a well-defined flux foliation and moderate banding, with melt-rich bands alternating with residue-rich ones. Melt-rich bands are fine to coarse-grained and composed of biotite, garnet, quartz, orthoclase and with accessory amounts of hercynite, zircon, monazite, ilmenite and magnetite; mafic minerals reaches up to 10 vol%. Plagioclase, quartz, orthoclase and biotite crystals are preferably oriented or elongated along the foliation, as well as some garnet crystals.

Residue-rich bands are fine to medium-grained, reaching up to 20-30 vol% of mafic minerals and are composed of hercynite (1%), ilmenite, magnetite (opaques up to 5%), biotite (3%), garnet (5%), orthopyroxene (10%), orthoclase (7%), quartz (14%) and plagioclase

(55%), with accessory apatite, zircon and monazite; garnet-absent zones are observed (Figure 10A), where orthopyroxene and biotite crystals usually reach medium grain-size and orthoclase is more abundant. The foliation is defined by oriented orthopyroxene, biotite, ilmenite and magnetite crystals. Stable contacts are usually observed between garnet and hercynite and between orthopyroxene and hercynite (Figure 10A-B), and between these and the felsic minerals, although local disequilibrium textures are also present. Hercynite is predominantly associated with magnetite and ilmenite (Figure 10A-C), sometimes isolated from the matrix between orthopyroxene and ilmenite crystals or as inclusions in garnet but mostly as a free phase, and can be divided into two generations (Figure 11): Hc₁ occurs in garnet-absent zones, showing higher Zn contents ($G_{\text{hn}} = 7.2\text{-}8.9\%$), and Hc₂

occurs associated with garnet, showing lower Zn ($G_{Hn} = 4.7-5.3\%$). Biotite usually show stable contacts with anhydrous phases, but reactive borders are also present between biotite-orthopyroxene and garnet-biotite; rare biotite inclusions are observed in some hercynite crystals. Biotite is divided into two generations (Figure 11): biotite from garnet-free zones (Bt_1) exhibit TiO_2 contents between 4.60-5.00 wt.% and X_{Mg} values between 0.673-0.685, while biotite associated with garnet (Bt_2) shows slightly lower TiO_2 (4.28-4.41%) and higher X_{Mg} (0.732-0.740). Garnet crystals are anhedral to subhedral, commonly inclusion-poor, showing orthopyroxene (Figure 10D), quartz or plagioclase inclusions, often exhibiting symplectitic intergrowths with quartz at the rims (Figure 10B-D), and show little differences between core and rim compositions, comprising a single generation (Figure 11) exhibiting a small increase in Alm and Prp from cores (max. 53.8% and 34.6% respectively) to rims (max. 54.5% and 34.7%, respectively) associated with a decrease in Sps (max. 7.92% cores, 7.70% rims) and Grs (max. 6.46% cores, 6.28% rims). Orthopyroxene crystals show strong shades of pink (Figure 10A, D), are mainly subhedral, belong to a single generation (Figure 11) with hypersthene composition ($En = 60.7-62.7\%$), high X_{Al} values (0.146-0.27) and relatively high Mn^{2+} (up to 0.039 apfu.), and often contain inclusions of opaque minerals (Figure 10A), biotite, quartz or zircon. Plagioclase, orthoclase and quartz are fine to medium-grained and commonly show polygonal contacts. Perthitic orthoclase and anti-perthitic plagioclase are observed, sometimes with well-

developed exsolution lamellae. Orthoclase show little compositional variations ($Or = 89.2-94.4\%$), while plagioclase is divided into two generations (Figure 11): plagioclase from garnet-free zones (Pl_1) have andesine composition ($An = 43.2-47.3\%$), while plagioclase associated with garnet (Pl_2) shows labradorite composition ($An = 53.9-55.2\%$). Ilmenite crystals are divided into three distinct generations (Figure 11, Supplementary File S3): Ilm_1 is found in association with hercynite in garnet-present zones and as inclusions in orthopyroxene in garnet-free zones, showing relatively high Mn^{2+} contents ($P_{ph} = 4.60-4.70\%$) and moderate substitution for hematite ($Hem = 8.20-8.60\%$); Ilm_2 is observed in the matrix of garnet-free zones associated with hercynite, showing low to high Mn^{2+} contents ($P_{ph} = 2.70-5.30\%$) and little substitution for hematite (3.00-5.90%); Ilm_3 is found as a free phase in the matrix of garnet-present zones, showing low Mn^{2+} contents (1.50-2.20%) and intercalating hematite-rich (up to 25.3%) to hematite-poor (up to 13.7%) lamellae. Metamorphic peak assemblage is interpreted to be $Grt+Opx+Hc+Pl+Or+Qz\pm Ilm$.

Based on petrography, the migmatites from the four selected outcrops were divided into two groups: the hercynite-sillimanite-garnet migmatites, corresponding to samples P4E and P008, and the orthopyroxene-garnet-biotite migmatites, corresponding to samples P1, P1D, P010A and P013. The similarities are also observed on the results of other analytical methods, as presented on the following sections.

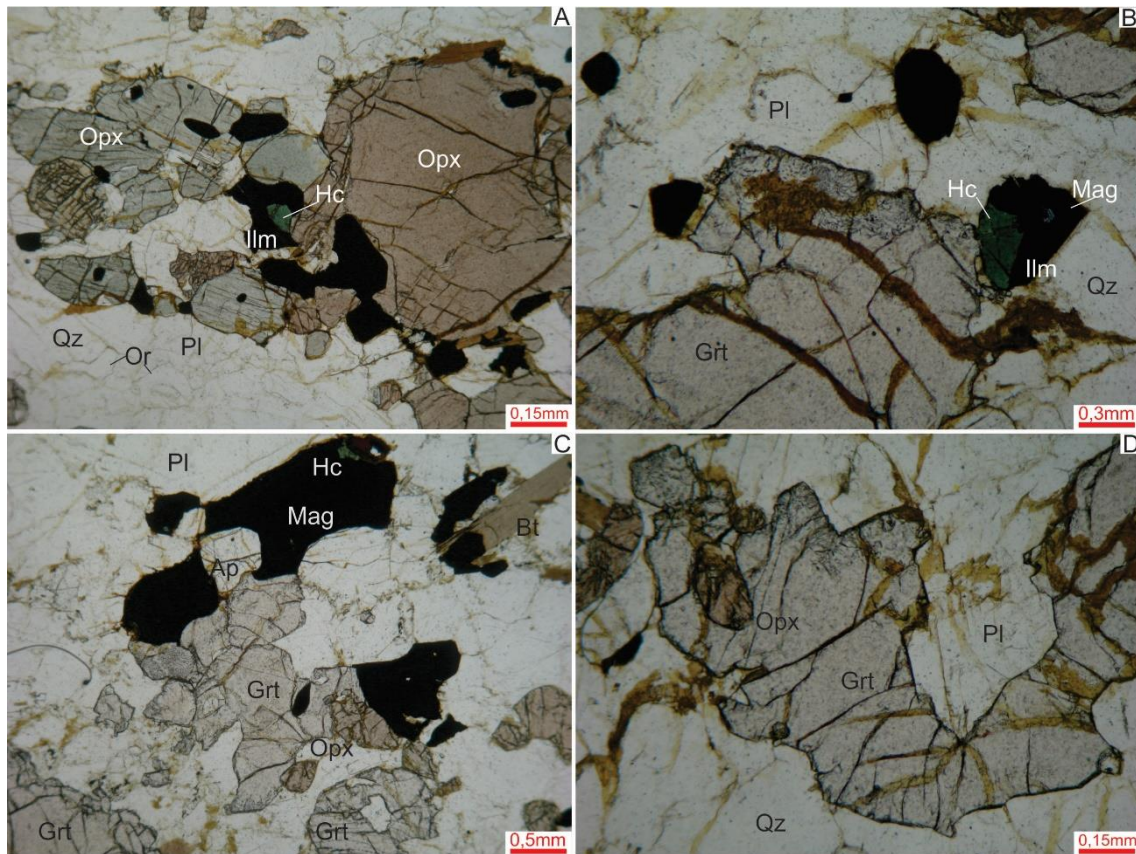


Figure 10 - Textural features of the hercynite-orthopyroxene-garnet-biotite diatexites (sample P010A). A) Hercynite crystal isolated from the matrix by orthopyroxene and ilmenite, Grt-free zone; B) Garnet crystal showing stable contacts with hercynite and symplectitic borders (Grt+Qz); C) Garnet crystal in stable contacts with orthopyroxene and magnetite; D) Orthopyroxene inclusion in garnet.

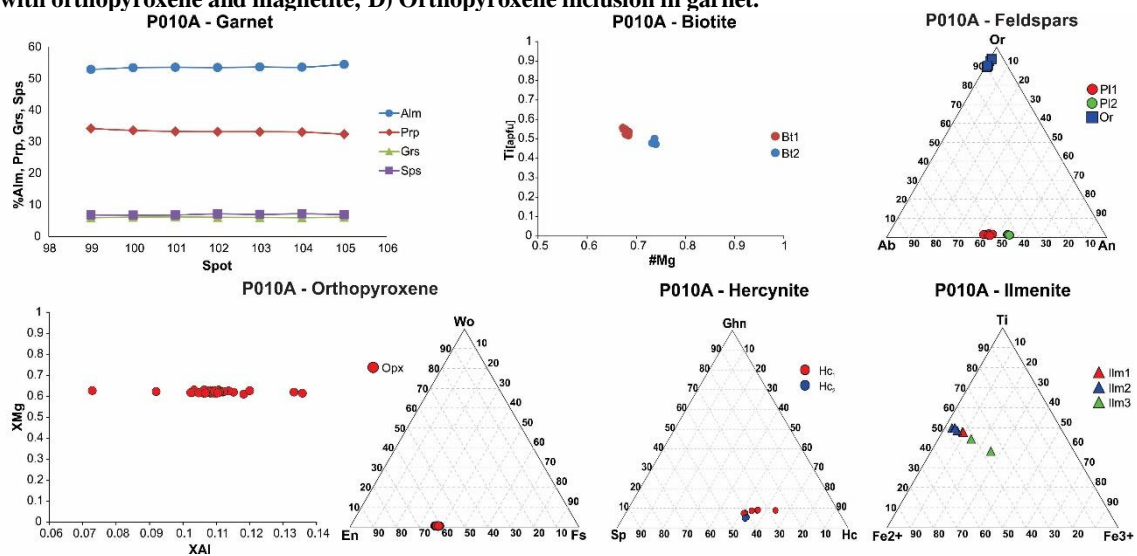


Figure 11 - Compositional plots for the main analyzed phases of sample P010A. $\#Mg = X_{Mg} = Mg/(Mg+Fe)_{[apfu]}$; $X_{Al} = Al_{[apfu]}/2$ (Pattison et al. 2003).

4.2 Thermobarometry

P-T conditions were calculated using melanosome/residuum assemblages

whenever possible for a better constraint of the data, as suggested by Sawyer (2008). Figures 12 presents the P-T plots

for the values calculated with THERMOCALC Average P-T mode.

Spr-Sil-Hc-Grt-Diatexites (sample P008)

Average P-T values (Figure 12) for Grt cores and inclusion assemblages (Grt_{cores}+Bt₁+Pl_{incl}+Or+Sill+Qz) range between 704±34 °C, 5.4±1.7 kbar and 753±43 °C, 5.8±2.2 kbar at a_{H2O} = 0.1. Matrix assemblage (Spr+Hc+Grt_{rims}+Sill+Qz+Pl_{matrix}+Or±Ilm±Ru) yield high error values for both temperature and pressure on AvPT mode, while calculations using AvP and AvT give statistically better values with AvT between 1037±64 and 1076±83 °C and AvP between 6.5±0.9 and 7.9±0.9 kbar; as no hydrated phases are present at metamorphic peak assemblage, a_{H2O} is not accounted on the calculations.

Hc-Sil-Crd-Bt-Grt-Diatexite (sample P4E)

The best values obtained with Average P-T approach for garnet cores and inclusion assemblages (Grt₁₋₃+Hc₁+Pl_{incl}+Or_{incl}+Bt₁+Sill+Qz±Ilm) were (Figure 12): 840±43 °C, 5.0±1.4 kbar for Grt₁ at a_{H2O} = 0.5; 744±41 °C, 6.3± 2.0 kbar for Grt₂ at a_{H2O} = 0.2; 887±55 °C, 5.4±1.6 kbar for Grt₃ at a_{H2O} = 0.1. Matrix P-T conditions calculated for the assemblage Grt_{rims}+Bt₃+Or_{matrix}+Pl_{matrix}+Crd_{2(pin.)}+Sill+Qz range between 648±24 °C, 5.4±0.4 kbar and 748±29 °C, 6.5±0.5 kbar at a_{H2O} (cordierite) between 0.1 and 0.3, while the assemblage Grt_{rims}+Hc₂+Crd₂+Sill+Pl_{matrix}+Or_{matrix}+Qz±Ilm±Bt₂ yielded values between 834±65 °C, 5.6±0.4 kbar and

1023°C±55, 7.8±0.7 kbar at a_{H2O} between 0 and 0.3.

Opx-Grt-Bt-Metatexite, sample P013

Average P-T for paleosome's Grt cores + inclusion assemblages (Grt_{1, cores}+Bt₁+Pl₁+Or+Qz) yield P-T values ranging between 604±36 °C, 7.6±1.4 kbar and 664±46 °C, 8.6±1.9 kbar at a_{H2O} = 0.1, while at a_{H2O} = 0.4 a peak value of 966±76 °C, 8.6±1.7 kbar was obtained. Matrix assemblage (Grt_{1, rims}+Bt₂+Pl₂+Or+Qz) show a range of P-T between 835±54 °C, 4.6±1.8 kbar and 1010±77, 6.7±2.0 kbar at a_{H2O} between 0.15 and 0.5.

Average P-T calculations for neosome cores (garnet and orthopyroxene) and inclusion assemblages (Grt_{1-2, cores}+Opx_{1, cores}+Bt₂+Pl_{incl}+Or₁₋₂+Qz) yield temperatures that range between 837±31 °C, 6.9±1.3 kbar and 1023±60 °C, 9.8±1.6 kbar at a_{H2O} between 0.9 and 1.0. Matrix assemblages (Grt_{2, rims}+Opx_{1, rims} and skeletal+Bt₃+Pl_{matrix}+Or₂+Qz) provide P-T values between 923±58 °C, 7.9±1.8 kbar and 1006±57 °C, 8.9±1.6 kbar at a_{H2O} between 0.6 and 1.0.

Opx-Grt-Bt-Diatexite (samples P1 and PID)

Thermobarometrical data was obtained separately for melanosome and leucosome of sample P1 (Figure 13). P1 **melanosome** cores (Grt and Opx) + Grt inclusions assemblages (Grt_{core}+Opx_{1,2} cores +Bt₁+Pl_{incl}+Or_{cores}+Qz) yielded values between 841±42 °C, 7.6±1.2 kbar and 930±61 °C, 9.0±1.8 kbar at a_{H2O} between 0.2 and 0.5. Higher temperatures,

between 936 ± 39 °C, 8.3 ± 1.8 kbar and 1012 ± 70 °C, 8.4 ± 1.8 kbar, were also obtained at $a_{\text{H}_2\text{O}}$ between 0.7 and 1.0, using the same assemblage, and between 0.1 and 0.2 removing the orthoclase and adding a kspL component to the calculations; slightly lower values are obtained using Opx₂ cores (corresponding to the minimum values). Matrix assemblages ($\text{Grt}_{\text{rims}}+\text{Opx}_1+\text{Bt}_2+\text{Pl}_{\text{matrix}}+\text{Or}_{\text{rims}}+\text{Qz}$) also yield different ranges of values depending on $a_{\text{H}_2\text{O}}$: from 858 ± 50 °C, 7.6 ± 1.6 kbar to 965 ± 46 °C, 7.9 ± 1.4 kbar at $a_{\text{H}_2\text{O}}$ between 0.3 and 0.5, and from 949 ± 53 °C, 8.4 ± 1.5 kbar to 1054 ± 55 °C, 8.8 ± 1.6 kbar at $a_{\text{H}_2\text{O}}$ between 0.7 and 1.0. Calculations involving the addition of a kspL component and the removal of orthoclase from the assemblage leads to a range of P-T from 876 ± 47 °C, 7.1 ± 1.5 kbar to 1090 ± 43 °C, 9.0 ± 1.9 kbar at $a_{\text{H}_2\text{O}}$ between 0.1 and 0.5, and from 1023 ± 77 °C, 8.4 ± 2.0 kbar to 1046 ± 75 °C, 9.1 ± 1.9 kbar at $a_{\text{H}_2\text{O}}$ between 0.7 and 1.0. As the rock underwent partial melting, values corresponding to lower $a_{\text{H}_2\text{O}}$ were considered more accurate and, therefore, representative of the P-T trajectory of the Opx-Grt-Bt diatexite. As the proximal leucosome shows many evidences of alteration, Average P-T thermobarometry hasn't been calculated for this part.

Sample P1D calculations (Figure 13) with Grt cores + inclusion assemblages ($\text{Grt}_{\text{cores}}+\text{Bt}_1+\text{Pl}+\text{Or}_{\text{incl}}+\text{Qz}$) yield P-T

values ranging from 637 ± 40 °C, 7.0 ± 1.5 kbar to 815 ± 54 °C, 7.6 ± 1.6 kbar at $a_{\text{H}_2\text{O}}$ between 0.1 and 0.5, while matrix assemblages show two sets of values: for $\text{Grt}_{\text{rims}}+\text{Bt}_2+\text{Pl}+\text{Or}_{\text{matrix}}+\text{Qz}$, P-T conditions range between 827 ± 61 °C, 8.0 ± 1.7 kbar and 909 ± 74 °C, 8.4 ± 2.0 kbar, $a_{\text{H}_2\text{O}}$ between 0.4 and 0.7, and for $\text{Grt}_{\text{rims}}+\text{Bt}_3+\text{Pl}+\text{Or}_{\text{matrix}}+\text{Qz}$ calculations yield values between 643 ± 40 °C, 5.9 ± 1.5 kbar and 825 ± 48 °C, 7.8 ± 1.6 kbar, $a_{\text{H}_2\text{O}}$ between 0.1 and 0.3.

Hc-Opx-Grt-Bt-Diatexite (sample P010A)

Average P-T data obtained for sample P010A exhibit a range of P-T values for core assemblages ($\text{Grt}_{\text{cores}}+\text{Opx}_{\text{cores}}+\text{Pl}_{\text{cores}}+\text{Or}_{\text{cores}}+\text{Bt}_2$) between 882 ± 39 °C, 6.8 ± 1.4 kbar and 1012 ± 54 °C, 8.0 ± 1.9 kbar at $a_{\text{H}_2\text{O}}$ values between 0.6 and 1.0. Calculations for matrix assemblage ($\text{Grt}_{\text{rims}}+\text{Opx}_{\text{rims}}+\text{Hc}_2+\text{Pl}_{\text{rims}}+\text{Or}_{\text{rims}}+\text{Bt}_2\pm\text{Ilm}_{1-2}$) yield temperatures ranging from 804 ± 44 °C, 5.5 ± 1.5 kbar to 842 ± 49 °C, 5.5 ± 1.7 kbar at $a_{\text{H}_2\text{O}}$ values between 0.3 and 0.4, and from 900 ± 53 °C, 6.4 ± 1.8 kbar to 928 ± 61 °C, 6.0 ± 1.8 kbar at $a_{\text{H}_2\text{O}} = 1$. Higher values for matrix assemblages are assumed to better represent matrix P-T conditions as $a_{\text{H}_2\text{O}}$ values are similar to those calculated for core assemblages.

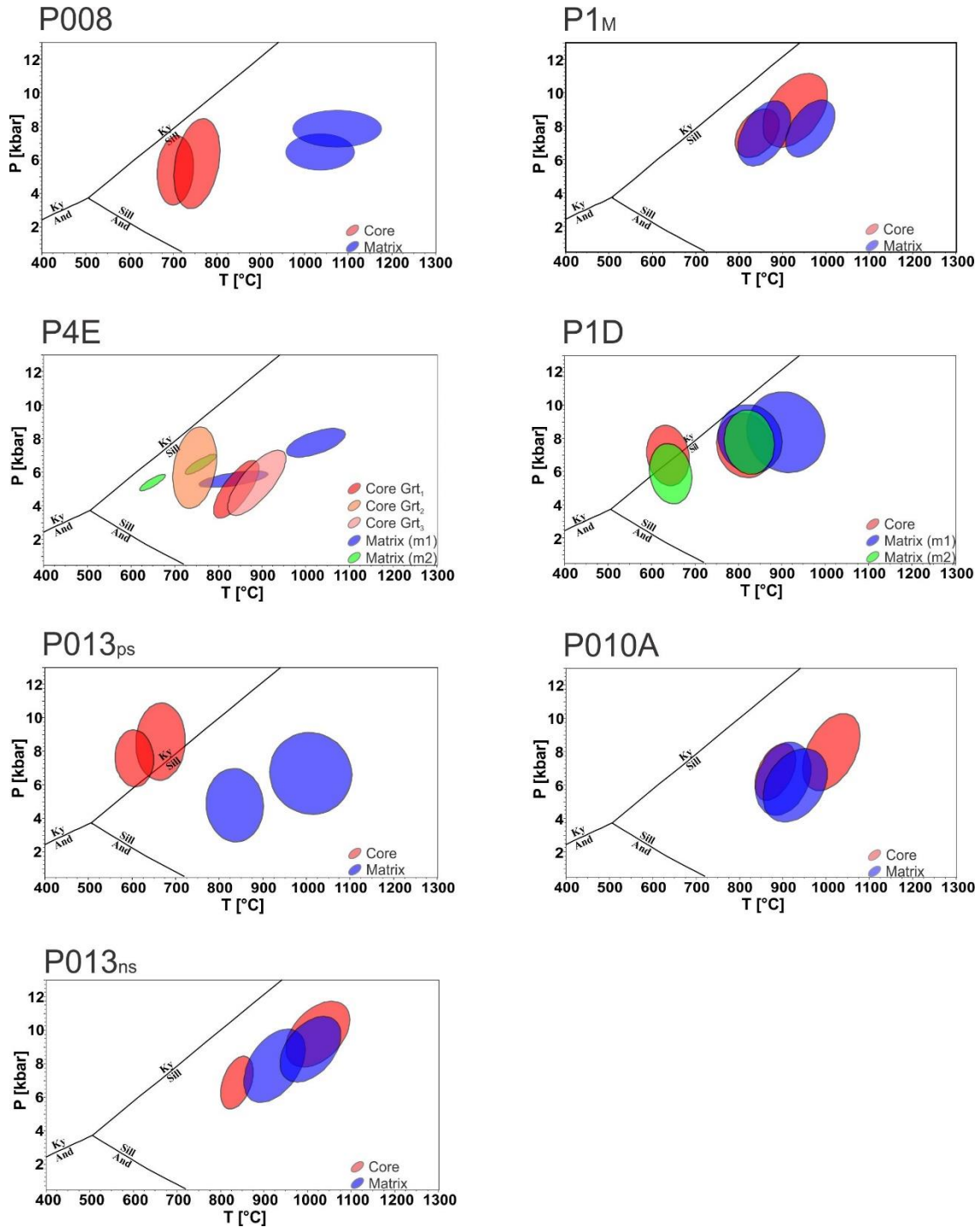


Figure 12 - THERMOCALC Average P-T thermobarometry for analyzed samples. P-T values are represented with the corresponding error ellipses (for error values, see text). Al_2SiO_5 polymorphs stability fields are represented for reference. m1 - progressive metamorphism observed on matrix assemblages; m2 - retrogressive metamorphism observed on matrix assemblages.

4.3 Phase-equilibria modelling

The bulk-rock compositions of each analyzed sample are listed at Supplementary File S4. For phase-equilibria modelling of the three selected samples (P4E, P008 and P013) both H_2O

and Fe^{3+} were determined using binary diagrams, as the values obtained by geochemical analyses usually don't represent the actual contents of analyzed samples and as Fe^{3+} plays an important role on the stability of both spinel (Waters, 1991; Das et al. 2001; White et

al. 2002; Kelsey, 2008) and sapphirine (Taylor-Jones & Powell, 2010).

H₂O contents (“H”) were determined using binary T-X diagrams, initially setting H₂O from 0 to 3% at constant pressures and then refining the analysis for best fitting the observed mineral assemblages by changing the pressure if needed. Fe³⁺ contents (“F3”) were determined using binary P-X diagrams (as suggested by Kelsey & Hand, 2015) at constant temperature using the following procedure: 1) set the Fe₂O₃ content of each sample from 0 to 10% of the FeO_T; 2) calculate hematite isopleths for ilmenite and andradite isopleths for garnet; 3) analyze if the crossing of both isopleths is coherent with the observed assemblage, and then identifying the correspondent X value; 4) change the temperature conditions and repeat steps 1 to 3 if needed. In order to elaborate a phase equilibria model for migmatites capable of predicting the rock’s behavior during the anatexis story, samples with composition close to the protolith’s must be selected or melt reintegration techniques must be applied (White & Powell 2002; White et al. 2004; White, 2008), however true protolith compositions are much harder to obtain on granulite terrains (Sawyer, 2008; White, 2008). In this work, phase-equilibria modelling is used mainly for the purpose of determining peak metamorphic conditions, peak assemblages’ stability fields and post-peak retrograde paths, so melt reintegration is outside its scope. Nonetheless, the less melt-depleted samples identified for each migmatite type were selected for modelling.

For orthopyroxene-garnet-biotite migmatites, the orthopyroxene-garnet-biotite metatexite (sample P013) best fits this prerogative as melt-migration features are rare and most neosome/leucosome seems to be *in situ*; samples P1_M (orthopyroxene-garnet-biotite diatexite melanosome) and P010A (hercynite-garnet-orthopyroxene-biotite diatexite) seems to represent the most melt-depleted stages, and both P1_L and P1D (orthopyroxene-garnet-biotite diatexite proximal and distal leucosome, respectively) the melt-rich fractions. Although relatively high Mn contents are observed on sample P010A orthopyroxene and garnet crystals (see Supplementary File S2 and S3), its MnO contents are similar to the other migmatites in the group (even smaller than P013 or P1_M, see Supplementary File S4). For hercynite-sillimanite-garnet migmatites, P4E (hercynite-sillimanite-cordierite-garnet-biotite diatexite) presents higher Na₂O and K₂O contents than P008 (sapphirine-hercynite-sillimanite-garnet diatexite), and considering the pattern of melt extraction processes that are widely observed on diatexite terrains (Sawyer, 2008) the former probably represents a less melt-depleted state than the later, but as both show diatexite structures phase-equilibria modelling was made using both compositions.

Hercynite-sillimanite-garnet migmatites

Using sample P4E bulk-rock composition (Figure 13), the calculated stability field for its metamorphic peak assemblage is the boundary between

fields identified as “2” (Figure 13A-B), constrained between 948 °C, 6.0 kbar and 1014 °C, 6.7 kbar in which the assemblage

Mag+Ilm+Sp+Sil+Crd+Grt+Or+Pl+Qz+liquid was calculated; a melt-free corresponding assemblage is predicted to exist from the lower limit of “2” up to 927 °C, 5.7 kbar. Disequilibrium textures observed at thin section are represented by the adjacent field to the left, as hercynite crystals are observed rimmed by Crd and Sill. P008 peak metamorphic assemblage is also observed as the boundary “3” with assemblage

Mag+Ilm+Grt+Sp+Spr+Sill+Or+Pl+Qz+liquid, defining a range between 1014 °C, 6.7 kbar and 1019 °C, 6.8 kbar. The P-T estimative for P4E was obtained by combining almandine isopleths with hercynite X_{Mg} isolines. For Alm isopleths, the values between 0.55-0.57 were considered as an approximation of analyzed rims compositions of Grt₁₋₂ (see section 4.1 and Supplementary File S3), although actual values should be slightly lower if the calculations considered Sps contents of garnet crystals; it's notable that Alm isopleth values decrease with increasing temperature (Figure 13B). For hercynite X_{Mg} isolines, the value of 0.36 was selected as an approximation for the minimum value obtained on analyzed hercynite crystals in the matrix, although: I) most calculated values were considerably higher (Supplementary File S3); II) considering Mg partition between hercynite-garnet, the presence of high-Mg cordierite coronas, magnetite exsolution lamellae and frequent association with ilmenite, actual peak compositions should be considerably

richer in Mg. With these considerations, the calculated conditions of 1008 °C, 6.6 kbar (Figure 13B) must be taken as a minimum estimative.

The diagram for P008 bulk composition (Figure 14) exhibits a considerable gap between P4E and P008 fields, which are also defined as the limits between adjacent fields containing spinel-free or sillimanite-free assemblages, although the field corresponding to P4E assemblage without liquid (“1”) is broader and extends from 962°C, 6.2 kbar to less than 872 °C, 5.0 kbar (Figure 14A). P4E field (melt-present) is defined between 962°C, 6.2 kbar and 991 °C, 6.5 kbar (“2”, Figure 14A). The field corresponding to P008 peak assemblage is constrained between 1067 °C, 7.6 kbar and 1078 °C, 7.9 kbar (“3”, Figure 14A-B) at the limit between a sillimanite-free and a sapphirine-free field. The P-T estimative for P008, obtained by combining the phase-equilibria model with isolines for modal quantities (isomodes) of 1% sapphirine and 14% garnet, provide a single point at 1066 °C, 7.6 kbar. The path between P4E and P008 assemblage fields is defined by the assemblage

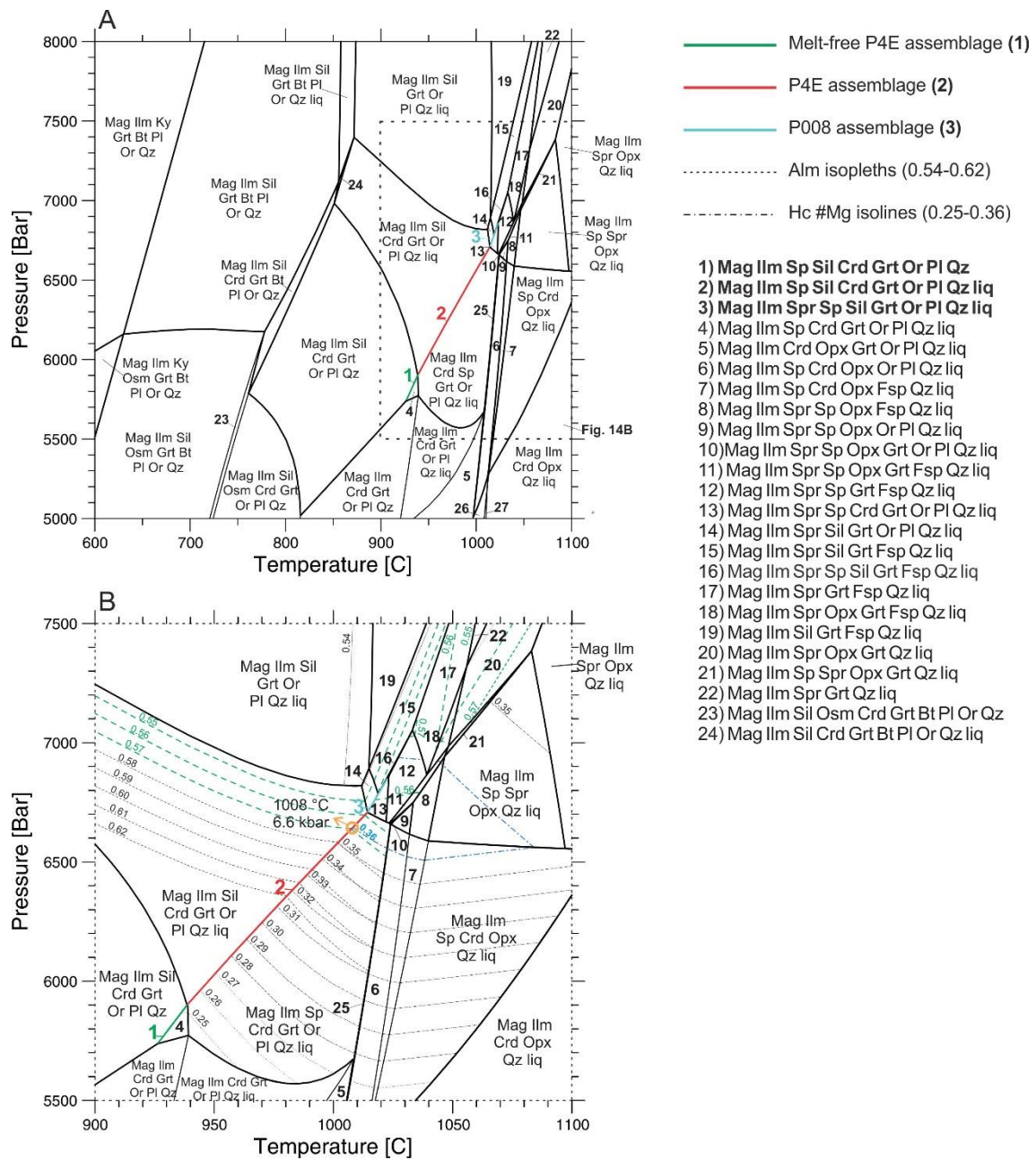
Ilm+Mag+Sp+Sil+Grt+Or+Pl+Qz+Mag+liquid, consistent with observations on sapphirine-free thin sections of the same outcrop. At higher pressure and temperature, a field containing a sillimanite and sapphirine-present, spinel-free assemblage (“18”, Figure 14A-B) is observed, consistent with the textural observation of sapphirine forming by the borders of hercynite (see section 4.1).

*Orthopyroxene-garnet-biotite
migmatites*

Using P013 bulk-rock composition, the calculated stability fields are wide and provide the assemblages observed on samples P1, P1D and P013 (Figure 15). P010A hercynite-bearing assemblage isn't observed at any point of the considered P-T space, which leads to the hypothesis that hercynite-bearing assemblages are only possible for orthopyroxene-garnet-biotite migmatites if considerable melt loss takes place.

P013 paleosome assemblage is constrained of the field $\text{Mag+Ilm+Grt+Bt+Or+Pl+Qz}$ (Figure 15A), as confirmed by P-T estimatives combining Alm and Ab isopleths (Figure 16A). Minimum conditions of 603 °C, 8.7 kbar (P013_(PS) min.) are calculated for Alm = 0.63 and Ab = 0.57, and maximum conditions of 889 °C, 10.2 kbar correspond to the onset of partial melting (P013_(PS) melt-in, Alm = 0.61, Ab = 0.53), which confirms the observation that orthopyroxene-forming reactions is associated with the generation of neosome, probably

involving the breakdown of biotite. High-Ca plagioclase inclusions on paleosome's garnets aren't predicted by the model as An contents tend to increase with increasing temperature. Minimum P-T conditions for the neosome (P013_(NS) melt-in, Alm = 0.60, Ab = 0.54; Figure 16A) are 892 °C, 10.5 kbar, inside the predicted metatexite field ($\text{Mag+Ilm+Opx+Grt+Bt+Or+Pl+Qz+liquid}$), and the metamorphic peak is calculated (Figure 16B) at 988 °C, 10.9 kbar using Alm isopleths (0.58) and $\text{Al}_{[\text{apfu}]}$ -in-Opx isolines (0.23), inside the diatexite field ($\text{Mag+Ilm+Opx+Grt+Or+Pl+Qz+liquid}$) at which biotite is completely consumed. The onset of the retrograde path is registered by skeletal orthopyroxene and garnet compositions ($\text{Al-in-Opx} = 0.23 \text{ apfu}$; Alm = 0.64), at 875 °C, 8.5 kbar (metatexite field), reaching minimum P-T conditions at 590 °C, 7.5 kbar (Alm = 0.64, Ab = 0.56), inside the paleosome assemblage field and coherent with the observation of retrograde biotite formed at the rims of orthopyroxene crystals.



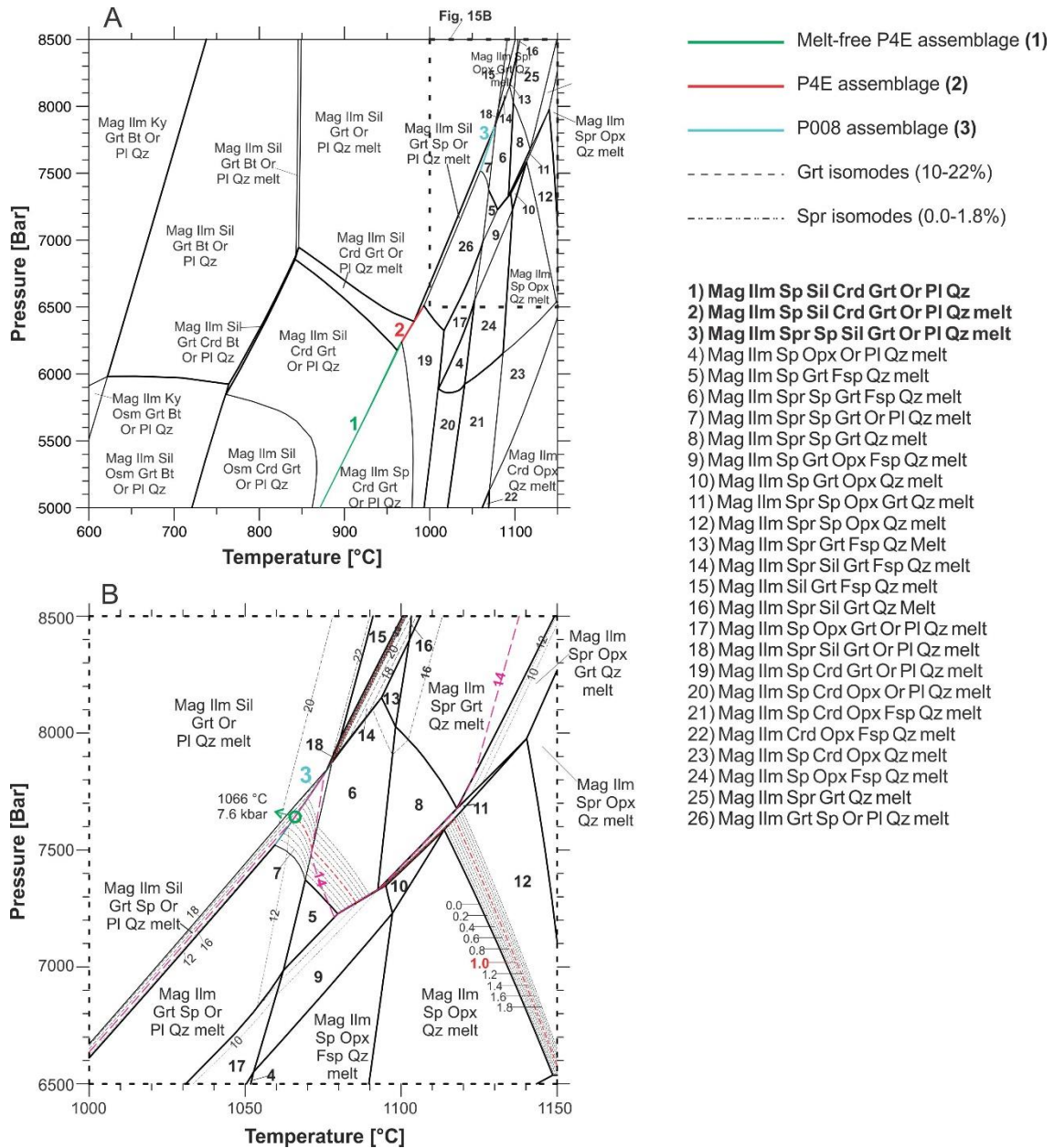
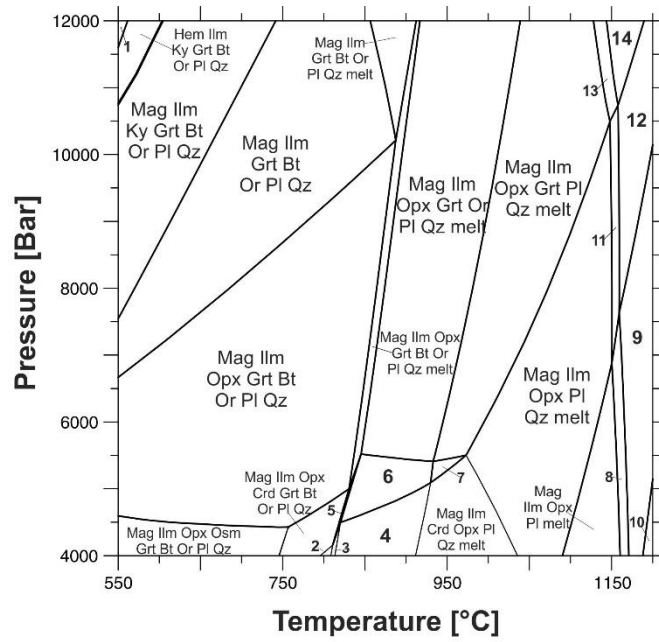


Figure 14 - Phase-equilibria modelling of sample P008, showing many similarities with the modelling of sample P4E (Figure 13). A) Stable assemblages on a P-T space between 600-1150 °C, 5.0-8.5 kbar. The colored fields and boundaries represent the assemblages of samples P4E (1 and 2) and P008 (3); B) Detail between 1000-1150 °C, 6.5-8.5 kbar, showing the calculated peak metamorphic conditions using the intersection of sapphirine (1%) and garnet (14%) isomodes.



- | | |
|---|-----------------------------------|
| 1) Hem Ilm Ky Omp Grt Bt Or Pl Qz | 8) Rt Mag Ilm Opx Pl melt |
| 2) Mag Ilm Opx Crd Bt Or Pl Qz | 9) Rt Mag Opx Pl melt |
| 3) Mag Ilm Opx Crd Bt Or Pl Qz melt | 10) Rt Mag Pl melt |
| 4) Mag Ilm Opx Crd Or Pl Qz melt | 11) Rt Mag Ilm Opx Pl Qz melt |
| 5) Mag Ilm Opx Crd Grt Bt Or Pl Qz melt | 12) Rt Mag Opx Pl Qz melt |
| 6) Mag Ilm Opx Crd Grt Or Pl Qz melt | 13) Rt Mag Ilm Opx Grt Pl Qz melt |
| 7) Mag Ilm Opx Crd Grt Pl Qz melt | 14) Rt Mag Opx Grt Pl Qz melt |

Figure 15 – Phase-equilibria modelling calculated with P013 bulk-rock composition, showing stable assemblages for a P-T space between 550-1200 °C, 4.0-12.0 kbar.

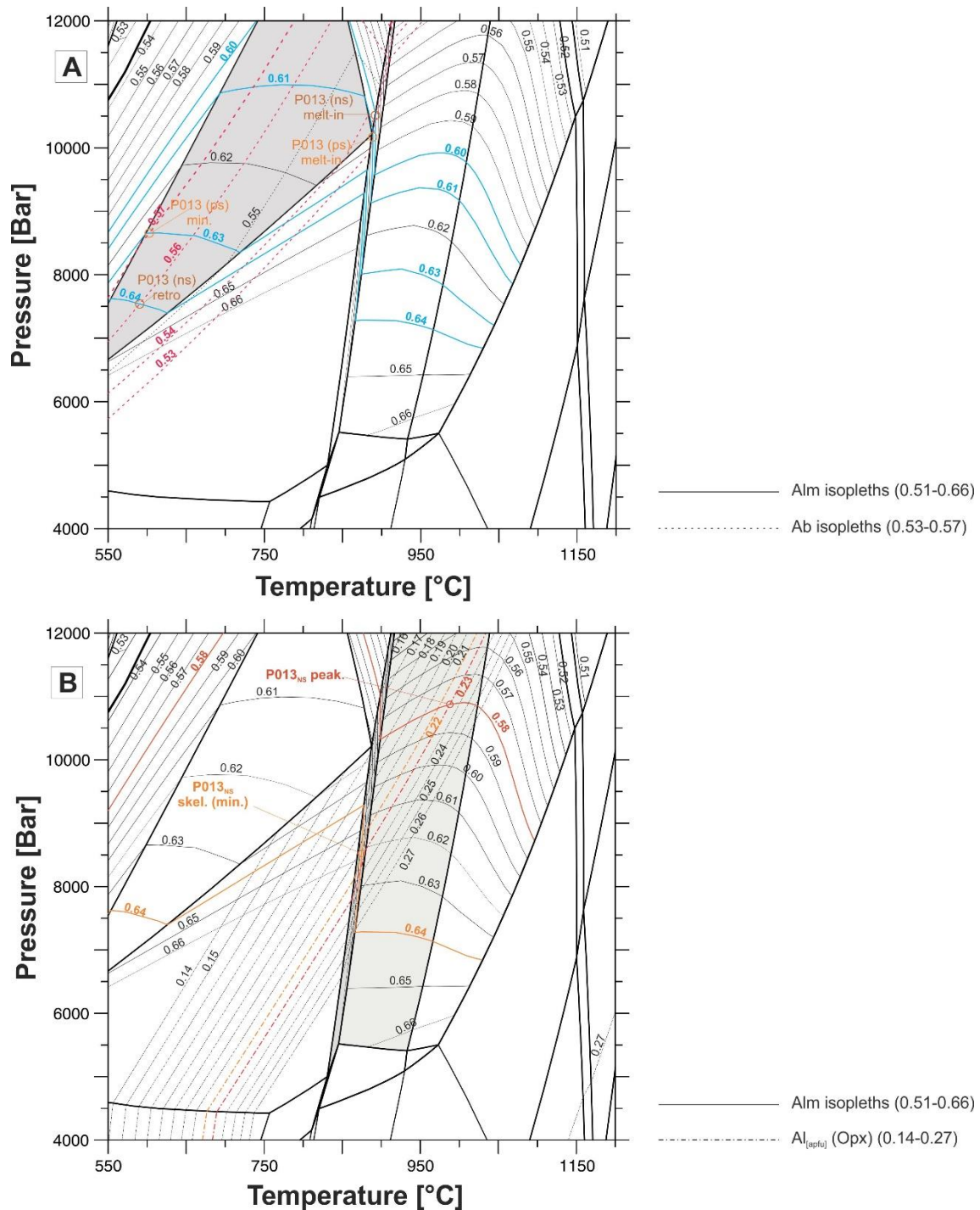


Figure 16 – Phase equilibria models calculated for obtaining P013 paleosome and neosome P-T conditions. A) P-T estimatives inside paleosome assemblage field (shaded in gray) based on Alm and Ab isopleths for both paleosome and neosome, showing initial conditions of melting (P013_{PS} melt-in) and final retrograde conditions (P013_{NS} retro); B) P-T estimatives inside metatextite (narrow gray-shaded field) and diatextite (broader gray-shaded field) fields based on Alm isopleths and $Al_{[apfu]}$ -in-Opx isopleths, showing various conditions calculated for P013_{NS} (neosome). P013_{PS} min. = 603 °C, 8.7 kbar; P013_{PS} melt-in = 889 °C, 10.2 kbar; P013_{NS} melt-in = 892 °C, 10.5 kbar; P013_{NS} peak = 988 °C, 10.9 kbar; P013_{NS} skel. = 875 °C, 8.5 kbar; P013_{NS} retro = 590 °C, 7.5 kbar.

4.4 U-PB Geochronology

The geochronological studies were carried out using the U-Pb (LA-ICP-MS) method on two samples: a sample of the

orthopyroxene-garnet-biotite metatextite (P013) and a sample of the hercynite-sillimanite-cordierite-garnet-biotite diatextite (P4E). The main goal was to identify and determine possible

sedimentary source ages and the isotopic system opening related to the main metamorphic event. Based on the morphological features observed both by external shapes and on cathodoluminescence images, four principal zircon types were identified on both samples: high luminescence crystals, soccerball crystals, zoned crystals and crystals containing inherited cores (“inherited crystals”). Figure 16 shows examples observed on both samples, analytical spot sites and related $^{238}\text{U}/^{206}\text{Pb}$ ages.

As a noteworthy characteristic of the analyzed samples, the zircon U-Pb spot data spread along the Concordia diagram (Figures 17 and 18). As discussed by Kelsey (2008) and Kelsey & Hand (2015), at temperatures past 900 °C zircon grains may exhibit a spreading over Concordia diagrams as a signal of opening of the isotopic system, resorption of grains or dissolution by metamorphic and/or melting reactions. The assumptions for the best metamorphic age thus requires a careful evaluation of the isotopic data. Therefore we applied a similar approach to the one described by Whitehouse & Kemp (2010) for high-grade metamorphic zones and proceeded with careful investigation of the internal structure of the zircons through cathodoluminescence (CL) imaging, allowing the determination of cores, rims and entire grains formed by a unique CL-response (single grain). The younger dates are attributed to be the result of either Pb loss or resetting during metamorphism, especially in areas strongly affected by partial melting (Gerdes & Zeh, 2009; Rubatto, 2017;

Vervoort & Kemp, 2016). Possible inherited cores were identified and aimed for analytical spots on both samples, but as exposed below, most led to ages similar to the metamorphic ones.

Schlieren/Schollen hercynite-sillimanite-cordierite-garnet-biotite diatexite (Sample P4E)

For sample P4E, 112 spots were analyzed in 75 zircon grains to obtain U-Pb ages. Cathodoluminescence images (Figure 17) show slightly rounded to prismatic grains, with approximate 1:1 ratio, with ratios 2:1 and 3:1 occurring in a subordinate way and a maximum length of 150 μm . Various crystals (ca. 41.9 %) exhibit the unique homogeneous to sub-homogeneous internal aspect in CL images characteristic of high-grade metamorphic zircons (high luminescence crystals and soccerball crystals, Figure 17). A similar proportion of grains with relict xenocrystic cores is observed (inherited crystals, Figure 17; ca. 40.5%), displaying a variety of internal structured. Crystals with preserved original igneous features (e.g. oscillatory zoning) represent the less frequent type (zoned crystals, Figure 16; ca. 17.6%), exhibiting thin bands of 10 to 30 μm thickness. Thick luminescent overgrowths (up to 60 μm) are widely observed in all varieties.

U-Pb dates obtained from zircon crystals of all types (high luminescence crystals, soccerball crystals, zoned crystals and “inherited crystals”) are strongly concentrated in a relatively narrow range (Figure 18). Zoned crystals provided core dates between 588 ± 11 Ma and 635 ± 10 Ma, exhibiting a higher

concentration of dates between ca. 619 Ma and ca. 588 Ma. Soccerball and high luminous crystals exhibit dates distributed between 617 ± 10 Ma and 585 ± 10 Ma. Inherited crystal core dates range between 1190 ± 18 Ma and 585 ± 10 Ma, exhibiting a stronger concentration between ca. 633 Ma and ca. 586 Ma as few cores older than ca. 633 have been found (5 grains). Luminous overgrowths at the rims of all types exhibit a main distribution of dates between ca. 615 Ma and ca. 588 Ma, ranging from 633 ± 11 Ma (at the rims of a zoned crystal) to 581 ± 11 Ma (at the rims of an inherited crystal).

Considering the data presented above (see Figure 18 and Supplementary File S5), the strong density of dates between ca. 619 Ma and ca. 585 Ma is probably correlated to the main metamorphic imprint on this sample. Considering the high concentration of dates and relatively low number of inherited cores analyzed with dates older than ca. 633 Ma, the hercynite-sillimanite-cordierite-garnet-biotite diatexite might have been submitted to a strong isotopic resetting at UHT conditions, as discussed at Section 5.

Stromatic orthopyroxene-garnet-biotite metatexite (sample P013)

124 spots were dated in 110 zircon grains to obtain U-Pb ages. Cathodoluminescence images shows some variability in the morphology of grains, and the majority of crystals are prismatic to gently round with approximate 2:1 ratio (other crystal proportions are observed in a lesser extent) with a maximum length of 200

μm . Approximately ca. 28% of the analyzed grains show a unique homogeneous to near-homogeneous isotropic internal aspect in CL-response, typical to high-grade metamorphic zircons (high luminescence crystals and soccerball crystals, Figure 17), and most soccerball crystals display uniform textures and diameter smaller than $75 \mu\text{m}$. Ca. 23% of the crystals preserve a well-defined oscillatory zoning with thin bands of 10 to $20 \mu\text{m}$ thick surrounded by metamorphic overgrowth with high luminescence (zoned crystals, Figure 16). Ca. 49% correspond to inherited zircon grains, often containing thick luminescent rims surrounding irregular-shaped cores or exhibiting preserved oscillatory zoning with little or no luminescent rims (inherited crystals, Figure 17).

The zircon U-Pb spot data spread broadly along the Concordia diagram, but as stated before those dates must be taken with caution, and for a careful analysis the spectra of crystal cores, crystal rims and for inherited cores were considered separately (Figure 19). High luminescence crystal cores provide dates distributed between 784 ± 17 Ma and 593 ± 10 Ma with a slightly higher peak of ca. 772 Ma. Soccerball crystals exhibit dates distributed between 710 ± 11 Ma and 597 ± 11 Ma with a discrete peak of ca. 616 Ma for core dates. Zoned crystal cores provided a range of dates between 844 ± 14 Ma and 604 ± 9 Ma with a main peak of ca. 623 Ma, and rims exhibit dates between 657 ± 11 Ma and 602 ± 10 Ma with a prominent peak of ca. 605 Ma. Inherited crystal cores display dates spread between 1701 ± 25 Ma and 595 ± 10 Ma, exhibiting the following

peak distribution: 1) main peak at ca. 599 Ma; 2) two lower peaks at ca. 746 and ca. 634 Ma; 3) smaller peaks distributed between ca. 780 and ca. 679 Ma. Rim dates for inherited grains and high luminescence crystals (“non-zoned crystals” on Figure 19) provide dates distributed between 806 ± 13 Ma and 594 ± 10 Ma, with two main peaks of ca. 597 Ma and ca. 707 Ma and slightly lower peaks between ca. 626 and ca. 610 Ma

Considering the data presented above (see Figure 19 and Supplementary File S5), the higher population of zircon crystals observed with dates between ca. 626 Ma and ca. 597 Ma is probably correlated to the main metamorphic imprint in this sample, while another important thermal event is registered by the population with dates between ca. 746 Ma and 707 Ma (see Section 5).

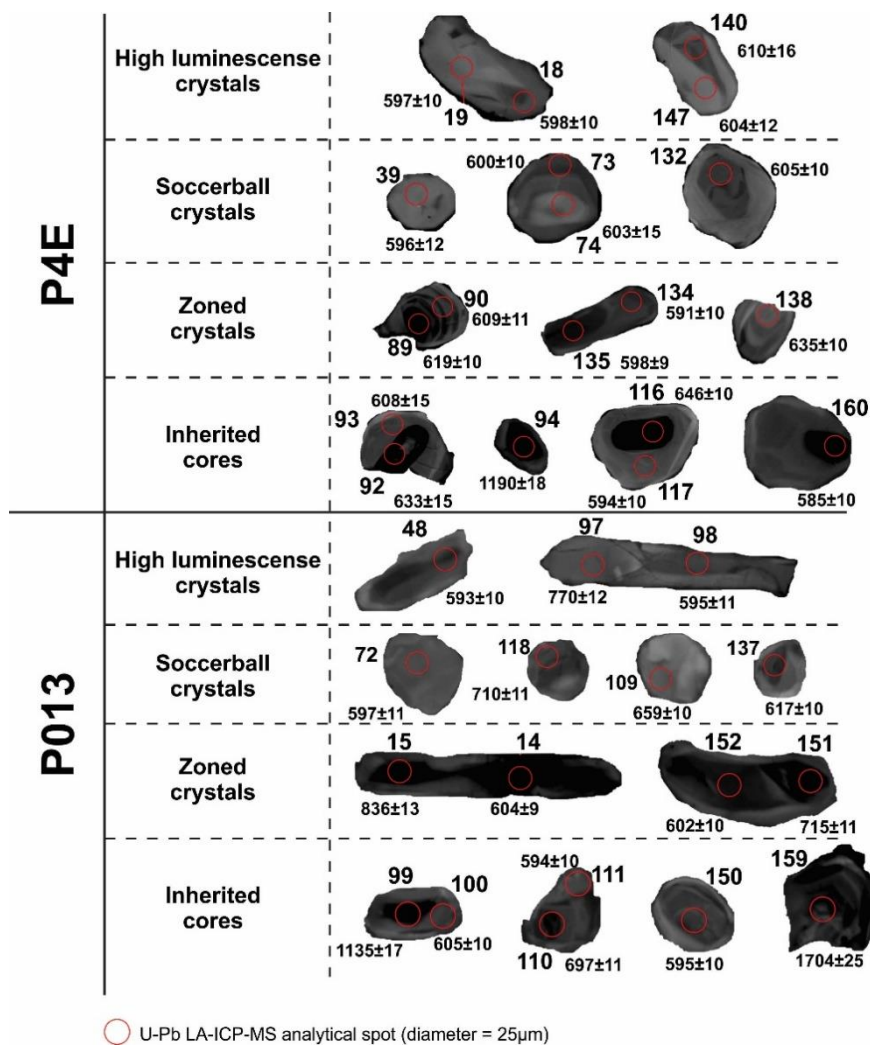


Figure 17 – Cathodoluminescence images of zircon grains analyzed on samples P4E and P013, exhibiting external shapes, internal morphologies, spot sites and $^{238}\text{U}/^{206}\text{Pb}$ ages.

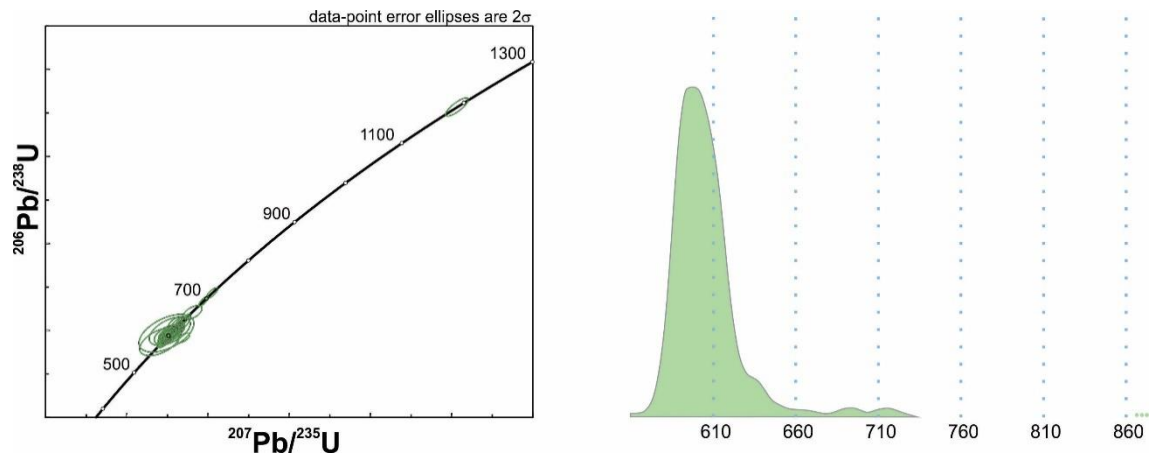


Figure 18 – Concordia diagram and age spectra obtained by U-Pb LA-ICP-MS dating of sample P4E.

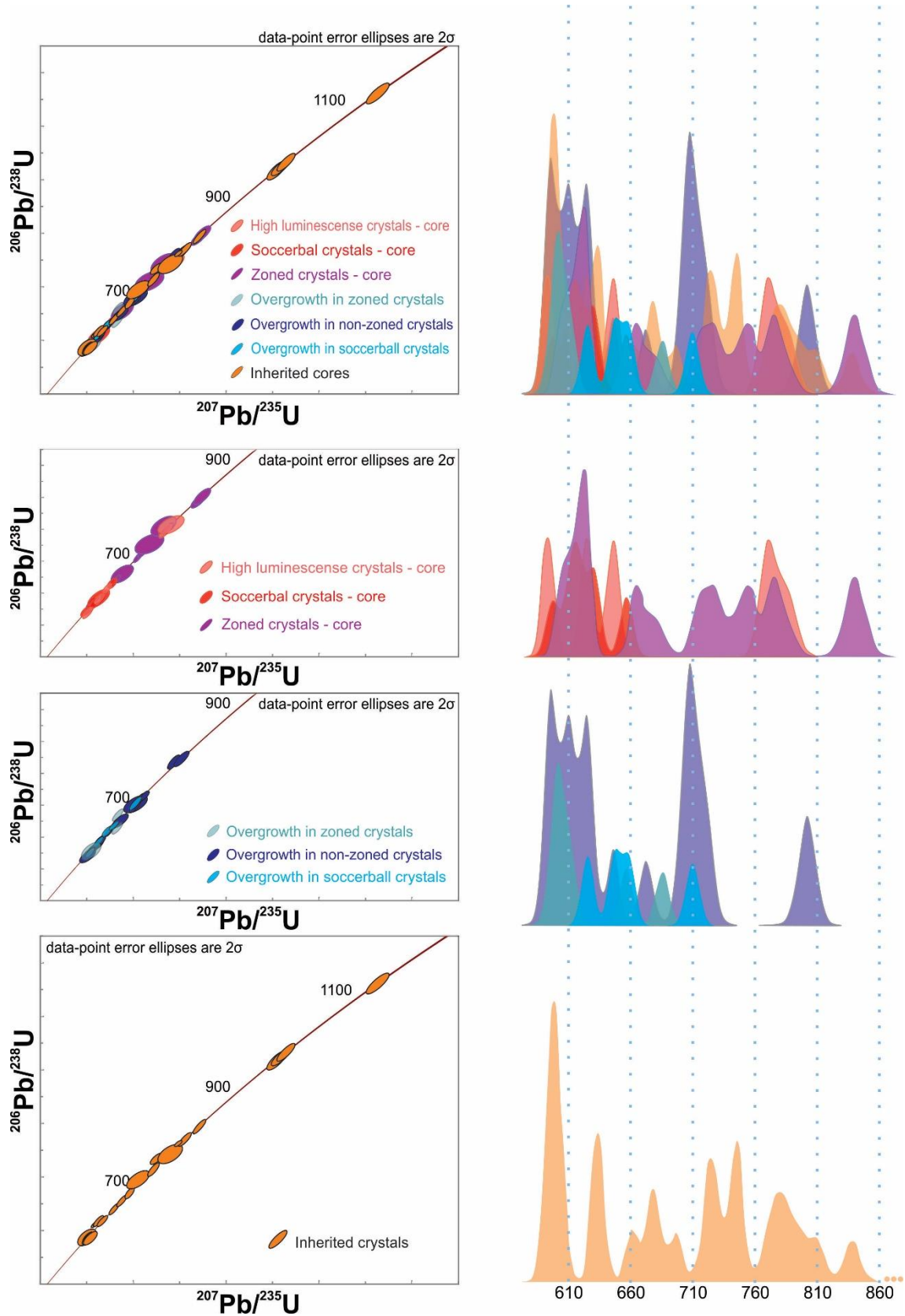


Figure 19 – Concordia diagrams and age spectra obtained by U-Pb LA-ICP-MS dating of sample P013. An overall distribution of dates is presented by juxtaposing core and rim dates of all four types of zircons described in the text (zoned, high luminous, soccerball and inherited), followed by separate diagrams for each.

5 Discussions

Metamorphic conditions registered on Caparao Range migmatites

Although several different rocks were studied in this work, exhibiting varied mineral assemblages and/or degrees of partial melting, the thermodynamic data obtained shows that both types of migmatites were submitted to ultrahigh temperature conditions during their metamorphic evolution. Hercynite-sillimanite-garnet migmatites provided concordant peak conditions on both thermobarometry methods: 1008 °C, 6.6 kbar via phase-equilibria modelling and 1023±55 °C, 7.8±0.8 kbar via Average P-T for hercynite-sillimanite-cordierite-garnet-biotite diatexites (sample P4E), and 1066 °C, 7.6 kbar via phase-equilibria modelling and 1076±83 °C, 7.9±0.9 kbar via Average P-T. Phase-equilibria modelling for orthopyroxene-garnet-biotite migmatites was calculated only for the best suited sample, orthopyroxene-garnet-biotite metatexite (sample P013), providing peak conditions of 988 °C, 10.9 kbar which differ from the results obtained with Average P-T inside the error margin for both temperature (1023±60 °C) and pressure (9.8±1.6 kbar). Orthopyroxene-garnet-biotite diatexites provided peak conditions of 965±46 °C, 7.9±1.4 kbar (disconsidering calculations involving the addition of a kspL component, which provided temperature values as high as

1090 °C, clearly overestimating peak conditions) and hercynite-orthopyroxene-garnet-biotite diatexites exhibited peak conditions at 1012±54 °C, 8.0±1.9 kbar, both calculated via Average P-T.

Metamorphic peak conditions obtained in this work were compared with previous thermobarometry works realized on the crystalline nuclei of the Araçuaí Orogen, specially the ones conducted on the surroundings of Caparao Range (Figure 19). High-amphibolite to granulite-facies rocks are well known on the crystalline nuclei (see Figure 19), and the compiled data presented shows that the works of Moreira (1997) and Costa (1998) obtained information on UHT conditions calculated from Opx-Cpx, Ca-in-Opx and Al-in-Opx thermometers (Bertrand & Mercier, 1985; Brey & Kohler, 1990) for Juiz de Fora Complex mafic (gabbroic to quartz-gabbroic) granulites (Figure 19). However, as discussed by Kelsey (2008), it is debatable if employing these types of calibrations for metamafic rocks without constraints to crystallization and metamorphic ages are a good mean to evaluate UHT metamorphic conditions or if the high temperatures may be related to the igneous crystallization of the protolith as both minerals are likely to be present on pre-metamorphic assemblages for these rocks.

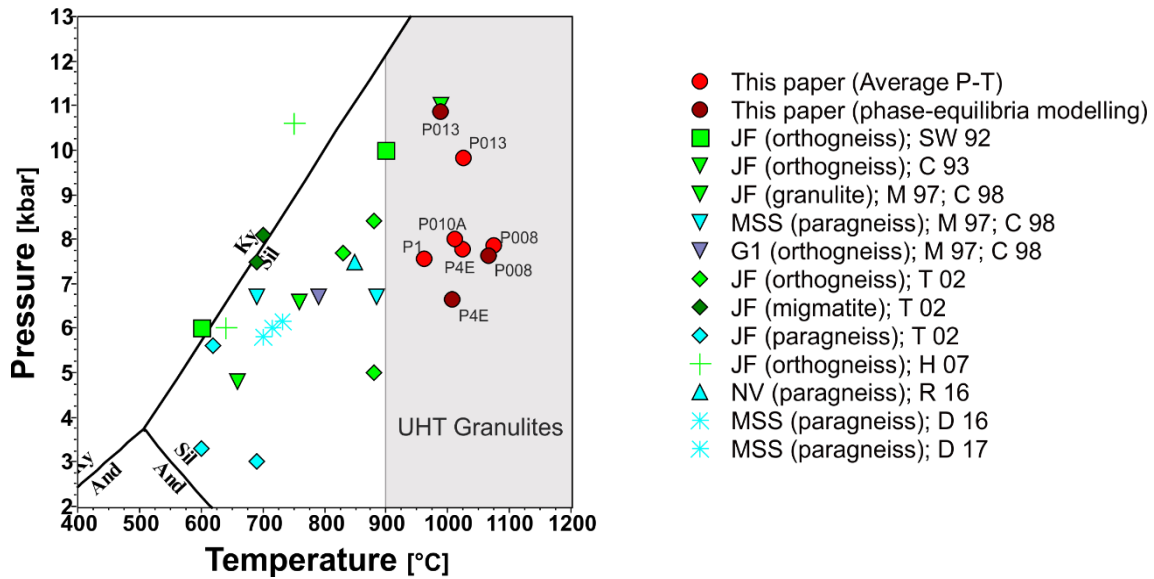
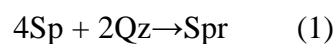


Figure 20 – Comparison between metamorphic conditions calculated for basement and metasedimentary units of the Araçuaí-West Congo Orogogen from previous works with the results obtained in in this paper. Samples studied in this work are named as in the previous sections. The gray field correspond to the UHT Granulites field (modified from Kelsey, 2008, and Brown, 2007). JF – Juiz de Fora Complex. MSS – Metasedimentary sequences, usually considered part of the Andrelândia Group. G1 – G1 Supersuite. NV – Nova Venécia Complex. SW 92 – Seidensticker & Wiedemann (1992). C 93 – Costa et al. (1993). M97; C 98. Moreira (1997) and Costa (1998). T 02 – Tsunogae et al. (2002). H 07 – Horn (2007). R 16 – Richter et al. (2016). D 16 – Degler et al. (2015). D 17 – Degler et al. (2017).

Metamorphic evolution of Caparao Range migmatites

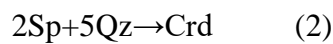
Results from petrography and mineral chemistry showed many similarities between the sapphirine-hercynite-sillimanite-garnet diatexites (sample P008) and the hercynite-cordierite-sillimanite-garnet-biotite diatexites (sample P4E), and whole-rock geochemistry (Supplementary File S4) shows that their compositions is correlated by a probable melt loss as: 1) P008 composition shows lower K₂O+Na₂O contents than P4E's; 2) phase-equilibria modelling for both samples provided highly similar models, and the main difference between them lie on the stability fields of peak metamorphic assemblages; 3) although Average P-T and phase-equilibria modelling provided similar peak P-T conditions for both, inside the UHT

metamorphism field (1023±55 °C, 7.8±0.7 kbar for P4E and 1037±64-1076±83 °C, 6.5±0.9-7.9±0.9 kbar for P008, Figures 12, 13, 14 and 20) and inside the predicted Spr+Qz stability field (Kelsey, 2008; Taylor-Jones & Powell, 2010), only P008 developed or preserved this paragenesis, described as the indicative of the highest temperature assemblage achievable by continental crust (Kelsey, 2008), as predicted by melt-loss modelling of granulite-facies rocks (White & Powell, 2002). As Spr+Qz assemblages are predominantly observed at the borders of hercynite crystals, a possible sapphirine-forming reaction for these rocks is represented by the equation:



Caparao Range hercynite-sillimanite-garnet migmatites show moderately to well preserved stable contacts between

hercynite and quartz (P4E, P008), also considered good indicatives of UHT metamorphism. Textural evidence for hercynite-forming reactions is absent on both samples, however a number of retrograde reactions may be proposed based on textural relations between minerals. The main hercynite breakdown products observed are cordierite, sillimanite or garnet coronas around crystals, described by the following equations:



As cordierite is rarely observed on sapphirine-hercynite-sillimanite-garnet diatexites (sample P008) and contacts between hercynite and quartz are commonly stable, a reverse reaction following equation (2) might have been developed during prograde metamorphism, as illustrated by the path between fields “2” and “3” on the phase-equilibria model (Figure 14) where cordierite become absent from the stable mineral assemblage.

P-T conditions calculated with Average P-T for sample P4E garnet cores and inclusion assemblages range from 744 ± 41 °C, 6.3 ± 2.0 kbar to 887 ± 55 °C, 5.4 ± 1.6 kbar, and for sample P008 it ranges from 704 ± 34 °C, 5.4 ± 1.7 kbar to 753 ± 43 °C, 5.8 ± 2.2 kbar. Phase-equilibria modelling for both samples isn't capable of predicting the actual assemblages that existed at these lower P-T conditions because melt loss changed its composition along the progressive metamorphism, but based on the observed inclusion assemblages some inferences are possible. P4E garnets usually contain hercynite

inclusions, sometimes preserving stable contacts with quartz (see Figure 3A), which are incompatible with the lower temperature values. As discussed by Waters (1991) and Kelsey (2008), hercynite is subject to exsolution upon cooling, separating into hercynite, magnetite and even ilmenite, and all observed crystals from sample P4E shows micrometer-scale magnetite exsolution lamellae; as a consequence, hercynite compositions are different from the ones present during either the early or late stages of metamorphism, as commonly observed with mineral phases on granulite-facies rocks (Pattison et al., 2003; Powel & Holland, 2008; Moraes et al., 2015). Therefore, the highest values calculated with Average P-T for garnet cores of sample P4E (840 ± 43 °C, 5.0 ± 1.4 kbar, Grt₁; 887 ± 55 °C, 5.4 ± 1.6 kbar, Grt₃) better represent the lowest prograde metamorphic conditions recorded on analysed hercynite-sillimanite-garnet migmatite samples, concordant with the calculated conditions for the stability of hercynite obtained by phase-equilibria modelling of both P4E and P008 (Figures 13, 14 and 21).

A possible P-T trajectory registered by samples P4E and P008 (Figure 21), considering the data presented in this work, starts at 840 ± 54 °C, 5.0 kbar, following a prograde path with peak on at least $1066\text{-}1076$ °C, 7.6-7.9 kbar. On the more melt-depleted zones (P008) the Spr+Qz assemblage stable at these conditions are better preserved than in the melt-richer zone (P4E), where lower peak conditions of $1008\text{-}1023$ °C, 6.6-7.8 kbar are registered. The lower set of P-T values obtained for P4E matrix

might represent the final cooling register of these rocks, attaining equilibrium

between 648-748 °C and 5.4-6.5 kbar, thus defining an anti-clockwise path.

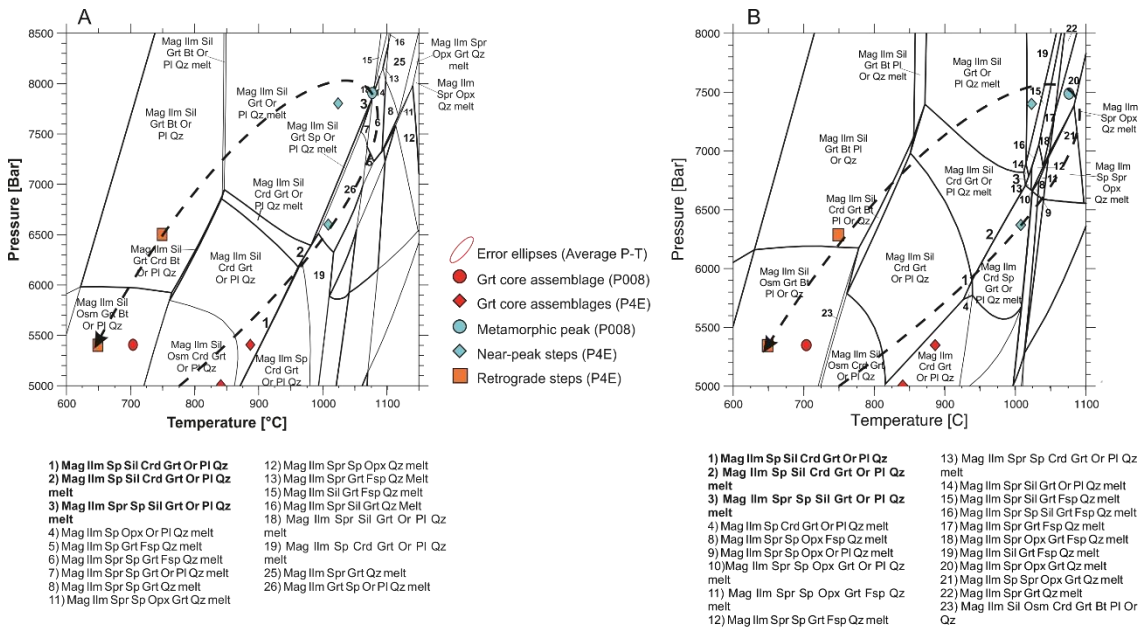


Figure 21 - Metamorphic evolution of Hc-Sil-Grt migmatites. P-T values obtained for metamorphic steps with Average P-T are combined with data from phase-equilibria modelling of samples P008 (A) and P4E (B) in order to better constrain the metamorphic story (see Figure 13).

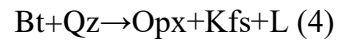
Orthopyroxene-garnet-biotite migmatites are more broadly distributed along Caparao Range and thus a greater variety of migmatitic structures can be observed. Although few samples were taken to whole-rock geochemical analyses, macroscopic structures, textures, mineral assemblages and mineral compositions from all samples of this type analyzed in this work (orthopyroxene-garnet-biotite metatexite, P013; orthopyroxene-garnet-biotite diatexite, P1 and P1D; hercynite-orthopyroxene-garnet-biotite diatexite, P010A) showed variations consistent to a set of samples from the same migmatite collected at different sites and thus are considered to represent different stages of evolution, similar to some examples presented and discussed by Sawyer (2008), however a detailed study of partial melting is outside the scope of this work.. As for their differences, the preserved gneiss features observed on

P013, associated with a stromatic structure where neosome was formed in situ, is characteristic of lower melting ratio migmatites, where melt migration is very limited. P1 and P1D represent a higher melt fraction state, as paleosome and gneiss structures are completely absent, and their differences probably lie on melt-migration dynamics and fractional crystallization processes. P010A might represent the most melt-depleted state as it contains preserved hercynite crystals, which could only be found as inclusions in P1D garnets, commonly in stable contacts with quartz. Although the association of garnet and high-Al orthopyroxene in stable contacts with quartz is not sufficient for attesting UHT-metamorphic conditions (Kelsey, 2008), it is observed in many of these terrains worldwide and Grt-Opx pairs have been used for Al-in-orthopyroxene thermobarometry successfully for determinate peak metamorphic

conditions (Pattison et al., 2003; Kelsey, 2008; Kelsey & Hand, 2015), with recent examples in the works of Rocha, Moraes, Möller, Cioffi & Jercinovic (2017) and Rocha, Moraes, Möller & Cioffi (2018). Orthopyroxene crystals with preserved peak-metamorphic compositions of samples P1, P010A and P013 range between $Al_{[apfu]}$ values between 0.14-0.27 as seen in many worldwide granulite to UHT-granulite terrains (Pattison et al., 2003), and peak metamorphic conditions calculated both with Average P-T (between 1006 ± 57 °C, 8.9 ± 1.6 kbar and 1023 ± 60 °C, 9.8 ± 1.6 kbar for sample P013 neosome; between 930 ± 61 °C, 9.0 ± 1.8 kbar and 965 ± 46 °C, 7.9 ± 1.4 kbar for sample P1 melanosome; between 928 ± 61 °C, 6.0 ± 1.8 kbar and 1012 ± 54 °C, 8.0 ± 1.9 kbar for sample P010A, see Section 4.2) and phase-equilibria modelling (988 °C, 10.9 kbar for sample P013 neosome) for these samples also indicate the occurrence of ultrahigh temperature metamorphism. As for the register of cooling stories, Average P-T results are mostly concordant (see Section 4.2 and Figure 22 below), and are complemented with information from phase-equilibria modelling. Although hercynite is present in two of the orthopyroxene-garnet-biotite migmatite samples (P1D and P010A, see Figures 8C and 10A-C), phase-equilibria modelling wasn't capable of predict Hc-bearing assemblages at any point of the P-T space.

The initial P-T conditions obtained for the orthopyroxene-garnet-biotite migmatites were calculated for P013 paleosome (garnet-biotite gneiss), between 604 ± 36 °C, 7.6 ± 1.4 kbar and

664 ± 46 °C, 8.6 ± 1.9 kbar (Figure 22), coinciding with the corresponding stability field calculated on the phase-equilibria model. As orthopyroxene is observed only on the neosome, the biotite-consuming, orthopyroxene-forming reactions:



served as spatial focuses of anatexis (White, 2008) starting at 889 °C, 10.2 kbar (Figures 16 and 22), and as T advanced beyond 900 °C biotite became unstable, indicative that all biotite observed on the matrix actually crystallized through interaction with melt or retrograde reactions. Apex thermodynamic conditions followed from 988 °C, 10.9 kbar to 1023 ± 60 °C, 9.8 ± 1.6 kbar, giving place to a retrograde path marked initially by skeletal textures on Grt and Opx at 875 °C, 8.5 kbar with final stabilization at ca. 590 °C, 7.5 kbar. P1 and P1D register a similar history: P1D Grt-core assemblages provide initial conditions of 637 °C, 7.0 kbar, below the melt-in isograd, which rise to initial anatectic conditions between 815 ± 54 °C, 7.6 ± 1.6 kbar and 841 ± 42 °C, 7.6 ± 1.2 kbar (garnet cores and inclusion assemblages of samples P1_M and P1D, Average P-T). Peak conditions calculated with P1_M assemblage are attained between 930 ± 61 °C, 9.0 ± 1.8 kbar and 965 ± 46 °C, 7.9 ± 1.4 kbar. P1D peak conditions of 909 ± 74 °C, 8.4 ± 2.0 kbar must represent the minimum P-T of melt crystallization. The retrograde path downgrade to a range between 825 ± 48 °C, 7.8 ± 1.6 kbar and 858 ± 50 °C, 7.6 ± 1.6 kbar, corresponding to a range observed both at P1 melanosome, related to Opx₂, and P1D. The final retrograde step is registered at 643 ± 40 °C, 5.9 ± 1.5 (Figure

22). Sample P010A register initial metamorphic conditions of 882 ± 39 °C, 6.8 ± 1.4 kbar, rising to peak conditions at 1012 ± 54 °C, 8.0 ± 1.9 kbar. Retrograde conditions are registered by matrix

assemblages on a range between 900 ± 53 °C, 6.4 ± 1.8 kbar and 928 ± 61 °C, 6.0 ± 1.8 kbar. All metamorphic paths from orthopyroxene-garnet-biotite migmatites define anti-clockwise paths.

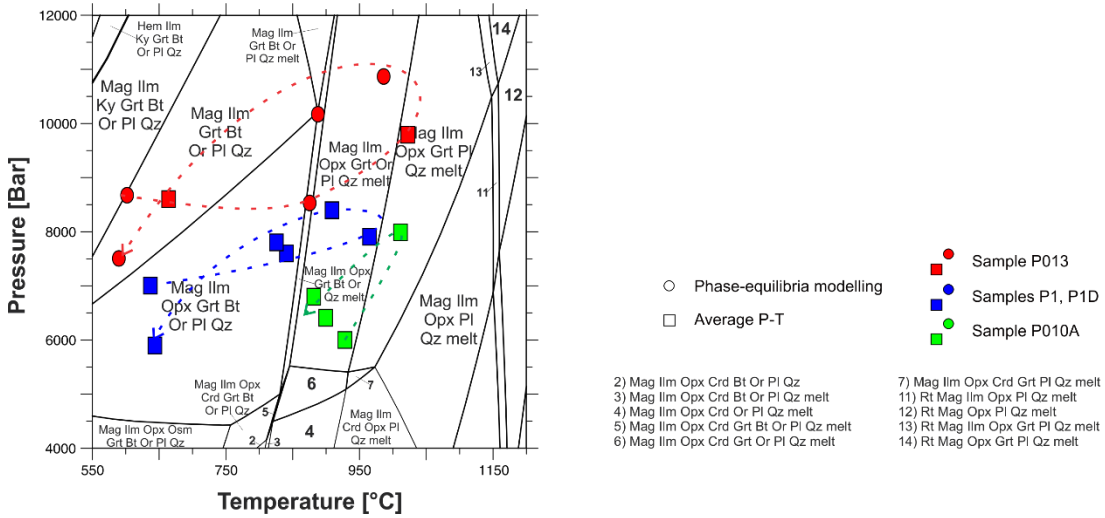


Figure 22 - Metamorphic evolution of Opx-Grt-Bt migmatites. Thermodynamic data obtained with the three methods (conventional thermobarometry, Average P-T and phase-equilibria modelling) is combined with the modelling of sample P013 in order to constrain a more complete metamorphic story for samples P013, P1, P1D and P010A, and each metamorphic path is presented as dashed curves. All metamorphic stories define an anti-clockwise path.

Zircon geochronology and age constraints in the light of the Araçuaí Orogen evolution

Zircon populations from both samples exhibit remarkable differences on age distributions as presented on Section 4.4. Hercynite-sillimanite-cordierite-garnet-biotite diatexite (samle P4E) display the highest concentration of ages between ca. 619 Ma and ca. 585 Ma as a single peak on date histogram (Figure 18), a pattern observed on the analysis of all zircon types of the sample. Inherited zircon cores show rare dates older than ca. 633, (5 spots), pointing out to a probable large-scale erasure of U-Pb chronometers due to UHT metamorphism as peak metamorphic conditions registered on this sample reached temperatures beyond 1000 °C and this migmatite underwent high degrees of partial melting, as discussed

by several authors (Gerdes & Zeh, 2009; Rubatto, 2017; Vervoort & Kemp, 2016).

Orthopyroxene-garnet-biotite metatexite (sample P013), on another hand, exhibit a wider distribution of ages along the Concordia diagram and different histogram shapes depending on zircon type and crystal domain (rims or cores, Figure 19). Inherited zircon core dates are distributed between ca. 1701 Ma and ca. 595 Ma, showing a main statistical peak at ca. 599 Ma, second-order peaks at ca. 746 Ma and ca. 634 Ma and a considerable number of dates older than 635 Ma (52 spots), indicating that inherited ages have been preserved to a considerable extent. The general distribution of dates (Figure 19) shows a higher population of spots (both from cores and luminescent rims) between ca. 626 Ma and ca. 597 Ma and a second

important range (mostly from luminescent rims) between ca. 746 Ma and 707 Ma. Although the sample also records UHT metamorphic conditions, reaching temperatures between 988 °C and ca. 1023 °C, erasure of U-Pb chronometers isn't extensive as observed on sample P4E. A possible explanation for the better preservation of the isotopic system might be the low degree of partial melting observed on the orthopyroxene-garnet-biotite metatexite.

Both samples provided higher concentration of U-Pb dates (specially on metamorphic overgrowths) on a similar time range (ca. 619-585 Ma on sample P4E and ca. 626-597 Ma on sample P013) which is concordant to the metamorphic ages obtained for Caparaó Suite and Juiz de Fora (ortho)granulites and migmatites on the works of Söllner, Weber-Diefenbach & Lammerer (1991; ca. 586 Ma), Da Silva et al. (2002; ca. 587 Ma), Noce et al. (2007; ca. 594 Ma), Heilbron et al. (2010; ca. 654-584 Ma), Gualandi, Geraldes, Inacio, Almeida & Rodrigues (2015; ca. 603-584 Ma), and Andrelândia Group and other Neoproterozoic metasedimentary units on the works of Alves, Geraldes, Gualandi & Almeida (2015; ca. 598-583 Ma) and Degler, Pedrosa-Soares, Dussin, Queiroga & Schulz (2017; ca. 618-573 Ma). This range of ages also is concordant with magmatic ages constrained by: G1 Supersuite pre-collisional magmatism (ca. 630-630 Ma: Pedrosa-Soares et al., 2008); charnockite intrusions northwest (Galileia Suite, ca. 584 Ma: Da Silva et al., 2002) and southwest (Divino Suite, 592-603 Ma; Novo, Pedrosa-Soares, Noce, Alkmim & Dussin, 2010) of the studied area;

crystallization ages for metapyroclastics associated to Rio Doce arc magmatism (584-595 Ma: Novo, Pedrosa-Soares, Vieira, Dussin & Da Silva, 2018); a granodiorite intrusion on Nova Venécia paragneisses (593 Ma: Richter et al., 2016). Those ages are considerably older from the peak metamorphic ages recorded on the paragneiss complexes of the Araçuaí Orogen and northern Ribeira Belt (560-575 Ma; De Campos et al., 2004a; Bento dos Santos, Munhá, Tassinari, Fonseca & Dias Neto, 2011; Bento dos Santos, Tassinari & Fonseca, 2015; Gradim et al., 2014; Dias et al., 2016; Richter et al., 2016). Sample P013 also exhibit a considerable density of dates between ca. 746 and 707 Ma, registered both on luminescent overgrowths and grain cores of all four types. This range of ages is analogue to the period of oceanic crust generation on the Macaúbas Basin, which preceded the Araçuaí Orogen (ca. 740 Ma; Pedrosa-Soares et al., 2008), to the rift-related Southern Bahia alkaline province (ca. 732-696 Ma; Rosa et al., 2007) and to the Rio Negro-Serra da Prata magmatic arc in the Ribeira Fold Belt (ca. 860-600 Ma). A compilation of U-Pb ages is presented on Supplementary File S6.

As granulite-facies metamorphism and specially UHT metamorphic conditions might cause both erasure and multiple zircon crystallization peaks during the thermodynamic evolution of an orogeny, and as zircon crystallization usually isn't observed during the metamorphic peak on UHT terrains (Hoskin & Schaltegger, 2003; Korhonen et al., 2013; Kelsey & Hand, 2015), the ranges of ages between ca. 619-585 Ma for sample P4E and ca. 626-597 Ma for sample P013 are

considered to be minimum estimatives for the metamorphic peak that affected the studied rocks, because even considering a hypothesis where all the zircons taken into account for this analysis are crystallized from migmatitic melt – what's discarded due to the CL features, characteristic of metamorphic zircons - the associated metamorphic ages are necessarily older.

Final remarks: implications to the context of the Araçuaí Orogen

As the minimum metamorphic ages presented here are considerably older than the metamorphic peak age observed on several other metasedimentary units, it might suggest that an actual peak occurred before what was obtained on previous studies (see Supplementary File S6) and involved ultrahigh temperatures during the pre- to early syn-collisional stage of the Araçuaí Orogen. The processes responsible for attaining those conditions on the continental crust are still debated (Kelsey, 2008; Korhonen et al., 2013; Kelsey & Hand, 2015), and two complementary hypothesis are proposed for explaining the UHT conditions observed in these rocks:

- 1) As the minimum metamorphic ages presented here suggest a correlation with arc-related magmatism (G1 Supersuite), magma underplating processes might be responsible for attaining UHT metamorphism, as suggested by Costa (1998): combining increased radiogenic heat production due to crustal thickening and the large-scale generation of magmas might be responsible for achieving UHT

conditions at middle to lower crust. The presence of charnockite plutons on nearby areas (Manhuaçu and Divino regions) and even intruded on the orthopyroxene-garnet-biotite diatexites (Amaral et al., 2016; Vieira et al., 2017; outside of map scale of Figure 1) corroborate this proposition;

- 2) Orthopyroxene-garnet-biotite migmatites also presented high pressures, reaching up to 10.9 kbar (orthopyroxene-garnet-biotite metatexites, sample P013) in contrast to maximum pressures of 7.9 kbar observed on the hercynite-sillimanite-garnet migmatites (sapphirine-hercynite-sillimanite-garnet diatexite, sample P008). The data suggest that the two migmatite types must represent rocks from different crustal levels (those values implies on depths of 36.3 km and 26.3 km respectively, as discussed by Hacker et al., 2015). As ages are arc-related, the higher pressures observed on the orthopyroxene-garnet-biotite migmatites might correspond to tectonic slices of sedimentary sequences subducted along the slab, which were thrust and juxtaposed to shallower UHT rocks during the pre- to syn-collisional stage of the Araçuaí Orogen.

The proposition of a subduction-related environment for explaining UHT metamorphism is in concordance with observations on UHT terrains worldwide, as discussed by Kelsey & Hand (2015). A “slab window” mechanism is discussed as a source of heat for UHT metamorphism during subduction, as the upwelling of the asthenosphere promotes a large influx of

heat into the upper plate. This might explain the restricted occurrence of UHT metamorphic rocks in the Araçuaí Orogen: the extension of the “slab window” would be the limitation for this kind of metamorphism (Kelsey & Hand, 2015). A model based solely on crustal thickening is discarded as complex nappe systems are absent on the Araçuaí Orogen; an example of nappe-related UHT systems is observed on the Brasília Fold Belt, as discussed by Del Lama, Zanardo, Oliveira & Morales (2000), Campos Neto & Caby (2000), Rocha et al. (2018) and Tedeschi et al. (2018).

As stated before, this is the first UHT metamorphism occurrence registered on metasedimentary sequences in the Araçuaí Orogen attested by characteristic mineral assemblages and thermodynamic data. As discussed by Kelsey (2008) and Kelsey & Hand (2015), with the advance of studies on granulite-facies terrains more of these

occurrences are likely to be reported on the scientific literature (Figure 22). Still, some questions remain unanswered. As P-T conditions for all analyzed orthopyroxene-garnet-biotite migmatite samples are similar, the question about what caused the different degrees of melting remains open. It is notable that along the Caparao Range there are also lower and higher melting degree zones among these migmatites (see Figure 1 for a schematic map), and the diatexite zones are commonly associated with major structures like regional shear zones and fold hinge zones. It is possible that the deformation that created those structures generated preferential migration paths for fluids related to the arc-related plutons crystallization, causing a large scale anatexis process by lowering the regional solidus curve and thus increasing partial melting ratios. More detailed studies are needed to better comprehend the causes of the differences in migmatitic structures.



Figure 23 - Modified Kelsey & Hand (2015) map of known worldwide occurrences of UHT terrains, with addition of the Caparao Range (red star) and the Guaxupé Nappe System (red square; Rocha et al., 2018; Tedeschi et al., 2018).

The processes that led to the uplift of the rocks exposed on Caparao Range also need to be better understood. As peak metamorphic assemblages are well preserved, fast uplift rates are expected in order to have prevented even the metastable assemblages from complete retrograde reactions, although the extraction of melt is also capable of expanding the P-T range in which those assemblages are stable (White et al., 2002; Kelsey, 2008; Kelsey & Hand, 2015).

6 Conclusions

Within the Caparao Range, migmatites derived from metasedimentary protoliths are juxtaposed to the orthogneisses and associated migmatites of the Caparao Suite/Juiz de Fora Complex by shear zones. These have been divided in two types: orthopyroxene-garnet-biotite migmatites and hercynite-sillimanite-garnet migmatites, and the differences in their mineral assemblages is indicative that both had different protoliths. Peak metamorphic conditions calculated for the orthopyroxene-garnet-biotite migmatites are between 988-1023 °C and 9.8-10.9 kbar, preserving a peak metamorphic assemblage composed of orthopyroxene, garnet, plagioclase, orthoclase, quartz and accessory ilmenite and rutile. Hercynite-sillimanite-garnet migmatites register peak metamorphism at 1066-1076 °C, 7.6-7.9 kbar, preserving a peak metamorphic assemblage composed of sapphirine, ilmenite, hercynite, sillimanite, plagioclase, orthoclase, quartz with accessory magnetite, and as the coexistence of sapphirine and quartz is

preserved, a new ultrahigh temperature (UHT) metamorphism occurrence is confirmed both with thermodynamic and mineral assemblage constraints. Minimum metamorphic ages for the two types of migmatites lies between ca. 626-585 Ma, coeval with arc-related magmatism observed on the Araçuaí Orogen and thus the geotectonic setting for attaining UHT metamorphic conditions is considered to be related to subduction. More detailed petrological and geochronological studies are needed to better understand differences observed on degrees of partial melting between Caparao Range migmatites and to better correlate the migmatites studied in this work with other metasedimentary units observed on the Araçuaí Orogen.

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4 RESULTADOS COMPLEMENTARES - PETROGRAFIA

As diferentes litologias descritas na Serra do Caparaó ao longo deste trabalho são abaixo abordadas em detalhe. Na Tabela 4.1, abaixo, constam as coordenadas (datum WGS 84, UTM 24S) e litotipos descritos em cada ponto (ver Figura 2, Capítulo 2, para representação dos pontos em mapa; A.P. – fases acessórias).

Ponto	Amostra	Litotipo	X (m)	Y (m)	Z (m)	Associação Mineral
P1	P1	Opx-Grt-Bt diatexito	207104	7729088	1347	Ilm+Opx+Grt+Bt+Or+Pl+Qz; A.P.: Rt, Zr, Mnz, Ap, Py, Cpy, Po
	P1C	Bt-Opx-Cpx gnaiss				Bt+Opx+Cpx+Qz+Or+Pl; A.P.: Opc, Zr
	P1D	Opx-Grt-Bt diatexito (leucossoma)	207175	7729248	1352	Rt+Grt+Bt+Or+Pl+Qz; A.P.: Ilm, Zr, Mnz, Ap, Py, Cpy
P2	P2A	Opx-Cpx-Hbl meta a diatexito	207836	7736674		Cpx+Opx+Hbl+Or+Pl+Qz; A.P.: Opc, Ap, Zr, Bt, Aln
P3	P3	Opx-Cpx diatexito	207909	7737316		Opx+Cpx+Pl+Qz±Hbl; A.P.: Ap, Opc, Zr
P4	P4A					Cpx+Opx+Pl+Qz; A.P.: Or, Opc, Ap, Zr.
	P4B					Cpx+Opx+Bt+Pl+Qz; A.P.: Opc, Ap, Zr.
	P4C	(Hbl-Bt)-Opx-Cpx diatexito	207977	7737495	2839	Bt+Hbl+Cpx+Opx+Pl+Qz; A.P.: Opc, Ap, Zr.
	P4D					Bt+Opx+Cpx+Hbl+Pl+Qz; A.P.: Opc, Ap, Zr.
	P4E	Hc-Sil-Crd-Grt-Bt diatexito				Ilm+Hc+Sill+Crd+Grt+Bt+Pl+ Or+Qz; A.P.: Ap, Zr, Mnz, Mag
P010A					Ilm+Hc+Opx+Grt+Bt+Or+Pl+ Qz; A.P.: Rt, Zr, Ap, Mnz, Py,	
P010B	Hc-Opx-Grt-Bt diatexito	207970	7737514	2838	Mag	
	P009	Opx-Cpx quartzito				Opx+Cpx+Qz. A.P.: Pl, Zr, Opc

P005	P005	Grt-Bt gnaiss	202666	7740612	1517	Bt+Grt+Qz+Pl+Or; A.P.: Opc+Zr+Mnz+Ap+Rt
	P006A	Grt-Bt metatexito				Bt+Grt+Qz+Pl+Or; A.P.: Crd+Sil+Hc+Zr+Opc
P006	P006B	Bt-Opx-Cpx gnaiss	203491	7741207	1797	Bt+Opx+Cpx+Or+Pl+Qz; A.P.: Ap, Opc, Zr, Hbl
	P006C	Cpx-Bt-Opx-Hbl metatexitos				Cpx+Bt+Opx+Hbl+Or+Pl+Qz; A.P.: Opc, Zr, Ap
P007	P007	Opx-Hbl-Cpx diatexito	204207	7740351	2054	Opx+Hbl+Cpx+Pl+Qz; A.P.: Opc, Or, Zr, Ap
P008	P008	Spr-Hc-Sil-Grt diatexito	206475	7739546	2321	Spr+Ilm+Hc+Sill+Grt+Pl+Or+ Qz; A.P.: Ap, Zr, Mnz, Mag
	P012A	(Rt)-Bt-Grt diatexito (leucossoma)	206484	7734351	2230	Bt+Rt+Grt+Or+Pl+Qz; A.P.: Opc, Zr, Mnz.
P012	P012B	(Ecp)-Ttn-Aug gnaiss				Ecp+Ttn+Aug+Pl; A.P.: Opc, Ap, Zr
P013	P013	Opx-Grt-Bt metatexito	204722	7732591	1847	Ilm+Opx+Grt+Bt+Or+Pl+Qz; A.P.: Ap, Zr, Mnz, Mag, Py

4.1 Hc-Sil-Grt migmatitos

Os Hc-Sil-Grt migmatitos são observados apenas na parte central da Serra do Caparaó. Sua área de exposição é variável, se apresentando em faixas cuja continuidade lateral se dá na ordem de dezenas a centenas de metros, intercalados tectonicamente aos Opx-Cpx migmatitos da Suíte Caparaó ou aos Opx-Grt-Bt migmatitos por meio de zonas de cisalhamento.

São diatexitos primários, exibindo morfologias variadas: na porção centro-oeste da Serra, próximo ao acampamento do Terreirão (Figura 1A-E, afloramento P008), são observadas estruturas do tipo *schlieren*, com *schliere* de resíduo cinza-azulado, exibindo granadas milimétricas, localmente intercalados ao leucossoma branco-acinzentado que por vezes forma bolsões com granadas de dimensões centimétricas. A paragênese observada registra um pico metamórfico em condições de temperatura ultra-alta (UHT), com formação de safirina e córindon no resíduo em contatos estáveis com quartzo (Spr-Hc-Sil-Grt±Crn diatexitos). Próximo aos contatos com os Opx-Cpx migmatitos, as texturas migmatíticas são parcialmente deformadas e as rochas exibem uma foliação milonítica pronunciada. No centro da Serra, entre o Pico da Bandeira e o Pico Calçado (afloramento P4), o migmatito peraluminoso apresenta uma transição entre morfologias estromáticas, nas proximidades do contato com os Opx-Cpx migmatitos, para diatexitos *schollen* a *schlieren* primários, exibindo

quantidades variadas de leucossoma e resíduo, porém geralmente em proporções semelhantes. A associação mineralógica observada evidencia reações associadas tanto ao pico metamórfico quanto a estabilização em condições retrógradas (ver abaixo), com preservação local de hercinita em contatos estáveis com quartzo (Hc-Sil-Crd-Grt-Bt diatexitos). Nesta localidade exibem uma estruturação “bandada” bem pronunciada, marcada pela orientação preferencial dos *schlieren* segundo a foliação e possivelmente impressa pela deformação sin-anatética.



Figura 1- Aspectos de campo e detalhes macroscópicos do diatexitos *schlieren* primário, afloramento próximo ao Terreirão. A) Vista do lajedo (Ponto P008); B) Detalhe da estruturação *schlieren*, destacada pelo intemperismo; C) Leucossoma rico em granada, com cristais de dimensões centimétricas; D) Interior da rocha, exibindo leucossoma em tons branco a cinza-claro e resíduo de coloração azul a cinza-azulado); E) Amostra do resíduo, exibindo núcleo fresco de coloração azul escuro acinzentado. A-E – afloramento P008.

4.1.1 Spr-Hc-Sil-Grt diatexitos

O resíduo se dispõe como *schliere* milimétricos a centimétricos, localmente exibindo orientação preferencial mas predominantemente difusos em meio ao leucossoma. Podem perfazer de 30 a 50% do migmatito, e consistem em granulitos cuja associação mineralógica é composta por Spr+Ilm+Sill+Herc+Grt+Pl+Or+Qz±Crd±Crn. A safirina e o córindon ocorrem em quantidades acessórias e formam cristais diminutos, com dimensões sub-milimétricas, e a paragênese de pico é marcada por raros contatos estáveis observados entre Spr+Qz±Crn (Figura 2A, B) e/ou por cristais de Spr formados a partir das bordas de cristais de Hc (Figura 2C, D). A hercinita ocorre em quantidades essenciais, se apresentando principalmente como cristais milimétricos livres na matriz, exibindo contatos estáveis com quartzo (Figura 2E e 2F), podendo ainda se encontrar envoltos por mantos de Sill, ou, mais raramente, Crd e/ou Bt. A silimanita ocorre predominantemente como fase livre na rocha, na forma de cristais prismáticos desprovidos de orientação preferencial, e na bordas de alguns cristais são observados intercrescimentos simplectíticos com cordierita (Figura 2G, H). A cordierita é escassa e ocorre preferencialmente nas bordas de Spr, Hc ou Sill, comumente contendo diminutas inclusões de minerais opacos e podendo exibir pinitização intensa. A biotita, de um modo geral, é rara e observada majoritariamente associada às bordas de outras fases aluminosas e/ou ferromagnesianas (Bt₂), ocorrendo como inclusões apenas em poucos cristais de Grt (Bt₁). As granadas (Figuras 2I, J) são abundantes, podendo exibir inclusões de Qz, Pl, Or, Opc, Bt e/ou Hc (esta preferencialmente próximo às bordas) ou ocorrer como cristais límpidos, e por vezes exibem um leve alongamento preferencial; em alguns cristais se observam embainhamentos preenchidos por Pl, Qz, Or ou, ainda, Hc envolta por estes minerais, e intercrescimentos simplectíticos entre Grt+Hc+Qz são observados (Figura 2K) nas bordas de alguns cristais.

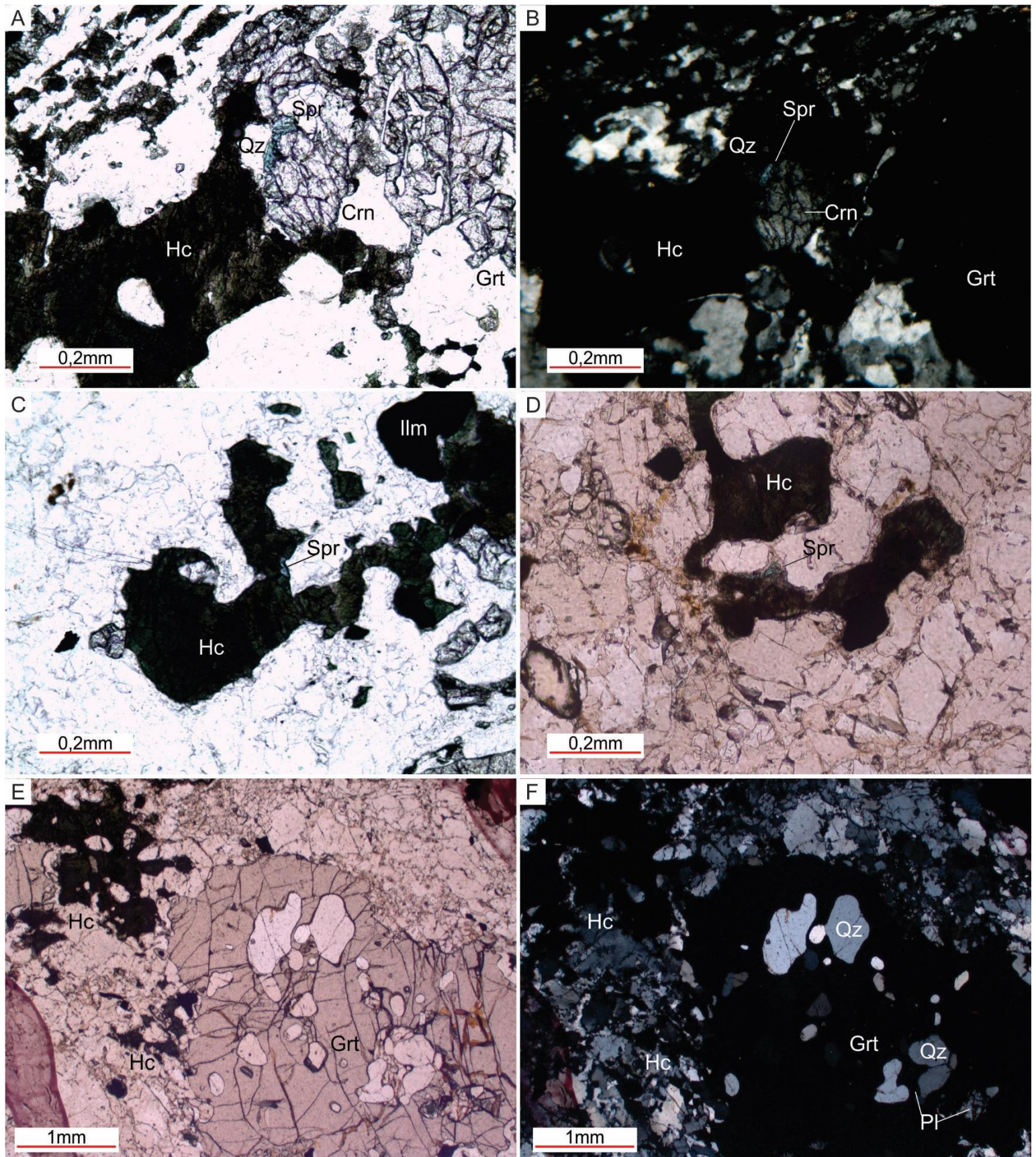


Figura 2 - A e B) Cristal de safirina associado ao córdon, em contatos estáveis com quartzo; C e D) Cristais de safirina formados a partir das bordas de hercinita; E e F) Cristais de hercinita em contatos estáveis com quartzo, associados à granada (cont.). A-D – objetiva 10x; E, F – objetiva 2,5x. Amostra P008.

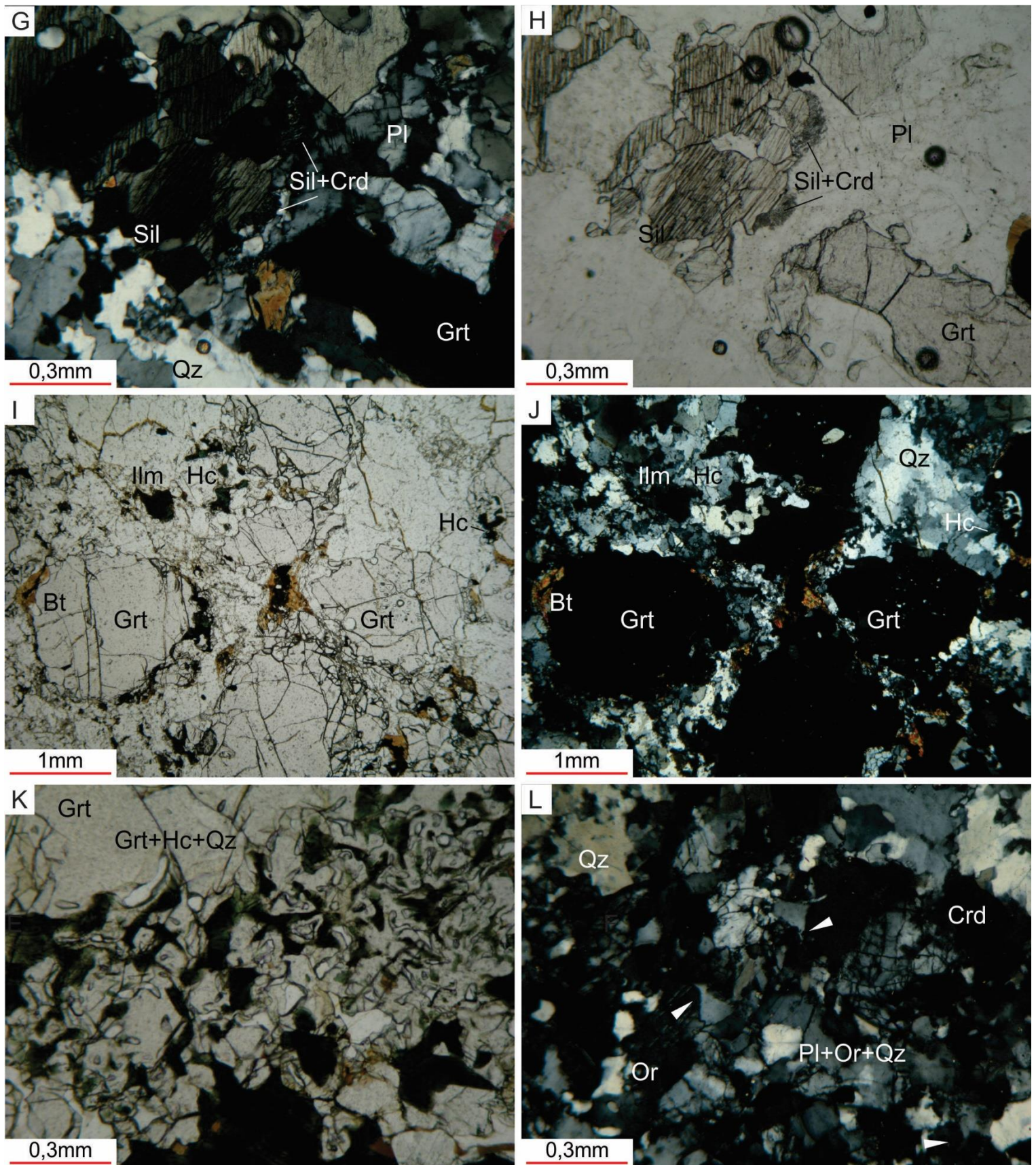


Figura 2 (cont.) - G) Intercrescimentos simplectíticos entre silimanita e cordierita nas bordas de cristais de Sill; H) Cristal livre de cordierita, associado a granada e hercinita; I e J) Cristais de granada límpidos e poiquiloblásticos; K) Intercrescimentos simplectíticos entre granada, hercinita e quartzo; L) Matriz (Pl+Or+Qz±Crd) exibindo cristais com geometrias em cúspide (triângulos brancos), indicando cristalização em espaços intersticiais durante cristalização do melt. G, H, K, L – objetiva 10x; I, J – objetiva 2,5x. K – amostra RS059. Demais – amostra P008.

Plagioclásio, ortoclásio e quartzo são principalmente xenoblásticos, exibem contatos predominantemente engrenados a poligonais entre si, denotando forte recristalização, porém pontualmente se observam contatos lobulados e geometrias agudas ou em cúspide, indicando que localmente parte do *melt* ficou aprisionado e cristalizou nos espaços remanescentes entre os cristais do resíduo (Figura 2L).

O leucossoma é predominantemente granoblástico, apresenta associação mineralógica a Bt+Ilm+Hc+Sill+Grt+Pl+Or+Qz, com Bt, Ilm, Hc e Sill somando menos que 10% do volume da rocha; não se observam Spr ou Crn. Hercinita ocorre na forma de cristais escassos no leucossoma, comumente associada a ilmenita e predominantemente em desequilíbrio com os minerais félsicos, exibindo mantos de Sill ou, mais raramente, Crd. Cordierita é rara, comumente associada a alteração de Hc ou Sill. Biotita ocorre majoritariamente associada às bordas de Grt, Hc, Ilm e Sill. A silimanita ocorre como cristais prismáticos sem orientação preferencial, predominantemente em equilíbrio mas podendo exibir localmente intercrescimentos simplectíticos, nas bordas, com Crd. Granada é o principal máfico, formando cristais límpidos ou com inclusões tanto dos demais minerais essenciais quanto de Zr e Mnz; nas bordas dos cristais também se observam embainhamentos, preenchidos por Pl, Qz, Or, Bt e, em menor frequência, também Sill, Hc ou Crd. Plagioclásio costuma ocorrer como cristais xenoblásticos de granulação fina, raramente anti-pertíticos e exibem maclas ocasionalmente recurvadas; ortoclásio é comumente micropertítico, podendo ocorrer como cristais tabulares ou xenoblásticos de granulação fina a média; quartzo ocorre como cristais xenoblásticos de granulação fina a média, podendo exibir embainhamentos preenchidos pela matriz. A matriz perfaz um volume considerável do leucossoma, e é composta por intercrescimentos de Pl+Or+Qz de granulação muito fina, em contatos lobulados a sinuosos e podendo exibir geometrias em cúspide e ramificadas, o que atesta a origem a partir de cristalização do melt residual; pode ainda exibir recristalização incipiente, exibindo contatos poligonais a engrenados localmente.

Os Spr-Hc-Sil-Grt diatexitos exibem estruturas miloníticas próximo aos contatos com os Opx-Cpx migmatitos, que oblitera parcialmente a estruturação original da rocha; cordierita passa a ser observada como parte da matriz da rocha, ao passo que não se observa safirina. A foliação milonítica é marcada pela orientação da trama da matriz (Qz+Or+Crd), por cristais de Qz, Or, Pl, Ilm, Crd e Herc estirados (Figura 3A, B) ou alongados segundo a mesma e cristais de Bt, Sill e, com menor frequência, Grt preferencialmente orientados e/ou alongados segundo a mesma; o fluxo é anastomosado, contornando porfiroblastos de Grt, porfiroclastos de Pl ou Or (Figura 3C, D) domínios quartzo-feldspáticos de granulação fina a média, agregados de cristais de Sill ou de Sill+Herc+Opc±Grt+Qz+Or. A matriz da rocha é constituída por cristais recuperados e recristalizados

de Qz e, em menor proporção, Pl e Or, além da blastese de Crd e Bt a partir de outros minerais aluminosos.

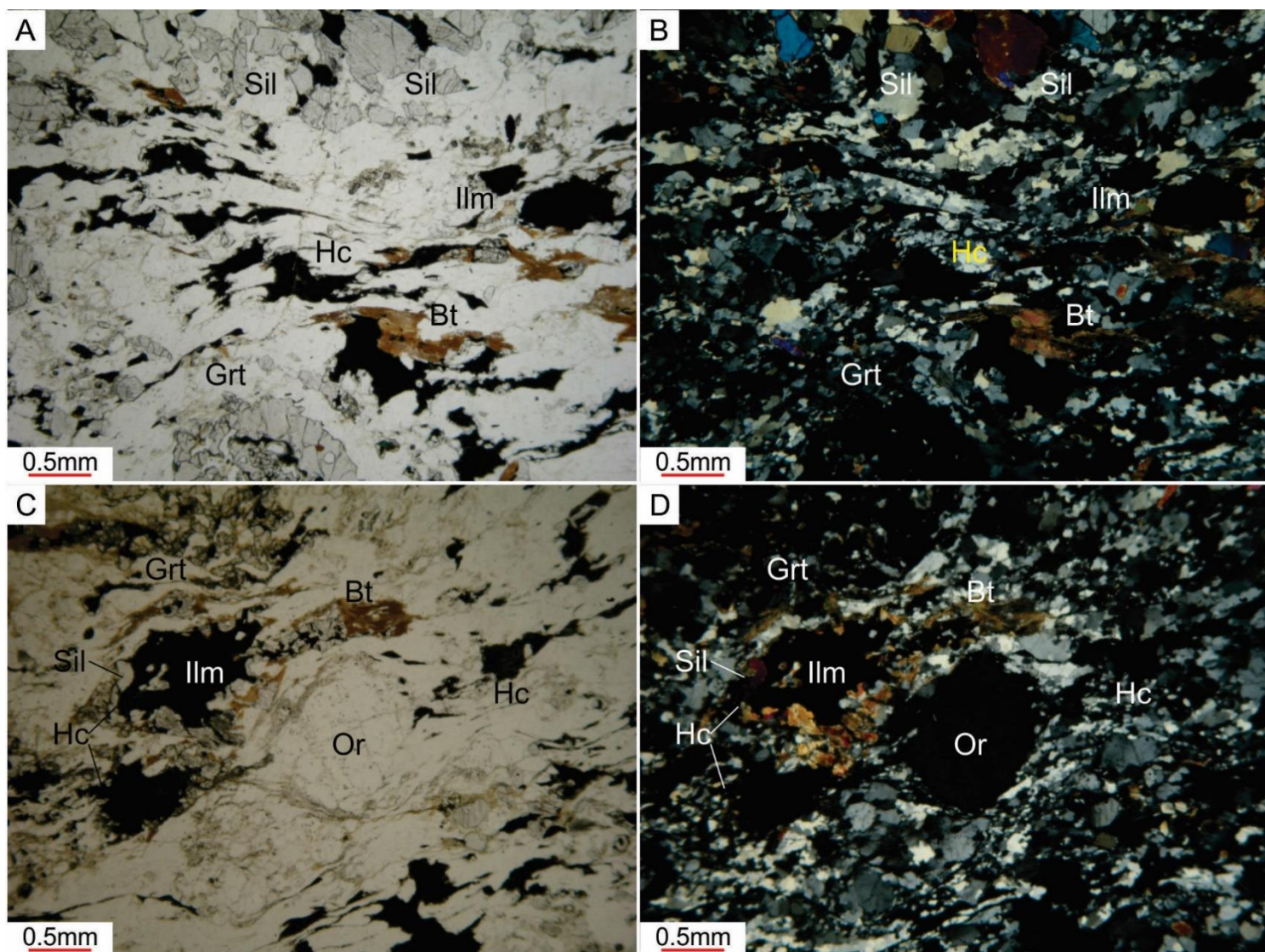


Figura 3 - Feições miloníticas em Spr-Hc-Sil-Grt diatexitos (objetiva 2,5x). A e B) Foliação milonítica marcada pelo fluxo da matriz e por cristais estirados de ilmenita e hercinita; C e D) Matriz anastomosada ao redor de porfiroclasto de ortoclásio e de agregados de Ilm+Sil+Herc. Amostra RS059.

4.1.2 Hc-Sill-Crd-Grt-Bt diatexitos

No resíduo se observa uma associação mineral constituída por $\text{Ilm} + \text{Hc} + \text{Qz} + \text{Bt} + \text{Sill} + \text{Grt} + \text{Crd} \pm \text{Or} \pm \text{Pl}$, exibindo granulação predominantemente de fina a média à exceção dos cristais de Grt, que podem apresentar granulação grossa, Or e Pl, podendo exibir granulação muito fina a fina. A paragênese de pico é marcada por raros contatos estáveis entre Hc+Qz, observável através de algumas inclusões em granadas centimétricas (Figura 4A) ou de forma esparsa no resíduo; normalmente, os cristais de hercinita do resíduo (Hc_2) exibem texturas de desequilíbrio nas bordas, encapsuladas por mantos de Sill, Crd e/ou Bt (Figura 4B). Frequentement a Hc exibe lamelas de exsolução de uma fase rica em Mt (Hc_3 , Figura 4C). Os cristais de ilmenita exibem lamelas ricas em Ilm intecaladas a outras ricas em Hem (Figura 4D), sendo raros cristais monofásicos. Biotita (Figuras 4B, E e F) ocorre como

inclusões em granada e/ou fase livre no resíduo (Bt_1), preferencialmente orientada segundo a foliação, também podendo se formar em embainhamentos ou a partir das bordas (Bt_2) de cristais de Grt, Crd e Sill, provavelmente devido a reações com o fundido. Silimanita prismática é predominante (Figuras 4G, H), preferencialmente orientada marcando a foliação da rocha juntamente à Bt, podendo exibir localmente texturas de desequilíbrio em suas bordas (Figura 4H) marcadas por armaduras de Crd ou Bt; ocorre também em hábitos aciculares quando inclusa em cristais de Grt, ou esqueléticos, quando formada a partir das bordas de cristais de Hc. A granada (Grt_{2-3}) ocorre predominantemente como porfiroblastos de granulação média a grossa, xenoblásticos a hipidioblásticos dodecaédricos, poiquilíticos, exibindo inclusões (Figura 4F, I, J) de Bt, Pl, Qz, Or, Hc, Ilm, Sill (principalmente acicular), Mnz, Zr ou Ap; podem exibir hábitos esqueléticos, formando intercrescimentos com Hc, Ilm, Sill e Qz, e ocorrem também como sobrecrecimentos a Ilm e/ou Hc (Grt_4). A cordierita é observada ora como “matriz” do resíduo, na forma de agregados xenoblásticos de granulação fina exibindo contatos poligonais a sinuosos (Figura 4K), ora como cristais xenoblásticos arredondados de granulação fina a média (ambas Crd_1), podendo se encontrar alterados em intensidades variáveis para “pinita”; pode ocorrer também como “mantos” sobre Hc, Sill ou Ilm (Crd_2 , Figura 4L). O quartzo pode exibir extinção bidirecional (“tabuleiro de xadrez”), denotando deformação em condições de elevada temperatura.

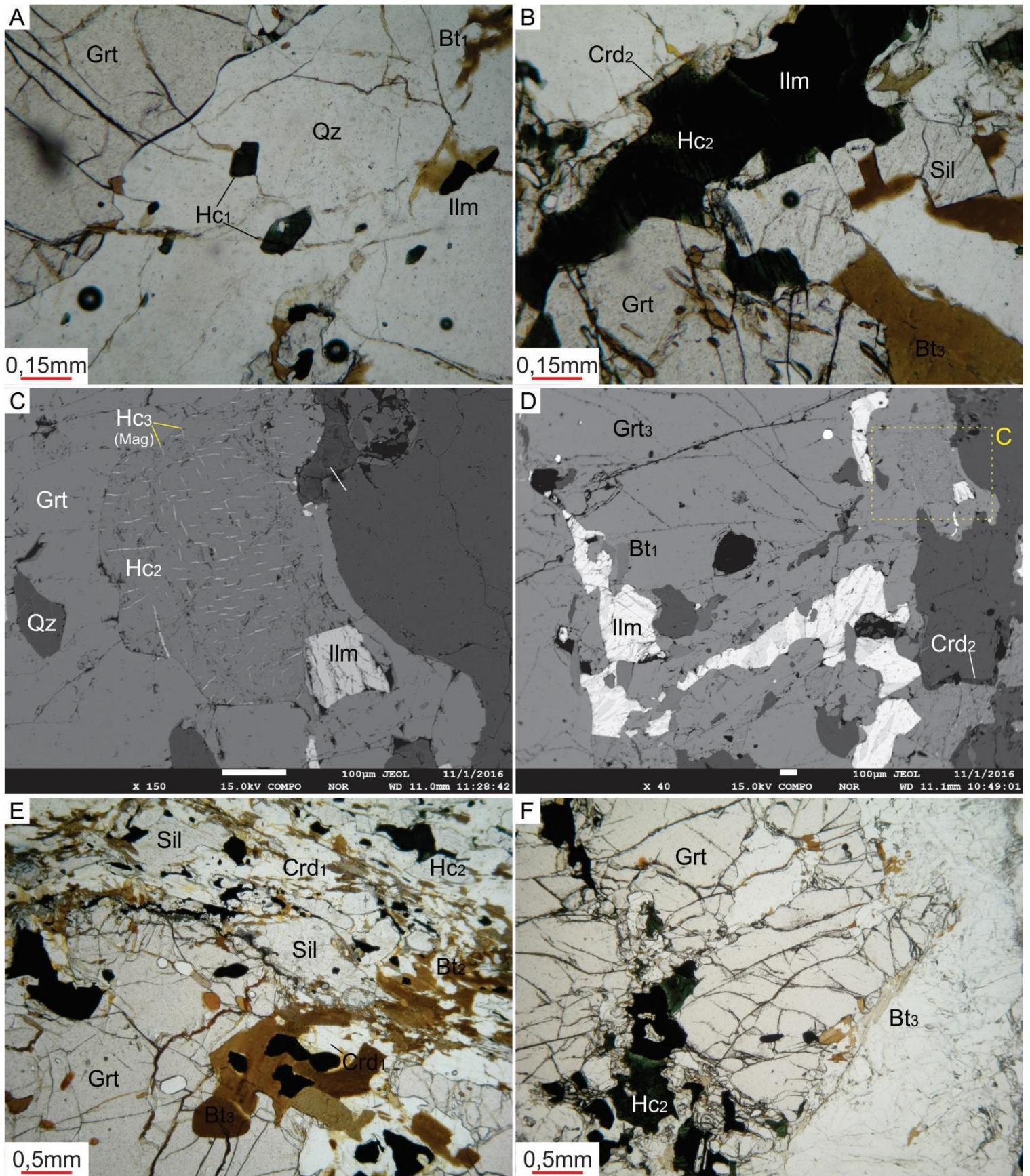


Figura 4 - A) Cristais de hercinita e quartzo inclusos em granada, em contato estavel; B) Granada, biotita e silimanita formadas nas bordas de cristal de hercinita; C) Imagem MEV de cristal de hercinita exibindo lamelas ricas em ferro; D) Imagem MEV de cristal de ilmenita contendo lamelas ricas em hematita; E) Limite entre leucossoma e resíduo, exibindo biotita livre e biotita formada nas bordas ou em embainhamentos no cristal de granada, além de cristais de silimanita, ilmenita e cordierita do resíduo; F) Inclusões de biotita, hercinita, ilmenita e plagioclásio em granada (cont.). A, B – objetiva 10x; C, D – imagens de *back-scattered eletronic microscopy*, com indicação do aumento; E, F – objetiva 2,5x. Amostra P4E.

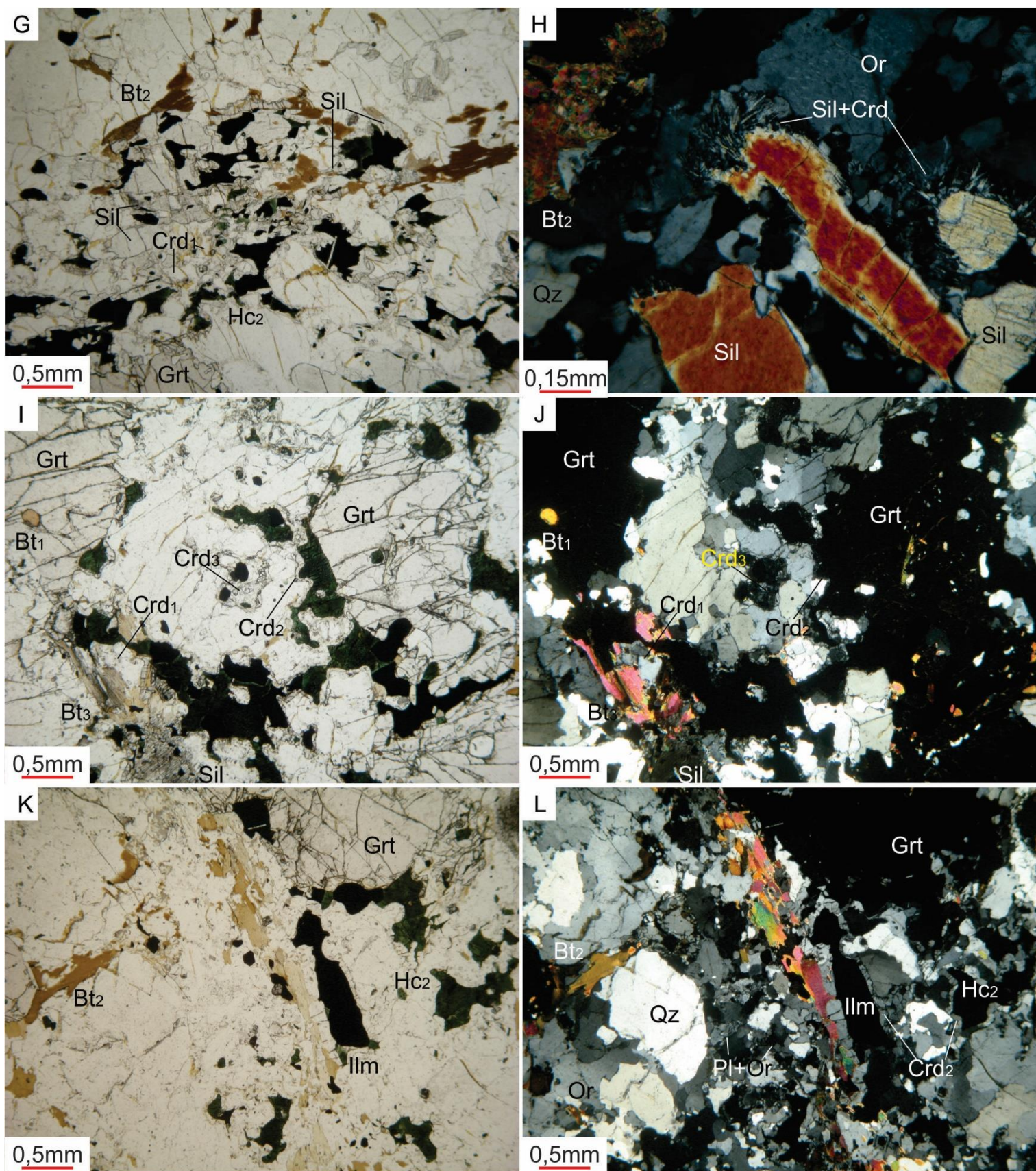


Figura 4 (cont.) - G) Cristais prismáticos de silimanita no resíduo; H) Bordas simplectíticas em cristais de silimanita; I e J) Inclusões de quartzo, biotita, hercinita, silimanita, plagioclásio e ilmenita em granadas; K e L) Cordierita da matriz do resíduo (Crd₁) e cordierita formada a partir das bordas de cristais de hercinita e ilmenita (Crd₂ e Crd₃). G, I, J, K, L – objetiva 2,5x. H – objetiva 10x. Amostra P4E.

A associação mineralógica do leucossoma compreende $Grt+Bt+Pl+Or+Qz\pm Hc\pm Crd$, de granulação predominantemente média a grossa, sendo exceções Hc e Crd_1 (Figura 5A, B), que ocorrem como esparsos cristais de granulação preferencialmente fina a muito fina, incorporados a partir do resíduo. Silimanita e ilmenita ocorrem em quantidades acessórias e não apresentam diferenças significativas para as contrapartes encontradas no resíduo. A hercinita ocorre como inclusões em granadas (Hc_1) ou como componente da matriz (Hc_2), comumente apresentando sobrecrecimentos de Crd; a paragênese de pico $Hc+Qz$ também é observada, sobretudo em raros cristais de Qz contendo inclusões de Hc_2 idioblástica de granulação muito fina (Figura 5C, D). A cordierita é observada como cristais livres na matriz (Crd_1) ou como sobrecrecimentos em ilmenita, hercinita ou silimanita (Crd_2); em ambos os casos, observa-se grande quantidade de cristais fortemente pinitizados (Crd_3). A granada ocorre de forma semelhante à do resíduo (Grt_2), à exceção de cristais de granulação muito grossa, chegando a até 4cm de diâmetro (Grt_1), que são mais ricos em inclusões (Figura 5E), podendo exibir também Crd inclusa (associada a Hc, Figura 5E, F), ocasionalmente contendo trilhas alinhadas de inclusões (Figura 5G) que marcam uma foliação de orientação distinta da foliação principal da rocha (granadas pré a sin-cinemáticas). Biotita ocorre como fase livre (Bt_2), marcando a foliação do leucossoma, como inclusões em Grt (Bt_1) ou se formando a partir de bordas ou fraturas nos cristais da mesma (Bt_3 , Figura 5H), porém em proporção ligeiramente inferior à observada no resíduo. Plagioclásio varia de granulação muito fina a média e o ortoclásio de muito fina a grossa, ambos formando cristais xenoblásticos a hipidioblásticos tabulares, exibindo uma discreta orientação preferencial segundo a foliação, e podendo ocasionalmente exibir embainhamentos preenchidos pela matriz; ainda, o Pl é ocasionalmente anti-pertítico e o Or comumente pertítico, e no contato entre ambos é frequente a formação de mirmequita (Figura 5I, J). Ambos os feldspatos, juntamente com o quartzo e, ocasionalmente, $Bt\pm Crd$, também ocorrem em granulação muito fina, exibindo contatos lobulados, sinuosos ou poligonais, e compõe a matriz da rocha, percolando por entre cristais maiores ou preenchendo embainhamentos nos mesmos (Figura 5J).

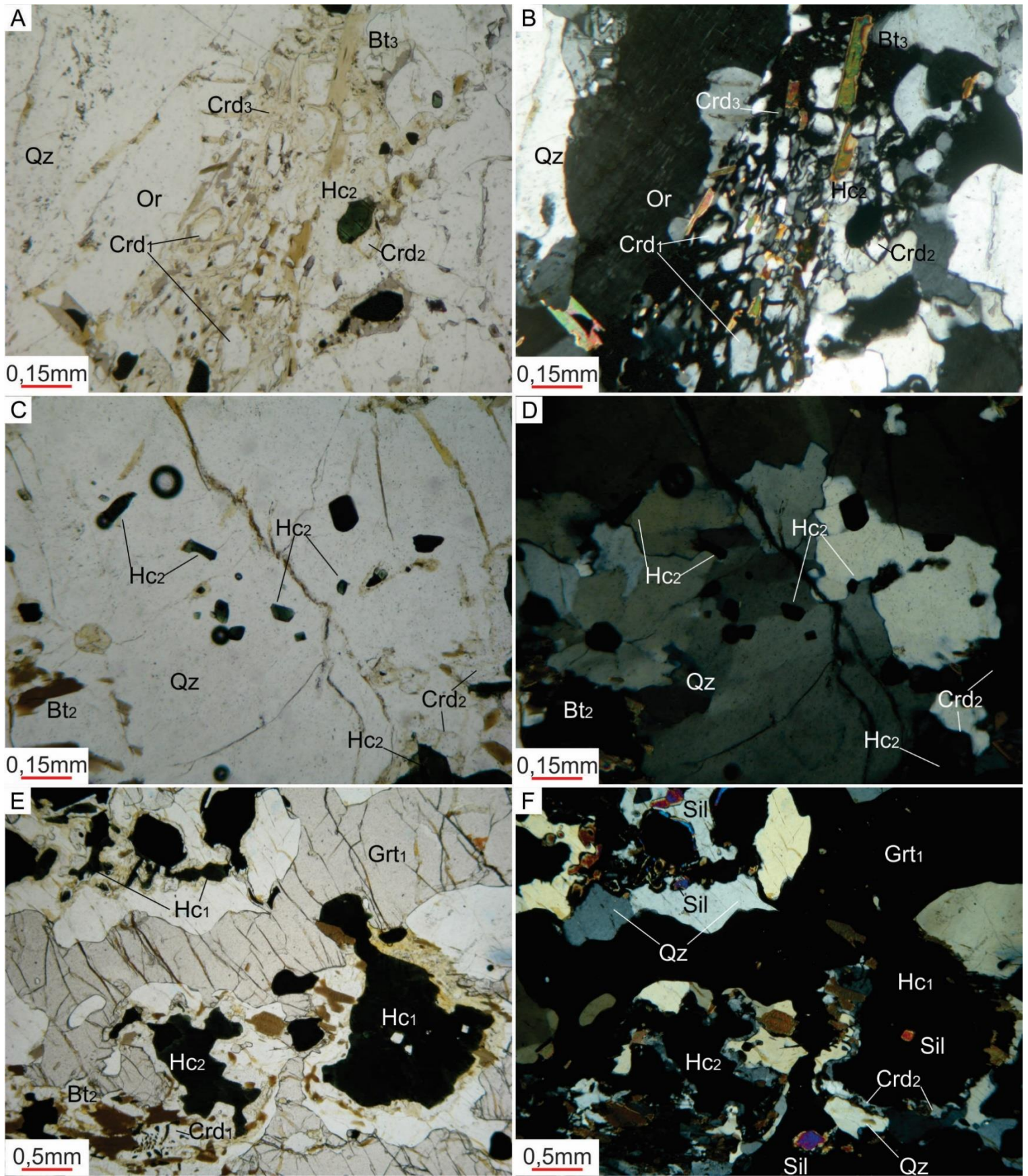


Figura 5 - A e B) Cristais de cordierita (Crd₁) e hercinita incorporados a partir do resíduo; C e D) Cristais euédricos de hercinita em contatos predominantemente estáveis com quartzo; E e F) Inclusões de ilmenita, hercinita, biotita, silimanita, quartzo e cordierita em granada, exibindo variedade de texturas de desequilíbrio; (cont.). A-D – objetiva 10x; E, F – objetiva 2,5x. Amostra P4E.

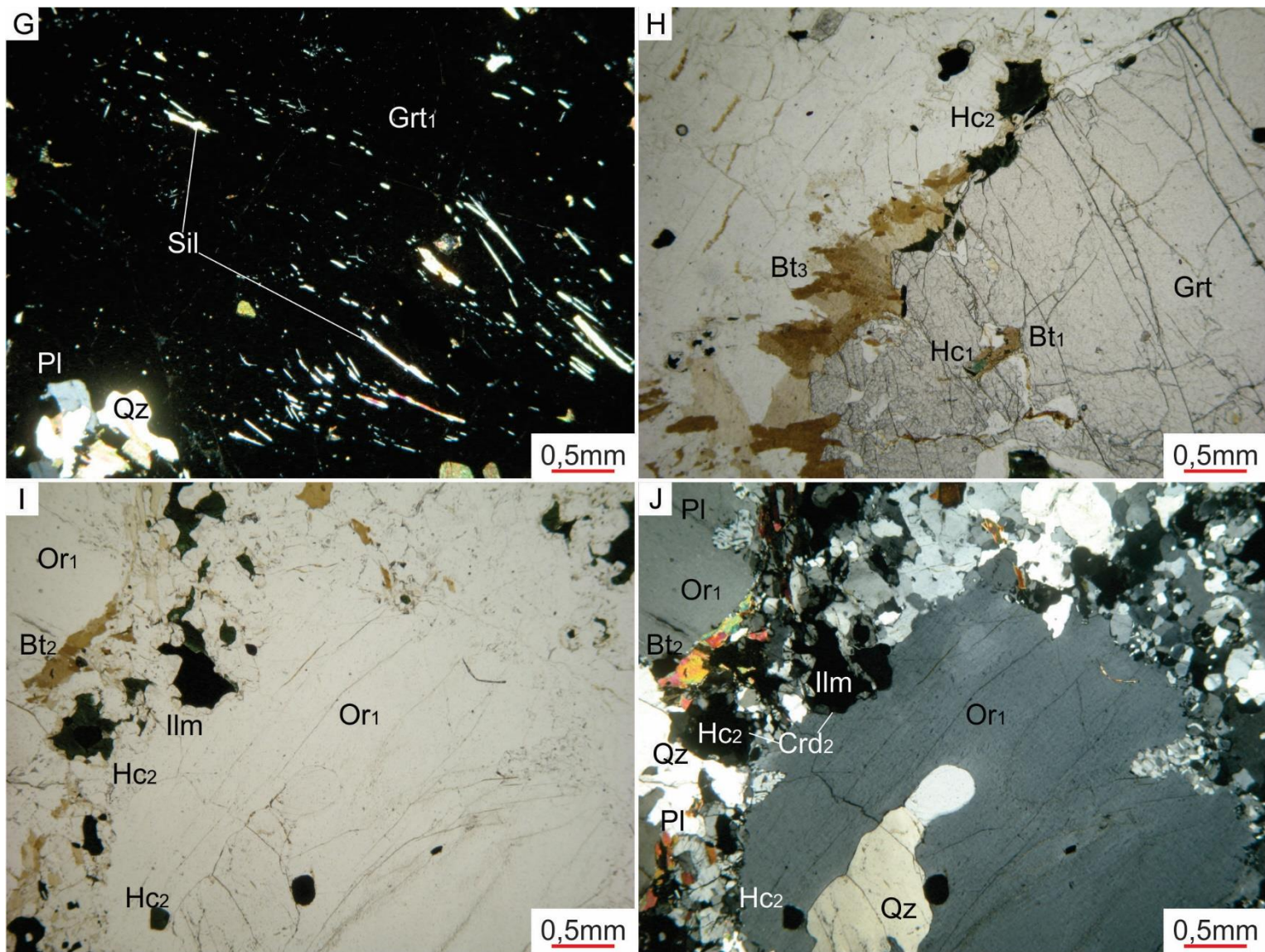


Figura 5 (cont.) -G) Trilha de inclusões orientadas de silimanita acicular e ilmenita em granada centimétrica; H) Biotita inclusa em granada (Bt_2), associada a hercinita, e biotita formada a partir das bordas de granada (Bt_1); I e J) Fenocristal de ortoclásio no leucossoma, exibindo golfo de corrosão preenchido por quartzo e mirmequita nas bordas, devido a reação com o plagioclásio da matriz. G-J – objetiva 2,5x. Amostra P4E.

4.2 (Opx)-Grt-Bt Migmatitos

(Opx)-Grt-Bt-Migmatitos ocorrem em vários pontos da Serra do Caparaó, se encontrando preferencialmente distribuídos em várias regiões ao longo da faixa central da mesma porém com algumas ocorrências associadas à zona de cisalhamento N-S à Oeste da Serra, que justapõe as litologias da Suíte Caparaó sobre as do Grupo Andrelândia. Representam um volume de rochas aflorantes muito menor que o dos Opx-Cpx migmatitos e maior que o dos Hc-Sill-Grt migmatitos, e sua colocação se dá por dois mecanismos principais: encaixados ao longo zonas de cisalhamento, onde comumente exibem foliação milonítica bem pronunciada, ou como veios e bolsões leucocráticos, encaixados ao longo de zonas de charneira do antiforme regional da Suíte Caparaó ou como intrusões irregulares nos ortognaisses. Ocorrem tanto como metatexitos quanto como diatexitos.

4.2.1 Grt-Bt metatexitos

Os Grt-Bt-Metatexitos são observados principalmente na parte Oeste da Serra, onde afloram em intercalações tectônicas com os ortognaisses e Cpx-Bt-Opx-Hbl-Metatexitos, formando lascas métricas a decamétricas justapostas por zonas de cisalhamento. Exibem “*patches*” de neossoma *in situ* (Figura 6A), formados ao redor de cristais de granada e biotita em meio ao paleossoma, a *in source*, ocorrendo como pequenos veios e bolsões de neossoma granatífero que rompem o limite das bandas (Figura 6B). É encontrado no afloramento P006.

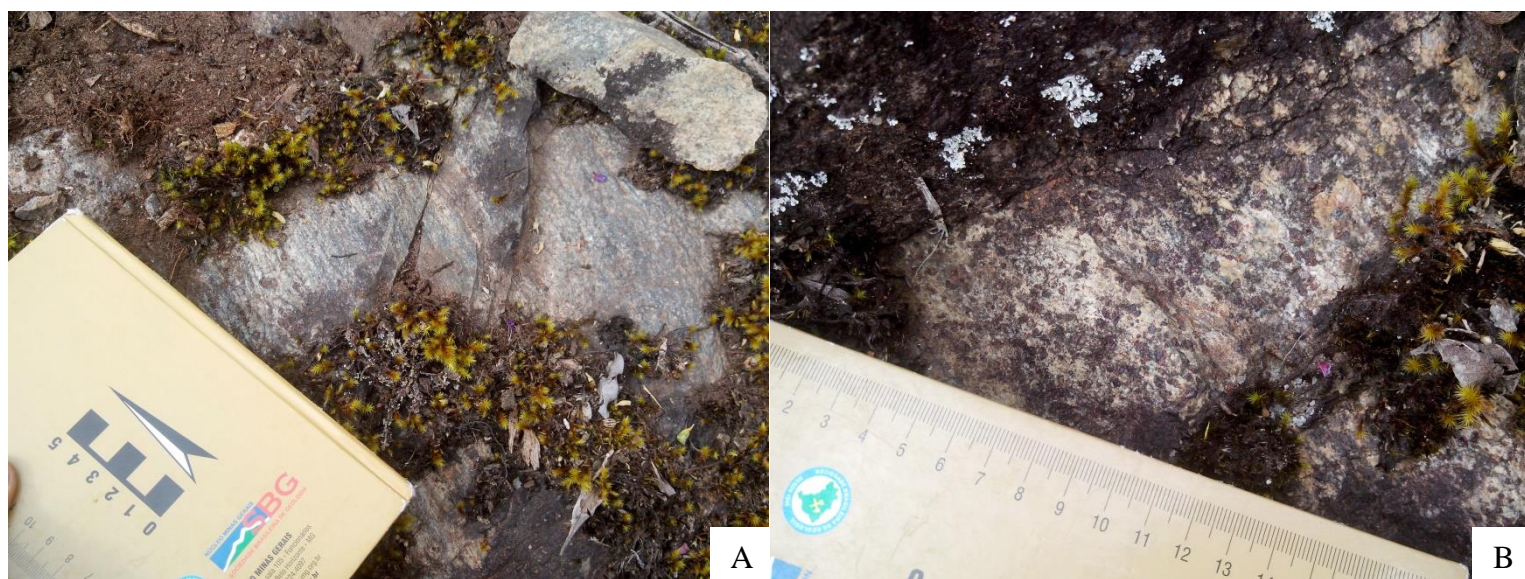


Figura 6 - Afloramento de Grt-Bt metatexito na estrada para o Terreirão, ponto P006. Metatexito estromático, exibindo bandamento gnaissico preservado e leucossoma predominantemente intrabanda (A), localmente formando bolsões *in source* (B).

O bandamento destas rochas é bem preservado no paleossoma e acentuado pela foliação milonítica (Figura 7A, B). Uma fina matriz de Or+Pl+Qz é gerada a partir da recuperação e recristalização dinâmica dos porfiroclastos, acompanhada de elevada deformação interna dos mesmos (Figuras 7C, D), e sua trajetória define uma foliação anastomosada, contornando e rotacionando porfiroblastos pré a sin-tectônicos de granada (Figura 7E) que ocasionalmente preservam uma foliação anterior à milonitização, marcada por inclusões aciculares de silimanita.

Apesar da intensa deformação, feições oriundas dos processos de fusão parcial (Sawyer, 2008) são observáveis, como embainhamentos nos porfiroblastos de granada, preenchidos por Pl+Qz exibindo formas em cúspide (Figura 7F), e cristais de Grt com faces retas contra Or (Figura 7G, H), sugerindo que a anatexia tenha se desenvolvido predominantemente em concomitância com a deformação regional. Ao longo da matriz são observadas linhas de opacos+biotita, paralelas a oblíquas (até 60°) à foliação principal, podendo marcar zonas de concentração destes minerais geradas pela expulsão de *melt* residual ou mesmo superfícies de dissolução por pressão (Figura 7I, J).

A associação mineralógica observada no neossoma compreende Bt+Grt+Qz+Pl+Or, com Opc, Zr e Crd como principais minerais acessórios e Sill, Hc e Ms sendo observadas apenas como inclusões em Grt. Grt é a principal fase incongruente do processo de fusão observada, que compreende também agregados de cristais de Bt de granulação fina e Opc, que ocorrem dispersos no neossoma. Entretanto, inclusões de minerais de paragêneses de T mais elevada (Sill+Hc), ausentes na matriz da rocha, sugerem que ao menos parte da Grt observada pode ter sido gerada pela cristalização do *melt* (Figura 8). Os principais produtos da cristalização do *melt* são Or+Pl+Qz de granulação muito fina a fina, exibindo contatos lobulados e formas ramificadas ou em cúspide, preenchendo espaços entre cristais maiores, além de Bt de granulação muito fina na matriz, apresentando hábitos ovalados, ou sobrecrescida às bordas de cristais de Grt, possivelmente devido à reação dos mesmos com o *melt* residual. Não ocorre segregação do leucossoma nestes metatexitos, constituindo um neossoma indiferenciado.

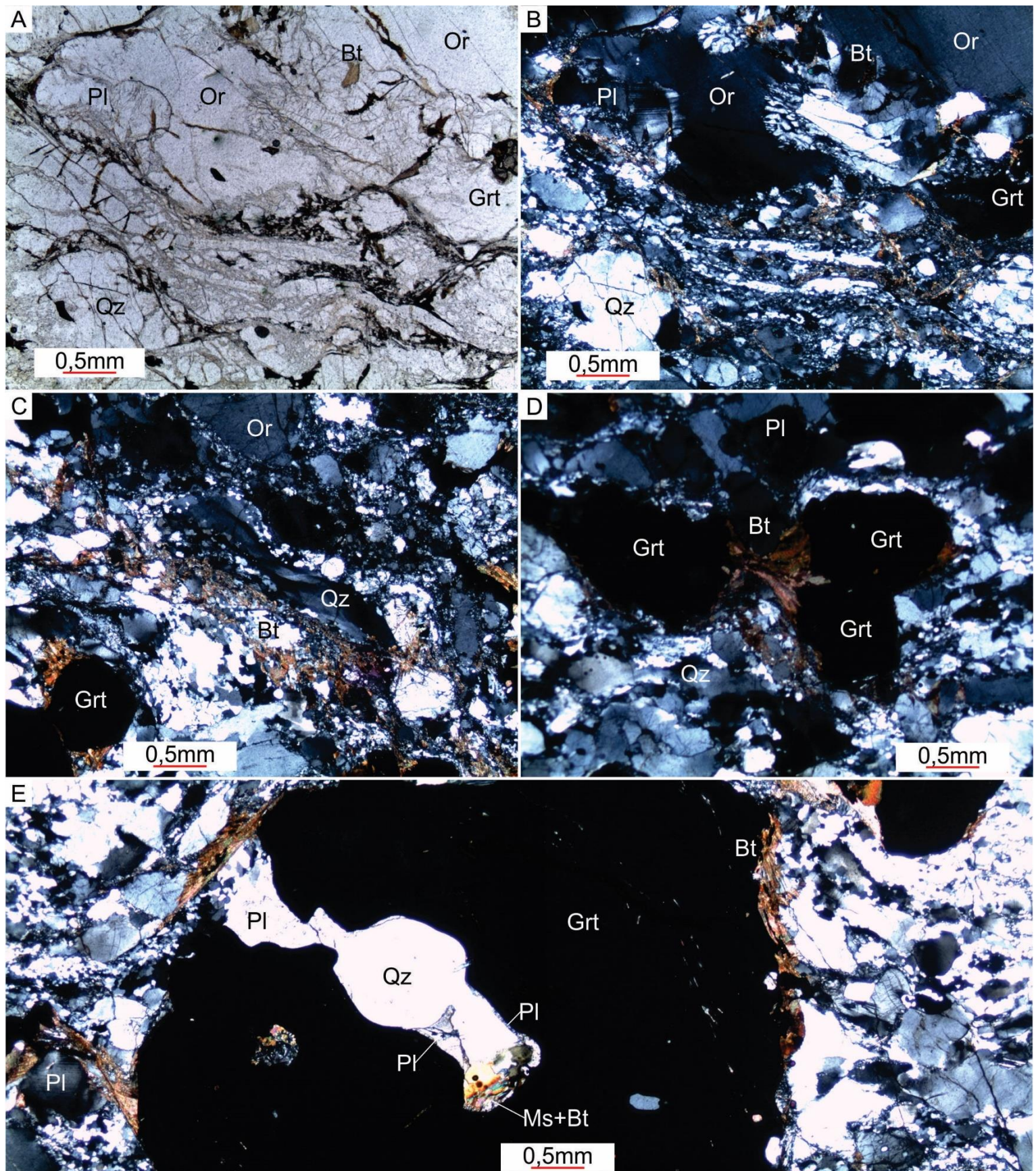


Figura 7 - Feições microscópicas do Grt-Bt-metatexito. A e B) Matriz milonítica formada por caudas de recristalização dinâmica de porfiroclastos de Or, Pl e Qz; C) Cristal de Qz com bandas de deformação interna sigmoidais; D) Qz com extinção ondulante “tabuleiro de xadrez”; E) Desvio da foliação milonítica nos arredores de porfiroblasto de granada, com destaque para a foliação interna do mesmo, discordante da foliação principal (cont.). A-E – objetiva 2,5x. Amostra P006A.

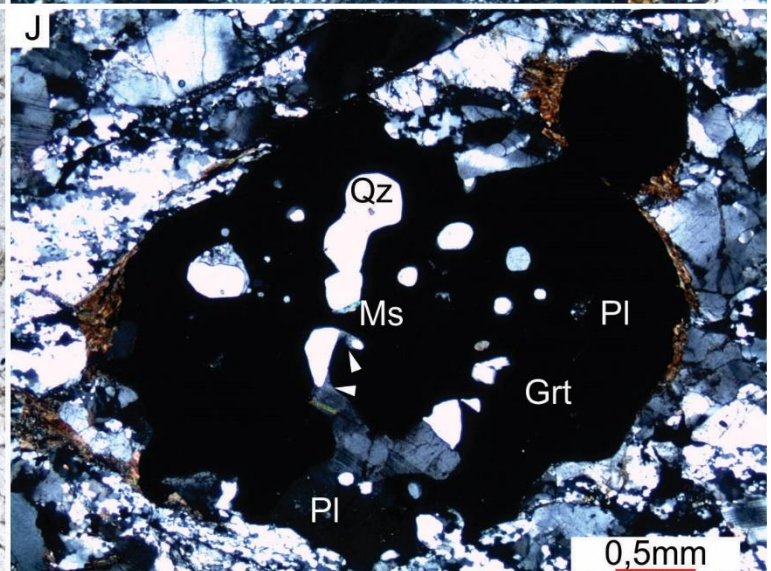
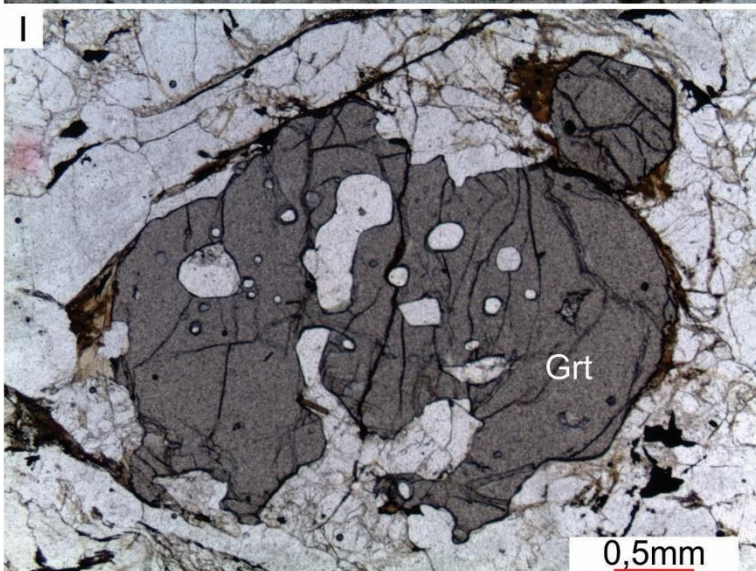
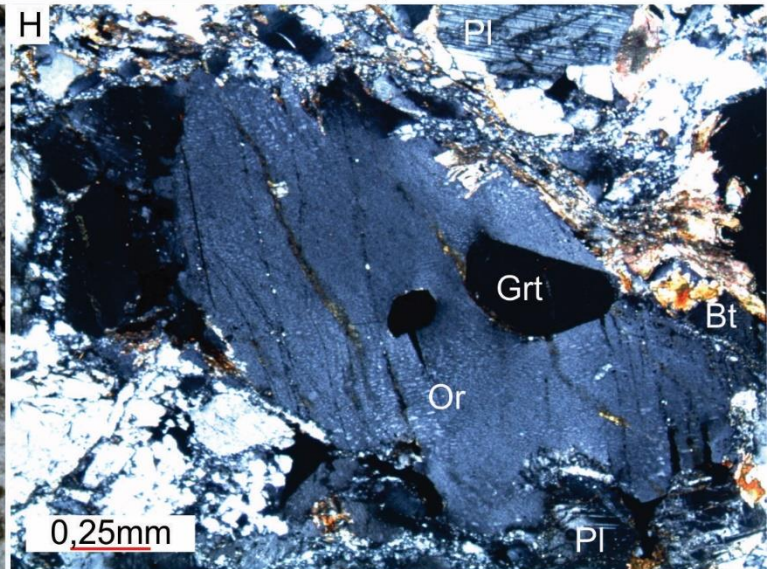
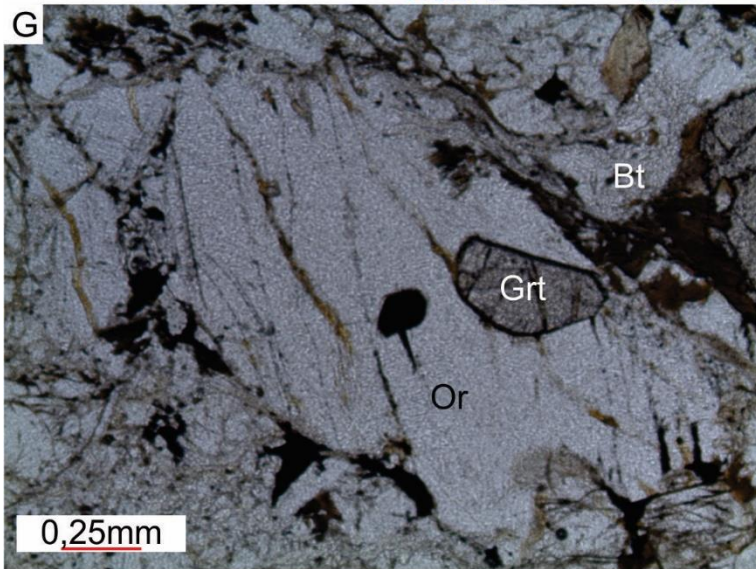
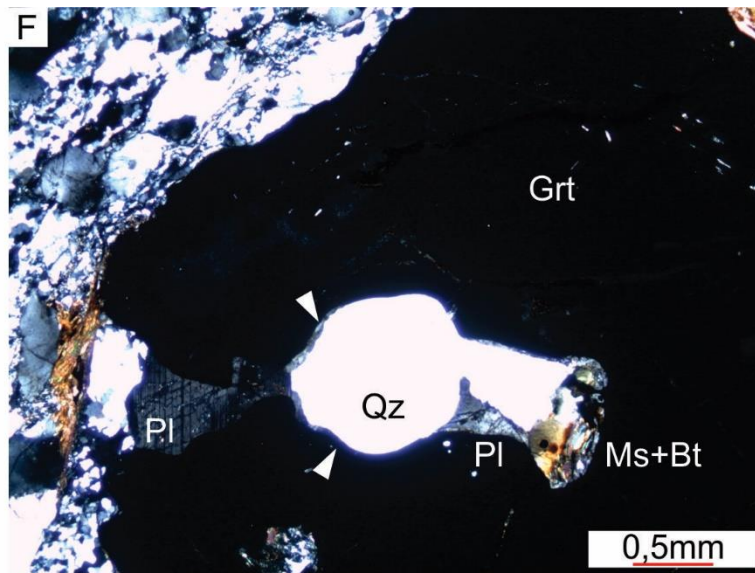


Figura 7 - (cont.) F) Embainhamento em granada preenchido por Qz+Pl, sendo observadas formas ramificadas e em cuspide no Pl, indicativas de origem a partir de *melt* (triângulos brancos); G e H) Cristal de Grt com faces retas incluso em Or, indicativo de cristalização a partir de *melt*; I e J) Linhas de Opc+Bt, possíveis superfícies de dissolução por pressão, e embainhamento em granada preenchido por Pl e Qz, exibindo formas sinuosas e em cuspide, indicativas de origem a partir da cristalização de *melt* residual (triângulos brancos). F, I, J – objetiva 2,5x; G, H – objetiva 5x Amostra P006A.

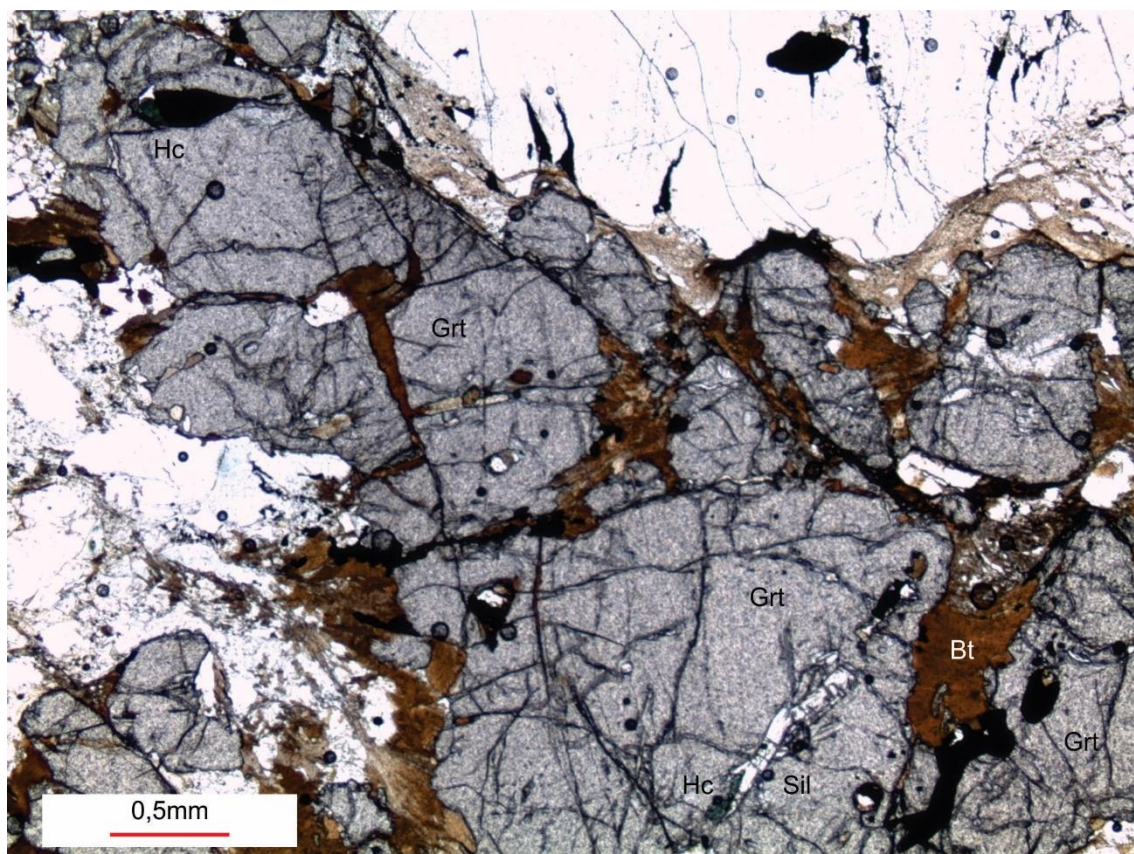


Figura 8 - Inclusões de biotita (Bt), silimanita (Sil) e hercinita (Hc) em granada. Objetiva 2,5x. Amostra P006A.

4.2.2 Opx-Grt-Bt metatexitos

Metatexitos a ortopiroxênio e granada são observados de maneira descontínua ao longo da porção Centro-Oeste da Serra do Caparaó. Encontram-se predominantemente associados a zonas de cisalhamento e exibem foliação milonítica marcante, que torna o bandamento destas rochas bem pronunciado (Figura 9A). O grau de fusão parcial é moderado a alto, evidenciado por morfologias aparentemente transicionais entre metatexitos estromáticos *in situ* e diatexitos *schlieren* (Figura 9B); localmente são observados bolsões de leucossoma granatífero *in source* que rompem o bandamento (Figura 9C). Correspondem ao afloramento P013.

O paleossoma corresponde a um Grt-Bt gnaiss de granulação predominantemente fina a muito fina, apresentando porfiroblastos de granada que podem chegar a até 5mm de diâmetro e bandamento marcado por intercalações milimétricas de bandas predominantemente quartzo-feldspáticas a bandas ricas em biotita e granada (Figura 10A, B). Exibe foliação milonítica paralela ao bandamento, marcada principalmente pela formação de uma matriz orientada composta por Qz, Pl, Or e Bt oriundos da recristalização dinâmica de porfiroclastos destes minerais ou das granadas (no caso da Bt). Ortopiroxênio é raramente observado, ocorre em quantidades acessórias e



Figura 9 - A) Bandamento pronunciado em escala de afloramento (Ponto P013, x,y,z); B) Amostra de Opx-Grt-Bt-Metatexito, evidenciando transição gradual do paleossoma (parte mais escura) para o neossoma (parte mais clara); C) Bolsões de leucossoma (Ponto P013).

como cristais de granulação muito fina a fina comumente envolvidos por armaduras de biotita, podendo estar associados também à granada. A biotita ocorre como fase livre (Bt_2), como fase associada a alteração das bordas dos cristais de granada (Bt_3), comumente formada em sombras de pressão ou caudas de recristalização ao redor das mesmas, ou ainda como inclusões nas granadas (Bt_1); Bt_2 e Bt_3 são preferencialmente orientadas segundo a foliação, exibem granulação muito fina a fina e são hipidioblásticas lamelares a xenoblásticas. Os porfiroblastos de granada são hipidioblásticos dodecaédricos a xenoblásticos arredondados, comumente exibindo alongamento preferencial segundo a foliação, granulação variando entre fina a grossa, e são comumente poiquilíticos, contendo inclusões de Qz, Bt, Pl, Zr, Mnz ou Opc sem orientação preferencial, e a ausência de foliação interna sugere blastese pré-cinemática para a Grt do paleossoma. Plagioclásio e ortoclásio costumam ocorrer como cristais xenoblásticos, com porfiroclastos não excedendo granulação fina e cristais de granulação muito fina compondo a matriz (Figura 10C, D) formada a partir dos mesmos; ocasionalmente se apresentam anti-pertíticos ou pertíticos (respectivamente), e contatos mirmequíticos entre ambos são observados com pouca frequência.

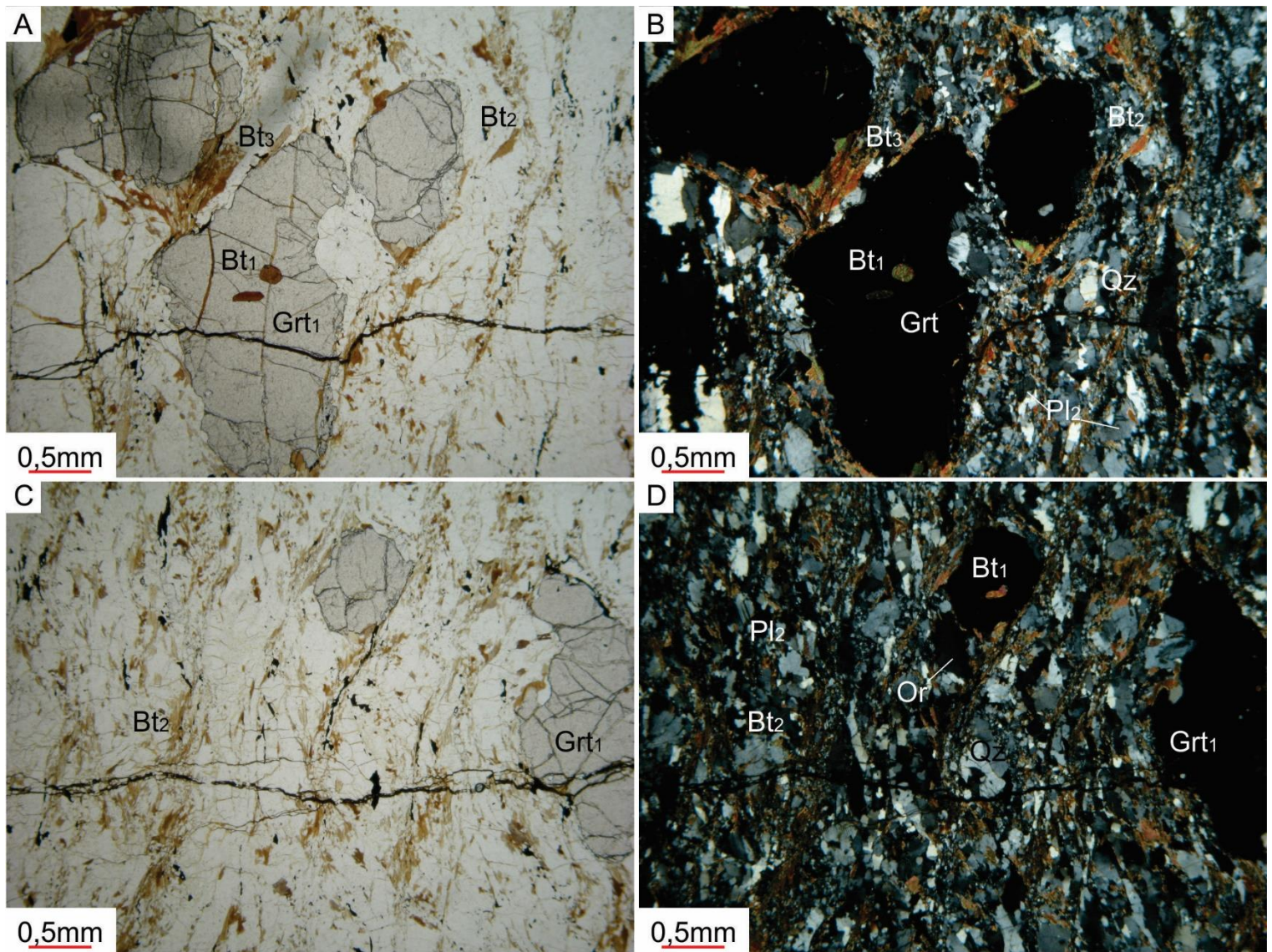


Figura 10 - Feições do paleossoma. A e B) Bandas ricas em biotita e granada, exibindo alongamento preferencial de cristais de Grt, e bandas quartzo-feldspáticas, sendo observáveis fitas de quartzo estiradas paralelamente ao bandamento; C e D) Caudas de biotita e opacos oriundas da recrystalização dinâmica de granada em banda máfica, porfiroclastos de ortoclásio e plagioclásio nas bandas félsicas. A-D – objetiva 2,5x. Amostra P013.

Os cristais de quartzo também são xenoblásticos, podem se encontrar estirados paralelamente à foliação ou na forma de porfiroclastos e matriz associada, e cristais com extinção ondulante bidirecional são ocasionalmente observados.

O neossoma dos Opx-Grt-Bt metatexitos consiste de “patches” de fusão interligados e formados paralelamente ao bandamento/foliação do paleossoma que exibem uma foliação interna de mesma orientação (principalmente máficos/melanossoma), indicativo de que a migmatização destas rochas ocorreu ao menos parcialmente sin-cinemática ao transporte tectônico das mesmas. Estes “patches” podem ocorrer tanto “*in situ*” quanto “*in source*”, rompendo os limites das bandas e formando acumulações locais na forma de bolsões (Figura 9C); entretanto, partes com escassez de paleossoma e que consistem somente de bandas de neossoma indiferenciado, por vezes com uma fina segregação entre leucossoma e melanossoma, são observadas, o que caracteriza a transição de morfologias originalmente de um metatexito estromático para um diatexito “*schlieren*” bandado. As intercalações entre leucossoma e melanossoma também são milimétricas, porém o espaçamento entre ambas é sutilmente maior que o observado entre as bandas do paleossoma e os cristais de Qz, Pl, Or, Bt e Opx

atingem dimensões ligeiramente maiores (Figura 11A, B), ainda que afetados pela milonitização. A segregação entre máficos e félsicos é mais bem pronunciada devido ao processo de fusão e geração de fases incongruentes.

O leucossoma (Figura 12A, B) exhibe associação mineralógica composta por $Pl+Or+Qz+Bt\pm Opx\pm Grt$, com mineralogia acessória representada por opacos (ilmenita, magnetita e raros sulfetos), zircão e apatita; máficos somam até 10% em volume total. A biotita costuma se apresentar como cristais hipidioblásticos lamelares a xenoblásticos, de granulação muito fina e preferencialmente orientados segundo a foliação (Figura 12C, D) juntamente aos opacos, podendo ocorrer associados às bordas de cristais de Grt e Opx ou mesmo se formar a partir da recristalização dinâmica dos mesmos (Bt_3).

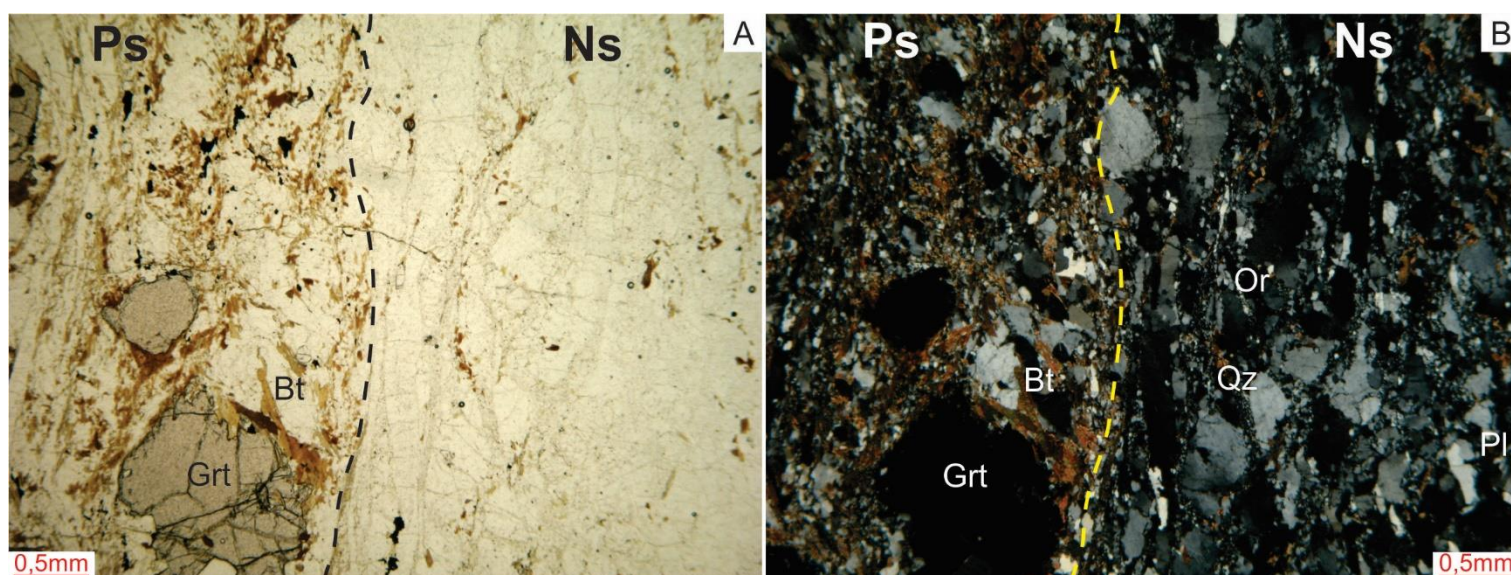


Figura 11 - A e B) Limite entre paleossoma (Ps) e neossoma (Ns) do Opx-Grt-Bt metatexito. A, B – objetiva 2,5x. Amostra P013.

A granada ocorre como cristais xenoblásticos, arredondados a ovalados, a hipidioblásticos, dodecaédricos ou tabulares (Figura 12C, D), de granulação fina a média, podendo conter inclusões de Bt_{1-2} , Pl, Qz, Opc ou Opx e ocasionalmente exibindo alongamento preferencial segundo a foliação. O ortopiroxênio (Figura 12E) exhibe granulação predominantemente muito fina a fina, é xenoblástico a hipidioblástico prismático e exhibe orientação preferencial segundo a foliação; contatos estáveis com Qz são observados, embora seja comum observar Bt formada a partir de suas bordas ou mesmo “armaduras” de biotita ao redor dos cristais. Plagioclásio e ortoclásio ocorrem como cristais xenoblásticos, irregulares a ovalados, a hipidioblásticos tabulares, podendo exhibir alongamento preferencial segundo a foliação, apresentando granulação fina a média na fração dos porfiroclastos e muito fina a fina na matriz; comumente são anti-pertíticos ou pertíticos (Figura 12C, D), e maclas recurvadas são ocasionalmente observadas nos cristais de plagioclásio (Figura 12F). O quartzo ocorre como cristais xenoblásticos, comumente formando “fitas” de granulação fina a média orientadas

segundo a foliação e a partir das quais se forma o Qz de granulação muito fina da matriz (Figura 12A-D).

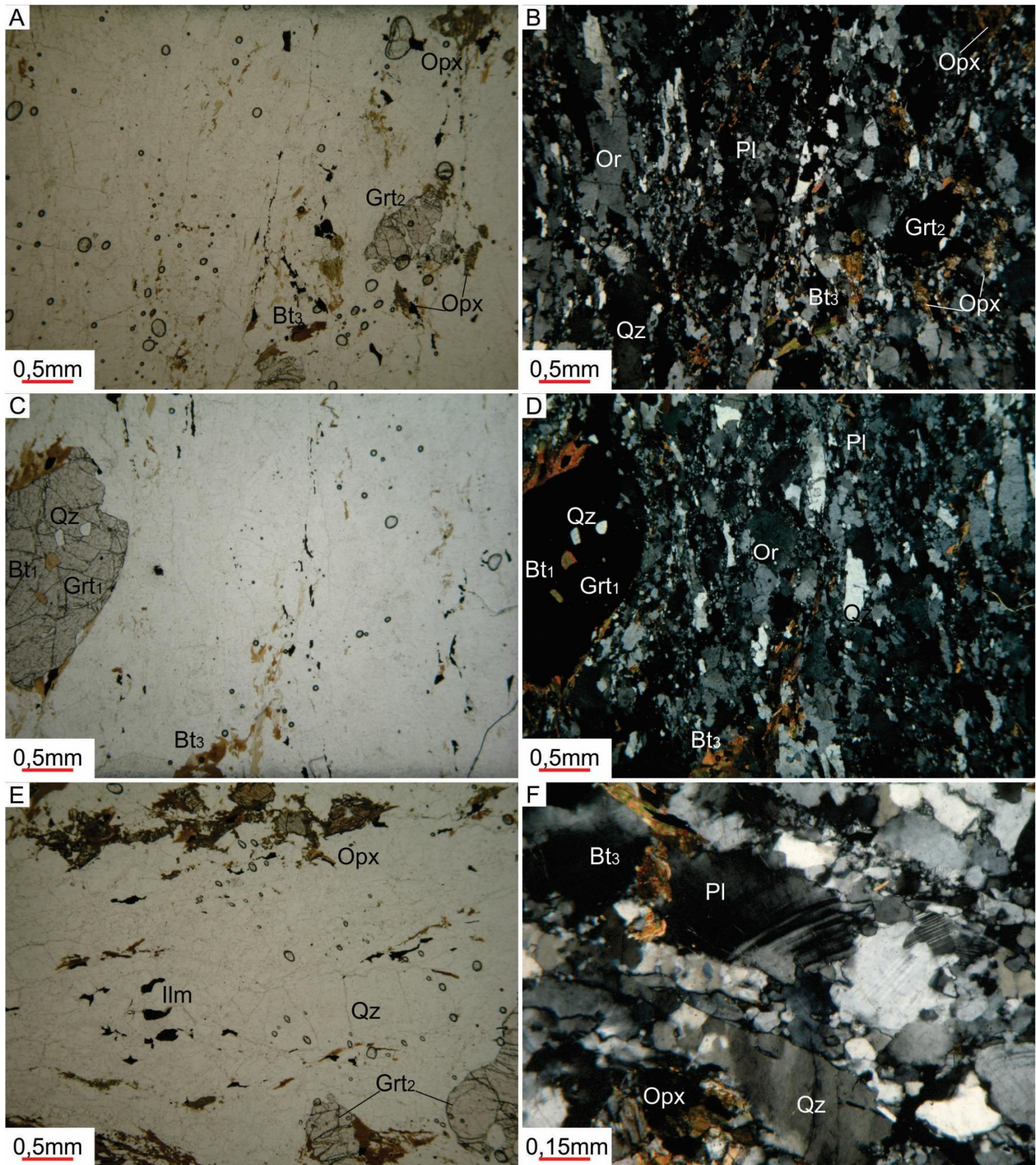


Figura 12 - Feições do leucossoma do Opx-Grt-Bt-Metatexito. A e B) Cristais de quartzo estirados segundo a foliação e máficos do leucossoma; C e D) Cristal tabular de granada e ortoclásio perfítico; E) Cristais de ortopiroxênio, opacos e biotita orientados segundo a foliação milonítica; F) Maclas recurvadas em cristais de plagioclásio e extinção ondulada “tabuleiro de xadrez” em quartzo. A-E – objetiva 2,5x; F – objetiva 10x. Amostra P013.

O melanossoma consiste em delgadas bandas (milimétricas) e “*patches*” enriquecidos em minerais máficos, podendo chegar a até 50% em volume localmente. Sua associação mineralógica consiste em Ilm+Opx+Grt+Or+Bt+Pl+Qz, podendo apresentar também apatita e zircão como acessórios. Os cristais de ilmenita são mais abundantes que no leucossoma e no paleossoma, comumente xenoblásticos, preferencialmente orientados segundo a foliação e podem atingir até granulação fina. O ortopiroxênio se apresenta como cristais hipidioblásticos prismáticos a xenoblásticos, irregulares a esqueletais, de granulação muito fina a média e comumente orientado preferencialmente segundo a foliação (Figura 13A, B). É comum observar a formação de Bt₃ nas bordas dos cristais de Opx, entretanto exibem comumente contatos estáveis com Qz; com a Grt podem exibir contatos estáveis, porém contatos entre as variedades esqueletais de ambos e relações de inclusão sugerem relações complexas entre ambos os minerais, nas quais ora parte do Opx se formou a partir das bordas de Grt (Figura 13C, D), ora parte da Grt se formou pelo consumo de Opx (Figura 13E, F). A granada ocorre como cristais xenoblásticos a hipidioblásticos dodecaédricos, de granulação fina a média, podendo conter abundância de inclusões de Bt, Opc, Pl, Qz, Zr, Ap ou Opx (Grt₁) ou mesmo ocorrer como cristais pobres nas mesmas (Grt₂); podem exibir embainhamentos preenchidos por Pl, Qz, Or ou Bt, e comumente se observa Bt e Opc formados a partir de suas bordas. Podem ocorrer também como cristais esqueletais (Grt₃) comumente associados ao Opx. O ortoclásio ocorre com menor frequência no melanossoma, comumente na forma de cristais xenoblásticos irregulares de granulação muito fina a fina, associados ao Pl e ao Qz e compoem a parte félsica da matriz milonítica com ambos; cristais pertíticos são raros no melanossoma. Biotita se apresenta como cristais hipidioblásticos lamelares a xenoblásticos, de granulação muito fina a fina, ocorrendo como fase livre ou oriunda da recristalização dinâmica e/ou retrometamorfismo de Opx e Grt (Bt₃), como inclusões em porfiroblastos destes os minerais (Bt₁) ou como inclusões nas granadas da matriz (Bt₂). Plagioclásio e quartzo ocorrem como cristais xenoblásticos, de granulação muito fina a fina, e ocorrem comumente associados; ocasionalmente se observam maclas recurvadas nos cristais de plagioclásio.

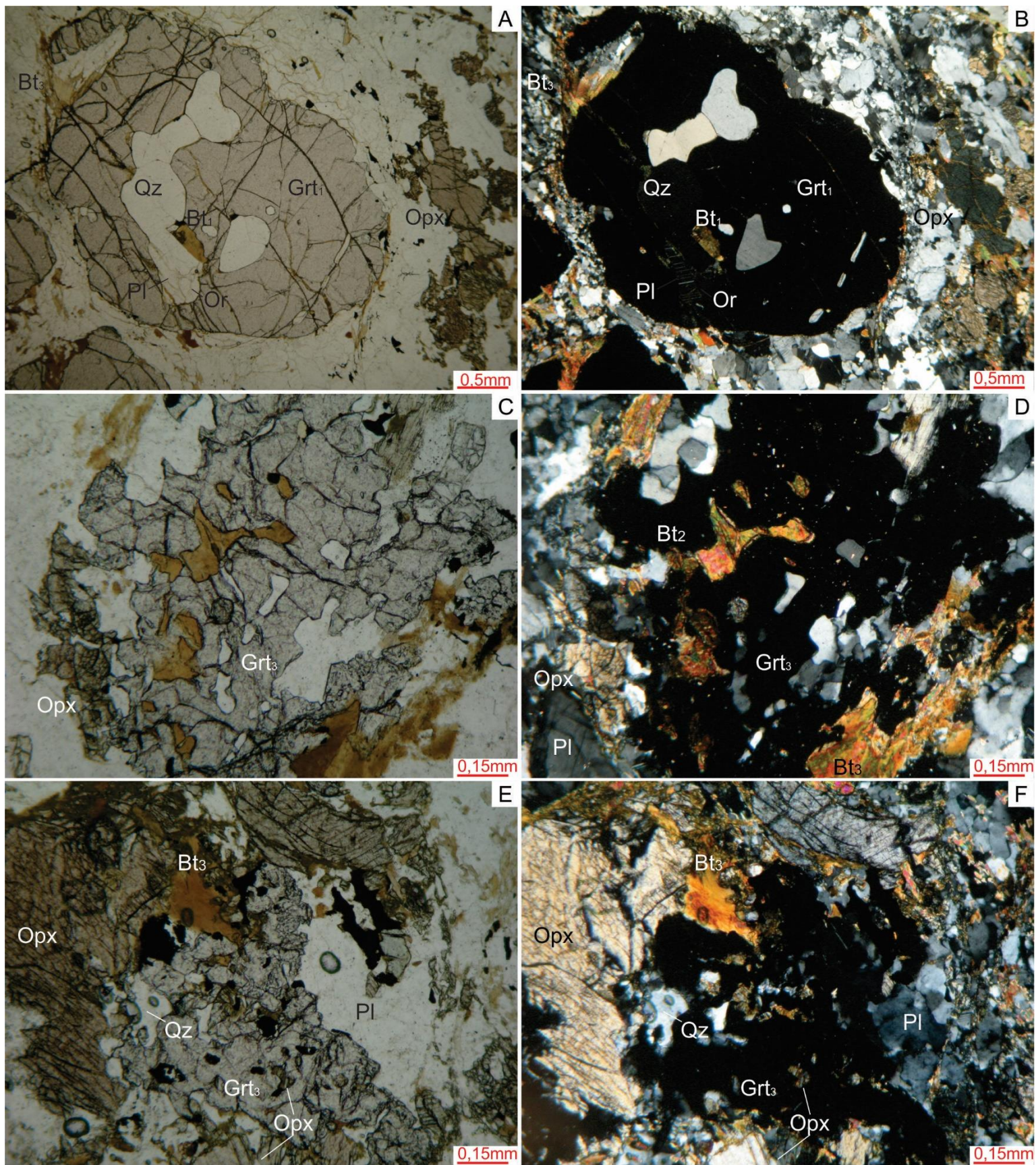


Figura 13 - A e B) Cristal de granada com inclusões de quartzo, plagioclásio e biotita ao lado de cristais prismáticos de ortopiroxênio, orientados segundo a foliação; C e D) Cristal de ortopiroxênio aparentemente se formando a partir do consumo de granada; E e F) Cristal de granada aparentemente se formando a partir do consumo de ortopiroxênio, contendo inclusões de Opx e Bt. A, B – objetiva 2,5x. C-F – objetiva 10x. Amostra P013.

4.2.3 Opx-Grt-Bt diatexitos

Os Opx-Grt-Bt-Diatexitos são o subtipo com maior distribuição espacial na Serra do Caparaó dentre os Opx-Grt-Bt migmatitos. São migmatitos de alta taxa de fusão parcial, não sendo observados resquícios da estruturação original na maior parte dos afloramentos e apresentando estruturas do tipo *schlieren* ou *schöllén* (Figura 14A, B). Podem ocorrer como diatexitos primários, contendo proporções apreciáveis de melanossoma e formados “*in source*”, ou secundários, se apresentando como veios leucocráticos com baixa proporção melanossoma associado, ora como intrusões cortando as litologias da Suíte Caparaó (Figura 14C, D), ora como bolsões preferencialmente acumulados ao longo de zonas de charneira (Figura 14E, F), ora encaixados e milonitizados ao longo de zonas de cisalhamento. Em algumas localidades, os Opx-Grt-Bt diatexitos são afetados por fraturamento preenchido por intensa venulação, gerando minerais secundários tanto no leuco quanto no melanossoma a partir do consumo principalmente de Opx, Grt e Bt, como carbonatos, clorita e sulfetos secundários (pirita e calcopirita principalmente). Correspondem aos pontos P1 e P012.

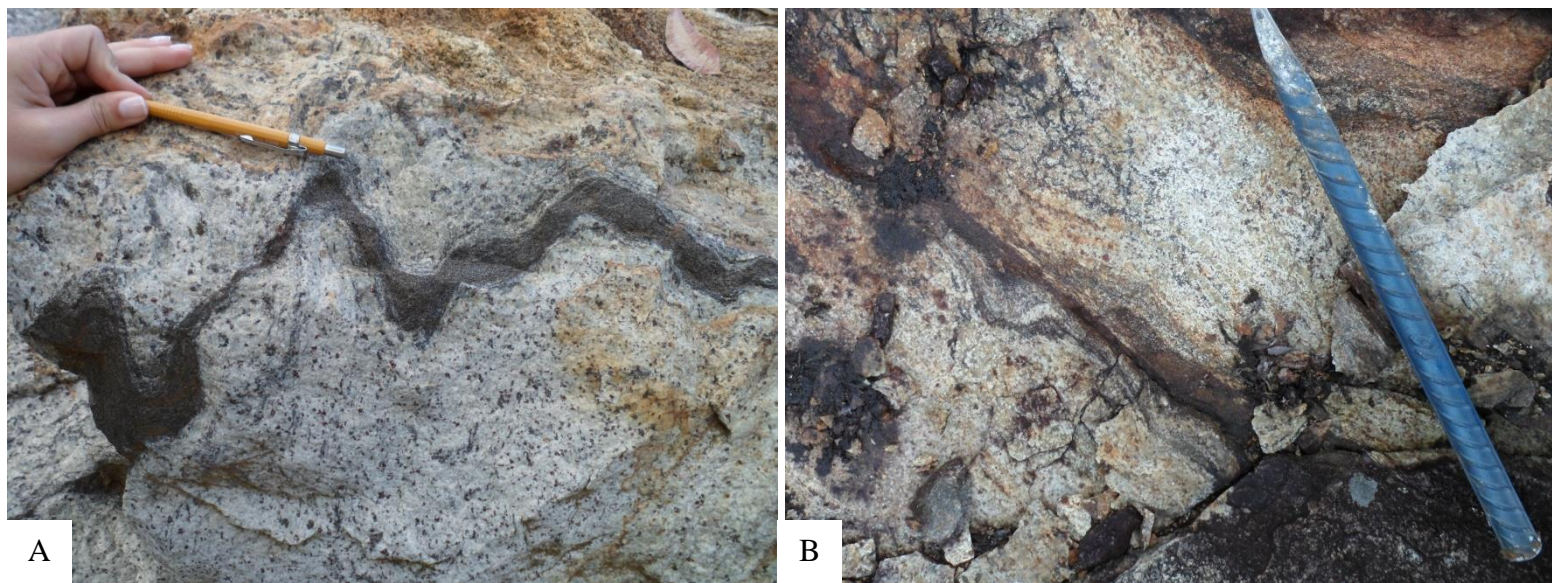


Figura 14 - A e B) Estruturas *schlieren* em Opx-Grt-Bt-Diatexitos. (cont.) A – afloramento P1. B – afloramento P012.

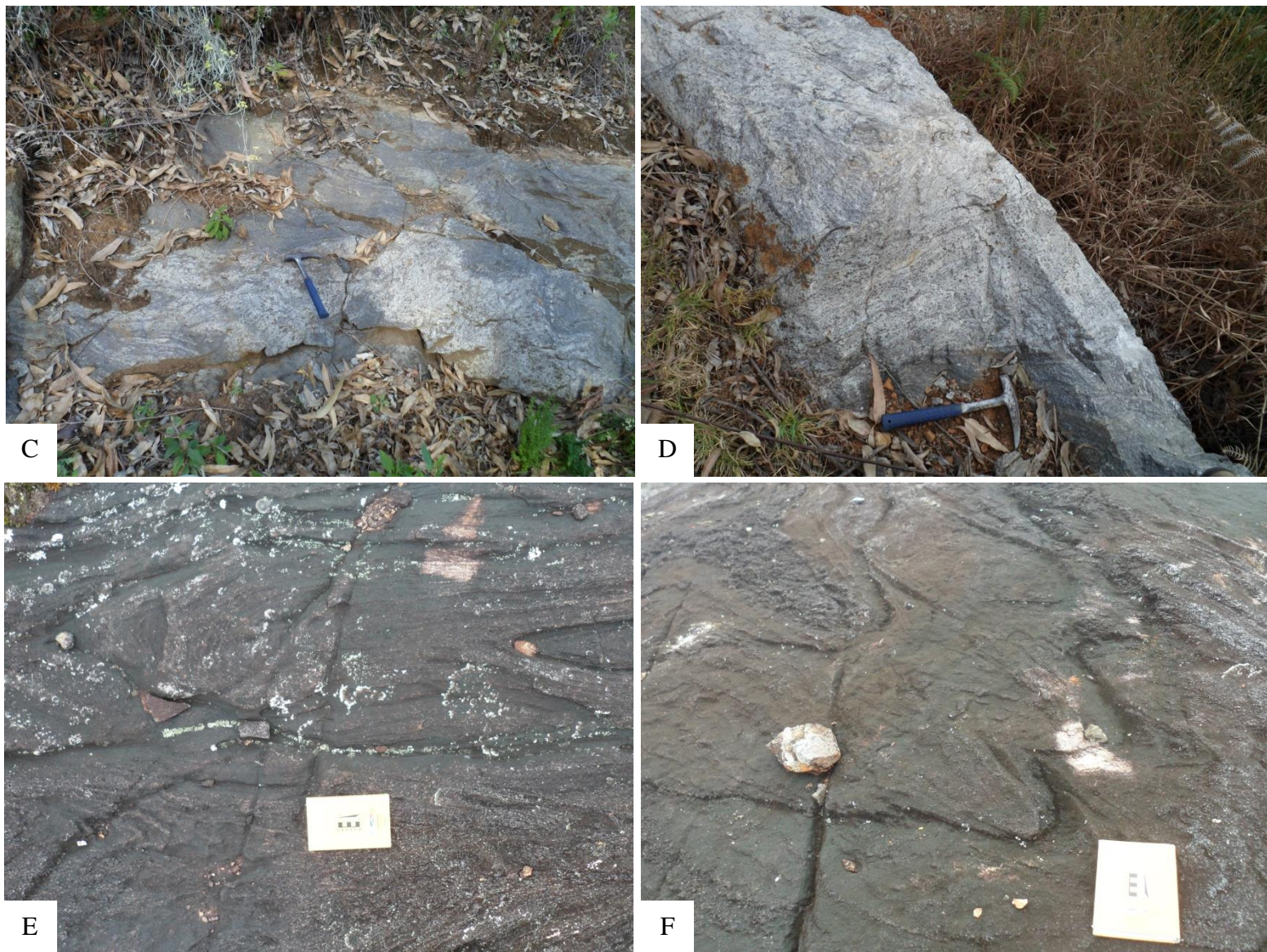


Figura 14 - C) Bolsões de leucossoma *in source* encaixados em ortogneisse da Suíte Caparaó; D) Veio leucocrático cortando ortogneisse da Suíte Caparaó; E e F) Dobras no bandamento em zona de charneira. C, D – afloramento P1; E, F – afloramento P012.

O melanossoma se apresenta predominantemente como *schlieres* distribuídos em meio a massas de leucossoma (Figura 14A, B), sem foliação interna, e sua associação mineralógica é constituída por $Or+Ilm+Mt+Opx+Grt+Bt+Pl+Qz$, podendo apresentar sulfetos primários (pirita, calcopirita e raramente pirrotita), rutilo, apatita e zircão como minerais acessórios. O ortoclásio é raramente observado como cristais individualizados, que ocorrem apenas como relictos parcialmente preservados das reações de fusão (Figura 15A, B), se apresentando como cristais xenoblásticos irregulares, de granulação fina; entretanto, ocorre frequentemente associado ao Pl e ao Qz como parte da matriz fina, composta por intercrescimentos granofíricos destes três minerais e oriunda da cristalização de *melt* aprisionado em espaços intersticiais entre os cristais do melanossoma (Figura 15B). Os minerais opacos são relativamente abundantes, podendo ocorrer tanto como fases livres, comumente associadas a biotita ou ortopiroxênio, quanto como inclusões em granadas; algumas

contém quantidades significativas de inclusões de sulfetos, e a pirrotita só é observada inclusa em Grt (Figura 15C, D). O ortopiroxênio se apresenta como cristais hipidioblásticos prismáticos a xenoblásticos, irregulares ou arredondados, de granulação fina a raramente média, exibindo contatos predominantemente estáveis com quartzo e granada e contatos reativos com biotita (Figura 15E, F), que se forma a partir das bordas de alguns cristais, além de se encontrarem frequentemente uralitizados. O Opx é o mineral mais afetado pela alteração secundária, com alguns cristais fortemente substituídos por clorita e carbonato (Opx₂). A granada ocorre como cristais xenoblásticos arredondados a hipidioblásticos dodecaédricos, de granulação fina a média, comumente poiquilíticos (Figura 15G), contendo inclusões de Bt, Pl, Qz, Ilm, Zr, Ap e, menos frequentemente, Opx, Rt e sulfetos; as inclusões costumam ser isentas de orientação interna, sendo comum exibirem padrões circulares dentro dos cristais (Figura 15D). Embainhamentos preenchidos pela matriz também são frequentes nas Grt. A biotita ocorre como máfico mais abundante, na forma de cristais hipidioblásticos lamelares a xenoblásticos, de granulação muito fina a média, ocorrendo como fase livre (Bt₂, Figura 15H), como inclusões em Grt (Bt₁, Figura) ou como fase sobrecrecida às bordas de Grt e Opx (Bt₃, Figura 15G, H). Plagioclásio e quartzo ocorrem como cristais xenoblásticos e granoblásticos, de granulação fina e exibindo contatos predominantemente sinuosos a poligonais entre si, como parte da matriz juntamente com o ortoclásio ou como inclusões em Grt (Figura 15G, H).

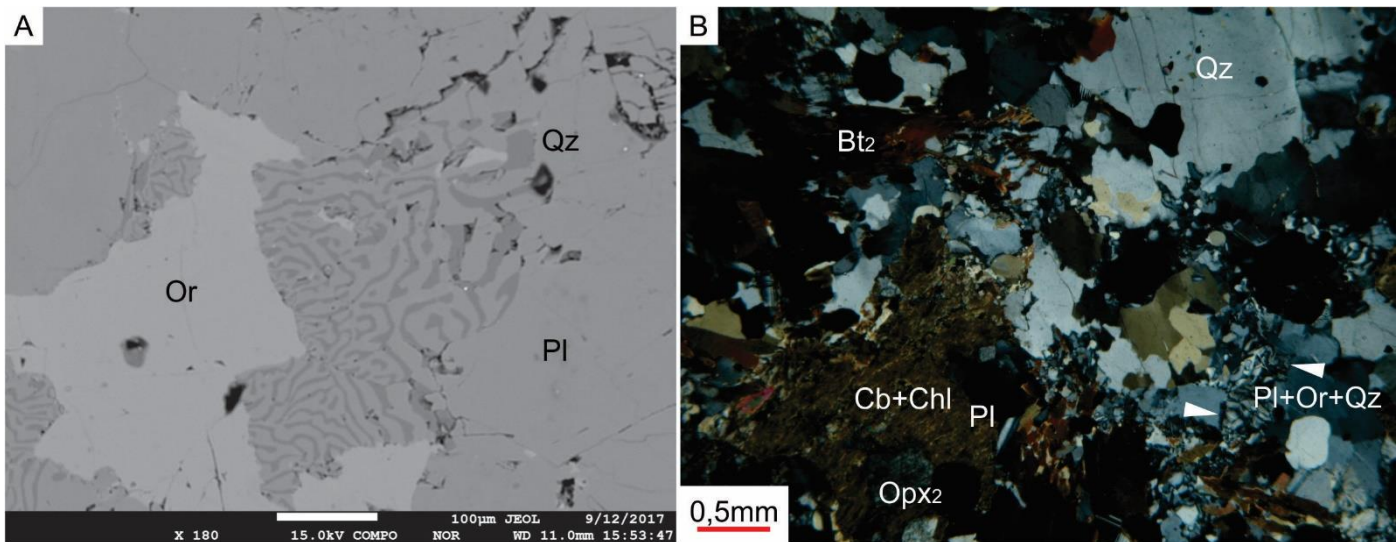


Figura 15 - Feições microscópicas observadas no melanossoma do Grt-Opx-Bt-Diatexito. A) Cristal de ortoclásio reliquial parcialmente consumido pela reação de fusão; B) Filetes de melt cristalizado em espaços intergranulares (triângulos brancos); (cont.). A – imagem de *back-scattered electron microscopy*, ampliação de 180x; B – objetiva de 2,5x. A e B – amostra P1.

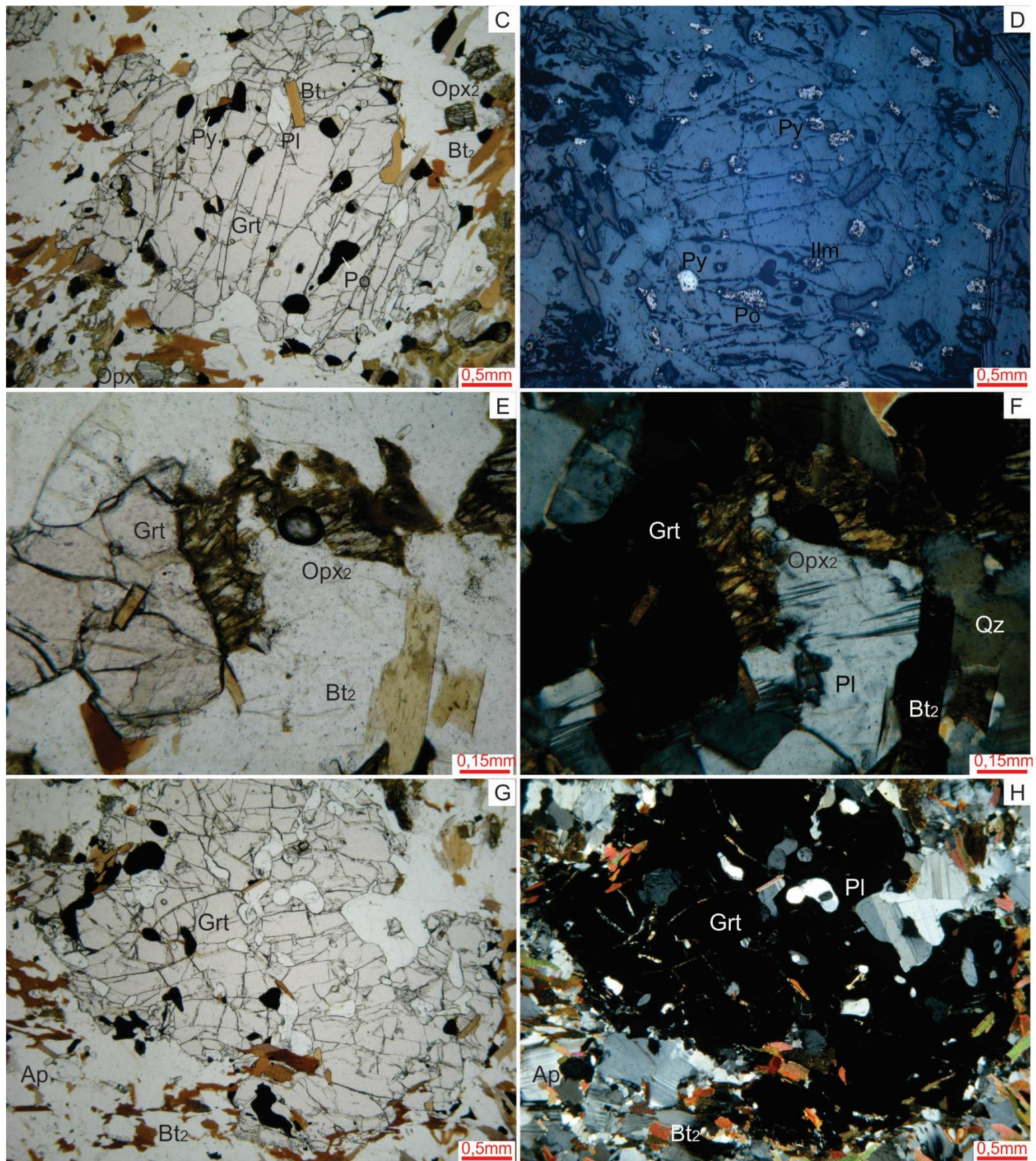


Figura 15- (cont.) C e D) Cristal de granada com inclusões de biotita, plagioclásio, ilmenita, pirita e pirrotita, exibindo padrão circular; E e F) Cristais de ortopiroxênio em contatos retos com granada, exibindo uralitização e biotização avançada; G e H) Cristal poiquiloblástico de granada, contendo inclusões de quartzo, plagioclásio, apatita, biotita e opacos, além de exibir embainhamentos preenchidos ora por plagioclásio e quartzo, ora por plagioclásio e biotita. C, D, G, H – objetiva 2,5x. E, F – objetiva 10x. C-H – amostra P1.

O leucossoma ocorre como corpos de composição aproximadamente granítica a granodiorítica, com raros termos tonalíticos, exibindo foliação incipiente e teor de máficos variando entre 10-30%. Apresenta uma associação mineral composta por $Rt+Bt+Grt+Or+Pl+Qz\pm Opx$, apresentando sulfetos primários (pirita e calcopirita), ilmenita, zircão e monazita como minerais acessórios. A alteração secundária, quando presente, é mais intensamente observada no leucossoma, afetando a Bt, o Opx e a Grt (Figuras 16A, B). Ortopiroxênio, quando presente, encontra-se predominantemente substituído por pseudomorfos a clorita e carbonato, podendo estar associados a pirita secundária, sendo observados apenas relictos em meio a massas destes minerais (Figura 16B). O rutilo ocorre como cristais hipidioblásticos, prismáticos ou aciculares, a xenoblásticos, arredondados ou massivos, de granulação muito fina a fina, comumente associados à Bt e que se apresentam como fase livre, como fase cristalizada em sombras de pressão ou como inclusões em Grt ou Qz (Figuras 16C, D). A biotita (Figuras 16 E, F) ocorre como cristais hipidioblásticos lamelares a xenoblásticos, de granulação muito fina a média, ocorrendo como fase livre (Bt_2), como inclusões em Grt (Bt_1) ou como fase associada às bordas de cristais de Grt (Bt_2 e Bt_3); é comum também ocorrer associada a Rt, Zr e Mnz. A granada se apresenta como cristais hipidioblásticos, dodecaédricos, tabulares ou cúbicos, a xenoblásticos, irregulares a arredondados (Figuras 16B, F), de granulação fina a muito grossa, comumente poiquiloblásticos, contendo inclusões de Bt, Pl, Or, Qz, Rt, Ilm, Zr, Mnz, Ap ou, raramente, de Hc (Figuras 16G, H), que podem apresentar orientação interna concordante com a foliação externa (Figura 16F); embainhamentos nas granadas do leucossoma preenchidos por *melt* residual são comumente observados, bem como acumulações do mesmo entre os porfiros de granada e os cristais adjacentes (Figuras 16E, F, I e J). Ortoclásio e plagioclásio ocorrem como cristais xenoblásticos a hipidioblásticos tabulares, de granulação fina a média (plagioclásio) ou grossa (ortoclásio), sendo comumente observados cristais peritéticos de Or e maclas recurvadas em Pl, além de bordas mirmequíticas entre ambos (Figuras 16K); juntamente ao Qz compõe filetes de *melt* residual de granulação muito fina, exibindo intercrescimentos granofíricos (podendo se encontrar recristalizados, com contatos poligonais) que percola por entre os cristais maiores (Figura 16L). O quartzo pode, ainda, se apresentar como cristais xenoblásticos de granulação fina a grossa.

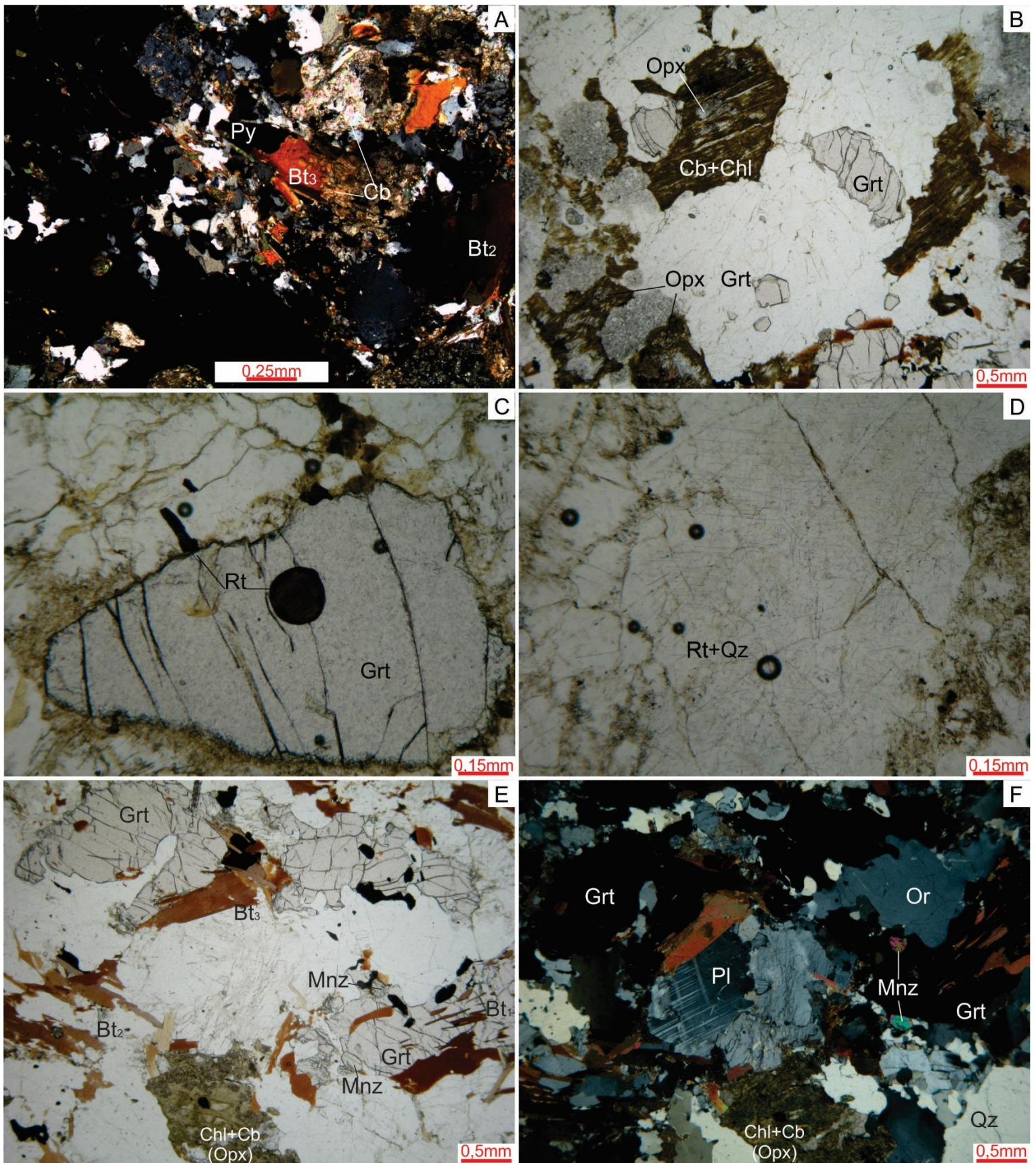


Figura 16- Feições observadas no leucossoma do Grt-Opx-Bt-Diatexitito. A) Cristal de Bt afetado por alteração hidrotermal, formando pirita (opaco à esquerda) e carbonato (direita) a partir de seu consumo; B) Cristais de Opx afetados por alteração hidrotermal, formando massas de clorita e carbonato a partir de seu consumo, associados a cristais idio a hipidioblásticos de Grt; C) Inclusão arredondada de Rt em Granada; D) Inclusões aciculares de Rt em Qz; E-F) Aspectos gerais do leucossoma: cristais irregulares a tabulares de Grt, contendo inclusões de Opx e Bt (orientada segundo a foliação), exibindo embainhamento preenchido pela matriz (cristal do canto superior esquerdo) e associados às três gerações de Bt; (cont.) A – objetiva 5x; B, E, F – objetiva 2,5x; C, D – objetiva 10x. A, B, E, F – amostra P1; C e D – amostra P012.

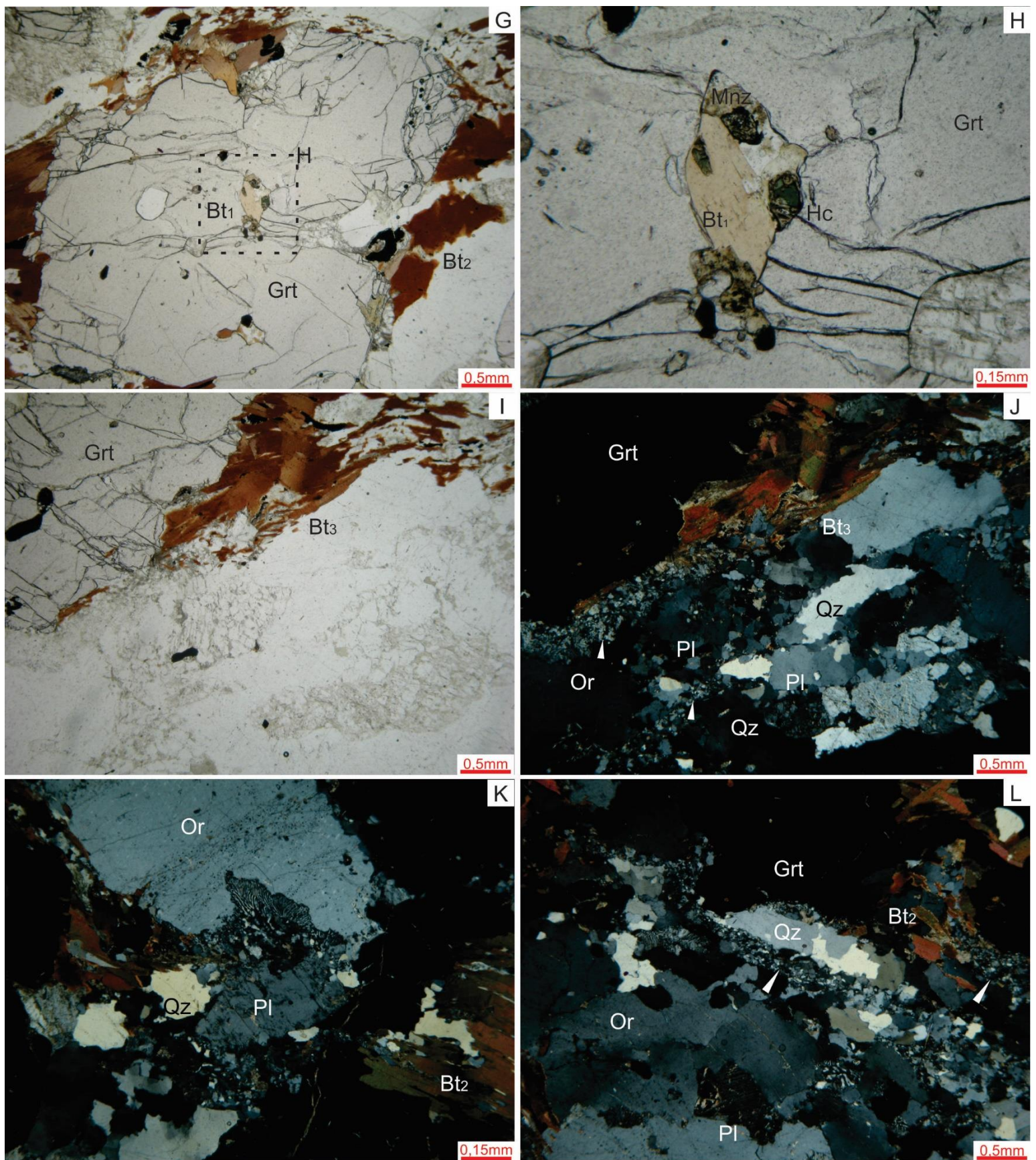


Figura 16 - (cont.) G-H) Cristal de Grt contendo inclusões de Qz, Pl, Bt e Hc; I-J) Acumulação de *melt* residual entre porfiroblasto de Grt e cristais de Or e Pl, adjacente a sombra de pressão formada por Bt; K) Borda mirmequítica entre Or perítico e Pl; L) Acumulações de *melt* residual entre cristais de Qz, Or e Pl, com formação de mirmequita na interface entre os feldspatos. G, I, J, L – objetiva 2,5x. H, K – objetiva 10x. G-L – amostra PID.

4.2.4 Hc-Opx-Grt-Bt diatexitos

Nas proximidades do Pico Calçado, ao longo do contato entre os Hc-Sill-Crd-Grt-Bt diatexitos e os Opx-Cpx migmatitos ocorre uma faixa de Opx-Grt-Bt migmatitos diatexiticos com bandamento moderado e foliação de fluxo marcante (Figura 17A). Diferem dos demais migmatitos deste tipo por serem portadores de hercinita e exibirem intercalações de zonas com e sem granada (Figuras 17A-C). Sua estruturação possivelmente foi estabelecida em concomitância com o transporte tectônico sin a pós-anatético, não tendo sido observadas estruturas reliquiaes preservadas.



Figura 17 - Feições macroscópicas dos Hc-Opx-Grt-Bt-Diatexitos. A) Bandamento e foliação de fluxo observados no afloramento; B) Porção rica em *melt* exibindo cristais esqueletais de Grt; C) Bolsão de leucossoma exibindo cristais diminutos de Grt (parte inferior da foto). A - afloramento P4. B - amostra P010A. C - amostra P010B.

O leucossoma exibe granulação fina a grossa, predominantemente média, e apresentam uma associação mineral a Hc+Bt+Grt+Pl+Or+Qz, sendo observados Opc(Mt, Ilm, Rt), Zr e Mnz como acessórios; os máficos totalizam aproximadamente 10% do volume desta fração da rocha. De um modo geral os minerais presentes se encontram em equilíbrio, embora alguns dos cristais de biotita tenham se formado a partir do contato do *melt* com as bordas de cristais de Grt e Hc. A hercinita (Figuras 18 A, B) se apresenta como cristais esparsos, xenoblásticos a raramente idioblásticos

octaédricos, de granulação fina a muito fina, comumente associada a Grt, Ilm ou Mt, podendo ocorrer como inclusões em Grt (Hc_1) ou como fase livre (Hc_{1-2}). A granada (Figuras 18A-D) ocorre como cristais xenoblásticos arredondados a hipidioblásticos, dodecaédricos, tabulares ou cúbicos, de granulação fina a média, comumente apresentando inclusões dos demais minerais e podendo exibir alongamento discreto segundo a foliação; embainhamentos preenchidos por Pl, Or e Qz são ocasionalmente observados (Figura 18B). A biotita (Bt_{melt}) pode ocorrer isolada na matriz, como cristais idio a hipidioblásticos lamelares de granulação fina a média, ou como cristais de granulação muito fina a fina formados em contato com os máficos anidros, sendo xenoblásticos a hipidioblásticos lamelares (Figuras 18C-F); ocasionalmente exibem inclusões de Opc paralelas às clivagens, além de Zr e Mnz. Plagioclásio e ortoclásio (Figuras 18C-F) ocorrem como cristais xenoblásticos a hipidioblásticos tabulares, de granulação fina a grossa, exibindo orientação moderada segundo a foliação, são comumente antipertíticos (Pl)/pertíticos (Or) e no contato entre ambos frequentemente se observa a formação de mirmequita; podem ocorrer, juntamente com o Qz, formando localmente filetes de granulação muito fina a fina, exibindo contatos lobulados entre si e percolando entre cristais maiores, possivelmente oriundos da cristalização final do *melt* aprisionado em espaços intergranulares. O quartzo ocorre como cristais de granulação fina a grossa (Figuras 18C-F), podendo ocorrer alongado segundo a foliação, e ocasionalmente exibindo extinção ondulante em padrões “tabuleiro de xadrez”.

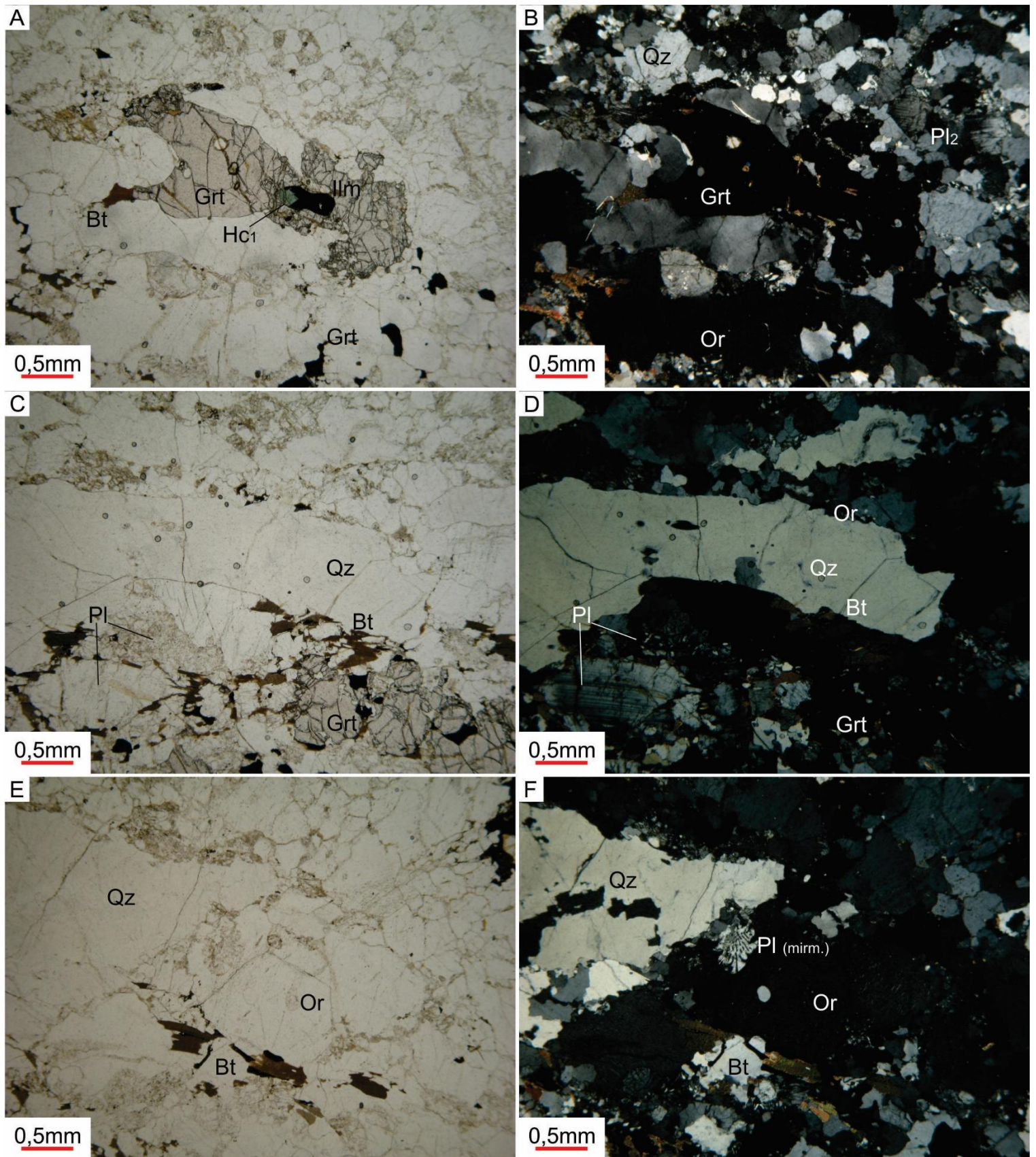


Figura 18 - Feições observadas nas porções ricas em *melt* do Hc-Opx-Grt-Bt-Diatexit. A e B) Inclusões de Ilm e Hc em granada; C e D) Minerais félsicos – Qz, Pl e Or – exibindo granulação média a grossa, associados a cristais hipidioblásticos de Grt e Bt; E-F) Cristais peritéticos de Or exibindo bordas mirmequíticas no contato com cristais de Pl ou filetes de *melt* residual. A-F – objetiva 2,5x; amostra P010B.

Entre o resíduo e o leucossoma ocorre uma zona intermediária (possível *selvedge*), com proporção de máficos em torno de 30%, predominantemente Bt, e podendo apresentar um volume de *melt* residual (filetes) chegando localmente a 20% (Figuras 19A, B). Exibe foliação marcada pela orientação preferencial de Bt e Opc, e a associação mineral desta zona intermediária compreende Opc+Bt+Pl+Or+Qz, sendo observados granada, hercinita, ortopiroxênio, monazita (chegando a cristais milimétricos, Figuras 19C, D) e zircão como acessórios. A granada se apresenta tanto como cristais idioblásticos dodecaédricos de granulação muito fina a fina quanto como cristais hipidioblásticos tabulares a xenoblásticos de granulação fina a média, podendo exibir inclusões de opacos e biotita neste caso. A hercinita ocorre como esparsos cristais xenoblásticos inclusos ou associados com magnetita ou ilmenita, de granulação muito fina a fina. O ortopiroxênio é raro, ocorrendo apenas associado a cristais de Bt e exibindo granulação muito fina (Figuras 19E, F). A biotita ocorre como cristais hipidioblásticos lamelares a xenoblásticos, de granulação muito fina a fina, comumente associada a opacos (Ilm/Mt). Quartzo, plagioclásio e ortoclásio ocorrem de forma semelhante à porção enriquecida em *melt*, porém não são observados cristais de granulação grossa.

O resíduo apresenta granulação muito fina a média, predominantemente fina, exibindo contatos predominantemente retos a poligonais entre os cristais (Figuras 20A, B). Se observa pequena proporção de *melt* residual (Pl-Or-Qz), que ocorre ocupando espaços intergranulares entre alguns dos componentes da rocha e exibe contatos lobulados a sinuosos entre si, sendo observadas geometrias ramificadas ou em cúspide no Pl e Or cristalizados do *melt*. A proporção de máficos chega a aproximadamente 20-30%, e sua associação mineral é composta por Hc+Mt+Ilm+Or+Qz+Opx+Bt_{res}+Pl±Grt; zonas onde a granada é ausente são ocasionalmente observadas, comumente também pobres em ortoclásio. Os minerais se apresentam em equilíbrio, excetuando-se pela formação de biotita a partir da interação com o *melt* residual (Bt_{melt}) com alguns cristais de máficos anidros. Apresenta foliação marcada por cristais de Opx, Bt, Ilm e Mt orientados em meio a uma matriz granoblástica de Pl+Or+Qz (Figura 20A, B). A granada ocorre como cristais hipidioblásticos dodecaédricos a xenoblásticos arredondados, de granulação fina a média, comumente límpidos

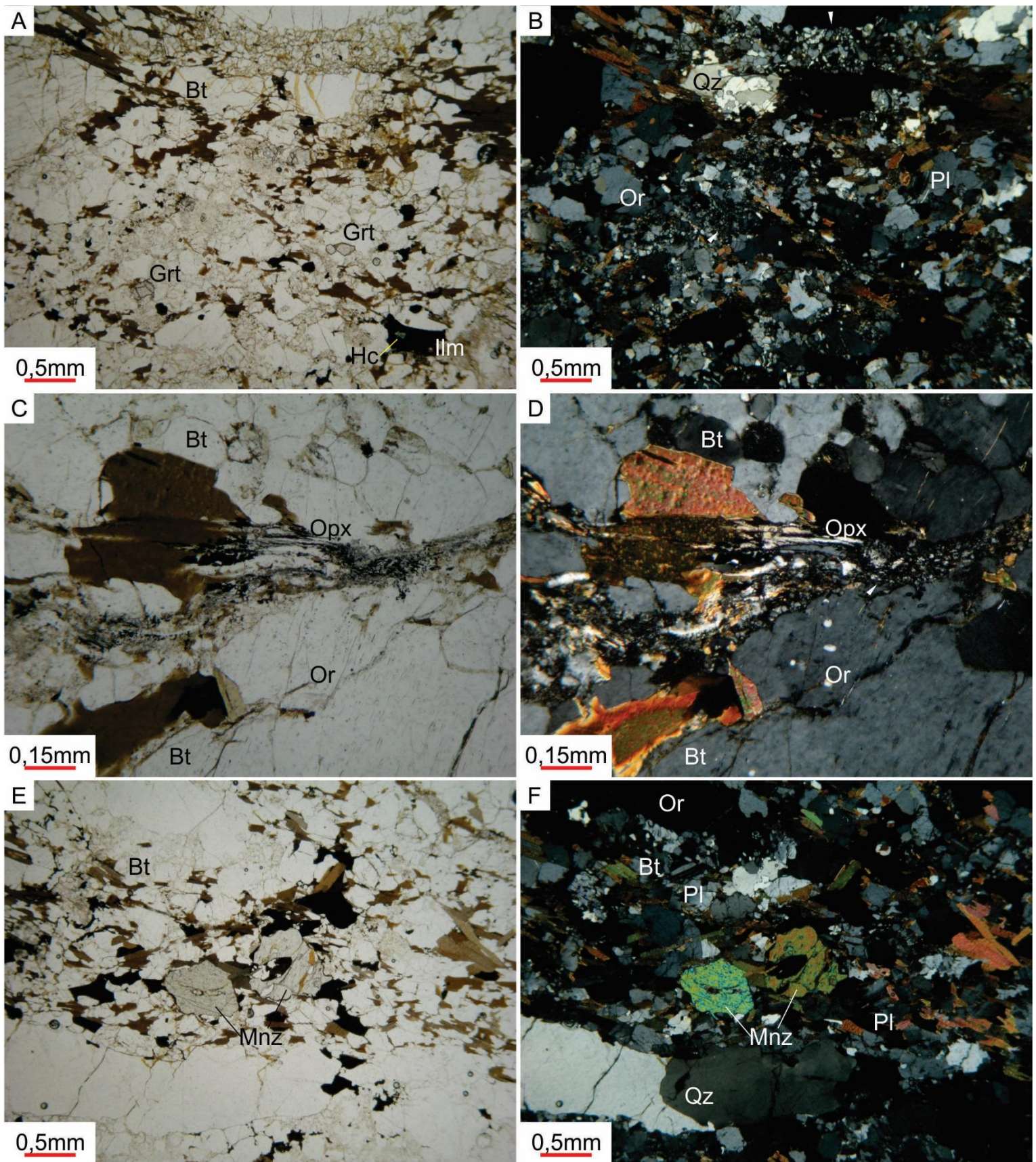


Figura 19 - Feições observadas na zona transicional (*selvedge*). A e B) Aspectos gerais: elevada proporção de Bt, granulação predominantemente fina a muito fina, abundância de filetes de *melt* residual (triângulos brancos), cristais idioblásticos a hipidioblásticos de Grt de granulação muito fina a fina associados a filetes de *melt* residual (triângulo branco); C e D) Cristais de Opx, de granulação muito fina, associados à Bt; E e F) Cristais de Mnz de granulação média. A, B, E, F – objetiva 2,5x. C, D – objetiva 10x. Amostra P010B.

mas podendo conter inclusões de Ilm, Hc, Bt ou Opx. A hercinita se apresenta como cristais esparsos (embora em proporção sutilmente mais elevada que na porção enriquecida em *melt*) xenoblásticos a hipidioblásticos octaédricos, de granulação fina, podendo desenvolver cristais levemente alongados segundo a foliação; é comumente associada a Ilm, Mt ou Opx, podendo ocorrer isolada da matriz como “inclusões” entre estes minerais (Hc₁, Figuras 20C, D) ou como cristais livres na matriz (Hc₂, Figuras 20A, B), sendo observados contatos estáveis com Qz, Pl e Or e localmente associação com a Bt, com quem pode exibir contatos reativos. Magnetita e ilmenita ocorrem em proporções mais elevadas que no leucossoma, normalmente desenvolvendo cristais xenoblásticos alongados ou hipidioblásticos tabulares, de granulação fina, preferencialmente alongados segundo a foliação; a ilmenita pode, ocorrer como inclusões em Opx (Ilm₁) ou como cristais livres na matriz, comumente associados a Hc (Ilm₂). Ortoclásio e quartzo ocorrem em menor proporção que no leucossoma, comumente se apresentando como cristais xenoblásticos de granulação fina e raramente chegando a média. No ortoclásio é comumente observado o desenvolvimento de micro a mesoperititas (Figura 20E); o quartzo pode ocasionalmente apresentar extinção “tabuleiro de xadrez”, sendo mais comum o desenvolvimento de padrões unidirecionais da extinção ondulante. Ortopiroxênio é o máfico mais abundante, comumente desenvolvendo cristais idio a hipidioblásticos prismáticos orientados segundo a foliação, de granulação muito fina a média, exibindo pleocroísmo entre rosa acastanhado, verde pálido e amarelo pálido; podem exibir inclusões de Bt, Qz, Zr ou Opc em orientações variáveis ou ocorrer como inclusões em Grt ou Qz, ocasionalmente se observa a formação de Bt a partir de suas bordas e comumente apresenta contatos estáveis com Qz. A biotita ocorre como fase livre (Bt_{res}, Figuras 20A, B), em cristais idio a hipidioblásticos lamelares de granulação fina a média, preferencialmente orientados, ou como fase retrógrada (Bt_{melt}), associada a reações com o melt nas bordas de cristais de Opx, Hc, Ilm e Mt; em ambos os casos, é comumente associada aos Opc. Plagioclásio é o mineral mais abundante do resíduo, comumente ocorrendo como cristais xenoblásticos de granulação fina, ocasionalmente anti-peritíticos, e comumente apresentando maclas recurvadas (Figura 20F).

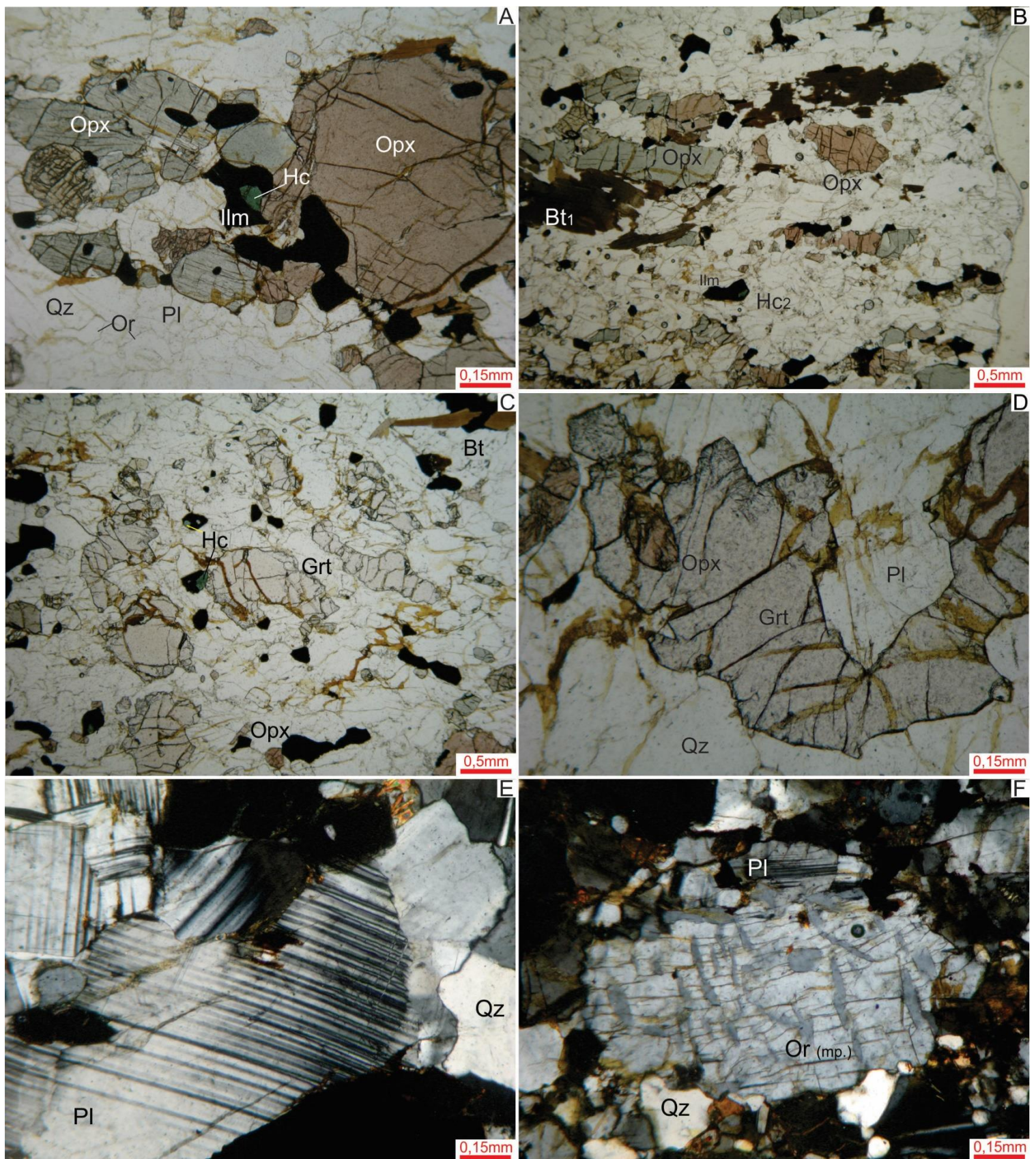


Figura 20 - Feições observadas no resíduo do Hc-Opx-Grt-Bt diatexito. A) Cristal de Hc incluído entre cristais de Ilm e Opx; B) Zona sem granada, exibindo foliação bem pronunciada e marcada pela orientação de Opx e Bt; C) Zona granatífera; D) Cristal de granada com texturas simplectíticas nas bordas, exibindo inclusão de Opx; E) Cristal de Pl exibindo macla levemente recurvada; F) Cristal de Or mesoperfítico. A, D, E, F – objetiva 10x; B, C – objetiva 2,5x. Amostra P010A.

4.3 Opx-Cpx migmatitos

Os Opx-Cpx migmatitos são o tipo mais abundante na Serra do Caparaó, compondo o arcabouço litológico da Suíte Caparaó juntamente com os ortognaisses, dos quais aparentemente guardam uma

relação genética. Sua área de afloramento compreende praticamente toda a extensão da Serra, porém são o litotipo predominante na parte central da mesma, sendo observadas desde morfologias metatexíticas (migmatitos *patch*) a diatexíticas (nebulíticos, *schollen* e *schlieren*). Em algumas localidades se observa sua juxtaposição aos ortognaisses, exibindo uma transição em curtas distâncias entre morfologias de gnaiss granulítico com pouco ou nenhum sinal de fusão para diatexitos. De um modo geral, possuem caráter charnockítico, exibindo coloração predominantemente cinza-esverdeada quando frescos que grada para tons cinza-claros a avermelhados conforme o avanço do intemperismo. Enclaves ultramáficos são observados em diversas localidades na Serra, correspondendo a piroxenitos ou hornblenditos, porém uma maior concentração dos mesmos é notada nos diatexitos que ocorrem nas proximidades do Pico da Bandeira.

4.3.1 Cpx-Bt-Opx-Hbl metatexitos

Na parte Oeste da Serra do Caparaó, intercalados tectonicamente a Grt-Bt-Metatexitos e ortognaisses em lascas métricas a decamétricas, são observados Cpx-Bt-Opx-Hbl-Metatexitos. Estes migmatitos exibem uma transição entre morfologias *patch*, exibindo “filmes” de fusão ao redor de cristais de hornblenda de granulação média que contrastam com a granulação fina predominantemente observada ao longo das bandas (Figura 21A), a estromática, formando uma trama de neossomas paralelos ao bandamento (Figura 21B).



Figura 21 – Cpx-Bt-Opx-Hbl metatexito. A) “Patch” de fusão ao redor de cristal de Hbl, mesmo das Figuras 22E e F. Amostra P006C; B) Neossoma “*in situ*” a “*in source*” em metatexito estromático. Afloramento P006.

O bandamento da rocha é milimétrico, discreto (Figuras 22A, B), sendo observados espaçamentos maiores onde o mesmo é rompido pelos locais onde o *melt* se formou/acumulou. Sua associação mineral é composta por Cpx+Bt+Opx+Qz+Hbl+Or+Pl, sendo observados Zr, Ap e Opc como acessórios. De um modo geral, a granulação varia entre muito fina a média, sendo predominantemente

fina: nas bandas máficas ocasionalmente se observam ocasionalmente cristais de Cpx, Opx e Hbl de granulação média, e a orientação dos cristais destes minerais e da Bt é mais bem pronunciada, ao passo que nas nas bandas félsicas Pl e Or por vezes atingem granulação média, sendo possível observar cristais anti-pertíticos/pertíticos destes minerais. A foliação também é marcada também pela geração incipiente de uma matriz oriunda da recristalização de porfiroclastos de Cpx, Opx, Hbl, Pl, Or e Qz, formada pelos mesmos minerais e também por Bt (Figura 22C, D), exibindo contatos predominantemente engrenados ou poligonais e conferindo à rocha um caráter milonítico. Cristais exibindo maclas ou clivagens deformadas são comumente observados, e extinção ondulante é observada em todos os componentes da rocha.

Os *patches* de neossoma comumente se formam ao redor de porfiroblastos de Hbl de granulação média (Figura 22E, F) que, por vezes, se destacam mesmo em amostras de mão (Figura 21A); estes costumam exibir inclusões de Opc, Opx, Cpx ou Pl, podem apresentar embainhamentos preenchidos pela matriz e constituem a principal fase incongruente das reações de fusão. A intensa deformação torna difícil discernir entre feições geradas pela recristalização dinâmica dos componentes e as feições geradas pelos processos anatéticos, como filmes de fusão e acúmulos de *melt* residual. Bolsões contendo Bt, Pl, Or e Qz de granulação muito fina a fina, sem orientação preferencial e envolvendo relictos de Opx ou Cpx também são observados localmente no neossoma.

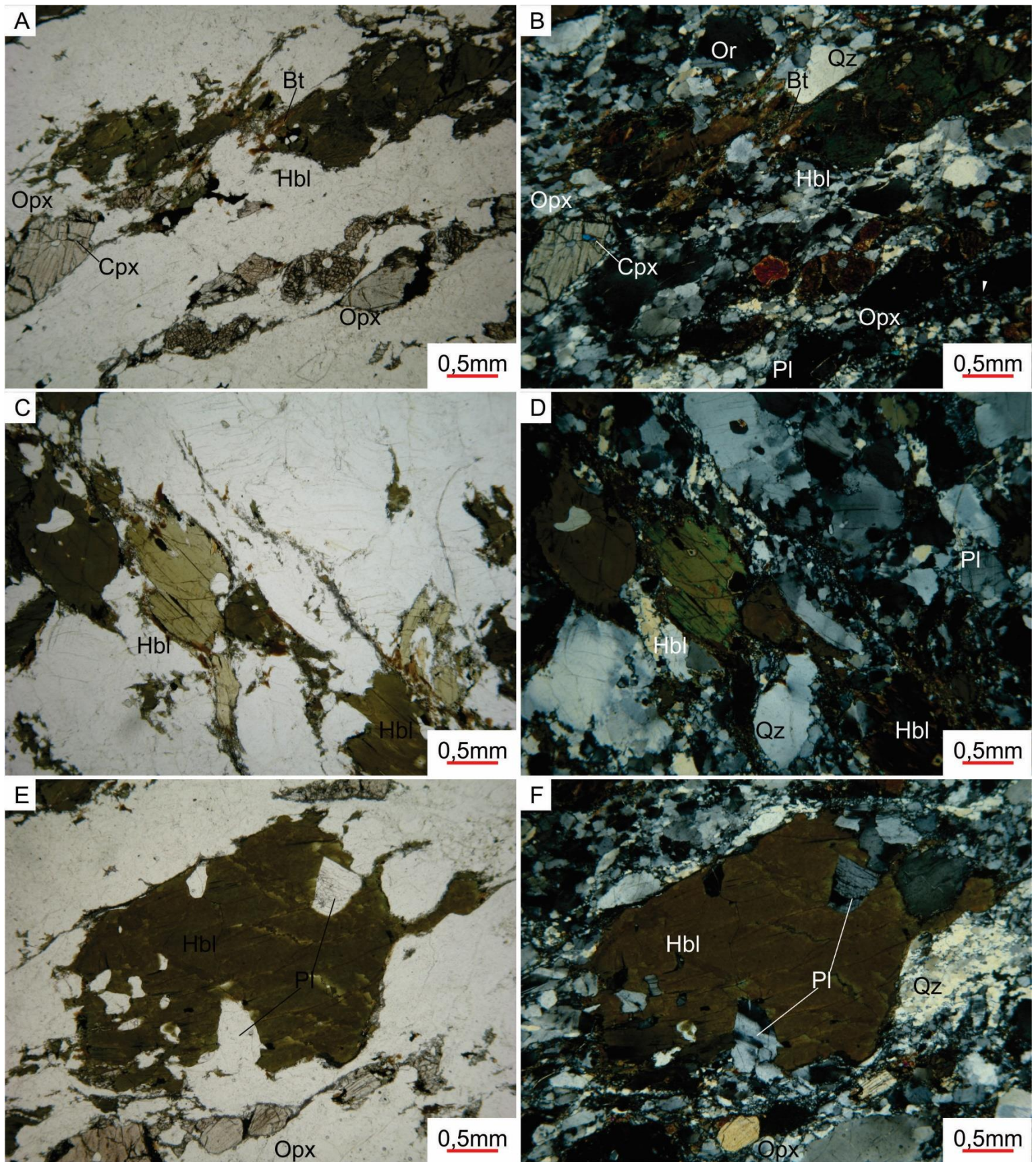


Figura 22 – A e B) Bandamento milimétrico, marcado por intercalação de bandas ricas em Opx-Cpx ou Hbl e bandas ricas em Pl+Qz±Or; C e D) Matriz milonítica formada a partir da recristalização de porfiroclastos de Hbl, Pl e Qz; E e F) Patch de fusão fortemente recristalizado, formado ao redor de cristal peritético de Hbl exibindo embainhamentos preenchidos por Pl+Qz. A-F - Objetiva 2,5x. Amostra P006.

4.3.2 Cpx-Opx diatexitos

Constituem os migmatitos predominantes da Serra do Caparaó, observados ao longo de toda sua extensão. Exibem uma ampla variedade de morfologias, sendo observados nebulitos (Figura 23A), *schollen* (Figura 23B), *schlieren* (Figura 23C), migmatitos bandados e dobrados (Figura 23D) ao longo de toda extensão da Serra, e comumente apresentam uma segregação bem definida entre o leucossoma e o melanossoma, embora o primeiro possa exibir proporções consideráveis de minerais máficos (por vezes chegando a 30%).

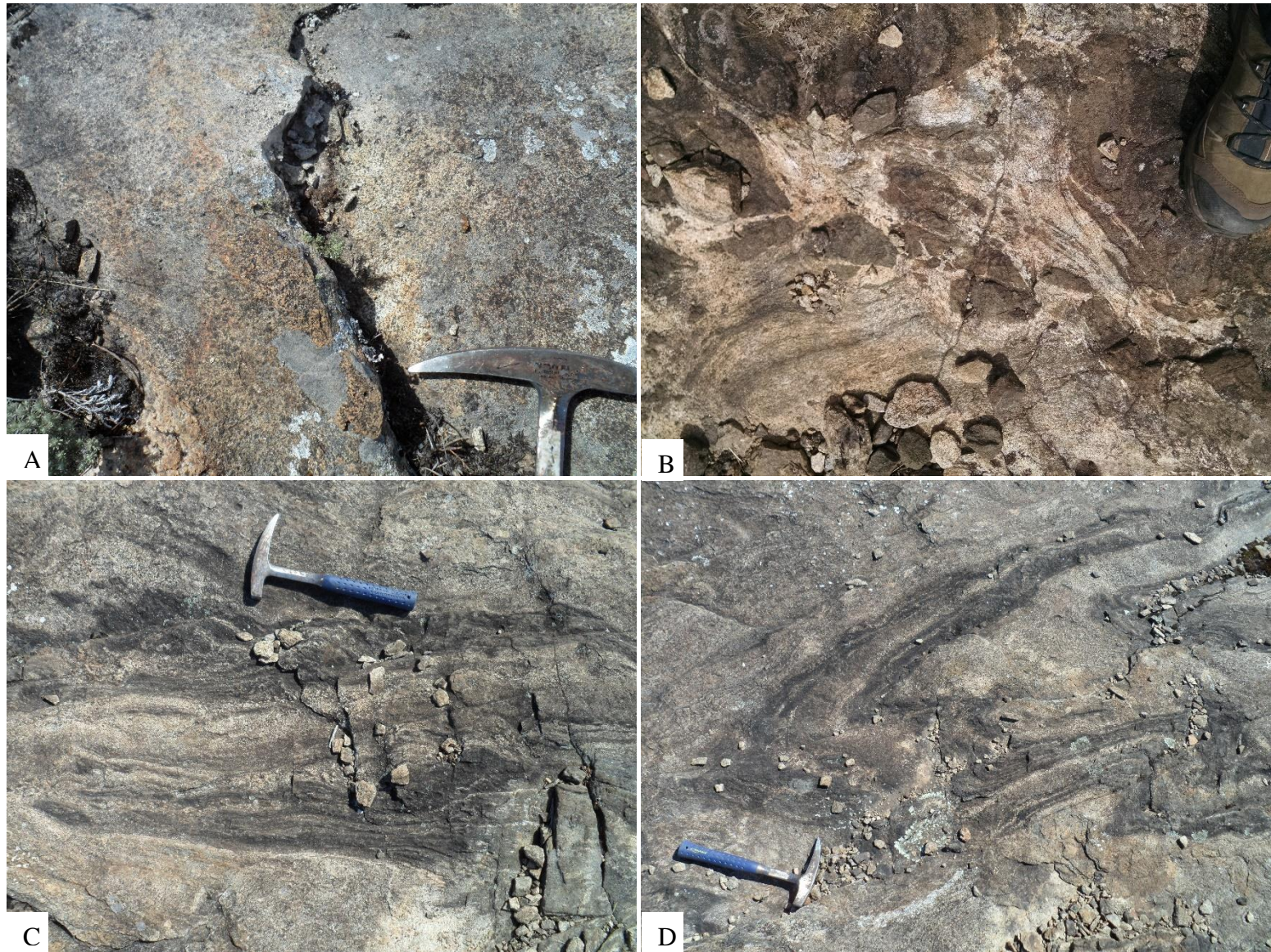


Figura 23– Morfologias do Cpx-Opx-Diatexito. A) Nebulítica; B) *Schollen*; C) *Schlieren*; D) Diatexito dobrado, com núcleo da dobra contendo neossoma nebulítico. A, B – afloramento P3; C-D - afloramento P4.

A associação mineral destes migmatitos compreende, de uma maneira geral, $\text{Opc}+\text{Cpx}+\text{Opx}+\text{Or}+\text{Pl}+\text{Qz}\pm\text{Hbl}\pm\text{Bt}\pm\text{Grt}$, com Ap e Zr como acessórios. A paragênese de pico, representada por Opx e Cpx em contatos estáveis com Qz na ausência de Hbl ou Bt, se encontra predominantemente preservada (Figura 24A, B), porém exceções importantes são observadas ao longo da Serra (ver abaixo). Paragêneses com Grt são raramente observadas (Figura 24 C, D) e, quando presentes, as granadas ocorrem em quantidades acessórias, comumente associadas aos contatos entre Opx, Cpx ou Hbl e Pl formando notáveis estruturas ao redor e com estes minerais (Figura 24C, D). A granulação oscila entre muito fina e média, sendo predominantemente fina, e porfiroblastos são extremamente raros.

O leucossoma exhibe composição modal leucogabroica a (Opx-)granodiorítica, exibindo proporção de máficos entre 10-30%. Predominam texturas nematogranoblásticas, porém em algumas amostras é possível observar feições oriundas da cristalização do *melt*, como geometrias em cúspide nos cristais de Pl, Qz e Or preenchendo espaços intergranulares (Figura 24E, F). Plagioclásio é o principal componente, e oscila entre andesina e labradorita; comumente ocorre como cristais anti-perfíticos e, na presença de ortoclásio (comumente perfítico), intercrescimentos mirmequíticos são frequentemente observados no contato entre ambos. O máfico com maior afinidade pelo leucossoma é o ortopiroxênio, que ocorre comumente alinhado ou orientado segundo a foliação juntamente ao Cpx, Opc e, quando presente, Hbl (Figura 24G, H).

O melanossoma exhibe composição oscilando de piroxenítica a Qz-(Opx-)diorítica (Figura 24I, J), apresentando proporção de máficos entre 60-90%. Predominam texturas nematoblásticas, marcadas por orientação de Cpx, Opx, Hbl e Bt (quando presentes), embora melanossomas isotrópicos sejam observados. Clino e ortopiroxênio muitas vezes ocorrem em proporções semelhantes e são os máficos predominantes na maior parte destes migmatitos. Quando presente, a Hbl costuma ocorrer associada a Bt (Figura 24K, L), comumente de forma restrita e formada a partir das bordas de alguns cristais de Opx e Cpx ou ao longo de “bandas” isoladas onde predominam fases hidratadas; em casos excepcionais, observados como “zonas hidratadas” associadas lateralmente a zonas de cisalhamento, Hbl e Bt chegam a predominar em relação aos demais máficos.

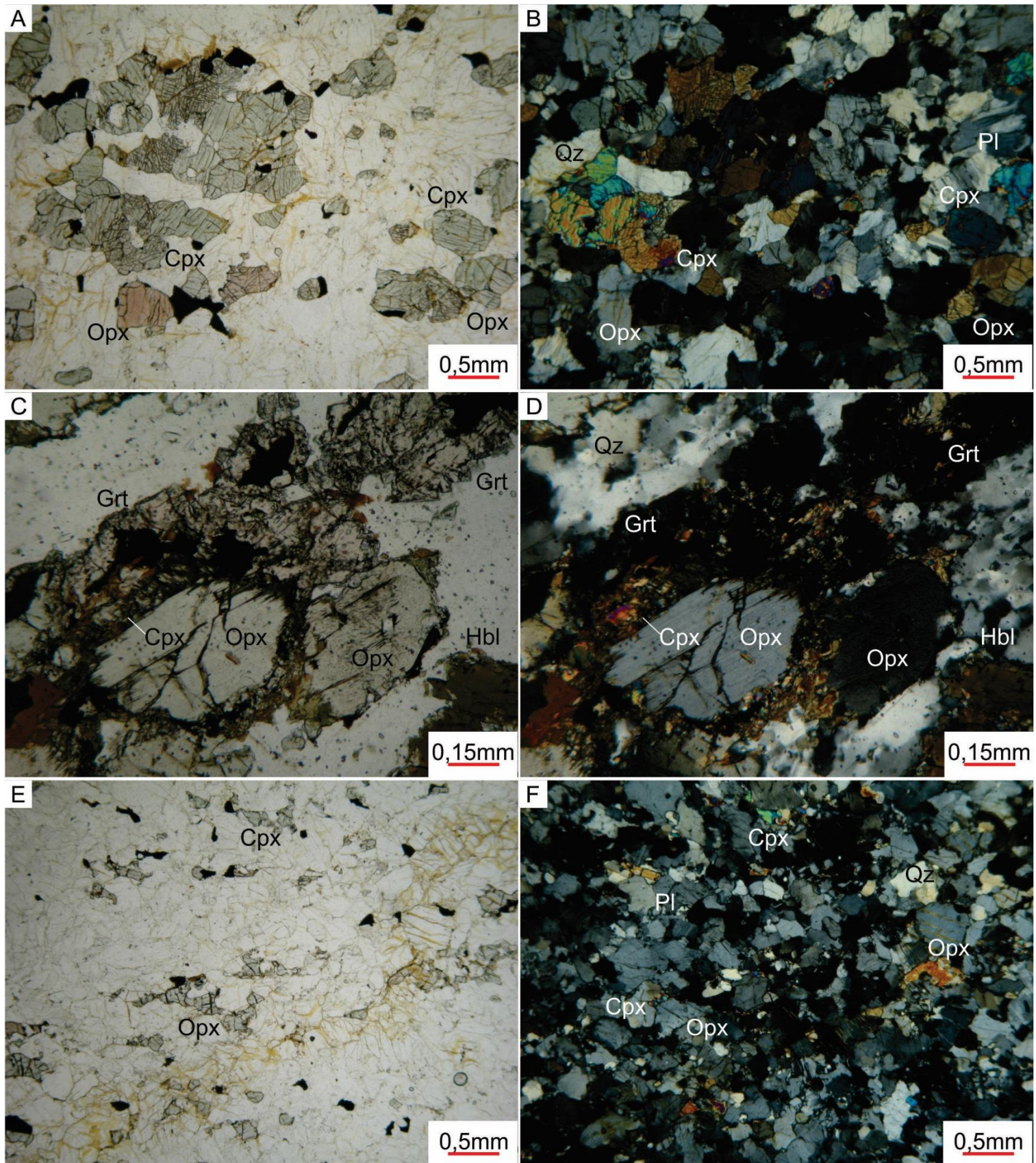


Figura 24 – Microtexturas dos Cpx-Opx-Diatexitos. A e B) Paragênese de pico, $\text{Opx}+\text{Cpx}+\text{Pl}+\text{Qz}$ estáveis sem quantidades significativas de Hbl e Bt; C e D) Paragênese com Grt ($\text{Opx}+\text{Cpx}+\text{Grt}+\text{Pl}$), observada em pontos isolados da Serra, sendo notável a formação de simplectitos destes minerais a partir das bordas de cristais de piroxênio e Hbl; E e F) Típico leucossoma dos Cpx-Opx-Diatexitos, sendo observáveis relictos das microestruturas oriundas da fusão e cristalização de *melt* (geometrias em cuspide e formas “fluidizadas” em cristais de Pl, Or e Qz; (cont.)). A-F – objetiva 2,5x. A, B – amostra P4A; C, D – amostra SC125; E, F – amostra P3.

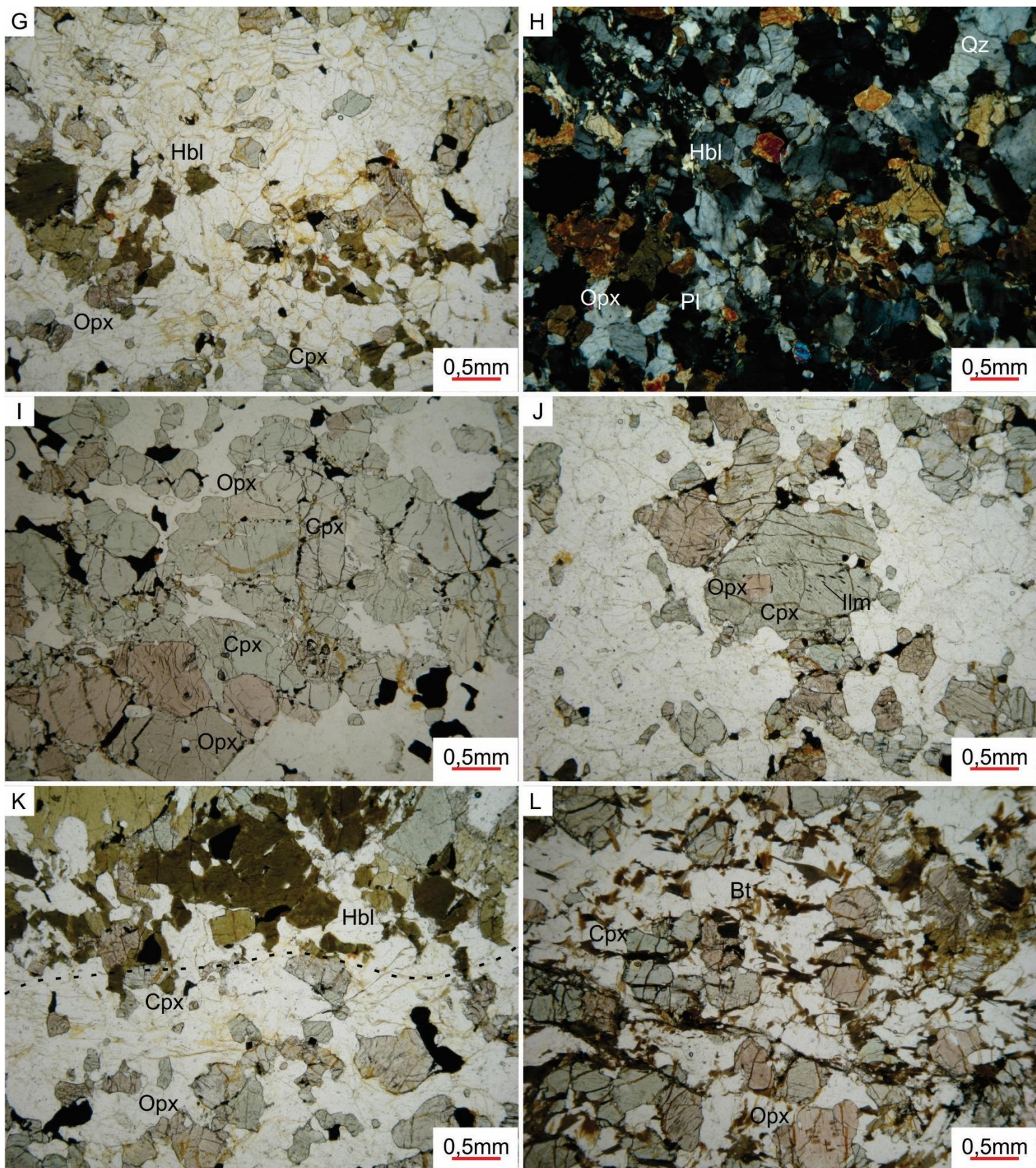


Figura 24 – (cont.) G e H) Leucossoma rico em máficos (~25%), apresentando Opx e Hbl; I) Melanossoma gabróico com aproximadamente 70% de máficos (Cpx, Opx e Opc); J) Melanossoma contendo em torno de 40% de máficos; K) Limite entre banda rica em Hbl e banda rica em Cpx e Opx (linha tracejada); L) Melanossoma rico em Bt, além de Cpx e Opx. Objetiva 2,5x. G, H, K – amostra P4B; I, J – amostra P4A; L – amostra P4C.

5 CONCLUSÕES

Ao longo da Serra do Caparaó, migmatitos granatíferos, derivados de protólitos metassedimentares, foram justapostos lateralmente aos ortognaisses e migmatitos associados da Suíte Caparaó/Complexo Juiz de Fora por meio de zonas de cisalhamento. Esses migmatitos foram divididos em dois tipos: Opx-Grt-Bt migmatitos e Hc-Sil-Grt migmatitos, e as diferenças entre suas associações mineralógicas e paragêneses de pico são indicativas de protólitos distintos. As condições de pico metamórfico calculadas para os Opx-Grt-Bt migmatitos são entre 988-1024 °C e 9,8-10,9 kbar, preservando a associação mineral de pico composta por ortopiroxênio, granada, plagioclásio, ortoclásio e quartzo, além de ilmenita e rutilo como acessórios. Hc-Sil-Grt migmatitos registram pico metamórfico a 1066-1076 °C, 7,6-7,9 kbar, preservando uma mineralogia composta por safirina, ilmenita, hercinita, silimanita, plagioclásio, ortoclásio e quartzo, com magnetita acessória, e como a paragênese safirina+quartzo se encontra preservada, esta nova ocorrência de metamorfismo de temperatura ultra-alta (UHT) é confirmada tanto por uma abordagem termodinâmica quanto pela associação mineralógica. Idades mínimas para o metamorfismo de ambos os tipos de migmatitos recaem entre 626-585 Ma, contemporâneo à fase de arco magmático do Orógeno Araçuai e, portanto, o contexto geotectônico mais provável para terem se desenvolvido condições UHT é o de subdução.

Embora não tenham constituído o foco deste trabalho, observou-se que as litologias típicas da Suíte Caparaó também exibem associações minerais condizentes com metamorfismo em fácies granulito. Localidades com maior proporção de produtos anatéticos, por vezes associadas a zonas onde os Opx-Grt-Bt e Hc-Sil-Grt migmatitos também apresentam maior grau de fusão, são observadas ao longo de toda a Serra. Embora alguns autores tenham considerado todo o pacote de rochas aflorantes ao longo da Serra do Caparaó como paraderivadas (Barbosa & Sad, 1983; Söllner et al., 1991; Seidensticker & Wiedemann, 1992; Söllner et al., 2000; De Campos et al., 2004b; Söllner 2004), trabalhos recentes de mapeamento da Serra do Caparaó (Amaral et al., 2016; Vieira et al., 2017) levaram a uma distinção inicial entre o gnaiss granulítico e migmatitos associados clássicos da Suíte Caparaó, extremamente semelhantes aos observados no Complexo Juiz de Fora (Campos Neto & Figueiredo 1990; Da Silva et al., 2002; Da Silva et al., 2004; Da Silva et al., 2011; Novo et al., 2011), e às unidades granatíferas dentro de seus domínios. Neste trabalho, foram apresentadas as seguintes ponderações petrológicas que atestam a favor da separação dos migmatitos peraluminosos de seus hospedeiros metaluminosos, os ortognaisses e migmatitos da Suíte Caparaó/Complexo Juiz de Fora:

- 1) As associações mineralógicas fornecem evidências de que cada tipo de migmatito possua uma origem distinta. Os Opx-Grt-Bt migmatitos são caracterizados por ortopiroxênio, granada, biotita, plagioclásio, ortoclásio, quartzo e, ocasionalmente, hercinita, com ilmenita, rutilo, apatita, sulfetos, magnetita, zircão e apatita como fases acessórios. Os Hc-Sil-Grt migmatitos são compostos por ilmenita, hercinita, silimanita, granada, biotita, plagioclásio, ortoclásio, quartzo, apresentando safirina nos termos empobrecidos em fundido e cordierita nos

- enriquecidos, com zircão, monazita, apatita, rutilo e magnetita como fases acessórias. O migmatito característico da Suíte Caparaó/Complexo Juiz de Fora possui aspecto charnockítico, e é composto por ortopiroxênio, clinopiroxênio, plagioclásio, quartzo com quantidades variáveis de hornblenda e ortoclásio, biotita retrógrana e raramente exibe granada, esta principalmente como produto de reação entre piroxênios e plagioclásio;
- 2) Estas diferenças não podem ser explicadas pelo grau metamórfico pois estes migmatitos atingiram condições semelhantes de pico metamórfico, em condições de temperatura ultra alta (granulitos do complexo Juiz de Fora nas proximidades de Manhauçu: 990 °C, 11 kbar; Moreira, 1997; Costa et al, 1998). Embora as pressões calculadas possam apresentar diferenças de até 3 kbar entre os dois tipos principais abordados nesta dissertação, os modelos de equilíbrio de fases fornecem fases possíveis distintas no espaço P-T para ambas;
 - 3) As idades obtidas por datação U-Pb em zircão dos Opx-Grt-Bt migmatitos e Hc-Sil-Grt migmatitos não forneceram idades Riacianas, praticamente onipresentes em estudos anteriores da Suíte Caparaó e Complexo Juiz de Fora (Söllner et al., 1991; Da Silva et al., 2002; Da Silva et al., 2011) e presentes na maior parte das amostras estudadas por Gualandi et al. (2015). Embora os hercinita-silimanita-cordierita-granada-biotita diatexitos (amostra P4E) apresentem forte resetamento isotópico, a preservação parcial observada na amostra P013 não evidenciou quaisquer zircões mais antigos que 1,7 Ga. Ainda, populações consideráveis de zircões estudados nas duas amostras apresentam feições de grãos detríticos, não observados nos estudos conduzidos por outros autores na Suíte Caparaó/Complexo Juiz de Fora.

Portanto, é proposto que ambos os migmatitos abordados neste trabalho sejam correlacionados às unidades metassedimentares neoproterozóicas do Orógeno Araçuaí, e não às unidades pertencentes ao embasamento. Estudos petrológicos e geocronológicos mais detalhados ainda são necessários tanto para melhor compreender as diferenças observadas nos graus de fusão parcial entre os migmatitos observados na Serra do Caparaó, quanto para melhor correlacionar as rochas estudadas neste trabalho a outras unidades metassedimentares aflorantes ao longo do Orógeno Araçuaí.

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Appendix S1 - Standards for EMPA and WRG preparation

S1.1: Analytical standards for electron microprobe analysis (EMPA)

Element	Count. Time (Peak) [s]	Count. Time (Backgr.) [s]	X-ray	Spectrometer	Channel	Standard
Na	10	5	K α	TAPH	1	Anorthoclase
F	10	5	K α	TAPH	1	CaF ₂
Si	10	5	K α	TAP	2	Quartz
Al	10	5	K α	TAP	2	Corundum
Mg	10	5	K α	TAP	2	Olivine
Zn	10	5	K α	LIFH	3	Gahnite
Fe	10	5	K α	LIFH	3	Fe
Cl	30	15	K α	PETH	3	Scapolite (Meionite)
Cr	30	15	K α	LIFH	3	Chromite
Ca	10	5	K α	PETJ	4	Fluor-Apatite
Ti	10	5	K α	PETL	5	Rutile
K	10	5	K α	PETL	5	Microcline
Mn	10	5	K α	LIFL	5	MnO ₂

S1.2: Analytical procedures for whole-rock geochemical analysis

Preparation of samples P1, P1D (orthopyroxene-garnet-biotite diatexite), P008 (sapphirine-hercynite-sillimanite-garnet diatexite), P010A (hercynite-orthopyroxene-garnet-biotite diatexite) and P013 (orthopyroxene-garnet-biotite metatexite) for whole-rock geochemical analysis at the SGS GEOSOL Laboratories (Brazil) were performed under the following protocol. Samples were dried at 105 °C, crushed to 3mm, homogenized, submitted to quartering and then 250-300g of the sample was pulverized to 150 mesh at a steel (95%) mill. Loss on Ignition (LOI) was determined by calcination under 1000 °C. 10g of each sample was then submitted to fusion with lithium metaborate (LiBO₂), underwent dissolution with an acid solution of C₄H₆O₆+HNO₃ for complete opening and then analysed under ICP/OES (Inductively Coupled Plasma Optical Emission Spectrometry) for determining major element compositions.

Preparation of sample P4E (hercynite-sillimanite-cordierite-garnet-biotite diatexite) for whole-rock geochemical analysis at the GeoX Laboratory (Federal University of Ouro Preto – UFOP, Brazil) were performed under the following protocol. Samples were dried at 105 °C, crushed to 3mm, homogenized, submitted to quartering and then 250-300g of the sample was pulverized to 150 mesh at a steel (95%) mill. Loss on Ignition (LOI) was determined by calcination under 1000 °C. 1g of each sample was used for

preparing glass disks with 6g of $\text{Li}_2\text{B}_4\text{O}_7$ and LiBO_2 (1:1 proportion) for X-Ray Fluorescence analysis.
Analysis were conducted using a Phillips PANanalytical MagiX X-Ray Fluorescence Spectrometer.

Appendix S2: Representative mineral compositions

S2.1: Representative major element compositions of biotite crystals

Structure formulas calculated after Tindle & Webb (199)

spot/analysis	type	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	ZnO	F	Cl	Cr2O3	O=F,Cl	Total	Si	Al iv	Al vi	Ti	Cr	Fe	Mn	Mg	Zn	Ca	Na	K	Total cations	X/Mg	
<i>Sample P008</i>																															
P008F02Mbt59	Inclusion	40.08	1.56	15.45	5.93	0.04	22.52	0.01	0.02	10.31	0.00	2.75	0.03	0.01	1.17	97.55	5.69	2.31	0.27	0.17	0.00	0.70	0.00	4.76	0.00	0.00	0.01	1.87	15.79	0.8712	
P008F02Mbt60	Inclusion	39.34	1.42	15.16	6.16	0.02	22.13	0.03	0.05	10.21	0.02	2.45	0.02	0.00	1.04	95.97	5.68	2.32	0.26	0.15	0.00	0.74	0.00	4.76	0.00	0.01	0.01	1.88	15.82	0.8649	
P008F03Mbt88	Inclusion	38.39	6.26	15.11	7.33	0.02	18.40	0.03	0.28	9.65	0.00	1.87	0.01	0.02	0.79	96.57	5.52	2.48	0.08	0.68	0.00	0.88	0.00	3.95	0.00	0.00	0.08	1.77	15.44	0.8173	
P008F03Mbt89	Inclusion	37.60	6.07	14.96	7.84	0.02	17.49	0.03	0.28	9.42	0.03	1.89	0.02	0.03	0.80	94.86	5.52	2.48	0.11	0.67	0.00	0.96	0.00	3.83	0.00	0.00	0.08	1.76	15.43	0.7991	
<i>Sample P4E(L)</i>																															
<i>Bt1</i>																															
P4EF01Cbt30	Inclusion	38.48	3.71	15.26	7.11	0.01	20.13	0.06	0.40	9.82	0.00	2.64	0.00	0.00	1.11	96.50	5.56	2.44	0.16	0.40	0.00	0.86	0.00	4.34	0.00	0.01	0.11	1.81	15.70	0.8346	
P4EF01Cbt33	Inclusion	38.19	3.68	16.17	7.20	0.02	19.61	0.02	0.33	9.85	0.00	2.68	0.00	0.00	1.13	96.62	5.51	2.49	0.26	0.40	0.00	0.87	0.00	4.22	0.00	0.00	0.09	1.81	15.66	0.8292	
P4EF02Cbt63	Inclusion	38.27	5.04	14.71	7.51	0.03	18.84	0.02	0.36	9.56	0.00	1.99	0.00	0.00	0.84	95.49	5.58	2.42	0.10	0.55	0.00	0.92	0.00	4.09	0.00	0.00	0.10	1.78	15.55	0.8171	
P4EF02Cbt65	Inclusion	38.54	3.23	15.81	6.70	0.02	20.05	0.08	0.46	9.11	0.00	1.61	0.00	0.00	0.68	94.94	5.59	2.41	0.29	0.35	0.00	0.81	0.00	4.33	0.00	0.01	0.13	1.69	15.62	0.8420	
P4EF02Cbt66	Inclusion	38.30	3.33	15.93	6.78	0.00	19.80	0.61	0.48	9.16	0.00	1.49	0.00	0.00	0.63	95.24	5.55	2.45	0.27	0.36	0.00	0.82	0.00	4.27	0.00	0.09	0.13	1.69	15.64	0.8388	
P4EF02Cbt67	Inclusion	38.19	3.34	15.95	7.00	0.00	20.03	0.08	0.48	9.06	0.00	1.59	0.00	0.00	0.67	95.06	5.54	2.46	0.27	0.36	0.00	0.85	0.00	4.23	0.00	0.01	0.13	1.68	15.64	0.8361	
P4EF02Cbt88	Inclusion	38.03	3.78	15.49	8.08	0.01	19.39	0.08	0.25	9.32	0.00	1.36	0.00	0.00	0.57	95.21	5.54	2.46	0.20	0.41	0.00	0.98	0.00	4.21	0.00	0.01	0.07	1.73	15.62	0.8105	
<i>Bt2</i>																															
P4EF02Mbt89	Matrix	37.38	5.17	15.21	12.46	0.04	14.79	0.06	0.09	9.18	0.00	1.29	0.00	0.00	0.54	95.12	5.56	2.44	0.23	0.58	0.00	1.55	0.00	3.28	0.00	0.01	0.03	1.74	15.41	0.6790	
P4EF02Mbt19	Matrix	37.64	4.36	14.98	12.83	0.02	15.47	0.03	0.16	9.62	0.09	1.46	0.55	0.05	0.74	96.50	5.57	2.43	0.19	0.49	0.01	1.59	0.00	3.41	0.01	0.00	0.04	1.82	15.56	0.6824	
P4EF02Mbt23	Matrix	37.61	4.61	15.10	12.75	0.06	15.25	0.00	0.11	9.49	0.00	1.40	0.55	0.03	0.72	96.23	5.57	2.43	0.21	0.51	0.00	1.58	0.01	3.37	0.00	0.00	0.03	1.79	15.51	0.6807	
P4EF03Mbt39	Matrix	36.97	5.51	14.63	13.91	0.04	14.01	0.02	0.11	9.50	0.05	1.21	0.53	0.03	0.63	95.89	5.54	2.46	0.12	0.62	0.00	1.74	0.01	3.13	0.01	0.00	0.03	1.81	15.47	0.6423	
P4EF03Mbt40	Matrix	38.89	5.41	14.77	13.87	0.04	13.70	0.02	0.12	9.28	0.00	1.25	0.53	0.00	0.65	95.24	5.55	2.45	0.17	0.61	0.00	1.75	0.01	3.08	0.00	0.00	0.04	1.78	15.43	0.6378	
<i>Bt3</i>																															
P4EF01Mbt49	Matrix	37.65	2.02	15.59	10.75	0.04	18.29	0.09	0.10	9.64	0.00	1.71	0.00	0.00	0.72	95.16	5.58	2.42	0.30	0.22	0.00	1.33	0.01	4.04	0.00	0.01	0.03	1.82	15.76	0.7520	
P4EF01Mbt50	Matrix	37.38	2.05	15.70	10.83	0.01	18.32	0.08	0.09	9.46	0.00	1.59	0.00	0.00	0.67	94.83	5.55	2.45	0.30	0.23	0.00	1.34	0.00	4.06	0.00	0.01	0.03	1.79	15.76	0.7510	
P4EF01Mbt51	Matrix	37.14	2.83	15.68	10.66	0.02	17.93	0.06	0.07	9.56	0.00	1.59	0.00	0.00	0.67	94.86	5.52	2.48	0.26	0.32	0.00	1.32	0.00	3.97	0.00	0.01	0.02	1.81	15.71	0.7499	
P4EF01Mbt52	Matrix	36.80	2.92	15.80	11.98	0.06	17.38	0.06	0.10	9.52	0.00	1.54	0.00	0.00	0.65	95.51	5.47	2.53	0.23	0.33	0.00	1.49	0.01	3.85	0.00	0.01	0.03	1.80	15.74	0.7212	
P4EF01Cbt36	Inclusion	37.47	1.23	18.76	9.14	0.04	18.66	0.03	0.21	9.72	0.00	0.61	0.00	0.00	0.26	95.61	5.43	2.57	0.63	0.13	0.00	1.11	0.01	4.03	0.00	0.00	0.06	1.80	15.77	0.7845	
<i>Sample P4E(R)</i>																															
<i>Bt1</i>																															
P4EF01Cbt13	Inclusion	37.05	4.47	15.65	9.37	0.00	17.51	0.02	0.16	10.11	0.00	1.27	0.00	0.00	0.54	95.07	5.47	2.53	0.19	0.50	0.00	1.16	0.00	3.85	0.00	0.00	0.04	1.90	15.65	0.7691	
P4EF03Cbt01	Inclusion	37.51	4.55	15.87	9.41	0.02	17.78	0.08	0.15	9.60	0.00	1.58	0.00	0.00	0.66	95.88	5.48	2.52	0.21	0.50	0.00	1.15	0.00	3.87	0.00	0.01	0.04	1.79	15.57	0.7710	
P4EF03Cbt102	Inclusion	38.16	4.31	15.63	9.35	0.04	18.38	0.07	0.14	9.77	0.00	1.61	0.00	0.00	0.68	96.78	5.52	2.48	0.18	0.47	0.00	1.13	0.00	3.96	0.00	0.01	0.04	1.80	15.60	0.7781	
P4EF03Mbt117	Matrix	38.41	4.18	15.06	9.48	0.04	18.10	0.04	0.08	9.98	0.00	1.58	0.00	0.00	0.66	96.28	5.59	2.41	0.17	0.46	0.00	1.15	0.00	3.93	0.00	0.01	0.02	1.85	15.60	0.7729	
P4EF03Mbt118	Matrix	38.18	4.01	14.82	9.39	0.02	18.10	0.03	0.10	9.86	0.00	1.75	0.00	0.00	0.74	95.53	5.60	2.40	0.17	0.44	0.00	1.15	0.00	3.96	0.00	0.00	0.03	1.85	15.61	0.7745	
<i>Bt2</i>																															
P4EF01Mbt12	Matrix	37.25	5.08	15.40	10.87	0.01	16.35	0.00	0.13	10.07	0.00	1.12	0.00	0.00	0.47	95.81	5.49	2.51	0.16	0.56	0.00	1.34	0.00	3.59	0.00	0.00	0.04	1.89	15.58	0.7283	
P4EF01Mbt09	Matrix	36.83	5.72	14.76	11.41	0.00	15.29	0.03	0.15	9.93	0.00	1.00	0.00	0.00	0.42	94.69	5.50	2.50	0.10	0.64	0.00	1.43	0.00	3.41	0.00	0.01	0.04	1.89	15.52	0.7049	
P4EF01Mbt10	Matrix	37.25	5.33	14.83	11.41	0.02	15.59	0.04	0.12	9.82	0.00	1.18	0.00	0.00	0.50	95.08	5.54	2.46	0.14	0.60	0.00	1.42	0.00	3.46	0.00	0.01	0.03	1.86	15.51	0.7091	
P4EF01Mbt29	Matrix	37.21	4.82	15.09	11.69	0.00	15.66	0.03	0.13	9.93	0.00	1.27	0.00	0.00	0.54	95.31	5.53	2.47	0.18	0.54	0.00	1.45	0.00	3.47	0.00	0.01	0.04	1.88	15.57	0.7048	
P4EF01Mbt30	Matrix	36.84	4.70	15.01	11.61	0.03	15.62	0.03	0.07	9.87	0.00	1.29	0.00	0.00	0.54	94.52	5.52	2.48	0.18	0.53	0.00	1.46	0.00	3.49	0.00	0.00	0.02	1.89	15.57	0.7058	
<i>Sample P013(ps)</i>																															
<i>Bt1</i>																															
P013F01Cbt145	Inclusion	36.84	1.99	17.26	9.86	0.01	17.83	0.06	0.10	9.27	0.05	1.10	0.29	0.02	0.53	94.15	5.47	2.53	0.49	0.22	0.00	1.22	0.00	3.95	0.01	0.01	0.03	1.76	15.69	0.7632	
P013F01Cbt146	Inclusion	37.40	1.89	17.12	9.64	0.03	18.10	0.00	0.11	9.78	0.00	1.07	0.29	0.00	0.52	94.91	5.51	2.49	0.48	0.21	0.00	1.19	0.00	3.98	0.00	0.00	0.03	1.84	15.73	0.7700	
<i>Bt2</i>																															
P013F02Mbt107	Matrix	37.32	5.34	13.87	13.14	0.03	14.58	0.06	0.10	9.44	0.05	1.27	0.21	0.10	0.58	94.94	5.61	2.39	0.07	0.60	0.01	1.65	0.00	3.27	0.01	0.01	0.03	1.81	15.47	0.6641	
P013F02Mbt108	Matrix	37.93	5.28	14.04	13.23	0.02	14.89	0.01	0.02	9.55	0.03	1.43	0.20	0.08	0.65	96.07	5.63	2.37	0.09	0.59	0.01	1.64	0.00	3.30	0.00	0.00	0.01	1.81	15.45	0.6673	
P013F02Mbt109	Matrix	38.17	5.17	14.08	13.01	0.02	14.83	0.03	0.10	9.58	0.02	1.35	0.21	0.06	0.61	96.00	5.66	2.34	0.12	0.58	0.01	1.61	0.0								

Sample P1(M)																														
Bt1																														
P1mF05Cbt137	Inclusion	37.23	6.25	14.11	11.88	0.00	14.84	0.00	0.13	9.68	0.00	1.46	0.00	0.00	0.61	94.96	5.57	2.43	0.05	0.70	0.00	1.48	0.00	3.31	0.00	0.00	0.04	1.84	15.43	0.6902
P1mF05Cbt139	Inclusion	37.55	6.34	14.22	11.80	0.03	15.23	0.04	0.15	9.62	0.00	1.51	0.00	0.00	0.63	95.86	5.56	2.44	0.04	0.71	0.00	1.46	0.00	3.36	0.00	0.01	0.04	1.82	15.43	0.6970
P1mF05Cbt140	Inclusion	37.47	6.21	14.17	11.98	0.02	15.38	0.01	0.19	9.62	0.00	1.52	0.00	0.00	0.64	95.92	5.55	2.45	0.02	0.69	0.00	1.48	0.00	3.39	0.00	0.00	0.05	1.82	15.46	0.6959
Bt2																														
P1mFDMbt52	Matrix	37.99	4.69	13.91	12.95	0.02	14.65	0.50	0.32	9.68	0.01	1.41	0.28	0.08	0.66	95.83	5.67	2.33	0.11	0.53	0.01	1.62	0.00	3.26	0.00	0.08	0.09	1.84	15.54	0.6685
P1mFDMbt56	Matrix	37.49	5.26	13.72	13.84	0.00	14.46	0.04	0.11	10.05	0.00	1.65	0.28	0.08	0.76	96.21	5.61	2.39	0.03	0.59	0.01	1.73	0.00	3.23	0.00	0.01	0.03	1.92	15.55	0.6505
P1mF05Mbt154	Matrix	37.49	5.54	13.90	14.14	0.00	14.38	0.00	0.08	9.75	0.00	1.44	0.00	0.00	0.61	96.11	5.59	2.41	0.04	0.62	0.00	1.76	0.00	3.20	0.00	0.00	0.02	1.86	15.50	0.6445
Bt3																														
P1mF07Mbt81	Matrix	38.39	3.71	13.80	10.86	0.00	17.81	0.03	0.06	9.95	0.00	2.05	0.00	0.00	0.86	95.78	5.68	2.32	0.08	0.41	0.00	1.34	0.00	3.92	0.00	0.00	0.02	1.88	15.66	0.7452
P1mF07Mbt82	Matrix	37.97	4.04	13.78	11.34	0.00	17.40	0.03	0.03	9.98	0.00	1.94	0.00	0.00	0.82	95.69	5.64	2.36	0.05	0.45	0.00	1.41	0.00	3.85	0.00	0.00	0.01	1.89	15.66	0.7322
P1mF07Mbt83	Matrix	38.00	3.64	13.80	10.95	0.01	17.56	0.05	0.06	9.83	0.00	1.98	0.00	0.00	0.83	95.04	5.66	2.34	0.09	0.41	0.00	1.37	0.00	3.90	0.00	0.01	0.02	1.87	15.66	0.7408
P1mF07Mbt87	Matrix	37.41	4.88	13.66	12.64	0.00	15.51	0.03	0.03	9.80	0.00	1.60	0.00	0.00	0.67	94.88	5.63	2.37	0.05	0.55	0.00	1.59	0.00	3.48	0.00	0.00	0.01	1.88	15.56	0.6863
P1mF07Mbt89	Matrix	37.78	4.74	13.51	12.35	0.00	15.48	0.02	0.05	9.67	0.00	1.69	0.00	0.00	0.71	94.57	5.58	2.32	0.08	0.54	0.00	1.55	0.00	3.47	0.00	0.00	0.01	1.86	15.52	0.6909
P1mF06Mbt115	Inclusion	38.65	4.58	13.61	11.54	0.00	17.05	0.02	0.09	9.93	0.00	1.87	0.00	0.00	0.79	95.54	5.68	2.32	0.03	0.51	0.00	1.42	0.00	3.73	0.00	0.00	0.03	1.86	15.58	0.7247
P1mF06Mbt117	Matrix	37.22	5.10	13.82	12.32	0.04	15.80	0.02	0.08	9.72	0.00	1.62	0.00	0.00	0.68	95.05	5.58	2.42	0.02	0.58	0.00	1.54	0.01	3.53	0.00	0.00	0.02	1.86	15.56	0.6957
Sample P1(L)																														
Bt1																														
P1F01Cbt20	Inclusion	37.76	6.03	14.01	11.59	0.03	15.80	0.03	0.12	9.87	0.00	1.63	0.00	0.00	0.69	96.18	5.57	2.43	0.01	0.67	0.00	1.43	0.00	3.48	0.00	0.01	0.03	1.86	15.48	0.7084
P1F01Cbt21	Inclusion	38.07	6.00	14.02	11.42	0.01	15.95	0.00	0.11	9.82	0.00	1.57	0.00	0.00	0.66	96.30	5.60	2.40	0.03	0.66	0.00	1.40	0.00	3.49	0.00	0.00	0.03	1.84	15.46	0.7135
Bt2																														
P1FF0Mbt5	Matrix	38.01	4.27	13.86	12.32	0.08	16.13	0.04	0.12	9.81	0.00	1.70	0.28	0.12	0.78	95.97	5.65	2.35	0.08	0.48	0.01	1.53	0.01	3.58	0.00	0.01	0.04	1.86	15.60	0.7000
P1FF0Mbt6	Matrix	38.46	4.15	13.65	13.90	0.01	16.16	0.08	0.11	8.92	0.02	1.74	0.26	0.06	0.79	96.74	5.68	2.32	0.06	0.46	0.01	1.72	0.00	3.56	0.00	0.01	0.03	1.68	15.52	0.6745
P1F01Mbt24	Matrix	37.77	5.03	14.04	12.75	0.05	15.42	0.05	0.05	9.86	0.00	1.68	0.00	0.00	0.71	95.99	5.61	2.39	0.07	0.56	0.00	1.59	0.01	3.42	0.00	0.01	0.01	1.87	15.54	0.6831
P1F01Mbt26	Matrix	37.54	4.91	14.25	12.32	0.04	15.60	0.06	0.12	9.75	0.00	1.65	0.00	0.00	0.69	95.53	5.59	2.41	0.10	0.55	0.00	1.53	0.00	3.47	0.00	0.01	0.03	1.85	15.55	0.6930
P1F02Mbt59	Matrix	37.32	5.47	13.84	12.95	0.02	14.99	0.00	0.10	9.68	0.00	1.51	0.00	0.00	0.64	95.24	5.59	2.41	0.04	0.62	0.00	1.62	0.00	3.35	0.00	0.00	0.03	1.85	15.51	0.6735
P1F02Mbt60	Matrix	37.32	5.49	13.99	12.67	0.03	15.07	0.01	0.08	9.58	0.00	1.46	0.00	0.00	0.61	95.08	5.59	2.41	0.06	0.62	0.00	1.59	0.00	3.36	0.00	0.00	0.02	1.83	15.49	0.6794
P1F02Mbt61	Matrix	37.69	5.49	14.15	12.53	0.00	15.46	0.01	0.05	9.69	0.00	1.64	0.00	0.00	0.69	96.00	5.59	2.41	0.06	0.61	0.00	1.55	0.00	3.42	0.00	0.00	0.01	1.83	15.49	0.6875
Bt3																														
P1FFMbt24	Matrix	37.56	3.60	13.72	13.13	0.03	16.23	0.04	0.08	9.16	0.00	1.76	0.26	0.07	0.80	94.83	5.66	2.34	0.10	0.41	0.01	1.65	0.00	3.65	0.00	0.01	0.02	1.76	15.60	0.6879
P1FFMbt25	Matrix	38.30	3.99	13.99	11.76	0.04	16.81	0.06	0.10	9.97	0.00	2.02	0.30	0.07	0.92	96.49	5.66	2.34	0.10	0.44	0.01	1.45	0.00	3.70	0.00	0.01	0.03	1.88	15.63	0.7181
P1FF02Mbt51	Inclusion	39.21	2.27	15.64	9.91	0.00	19.40	0.06	0.10	9.84	0.00	2.29	0.00	0.00	0.97	97.76	5.63	2.37	0.28	0.25	0.00	1.19	0.00	4.15	0.00	0.01	0.03	1.80	15.71	0.7772
P1F02Mbt52	Inclusion	38.90	2.49	14.85	9.73	0.01	19.27	0.07	0.07	9.94	0.00	2.16	0.00	0.00	0.91	95.57	5.66	2.34	0.21	0.27	0.00	1.18	0.00	4.18	0.00	0.01	0.02	1.85	15.72	0.7792
P1F02Mbt55	Matrix	38.65	3.65	13.60	11.43	0.00	17.41	0.02	0.09	9.67	0.00	2.33	0.00	0.00	0.98	96.16	5.74	2.26	0.00	0.40	0.00	1.41	0.00	3.83	0.00	0.00	0.00	1.82	15.58	0.7308
P1F02Mbt56	Matrix	38.24	3.48	13.76	12.61	0.00	16.76	0.00	0.09	9.60	0.00	2.08	0.00	0.00	0.88	95.74	5.69	2.31	0.11	0.39	0.00	1.57	0.00	3.72	0.00	0.00	0.03	1.82	15.63	0.7031
Sample P1D																														
Bt1																														
P1DF02Cbt59	Inclusion	37.25	4.91	16.06	12.36	0.00	15.09	0.00	0.06	10.00	0.00	1.04	0.00	0.00	0.44	96.33	5.48	2.52	0.27	0.54	0.00	1.52	0.00	3.31	0.00	0.00	0.02	1.88	15.53	0.6852
P1DF02Cbt60	Inclusion	37.05	4.68	16.01	12.50	0.02	14.78	0.02	0.06	9.97	0.00	1.13	0.00	0.00	0.48	95.72	5.49	2.51	0.29	0.52	0.00	1.55	0.00	3.27	0.00	0.00	0.02	1.88	15.54	0.6782
P1DF04Cbt99	Inclusion	38.14	4.43	15.21	10.60	0.00	16.71	0.05	0.14	9.73	0.00	0.96	0.00	0.00	0.40	95.55	5.59	2.41	0.22	0.49	0.00	1.30	0.00	3.65	0.00	0.01	0.04	1.82	15.53	0.7375
Bt2																														
P1DF01Mbt10	Matrix	37.69	4.07	15.50	11.43	0.02	15.97	0.05	0.08	9.98	0.00	1.30	0.00	0.00	0.55	95.52	5.57	2.43	0.27	0.45	0.00	1.41	0.00	3.52	0.00	0.01	0.02	1.88	15.58	0.7135
P1DF01Mbt12	Matrix	37.90	4.13	15.60	11.33	0.00	15.99	0.00	0.03	10.04	0.00	1.38	0.00	0.00	0.58	95.81	5.58	2.42	0.29	0.46	0.00	1.40	0.00	3.51	0.00	0.00	0.01	1.89	15.55	0.7154
P1DF01Mbt14	Matrix	37.76	4.73	15.33	11.68	0.06	15.55	0.03	0.07	9.93	0.00	1.00	0.00	0.00	0.42	95.71	5.57	2.43	0.23	0.52	0.00	1.44	0.01	3.42	0.00	0.00	0.02	1.87	15.52	0.7035
P1DF01Mbt15	Matrix	37.66	4.21	15.55	12.07	0.01	15.78	0.02	0.05	9.93	0.00	1.60	0.00	0.00	0.67	96.20	5.55	2.45	0.26	0.47	0.00	1.49	0.00	3.47	0.00	0.00	0.01	1.87	15.57	0.6996
P1DF04Mbt104	Matrix	36.46	5.19	15.28	13.43	0.00	14.35	0.05	0.07	9.23	0.00	0.95	0.00	0.00	0.40	94.60	5.48	2.52	0.19	0.59	0.00	1.69	0.00	3.22	0.00	0.01	0.02	1.77	15.47	0.6557
P1DF04Mbt105	Matrix	36.72	4.98	15.42	13.77	0.01	13.93	0.08	0.11	8.74	0.00	0.90	0.00	0.00	0.38	94.28	5.52	2.48	0.26	0.56	0.00	1.73	0.00	3.12	0.00	0.01	0.03	1.68	15.40	0.6433
Bt3																														
P1DF03Mbt76	Matrix	37.34																												

S2.2: Representative major element compositions of cordierite crystals

Structural formulas calculated after Deer et al. (1992)

spot/analysis	type	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	TOTAL	Si	Ti	Al	Fe	Mn	Mg	Ca	Na	K	Total cations	XMg
<i>Crd1</i>																						
P4EF03Mcrd47	Core	51.26	0.04	33.89	3.69	0.03	11.59	0.01	0.00	0.02	100.52	5.09	0.00	3.97	0.31	0.00	1.72	0.00	0.00	0.00	11.10	0.8483
P4EF03Mcrd48	Core	50.74	0.01	33.68	3.80	0.07	11.59	0.01	0.05	0.00	99.95	5.04	0.00	3.95	0.32	0.01	1.72	0.00	0.01	0.00	11.04	0.8447
P4EF03Mcrd49	Rim	50.36	0.01	33.68	3.83	0.07	11.43	0.01	0.00	0.00	99.39	5.00	0.00	3.94	0.32	0.01	1.69	0.00	0.00	0.00	10.97	0.8418
P4EF02Mcrd04	Core	50.07	0.00	33.31	3.58	0.00	11.59	0.12	0.08	0.01	98.75	4.98	0.00	3.90	0.30	0.00	1.72	0.01	0.02	0.00	10.92	0.8522
P4EF02Mcrd09	Rim	50.41	0.03	33.68	3.72	0.06	11.66	0.00	0.04	0.01	99.59	5.01	0.00	3.95	0.31	0.01	1.73	0.00	0.01	0.00	11.01	0.8482
P4EF02Mcrd12	Core	50.30	0.01	33.84	3.70	0.06	11.74	0.02	0.05	0.01	99.73	5.00	0.00	3.96	0.31	0.01	1.74	0.00	0.01	0.00	11.03	0.8499
P4EF02Mcrd13	Rim	50.04	0.01	33.75	3.74	0.08	11.45	0.03	0.05	0.01	99.15	4.97	0.00	3.95	0.31	0.01	1.70	0.00	0.01	0.00	10.95	0.8452
<i>Crd2</i>																						
P4E'F01Mcrd43	Overgrowth	50.84	0.00	34.06	3.37	0.01	12.13	0.05	0.03	0.02	100.51	5.00	0.00	3.95	0.28	0.00	1.78	0.01	0.01	0.00	11.02	0.8647
P4E'F01Mcrd44	Overgrowth	50.86	0.00	34.44	3.34	0.05	11.94	0.03	0.06	0.02	100.73	5.00	0.00	3.99	0.27	0.00	1.75	0.00	0.01	0.00	11.05	0.8627
P4E'F01Mcrd45	Overgrowth	51.16	0.00	34.53	3.29	0.04	12.03	0.02	0.03	0.01	101.11	5.04	0.00	4.00	0.27	0.00	1.77	0.00	0.01	0.00	11.09	0.8657
P4E'F01Mcrd46	Overgrowth	51.05	0.00	34.51	3.30	0.05	12.15	0.02	0.03	0.01	101.12	5.02	0.00	4.00	0.27	0.00	1.78	0.00	0.01	0.00	11.09	0.8660
P4EF01Mcrd53	Overgrowth	50.30	0.03	34.02	3.41	0.06	11.67	0.00	0.03	0.01	99.53	5.00	0.00	3.98	0.28	0.01	1.73	0.00	0.01	0.00	11.01	0.8590
P4EF01Mcrd54	Overgrowth	50.29	0.02	34.02	3.53	0.04	11.90	0.00	0.03	0.01	99.84	5.00	0.00	3.99	0.29	0.00	1.76	0.00	0.01	0.00	11.05	0.8571
<i>Crd3</i>																						
P4EF03Mcrd24	Pinitized	50.27	0.01	33.60	4.05	0.07	11.34	0.04	0.01	0.01	99.39	5.00	0.00	3.94	0.34	0.01	1.68	0.00	0.00	0.00	10.96	0.8330
P4EF03Mcrd25	Pinitized	50.63	0.00	33.66	3.96	0.03	11.42	0.02	0.02	0.02	99.75	5.03	0.00	3.94	0.33	0.00	1.69	0.00	0.00	0.00	11.00	0.8369
P4EF03Mcrd26	Pinitized	50.39	0.01	33.56	3.91	0.04	11.30	0.02	0.03	0.01	99.25	5.01	0.00	3.93	0.33	0.00	1.67	0.00	0.01	0.00	10.95	0.8373
P4EF03Mcrd53	Pinitized	50.00	0.06	33.41	4.02	0.09	11.15	0.04	0.05	0.02	98.84	4.97	0.00	3.91	0.33	0.01	1.65	0.00	0.01	0.00	10.90	0.8318
P4EF03Mcrd54	Pinitized	50.65	0.19	33.69	4.06	0.03	11.52	0.03	0.06	0.00	100.23	5.03	0.01	3.95	0.34	0.00	1.71	0.00	0.01	0.00	11.06	0.8351

S2.3: Representative major element compositions of orthoclase and plagioclase crystals

Structural formulas calculated after Perkins (2007)

spot/analysis	Mineral	type	SiO2	Al2O3	FeO	CaO	Na2O	K2O	Total	Si	Al	Fe3+	Ca	Na	K	Total cations	An%	Ab%	Or%
<i>Sample P008</i>																			
P008F02Mpl41	Pl	Matrix	58.55	25.89	0.05	7.75	7.16	0.13	99.53	2.63	1.37	0.00	0.37	0.62	0.01	5.00	37.13	62.12	0.75
P008F02Mpl42	Pl	Matrix	58.28	24.79	1.85	6.97	6.97	0.17	99.03	2.65	1.33	0.07	0.34	0.61	0.01	5.00	35.22	63.76	1.02
P008F02Mpl43	Pl	Matrix	59.21	26.17	0.02	7.74	7.21	0.15	100.50	2.63	1.37	0.00	0.37	0.62	0.01	5.00	36.91	62.22	0.87
P008F03Cpl83	Pl	Inclusion	58.13	26.14	0.15	8.21	6.38	0.58	99.59	2.61	1.39	0.01	0.40	0.56	0.03	4.99	40.16	56.47	3.37
P008F03Cpl87	Pl	Inclusion	59.20	25.88	0.08	7.41	6.97	0.29	99.83	2.64	1.36	0.00	0.35	0.60	0.02	4.98	36.38	61.93	1.69
P008F01Mor15	Or	Matrix	64.50	19.02	0.02	0.40	1.23	14.65	99.82	2.97	1.03	0.00	0.02	0.11	0.86	5.00	2.01	11.08	86.91
P008F01Mor16	Or	Matrix	64.37	18.94	0.04	0.41	1.20	14.52	99.48	2.97	1.03	0.00	0.02	0.11	0.86	4.99	2.07	10.95	86.98
P008F01Mor46	Or	Matrix	64.54	18.64	0.00	0.14	1.45	14.36	99.14	2.99	1.02	0.00	0.01	0.13	0.85	4.99	0.70	13.23	86.06
<i>Sample P4E</i>																			
<i>Pl</i>																			
P4EF01Cpl26	Pl	Inclusion	59.05	26.57	0.23	8.04	6.86	0.18	100.92	2.62	1.39	0.01	0.38	0.59	0.01	5.00	38.90	60.10	1.00
P4EF01Cpl27	Pl	Inclusion	58.58	26.59	0.09	8.27	6.66	0.20	100.37	2.61	1.40	0.00	0.39	0.57	0.01	4.98	40.20	58.60	1.10
P4EF01Mpl55	Pl	Matrix	59.82	25.79	0.12	7.32	7.26	0.09	100.40	2.65	1.35	0.00	0.35	0.62	0.00	4.97	35.60	63.90	0.50
P4EF01Mpl56	Pl	Matrix	58.29	26.56	0.07	7.97	7.05	0.10	100.03	2.60	1.40	0.00	0.38	0.61	0.01	5.00	38.30	61.20	0.50
P4EF02Cpl68	Pl	Inclusion	58.09	26.75	0.13	8.45	6.76	0.09	100.26	2.59	1.41	0.00	0.40	0.58	0.01	4.99	40.70	58.80	0.50
P4EF02Cpl69	Pl	Inclusion	58.15	26.93	0.27	8.35	6.78	0.10	100.58	2.59	1.41	0.01	0.40	0.59	0.01	5.01	40.30	59.20	0.60
P4EF02Mpl99	Pl	Matrix	59.92	25.49	0.01	6.98	7.52	0.10	100.02	2.67	1.34	0.00	0.33	0.65	0.01	5.00	33.70	65.70	0.60
P4E'F01Mpl35	Pl	Matrix	59.42	25.95	0.02	7.50	7.12	0.14	100.15	2.64	1.36	0.00	0.36	0.61	0.01	4.98	36.50	62.70	0.80
P4E'F01Mpl37	Pl	Matrix	59.36	26.57	0.05	7.88	6.90	0.13	100.87	2.62	1.38	0.00	0.37	0.59	0.01	4.97	38.40	60.90	0.70
P4E'F01Mpl38	Pl	Matrix	59.21	26.26	0.05	7.87	7.00	0.10	100.49	2.63	1.37	0.00	0.37	0.60	0.01	4.98	38.10	61.30	0.60
<i>Or1</i>																			
P4EF01Mor43	Or	Matrix	65.04	19.20	0.00	0.29	2.00	13.52	100.04	2.98	1.04	0.00	0.01	0.18	0.79	5.00	1.50	18.10	80.50
P4EF02Cor84	Or	Inclusion	64.70	18.85	0.21	0.22	1.68	13.85	99.50	2.98	1.02	0.01	0.01	0.15	0.81	4.98	1.10	15.40	83.50
P4EF02Cor85	Or	Inclusion	64.70	18.95	0.12	0.28	1.95	13.53	99.52	2.98	1.03	0.00	0.01	0.17	0.79	4.98	1.40	17.70	80.90
P4EF02Mor94	Or	Matrix	65.22	18.83	0.00	0.15	2.11	13.50	99.80	2.99	1.02	0.00	0.01	0.19	0.79	5.00	0.70	19.00	80.20
P4E'F01Cor14	Or	Inclusion	64.41	18.98	0.22	0.12	1.84	13.85	99.42	2.97	1.03	0.01	0.01	0.16	0.82	5.00	0.60	16.70	82.70
P4E'F01Mor31	Or	Matrix	64.82	18.92	0.00	0.15	1.90	14.00	99.79	2.98	1.03	0.00	0.01	0.17	0.82	5.01	0.80	17.00	82.30
<i>Or2</i>																			
P4EF02Mor81	Or	Matrix	64.31	19.47	0.05	0.48	2.80	12.15	99.26	2.96	1.05	0.00	0.02	0.25	0.71	4.99	2.40	25.30	72.30
P4EF02Mor82	Or	Matrix	63.83	19.18	0.02	0.47	2.40	12.84	98.75	2.96	1.05	0.00	0.02	0.22	0.76	5.01	2.30	21.60	76.00
P4E'F02Mor69	Or	Matrix	64.20	19.29	0.45	0.19	2.31	12.56	99.00	2.96	1.05	0.02	0.01	0.21	0.74	4.99	1.00	21.70	77.40
P4E'F02Mor70	Or	Matrix	63.88	19.93	0.25	0.23	3.11	11.27	98.66	2.94	1.08	0.01	0.01	0.28	0.66	4.98	1.20	29.20	69.60
<i>Sample P013(ps)</i>																			
<i>Pl1</i>																			
P013F01Cpl127	Pl	Inclusion	54.08	29.60	0.16	11.95	4.41	0.27	100.46	2.43	1.57	0.01	0.58	0.38	0.02	4.99	59.00	39.40	1.60
P013F01Cpl128	Pl	Inclusion	51.08	31.36	0.30	13.89	3.22	0.15	100.00	2.32	1.68	0.01	0.68	0.28	0.01	4.98	69.80	29.30	0.90
P013F01Cpl129	Pl	Inclusion	50.61	31.56	0.19	13.71	3.26	0.17	99.50	2.31	1.70	0.01	0.67	0.29	0.01	4.99	69.20	29.80	1.00
P013F01Cpl131	Pl	Inclusion	49.50	32.44	0.17	15.46	2.61	0.07	100.26	2.25	1.74	0.01	0.75	0.23	0.00	4.98	76.30	23.30	0.40
<i>Pl2</i>																			
P013F02Mpl114	Pl	Matrix	56.75	27.33	0.09	9.46	5.99	0.12	99.74	2.55	1.45	0.00	0.46	0.52	0.01	4.99	46.30	53.00	0.70
P013F02Mpl115	Pl	Matrix	56.90	27.25	0.06	9.56	6.08	0.17	100.02	2.55	1.44	0.00	0.46	0.53	0.01	4.99	46.10	53.00	1.00
P013F02Mpl117	Pl	Matrix	58.17	26.76	0.05	8.60	6.41	0.21	100.19	2.60	1.41	0.00	0.41	0.55	0.01	4.98	42.10	56.70	1.20
P013F01Cpl132	Pl	Matrix	56.97	27.02	0.03	8.98	6.26	0.23	99.50	2.57	1.44	0.00	0.43	0.55	0.01	5.00	43.60	55.10	1.30
P013F01Cpl134	Pl	Matrix	57.52	27.00	0.09	9.33	6.07	0.15	100.15	2.57	1.42	0.00	0.45	0.53	0.01	4.98	45.50	53.60	0.90

Or																			
P013F02Mpl118	Or	Matrix	64.71	18.71	0.07	0.09	0.94	14.50	99.02	3.00	1.02	0.00	0.00	0.08	0.86	4.96	0.50	9.00	90.60
P013F02Mpl121	Or	Matrix	64.77	18.70	0.11	0.10	1.12	14.34	99.15	2.99	1.02	0.00	0.01	0.10	0.85	4.97	0.50	10.60	88.90
P013F01Mpl136	Or	Matrix	64.47	18.88	0.00	0.11	0.97	14.46	98.89	2.99	1.03	0.00	0.01	0.09	0.85	4.97	0.60	9.20	90.20
P013F01Mpl137	Or	Matrix	65.29	18.44	0.04	0.07	0.91	14.60	99.36	3.01	1.00	0.00	0.00	0.08	0.86	4.95	0.40	8.60	91.00
<i>Sample P013(ns)</i>																			
P013F05Mpl28	Pl	Core	57.72	26.86	0.05	8.60	6.08	0.26	99.57	2.59	1.42	0.00	0.41	0.53	0.01	4.96	43.20	55.30	1.50
P013F04Cpl51	Pl	Inclusion	58.30	27.02	0.07	8.90	6.40	0.19	100.89	2.59	1.41	0.00	0.42	0.55	0.01	4.98	43.00	55.90	1.10
P013F04Cpl58	Pl	Core	57.38	27.08	0.06	9.27	6.16	0.18	100.13	2.57	1.43	0.00	0.44	0.54	0.01	4.99	44.90	54.00	1.10
P013F04Cpl60	Pl	Rim	56.77	26.89	0.39	8.95	6.01	0.36	99.37	2.57	1.43	0.01	0.43	0.53	0.02	4.99	44.20	53.70	2.10
P013F03Cpl78	Pl	Core	57.60	26.78	0.02	8.81	6.28	0.24	99.73	2.59	1.42	0.00	0.42	0.55	0.01	4.99	43.10	55.60	1.40
P013F05Mor30	Or	Core	64.65	18.44	0.56	0.13	0.90	14.08	98.76	3.00	1.01	0.02	0.01	0.08	0.83	4.95	0.70	8.80	90.50
P013F05Mor31	Or	Rim	64.63	18.61	0.16	0.08	0.85	14.22	98.54	3.00	1.02	0.01	0.00	0.08	0.84	4.95	0.40	8.30	91.30
P013F04Mor53	Or	Inclusion	64.32	18.56	0.14	0.17	1.05	14.08	98.32	3.00	1.02	0.01	0.01	0.10	0.84	4.98	0.90	10.10	89.00
P013F04Mor54	Or	Inclusion	64.49	18.85	0.09	0.18	1.25	13.92	98.78	2.99	1.03	0.00	0.01	0.11	0.82	4.96	0.90	11.90	87.20
P013F04Mor55	Or	Rim	65.35	18.62	0.05	0.04	0.97	14.51	99.54	3.01	1.01	0.00	0.00	0.09	0.85	4.96	0.20	9.20	90.60
<i>Sample P1(M)</i>																			
P1mFAMpl91	Pl	Matrix	56.18	28.16	0.07	9.84	5.44	0.22	99.90	2.52	1.49	0.00	0.47	0.47	0.01	4.96	49.30	49.30	1.30
P1mFAMpl92	Pl	Matrix	55.71	28.59	0.04	10.40	5.32	0.17	100.23	2.50	1.51	0.00	0.50	0.46	0.01	4.98	51.40	47.60	1.00
P1mF05Mpl141	Pl	Inclusion	56.46	27.78	0.12	10.01	5.75	0.29	100.40	2.53	1.47	0.00	0.48	0.50	0.02	5.00	48.20	50.10	1.70
P1mF05Mpl142	Pl	Inclusion	56.48	27.93	0.15	10.14	5.69	0.29	100.68	2.52	1.47	0.01	0.49	0.49	0.02	5.00	48.80	49.60	1.60
P1mF05Mpl143	Pl	Inclusion	56.21	27.84	0.05	10.02	5.68	0.33	100.14	2.52	1.47	0.00	0.48	0.49	0.02	4.98	48.40	49.60	1.90
P1mF05Mpl148	Pl	Matrix	56.55	27.85	0.04	10.02	5.58	0.31	100.34	2.53	1.47	0.00	0.48	0.48	0.02	4.98	48.90	49.30	1.80
P1mFAMor93	Or	Matrix	63.94	18.11	0.03	0.03	0.62	15.91	98.62	3.00	1.00	0.00	0.00	0.06	0.95	5.01	0.10	5.60	94.30
P1mFAMor94	Or	Matrix	63.66	18.23	0.00	0.01	0.65	15.82	98.36	2.99	1.01	0.00	0.00	0.06	0.95	5.01	0.00	5.90	94.10
P1mFAMor95	Or	Matrix	64.35	18.55	0.03	0.03	0.68	15.85	99.48	2.99	1.02	0.00	0.00	0.06	0.94	5.01	0.20	6.10	93.80
<i>Sample P1(L)</i>																			
P1FEMpl39	Pl	Matrix	56.72	27.41	0.06	9.40	5.92	0.31	99.81	2.55	1.45	0.00	0.45	0.52	0.02	4.99	45.90	52.30	1.80
P1FEMpl40	Pl	Matrix	56.97	27.20	0.03	8.79	6.00	0.25	99.24	2.57	1.45	0.00	0.42	0.52	0.01	4.97	44.10	54.40	1.50
P1F01Mpl32	Pl	Matrix	56.77	27.82	0.05	9.72	6.06	0.18	100.60	2.53	1.46	0.00	0.47	0.52	0.01	4.99	46.50	52.40	1.00
P1F01Mpl34	Pl	Matrix	56.33	28.29	0.10	10.15	5.77	0.20	100.84	2.51	1.49	0.00	0.49	0.50	0.01	5.00	48.70	50.10	1.20
P1F02Mpl64	Pl	Matrix	55.82	28.11	0.08	10.29	5.74	0.12	100.15	2.51	1.49	0.00	0.50	0.50	0.01	5.01	49.40	49.90	0.70
P1F02Mpl65	Pl	Matrix	56.83	27.82	0.02	9.87	5.96	0.20	100.70	2.53	1.46	0.00	0.47	0.52	0.01	4.99	47.20	51.60	1.20
P1F01Mor13	Or	Inclusion	64.51	18.80	0.06	0.19	1.29	14.60	99.44	2.98	1.02	0.00	0.01	0.12	0.86	4.99	0.90	11.70	87.40
P1F01Mor14	Or	Inclusion	64.99	18.97	0.10	0.18	1.38	14.19	99.81	2.98	1.03	0.00	0.01	0.12	0.83	4.97	0.90	12.80	86.30
P1F01Mor18	Or	Inclusion	64.54	18.77	0.12	0.11	1.04	14.77	99.33	2.99	1.02	0.00	0.01	0.09	0.87	4.98	0.50	9.60	89.90
P1F01Mor19	Or	Inclusion	64.61	18.83	0.13	0.10	1.18	14.79	99.64	2.98	1.02	0.00	0.00	0.11	0.87	4.98	0.50	10.70	88.80
P1F02Mor49	Or	Inclusion	64.68	18.43	0.07	0.06	1.19	14.99	99.43	2.99	1.01	0.00	0.00	0.11	0.89	5.00	0.30	10.70	89.00
P1F02Mor50	Or	Inclusion	65.35	18.66	0.17	0.04	1.08	15.03	100.33	3.00	1.01	0.01	0.00	0.10	0.88	5.00	0.20	9.80	90.00
<i>Sample P1D</i>																			
P1DF01Mpl26	Pl	Matrix	58.93	26.35	0.04	7.91	6.89	0.19	100.31	2.62	1.38	0.00	0.38	0.59	0.01	4.98	38.40	60.50	1.10
P1DF01Mpl27	Pl	Matrix	58.93	26.40	0.05	8.25	6.75	0.20	100.56	2.62	1.38	0.00	0.39	0.58	0.01	4.98	39.90	59.00	1.10
P1DF01Mpl28	Pl	Matrix	58.87	25.83	0.03	7.57	6.92	0.18	99.41	2.64	1.37	0.00	0.36	0.60	0.01	4.98	37.20	61.70	1.10
P1DF03Mpl80	Pl	Matrix	59.59	25.79	0.07	7.42	6.81	0.37	100.06	2.65	1.35	0.00	0.35	0.59	0.02	4.96	36.70	61.10	2.20
P1DF04Mpl111	Pl	Matrix	59.27	25.81	0.09	7.68	6.90	0.14	99.88	2.65	1.36	0.00	0.37	0.60	0.01	4.99	37.80	61.40	0.80
P1DF04Mpl112	Pl	Matrix	59.84	25.31	0.23	5.88	6.98	0.15	98.38	2.69	1.34	0.01	0.28	0.61	0.01	4.94	31.50	67.60	0.90
P1DF01Mor18	Or	Matrix	64.69	18.91	0.03	0.02	0.80	15.37	99.82	2.98	1.03	0.00	0.00	0.07	0.90	4.98	0.10	7.30	92.60
P1DF01Mor24	Or	Matrix	65.15	18.76	0.01	0.03	0.97	15.39	100.31	2.99	1.02	0.00	0.00	0.09	0.90	5.00	0.10	8.80	91.10
P1DF01Mor29	Or	Matrix	64.61	18.84	0.00	0.13	1.15	14.92	99.64	2.98	1.03	0.00	0.01	0.10	0.88	5.00	0.60	10.40	89.00
P1DF02Mor62	Or	Inclusion	64.93	18.62	0.29	0.27	1.15	14.84	100.10	2.99	1.01	0.01	0.01	0.10	0.87	4.99	1.40	10.40	88.20
P1DF03Mor86	Or	Matrix	65.33	18.79	0.16	0.06	0.94	15.11	100.39	2.99	1.01	0.01	0.00	0.08	0.88	4.97	0.30	8.60	91.00
P1DF04Mor107	Or	Matrix	64.61	18.87	0.00	0.05	1.23	14.58	99.34	2.99	1.03	0.00	0.00	0.11	0.86	4.99	0.20	11.30	88.40
P1DF04Mor109	Or	Matrix	64.61	18.68	0.01	0.11	1.11	14.84	99.35	2.99	1.02	0.00	0.01	0.10	0.88	5.00	0.50	10.20	89.30

Sample P010A

P11

P010AF01Mpl12	PI	Matrix	57.06	27.07	0.03	8.92	6.00	0.23	99.30	2.57	1.44	0.00	0.43	0.52	0.01	4.97	44.50	54.10	1.40
P010AF01Mpl13	PI	Matrix	57.25	26.90	0.06	8.90	6.16	0.25	99.51	2.58	1.43	0.00	0.43	0.54	0.01	4.99	43.80	54.80	1.50
P010AF03Mpl66	PI	Matrix	56.78	27.61	0.07	9.34	5.84	0.32	99.95	2.55	1.46	0.00	0.45	0.51	0.02	4.99	46.00	52.10	1.90
P010AF03Mpl67	PI	Matrix	56.96	27.70	0.09	9.17	5.87	0.35	100.13	2.55	1.46	0.00	0.44	0.51	0.02	4.98	45.40	52.60	2.00
P010AF03Mpl68	PI	Matrix	56.85	27.69	0.05	9.53	5.69	0.29	100.10	2.55	1.46	0.00	0.46	0.49	0.02	4.98	47.30	51.00	1.70

P12

P010AF04Mpl94	PI	Matrix	54.59	28.91	0.04	10.85	4.91	0.26	99.56	2.47	1.54	0.00	0.53	0.43	0.02	4.99	54.10	44.30	1.60
P010AF04Mpl95	PI	Matrix	54.60	29.02	0.05	10.84	4.96	0.25	99.72	2.47	1.55	0.00	0.52	0.43	0.01	4.98	53.90	44.60	1.50
P010AF04Mpl96	PI	Matrix	54.47	29.17	0.04	11.27	4.92	0.22	100.09	2.45	1.55	0.00	0.54	0.43	0.01	4.98	55.20	43.50	1.30
P010AF04Mpl97	PI	Matrix	53.83	28.49	0.04	10.69	4.81	0.23	98.08	2.47	1.54	0.00	0.53	0.43	0.01	4.98	54.40	44.20	1.40
P010AF05Mpl123	PI	Matrix	54.71	28.86	0.01	10.87	4.79	0.23	99.46	2.47	1.54	0.00	0.53	0.42	0.01	4.97	54.90	43.70	1.40
P010AF05Mpl124	PI	Matrix	54.31	29.07	0.05	10.94	4.80	0.18	99.34	2.46	1.55	0.00	0.53	0.42	0.01	4.97	55.10	43.80	1.10

Or

P010AF01Mor15	Or	Matrix	65.13	18.75	0.04	0.16	1.06	15.37	100.51	2.99	1.01	0.00	0.01	0.09	0.90	5.00	0.80	9.40	89.80
P010AF01Mor16	Or	Matrix	64.76	18.38	0.02	0.08	1.08	15.43	99.76	2.99	1.00	0.00	0.00	0.10	0.91	5.00	0.40	9.60	90.00
P010AF03Mor70	Or	Matrix	64.83	18.63	0.00	0.08	0.77	15.95	100.25	2.99	1.01	0.00	0.00	0.07	0.94	5.01	0.40	6.80	92.80
P010AF03Mor71	Or	Matrix	64.57	18.41	0.04	0.10	0.58	16.20	99.89	2.99	1.01	0.00	0.01	0.05	0.96	5.02	0.50	5.10	94.40
P010AF06Mor137	Or	Matrix	65.06	18.45	0.03	0.09	1.11	15.32	100.06	3.00	1.00	0.00	0.00	0.10	0.90	5.00	0.40	9.90	89.70
P010AF06Mor138	Or	Matrix	64.91	18.72	0.00	0.08	0.98	15.25	99.95	2.99	1.02	0.00	0.00	0.09	0.90	5.00	0.40	8.90	90.70

S2.4: Representative major element compositions of garnet crystals

*Structural formulas and Fe³⁺ contents calculated after Perkins (2007)

spot/analysis	type	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Total	Si	Ti	Al	Cr	Fe ³⁺ *	Fe ²⁺	Mn	Mg	Ca	Total cations	Alm%	Sps%	Prp%	Gr _s %
<i>Sample P008</i>																									
P008F03Cg74	Rim	39.65	0.07	22.36	0.02	0.00	23.53	1.23	12.42	1.05	100.32	2.98	0.00	1.98	0.00	0.05	1.43	0.08	1.39	0.08	8.00	47.91	2.62	46.64	2.75
P008F03Cg79	Core	40.02	0.03	22.14	0.03	0.00	23.17	1.10	12.49	1.18	100.16	3.01	0.00	1.96	0.00	0.01	1.45	0.07	1.40	0.10	8.00	48.01	2.32	46.51	3.14
P008F03Cg80	Core	39.66	0.04	22.08	0.03	0.00	23.15	1.16	12.21	1.19	99.51	3.01	0.00	1.97	0.00	0.01	1.46	0.07	1.38	0.10	8.00	48.46	2.48	45.86	3.18
P008F03Mg81	Rim	40.25	0.05	22.53	0.02	0.00	23.17	1.17	12.67	1.12	100.97	3.00	0.00	1.98	0.00	0.01	1.43	0.07	1.41	0.09	8.00	47.71	2.46	46.86	2.94
P008F03Mg82	Rim	39.95	0.05	22.25	0.02	0.00	23.29	1.17	12.49	0.99	100.20	3.00	0.00	1.97	0.00	0.01	1.45	0.07	1.40	0.08	8.00	48.32	2.47	46.56	2.63
P008F02Cg34	Rim	40.06	0.05	22.21	0.03	0.00	23.20	1.10	12.54	1.01	100.20	3.01	0.00	1.97	0.00	0.00	1.46	0.07	1.41	0.08	8.00	48.35	2.33	46.63	2.69
P008F02Cg35	Rim	40.12	0.05	22.54	0.00	0.00	23.07	1.18	12.67	1.10	100.72	3.00	0.00	1.98	0.00	0.01	1.43	0.07	1.41	0.09	8.00	47.55	2.49	47.04	2.90
P008F02Cg54	Core	40.41	0.07	22.26	0.02	0.00	22.81	1.28	12.60	1.19	100.63	3.02	0.00	1.96	0.00	0.00	1.43	0.08	1.41	0.10	8.00	47.42	2.70	46.70	3.17
P008F02Cg55	Core	40.27	0.04	22.25	0.02	0.00	23.05	1.14	12.32	1.27	100.36	3.02	0.00	1.97	0.00	0.00	1.45	0.07	1.38	0.10	8.00	48.23	2.41	45.95	3.40
P008F02Mg57	Rim	39.88	0.08	22.09	0.02	0.00	23.45	1.15	12.25	1.37	100.28	3.00	0.00	1.96	0.00	0.03	1.45	0.07	1.37	0.11	8.00	48.18	2.43	45.71	3.62
P008F02Mg58	Rim	39.73	0.06	22.13	0.04	0.00	23.78	1.15	12.02	1.20	100.10	3.00	0.00	1.97	0.00	0.02	1.48	0.07	1.35	0.10	8.00	49.26	2.45	45.06	3.18
<i>Sample P4E</i>																									
<i>Grt1</i>																									
P4EF02Mg01	Rim	40.12	0.06	22.15	0.00	0.00	24.26	1.31	11.27	1.31	100.47	3.03	0.00	1.97	0.00	0.00	1.53	0.08	1.27	0.11	8.00	51.23	2.80	42.41	3.55
P4EF02Mg02	Rim	39.85	0.05	22.17	0.00	0.00	24.41	1.30	11.44	1.32	100.54	3.01	0.00	1.97	0.00	0.01	1.53	0.08	1.29	0.11	8.00	50.96	2.76	42.73	3.53
P4EF02Cg10	Core	40.18	0.03	22.42	0.00	0.00	23.46	1.21	12.12	1.61	101.02	3.00	0.00	1.97	0.00	0.02	1.45	0.08	1.35	0.13	8.00	48.22	2.55	44.95	4.24
P4EF02Cg11	Core	40.16	0.00	22.43	0.00	0.00	23.03	1.29	12.29	1.46	100.66	3.01	0.00	1.98	0.00	0.01	1.44	0.08	1.37	0.12	8.00	47.76	2.72	45.62	3.89
P4EF02Cg12	Core	40.29	0.03	22.23	0.00	0.00	23.22	1.21	12.24	1.16	100.37	3.03	0.00	1.97	0.00	0.00	1.46	0.08	1.37	0.09	8.00	48.65	2.56	45.69	3.10
P4EF02Cg36	Core	39.71	0.02	21.86	0.00	0.00	23.59	1.15	12.08	1.35	99.75	3.01	0.00	1.95	0.00	0.03	1.46	0.07	1.36	0.11	8.00	48.60	2.45	45.32	3.58
P4EF02Cg37	Core	39.94	0.03	22.36	0.00	0.00	23.36	1.20	12.08	1.57	100.54	3.00	0.00	1.98	0.00	0.02	1.45	0.08	1.35	0.13	8.00	48.19	2.54	45.06	4.16
P4EF02Mg61	Rim	39.84	0.01	22.00	0.00	0.00	24.59	1.34	11.23	1.39	100.40	3.01	0.00	1.96	0.00	0.01	1.55	0.09	1.27	0.11	8.00	51.40	2.85	42.01	3.73
P4EF02Mg62	Rim	39.53	0.06	21.89	0.00	0.00	24.89	1.37	10.97	1.41	100.12	3.01	0.00	1.96	0.00	0.02	1.56	0.09	1.24	0.11	8.00	51.95	2.94	41.31	3.76
<i>Grt2</i>																									
P4EF01Mg05	Rim	39.26	0.04	22.16	0.00	0.00	27.35	1.23	10.00	1.20	101.24	2.98	0.00	1.98	0.00	0.06	1.67	0.08	1.13	0.10	8.00	56.12	2.65	37.95	3.18
P4EF01Mg06	Rim	39.33	0.07	21.98	0.00	0.00	26.08	1.32	10.40	1.53	100.71	2.99	0.00	1.97	0.00	0.05	1.60	0.08	1.18	0.12	8.00	53.63	2.84	39.38	4.03
P4EF01Cg10	Core	39.46	0.03	22.22	0.00	0.00	25.56	1.45	10.89	1.58	101.19	2.97	0.00	1.97	0.00	0.08	1.53	0.09	1.22	0.13	8.00	51.48	3.11	41.12	4.12
P4EF01Cg11	Core	39.88	0.08	22.37	0.00	0.00	25.56	1.47	10.90	1.50	101.76	2.99	0.00	1.98	0.00	0.04	1.56	0.09	1.22	0.12	8.00	52.18	3.12	40.67	3.94
P4EF01Cg17	Core	39.62	0.04	22.33	0.00	0.00	25.42	1.50	11.05	1.70	101.66	2.97	0.00	1.97	0.00	0.09	1.50	0.10	1.23	0.14	8.00	50.64	3.21	41.55	4.39
P4EF01Cg18	Core	39.42	0.05	22.26	0.00	0.00	25.15	1.43	11.18	1.46	100.94	2.97	0.00	1.98	0.00	0.08	1.51	0.09	1.26	0.12	8.00	50.75	3.06	42.23	3.80
P4EF01Mg23	Rim	39.69	0.04	22.23	0.00	0.00	25.95	1.46	10.67	1.40	101.44	2.99	0.00	1.97	0.00	0.05	1.59	0.09	1.20	0.11	8.00	53.08	3.12	40.02	3.68
P4EF01Mg24	Rim	38.98	0.05	21.88	0.00	0.00	25.75	1.42	10.61	1.34	100.02	2.98	0.00	1.97	0.00	0.07	1.57	0.09	1.21	0.11	8.00	52.72	3.08	40.52	3.53
<i>Grt3</i>																									
P4EF01Mg01	Rim	39.49	0.03	22.42	0.00	0.00	25.99	1.15	10.15	1.09	100.31	3.01	0.00	2.01	0.00	0.00	1.66	0.07	1.15	0.09	8.00	55.72	2.50	38.80	2.98
P4EF01Cg03	Core	39.42	0.07	22.25	0.00	0.00	25.52	1.17	10.72	1.25	100.40	2.99	0.00	1.99	0.00	0.01	1.61	0.08	1.21	0.10	8.00	53.60	2.51	40.49	3.37
P4EF01Cg04	Core	39.22	0.04	22.02	0.00	0.00	25.78	1.17	10.30	1.15	99.67	3.01	0.00	1.99	0.00	0.00	1.65	0.08	1.18	0.09	8.00	55.09	2.53	39.22	3.16
P4EF01Mg06	Rim	39.37	0.06	22.15	0.00	0.00	26.07	1.18	10.47	1.12	100.42	3.00	0.00	1.99	0.00	0.01	1.65	0.08	1.19	0.09	8.00	54.84	2.54	39.59	3.01
P4EF01Mg07	Rim	39.30	0.01	21.81	0.00	0.00	27.21	1.20	9.32	1.03	99.89	3.03	0.00	1.98	0.00	0.00	1.75	0.08	1.07	0.08	8.00	58.70	2.62	35.85	2.84
P4EF03Mg82	Rim	39.39	0.04	22.26	0.00	0.00	26.68	1.12	9.82	1.04	100.35	3.01	0.00	2.01	0.00	0.00	1.71	0.07	1.12	0.09	8.00	57.19	2.42	37.52	2.86
P4EF03Cg87	Core	39.31	0.02	22.15	0.00	0.00	26.47	1.09	10.32	1.04	100.40	3.00	0.00	1.99	0.00	0.02	1.67	0.07	1.17	0.08	8.00	55.72	2.35	39.10	2.80
P4EF03Cg88	Core	39.33	0.00	21.83	0.00	0.00	26.60	1.26	9.80	1.13	99.95	3.02	0.00	1.98	0.00	0.00	1.71	0.08	1.12	0.09	8.00	56.86	2.72	37.33	3.09
P4EF03Mg91	Rim	39.81	0.03	22.29	0.00	0.00	25.58	1.16	10.62	1.00	100.50	3.02	0.00	1.99	0.00	0.00	1.62	0.07	1.20	0.08	8.00	54.45	2.50	40.31	2.74
<i>Grt4</i>																									
P4EF02Mg77	Rim (bt)	39.29	0.01	22.04	0.00	0.00	27.44	1.07	9.46	1.05	100.37	3.01	0.00	1.99	0.00	0.00	1.76	0.07	1.08	0.09	8.00	58.71	2.33	36.08	2.88
P4EF02Mg78	Rim (bt)	39.10	0.07	21.96	0.00	0.00	27.19	1.12	9.68	1.09	100.21	3.00	0.00	1.98	0.00	0.01	1.73	0.07	1.11	0.09	8.00	57.72	2.43	36.86	2.97
P4EF02Mg79	Rim (bt)	39.38	0.08	22.02	0.00	0.00	28.15	1.12	8.99	1.05	100.78	3.02	0.00	1.99	0.00	0.00	1.80	0.07	1.03	0.09	8.00	60.33	2.44	34.35	2.87
P4EF04Mg151	Rim (ilm)	39.42	0.14	21.84	0.00	0.00	26.86	1.19	9.67	1.08	100.19	3.02	0.01	1.97	0.00	0.00	1.72	0.08	1.11	0.09	8.00	57.54	2.57	36.92	2.96
P4EF04Mg152	Rim (ilm)	39.70	0.09	22.16	0.00	0.00	27.07	1.24	9.78	1.14	101.18	3.01	0.01	1.98	0.00	0.00	1.72	0.08	1.11	0.09	8.00	57.34	2.66	36.93	3.07
P4EF04Mg153	Rim (ilm)	38.15	0.10	21.83	0.00	0.00																			

Sample P013(ns)																									
Grt1																									
P013F03Mgrt84	Rim	39.08	0.04	21.17	0.04	0.00	28.79	0.96	7.78	2.00	99.84	3.04	0.00	1.94	0.00	0.00	1.88	0.06	0.90	0.17	8.00	62.32	2.10	30.03	5.54
P013F03Mgrt85	Core	39.45	0.06	21.28	0.02	0.00	28.26	0.88	8.60	2.12	100.66	3.03	0.00	1.93	0.00	0.00	1.82	0.06	0.99	0.17	8.00	59.89	1.89	32.48	5.73
P013F03Mgrt86	Core	38.94	0.07	21.46	0.02	0.00	27.89	0.97	8.55	2.36	100.25	3.00	0.00	1.95	0.00	0.03	1.77	0.06	0.98	0.19	8.00	58.75	2.10	32.67	6.36
P013F03Mgrt87	Core	39.02	0.05	21.33	0.03	0.00	27.19	0.87	8.33	2.62	99.43	3.03	0.00	1.95	0.00	0.00	1.77	0.06	0.96	0.22	8.00	58.76	1.91	32.07	7.24
P013F03Mgrt89	Rim	38.77	0.06	21.18	0.05	0.00	29.53	0.90	7.36	2.04	99.88	3.03	0.00	1.95	0.00	0.00	1.93	0.06	0.86	0.17	8.00	63.95	1.98	28.42	5.63
Grt2																									
P013F05Mgrt01	Rim	39.25	0.04	21.40	0.05	0.00	27.86	0.91	8.63	2.02	100.16	3.03	0.00	1.95	0.00	0.00	1.80	0.06	0.99	0.17	8.00	59.60	1.96	32.89	5.53
P013F05Mgrt02	Core	39.28	0.05	21.36	0.03	0.00	28.23	0.79	8.72	1.92	100.38	3.03	0.00	1.94	0.00	0.00	1.82	0.05	1.00	0.16	8.00	60.01	1.70	33.05	5.23
P013F05Mgrt03	Core	38.88	0.05	21.38	0.02	0.00	28.00	0.82	8.56	1.93	99.65	3.02	0.00	1.96	0.00	0.00	1.81	0.05	0.99	0.16	8.00	60.08	1.79	32.80	5.31
P013F05Mgrt05	Core	38.94	0.05	21.55	0.05	0.00	28.24	0.76	8.38	1.83	99.79	3.02	0.00	1.97	0.00	0.00	1.83	0.05	0.97	0.15	8.00	61.01	1.67	32.25	5.06
P013F05Mgrt06	Rim	38.62	0.01	21.44	0.04	0.00	29.41	0.80	7.46	2.13	99.91	3.01	0.00	1.97	0.00	0.00	1.91	0.05	0.87	0.18	8.00	63.57	1.74	28.78	5.88
Grt3																									
P013F05Mgrt07	Skeletal	38.64	0.00	21.35	0.01	0.00	28.65	0.74	6.68	3.26	99.32	3.03	0.00	1.98	0.00	0.00	1.88	0.05	0.78	0.27	8.00	62.98	1.66	26.17	9.19
P013F05Mgrt08	Skeletal	38.60	0.00	21.43	0.06	0.00	28.96	0.77	7.22	2.54	99.58	3.02	0.00	1.98	0.00	0.00	1.89	0.05	0.84	0.21	8.00	63.14	1.70	28.06	7.09
P013F05Mgrt09	Skeletal	39.10	0.04	21.63	0.05	0.00	28.79	0.80	7.40	2.59	100.39	3.03	0.00	1.98	0.00	0.00	1.87	0.05	0.86	0.21	8.00	62.44	1.76	28.62	7.17
P013F05Mgrt10	Skeletal	38.69	0.01	21.46	0.07	0.00	29.70	0.71	6.85	2.77	100.26	3.01	0.00	1.97	0.00	0.00	1.94	0.05	0.80	0.23	8.00	64.31	1.56	26.45	7.66
Sample P1(M)																									
P1mF05Mgrt131	Rim	38.92	0.03	21.60	0.00	0.00	28.73	1.02	7.61	2.46	100.36	3.01	0.00	1.97	0.00	0.00	1.86	0.07	0.88	0.20	8.00	61.81	2.22	29.20	6.77
P1mF05Cgrt132	Core	38.90	0.04	21.66	0.00	0.00	28.34	0.97	8.00	2.58	100.49	3.00	0.00	1.97	0.00	0.02	1.81	0.06	0.92	0.21	8.00	60.16	2.10	30.64	7.01
P1mF05Cgrt133	Core	38.73	0.09	21.37	0.00	0.00	27.60	1.06	7.78	2.76	99.38	3.02	0.00	1.97	0.00	0.00	1.80	0.07	0.90	0.23	8.00	59.91	2.32	30.09	7.66
P1mF05Cgrt134	Core	38.86	0.08	21.67	0.00	0.00	27.85	1.05	7.84	2.79	100.14	3.01	0.00	1.98	0.00	0.00	1.80	0.07	0.91	0.23	8.00	59.94	2.28	30.08	7.68
P1mF05Cgrt135	Core	39.07	0.09	21.44	0.00	0.00	28.03	1.03	7.79	2.69	100.15	3.03	0.01	1.96	0.00	0.00	1.82	0.07	0.90	0.22	8.00	60.40	2.25	29.92	7.42
P1mF05Mgrt136	Rim	38.48	0.02	21.61	0.00	0.00	28.73	1.07	7.67	2.53	100.11	2.99	0.00	1.98	0.00	0.05	1.82	0.07	0.89	0.21	8.00	60.90	2.35	29.71	6.88
P1mF06Mgrt106	Rim	38.76	0.00	21.39	0.00	0.00	28.08	0.94	7.57	3.14	99.87	3.01	0.00	1.96	0.00	0.01	1.81	0.06	0.88	0.26	8.00	60.16	2.06	29.11	8.61
P1mF06Cgrt107	Core	38.74	0.04	21.28	0.00	0.00	28.97	1.07	7.22	2.45	99.77	3.03	0.00	1.96	0.00	0.00	1.89	0.07	0.84	0.21	8.00	62.89	2.35	27.94	6.81
P1mF06Cgrt108	Core	38.49	0.06	21.56	0.00	0.00	29.28	1.02	7.60	2.27	100.27	2.99	0.00	1.97	0.00	0.05	1.86	0.07	0.88	0.19	8.00	62.03	2.23	29.42	6.16
P1mF06Cgrt109	Core	38.79	0.03	21.39	0.00	0.00	28.85	0.94	7.26	2.54	99.79	3.03	0.00	1.97	0.00	0.00	1.88	0.06	0.85	0.21	8.00	62.73	2.06	28.14	7.06
P1mF06Cgrt110	Core	38.63	0.02	21.39	0.00	0.00	29.04	1.04	7.63	2.31	100.06	3.00	0.00	1.96	0.00	0.03	1.86	0.07	0.88	0.19	8.00	61.86	2.28	29.45	6.31
P1mF06Cgrt111	Core	38.79	0.02	21.28	0.00	0.00	29.06	1.05	7.44	2.34	99.98	3.02	0.00	1.95	0.00	0.00	1.89	0.07	0.86	0.20	8.00	62.65	2.28	28.60	6.46
P1mF06Mgrt112	Rim	38.63	0.02	21.26	0.00	0.00	29.08	1.02	7.33	2.42	99.75	3.02	0.00	1.96	0.00	0.00	1.90	0.07	0.85	0.20	8.00	62.78	2.24	28.26	6.70
Sample P1(L)																									
P11F02Mgrt37	Rim	39.22	0.05	21.82	0.00	0.00	29.04	0.94	7.64	3.01	101.72	3.00	0.00	1.97	0.00	0.03	1.82	0.06	0.87	0.25	8.00	60.74	2.03	29.01	8.06
P11F02Cgrt38	Core	38.94	0.03	21.65	0.00	0.00	28.88	1.02	7.85	2.28	100.65	3.01	0.00	1.97	0.00	0.02	1.85	0.07	0.90	0.19	8.00	61.48	2.21	30.03	6.23
P11F02Cgrt39	Core	38.74	0.21	21.61	0.00	0.00	28.58	0.97	8.01	2.34	100.47	2.99	0.01	1.97	0.00	0.02	1.83	0.06	0.92	0.19	8.00	60.75	2.11	30.70	6.35
P11F02Cgrt40	Core	38.72	0.04	21.50	0.00	0.00	28.13	0.99	7.98	2.38	99.72	3.01	0.00	1.97	0.00	0.00	1.83	0.06	0.92	0.20	8.00	60.58	2.15	30.70	6.55
P11F02Cgrt41	Core	38.73	0.01	21.37	0.00	0.00	28.18	0.91	7.88	2.52	99.60	3.02	0.00	1.96	0.00	0.00	1.83	0.06	0.91	0.21	8.00	60.73	1.99	30.31	6.96
P11F02Cgrt42	Core	38.98	0.07	21.48	0.00	0.00	28.24	0.90	8.05	2.32	100.03	3.02	0.00	1.96	0.00	0.00	1.83	0.06	0.93	0.19	8.00	60.77	1.97	30.87	6.38
P11F02Cgrt43	Core	38.98	0.02	21.58	0.00	0.00	28.32	1.03	7.90	2.34	100.16	3.02	0.00	1.97	0.00	0.00	1.83	0.07	0.91	0.19	8.00	60.98	2.25	30.33	6.44
P11F02Mgrt44	Rim	38.49	0.00	21.56	0.00	0.00	28.68	1.00	7.39	2.57	99.68	3.00	0.00	1.98	0.00	0.01	1.86	0.07	0.86	0.22	8.00	62.02	2.21	28.61	7.13
Sample P1D																									
P1DF02Mgrt33	Rim	38.96	0.06	21.83	0.00	0.00	28.81	0.79	8.21	1.79	100.45	3.01	0.00	1.99	0.00	0.00	1.86	0.05	0.94	0.15	8.00	61.91	1.71	31.46	4.91
P1DF02Cgrt34	Core	39.18	0.09	21.85	0.00	0.00	28.46	0.81	8.35	1.74	100.48	3.02	0.01	1.99	0.00	0.00	1.83	0.05	0.96	0.14	8.00	61.35	1.77	32.08	4.78
P1DF02Cgrt35	Core	38.66	0.06	21.67	0.00	0.00	29.39	0.80	7.74	1.71	100.03	3.01	0.00	1.99	0.00	0.00	1.91	0.05	0.90	0.14	8.00	63.63	1.75	29.87	4.74
P1DF02Cgrt36	Core	39.07	0.05	21.84	0.00	0.00	28.77	0.77	7.99	1.76	100.25	3.02	0.00	1.99	0.00	0.00	1.86	0.05	0.92	0.15	8.00	62.48	1.70	30.92	4.90
P1DF02Cgrt37	Core	39.22	0.07	22.00	0.00	0.00	28.32	0.75	8.62	1.71	100.69	3.01	0.00	1.99	0.00	0.00	1.82	0.05	0.99	0.14	8.00	60.73	1.64	32.94	4.68
P1DF02Cgrt38	Core	39.13	0.05	21.70	0.00	0.00	28.13	0.79	8.53	1.81	100.15	3.02	0.00	1.97	0.00	0.00	1.82	0.05	0.98	0.15	8.00	60.54	1.73	32.73	4.99
P1DF02Cgrt39	Core	39.09	0.07	22.02	0.00	0.00	28.55	0.83	8.51	1.76	100.83	3.00	0.00	1.99	0.00	0.00	1.83	0.05	0.97	0.14	8.00	60.97	1.80	32.43	4.79
P1DF02Cgrt40	Core	39.14	0.06	21.93	0.00	0.00	28.42	0.76	8.34	1.79	100.44	3.02	0.00	1.99	0.00	0.00	1.83	0.05	0.96	0.15	8.00	61.31	1.67	32.07	4.94
P1DF02Cgrt41	Core	38.95	0.02	21.78	0.00	0.00	28.96	0.76	7.96	1.80	100.22	3.02	0.00	1.99	0.00	0.00	1.88	0.05	0.92	0.15	8.00	62.64	1.66	30.71	4.99
P1DF02Cgrt42	Core	39.08	0.04	21.74	0.00	0.00	29.17	0.78	8.03	1.73	100.55	3.02	0.00	1.98	0.00	0.00	1.88	0.05	0.92	0.14	8.00	62.74	1.70	30.79	4.76
P1DF02Mgrt43	Rim	38.74	0.04	21.69	0.00	0.00	29.46	0.83	7.78	1.70	100.24	3.01	0.00	1.98	0.00	0.00	1.91	0.05	0.90	0.14	8.00	63.56	1.82	29.93	4.68
Sample P010A																									
P010AF04Mgrt85	Rim	38.92	0.01	21.13	0.04	0.00	24.13	3.52	8.84	2.28	98.87	3.03	0.00	1.94	0.00	0.00	1.57	0.23	1.03	0.19	8.00	52.02	7.70	33.99	6.28
P010AF04Cgrt86	Core	38.89	0.02	21.06	0.01	0.00	24.23	3.58	8.69	2.34	98.81	3.04	0.00	1.94	0.00	0.00	1.58	0.24	1.01	0.20	8.00	52.29	7.82	33.42	6.46
P010AF04Cgrt87	Core	38.51	0.03	20.98	0.02	0.00	24.52	3.60	8.95	2.30	98.91	3.00	0.00	1.93	0.00	0.06	1.53	0.24	1.04	0.19	8.00	51.08	7.92	34.61	6.17
P010AF04Cgrt88	Core																								

S2.5: Representative major element compositions of ilmenite crystals

*Structural formulas and Fe3+ contents calculated after Droop (1987)

spot/analysis	Mineral	type	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	ZnO	Total	Si	Ti	Al	Cr	Fe3+*	Fe2+	Mn	Mg	Ca	Zn	Total cations	Hem	Ilm	Pph	Gk	
<i>Sample P008</i>																													
P008F01Milm29	Ilm-lamellae	Rim	0.09	46.18	0.10	0.07	0.00	48.46	0.13	1.88	0.00	0.00	96.91	0.00	1.77	0.01	0.00	0.44	1.63	0.01	0.14	0.00	0.00	4.00	11.03	81.52	0.28	7.17	
P008F01Milm32	Hem-lamellae	Core	0.04	16.09	0.20	0.29	0.00	73.46	0.08	0.47	0.00	0.03	90.66	0.00	0.65	0.01	0.01	2.68	0.61	0.00	0.04	0.00	0.00	4.00	67.40	30.54	0.18	1.88	
P008F02Milm47	Ilm-lamellae	Core	0.02	46.37	0.03	0.08	0.00	49.21	0.18	1.39	0.01	0.02	97.31	0.00	1.78	0.00	0.00	0.44	1.66	0.01	0.11	0.00	0.00	4.00	10.90	83.39	0.40	5.31	
P008F02Milm50	Hem-lamellae	Core	0.04	17.91	0.27	0.22	0.00	71.94	0.05	0.38	0.00	0.03	90.85	0.00	0.72	0.02	0.01	2.53	0.69	0.00	0.03	0.00	0.00	4.00	63.68	34.67	0.11	1.54	
<i>Sample P4E</i>																													
P4EF04Milm68	Ilm-lamellae	Core	0.05	47.19	0.00	0.04	0.00	49.28	0.31	1.02	0.00	0.04	97.92	0.00	1.81	0.00	0.00	0.38	1.72	0.01	0.08	0.00	0.00	4.00	9.53	85.93	0.66	3.88	
P4EF04Milm69	Hem-lamellae	Core	0.01	18.29	0.14	0.11	0.00	72.12	0.07	0.31	0.00	0.00	91.06	0.00	0.74	0.01	0.00	2.51	0.71	0.00	0.02	0.00	0.00	4.00	63.10	35.50	0.15	1.25	
P4E F01Cilm24	Ilm-lamellae	Inclusion	0.03	44.70	0.03	0.00	0.00	51.54	0.15	1.09	0.02	0.00	97.57	0.00	1.71	0.00	0.00	0.57	1.62	0.01	0.08	0.00	0.00	4.00	14.31	81.21	0.33	4.15	
P4E F01Cilm25	Hem-lamellae	Inclusion	0.00	20.30	0.12	0.00	0.00	70.25	0.04	0.42	0.02	0.00	91.15	0.00	0.82	0.01	0.00	2.36	0.78	0.00	0.03	0.00	0.00	4.00	59.15	39.07	0.10	1.69	
P4E F03Cilm95	Hem-lamellae	Inclusion	0.00	13.49	0.08	0.00	0.00	76.29	0.01	0.24	0.02	0.00	90.13	0.00	0.55	0.01	0.00	2.90	0.52	0.00	0.02	0.00	0.00	4.00	72.72	26.30	0.02	0.97	
P4E F03Cilm96	Ilm-lamellae	Inclusion	0.05	48.93	0.00	0.00	0.00	48.26	0.14	1.23	0.00	0.00	98.60	0.00	1.86	0.00	0.00	0.28	1.76	0.01	0.09	0.00	0.00	4.00	6.91	88.17	0.29	4.63	
<i>Sample P013(rs)</i>																													
P013F05Milm33	Ilmenite	Core	0.00	45.35	0.03	0.11	0.00	51.43	0.19	0.53	0.02	0.00	97.65	0.00	1.74	0.00	0.00	0.50	1.70	0.01	0.04	0.00	0.00	4.00	12.63	84.95	0.40	2.01	
P013F05Milm34	Ilmenite	Rim	0.26	45.85	0.07	0.08	0.00	50.51	0.13	0.52	0.02	0.02	97.45	0.01	1.77	0.00	0.00	0.43	1.73	0.01	0.04	0.00	0.00	4.00	10.86	86.87	0.27	2.00	
<i>Sample P1(M)</i>																													
P1MFD0Milm48	Ilmenite	Rim	0.13	45.05	0.03	0.08	0.00	48.73	0.21	0.42	0.02	0.00	94.66	0.01	1.79	0.00	0.00	0.40	1.75	0.01	0.03	0.00	0.00	4.00	10.02	87.87	0.46	1.65	
P1MFD0Milm49	Ilmenite	Rim	0.07	47.06	0.00	0.08	0.00	49.55	0.14	0.35	0.01	0.00	97.26	0.00	1.82	0.00	0.00	0.34	1.79	0.01	0.03	0.00	0.00	4.00	8.54	89.81	0.31	1.34	
P1MFD0Milm50	Ilmenite	Rim	0.08	46.45	0.00	0.08	0.00	49.63	0.14	0.34	0.03	0.00	96.75	0.00	1.81	0.00	0.00	0.37	1.78	0.01	0.03	0.00	0.00	4.00	9.28	89.09	0.30	1.33	
P1MFB0Milm87	Ilmenite	Core	0.10	45.20	0.40	0.08	0.00	48.74	0.29	0.43	0.04	0.11	95.39	0.01	1.78	0.02	0.00	0.40	1.73	0.01	0.03	0.00	0.00	4.00	10.16	87.49	0.65	1.70	
<i>Sample P010A</i>																													
<i>ilm1</i>																													
P010AF03Milm62	Ilmenite	Core	0.06	47.36	0.04	0.02	0.00	46.86	2.12	0.92	0.01	0.00	97.39	0.00	1.82	0.00	0.00	0.34	1.66	0.09	0.07	0.00	0.00	4.00	8.58	83.29	4.61	3.51	
P010AF03Milm63	Ilmenite	Core	0.01	47.68	0.01	0.02	0.00	46.49	2.15	1.03	0.00	0.02	97.41	0.00	1.84	0.00	0.00	0.33	1.66	0.09	0.08	0.00	0.00	4.00	8.17	83.24	4.66	3.92	
P010AF03Milm64	Ilmenite	Rim	0.02	47.55	0.00	0.03	0.00	46.51	2.18	1.05	0.00	0.11	97.45	0.00	1.83	0.00	0.00	0.34	1.65	0.09	0.08	0.00	0.00	4.00	8.47	82.78	4.72	4.03	
<i>ilm2</i>																													
P010AF04Milm81	Ilmenite	Core	0.06	49.39	0.05	0.03	0.00	44.54	1.23	0.77	0.07	0.01	96.13	0.00	1.93	0.00	0.00	0.12	1.82	0.05	0.06	0.00	0.00	4.00	3.02	91.27	2.71	3.00	
P010AF01Milm21	Ilmenite	Core	0.21	48.06	0.16	0.04	0.00	43.97	2.31	0.59	0.00	0.08	95.42	0.01	1.90	0.01	0.00	0.17	1.76	0.10	0.05	0.00	0.00	4.00	4.38	88.15	5.16	2.30	
P010AF04Milm82	Ilmenite	Rim	0.01	48.79	0.03	0.03	0.00	46.44	1.57	0.76	0.00	0.00	97.64	0.00	1.88	0.00	0.00	0.24	1.75	0.07	0.06	0.00	0.00	4.00	5.90	87.78	3.42	2.90	
<i>ilm3</i>																													
P010AF06Milm142	Ilmenite	Core	0.00	44.76	0.02	0.04	0.00	50.32	1.03	0.94	0.02	0.02	97.14	0.00	1.72	0.00	0.00	0.55	1.61	0.04	0.07	0.00	0.00	4.00	13.74	80.42	2.24	3.60	
P010AF06Milm143	Ilmenite	Rim	0.08	37.66	0.12	0.08	0.00	54.85	0.66	0.75	0.00	0.03	94.22	0.00	1.49	0.01	0.00	1.01	1.40	0.03	0.06	0.00	0.00	4.00	25.27	70.32	1.48	2.94	

S2.6: Representative major element compositions of orthopyroxene crystals

Structural formulas calculated after Perkins (2007)

spot/analysis	type	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	ZnO	Total	Si	Ti	Al	Cr	Fe	Mg	Mn	Zn	Ca	Na	K	Total cations	En	Fs	Wo	XAl	XMg
<i>Sample P013(ns)</i>																														
P013F05Mopx11	Skeletal	50.26	0.08	4.58	0.06	24.81	0.19	19.33	0.22	0.00	0.00	0.19	99.72	1.90	0.00	0.20	0.00	0.78	1.09	0.01	0.01	0.01	0.00	0.00	4.00	0.58	0.42	0.00	0.10	0.5814
P013F05Coxp12	Skeletal	49.46	0.11	5.02	0.07	25.09	0.25	18.86	0.20	0.05	0.01	0.17	99.28	1.88	0.00	0.23	0.00	0.80	1.07	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.43	0.00	0.11	0.5726
P013F05Coxp14	Skeletal	50.26	0.10	4.23	0.09	24.98	0.21	19.33	0.19	0.02	0.01	0.09	99.51	1.90	0.00	0.19	0.00	0.79	1.09	0.01	0.00	0.01	0.00	0.00	4.00	0.58	0.42	0.00	0.09	0.5797
P013F05Mopx15	Skeletal	49.90	0.09	4.91	0.07	25.43	0.18	18.84	0.16	0.02	0.00	0.11	99.71	1.89	0.00	0.22	0.00	0.81	1.06	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.43	0.00	0.11	0.5690
P013F04Mopx61	Rim	49.74	0.11	5.03	0.06	25.61	0.25	18.82	0.20	0.03	0.01	0.12	99.98	1.88	0.00	0.22	0.00	0.81	1.06	0.01	0.00	0.01	0.00	0.00	4.00	0.56	0.43	0.00	0.11	0.5670
P013F04Coxp62	Core	49.12	0.10	5.15	0.05	25.37	0.22	18.63	0.17	0.04	0.00	0.02	98.86	1.88	0.00	0.23	0.00	0.81	1.06	0.01	0.00	0.01	0.00	0.00	4.00	0.56	0.43	0.00	0.12	0.5668
P013F03Mopx69	Rim	48.90	0.06	5.03	0.09	25.24	0.22	18.65	0.14	0.02	0.01	0.05	98.41	1.88	0.00	0.23	0.00	0.81	1.07	0.01	0.00	0.01	0.00	0.00	4.01	0.57	0.43	0.00	0.11	0.5684
P013F03Coxp70	Core	49.50	0.08	4.92	0.09	25.08	0.25	19.03	0.19	0.00	0.01	0.05	99.19	1.88	0.00	0.22	0.00	0.80	1.08	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.42	0.00	0.11	0.5749
P013F03Coxp71	Core	48.86	0.30	4.44	0.04	25.19	0.29	18.66	0.14	0.01	0.00	0.15	98.07	1.89	0.01	0.20	0.00	0.81	1.07	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.43	0.00	0.10	0.5690
<i>Sample P1(M)</i>																														
<i>Opx1</i>																														
P1mFBMopx72	Rim	50.10	0.11	3.86	0.06	25.08	0.34	19.22	0.27	0.03	0.01	0.17	99.23	1.91	0.00	0.17	0.00	0.80	1.09	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.42	0.01	0.09	0.5773
P1mFBCoxp74	Core	50.09	0.35	3.86	0.06	25.25	0.31	19.04	0.28	0.04	0.02	0.01	99.29	1.91	0.01	0.17	0.00	0.80	1.08	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.42	0.01	0.09	0.5735
P1mFBCoxp75	Core	49.57	0.10	4.41	0.07	24.95	0.31	18.83	0.24	0.04	0.00	0.12	98.63	1.90	0.00	0.20	0.00	0.80	1.07	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.42	0.01	0.10	0.5737
P1mFBCoxp76	Core	50.02	0.09	4.28	0.05	25.32	0.36	19.11	0.23	0.03	0.02	0.09	99.58	1.90	0.00	0.19	0.00	0.80	1.08	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.42	0.00	0.10	0.5736
P1mFBMopx77	Rim	50.29	0.07	3.86	0.04	25.15	0.35	19.06	0.26	0.03	0.01	0.03	99.15	1.91	0.00	0.17	0.00	0.80	1.08	0.01	0.00	0.01	0.00	0.00	4.00	0.57	0.42	0.01	0.09	0.5746
P1mFBMopx78	Rim	50.64	0.07	3.44	0.07	25.08	0.27	19.53	0.27	0.01	0.01	0.07	99.45	1.92	0.00	0.15	0.00	0.80	1.10	0.01	0.00	0.01	0.00	0.00	4.00	0.58	0.42	0.01	0.08	0.5812
<i>Opx2</i>																														
P1mF05Coxp144	Core	51.42	0.10	2.25	0.00	25.43	0.30	19.92	0.33	0.00	0.02	0.00	99.77	1.95	0.00	0.10	0.00	0.80	1.12	0.01	0.00	0.01	0.00	0.00	4.00	0.58	0.41	0.01	0.05	0.5827
P1mF05Coxp145	Core	51.42	0.08	2.28	0.00	25.14	0.32	19.75	0.29	0.04	0.01	0.00	99.33	1.95	0.00	0.10	0.00	0.80	1.12	0.01	0.00	0.01	0.00	0.00	4.00	0.58	0.41	0.01	0.05	0.5834
P1mF05Mopx146	Rim	51.27	0.08	3.18	0.00	25.09	0.22	20.00	0.28	0.00	0.01	0.00	100.13	1.93	0.00	0.14	0.00	0.79	1.12	0.01	0.00	0.01	0.00	0.00	4.00	0.58	0.41	0.01	0.07	0.5869
P1mF05Mopx147	Rim	51.08	0.06	2.09	0.00	26.69	0.29	18.71	0.31	0.03	0.00	0.00	99.25	1.96	0.00	0.09	0.00	0.85	1.07	0.01	0.00	0.01	0.00	0.00	4.00	0.55	0.44	0.01	0.05	0.5554
<i>Sample P010A</i>																														
P010AF03Mopx52	Rim	49.51	0.11	4.97	0.00	22.23	1.12	20.50	0.17	0.00	0.01	0.03	98.65	1.88	0.00	0.22	0.00	0.70	1.16	0.04	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.11	0.6217
P010AF03Coxp53	Core	50.55	0.11	4.83	0.02	21.91	1.13	20.93	0.22	0.01	0.01	0.00	99.72	1.89	0.00	0.21	0.00	0.68	1.17	0.04	0.00	0.01	0.00	0.00	4.00	0.63	0.37	0.00	0.11	0.6300
P010AF03Coxp54	Core	49.90	0.13	4.88	0.01	22.31	1.08	20.83	0.25	0.02	0.00	0.09	99.48	1.88	0.00	0.22	0.00	0.70	1.17	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.37	0.01	0.11	0.6247
P010AF03Coxp55	Core	50.15	0.12	4.96	0.00	22.07	1.08	20.85	0.21	0.03	0.00	0.10	99.58	1.88	0.00	0.22	0.00	0.69	1.17	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.37	0.00	0.11	0.6275
P010AF03Coxp56	Core	50.22	0.10	4.91	0.02	22.15	1.18	20.92	0.19	0.01	0.00	0.00	99.70	1.88	0.00	0.22	0.00	0.69	1.17	0.04	0.00	0.01	0.00	0.00	4.01	0.62	0.37	0.00	0.11	0.6274
P010AF03Mopx57	Rim	50.15	0.11	4.99	0.00	22.05	1.11	20.81	0.16	0.04	0.00	0.02	99.45	1.88	0.00	0.22	0.00	0.69	1.16	0.04	0.00	0.01	0.00	0.00	4.01	0.62	0.37	0.00	0.11	0.6271
P010AF04Mopx90	Rim	50.46	0.10	5.12	0.00	22.68	0.97	20.94	0.15	0.01	0.00	0.02	100.44	1.88	0.00	0.22	0.00	0.71	1.16	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.11	0.6220
P010AF04Coxp91	Core	49.27	0.12	6.11	0.00	22.44	0.95	20.00	0.17	0.02	0.00	0.03	99.11	1.86	0.00	0.27	0.00	0.71	1.12	0.03	0.00	0.01	0.00	0.00	4.00	0.61	0.38	0.00	0.14	0.6137
P010AF04Coxp92	Core	49.32	0.18	6.03	0.00	22.51	0.93	20.53	0.18	0.00	0.00	0.06	99.75	1.85	0.01	0.27	0.00	0.71	1.15	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.13	0.6191
P010AF04Coxp93	Core	49.87	0.13	5.43	0.00	22.03	1.00	20.70	0.15	0.02	0.01	0.13	99.47	1.87	0.00	0.24	0.00	0.69	1.16	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.37	0.00	0.12	0.6261
P010AF05Mopx111	Rim	50.01	0.13	4.89	0.03	22.42	0.82	20.67	0.19	0.06	0.01	0.05	99.27	1.88	0.00	0.22	0.00	0.71	1.16	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.11	0.6216
P010AF05Coxp112	Core	51.54	0.08	3.32	0.02	22.64	0.95	21.32	0.19	0.01	0.00	0.03	100.10	1.92	0.00	0.15	0.00	0.71	1.19	0.03	0.03	0.00	0.01	0.00	4.00	0.62	0.37	0.00	0.07	0.6267
P010AF05Coxp113	Core	50.78	0.11	4.17	0.02	22.71	0.84	20.94	0.19	0.00	0.00	0.11	99.88	1.90	0.00	0.18	0.00	0.71	1.17	0.03	0.00	0.01	0.00	0.00	4.00	0.62	0.38	0.00	0.09	0.6218
P010AF05Mopx114	Rim	50.38	0.10	4.67	0.02	22.75	0.93	20.70	0.16	0.02	0.01	0.10	99.84	1.89	0.00	0.21	0.00	0.71	1.16	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.10	0.6186
P010AF06Mopx125	Rim	49.69	0.08	4.70	0.00	22.79	1.18	20.44	0.17	0.02	0.00	0.00	99.08	1.88	0.00	0.21	0.00	0.72	1.15	0.04	0.00	0.01	0.00	0.00	4.01	0.61	0.38	0.00	0.10	0.6152
P010AF06Coxp126	Core	50.10	0.10	4.60	0.01	22.60	1.09	20.45	0.13	0.03	0.01	0.11	99.22	1.89	0.00	0.20	0.00	0.71	1.15	0.03	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.10	0.6173
P010AF06Coxp127	Core	49.84	0.10	4.96	0.01	22.55	1.15	20.46	0.16	0.00	0.01	0.09	99.33	1.88	0.00	0.22	0.00	0.71	1.15	0.04	0.00	0.01	0.00	0.00	4.01	0.62	0.38	0.00	0.11	0.6179
P010AF06Coxp128	Core	50.13	0.10	5.02	0.00	22.33	1.22	20.45	0.14																					

S2.7: Representative major element compositions of sapphire crystals

*Structural formulas and Fe3+ contents calculated after Higgins (1979), Grew et al. (2008) and Taylor-Jones & Powell (2010)

spot/analysis	type	SiO2	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	K2O	ZnO	Total	Si	Ti	Al (IV)	Al (VI)	Cr	Fe3+*	Fe 2+	Mg	Mn	Zn	Ca	Na	K	Total cations	Al (t)	Fe (t)	XMg	
<i>Sample P008</i>																															
P008F01Mspr1	Core	12.59	0.03	59.71	0.03	10.11	0.08	15.35	0.03	0.04	0.03	0.02	98.02	1.55	0.00	4.45	4.22	0.00	0.22	0.82	2.82	0.01	0.00	0.00	0.01	0.00	0.00	14.12	8.67	1.04	0.7751
P008F01Mspr2	Core	12.64	0.01	60.36	0.03	9.33	0.10	15.52	0.05	0.02	0.01	0.00	98.06	1.55	0.00	4.45	4.27	0.00	0.18	0.78	2.84	0.01	0.00	0.01	0.00	0.00	14.09	8.72	0.96	0.7843	
P008F01Mspr3	Core	12.69	0.01	60.28	0.04	9.28	0.08	15.43	0.01	0.00	0.01	0.00	97.84	1.56	0.00	4.44	4.28	0.00	0.15	0.80	2.82	0.01	0.00	0.00	0.00	0.00	14.08	8.73	0.95	0.7796	
P008F01Mspr5	Core	13.24	0.01	61.44	0.02	8.27	0.10	16.14	0.04	0.01	0.00	0.00	99.26	1.59	0.00	4.41	4.30	0.00	0.10	0.73	2.89	0.01	0.00	0.00	0.00	0.00	14.05	8.71	0.83	0.7984	
P008F01Mspr6	Core	12.63	0.03	60.31	0.04	9.06	0.13	15.24	0.01	0.02	0.00	0.00	97.48	1.56	0.00	4.44	4.31	0.00	0.13	0.80	2.80	0.01	0.00	0.00	0.00	0.00	14.07	8.75	0.93	0.7771	

S2.9: Representative major element compositions of hercynite and magnetite crystals

*Structural formulas and Fe3+ contents calculated using the Spinel End-Member generator software (Ferracuti et al., 2015)

spot/analysis	Mineral	type	SiO2	TiO2	Al2O3	Cr2O3	Fe2O3	FeO	MnO	MgO	CaO	ZnO	Total	Si	Ti	Al	Cr	Fe3+*	Fe2+	Mn	Mg	Ca	Zn	Total	Sp	Hc	Ghn	Mfr	Mag	XMg
<i>Sample P008</i>																														
P008F01Mhc22	Hercynite	Core	0.76	0.01	60.63	0.09	0.00	24.28	0.17	11.00	0.00	0.32	97.27	0.02	0.00	1.96	0.00	0.00	0.56	0.00	0.45	0.00	0.01	3.00	44.40	54.96	0.64	0.00	2.00	0.4468
P008F02Mhc81	Hercynite	Core	0.00	0.01	59.49	0.15	0.00	26.09	0.10	11.66	0.00	0.58	98.10	0.00	0.00	1.91	0.00	0.08	0.51	0.00	0.47	0.00	0.01	3.00	45.57	49.18	1.12	1.98	0.00	0.4809
P008F03Mhc52	Hercynite	Rim	0.00	0.01	59.23	0.14	0.00	26.61	0.08	11.49	0.00	0.41	98.00	0.00	0.00	1.91	0.00	0.09	0.52	0.00	0.47	0.00	0.01	3.00	44.90	49.98	0.79	2.05	0.00	0.4732
P008F02Mhc64	Hercynite	Core	0.00	0.02	59.47	0.12	0.00	27.01	0.09	11.06	0.00	0.44	98.28	0.00	0.00	1.92	0.00	0.08	0.54	0.00	0.45	0.00	0.01	3.00	43.41	51.78	0.87	1.81	2.15	0.4560
<i>Sample P4E(L)</i>																														
<i>Hc1</i>																														
P4EF02Chc74	Hercynite	Inclusion	0.00	0.00	58.95	0.00	0.00	27.84	0.13	11.28	0.00	0.00	98.20	0.00	0.00	1.90	0.00	0.10	0.54	0.00	0.46	0.00	0.00	3.00	43.82	51.19	0.00	2.31	2.68	0.4612
P4EF02Chc75	Hercynite	Inclusion	0.06	0.07	58.10	0.00	0.00	28.11	0.16	11.19	0.01	0.00	97.69	0.00	0.00	1.89	0.00	0.11	0.54	0.00	0.46	0.00	0.00	3.00	43.49	51.10	0.00	2.49	2.93	0.4597
P4EF02Chc86	Spinel	Inclusion	0.00	0.00	59.02	0.00	0.00	25.24	0.07	12.80	0.02	0.00	97.15	0.00	0.00	1.90	0.00	0.10	0.48	0.00	0.52	0.00	0.00	3.00	49.64	45.96	0.00	2.62	2.39	0.5224
P4EF02Chc87	Spinel	Inclusion	0.00	0.03	59.01	0.00	0.00	25.40	0.07	12.71	0.01	0.00	97.25	0.00	0.00	1.90	0.00	0.10	0.48	0.00	0.52	0.00	0.00	3.00	49.25	45.79	0.00	2.57	2.39	0.5182
<i>Hc2</i>																														
P4EF01Mhc01	Hercynite	Core	0.01	0.05	59.10	0.00	0.00	29.26	0.02	9.75	0.00	0.00	98.19	0.00	0.00	1.92	0.00	0.08	0.60	0.00	0.40	0.00	0.00	3.00	38.57	57.65	0.00	1.51	2.26	0.4008
P4EF01Mhc02	Hercynite	Rim	0.05	0.01	57.26	0.00	0.00	30.56	0.11	9.84	0.01	0.00	97.83	0.00	0.00	1.88	0.00	0.12	0.59	0.00	0.41	0.00	0.00	3.00	38.40	55.59	0.00	2.46	3.56	0.4085
P4EF03Mhc32	Hercynite	Rim	0.00	0.01	57.98	0.22	0.00	30.30	0.23	8.66	0.02	0.30	97.12	0.00	0.00	1.91	0.00	0.09	0.62	0.01	0.36	0.00	0.01	3.00	34.95	60.00	0.59	1.64	2.82	0.3680
P4EF03Mhc34	Hercynite	Core	0.00	0.02	58.37	0.26	0.00	29.36	0.18	8.81	0.01	0.24	97.24	0.00	0.00	1.93	0.01	0.07	0.62	0.00	0.37	0.00	0.00	3.00	35.76	60.50	0.48	1.21	2.05	0.3714
<i>Sample P4E(R)</i>																														
<i>Hc2</i>																														
P4EF01Mhc39	Hercynite	Rim	0.00	0.00	59.73	0.00	0.00	28.58	0.11	9.84	0.00	0.00	98.26	0.00	0.00	1.94	0.00	0.06	0.59	0.00	0.40	0.00	0.00	3.00	39.16	57.67	0.00	1.28	1.89	0.4044
P4EF01Mhc40	Hercynite	Core	0.04	0.03	59.65	0.00	0.00	27.99	0.08	9.91	0.00	0.00	97.69	0.00	0.00	1.94	0.00	0.05	0.59	0.00	0.41	0.00	0.00	3.00	39.69	57.57	0.00	1.12	1.63	0.4081
P4EF03Chc107	Hercynite	Inclusion	0.03	0.08	59.42	0.00	0.00	27.87	0.08	10.43	0.02	0.00	97.94	0.00	0.00	1.93	0.00	0.07	0.57	0.00	0.43	0.00	0.00	3.00	41.28	55.30	0.00	1.47	1.96	0.4273
P4EF03Chc108	Hercynite	Inclusion	0.02	0.00	59.76	0.00	0.00	27.58	0.06	10.56	0.00	0.00	97.97	0.00	0.00	1.93	0.00	0.07	0.57	0.00	0.43	0.00	0.00	3.00	41.81	54.88	0.00	1.43	1.88	0.4323
<i>Hc3</i>																														
P4EF03Chc109	Magnetite	Mt-lamellae	0.08	0.05	26.98	0.00	0.00	64.16	0.02	5.48	0.07	0.00	96.84	0.00	0.00	1.02	0.00	0.98	0.74	0.00	0.26	0.00	0.00	3.00	13.32	37.71	0.00	12.78	36.20	0.2609
P4EF03Chc112	Magnetite	Mt-lamellae	0.06	0.00	27.91	0.00	0.00	61.69	0.06	5.81	0.00	0.00	95.52	0.00	0.00	1.06	0.00	0.94	0.72	0.00	0.28	0.00	0.00	3.00	14.76	38.25	0.00	13.08	33.91	0.2784
<i>Sample P010A</i>																														
<i>Hc1</i>																														
P010F01Mhc19	Hercynite	Core	0.04	0.09	58.88	0.54	0.00	25.82	0.52	8.21	0.00	4.35	98.44	0.00	0.00	1.94	0.01	0.04	0.56	0.01	0.34	0.00	0.09	3.00	33.80	55.31	8.87	0.77	1.25	0.3792
P010F03Chc58	Hercynite	Rim	0.02	0.19	59.35	0.28	0.00	23.58	0.56	9.85	0.00	3.52	97.34	0.00	0.00	1.95	0.01	0.04	0.51	0.01	0.41	0.00	0.07	3.00	40.49	50.56	7.15	0.80	0.99	0.4447
P010F03Chc60	Hercynite	Core	0.10	0.08	59.61	0.27	0.00	23.58	0.51	9.78	0.01	3.66	97.58	0.00	0.00	1.95	0.01	0.03	0.51	0.01	0.40	0.00	0.08	3.00	40.12	50.83	7.44	0.71	0.80	0.4410
P010F03Chc61	Hercynite	Core	0.00	0.17	59.41	0.27	0.00	23.75	0.41	9.95	0.00	3.57	97.54	0.00	0.00	1.94	0.01	0.04	0.51	0.01	0.41	0.00	0.07	3.00	40.63	50.17	7.21	0.89	1.10	0.4474
P010F05Mhc119	Hercynite	Rim	0.00	0.02	59.80	0.13	0.00	24.54	0.28	8.94	0.03	4.18	97.92	0.00	0.00	1.96	0.00	0.03	0.54	0.01	0.37	0.00	0.09	3.00	36.75	53.14	8.51	0.66	0.95	0.4087
P010F05Mhc121	Hercynite	Rim	0.11	0.02	58.27	0.12	0.00	28.49	0.23	6.35	0.00	4.21	97.81	0.00	0.00	1.95	0.00	0.04	0.64	0.01	0.27	0.00	0.09	3.00	26.52	63.08	8.70	0.50	1.20	0.2959
<i>Hc2</i>																														
P010F04Mhc78	Hercynite	Rim	0.73	0.07	59.06	0.18	0.00	23.66	0.32	10.28	0.00	2.32	96.61	0.02	0.00	1.94	0.00	0.01	0.54	0.01	0.43	0.00	0.05	3.00	41.88	52.85	4.67	0.27	0.33	0.4420
P010F04Mhc79	Hercynite	Core	0.02	0.02	59.39	0.15	0.00	25.29	0.34	9.88	0.01	2.59	97.69	0.00	0.00	1.94	0.00	0.05	0.53	0.01	0.41	0.00	0.05	3.00	40.04	52.15	5.20	1.14	1.48	0.4343
P010F04Mhc80	Hercynite	Rim	0.10	0.00	59.48	0.18	0.00	24.65	0.27	10.16	0.01	2.46	97.32	0.00	0.00	1.94	0.00	0.05	0.53	0.01	0.42	0.00	0.05	3.00	41.25	51.61	4.95	0.97	1.22	0.4442
<i>Mag</i>																														
P010F01Mmt24	Magnetite	Core	0.24	0.06	0.46	0.42	89.14	0.07	0.07	0.01	0.00	90.48	0.01	0.00	0.02	0.01	1.94	1.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	1.07	0.00	0.42	98.51	0.0043
P010F04Mmt84	Magnetite	Core	0.80	0.06	0.81	0.14	88.02	0.01	0.13	0.02	0.00	89.97	0.03	0.00	0.04	0.00	1.89	1.02	0.00	0.01	0.00	0.00	0.00	3.00	0.01	1.96	0.00	0.73	97.30	0.0074
P010AF05Mmt116	Magnetite	Core	0.03	0.05	0.24	0.10	91.15	0.00	0.01	0.00	0.01	91.59	0.00	0.00	0.01	0.00	1.98	1.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.55	0.00	0.06	99.39	0.0006
P010AF06Mmt144	Magnetite	Core	0.01	0.04	0.37	0.50	89.44	0.00	0.02	0.03	0.00	90.41	0.00	0.00	0.02	0.02	1.96	1.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.87	0.00	0.11	99.02	0.0011

Appendix S3 – Summary of mineral generations

Table S3.1 – End-member compositional range of garnet crystals from all samples, grouped by generations (Gen.). PS - paleosome; NS - neosome; M - melanosome; R – residuum; L - leucosome; Overgr. – overgrowths on Bt and Ilm; Skel. - skeletal. $X_{Ca} = Ca/(Mg+Fe^{2+}+Mg)$ [apfu]. Alm – almandine. Prp – pyrope. Sps – spessartine. Grs – grossular.

Sample	Gen.	Type	Alm (%)	Prp (%)	Sps (%)	Grs (%)	X_{Ca}
P4E _{L+R}	1	Cores	47.24-49.08	43.52-46.12	2.41-2.99	3.10-4.90	0.031-0.049
		Rims	49.25-55.37	38.50-43.60	2.75-3.15	3.09-4.92	0.031-0.049
	2	Cores	49.89-52.98	40.43-42.80	2.33-3.21	3.38-4.95	0.035-0.050
		Rims	51.94-56.80	37.15-42.14	2.23-3.28	2.95-4.14	0.030-0.044
	3	Cores	53.45-55.72	39.1-40.49	2.25-2.71	2.79-3.37	0.028-0.034
		Rims	54.45-58.70	35.85-40.31	2.35-2.62	2.71-3.01	0.027-0.030
	4	Overgr.	56.16-60.33	34.35-38.66	2.20-2.75	2.74-3.29	0.028-0.033
	P008	1	Cores	46.73-49.99	45.25-47.16	2.18-2.70	2.56-3.90
Rims			47.55-50.28	44.82-47.03	2.22-2.62	2.60-3.62	0.026-0.037
P013 _{PS}	1	Cores	56.68-59.57	31.37-33.15	1.85-1.99	5.70-9.01	0.057-0.090
		Rims	60.75-62.70	29.89-31.44	1.84-2.12	5.45-6.34	0.055-0.064
P013 _{NS}	1	Cores	58.16-59.89	31.56-34.52	1.81-2.10	5.19-7.24	0.052-0.073
	2	Cores	60.01-61.98	30.28-33.04	1.67-2.01	5.06-5.91	0.051-0.060
	1-2	Rims	59.60-63.95	28.42-32.89	1.74-2.32	4.79-5.88	0.048-0.059
	3	Skel.	62.44-64.31	26.17-28.62	1.56-1.76	7.09-9.19	0.071-0.092
P1 _M	1	Cores	59.91-63.27	27.50-30.64	2.06-2.48	5.93-7.68	0.059-0.077
		Rims	60.16-63.59	25.93-29.79	2.06-2.34	6.70-8.61	0.067-0.087
P1 _L	1	Cores	60.28-62.64	28.30-31.04	1.97-2.40	6.17-7.46	0.063-0.075
		Rims	60.74-63.22	27.53-29.55	2.03-2.32	6.36-8.06	0.065-0.082
P1 _D	1	Cores	57.25-65.94	28.61-35.83	1.49-2.03	4.67-5.70	0.047-0.057
		Rims	58.07-64.52	26.87-35.51	1.59-1.98	4.68-5.23	0.047-0.052
P010A	1	Cores	51.08-53.75	33.04-34.61	6.76-7.92	5.75-6.46	0.058-0.065
		Rims	51.84-54.54	32.40-34.68	6.86-7.70	5.99-6.28	0.060-0.063

Table S3.2 - Compositional range of orthopyroxene crystals from samples P013, P1 and P010A, grouped by generations (Gen.). NS - neosome; M – melanosome; $X_{Mg} = Mg/(Mg+Fe)$ [apfu]; $X_{Al} = Al_{[apfu]}/2$ (Pattison et al. 2003)

Sample	Gen.	Type	X_{Mg}	Al ₂ O ₃ (%)	X_{Al}
P013 _{NS}	1	Cores	0.562-0.581	4.23-5.15	0.094-0.116
		Rims	0.561-0.581	4.42-5.03	0.098-0.114
P1 _M	1	Cores+Rims	0.574-0.602	3.24-4.41	0.072-0.099
	2	Cores+Rims	0.555-0.619	2.09-3.18	0.047-0.070
P010A	1	Cores	0.610-0.630	3.32-6.11	0.073-0.136

Table S3.3 – End-member compositional range of ilmenite crystals from samples P4E, P008, P013, P1 and P010A, grouped by generations (Gen.). PS+NS – paleosome+neosome; M - melanosome; L+R – leucosome + residuum. Hem – hematite. Ilm – ilmenite. Gk – geikielite. Pph – pyrophanite.

Sample	Gen.	Mineral	Hem (%)	Ilm (%)	Gk (%)	Pph (%)
P4E _{L+R}	1	Ilm-lamellae	6.9-48.3	49.3-88.2	3.9-5.3	0.3-0.9
		Hem-lamellae	51.3-72.7	26.3-46.5	0.8-2.1	0.0-0.2
P008	1	Ilm-lamellae	10.9-14.8	78.4-83.4	5.0-7.2	0.3-0.4
		Hem-lamellae	63.7-67.4	30.5-34.7	1.5-1.9	0.1-0.2
P013 _{PS+NS}	1	Ilmenite	10.9-12.6	85.0-86.9	1.9-2.0	0.3-0.4
P1 _M	1	Ilmenite	8.5-10.2	87.5-89.8	1.4-1.7	0.3-0.6
P010A	1	Ilmenite	8.2-8.6	82.8-83.3	3.5-4.0	4.6-4.7
	2	Ilmenite	3.0-5.9	87.8-91.3	2.3-3.0	2.7-5.3
	3	Ilmenite	13.7-25.3	70.3-80.4	2.9-3.6	1.5-2.2

Table S3.4 - Compositional range of biotite crystals from all samples, grouped by generations (Gen.). PS - paleosome; NS - neosome; M - melanosome; R – residuum; L - leucosome; Incl. – inclusions. $X_{Mg} = Mg/(Mg+Fe)$ [apfu.]

Sample	Gen.	Type	TiO ₂ (%)	Ti _[apfu.]	X_{Mg}
P4E_{L+R}	1	Incl.+ Matrix	3.23-5.04	0.352-0.553	0.733-0.842
	2	Matrix	4.36-5.67	0.486-0.633	0.635-0.730
	3	Retrograde	1.18-2.93	0.131-0.326	0.721-0.784
P008	1	Inclusions	1.42-1.56	0.154-0.167	0.864-0.871
	2	Inclusions	6.06-6.26	0.670-0.677	0.799-0.817
P013_{PS}	1	Inclusions	1.89-1.99	0.209-0.223	0.763-0.770
	2	Matrix	5.17-5.52	0.577-0.619	0.654-0.684
	3	Retrograde	4.92-5.08	0.546-0.565	0.706-0.718
P013_{NS}	1	Inclusions	1.94-2.34	0.211-0.253	0.779-0.834
	2	Inclusions	6.22-6.35	0.697-0.706	0.711-0.730
	3	Matrix	4.57-5.75	0.516-0.639	0.636-0.703
P1_M	1	Inclusions	6.21-6.34	0.692-0.705	0.690-0.698
	2	Matrix	4.69-5.54	0.527-0.621	0.644-0.670
	3	Retrograde	3.64-5.10	0.408-0.576	0.680-0.748
P1_L	1	Inclusions	6.00-6.03	0.663-0.669	0.708-0.713
	2	Matrix	4.15-5.50	0.461-0.618	0.646-0.717
	3	Retrograde	2.27-3.99	0.245-0.448	0.688-0.779
P1_D	1	Inclusions	4.42-4.91	0.488-0.543	0.678-0.742
	2	Matrix	4.07-5.19	0.453-0.587	0.643-0.715
	3	Retrograde	3.98-4.81	0.446-0.537	0.720-0.744
P010A	1	Matrix	4.60-5.00	0.517-0.557	0.673-0.685
	2	Matrix	4.28-4.41	0.472-0.501	0.732-0.740

Table S3.5 – Compositional range of spinel crystals from samples P4E, P008 and P010A, grouped by generations (Gen.). R – residuum; L - leucosome; Incl.+Mat. – inclusions and matrix; Exs. – Exsolution. $X_{Mg} = Mg/(Mg+Fe)$ [apfu.], Sp – spinel. Hc – hercynite. Ghn – gahnite. Mag – magnetite. Mfr – magnesioferrite.

Sample	Mineral	Gen.	Type	Sp (%)	Hc (%)	Ghn (%)	Mag+Mfr (%)	X_{Mg}
P4E_L	Hc	1	Inclusions	43.0-49.7	45.4-52.0	0.0-1.7	4.5-5.6	0.454-0.522
		2	Matrix	35.0-40.5	56.0-60.5	0.0-1.7	3.2-6.0	0.368-0.421
P4E_R	Hc	2	Incl.+Mat.	39.0-44.7	52.4-58.0	0.0-1.7	1.5-4.2	0.404-0.460
	Hc-Mag	3	Exs.	13.3-14.8	37.7-38.2	0.0	46.7-49.3	0.261-0.278
P008	Hc	1	Matrix	41.2-45.6	48.7-58.0	0.6-1.1	0.0-7.2	0.416-0.481
P010A	Hc	1	Incl+Mat.	26.5-40.6	50.2-63.1	7.2-8.9	1.4-2.1	0.296-0.447
		2	Matrix	40.1-41.9	51.6-52.8	4.7-5.2	0.6-2.6	0.434-0.444

Table S3.6 - Compositional range of sillimanite (samples P4E and P008), cordierite (sample P4E) and sapphirine (sample P008) crystals. Cordierite is grouped by generations (Gen.). L+R – leucosome+residuum; Mat. – matrix; Ov. – overgrowths on ilmenite and hercynite; Pin. – pinitized; $X_{Mg} = Mg/(Mg+Fe)$ [apfu.]

Sample	Sillimanite		Sapphirine			Cordierite		
	FeO(%)	Fe[apfu]	Al _T [apfu]	Si ₁ [apfu]	X_{Mg}	Gen.	X_{Mg}	Mn _[apfu]
P4E_{L+R}	0.98-1.22	0.022-0.028	-	-	-	1 (Mat)	0.840-0.852	0.0-0.01
						2 (Ov.)	0.857-0.866	0.001-0.005
						3 (Pin.)	0.832-0.838	0.003-0.009
P008	1.10-1.20	0.025-0.027	8.67-8.75	1.50-1.59	0.775-0.798	-	-	-

Table S3.7 – End-member compositional range of plagioclase and orthoclase crystals from all samples, grouped by generations (Gen.). PS - paleosome; NS - neosome; M - melanosme; R – residuum; L - leucosome; Incl. – inclusions. An – anorthite. Ab – albite. Or – orthoclase.

Sample	Mineral	Gen.	Type	An (%)	Ab (%)	Or (%)
P4E_{L+R}	Pl	1	Incl. + Matrix	32.0-40.7	58.4-67.2	0.5-1.3
	Or	1	Incl. + Matrix	0.3-2.4	11.4-29.2	69.6-88.2
P008	Pl	1	Incl. + Matrix	34.8-40.2	56.5-63.8	0.7-3.7
	Or	1	Matrix	0.4-2.1	11.0-14.3	85.0-88.3
P013_{PS}	Pl	1	Inclusions	59.0-76.3	23.3-39.4	0.4-1.6
		2	Matrix	42.1-46.3	53.0-56.7	0.7-1.4
	Or	1	Matrix	0.4-0.6	8.6-10.6	88.9-91.0
P013_{NS}	Pl	1	Incl. + Matrix	43.0-44.9	53.7-55.9	1.1-2.1
	Or	1	Matrix	0.2-1.0	8.3-12.1	86.9-91.3
P1_M	Pl	1	Incl. + Matrix	45.9-51.4	47.6-53.0	0.9-1.9
	Or	1	Matrix	0.0-0.2	5.6-6.1	93.8-94.3
P1_L	Pl	1	Incl. + Matrix	44.1-49.4	49.9-54.4	0.7-1.8
	Or	1	Incl. + Matrix	0.2-0.9	9.6-12.8	86.3-90.0
P1_D	Pl	1	Matrix	31.5-39.9	59.0-67.6	0.7-2.2
	Or	1	Incl. + Matrix	0.1-1.4	7.3-11.6	88.0-92.6
P010A	Pl	1	Matrix	43.2-47.3	51.0-55.4	0.9-2.0
		2	Matrix	53.9-55.2	43.5-44.6	1.1-1.6
	Or	1	Matrix	0.3-0.9	5.1-10.1	89.2-94.4

Appendix S4 - Bulk-rock compositions of analysed samples

Sample	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃ ¹	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI	Total	Theriak-Domino input											
														Si	Ti	Al	Fe ³⁺ ²	Fe	Mg	Mn	Ca	Na	K	H ³	O
P1(L)	62.64	0.77	16.02	0.02	8.34	0.18	2.00	2.14	1.48	6.10	0.06	0.49	100.22	-	-	-	-	-	-	-	-	-	-	-	-
P1(M)	56.84	1.32	17.40	0.03	10.91	0.20	4.05	4.78	2.18	2.08	0.16	0.26	100.21	-	-	-	-	-	-	-	-	-	-	-	-
P1D	68.00	0.81	14.54	0.02	7.15	0.14	2.15	2.46	2.21	3.18	0.05	0.17	100.88	-	-	-	-	-	-	-	-	-	-	-	-
P013	61.63	1.13	16.49	0.02	10.47	0.22	3.33	3.98	2.23	1.66	0.19	-0.51	100.83	1.026	0.014	0.324	0.001	0.131	0.083	0.003	0.071	0.072	0.035	0.040	2.980
P10A	57.06	1.38	17.80	0.02	9.25	0.17	3.84	4.47	2.72	3.71	0.19	0.04	100.63	-	-	-	-	-	-	-	-	-	-	-	-
P4E	66.53	1.18	16.11	0.00	8.93	0.17	2.95	0.53	0.72	2.86	0.06	0.25	100.28	1.107	0.015	0.316	0.002	0.112	0.073	0.002	0.009	0.023	0.061	0.016	2.962
P008B	69.00	1.43	13.54	0.03	9.79	0.18	2.38	0.63	0.64	1.43	0.04	-0.15	98.94	1.148	0.018	0.266	0.002	0.123	0.059	0.003	0.011	0.021	0.030	0.003	2.951
P008B replicate	69.54	1.46	13.78	0.03	10.00	0.19	2.43	0.65	0.67	1.46	0.04	-	100.25	-	-	-	-	-	-	-	-	-	-	-	-
BRANCO_PREP standard	>90	<0,01	0.05	<0,01	1.72	0.02	<0,01	0.02	<0,01	<0,01	<0,01	-0.45	-	-	-	-	-	-	-	-	-	-	-	-	-
TILL-3 standard	69.86	0.53	12.70	0.02	4.26	0.07	1.74	2.71	2.93	2.58	0.11	-	97.51	-	-	-	-	-	-	-	-	-	-	-	-

¹Fe₂O₃T - total iron analysed as Fe₂O₃ by XRF and ICP/OES

²Fe³⁺ contents calculated with T-X and P-X phase-equilibria diagrams at Theriak-Domino

³H contents calculated with T-X and P-X phase-equilibria diagrams at Theriak-Domino

Appendix S5 - U-Pb LA-ICP-MS analyses
 S5.1a: U-Pb LA-ICP-MS analysis and ages of sample P4E

grain/spot position	U ppm	Th ppm	Th/U	Isotopic ratios						Ages (in Ma) ^a						Discordance ^b (%)	
				²⁰⁶ Pb/ ²³⁸ U	2σ	²⁰⁷ Pb/ ²³⁵ U	2σ	²⁰⁷ Pb/ ²⁰⁶ Pb	2σ	Rho	²⁰⁶ Pb/ ²³⁸ U	2σ	²⁰⁷ Pb/ ²⁰⁶ Pb	2σ	²⁰⁷ Pb/ ²³⁸ U		2σ
Schlieren/Schollen Hc-Sil-Crd-Grt-Bt datetext (P4E)																	
P4E007	77.83071	27.22741	0.363853	0.099946	2.621673	0.83491	4.46957	0.06058601	3.61993	0.58656	614.09	15.33	624.57	78.05	616.33	20.83	0.36
P4E008	41.09479	65.71553	1.380115	0.09815	3.645373	0.801028	6.765651	0.05919076	5.699587	0.538806	603.56	20.98	574.12	123.94	597.41	30.97	-1.03
P4E009	112.1822	65.91346	0.587557	0.096014	1.65082	0.792449	2.278409	0.05986	1.702345	0.572455	591.01	9.30	598.52	10.26	592.56	10.26	0.23
P4E010	47.35781	88.89352	1.877061	0.097839	1.738146	0.807924	2.528619	0.0598901	1.836508	0.68739	601.74	9.96	599.01	39.76	601.29	11.52	-0.07
P4E011	44.44688	24.49544	0.551117	0.096937	1.717893	0.802472	2.499408	0.06004	1.815456	0.68732	596.43	9.77	605.02	39.27	598.22	11.34	0.30
P4E013	19.5798	16.51447	0.84872	0.099756	1.641859	0.828268	2.030321	0.06021883	1.194363	0.80867	612.98	9.58	611.45	25.81	612.65	9.37	-0.05
P4E014	55.68656	37.44545	0.672432	0.098291	1.653399	0.811165	2.268273	0.05989	1.552847	0.728924	604.39	9.52	599.60	33.62	603.38	10.35	-0.17
P4E015	342.349	49.09344	0.142022	0.098232	2.457037	0.923127	1.194061	0.06195905	3.396922	0.785775	662.47	15.44	669.24	27.76	664.21	20.62	0.23
P4E016	98.74010	20.90217	0.209566	0.09769	1.658986	0.809662	2.171371	0.05999	1.400034	0.764027	602.44	9.52	602.13	30.32	602.38	9.90	-0.01
P4E017	83.22029	52.56051	0.631569	0.097579	1.644906	0.810074	2.146186	0.06021	1.378509	0.768442	600.20	9.41	611.13	29.79	602.50	9.78	0.38
P4E018	44.13552	37.30141	0.845003	0.097177	1.672344	0.801785	2.364189	0.05984	1.671123	0.707365	597.85	9.53	597.79	36.19	597.84	10.72	0.00
P4E019	24.46266	50.15761	2.050375	0.097067	1.839603	0.800607	3.042962	0.05982	2.423938	0.604544	597.20	10.47	597.07	52.17	597.17	13.81	0.00
P4E020	70.45223	42.73692	0.606609	0.095131	1.645049	0.784376	2.196081	0.0598	1.454849	0.749084	585.81	9.19	596.35	31.52	587.98	9.83	0.37
P4E027	74.83744	32.77077	0.437893	0.097127	1.652551	0.806193	2.152172	0.0602	1.378738	0.767853	597.55	9.41	610.77	29.80	600.32	9.78	0.46
P4E028	46.64283	41.65846	0.893138	0.096224	1.709758	0.794586	2.484992	0.05989	1.803306	0.688034	592.24	9.65	599.60	39.05	593.77	11.21	0.26
P4E029	61.34494	35.70699	0.582069	0.096355	1.728267	0.794068	2.440609	0.05977	1.723273	0.781029	593.01	9.77	595.26	37.34	593.48	11.01	0.08
P4E030	64.22211	38.21995	0.595121	0.097007	1.675284	0.802652	2.293514	0.06001	1.566406	0.730445	596.84	9.53	600.94	33.89	598.32	10.40	0.25
P4E031	81.11415	12.10534	0.149238	0.096826	1.636966	0.803027	2.130289	0.06015	1.633259	0.768424	595.78	9.30	603.97	29.49	598.53	9.66	0.46
P4E032	95.28109	29.88552	0.313656	0.096656	1.639855	0.798148	2.11505	0.05989	1.335782	0.775327	594.78	9.30	599.60	29.92	596.78	9.56	0.17
P4E033	201.2425	7.811446	0.038816	0.097769	1.695836	0.809613	2.173154	0.06005838	1.359848	0.780357	601.32	9.72	605.68	28.39	602.24	9.90	0.15
P4E034	80.69495	37.14629	0.46033	0.096335	1.666146	0.797224	2.219396	0.06002	1.466178	0.75072	592.89	9.42	604.30	31.72	595.26	10.03	0.40
P4E035	57.75181	36.0272	0.623828	0.095863	1.674341	0.793454	2.269841	0.06003	1.532567	0.737647	590.12	9.42	604.86	33.16	593.13	10.23	0.51
P4E036	67.06058	37.69401	0.562089	0.098321	1.673299	0.814746	2.201713	0.0601	1.430948	0.759989	604.56	9.64	607.18	30.94	605.11	10.07	0.09
P4E037	53.71473	36.67539	0.692781	0.095322	1.831193	0.787393	2.738639	0.05991	2.036388	0.698951	596.93	10.25	600.33	44.09	589.69	12.30	0.47
P4E038	49.79331	27.48447	0.551905	0.096769	1.948994	0.794923	3.065814	0.05958	2.366566	0.635718	595.43	11.06	598.36	51.34	593.96	13.56	-0.25
P4E039	46.80831	36.15388	0.772382	0.096826	2.115522	0.797806	3.552718	0.05978988	2.857146	0.59434	595.78	11.99	594.86	61.91	595.59	16.11	-0.03
P4E047	37.0696	38.90248	1.049444	0.095933	1.714943	0.793109	2.427325	0.05996	1.717812	0.706516	590.53	9.66	602.13	37.18	592.93	10.94	0.40
P4E048	42.36208	38.05079	0.898228	0.099144	1.720125	0.824943	2.518506	0.06034	1.839576	0.682994	609.39	9.98	615.79	39.72	610.75	11.60	0.22
P4E049	540.7286	42.35133	0.078323	0.099806	1.588099	0.801453	1.94105	0.05824	1.116071	0.818165	613.27	9.27	538.80	24.41	597.65	8.79	-2.61
P4E050	36.40091	48.51998	1.332933	0.096565	1.890713	0.878354	2.957158	0.0597	2.273761	0.639368	594.25	10.11	605.42	47.60	640.09	14.11	7.16
P4E051	75.8089	18.94322	0.249881	0.096907	1.697723	0.802624	2.286459	0.06007	1.531547	0.742512	596.25	9.65	600.10	33.13	598.31	10.37	0.34
P4E052	124.7441	18.18489	0.145245	0.097679	1.643217	0.776968	2.084593	0.05769	1.282718	0.788268	600.79	9.41	518.01	28.16	583.75	9.28	-2.92
P4E053	50.67532	34.57091	0.682204	0.097298	1.732137	0.805998	2.437089	0.06008	1.714381	0.71074	598.55	9.88	600.46	37.08	600.21	10.08	0.28
P4E054	45.77525	34.75484	0.63799	0.099264	1.697827	0.826803	2.269753	0.06041	1.506373	0.740403	610.09	9.86	618.29	32.51	611.84	10.42	0.28
P4E055	91.47297	39.35418	0.428792	0.098983	1.702645	0.826101	2.238885	0.06053	1.453825	0.760488	608.45	9.86	622.57	31.36	611.45	10.32	0.49
P4E056	38.69622	26.80231	0.692573	0.096325	1.749635	0.793555	2.503632	0.05975	1.790795	0.698839	592.83	9.89	594.53	38.81	593.19	11.29	0.06
P4E057	58.08815	22.19559	0.382102	0.099124	1.720474	0.823446	2.402119	0.06025	1.676349	0.716232	609.27	9.88	615.66	36.22	609.97	11.06	0.11
P4E058	195.1371	39.06092	0.200172	0.096626	1.66113	0.797899	2.060357	0.05989	1.218901	0.806234	594.60	9.41	599.60	26.39	595.64	9.31	0.17
P4E059	50.46395	19.78161	0.391995	0.096174	1.773235	0.791254	2.55778	0.05967	1.843472	0.693244	591.95	10.01	591.63	39.97	591.88	11.52	-0.01
P4E060	63.83727	32.94768	0.51612	0.096415	1.852375	0.79322	2.662384	0.05968991	1.912328	0.695758	593.37	10.48	591.59	41.46	593.00	12.01	-0.06
P4E061	48.91344	45.14757	0.921121	0.096933	1.654937	0.824027	2.147061	0.06047	1.356044	0.775392	607.59	9.69	600.43	39.62	601.29	9.88	0.45
P4E068	44.86277	29.86203	0.531889	0.094048	1.706445	0.836051	2.482235	0.06039	1.717817	0.700351	616.80	10.20	617.58	38.25	616.99	11.62	0.03
P4E069	45.0885	41.23336	0.914988	0.099144	1.740362	0.824296	2.415439	0.0603	1.674959	0.720516	609.39	10.10	614.36	36.18	610.44	11.12	0.17
P4E070	32.71003	27.46268	0.83958	0.09794	1.787522	0.809693	2.667997	0.05995978	1.980649	0.696987	602.32	10.26	602.12	42.87	602.17	-0.01	
P4E071	23.4345	17.97667	0.767103	0.09811	1.860941	0.81043	3.053021	0.05991	2.420297	0.609541	603.33	10.40	600.33	52.40	602.70	13.95	-0.10
P4E072	27.27936	17.19885	0.630471	0.099856	1.788226	0.831044	2.723613	0.06036	2.054341	0.656664	613.56	10.74	613.60	34.66	614.19	12.61	0.10
P4E073	48.52022	24.64502	0.507933	0.097609	1.747174	0.808978	2.412517	0.06011	1.663617	0.724212	600.38	9.99	607.54	39.62	601.88	10.99	0.25
P4E074	59.31075	26.70924	0.450327	0.09812	1.670455	0.81344	2.458869	0.06012636	3.68251	0.587059	603.38	13.36	608.12	75.67	604.38	20.90	0.17
P4E075	158.468	16.65999	0.105132	0.102133	1.669777	0.853376	2.078429	0.0606	1.237624	0.803384	626.90	9.59	625.07	26.68	626.50	9.75	-0.06
P4E076	75.418	73.75741	1.196467	0.103467	1.774272	0.827952	2.393541	0.05803647	1.606549	0.741275	634.70	10.70	531.14	35.19	612.48	10.47	-3.63
P4E077	34.12288	16.78261	0.491829	0.101712	1.854226	0.853081	2.854291	0.06083	2.169982	0.649628	624.43						

1.sMPABC121	397.1808	185.7892	0.46777	0.09151	1.661021	0.748716	2.027578	0.05934	1.162791	0.819214	564.4613	8.983315	579.59287	25.26186	567.479371	8.85314	0.53
1.sMPABC122	406.8547	182.6451	0.44892	0.0922	1.626898	0.758303	1.958117	0.05965	1.08969	0.830848	568.5351	8.859428	590.90209	23.62874	573.030421	8.611082	0.78
1.sMPABC141	422.6812	196.713	0.465393	0.09168	1.657941	0.749728	2.025393	0.05931	1.163379	0.818577	565.4652	8.981915	578.494448	25.27932	568.066628	8.850419	0.46
1.sMPABC161	409.2244	187.8641	0.459074	0.08973	1.710348	0.726986	2.216378	0.05876071	1.409624	0.771686	553.9401	9.085052	558.241796	30.73495	554.782609	9.517979	0.15
1.sMPABC162	380.0672	170.0978	0.447546	0.0897	1.627653	0.732038	1.982588	0.05918885	1.131989	0.820974	553.7626	8.642846	574.049363	24.61567	557.74863	8.544064	0.71
SECONDARY REF. MAT. (GJ1, Jackson et al. 2004; Morel et al. 2008)																	
1.sMPABC003	651.4834	21.06468	0.032333	0.09815	1.625754	0.811393	1.98663	0.05995672	1.141764	0.818347	603.5609	9.346849	602.012846	24.7118	603.235449	9.060282	-0.05
1.sMPABC004	616.7649	20.33783	0.032975	0.09803	1.596398	0.811659	1.90118	0.06005	1.032473	0.839688	602.8542	9.167692	605.376722	22.33377	603.384379	8.670483	0.09
1.sMPABC023	505.6737	16.7213	0.033067	0.09791	1.659836	0.811337	1.999463	0.0601	1.114809	0.830141	602.1474	9.521597	607.176812	24.10753	603.204044	9.118723	0.18
1.sMPABC024	541.0933	17.53383	0.032404	0.097288	1.670448	0.804708	2.037636	0.05999	1.166861	0.819797	598.4944	9.526983	603.213917	25.24991	599.480904	9.25128	0.16
1.sMPABC043	486.9422	15.88106	0.032614	0.097478	1.646599	0.804806	2.00975	0.05988	1.152305	0.819305	599.6141	9.407649	599.24111	24.95153	598.536109	9.12472	-0.01
1.sMPABC044	502.5627	15.88771	0.031613	0.098552	1.628664	0.814891	1.975029	0.05997	1.117225	0.824628	605.916	9.398477	602.492328	24.17875	605.19423	9.028658	-0.12
1.sMPABC063	453.5403	14.59614	0.032183	0.09806	1.639523	0.81113	1.989656	0.05999244	1.127251	0.824023	603.0308	9.418164	603.301864	24.39242	603.087797	9.072506	0.01
1.sMPABC064	456.726	14.46983	0.031682	0.098532	1.649359	0.813503	1.933071	0.05988	1.118904	0.827546	605.7982	9.516218	599.24111	24.22829	604.417049	9.102892	-0.23
1.sMPABC083	463.8877	15.243	0.032859	0.09855	1.613514	0.812911	1.94288	0.05982526	1.082292	0.830475	605.9061	9.321348	597.260458	23.44329	604.085509	8.875163	-0.30
1.sMPABC084	486.8646	15.89704	0.032652	0.097398	1.584199	0.803738	1.959292	0.05985	1.152882	0.808557	599.1412	9.054284	598.155891	24.96858	598.935302	8.89418	-0.03
1.sMPABC103	473.5527	15.45344	0.032633	0.097278	1.630161	0.803848	1.954933	0.05993218	1.079044	0.833871	598.4349	9.306673	601.126742	23.35778	598.997235	8.874981	0.09
1.sMPABC123	453.8325	14.6295	0.032235	0.09872	1.623871	0.817511	1.942283	0.06006	1.065601	0.836063	606.9055	9.395994	605.736903	23.04898	606.658714	8.900191	-0.04
1.sMPABC124	410.7098	13.29302	0.032366	0.098169	2.601351	0.814413	4.415499	0.06016829	3.567857	0.589141	603.6715	14.98182	609.632208	77.12256	604.926725	20.30444	0.21
1.sMPABC143	460.4352	14.66315	0.031846	0.0985	1.647849	0.806993	2.006252	0.05942	1.144396	0.821357	605.6121	9.515438	582.519087	24.84998	600.765976	9.128837	-0.81
1.sMPABC144	435.8551	14.06912	0.032279	0.09833	1.74272	0.808435	2.38853	0.05962929	1.476114	0.763061	604.6125	10.04784	590.149146	32.01197	601.575966	10.4088	-0.50
1.sMPABC163	414.1282	13.68918	0.033055	0.097989	1.697342	0.812265	2.126345	0.06012	1.280772	0.798244	602.6128	9.755098	607.892676	27.69312	603.723586	9.712976	0.18
1.sMPABC164	431.9506	13.65998	0.031624	0.096907	1.770663	0.80173	2.339313	0.06000289	1.528769	0.756916	596.2566	10.07428	603.678669	33.07872	597.803988	10.61351	0.26
TERCIARY REF. MAT. (Plešovice, Síma et al. 2008)																	
1.sMPABC005	851.7699	138.5089	0.162613	0.05377	1.641791	0.394267	2.058088	0.05318	1.241068	0.797726	337.6264	5.386499	336.484341	28.12075	337.481634	5.913097	-0.04
1.sMPABC006	883.3655	138.4672	0.15675	0.053961	1.561629	0.396557	1.914159	0.0533	1.106942	0.81583	338.7923	5.140633	341.589132	25.05894	339.148262	5.521406	0.10
1.sMPABC025	817.2914	141.1434	0.172697	0.05383	1.602684	0.394857	1.959738	0.0532	1.12782	0.817805	337.9946	5.263728	337.336261	25.55084	337.911058	5.6358	-0.02
1.sMPABC045	707.0355	110.7682	0.156666	0.054081	1.63235	0.396696	2.084888	0.0532	1.296992	0.782944	339.5285	5.384913	337.336261	29.38347	339.249326	6.016852	-0.08
1.sMPABC046	701.7492	108.2434	0.154248	0.053921	1.674419	0.395668	2.094891	0.05322	1.258925	0.799287	338.5469	5.508187	338.187731	28.51674	338.501222	6.034532	-0.01
1.sMPABC065	658.4468	103.2256	0.156771	0.054262	1.700869	0.398395	2.115671	0.05325	1.258216	0.803938	340.6328	5.628827	339.464096	28.49422	340.483445	6.124727	-0.04
1.sMPABC066	673.3858	100.6029	0.149399	0.054232	1.627821	0.392342	1.967663	0.05247	1.105394	0.827287	340.4487	5.384147	305.946636	25.18322	336.078516	5.632672	-1.30
1.sMPABC085	711.2146	113.0561	0.158962	0.053674	1.603958	0.393949	1.933661	0.05323272	1.3901587	0.721371	337.0356	5.33444	338.729103	28.36891	337.250043	16.27375	0.06
1.sMPABC086	754.5107	119.479	0.158353	0.053834	1.637819	0.394734	1.999542	0.05318	1.147048	0.819097	338.0163	5.385834	336.484341	25.99039	337.821907	5.754434	-0.06
1.sMPABC105	693.7407	106.0368	0.152848	0.053754	2.660844	0.392005	3.577586	0.05289106	2.39145	0.743754	337.5259	5.739877	324.126291	54.30589	335.833052	10.26744	-0.50
1.sMPABC106	768.5103	116.684	0.151831	0.054215	1.645945	0.398299	2.087221	0.05328344	1.283494	0.788582	340.3448	5.448897	340.885655	29.05935	340.413919	6.046448	0.02
1.sMPABC125	732.6087	116.1828	0.158588	0.054305	1.697417	0.399235	2.145866	0.05332	1.312828	0.791017	340.8962	5.62824	342.438364	29.71531	341.093535	6.22734	0.06
1.sMPABC126	732.2238	112.7415	0.153971	0.053914	1.797712	0.396012	2.24208	0.05327279	1.339834	0.801805	338.5066	5.920226	340.43287	30.33737	338.751495	6.46967	0.07
1.sMPABC146	606.2542	91.32539	0.150639	0.05408	1.627219	0.398031	2.13767	0.05338	1.386287	0.761211	339.522	5.384045	344.983384	31.36386	340.218891	6.198625	0.20

^aAges and errors calculated with ISOPLOT (Ludwig, 2003)

^bDiscordance in % = 100*(1-²⁰⁶Pb/²³⁸U age/²⁰⁷Pb/²³⁵U age)

SS.2a: U-Pb LA-ICP-MS analysis and ages of sample P013

grain/spot position	U ppm	Th ppm	Th/U	Isotopic ratios				Ages (in Ma) ^a				Discordance ^b (%)					
				²⁰⁶ Pb/ ²³⁸ U	2σ	²⁰⁷ Pb/ ²³⁵ U	2σ	²⁰⁷ Pb/ ²⁰⁶ Pb	2σ	Rho	²⁰⁶ Pb/ ²³⁸ U		2σ	²⁰⁷ Pb/ ²³⁵ U	2σ	²⁰⁷ Pb/ ²⁰⁶ Pb	2σ
Sromatic Opx-Gr-Bt metatexte (P013)																	
P013-053	806.2868	232.565	0.28844	0.127165	1.574927	1.100402	1.90265	0.06276	1.067559	0.827754	771.67	11.45	753.54	10.17	700.11	22.73	-2.37
P013-147	329.3785	121.4308	0.368667	0.112064	1.644178	0.934809	1.955089	0.0605	1.057851	0.840974	684.72	10.68	670.16	9.65	621.50	22.82	-2.14
P013-140	446.36	337.402	0.755897	0.128887	2.253127	1.130133	4.009633	0.06359436	3.16712	0.561929	781.51	16.58	767.82	21.82	728.17	70.31	-1.70
P013-056	439.341	45.23052	0.102951	0.102871	1.596418	0.842383	1.91672	0.05939	1.060785	0.832891	631.21	9.59	620.46	8.93	581.42	23.04	-1.75
P013-113	774.2077	561.8025	0.725648	0.119104	2.366168	1.020292	4.129865	0.0621295	3.384824	0.572941	725.40	16.23	714.06	21.39	678.57	72.33	-1.56
P013-075	87.22694	758.7419	8.698481	0.103452	1.664892	0.852274	2.200804	0.05975	1.439331	0.756493	634.61	10.06	625.90	2.00	594.53	31.19	-1.36
P013-167	892.2131	193.8004	0.217213	0.131991	1.604191	1.175258	1.938729	0.06457824	1.033294	0.846131	799.22	12.33	789.10	10.69	760.63	21.79	-1.25
P013-033	580.6048	765.3571	1.316207	0.099637	1.592528	0.817329	1.913888	0.05949422	1.06152	0.83209	612.28	9.30	606.56	8.77	580.23	23.04	-0.92
P013-127	180.3696	559.1583	3.100131	0.097824	2.489327	0.799027	4.195445	0.059352	3.228906	0.599578	600.47	14.07	596.28	18.73	580.37	71.60	-0.68
P013-094	214.3699	327.177	1.526227	0.097614	1.865532	0.800217	2.182378	0.05945568	1.386274	0.772337	600.41	9.66	596.95	9.89	583.62	30.10	-0.58
P013-047	15.84700	10.88628	0.68896	0.122158	2.500159	1.070871	4.747026	0.06357007	4.035277	0.526679	742.97	17.55	739.17	25.22	727.66	85.54	-0.48
P013-011	292.4087	93.9557	0.321316	0.105665	1.592115	0.888134	2.042553	0.06096	1.279528	0.779473	647.52	9.80	645.37	9.80	637.82	27.53	-0.31
P013-111	136.2724	168.711	1.238042	0.096563	1.765086	0.972202	2.364732	0.05951019	1.573667	0.746421	594.23	10.02	592.42	10.66	585.48	34.15	-0.28
P013-172	355.0662	115.7065	0.325873	0.133103	1.715317	1.205926	2.060354	0.06571	1.141379	0.832535	605.54	12.99	603.32	11.49	797.15	23.93	-0.24
P013-077	377.2688	133.7503	0.354523	0.105405	1.615048	0.886236	1.93509	0.06098	1.065923	0.836111	646.01	9.92	644.35	9.27	638.53	22.93	-0.23
P013-171	109.5719	303.1625	2.766792	0.097594	1.701665	0.804097	2.16416	0.05975622	1.337133	0.786294	600.29	9.75	599.14	9.83	594.76	28.98	-0.17
P013-073	1117.463	1315.231	1.176979	0.119394	1.660758	1.043909	1.968667	0.06341303	1.057133	0.843595	727.08	11.41	725.86	10.25	722.11	22.43	-0.14
P013-136	243.9279	152.2677	0.624333	0.128917	2.241378	1.157312	3.968811	0.0610856	3.275315	0.564748	781.69	16.50	780.69	21.84	777.85	68.87	-0.09
P013-099	409.1361	204.6055	0.500091	0.192455	1.65839	2.052765	2.01396	0.07735877	1.142706	0.823448	1134.66	17.26	1133.22	13.84	1130.45	66.70	-0.08
P013-096	199.6515	399.0644	1.999706	0.10162	1.665567	0.847456	2.072216	0.06048363	1.241255	0.801826	623.89	9.90	623.25	9.71	620.92	26.78	-0.07
P013-091	843.6694	321.1937	0.38071	0.131421	1.645843	1.188483	2.004102	0.06558852	1.143614	0.821237	795.97	12.32	795.26	11.10	793.27	23.99	-0.06
P013-158	420.1827	168.7486	0.401608	0.164947	1.689291	1.633774	2.000247	0.07183678	1.071115	0.844541	984.21	15.42	983.32	12.67	981.32	21.81	-0.05
P013-168	306.1804	246.9378	0.806511	0.103693	1.647959	0.869906	1.998494	0.06084483	1.127836	0.825241	636.01	9.98	635.52	9.47	633.75	24.28	-0.05
P013-160	1801.309	163.652	0.090852	0.129278	2.246321	1.16263	3.933446	0.06522535	3.228938	0.571082	783.74	16.58	783.19	21.69	781.61	67.86	-0.04
P013-177	239.7776	64.78427	0.270185	0.166499	1.659591	1.656797	1.973263	0.07217	1.068925	0.841221	992.79	15.27	992.15	12.57	990.74	21.70	-0.02
P013-060	209.0603	95.77265	0.45811	0.129037	1.644431	1.160736	2.127267	0.06521	1.349486	0.773025	782.71	12.12	782.30	11.66	781.12	28.36	-0.02
P013-137	116.7859	464.5005	3.977366	0.100468	1.694048	0.836001	2.112065	0.06035	1.275891	0.798848	617.15	9.97	616.94	9.85	616.15	27.55	-0.01
P013-092	564.171	174.3301	0.309002	0.11607	1.604428	1.00767	2.025365	0.06296491	1.236809	0.921677	707.90	10.77	707.70	10.37	707.05	26.29	0.00
P013-032	510.0263	418.5529	0.82065	0.098235	1.590214	0.812679	1.905592	0.06	1.05	0.834499	604.06	9.16	603.96	8.71	603.57	22.72	0.01
P013-078	363.2938	314.8371	0.866618	0.122839	1.63039	1.086341	1.944777	0.06414	1.060181	0.838343	746.88	11.49	746.72	10.33	746.25	22.41	0.01
P013-118	152.4135	235.6397	1.546055	0.11644	1.633987	1.012092	2.059212	0.06304	1.253173	0.793501	710.04	10.98	709.33	10.56	709.58	26.64	0.02
P013-100	71.18085	92.52881	1.299912	0.098405	1.767085	0.814584	2.529918	0.06003658	1.810496	0.698475	605.06	10.20	605.02	11.59	604.89	39.17	0.02
P013-052	661.0009	178.4044	0.2699	0.105435	1.614588	0.898687	1.906098	0.0612	1.013072	0.847065	646.18	9.92	646.20	9.15	646.27	21.77	0.03
P013-067	626.7193	69.18876	0.110398	0.11617	2.366707	1.009359	4.082985	0.0630161	3.327528	0.579497	708.48	15.87	708.55	21.03	708.77	70.76	0.04
P013-089	245.2569	213.1505	0.869091	0.10199	1.728816	0.852741	2.228368	0.06063971	1.405995	0.775821	626.06	10.31	626.10	10.46	626.48	30.31	0.04
P013-154	1039.374	322.8913	0.310659	0.108459	1.624965	0.922982	1.963254	0.06172	1.10175	0.82769	663.79	10.25	663.94	9.61	664.42	23.60	0.05
P013-095	378.2384	77.60315	0.20517	0.113363	1.672511	0.955219	2.015792	0.06221	1.125221	0.829704	680.66	10.80	680.02	10.04	681.34	24.04	0.05
P013-009	436.2544	185.2948	0.42474	0.119264	1.612091	1.045188	1.900718	0.06356	1.006923	0.848148	726.33	11.07	726.50	9.94	727.02	21.35	0.06
P013-149	155.3913	134.8298	0.866392	0.11613	1.656501	1.009234	2.076524	0.06303	1.253371	0.797294	708.25	11.10	708.49	10.64	709.24	26.65	0.06
P013-178	424.4024	144.8407	0.32693	0.102	1.649337	0.853221	1.968814	0.06066788	1.071469	0.838583	626.12	9.84	626.42	9.23	627.48	23.09	0.08
P013-059	426.2571	90.65989	0.212681	0.107327	1.58745	0.909824	1.943485	0.06154	1.121222	0.816806	656.68	9.91	657.02	9.44	656.16	24.04	0.08
P013-148	800.2863	198.1123	0.247621	0.118923	1.618068	1.040671	1.975544	0.06352	1.133501	0.819029	722.79	11.07	724.25	10.27	725.69	24.04	0.10
P013-151	411.9427	51.47378	0.117231	0.117231	1.674212	1.022363	1.989679	0.06325	1.075099	0.841448	714.61	11.32	715.10	10.26	716.65	22.83	0.10
P013-159	165.3181	92.9989	0.16744	0.302846	1.687457	0.436233	1.983597	0.06454	1.042663	0.850705	1704.42	25.30	1705.23	16.51	1706.24	19.19	0.10
P013-074	282.6946	186.895	0.839219	0.102841	1.635833	0.862555	1.981308	0.06083	1.117869	0.826533	631.04	9.83	631.52	9.35	633.23	24.07	0.10
P013-090	163.4878	206.4347	1.262764	0.097053	1.733388	0.801432	2.212938	0.05989	1.385874	0.781053	597.12	9.88	597.64	10.07	599.60	30.01	0.11
P013-068	50.82333	68.36601	1.34517	0.139942	1.745975	1.298378	2.302461	0.06729	1.500966	0.785308	844.34	13.82	845.01	13.29	846.76	31.22	0.11
P013-120	736.9377	268.1647	0.363891	0.138941	1.672072	1.285639	1.962892	0.06711	1.028163	0.851841	838.67	13.15	839.36	11.27	841.19	21.40	0.12
P013-174	126.9435	319.5033	2.516893	0.096963	1.755654	0.800554	2.236875	0.05988	1.386106	0.784869	596.59	10.00	597.14	10.14	599.24	30.01	0.12
P013-175	188.3777	131.7279	0.699276	0.124251	1.660643	1.104909	2.102167	0.06449499	1.288942	0.789967	754.98	11.83	755.72	11.26	757.97	27.19	0.13
P013-130	189.2015	92.82885															

Appendix S6 - Compilation of ages from the Araçuaí Orogen

Year	Author ¹	Unit	System	Type	Age
1991	Sollner et al. 1991	Caparaó Suite/Juiz de Fora Complex granulite	U-Pb	Magmatic crystallization	2176 Ma
1991	Sollner et al. 1991	Caparaó Suite/Juiz de Fora Complex granulite	U-Pb	Metamorphism	586 Ma
2002	Da Silva et al. 2002	Galileia Suite (G1) Grt-charnockite	U-Pb	Magmatic crystallization	584 Ma
2002	Da Silva et al. 2002	Caparaó Suite/Juiz de Fora Complex granulite	U-Pb	Magmatic crystallization	2195 Ma
2002	Da Silva et al. 2002	Caparaó Suite/Juiz de Fora Complex granulite	U-Pb	Metamorphism	587 Ma
2002	Da Silva et al. 2002	Juiz de Fora Complex (alloctonous) granulite	U-Pb	Magmatic crystallization	2985 Ma
2002	Da Silva et al. 2002	Juiz de Fora Complex (alloctonous) granulite	U-Pb	Metamorphism	808 Ma
2002	Da Silva et al. 2002	Juiz de Fora Complex (alloctonous) enderbite	U-Pb	Metamorphism	2856 Ma
2004; 2011; 2014; 2015; 2016	De Campos et al. 2004 Bento dos Santos et al. 2011 Gradim et al. 2014 Bento dos Santos et al. 2015 Dias et al. 2016 Richter et al. 2016	G2 Supersuite and regional metamorphic peak ages	U-Pb	Magmatic crystallization and metamorphism	560-575 Ma
2007	Noce et al. 2007	Juiz de Fora Complex mafic granulite	U-Pb	Magmatic crystallization	2119 Ma
2007	Noce et al. 2007	Juiz de Fora Complex granitic vein	U-Pb	Metamorphism	574-584 Ma
2007	Noce et al. 2007	Juiz de Fora Complex enderbitic migmatite	U-Pb	Magmatic crystallization	2084 Ma
2007	Noce et al. 2007	Juiz de Fora Complex enderbitic migmatite	U-Pb	Metamorphism	594 Ma
	Rosa et al. 2007	Southern Bahia alkaline province Ribeirão da Folha plagiogranite	U-Pb	Magmatic crystallization	696-732 Ma
	Pedrosa-Soares et al. 2008	(Macaubas basin ophiolite, oceanic crust generation)	U-Pb	Magmatic crystallization	740 Ma
2008	Pedrosa-Soares et al. 2008	G1 Supersuite ages	U-Pb	Magmatic crystallization	585-630 Ma
2010	Novo et al. 2010	Divino Suite (G1) charnockite	U-Pb	Magmatic crystallization	592-603 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex mafic granulite	U-Pb	Magmatic crystallization	2427 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex mafic granulite	U-Pb	Metamorphism	654 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex enderbitic granulite	U-Pb	Magmatic crystallization	1966 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex enderbitic granulite	U-Pb	Metamorphism	587 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex Charnockite	U-Pb	Magmatic crystallization	2199 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex Charnockite	U-Pb	Metamorphism	633 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex Charnockite	U-Pb	Magmatic crystallization	2154 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex alkaline mafic granulite	U-Pb	Magmatic crystallization	1765 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex alkaline mafic granulite	U-Pb	Metamorphism	586 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex alkaline mafic granulite	U-Pb	Magmatic crystallization	1687 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex alkaline mafic granulite	U-Pb	Metamorphism	619 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex alkaline mafic granulite	U-Pb	Metamorphism	584 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex calc-alkaline enderbite	U-Pb	Magmatic crystallization	1656 Ma
2010	Heilbron et al. 2010	Juiz de Fora Complex calc-alkaline enderbite	U-Pb	Metamorphism	591 Ma
2011	Da Silva et al. 2011	Caparaó Suite/Juiz de Fora Complex charnockitic granulite	U-Pb	Metamorphism	2095 Ma
2011	Da Silva et al. 2011	Caparaó Suite/Juiz de Fora Complex charnockitic granulite	U-Pb	Metamorphism	587 Ma
2011	Da Silva et al. 2011	Caparaó Suite/Juiz de Fora Complex charnockitic granulite	U-Pb	Magmatic crystallization	2195 Ma

	Tupinambá et al. 2012	Rio Negro-Serra da Prata magmatic arc	U-Pb	Magmatic crystallization	600-860 Ma
2014	Gradim et al. 2014	Ataléia Suite S-type granites	U-Pb	Magmatic crystallization	580-590 Ma
2014	Gradim et al. 2014	Carlos Chagas S-type granites (G2 Supersuite)	U-Pb	Magmatic crystallization	565-576 Ma
2014	Gradim et al. 2014	Ataléia and Carlos Chagas S-type granites	U-Pb	Metamorphism	563-571 Ma
2015	Gualandi et al. 2015	Caparaó Suite/Juiz de Fora Complex orthogneiss+migmatite	U-Pb	Magmatic crystallization	2060-2209 Ma
2015	Gualandi et al. 2015	Caparaó Suite/Juiz de Fora Complex migmatite(?)	U-Pb	Magmatic crystallization (?)	1775 Ma
2015	Gualandi et al. 2015	Caparaó Suite/Juiz de Fora Complex orthogneiss+migmatites	U-Pb	Metamorphism	603-584 Ma
2015	Alves et al. 2015	Andrelândia Group quartzite	U-Pb	Metamorphism	583-598 Ma
2015	Alves et al. 2015	Andrelândia Group quartzite	U-Pb	Sedimentary provenance	675-2670 Ma
2016	Richter et al. 2016	Nova Venécia Complex peraluminous granodiorite	U-Pb	Magmatic crystallization	593 Ma
2016	Richter et al. 2016	Nova Venécia Complex peraluminous granodiorite	U-Pb	Metamorphism	501-571 Ma
2016	Richter et al. 2016	Nova Venécia Complex granite	U-Pb	Magmatic crystallization	519.3 Ma
2016	Richter et al. 2016	Nova Venécia Complex granite	U-Pb	Metamorphism	497.7-506.8 Ma
2016	Richter et al. 2016	Nova Venécia Complex metatexite (Bt-Grt-Opx-metagreywacke)	U-Pb	Sedimentary provenance	606.1-877.3 Ma
2016	Richter et al. 2016	Nova Venécia Complex metatexite (Bt-Grt-Opx-metagreywacke)	U-Pb	Metamorphism	495-589.6 Ma
2016	Richter et al. 2016	Nova Venécia Complex metatexite (Bt-Grt-Crd-metagreywacke)	U-Pb	Sedimentary provenance	607.3-903.4 Ma
2016	Richter et al. 2016	Nova Venécia Complex metatexite (Bt-Grt-Crd-metagreywacke)	U-Pb	Metamorphism	498.6-560.8 Ma
2016	Richter et al. 2016	Nova Venécia Complex diatexite (Crd-Grt-granulite)	U-Pb	Sedimentary provenance	607.4-789.5 Ma
2016	Richter et al. 2016	Nova Venécia Complex diatexite (Crd-Grt-granulite)	U-Pb	Metamorphism	564.6 Ma
2016	Richter et al. 2016	Nova Venécia Complex metatexite (Bt-Grt-metagreywacke)	U-Pb	Metamorphism	502.6 Ma
2017	Degler et al. 2017	Metasedimentary Sequence paragneiss	U-Pb	Sedimentary provenance	614-2803 Ma
2017	Degler et al. 2017	Metasedimentary Sequence paragneiss	U-Pb	Metamorphism	482-613 Ma
2017	Degler et al. 2017	Metasedimentary Sequence paragneiss	U-Pb	Sedimentary provenance	579-1988 Ma
2017	Degler et al. 2017	Metasedimentary Sequence paragneiss	U-Pb	Metamorphism	573-618 Ma
2018	Novo et al. 2018	Rio Doce Group quartzite	U-Pb	Sedimentary provenance	619-2976 Ma
2018	Novo et al. 2018	Rio Doce Group Grt-schist	U-Pb	Sedimentary provenance	766-3252 Ma
2018	Novo et al. 2018	Rio Doce Group metapyroclastic rhyolite tuff	U-Pb	Magmatic crystallization	595 Ma
2018	Novo et al. 2018	Rio Doce Group metapyroclastic dacite tuff	U-Pb	Magmatic crystallization	584 Ma
2018	Novo et al. 2018	Rio Doce Group dacitic metavolcaniclastic	U-Pb	Magmatic crystallization	585 Ma

¹References are listed in the main file of this paper