UNIVERSIDADE FEDERAL DE MINAS GERAIS
Instituto de Geociências
Programa de Pós-Graduação em Geologia

Gabriel Aragão Rodrigues Soares

GEOLOGIA E ALTERAÇÃO HIDROTERMAL DO DEPÓSITO AURÍFERO TUCANO, NE DO CRÁTON AMAZÔNICO

Belo Horizonte
2023

Gabriel Aragão Rodrigues Soares

GEOLOGIA E ALTERAÇÃO HIDROTERMAL DO DEPÓSITO AURÍFERO TUCANO, NE DO CRÁTON AMAZÔNICO

Dissertação apresentada ao Programa de Pós-Graduação em Geologia da Universidade Federal de Minas Gerais como requisito parcial para obtenção do título de Mestre em Geologia.

Orientador(a): Prof(a). Dr(a). Rosaline Cristina Figueiredo e Silva

Coorientadores: Prof(a). Dr(a). Lydia Maria Lobato & Prof. Dr. Steffen Gerd Hagemann

Belo Horizonte
2023

S676g
2023

Soares, Gabriel Aragão Rodrigues.
Geologia e alteração hidrotermal do depósito aurífero Tucano, Ne do Cráton Amazônico [manuscrito] / Gabriel Aragão Rodrigues Soares. – 2023.
307 f., enc. il. (principalmente color.)

Orientadora: Rosaline Cristina Figueiredo e Silva.
Coorientadora: Lydia Maria Lobato.
Coorientador: Steffen Gerd Hagemann.
Dissertação (mestrado) – Universidade Federal de Minas Gerais, Instituto de Geociências, 2023.
Área de concentração: Geologia Econômica e Aplicada.
Bibliografia: f. 218-226.

1. Geologia econômica – Teses. 2. Minérios de ouro – Geologia – Teses. 3. Fácies (Geologia) – Teses. 4. Alteração hidrotermal – Amapá – Teses. I. Figueiredo e Silva, Rosaline Cristina. II. Lobato, Lydia Maria. III. Hagemann, Steffen Gerd. IV. Universidade Federal de Minas Gerais. Instituto de Geociências. V. Título.

CDU: 553(811.6)

Ficha catalográfica elaborada por Graciane Aparecida de Paula – CRB-6/3404
Biblioteca “Vitória Pedersoli”, Instituto de Geociências da UFMG

UNIVERSIDADE FEDERAL DE MINAS GERAIS

PROGRAMA DE PÓS-GRADUAÇÃO EM GEOLOGIA DO IGC-UFMG

FOLHA DE APROVAÇÃO

Geologia e alteração hidrotermal do depósito aurífero Tucano, NE do Cráton Amazônico

GABRIEL ARAGÃO RODRIGUES SOARES

Dissertação submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em GEOLOGIA, como requisito para obtenção do grau de Mestre(a) em GEOLOGIA, área de concentração GEOLOGIA ECONÔMICA E APLICADA, pelo Programa de Pós-graduação em Geologia do Instituto de Geociências da Universidade Federal de Minas Gerais.

Aprovada em 02 de junho de 2023, pela banca constituída pelos membros:

Profa. Dra. Rosaline Cristina Figueiredo e Silva – Orientadora
UFMG

Profa. Dra. Mariana Brando Soares
UERJ

Gustavo Henrique Coelho de Melo
Assinado de forma digital por Gustavo Henrique Coelho de Melo
Dados: 2023.07.03 08:23:36 -03'00'

Prof. Dr. Gustavo Henrique Coelho de Melo
UFOP

Belo Horizonte, 02 de junho de 2023.

AGRADECIMENTOS

Venho por meio deste expressar minha sincera gratidão a todos que de alguma forma contribuíram para a execução desse trabalho.

À orientadora Profa. Rosaline, pelo apoio, incentivo e ricas discussões para aperfeiçoamento do trabalho, bem como pela amizade construída ao longo dessa caminhada.

À co-orientadora Profa. Lydia pelo ávido empenho em compartilhar seu conhecimento, contribuindo sobremaneira nas discussões e refinamento do trabalho.

Ao co-orientador Prof. Steffen por sua contribuição ímpar neste trabalho, aprofundando as discussões e contribuindo decisivamente na qualidade técnica do trabalho.

À Pró-reitoria de Pós-graduação (PRPg) da UFMG e ao Programa de Pós-graduação em Geologia do Instituto de Geociências (IGC) da UFMG pelo apoio institucional e financeiro, bem como disponibilização de laboratórios para realização das atividades de pesquisa.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) pelo apoio financeiro concedido sob a forma de bolsa.

À AMIRA Global que, por intermediação da Fundação de Desenvolvimento da Pesquisa (Fundep), financiou o presente trabalho integrante do projeto de pesquisa intitulado “South American eXploration Initiative (SAXI): Stage 2 Module 7b: Mineral system analyses of deposits and mineralised areas in the Amapa region, Brazil”.

À Great Panther Mining pelo apoio logístico e financeiro durante as visitas de campo, e por tornar possível a disponibilização de dados essenciais ao cumprimento do trabalho.

Ao Rogério Lucena pela oportunidade e por todo o suporte técnico e logístico indispensável à realização do trabalho.

Ao time de exploração da Great Panther Mining pela hospitalidade, apoio e discussões valiosas para o trabalho, em especial aos geólogos(as) Roberto Silva (“Bebeto”), Pedro Foster, Jéssica de Sousa, Wiverson Sousa, Rafaela Sousa, Luis Fernando Quirino, Henrique Pires e Leonardo Fonseca.

Também expresso minha gratidão aos técnicos e demais membros do staff do time de exploração da Great Panther, principalmente pelo apoio logístico no deslocamento na mina, liberação de testemunhos e transporte de amostras, em especial ao Benedito Seabra, Nizan Soares, “Borrega” e Manoel Melo.

Aos técnicos do CPMTC-IGC-UFMG Carlos Torres, Denise da Silva, Júnio Barcelos, Jhonny da Silva, Stênio Nascimento e Tatiane Oliveira pelo suporte na preparação de amostras.

Ao Fernando Soares pela qualidade diferenciada na preparação das lâminas delgadas polidas e montagem de grãos.

Aos técnicos do Centro de Microscopia da UFMG Breno Barbosa, Márcio Flores, Luis Garcia, Teodoro Gauzzi e Douglas Miquita pelo apoio técnico e operacional durante realização de análises microscópicas em MEV e microssonda eletrônica.

Ao Prof. Cristiano Lana e ao mestrando Igor pelo suporte na realização das análises de LA-ICP-MS no Laboratório de Geoquímica Isotópica da UFOP.

Ao Prof. Stephane Perrouty pela enorme gentileza e disposição em nos disponibilizar seu material de referência certificado como ferramenta de controle de qualidade, e principalmente pelo suporte logístico na realização de análises litogeoquímicas na ALS Canadá.

À minha família, em especial meus pais, por todo amor e suporte incondicional ao longo de todos os momentos dessa caminhada, bem como por seus ensinamentos e exemplo de vida.

Aos meus amigos da cidade de Belo Horizonte e do Grande Rio pelo companheirismo, suporte e alegrias compartilhadas.

“The finest conquest is the conquest of right, and not might.”

(Ashoka “O Grande”, século III A.C.)

RESUMO

O depósito aurífero Tucano (1,8 Moz com teor médio de 1,7 g/t; Great Panther Mining public NI 43-101 report 2022), localizado no sudeste do Escudo das Guianas, é um depósito de ouro orogênico estruturalmente controlado por zona de cisalhamento e equilibrado sob condições metamórficas de fácies anfibolito em nível crustal médio. Mármore e formação ferrífera bandada (BIF) são as principais rochas hospedeiras da mineralização, constituindo o intervalo metassedimentar químico do greenstone belt paleoproterozoico Serra do Navio, de orientação NW-SE. Condições de pico metamórfico são estimadas em temperaturas de 570-640 °C e pressões de 4,1 ± 0.6 kbars. Alteração hidrotermal é caracterizada por paragêneses cálcio-silicáticas substituindo minerais metamórficos e transformando a trama da rocha precursora. A fase inicial de alteração (550-600 °C) é dada pela paragênese quartzo-clinopiroxênio-granada ± biotita, turmalina, ilmenita, manifestada sob a forma de veios, lentes e agregados irregulares. A frequente identificação de veios *boudinados* ou com dobras assimétricas posiciona esse estágio como pré- a cedo-cinemático. O estágio de alteração principal (480-590 °C) é caracterizado pela paragênese anfibólio-flogopita-magnetita-pirrotita ± calcita, com extensiva substituição das paragêneses metamórficas e da alteração hidrotermal inicial. Intensa percolação de fluidos nesse estágio resultou em grandes volumes de rocha alterada, segmentadas em zonas distal de largura variada (desde poucos mm em mármore até cerca de 10 m em BIF) e proximal mais estreitas (comumente < 2 m), com BIF exibindo mineralogia comparativamente menos diversa, tipicamente desprovido de granada e filossilicatos. No alvo TAP C, objeto do estudo, pirrotita é o sulfeto predominante, com traços de calcopirita. Outras fases, como loellingita, arsenopirita e esfalerita, são documentadas exclusivamente em mármore e indicam condições de fluido reduzidas. As texturas exibidas pelos minerais hidrotermais posicionam o estágio principal de alteração como sin- a tardi-tectônico. Ouro visível é encontrado em equilíbrio com sulfetos e loellingita assim como com silicatos e óxidos sem contato direto com sulfetos. Isso sugere que a deposição de ouro se deu não somente por sulfetação das rochas hospedeiras, mas também possivelmente por pequenas flutuações de fO_2 sem imediata desestabilização de sulfeto no fluido. Diques e stocks de muscovita leucogranito com granada são estéreis e não exibem deformação associada à zona de cisalhamento e são interpretados como posteriores ao evento mineralizador. A assinatura geoquímica Au-

Ag-S-Te-Na ± W-Bi-Se-V-Cu-P do fluido mineralizador é compatível com depósitos de ouro orogênico hipozonais descritos na literatura, exceto por Se, V e P. Se exibe altíssima correlação positiva com Te (R = 0.91), havendo sido possivelmente extraído junto com este e S de folhelhos negros piritosos metamorfizados. Adição de V é refletida na abundância de magnetita hidrotermal, cujo significativo volume em zona de alteração proximal é característica singular deste depósito. A alta correlação positiva entre P e W (R = 0.72) também sugere uma fonte comum para ambos os elementos. O depósito de ouro Tucano é, portanto, um sistema mineral do tipo orogênico hipozonal com destacada alteração sódica e desenvolvido sob condições relativamente reduzidas e de baixa atividade de enxofre, como sugerido pela persistência de localmente abundante magnetita hidrotermal em zona proximal.

Palavras-chave: Tucano; ouro orogênico; zona de cisalhamento; fácies anfibolito; pirrotita.

ABSTRACT

The Tucano gold deposit (1.8 Moz at 1.7 g/t; Great Panther Mining public NI 43-101 report 2022) in the southeastern portion of the Guiana Shield, is a shear-zone hosted orogenic gold deposit equilibrated under amphibolite facies conditions at mid crustal levels. Main host rocks are marble and banded iron formation (BIF), belonging to the chemical metasedimentary interval of the NW-SE trending, paleoproterozoic Serra do Navio greenstone belt. Peak metamorphic conditions are estimated at temperatures of 570-640 °C and pressures of 4.1 ± 0.6 kbars. Hydrothermal alteration is characterized by skarn-type calc-silicate assemblages replacing metamorphic minerals and overprinting precursors' fabric. The onset of alteration (550-600 °C) is given by a quartz-clinopyroxene-garnet ± biotite, tourmaline, ilmenite, manifested as veins, lenses and patchy aggregates. The common observation of boudinaged or assymetrically folded veins places the early alteration stage as pre- to early kinematic. The gold-bearing main alteration stage is characterized by the dominant amphibole-phlogopite-magnetite-pyrrhotite ± calcite assemblage, with widespread replacement of peak metamorphic and early hydrothermal assemblages. Enhanced fluid flow at this stage resulted in large volumes of altered rocks assembled into a distal zone of variable width (from few mm in marble up until 10 m in BIF) and a typically narrower proximal zone (usually < 2 m), with BIF alteration assemblage comparatively less varied, usually lacking garnet and phyllosilicates. The ore assemblage at the studied central TAP C orebody is largely dominated by pyrrhotite, with trace chalcopyrite. Additional species, such as loellingite, arsenopyrite and sphalerite are exclusive to the marble host rock and indicate reduced fluid conditions. Ore textures constrain the main stage alteration as syn- to late-tectonic. Visible gold is found in equilibrium with sulfide-arsenide assemblages as well as associated with silicate-oxide minerals with no direct contact with sulfides. This suggests that gold deposition was not only due to sulfidation of the host rocks, but possibly also as a result of small fO_2 fluctuations with no immediate sulfur destabilization in the ore fluid. Garnet-bearing muscovite leucogranite dikes and stocks are unmineralized and did not take up shear strain, thus interpreted as postdating the mineralization event. The Au-Ag-S-Te-Na ± W-Bi-Se-V-Cu-P fluid geochemical signature is largely compatible with hypozonal orogenic gold deposits worldwide, except for Se, V and P. Se has a very strong positive correlation with Te (R = 0.91), having possibly been sourced alongside S and Te from sulfidic metapelitic rocks. V gain is reflected in the abundance of V-bearing hydrothermal magnetite, of which high abundances in proximal alteration zone are a unique feature of this deposit. The strong positive correlation between P and W (R = 0.72) also suggests a common source for both elements. The Tucano gold deposit is thus a hypozonal orogenic gold system featuring sodic alteration and developed under relatively reduced conditions and low sulfur activity, as attested by the persistence of locally abundant hydrothermal magnetite in the proximal zone.

Keywords: Tucano; shear-zone; orogenic gold; amphibolite facies; pyrrhotite.

.

LISTA DE FIGURAS

Figure 1.1. Localização da área de estudo..25
Figure 2.1. Geotectonic map of the Amazon Craton and its tectonic-geochronological domains (after Santos et al., 2000, 2006; Vasquez and Rosa-Costa, 2008), with location of some major gold deposits. 31
Figure 2.2. Geologic map of the central Amapá state (Rosa Costa et al., 2014; Barbosa et al., 2015) and its context within the southeastern sector of the Guiana Shield (upper right inset) outlining the location of the greenstone belt sequences (after McReath and Faraco, 2006; Hoffman and Borghetti, 2018). 34
Figure 2.3. Geologic map of the Tucano area (modified from Scarpelli and Horikava, 2017) with location of the mining sites along the N-S trending Urucum Shear Zone. The black inset outlines the location of the study area, which is shown in more detail in Figure 2.7. 39
Figure 2.4. Main textural and mineralogical features of the principal host rocks to gold mineralization as well as granitic rocks affecting the supracrustal sequence along the Urucum shear zone.. 40
Figure 2.5. Geochemical characterization of BIF, marble and leucogranite from the Tucano region.. 43
Figure 2.6. Examples of structural elements associated with the evolution of the Tucano deposit.. 47
Figure 2.7. Geologic map and schematic cross section at the central part of TAP C open pit outlining the location of the drillholes logged and sampled for this study. The stereonet plots illustrate the overall steep N-S trending S2 and S3 foliation and the prevailing east-west orientation of faults and fractures. Combined surface and drillhole data indicate the metavolcano-sedimentary rocks are tightly folded against the Amapari Granite to the west. 48
Figure 2.8. Stacked cross sections from the TAP C deposit at the Tucano gold mine, showing Au grade shells and interpreted geometry of ore shoots. Sections provided by Great Panther Mining. 49
Figure 2.9. Hydrothermal alteration of marble and BIF in the Tucano gold deposit.. .55
Figure 2.10. Selection of alteration features commonly observed in thin sections at the Tucano gold deposit. 56

Figure 2.11. Hydrothermal alteration zoning in host rock A) Marble, and B) BIF. Note that late retrograde minerals are not included. 57
Figure 2.12. Paragenetic relationships of magnetite, sulfides and gold in the Tucano gold deposit. 59
Figure 2.13. Backscattered electron (BSE) images of key paragenetic relationships involving gold, sulfides, sulfarsenide and Bi phases..60
Figure 2.14. Selection of late-stage, retrograde alteration at the Tucano gold deposit. 61
Figure 2.15. Paragenetic sequence of the hydrothermal mineral assemblages developed at the Tucano gold deposit. The metamorphic minerals are also included. 63
Figure 2.16. EPMA data for selected anhydrous silicate minerals............................66
Figure 2.17. EPMA data for amphibole and biotite-phlogopite from different origins (metamorphic vs hydrothermal) and across distinct host rocks, as well as hydrothermal chlorite compositions.. 67
Figure 2.18. A) Atomic percent As measured in core-margin pairs of arsenopyrite in zoned and unzoned crystals. Single spot is reported for a very fine-grained, unzoned crystal. Figures beside data points indicate the weight percent sum of Co+Ni+Sb. The yellow box outlines the data points used for temperature estimates, i.e., crystals having <1 atomic percent As difference between core and margin and low trace elements. B) Arsenopyrite geothermometry (Sharp et al., 1985, after Kretschmar and Scott, 1976) showing with red lines the crystallization conditions of retrograde arsenopyrite in logaS_2 – temperature space. 69
Figure 2.19. Mineral chemistry of magnetite (data obtained by LA-ICP-MS).............72
Figure 2.20. Geochemistry of hydrothermal alteration in BIF and marble from the Tucano gold deposit.. 75
Figure 2.21. Linear correlation heatmap for a series of elements based on least altered and altered samples of both BIF and marble. Gold elemental correlation charts for BIF and marble are separately shown on the upper right corner. Values are arranged in decreasing order of linear correlation. 77
Figure 2.22. Gold linear correlation plots for both BIF and marble host rocks. 78
Figure 2.23. Pr versus Ce in least altered and variably altered marble. The linear trend with limited sample dispersion indicates that the ratio of these elements does not change with hydrothermal alteration...79

Figure 2.24. Isocon diagrams (Grant, 1986) contrasting average elemental values of least-altered rock types with corresponding average values for proximal alteration zone rocks. Values for Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, CO_2 and S are in wt. %, and in ppm for the remaining elements. Figures beside element symbols denote multiplying concentration factors as a means to have a more even, easily readable, distribution of the elements within the plot space. Isocons are traced through the selected immobile elements – Ce, Pr..........79
Figure 2.25. Mass balance modelling of major and trace elements utilizing the graphical solution for the Gresens (1967) mass transfer equation presented by Grant (1986)..........80
Figure 2.26. A) Stability relationships for selected minerals as a function of log fO_2 and log aH_2S at amphibolite facies conditions (600 °C and 4 Kbars) (Mikucki and Ridley, 1993). The shaded area indicates possible fluid conditions for the Tucano deposit based on observed mineral assemblages. Numbered circles indicate paragenetic succession with ongoing alteration and increasing sulfidation during the main alteration stage. B) Mineral stability relations between K-aluminosilicates, Ca-Mg silicates and carbonates with respect to calcium and potassium ion activities in an aqueous fluid at 600 °C and 4 kbar (Mikucki and Ridley, 1993). Shaded areas indicate possible fluid conditions for early stage and main stage alteration at Tucano based on observed mineral assemblages.. 83
Figure 2.27. Schematic model for the evolution of hydrothermal alteration and gold mineralization at the Tucano gold deposit. 85

LISTA DE TABELAS

Table 2.1. Summary of deformation events and their correlative structures at the Tucano gold deposit. 43
Table 2.2. Mineral reaction formulas (numbers for reactions are referenced throughout the text) 51
Table 2.3 Comparison of selected hypozonal orogenic gold deposits and districts with the Tucano gold deposit 88

LISTA DE ABREVIATURAS E SIGLAS

BIF	Banded iron formation
CN	Chondrite normalized
EDS	Energy dispersive X-ray spectroscopy
EPMA	Electron probe microanalyzer ou Electron microprobe
GBAR	Grain boundary area reduction recrystallization
g/ton	Grams per ton
HREE	Heavy rare earth elements
LA-ICP-MS	Laser ablation inductively coupled plasma mass spectrometry
LREE	Light rare earth elements
Moz	Millions of ounces
PAAS	Post-Archean Australian Shale
REE	Rare earth elements
SEM	Scanning electron microprobe
SN	Shale normalized
WDS	Wavelength-dispersive X-ray spectroscopy
ΣREE	Total rare earth element content

SUMÁRIO

1 CAPÍTULO 1 - INTRODUÇÃO 19
1.1 Apresentação do objeto de estudo e sua problemática 19
1.2 Breve revisão sobre depósitos de ouro do tipo orogênico 20
1.3 Objetivos e justificativa 23
1.4 Localização e vias de acesso 24
1.5 Estruturação da dissertação 25
2 CAPÍTULO 2 – ARTIGO: GEOLOGICAL SETTING AND HYDROTHERMAL ALTERATION AT THE TUCANO GOLD DEPOSIT IN AMAPÁ: EVIDENCE FOR A HYPOZONAL OROGENIC GOLD SYSTEM IN THE GUIANA SHIELD 27
Abstract 27
2.1 Introduction 28
2.2 Regional Geology 29
2.2.1 Geotectonic Setting 29
2.2.2 Paleoproterozoic Serra do Navio greenstone belt 31
2.3 Previous Studies on the Tucano Gold Deposit 33
2.4 Sampling and Methods 35
2.4.1 Drillcore logging, open-pit mapping and sample selection 35
2.4.2 Petrography, SEM and EPMA 35
2.4.3 Whole-rock geochemistry 36
2.4.4 LA-ICP-MS on magnetite and pyrrhotite 36
2.5 Geological Setting of the Tucano Gold Deposit 36
2.5.1 Lithostratigraphy 36
2.5.1.1 Basal metavolcanic unit 37
2.5.1.2 Chemical metasedimentary unit 37
2.5.1.3 Upper siliclastic unit 38
2.5.1.4 Intrusive rocks 38
2.5.2 Metamorphism 38
2.5.3 Whole-rock geochemistry 40
2.5.3.1 BIF chemistry 40
2.5.3.2 Marble chemistry 41
2.5.3.3 Granite chemistry 42
2.5.4 Structural setting 43
2.6 Orebody geometry 48

2.7 Hydrothermal Alteration and Mineralization 49
2.7.1 Early quartz-clinopyroxene-garnet hydrothermal stage (Late D2 to Early D3) 50
2.7.1.1 Marble 50
2.7.1.2 BIF 50
2.7.2 Main amphibole-phlogopite-magnetite-pyrrhotite ± calcite hydrothermal stage (Syn D3) 51
2.7.2.1 Marble – distal alteration zone 52
2.7.2.2 Marble – proximal alteration zone 52
2.7.2.3 BIF – distal alteration zone 54
2.7.2.4 BIF – proximal alteration zone 54
2.7.2.5 Ore sulfide assemblage 58
2.7.3 Late (retrograde) low-temperature stage alteration (Late D3 to D4) 60
2.7.4 Granite-related alteration 62
2.8 Mineral Chemistry 64
2.8.1 Olivine, clinopyroxene and garnet 64
2.8.2 Amphiboles, phlogopite, biotite and chlorite 64
2.8.3 Carbonates, ilmenite and spinel 65
2.8.4 Arsenopyrite, loellingite and gold 67
2.8.5 Geothermometry 68
2.8.5.1 Early calc-silicate hydrothermal alteration 68
2.8.5.2 Main stage hydrothermal alteration 68
2.8.5.3 Late-stage hydrothermal alteration 69
2.8.6 Magnetite 70
2.8.7 Pyrrhotite 71
2.9 Alteration Geochemistry 73
2.9.1 BIF alteration chemistry 73
2.9.2 Marble alteration chemistry 74
2.9.3 Hydrothermal footprint of gold mineralization 76
2.9.4 Mass balance calculations 77
2.10 Discussion 80
2.10.1 Constraints on the P-T conditions, redox state and pH of the gold-bearing fluids 80
2.10.2 Evolutionary model for the Tucano gold deposit 83
2.10.3 Implications for gold exploration 86

2.10.4 Comparison with other hypozonal orogenic gold deposits 86
Conclusions 89
Acknowledgements 90
References 90
ELECTRONIC APPENDIX FIGURE A1 – Analytic signal amplitude (ASA) inversion of total field magnetic anomaly map (CPRM, 2004), showing the location of the ore-hosting Urucum Shear Zone 99
ELECTRONIC APPENDIX FIGURE A2 – Trace element composition of pyrrhotite 100
ELECTRONIC APPENDIX TABLE A1 – Graphic logs 101
ELECTRONIC APPENDIX TABLE A2 - EPMA analytical conditions 119
ELECTRONIC APPENDIX TABLE A3 - Whole-rock geochemistry – Methodology 122
ELECTRONIC APPENDIX TABLE A4 - LA-ICP-MS – Methodology and analytical conditions 127
ELECTRONIC APPENDIX TABLE A5 - Whole-rock geochemistry – Results 129
TABLE A5-1 - Whole-rock geochemical data for least-altered and altered metasedimentary rocks 130
TABLE A5-2 - Whole-rock geochemical data for granite and altered amphibolite samples 138
TABLE A5-3 - Summary statistics of whole-rock geochemical data 140
TABLE A5-4 - Quality control tools for whole-rock analyses 146
ELECTRONIC APPENDIX TABLE A6 - EPMA – Results 148
TABLE A6-1 - Olivine compositional data 149
TABLE A6-2 - Clinopyroxene compositional data 151
TABLE A6-3 - Garnet compositional data 155
TABLE A6-4 - Amphibole compositional data 161
TABLE A6-5 - Biotite and phlogopite compositional data 174
TABLE A6-6 - Chlorite compositional data 181
TABLE A6-7 - Carbonate compositional data 182
TABLE A6-8 - Ilmenite compositional data 185
TABLE A6-9 - Spinel compositional data 186
TABLE A6-10 - Arsenopyrite compositional data 187
TABLE A6-11 - Loellingite compositional data 190
TABLE A6-12 - Gold compositional data 191

ELECTRONIC APPENDIX TABLE A7 - LA-ICP-MS – Magnetite......................192
TABLE A7-1 - Magnetite compositional data 193
TABLE A7-2 - Quality control...203
ELECTRONIC APPENDIX TABLE A8 - LA-ICP-MS – Pyrrhotite......................204
TABLE A8-1 - Pyrrhotite compositional data...205
TABLE A8-2 - Quality control...214
3 CONCLUSÃO..215
REFERÊNCIAS..218
APÊNDICE 1 - Fichas de descrição petrográfica..227

1 CAPÍTULO 1 - INTRODUÇÃO

A presente dissertação é ora apresentada como requisito parcial para obtenção do título de Mestre em Geologia pelo Programa de Pós-graduação em Geologia da Universidade Federal de Minas Gerais. Sob orientação da Profa. Dra. Rosaline Cristina Figueiredo e Silva, e co-orientação da Profa. Dra. Lydia Maria Lobato e do Prof. Dr. Steffen Gerd Hagemann, este trabalho se insere na área de concentração “Geologia Econômica e Aplicada”, e linha de pesquisa “Metalogênese de Bens Minerais Metálicos com Ênfase em Ouro, Ferro e Manganês”. O projeto de pesquisa resulta de termo de cooperação entre a University of Western Australia (UWA) e a Universidade Federal de Minas Gerais (UFMG), ora representada através da Fundação de Desenvolvimento da Pesquisa (FUNDEP). Os fundos para execução do presente estudo foram subsidiados pela AMIRA Global por meio do patrocínio de suas empresas associadas, estando o mesmo cadastrado dentro de um projeto maior intitulado “South American eXploration Initiative (SAXI): Stage 2 Module 7b: Mineral system analyses of deposits and mineralised areas in the Amapa region, Brazil”. Ademais, suporte financeiro adicional foi provido pela Great Panther Mining Limited, então detentora dos direitos de exploração e lavra da área objeto de estudo deste trabalho. Adicionalmente, o presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

1.1 Apresentação do objeto de estudo e sua problemática

O depósito Tucano representa uma das poucas minas de ouro ativas na Província Transamazônica (Santos et al., 2000) do nordeste do Cráton Amazônico. Enquanto os demais depósitos auríferos em greenstone belts conhecidos na região (por exemplo, Rosebel e Merian, no Suriname, Las Cristinas, na Venezuela, e Aurora, Omai e Karouni, na Guiana) estão hospedados principalmente em rochas siliciclásticas equilibradas sob condições metamórficas de fácies xisto verde (Voicu et al., 2001), Tucano se distingue por ocorrer em rochas metassedimentares químicas em terreno que alcançou condições de pico metamórfico mais elevadas (Melo, 2001; Horikava, 2008). Disto resultam paragêneses hidrotermais de ganga e minério notavelmente distintas daquelas observadas nos depósitos supracitados e indicativas de condições de formação em mais alta temperatura. Nestes termos, atestam-se semelhanças com depósitos de ouro orogênico da classe hipozonal (Groves et al., 1998; Hagemann and Cassidy, 2000; Ridley et al., 2000; Goldfarb et al., 2005; Goldfarb e Groves, 2015; Kolb et al., 2015).

A Província Transamazônica no Escudo das Guianas tem seu potencial metalogenético para ouro atestado pela intensa e prolongada atividade mineira artesanal de pequena escala, focada sobretudo em depósitos aluviais (Gibbs e Barron, 1993). Trabalhos exploratórios são dificultados pela densa cobertura vegetal, espessas coberturas Cenozoicas e infraestrutura precária, resultando em um número limitado de depósitos hipogênicos sendo descobertos ou desenvolvidos. Não obstante, descobertas recentes, além da herança tectônica compartilhada dessa província com o Orógeno Eburneano no Cráton do Oeste Africano (Onstott e Hargraves, 1981) reforçam o potencial dos greenstone belts Transamazônicos para hospedar depósitos de ouro de classe mundial. Isto porque o Cráton do Oeste Africano é reconhecido como a principal província aurífera de idade Paleoproterozoica no mundo (Goldfarb et al., 2017).

Com base no discorrido, o presente estudo consiste na primeira documentação detalhada de um depósito mineral até então pouco conhecido sob o ponto de vista científico. Ademais, concebe-se como uma contribuição ao estudo de uma classe restrita de depósitos de ouro orogênico cujo nível de maturidade de compreensão científica ainda é baixo no que concerne aos seus aspectos genéticos e enquadramento geotectônico. Por fim, um trabalho descritivo de depósito em província mineral carente de estudos de detalhe detém valor potencial como provedor de embasamento técnico-científico para futuros projetos de exploração.

1.2 Breve revisão sobre depósitos de ouro do tipo orogênico

Depósitos hidrotermais auríferos em cinturões metamórficos compartilham várias feições e características em comum, sendo por conseguinte coletivamente classificados sob a terminologia de depósitos de ouro orogênico (Groves et al., 1998). Tais características que permitem sua classificação como um grupo coeso se referem ao ambiente tectônico de formação, à geologia dos terrenos hospedeiros, controles estruturais, alteração hidrotermal, natureza de fluidos e timing da mineralização (Groves et al., 1998; Goldfarb et al., 2001,2005; Goldfarb and Groves, 2015; Groves et al., 2020). Amplamente distribuídos ao longo do tempo geológico, sua formação é registrada desde o Paleoarqueano ao presente (Groves et al., 2005), janela temporal esta compreendendo modificações capitais na dinâmica terrestre (Cawood and Hawkesworth, 2014).

Depósitos de ouro orogênico são conceituados como jazimentos hidrotermais formados durante circulação focalizada de fluidos em um ambiente orogênico durante metamorfismo, magmatismo e deformação (Hagemann and Cassidy, 2000; Groves et al., 2003). Postula-se que a maioria destes depósitos tenham sido gerados em temperaturas de 250 a 400 °C e pressões de 1 a 3 kbar em terrenos equilibrados sob condições de fácies xisto verde a anfibolito baixo. Contudo, exemplares formados em temperaturas mais baixas e mais altas que o supracitado intervalo também são documentados (Groves et al., 1992; Ridley et al., 2000; Goldfarb et al., 2005). Fluidos hidrotermais nesses sistemas são via de regra de baixa salinidade e com assinatura H_2O-CO_2-CH_4-N_2-H_2S (Kerrich and Fyfe, 1981). O modelo genético mais amplamente aceito para a origem de depósitos de ouro orogênico – o modelo metamórfico crustal – advoga que Au, S e outros componentes são liberados e incorporados em fluidos metamórficos via reações de devolatilização. Tais reações se processam à medida que condições metamórficas progressivas gradam de fácies xisto verde para anfibolito (Kerrich and Fyfe, 1981; Phillips and Groves, 1983; Powell et al., 1991). Componentes como Au, Ag, As, Bi, Sb e Te seriam mais suscetíveis ao fracionamento para uma fase fluida durante reações de dessulfetação de pirita e sua conversão em pirrotita (Finch and Tomkins, 2017). Muitos autores concordam que o maior volume de fluidos metamórficos é liberado pela quebra da clorita (Phillips and Powell, 2010; Tomkins, 2010). Ademais, Finch and Tomkins (2017) argumentam que a desintegração de pirita e clorita ocorre na mesma faixa de temperatura, de modo que as respectivas reações em conjunto permitiriam a complexação de Au e outros metais com o enxofre liberado (Phillips and Powell, 2010; Tomkins, 2010).

Episódios de mineralização estariam correlacionados com mudanças no campo de tensões devidas a reorganizações de placas durante estágios orogênicos tardios, levando a movimentações laterais ao longo de antigas estruturas compressionais, soerguimento regional de crosta espessada, e migração de fluidos sismicamente induzida (Goldfarb et al., 2001). Fluidos canalizados ao longo de sistemas de falhas regionais ascenderiam a partir de fontes profundas e precipitariam ouro ao longo de zonas de deformação de menor escala. Essa deposição estaria espacialmente associada com barreiras de permeabilidade e rochas de reologia contrastante nas imediações da transição rúptil-dúctil (Groves et al., 1987; Phillips et al., 1996).

Considerando que o maior volume de fluidos metamórficos é gerado na transição entre fácies xisto verde e anfibolito, e que a direção de migração de fluidos é predominantemente ascendente, torna-se mais desafiador justificar a ocorrência de mineralizações do tipo ouro orogênico em níveis crustais de maior grau metamórfico (Phillips and Powell, 2009, 2010; Tomkins and Grundy, 200 9). Isso se deve ao entendimento de que a produção de fluidos aquosos é deveras limitada além do limite de estabilidade da clorita acima de 550-600 °C. Ademais, esses fluidos seriam deficientes em Au e S visto que a pirita já teria sido amplamente convertida em pirrotita (Tomkins, 2010). O início de fusão parcial em cerca de 650 °C estabelece uma temperatura superior limite para mineralizações hidrotermais, visto que esse processo resulta em uma crosta saturada em água e inibe circulação de fluidos em larga escala. Acrescenta-se a isso ainda o fato de que quaisquer fluidos hidrotermais gerados nessas condições provavelmente seriam incorporados a um melt (Tomkins and Grundy, 2009; Tomkins, 2010). Portanto, aparentemente o modelo de devolatilização metamórfica justifica de forma convincente apenas os depósitos auríferos mesozonais a epizonais (Goldfarb et al., 2001). É necessário fazer uma ressalva, todavia, que um número significativo de depósitos de ouro orogênico hospedados em terrenos de fácies anfibolito a granulito são, na verdade, sistemas mesozonais metamorfizados (Kolb et al., 2015; Phillips and Powell, 2009,2010; Tomkins and Grundy, 2009).

Terrenos contendo depósitos de ouro orogênico hipozonais mostram uma evolução tectônica caracterizada por regimes que produzem inversão de gradientes metamórficos por sistemas imbricados de falhas de empurrão, ou que geram abruptos gradientes por sistemas de extensão e formação de complexos de núcleo metamórfico (Kolb et al., 2015). Esses mecanismos resultam na justaposição de unidades com diferentes heranças metamórficas e estados termais, permitindo assim devolatilização metamórfica progressiva em unidades de mais baixo grau e, por conseguinte, a formação de fluidos auríferos em temperaturas consideravelmente mais baixas do que em condições hipozonais (Kolb et al., 2000; Otto et al., 2007). Esse cenário representa um sistema muito mais dinâmico à medida que a fonte de fluidos pode estar localizada em outro terreno ou unidade tectônica, com focalização de fluidos através de corredores regionais criados pelas mesmas estruturas que justapuseram esses diferentes terrenos (Chen et al., 2001; Kolb et al., 2015). Esse modelo, discutido em detalhes em Kolb et al. (2015), encontra embasamento na observação de que a assinatura isotópica de fluido de vários depósitos hipozonais indica fonte externa ou mesmo o envolvimento de fluidos de derivação magmática. Pegmatitos e granitos são elencados como possíveis fontes de fluidos magmático-hidrotermais, os quais são liberados em fases avançadas de cristalização desses líquidos anatéticos, podendo potencialmente misturar-se com fluidos de proveniência metamórfica (Mueller et al., 2004; Krienitz et al., 2008; Bark and Weihed, 2012; Rogers et al., 2013).

Em contraste com sistemas mesozonais associados a orógenos acrescionários, mineralização de ouro hipozonal é formada mais tardiamente na evolução de orógenos acrescionários e colisionais (Kolb et al., 2015). Ademais, esses depósitos tipicamente se posicionam em segmentos centrais ou de antepaís, quando a subducção cessa ou migra, resultando em modificações no campo de tensões e deflagração de deformação transcorrente, soerguimento e metamorfismo retrógrado (Kerrich and Cassidy, 1994; Kolb et al., 2015).

1.3 Objetivos e justificativa

Esse estudo documenta uma investigação geológica detalhada de um depósito de ouro orogênico relativamente pouco conhecido no norte do Brasil. Nele serão apresentados novos dados geológicos, mineralógicos e gequímicos visando:

1) Caracterizar o contexto geológico da área mineralizada em termos de seu empilhamento litoestratigráfico (incluindo corpos intrusivos) e evolução metamórfica e estrutural;
2) Descrever a alteração hidrotermal e a mineralização em ouro quanto à sequência paragenética, zoneamento, texturas, controles estruturais e condições físico-químicas;
3) Caracterizar o magmatismo granítico que afeta a sequência metavulcanossedimentar na área da jazida, sua idade relativa especialmente no que tange ao evento hidrotermal e mineralizador, e sua eventual contribuição, se existir, na alteração hidrotermal registrada no depósito;
4) Estabelecer a sequência paragenética de eventos fornecendo idades relativas entre episódios metamórficos, magmáticos e hidrotermais.

Em última instância, o presente trabalho objetiva ser uma importante contribuição ao conhecimento geológico, em especial metalogenético, do estado do Amapá e, por extensão, do segmento sudeste do Escudo das Guianas. Dada a carência de pesquisa científica nessa região do país, espera-se que este trabalho possa servir como estímulo ao desenvolvimento de novos trabalhos acadêmicos nessa parte do território nacional. Vislumbra-se também que a contextualização deste depósito na evolução estrutural, metamórfica e magmática da província possa auxiliar o entendimento de mineralizações auríferas do tipo orogênico em escala regional na província Transamazônica e maximizar o potencial de novas descobertas.

1.4 Localização e vias de acesso

A área de estudo está situada no estado do Amapá, região Norte do Brasil, mais precisamente dentro dos limites do município de Pedra Branca do Amapari. Localizado na porção central do estado, o referido município dista cerca de 180 Km da capital do Amapá. O acesso se dá por rodovia pavimentada (BR-156) de Macapá à cidade de Porto Grande, de onde segue-se por estrada não pavimentada (BR-210) até o destino. A mina de ouro Tucano está localizada a nordeste do perímetro urbano de Pedra Branca do Amapari, com acesso por meio de estradas vicinais relativamente bem conservadas em um deslocamento total de cerca de 20 km (Fig. 1.1).

Figure 1.1. Localização da área de estudo.

1.5 Estruturação da dissertação

O presente trabalho está estruturado em torno de um artigo intitulado "Geological Setting and Hydrothermal Alteration at the Tucano Gold Deposit in Amapá: Evidence for a Hypozonal Orogenic Gold System in The Guiana Shield", submetido à publicação na revista Economic Geology, como requisito para a obtenção do título pretendido no Programa de Pós-Graduação em Geologia da UFMG. A maioria dos apêndices ora apresentados estão inseridos como material suplementar do artigo e, portanto, enumerados conforme citados ao longo do texto. Apenas as fichas de descrição petrográfica estão relacionadas como apêndice extra dissociado do artigo. Nestas, a nomenclatura das rochas seguirá a sistemática de elencar os minerais segundo ordem crescente de sua proporção modal, quando precedem o termo textural. As citações elencadas ao longo dessa seção estão incluídas nas referências bibliográficas apresentadas no artigo.

2 CAPÍTULO 2 – ARTIGO: GEOLOGICAL SETTING AND HYDROTHERMAL ALTERATION AT THE TUCANO GOLD DEPOSIT IN AMAPÁ: EVIDENCE FOR A HYPOZONAL OROGENIC GOLD SYSTEM IN THE GUIANA SHIELD

Gabriel A. R. Soares,[1,┼] Rosaline C. Figueiredo e Silva,[1] Steffen G. Hagemann,[2] Lydia M. Lobato,[1,3] Rogério A. Lucena,[4] and Cristiano C. Lana[5]

[1]*Graduate Program in Geology, Institute of Geosciences, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais 31270-901, Brazil*

[2]*Centre for Exploration Targeting, University of Western Australia, Perth, Western Australia 6009, Australia*

[3]*Hydro Fluids & Minerals, Rio de Janeiro, Rio de Janeiro 22793-105, Brazil*

[4]*Great Panther Mining Limited, Pedra Branca do Amapari, Amapá 68945-000, Brazil*

[5]*Department of Geology (School of Mines), Federal University of Ouro Preto, Ouro Preto, Minas Gerais 35400-000, Brazil*

Abstract

The Tucano orogenic gold deposit in the southeastern portion of the Guiana Shield is a structurally controlled deposit hosted in amphibolite facies metasedimentary rocks of the Paleoproterozoic Serra do Navio greenstone belt, mainly in marble and banded iron formation (BIF). Mineralization is controlled by the N-S trending brittle-ductile Urucum shear zone and associated subsidiary structures. Hydrothermal alteration is characterized by hypozonal skarn-type calc-silicate assemblages replacing peak metamorphic minerals. Early alteration stage (550-600 °C) is characterized by a quartz-clinopyroxene-garnet ± biotite, tourmaline, ilmenite assemblage, in veins as well as wallrock, and developed under moderately oxidized conditions. The gold-bearing main alteration stage (480-590 °C) has a dominant amphibole-phlogopite-magnetite-pyrrhotite ± calcite assemblage, with widespread replacement of metamorphic and early hydrothermal assemblages. Mineral

assemblages developed in altered BIF are comparatively less varied, usually lacking garnet and phyllosilicates. Sulfide precipitation is more intense towards proximal alteration zones and is dominated by pyrrhotite, with trace chalcopyrite. Additional species, such as loellingite, arsenopyrite and sphalerite are exclusive to the marble host rock and indicate reduced fluid conditions. Ore textures constrain the mineralization as syn- to late-tectonic. Visible gold is found in equilibrium with sulfide-arsenide assemblages as well as associated with silicate-oxide minerals with no direct contact with sulfides. This suggests that gold deposition was not only due to sulfidation of the host rocks, but possibly also as a result of small fO_2 fluctuations. The association Au-Ag-S-Te-Na ± W, Bi, Se, V, Cu, P defines the auriferous hydrothermal fluid geochemical signature. Leucogranite dikes and stocks did not take up shear strain and are hence interpreted as postdating the mineralization event. Tucano is the first documented hypozonal orogenic gold deposit in the Guiana Shield and is further distinguished from other high-temperature deposits by the high contents of hydrothermal magnetite in the proximal zone.

2.1 Introduction

The Tucano gold deposit is located in central Amapá state, northern Brazil, approximately 450 km northwest of the major city of Belém (Fig. 2.1). The deposit represents one of the few active gold mines in the Rhyacian (2.3-2.05 Ga) Transamazonian Province (Santos et al., 2000) of the northeastern Amazon Craton. Tucano consists of a series of deposits (TAP AB, TAP C and Urucum) aligned along a N-S trending belt, which collectively contain 1.8 Moz (millions of ounces) gold of combined measured, indicated and inferred resources at an average grade of 1.7 g/t (grams per ton) (Great Panther Mining, 2022). The Tucano gold deposit is hosted in amphibolite facies chemical metasedimentary rocks – marble and banded iron formation (BIF) – and structurally controlled by the ductile-brittle Urucum shear zone (Melo, 2001; Horikava, 2008). Alteration style and mineral assemblages are characteristic of orogenic gold deposits of hypozonal crustal level (Groves et al., 1998; Hagemann and Cassidy, 2000; Ridley et al., 2000; Goldfarb et al., 2005; Goldfarb and Groves, 2015; Kolb et al., 2015).

The Transamazonian Province in the Guiana Shield is known to host numerous small-scale, artisanal gold workings, exploiting primarily alluvial placer deposits for over 200 years (Gibbs and Barron, 1993). Exploration in the region is hampered by dense equatorial forests, thick Cenozoic sedimentary cover and lack of infrastructure, resulting in relatively few hard rock mines being discovered or developed. Nonetheless, a number of deposits have been discovered, such as Rosebel (7 Moz,) and Merian (3.1 Moz) in Suriname, Las Cristinas (32 Moz) in Venezuela, and Aurora (6.5 Moz), Omai (3.7 Moz) and Karouni (1 Moz) in Guyana. This indicates a significant potential for world-class gold mineralization across the region. In addition, the tectonic link between the Transamazonian Province and the Eburnean orogen in the highly endowed West African Craton (Onstott and Hargraves, 1981; Goldfarb et al., 2017) further points to the potential of the Transamazonian greenstone belts for major gold discoveries.

In this study, we document a detailed geological investigation of the poorly known high-temperature Tucano orogenic gold deposit, specifically the TAP C target, reporting new geological, mineralogical, and geochemical data in order to: (1) characterize the lithostratigraphic setting including magmatic stocks and dikes, (2) establish metamorphic conditions and relative timing of structures; (3) describe the hydrothermal alteration and gold mineralization, including assessment of structural controls, P-T conditions and paragenetic sequence, (4) assess the relative timing of magmatism with respect to hydrothermal alteration and its role on gold mineralization, if any, and finally, (5) constrain the geological sequence of events providing relative timing of key metamorphic, magmatic and hydrothermal episodes. Lastly, we expect our results to help open new venues for gold exploration in amphibolite facies terranes in the Guiana Shield and elsewhere.

2.2 Regional Geology

2.2.1 Geotectonic Setting

The Tucano gold deposit is located in the northeastern segment of the Amazon Craton, within the Guiana Shield (Fig. 2.1). The Amazon Craton comprises an Archean nucleus bounded by NW-SE trending Proterozoic domains (Almeida et al., 1981; Cordani and Brito Neves, 1982; Hasui et al., 1984; Tassinari and Macambira, 1999, 2004; Santos et al., 2000, 2006; Vasquez and Rosa-Costa, 2008). Its easternmost sector, referred to as Maroni-Itacaiúnas (Cordani et al., 1979; Tassinari and Macambira, 1999) or Transamazonian (Santos et al., 2000) Province, consists of an exceptionally large Paleoproterozoic belt stretching from northern Brazil to eastern Venezuela, and is interpreted to be an analogue to the Eburnean Orogen in the West Africa Craton (Onstott and Hargraves, 1981). It comprises granulitic-migmatitic-gneissic complexes, greenstone belts and granitoid plutons, defining several episodes of juvenile crustal accretion followed by crustal reworking (Rosa-Costa et al., 2006).

Geochronological data indicate that the evolution of this segment of the Amazon Craton is intimately bound to the Transamazonian orogenic cycle (2.26-1.95 Ga) (Avelar, 2002; Avelar et al., 2003; Delor et al., 2003a, b; Rosa-Costa et al., 2006, 2014). According to these authors, with additional contributions from McReath and Faraco (2006), the Transamazonian geodynamic evolution encompasses the following stages: (i) early orogenic phase starting at about 2.26 Ga, marked by tholeiitic magmatism at an oceanic stage, (ii) development of greenstone belt sequences and widespread tonalite-trondhjemite-granodiorite (TTG) magmatism in an island-arc environment, ranging from 2.19 to 2.13 Ga, (iii) granitic magmatism and migmatization of earlier TTG-greenstone sequences upon basin closure between 2.10 and 2.08 Ga, and (iv) late-orogenic phase (2.07-2.03 Ga) dominated by oblique plate convergence, granitic magmatism and renewed regional metamorphism, locally peaking granulite-facies conditions (Avelar, 2002; Avelar et al., 2003; Delor et al., 2003a,b; McReath and Faraco, 2006; Rosa-Costa et al., 2006, 2014).

The Transamazonian Province in the Brazilian territory can be subdivided in the Archean Amapá Block (Rosa-Costa et al., 2006) and the Paleoproterozoic Lourenço, Carecuru, Bacajá and Santana do Araguaia domains, the latter two representing a southward extension past the Amazon Basin and into the Brazilian Central Shield (Rosa-Costa et al., 2014). Although the Amapá Block represents an Archean continental landmass reworked during the Paleoproterozoic Transamazonian orogenic cycle, the others correspond to dominantly juvenile Rhyacian terranes with minor reworked remnants of Archean and Siderian continental crust (Rosa-Costa et al., 2014).

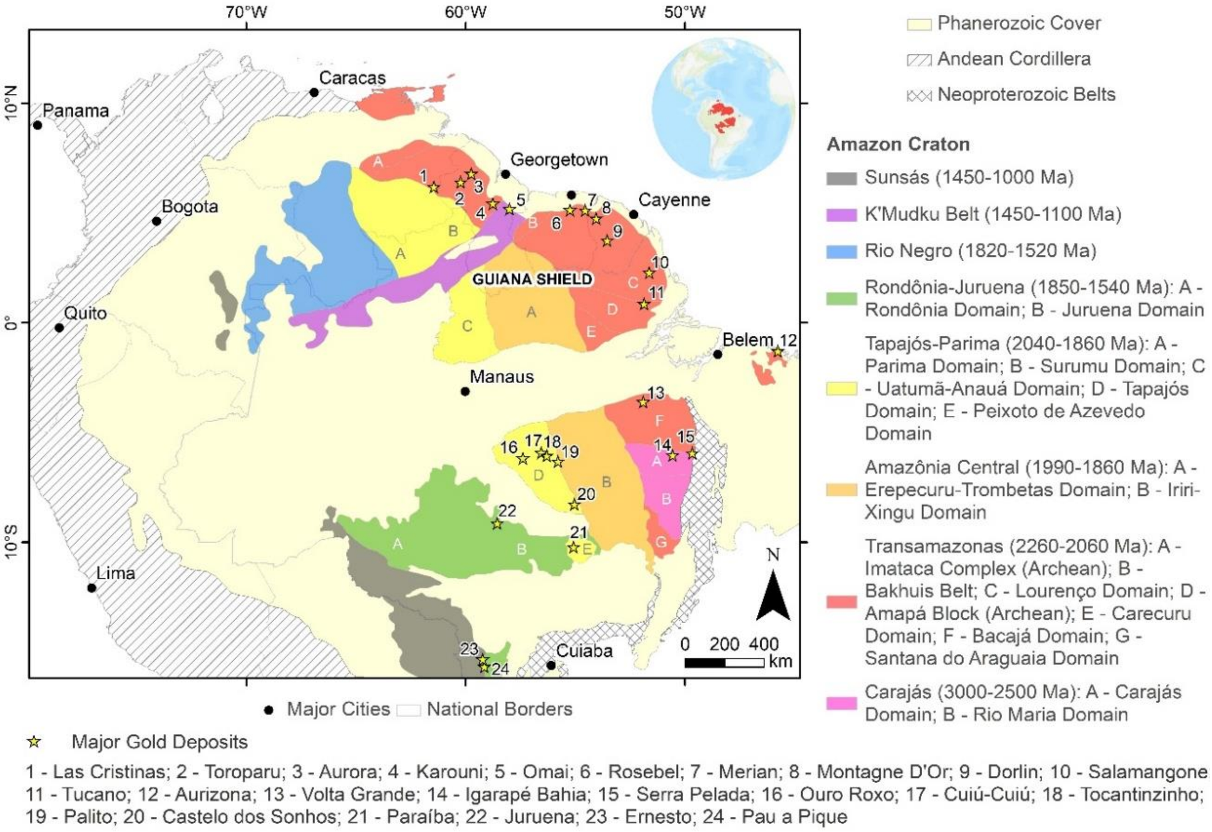


Figure 2.1. Geotectonic map of the Amazon Craton and its tectonic-geochronological domains (after Santos et al., 2000, 2006; Vasquez and Rosa-Costa, 2008), with location of some major gold deposits.

2.2.2 Paleoproterozoic Serra do Navio greenstone belt

Paleoproterozoic metavolcano-sedimentary sequences, trending NW-SE, have been identified in the southeastern portion of the Guiana Shield within Brazilian territory, collectively referred to as Vila Nova Group by Lima et al. (1974). These were individually classified into seven greenstone belts (McReath and Faraco, 2006; Hoffman et al., 2018) (Fig. 2.2). The Tucano deposit is located in the Serra do Navio greenstone belt. This supracrustal sequence lies unconformably on the Archean rocks of the Tumucumaque and Guianense Complexes, and Anauerapucu, Mungubas and Riozinho Granites (Barbosa et al., 2015; Borghetti and Philipp, 2017).

Barbosa et al. (2015) divide the Vila Nova Group in the Serra do Navio greenstone belt into the following units: Jornal, Igarapé Araújo, Serra do Navio, Serra das Coambas and Santa Maria do Vila Nova Formations, as well as an undivided Vila Nova Group. The latter broadly corresponds to the Serra da Canga Formation, reported by Scarpelli and Horikava (2017) as comprising a basal package of ortho-amphibolites and calc-silicate rocks overlain by a chemical-exhalative interval ranging upwards from manganese-bearing rocks (gondites and manganiferous schists) through metacarbonates (marbles and carbonate schists with subordinated calc-silicate intervals) to oxide- and silicate-type iron formations. The upper stratigraphic section is dominated by clastic rocks, encompassing mainly quartz-mica and garnet-quartz-biotite-muscovite schists, as well as quartzites (Scarpelli and Horikava, 2017).

According to Ricci et al. (2001), metamorphic assemblages in the Tumucumaque, Serra do Navio and Vila Nova greenstone belt units reveal peak conditions ranging from greenschist to upper amphibolite facies conditions. The metasedimentary rocks are intruded by various Transamazonian orogenic granites, the Amapari Granite being the main plutonic manifestation in the central sector of the Serra do Navio greenstone belt. Compositionally, they range from alkali-feldspar granites to monzogranites and rare granodiorites (Horikava, 2008; Barbosa et al., 2015; Borghetti and Philipp, 2017).

The regional structural evolution is described as starting with a compressional stage (D1) recorded by shallowly dipping foliation, thrusting and folding, with vergence from SW to NE (Rosa-Costa et al., 2014). The second deformation event (D2) is recorded by large-scale NW-SE striking, steeply dipping and dominantly sinistral shear zones that define the regional structural architecture of the province, juxtaposing distinct terranes and tectonic units, and controlling the geometry of supracrustal and crystalline entities as belts, lenses or elongated bodies (Rosa Costa et al., 2014). Steep brittle structures striking from N20E to N20W are the products of the last deformational event and may accommodate diabase dikes and quartz veins (Rosa-Costa et al., 2014). At the deposit location, the D2 NW-SE structures are bent toward a N-S to NNW-SSE direction, dipping at high angle to either east or west, and seemingly having controlled the emplacement of the Amapari Granite (Horikava, 2008). This pluton is the western boundary to the Serra do Navio greenstone belt at the mine district, and the supracrustal sequence is interpreted as the western limb of a N-S trending antiform (Great Panther, 2022). The Urucum Shear Zone N-S orientation is a deviation of the regionally prevailing NW-SE trending of the greenstone belts and basement terranes of the Transamazonian Province (see electronic Appendix Figure A1 for aerogeophysical map). This structure (Fig. 2.2) is a major ore-hosting structure at the Tucano gold deposit (Melo, 2001; Horikava, 2008).

2.3 Previous Studies of the Tucano Gold Deposit

The exploration history in the Tucano mining district is documented in the works of Horikava (2008) and Scarpelli and Horikava (2017) and briefly summarized here. First publicized evidence of gold hosted in iron formations in the region dates back to the late 1970s and reported by Unigeo and Minorco, subsidiaries of Anglo American Brazil, after follow-up of geochemical soil anomalies. The so-called Amapari Project has been a target of intermittent exploration work ever since, taking place in parallel to artisanal gold mining by garimpeiros. Following discovery of a mineralized shear zone in 1994, Anglo American and then Anglo Gold Ashanti undertook extensive exploration until 2002. Mine construction began in 2004, after the project was acquired by Wheaton River Minerals, with first gold poured late 2005. In 2010, Beadell Resources took ownership and commenced construction of a carbon in leach plant, which was commissioned in late 2012. From then up until 2018, more than 850 Koz gold were produced under Beadell. Following plant upgrade between 2018 and 2019, the project was acquired by Great Panther Mining in March 2019, which intensified exploration work, especially in near mine targets. Total production since mine commencement sums over 1.4 Moz gold (NI-43-101 Technical Report, Great Panther, 2022).

The first published comprehensive study on the gold mineralization at Tucano was carried out by Melo (2001), which defined a regional metamorphic event peaking amphibolite-facies conditions superimposed locally by thermal metamorphism related to granite intrusions. The main gold-bearing sulfide was described as disseminated, locally massive pyrrhotite. Melo (2001) determined the ore fluids to be CO_2-rich aqueous-carbonic fluids of low to moderate salinity. Faraco et al. (2005) advocate a magmatic source of ore fluids, although based solely on the spatial association of sulfides with skarn-type calc-silicate minerals. Even though his work is more geared towards exploration geochemistry, Horikava (2008) provides some petrographic data on alteration minerals, zoning and paragenetic sequence. Cavalcante (2009) argues that the N-S gold bearing Urucum shear zone developed after the emplacement of granitic intrusions, thus gold deposition would postdate plutonism.

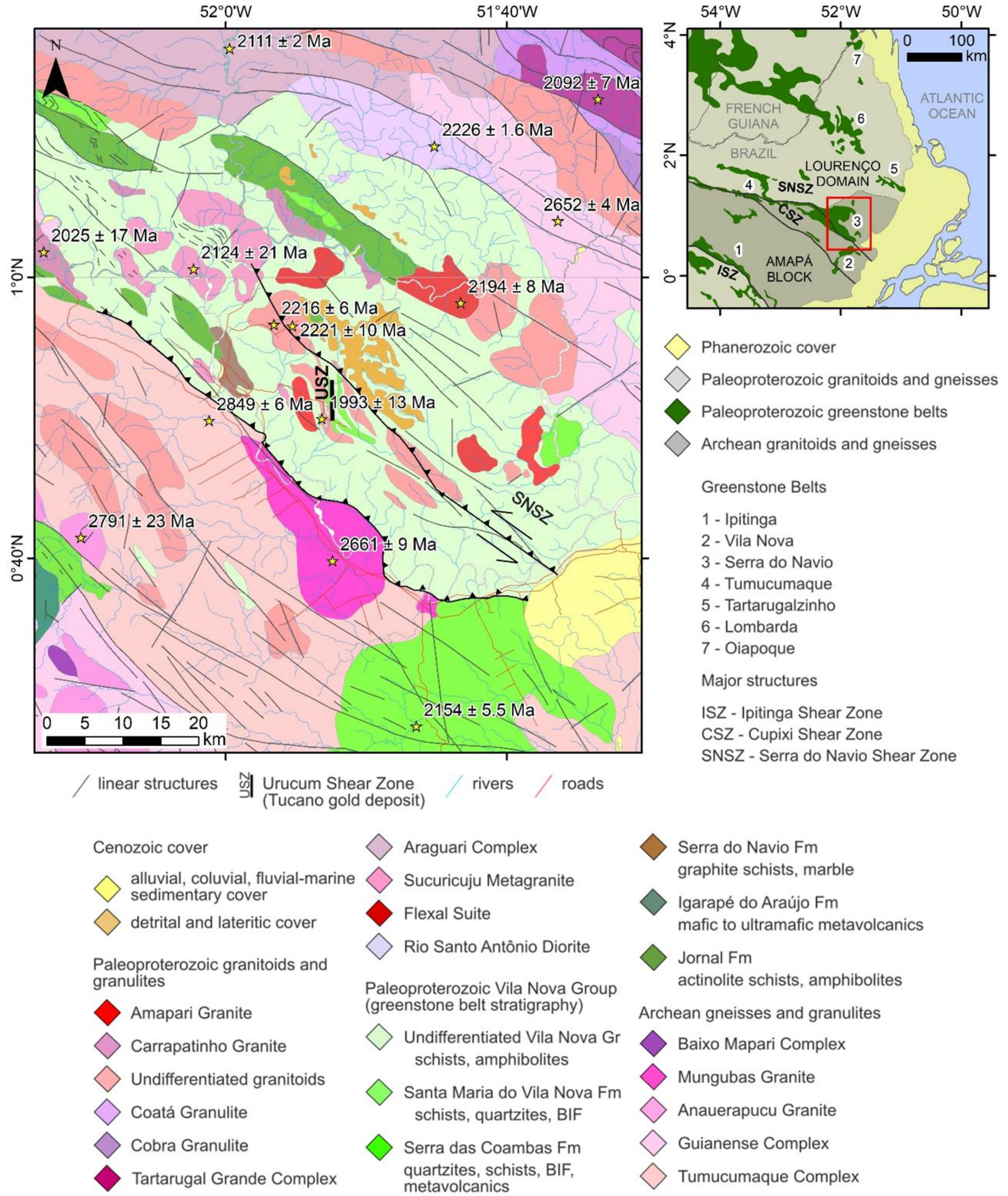


Figure 2.2. Geologic map of the central Amapá state (Rosa Costa et al., 2014; Barbosa et al., 2015) and its context within the southeastern sector of the Guiana Shield (upper right inset) outlining the location of the greenstone belt sequences (after McReath and Faraco, 2006; Hoffman and Borghetti, 2018).

2.4 Sampling and Methods

2.4.1 Drillcore logging, open-pit mapping and sample selection

Eight diamond cores (1663 m) were logged using the graphic logging technique. The location of the diamond holes is shown in Fig. 2.7. Graphic logs are presented in electronic Appendix Table A1. Systematic sampling of least altered, altered and ore rocks was carried out from selected drillholes, transecting the TAP C orebody, with the addition of selected surface samples and diamond cores from other targets, the latter aiming at sampling rock types not found at TAP C. A complete profile from least altered to distal and proximal (ore zone) alteration zones for both major host rocks – marble and BIF – was collected.

2.4.2 Petrography, SEM and EPMA

Polished thin sections were made for 101 samples and examined using conventional transmitted and reflected light microscopy for mineral assemblage and textural relationship characterization at the Metallogeny Laboratory, Manoel Teixeira da Costa Research Center, Federal University of Minas Gerais (CPMTC-UFMG). Microscale investigation was further supported by backscattered electron imaging (BSE) and energy-dispersive X-ray spectroscopy (EDS) semi-quantitative analyses using a FEG – Quanta 200 FEI scanning electron microscope (SEM) at the Microscopy Center of the Federal University of Minas Gerais (UFMG).

Electron microprobe (EPMA) analyses were done at the Microscopy Center of UFMG using a JEOL JXA-8900 automated wavelength-dispersive X-ray spectroscopy (WDS) scanning electron microprobe. Analyses were conducted on a selection of metamorphic, igneous, and hydrothermal silicates, oxides, carbonates and sulfides/arsenide. Analyses on olivine, clinopyroxene, amphiboles, garnet, biotite, phlogopite, chlorite, spinel, ilmenite, pyrrhotite, arsenopyrite, loellingite and native gold were acquired. See electronic Appendix Table A2 for details of methodology and analytical conditions.

2.4.3 Whole-rock geochemistry

Whole-rock geochemical analyses were conducted on 42 samples of least-altered and hydrothermally altered rocks, as well as vein samples, representing major alteration zones around gold mineralization in each major host rock (BIF and marble). In addition, the sample set also includes samples from granite and amphibolite. Due to severe weathering conditions, all samples were collected from diamond drill core. Analyses were carried out at the ALS Geochemistry Laboratory at Lima, Peru. See electronic Appendix Table A3 for details of analysis type, detection limits, and analytical precision and accuracy.

2.4.4 LA-ICP-MS on magnetite and pyrrhotite

In situ laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses of magnetite and pyrrhotite were conducted at the Isotope Geochemistry Laboratory of the Geology Department of Federal University of Ouro Preto using a Thermofinigan Element II ICP-MS coupled with a CETAC-213 nm Laser Ablation system. See electronic Appendix Table A4 for details of the methodology and analytical conditions.

2.5 Geological Setting of the Tucano Gold Deposit

2.5.1 Lithostratigraphy

The Tucano district comprises a 7 km long, N-S trending belt of multiply deformed metavolcano-sedimentary rocks - the Paleoproterozoic Serra do Navio greenstone belt. The stratigraphic sequence in the mine area was first documented by Scarpelli and Horikava (2017) and encompasses a basal package of mafic metavolcanic rocks overlain by a chemical sequence with BIF at the base and marbles at the top. Siliciclastic rocks are located on top of the marble and are represented by pelitic schists and minor quartzites. The supracrustal sequence is bounded to the west by the N-S trending Amapari Granite, and within the mine is intruded by several leucogranite dikes preferentially sub-parallel to the ore-hosting N-S trending Urucum shear zone (Fig. 2.3). Only the latter is discussed in this work. For detailed information on the Amapari Granite, please see Faraco et al. (2005). Diabase dikes, striking N-S to NW-SE, crosscut all the above units.

2.5.1.1 Basal metavolcanic unit

These rocks are represented by banded, medium-grained hornblende schists, characterized by alternating hornblende-, clinozoisite-, and chlorite-muscovite-rich bands, with minor amounts of interspersed plagioclase and trace quartz, as well as accessory ilmenite and titanite. Locally, subparallel, discontinuous biotite seams are observed.

2.5.1.2 Chemical metasedimentary unit

The base of the chemical metasedimentary interval consists of a fine- to medium-grained, magnetite-quartz-dominated banded rock (BIF), with millimeter- to centimeter-thick regular mesobands that can locally display internal microbands (Fig. 2.4a). Disseminated, fine-grained, light green metamorphic amphibole (grunerite + ferroactinolite) are observed throughout the BIF package (Fig. 2.4c). The BIF is overlain by a granoblastic, mostly isotropic, fine- to medium-grained marble (Fig. 2.4b), made up of calcite, dolomite and forsterite, with locally minor phlogopite and tremolite, rare garnet, and accessory fine-grained ilmenite and magnetite (Fig. 2.4d). Overall, calcite largely prevails over dolomite in the carbonate groundmass, which is characterized by either sutured or, more commonly, rectilinear grain margins within a polygonised fabric. With very few exceptions, the carbonate matrix features abundant subhedral, subequant to short prismatic crystals of forsterite. In contrast, thin lamellar phlogopite is less common and always occurs in minute proportions, as does tremolite, which forms euhedral to subhedral, prismatic crystals sharing grain boundaries with olivine. Garnet is even more locally distributed and compositionally made up of almandine (40 wt. %), spessartine (25 wt. %), pyrope (20 wt. %) and grossular (15 wt. %). Fine-grained, prismatic ilmenite is usually disseminated, whereas magnetite typically forms anhedral encroachments on forsterite.

2.5.1.3 Upper siliclastic unit

The upper stratigraphic section of the greenstone belt in the mine area encompasses semipelite and psammite siliciclastic rocks. The former is typified by medium-grained, plagioclase-muscovite-biotite-quartz schists, which commonly host garnet porphyroblasts. As opposed to garnet in marble, this is more almandine-rich (60 wt. %), yet having a similar spessartine component (28 wt. %). Pyrope (7 wt. %) and grossular (5 wt. %) are in contrast minor components. Psammitic rocks are mainly represented by strongly foliated, medium-grained muscovite quartzite.

2.5.1.4 Intrusive rocks

The supracrustal rocks are crosscut by coarse-grained, isotropic, garnet-bearing muscovite leucogranite (Fig. 2.4e). Alkali feldspars dominate with minor plagioclase characterized by albite composition. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Locally, a very coarse-grained to pegmatoid pinkish leucogranite with K-feldspar megacrysts is also featured (Fig. 2.4f). Zoned pegmatite dikes are rare and consist of a milky quartz nucleus and an outer part containing quartz, K-feldspar, albite, green biotite, garnet and trace spodumene. Average igneous garnet composition is almandine (72 wt. %), spessartine (22 wt. %) and pyrope (5 wt. %), with < 1% grossular. Diabase dikes are isotropic, homogeneous, ranging from aphanitic to fine-grained phaneritic, and dominated by plagioclase (andesine) and augite, with accessory magnetite, and subophitic texture. Although the inner parts of this rock are holocrystalline, the intrusive contacts with the country rocks are characterized by chilled margins (i.e., hypohaline texture).

2.5.2 Metamorphism

Main metamorphic assemblages are represented by plagioclase-muscovite-biotite-garnet in semipelite and forsterite-calcite-dolomite-phlogopite-tremolite in marble. Garnet-biotite (Holdaway, 2000) and Ti-in-biotite (Henry et al., 2005) geothermometry yielded the following estimates for peak metamorphic temperature: 592 ± 25 °C (1 σ, n = 5) and 612 ± 28 °C (1 σ, n = 5), respectively. The same garnet crystals resulted in pressure estimates of 4.1 ± 0.6 kbars (1 σ, n = 5) using the geobarometer from Wu (2019). With regards to metamorphosed carbonate rocks, assemblages containing forsterite + calcite + tremolite, with no diopside, are stable between 570° and 640 °C for a wide range of XCO_2 values (Winter 2010). Thus, metamorphic assemblage in marble suggests a peak temperature range compatible with above quoted estimates. Therefore, regional metamorphism is interpreted to have reached mid-amphibolite facies conditions. Intrusive rocks do not display metamorphic minerals and thus are interpreted to postdate regional metamorphism.

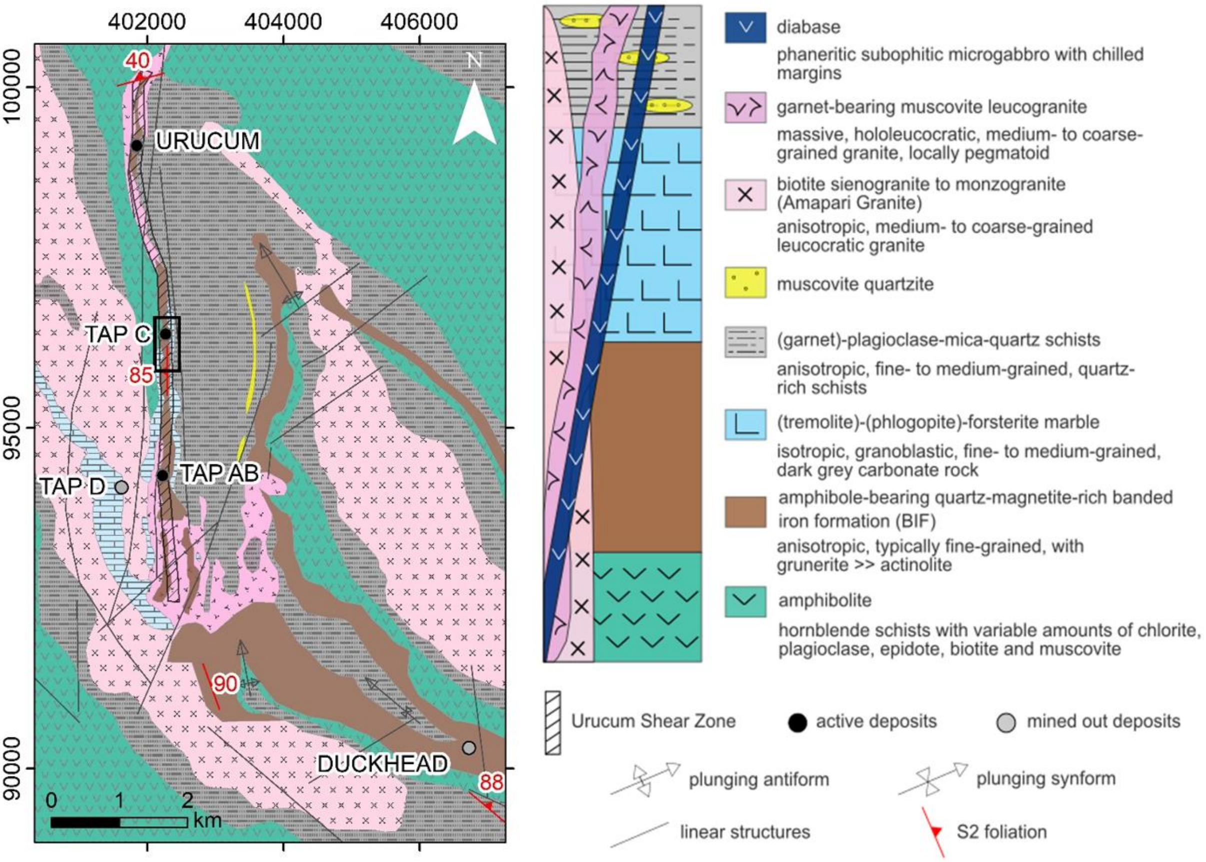


Figure 2.3. Geologic map of the Tucano area (modified from Scarpelli and Horikava, 2017) with location of the mining sites along the N-S trending Urucum Shear Zone. The black inset outlines the location of the study area, which is shown in more detail in Figure 2.7.

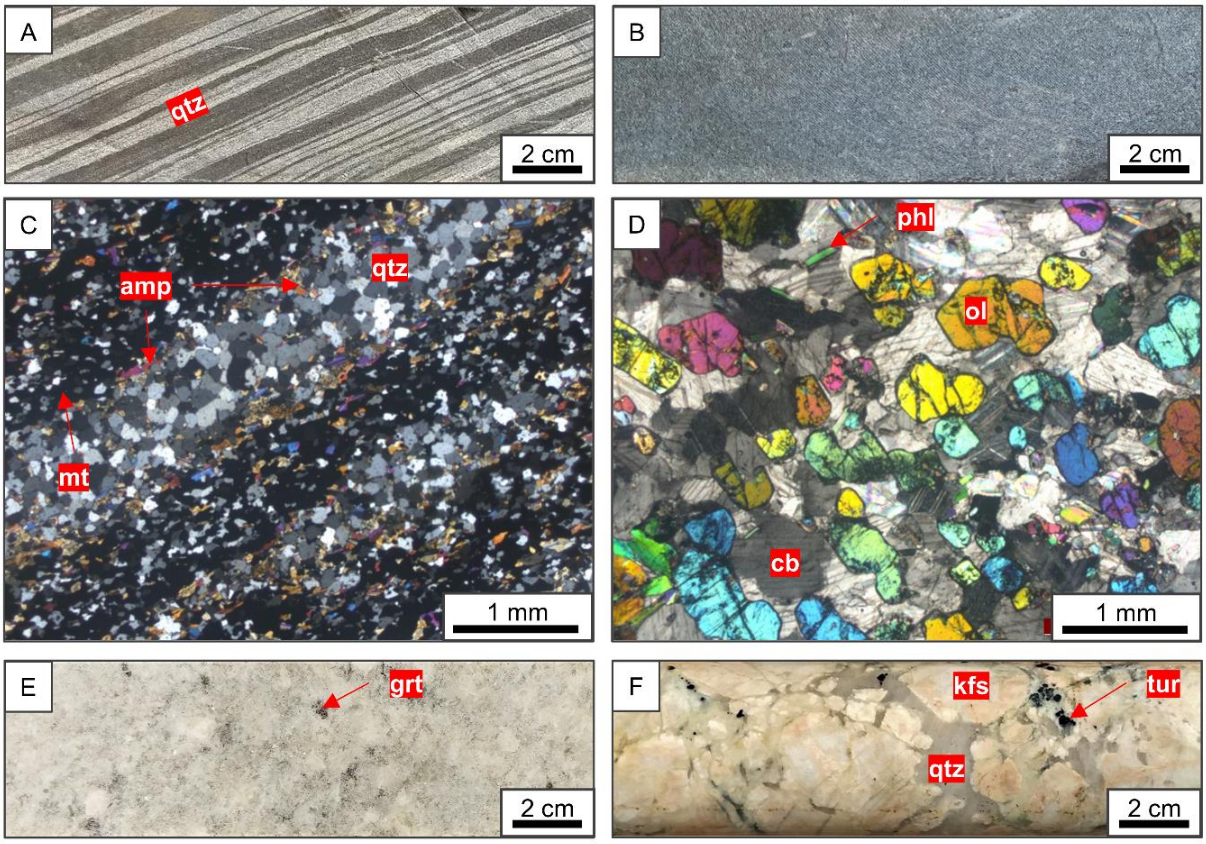


Figure 2.4. Main textural and mineralogical features of the principal host rocks to gold mineralization as well as granitic rocks affecting the supracrustal sequence along the Urucum shear zone. Macroscopic view of least-altered A) BIF. B) Marble. Photomicrographs of C) BIF highlighting fine-grained, disseminated amphibole (plane-polarized light). D) Marble showing the substantial volume proportion of olivine and subordinate phlogopite (plane-polarized light). E) Most common granite facies observed in surface exposures and drillcore in the mine area – garnet-bearing hololeucocratic granite. F) Lesser common granite facies seen only in diamond core that distinguishes itself by the occurrence of K-feldspar megacrysts. Abbreviations: amp – amphibole, cb – carbonate, grt – garnet, kfs – K-feldspar, mt – magnetite, ol – olivine, phl – phlogopite, qtz – quartz, tour – tourmaline.

2.5.3 Whole-rock geochemistry

2.5.3.1 BIF chemistry

Least-altered BIF samples have SiO2 contents in the range 34.3 – 60.8 wt. % and Fe_2O_3total comprised between 34.6 – 62.5 wt. %. Average SiO_2 + Fe_2O_3total ~95 wt. % and CaO + MgO ~ 4.7 wt. % reflect the modal mineralogy containing a few percent amphibole, of which occurrence may also justify relatively high contents of Al_2O_3 and alkalis – Na_2O + K_2O (averaging 0.46 and 0.13 wt. %, respectively). In addition, P_2O_5 is also high (0.19 – 0.32 wt. %). As for trace elements, most have mean values below 10 ppm, with some exceptions being Sr (18 – 50.3 ppm), Ba (4.1 – 85.7

ppm) and Zn (20 – 29 ppm). The total REE (rare earth element) content (ΣREE) is on average 24.7 ppm. Post-Archean Australian Shale (PAAS)-normalized REE+Y (Fig. 2.5a) show a moderate fractionation towards HREE (heavy rare earth elements) with $(La/Yb)_{SN\ (shale\ normalized)}$ = 0.304 on average and $(Gd/Yb)_{SN}$ = 0.546 on average. LREE (light rare earth elements) fractionation is weak, with $(La/Sm)_{SN}$ = 1.031 on average. A distinctive positive Y anomaly ($(Y/Y^*)_{SN}$ = 1.779 on average) is also reported, in addition to weak positive La and Eu anomalies ($(La/La^*)_{SN}$ = 2.033, $(Eu/Eu^*)_{SN}$ = 1.273), with no negative Ce anomaly reported (Fig. 2.5b). Y/Ho ratios (averaging 44) are seawater-like superchondritic (Bau and Dulski, 1999). Lithogeochemical data is available in the electronic appendix Table A5.

2.5.3.2 Marble chemistry

CaO contents in least-altered marble ranges between 25.7 and 29 wt. % and MgO varies from 12.1 to 16.1 wt. %. SiO_2 also displays a significant range (5.9 – 20 wt. %), thereby resulting in a collective classification as siliceous calcitic dolomite marble. In addition, Fe_2O_3total and MnO are relatively high, ranging between 7.2 and 13.4 wt. %, and 1.1 and 5.4 wt. %, respectively. Trace volume proportions of phlogopite accounts for the relatively low average contents of TiO_2 (0.08 wt. %), Al_2O_3 (0.78 wt. %), Na_2O (0.03 wt. %) and K_2O (0.08 wt. %). In contrast to least-altered BIF, P_2O_5 is lower (0.01 – 0.06 wt. %). Most trace elements are below 10 ppm on average, with some notable exceptions being Sr (37.8 – 144.5 ppm) and Ba (11.7 – 241 ppm). The total REE content (ΣREE) is on average 20.3 ppm. PAAS-normalized REE+Y (Fig. 2.5a) show a very similar pattern as reported for BIF, with a moderate fractionation towards HREE with $(La/Yb)_{SN}$ = 0.352 on average and $(Gd/Yb)_{SN}$ = 0.739 on average. A distinctive positive Y anomaly ($(Y/Y^*)_{SN}$ = 1.652 on average) is also reported, whereas La and Eu show very weak positive anomalies ($(La/La^*)_{SN}$ = 1.402 and $(Eu/Eu^*)_{SN}$ = 1.497, on average). No negative Ce anomaly is identified, although $(Pr/Pr^*)_{SN}$ is on average slightly higher than shown by BIF (Fig. 2.5b). Y/Ho ratios (43.4 on average) are closer to the mean BIF value, although showing a wider range (34-53).

2.5.3.3 Granite chemistry

Leucogranite dikes and stocks that crosscut the entire supracrustal sequence of the greenstone belt are compositionally evolved (SiO_2 > 69 wt. %) and have low contents of Fe_2O_3total (0.62 – 1.20 wt. %), MgO (0.05 – 0.4 wt. %) and CaO (0.24 – 0.80 wt. %). P_2O_5 is relatively high (0.24 – 0.77 wt. %) and fractionated into garnet. Alkali contents are high (Na_2O + K_2O = 7.90 to 11.54 wt. %) and result in rocks straddling the alkaline-sub-alkaline boundary curve in the TAS diagram (Fig. 2.5c) and ranging from high-K calc-alkaline to shoshonitic series, with two samples having $Na_2O/K_2O > 1$ and the other two with $Na_2O/K_2O < 0.5$. Alumina contents are high (14.20 – 15.95 Al_2O_3 wt. %) so that samples range from slightly to moderately peraluminous (Fig. 2.5d). Relatively high Rb contents (476 – 1235 ppm) in comparison with Nb + Y (16.95 – 24.1 ppm) prompt those rocks to fall in the syn-collision granites field of the tectonic discrimination diagram of Pearce et al. (1984) (Fig. 2.5e). Primitive mantle-normalized extended trace element diagram (Fig. 2.5f) highlights the high Rb, U, Ta, Pb and P, but low Ba, Th, Nb and LREE. In addition, Eu and Ti are anomalously low, with most values, in fact all for Eu, lying below detection limit (0.02 ppm and 0.01 wt. %, respectively). Overall, the total REE (ΣREE) content is low (1.53 – 8.82 ppm), with only a mild LREE enrichment with respect to HREE ($(La/Yb)_{CN\ (chondrite\ normalized)}$ = 2.836 on average).

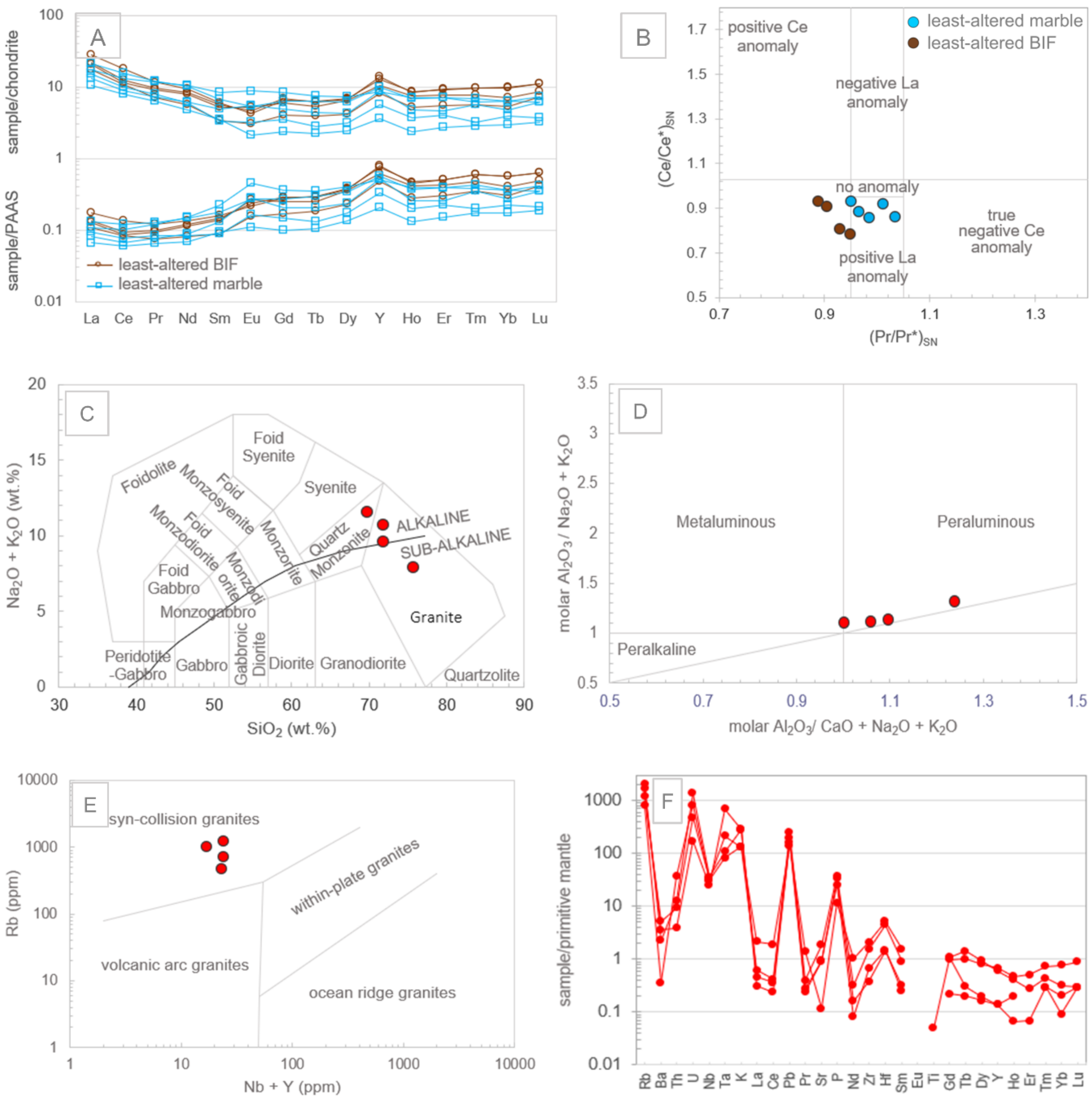


Figure 2.5. Geochemical characterization of BIF, marble and leucogranite from the Tucano region. A) Chondrite-normalized (Sun and McDonough, 1989) and PAAS-normalized (Taylor and McLennan, 1989) REE+Y diagram for least-altered BIF and marble. B) $(Ce/Ce^*)_{SN}$ versus $(Pr/Pr^*)_{SN}$ diagram (Bau and Dulski, 1996) for least-altered BIF and marble. C) SiO_2 versus $Na_2O + K_2O$ – TAS diagram (Middlemost, 1994) for granite classification. D) Alumina saturation index (Shand, 1943) for granite classification. E) Nb + Y versus Rb tectonic discrimination diagram (Pearce et al., 1984) for granite classification. F) Primitive mantle-normalized extended trace element diagram for granite samples. Normalization values from McDonough and Sun (1995).

2.5.4 Structural setting

The structural architecture of the Tucano gold deposit is characterized by distinct structural fabrics that display crosscutting relationships, summarized below and in Table 2.1. The regional S1 is described as shallowly SW dipping foliation (Rosa-

Costa et al., 2014), which is not observed in the Tucano district. The first deformation event recorded in the mine area resulted in the development of an intense, composite (S0/S1/S2) fabric, which is equivalent to the regional D2 (Rosa-Costa et al., 2014), and is characterized by a penetrative NNW-SSE to NNE-SSW-striking and subvertical dipping S2 foliation, as well as gently dipping to upright NNW-SSE to NNE-SSW-striking tight to isoclinal folds. Thus, D2 structures indicate E-W shortening. The sense of shear is difficult to ascertain due to reworking during progressive deformation events, but a dextral sense of motion is ascribed based on asymmetric boudins locally observed (Fig. 2.6a). The S2 fabric developed particularly well in the Amapari Granite (Fig. 2.6b), which, in conjunction with its elongated geometry, parallel to the Urucum Shear Zone, suggest a minimum structural age at early D2.

The third deformation event (D3) produces an approximately N-S-striking, subvertical penetrative S3 foliation. The D3 strain accommodation on the pre-existing S2 mylonitic fabric of the shear zone is common, thereby resulting in a composite S2-S3 fabric (Fig. 2.6c). Locally, however, the S3 foliation crosscuts S2 at low angle. This is observed in boudinaged clinopyroxene veins and stretched clinopyroxene lenses that trend slightly oblique to the S2 foliation. In addition, F3 folding has produced gently N-S plunging F3 folds (Fig. 2.6d), with interlimb angle characteristic of close to tight folds. Therefore, D3 fabrics indicate an E-W shortening.

Unlike the previous deformation events, D4 did not generate a distinct foliation, being recorded by local open to close F4 folds, which have axial planes striking WNW-ESE to NW-SE and dipping about 80 ° SW, and hence at high angle to the composite shear zone fabric. Fold axes show variable plunging in a SE direction, thereby resulting in folds ranging from upright to nearly vertical. Axial plane orientation indicates NNE-SSW shortening. The leucogranite that crosscuts the metasedimentary units and parallel to the shear zone does not show any evidence of S2 or S3 strain uptake, but can be locally affected by the F4 folding (Fig. 2.6e), which allows for a constrained structural age to be ascribed between late D3 and early D4. Minor veining of quartz-calcite-(pyrrhotite) or calcite-pyrite composition, striking from NW to NE, was likely emplaced during D4. The structural elements associated with this event suggest a NNW-SSE to NW-SE shortening. This far field stress could also explain the occurrence of shear zone parallel, subvertical faults observed on the regolith having distinctive pistachio-green epidote alteration. Moreover, moderately to steeply, dominantly S dipping E-W faults commonly filled by serpentine-dolomite veins (Fig. 2.6f) may also be related to a late D4 event. Direction of slickenlines and offsetting in weathered profiles indicate a reverse movement of these faults (Fig. 2.6g). Integration of drillhole data indicates substantial displacement (up to few tens of meters) along these E-W structures, commonly offsetting ore shoots (Fig. 2.7). The youngest structures (D5) are N-S to NNW-SSE fractures filled by diabase dikes.

DEFORMATION EVENT	STRUCTURES	MAGMATISM
D0 Deposition of volcano-sedimentary rocks	S0: bedding in BIF and protolith to siliclastic rocks (siltstones, sandstones)	Mafic volcanism associated with amphibolite protolith
D1 NE-SW shortening	S1: only distinguished within composite S0/S1/S2 fabric	
D2 NE-SW shortening with development of regional scale shear zones and local N-S deflections associated with jog formation	S2: dominant tectonic fabric – NNW-SSE to NNE-SSW striking, steeply dipping, with F2 folds having axis plunging gently to N or S, with subvertical axial plane; interlimb angles suggest tight to isoclinal folds; orientation of asymmetric boudins indicates a dextral sense of shear motion	Intrusion of Amapari Granite
D3 E-W shortening with reactivation of the Urucum Shear Zone	S3: N-S striking penetrative foliation with common D3 strain being accommodated on pre-existing S2 mylonitic fabric; F3 fold axis plunges gently to N or S, being upright, and with interlimb angle ranging from close to isoclinal	Intrusion of garnet-bearing leucogranite and associated pegmatites during late D3 to early D4
D4 N-S shortening	D4a: Local F4 folds with WNW-ESE to NW-SE plunging fold axis at low to high angle; axial plane	

	dipping high angle to SW; and interlimb angles resulting in open to close folds	
	D4b: E-W striking faults offsetting lithostratigraphy and mineralization	
D5	N-S to NNW-SSE striking fractures	Diabase dikes crosscutting all fabrics
N-S to NNW-SSE shortening		

Table 2.1. Summary of deformation events and their correlative structures at the Tucano gold deposit.

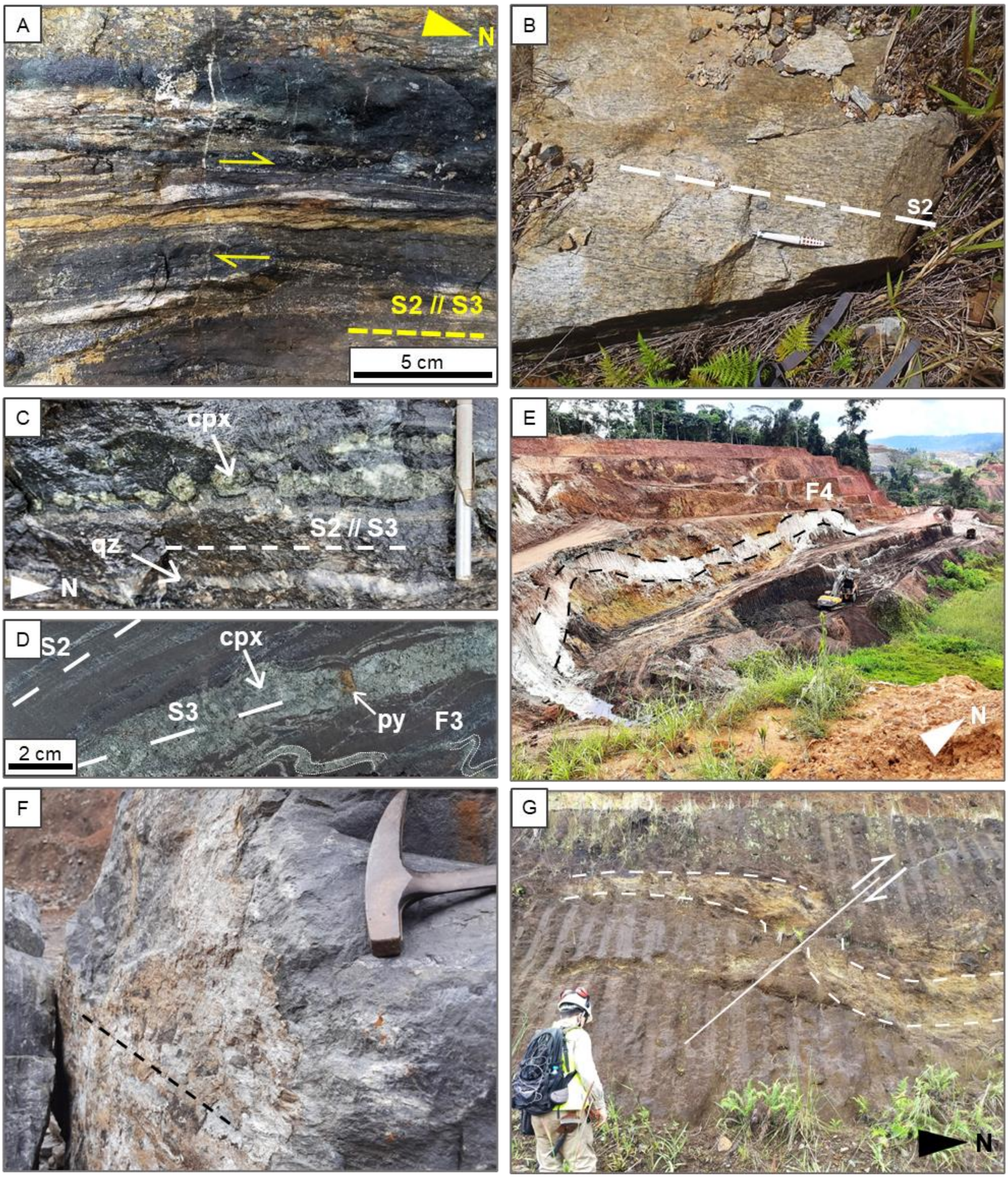


Figure 2.6. Examples of structural elements associated with the evolution of the Tucano deposit. A) asymmetric foliation indicating a dextral sense of movement for the Urucum Shear Zone. B) Foliated granite (Amapari Granite) displaying the S2 foliation (photo courtesy from Great Panther Mining). C) Boudinaged clinopyroxene (cpx) vein and stretched quartz (qz) lenses defining a composite S2-S3 foliation. D) Boudinaged clinopyroxene vein with pyrite (py) pinch filling, defining a S3 shear foliation slightly oblique to S2. Smaller scale veins emanating from the main one at high angle are folded (F3). E) Unfoliated leucogranite dike displaying open F4 folds with axial plane striking WNW-ESE and dipping about 80 degrees to SW. F) Fault surface in altered BIF boulder displaying serpentine filling and indication of slickenline direction. G) Reverse component of E-W faults in regolith.

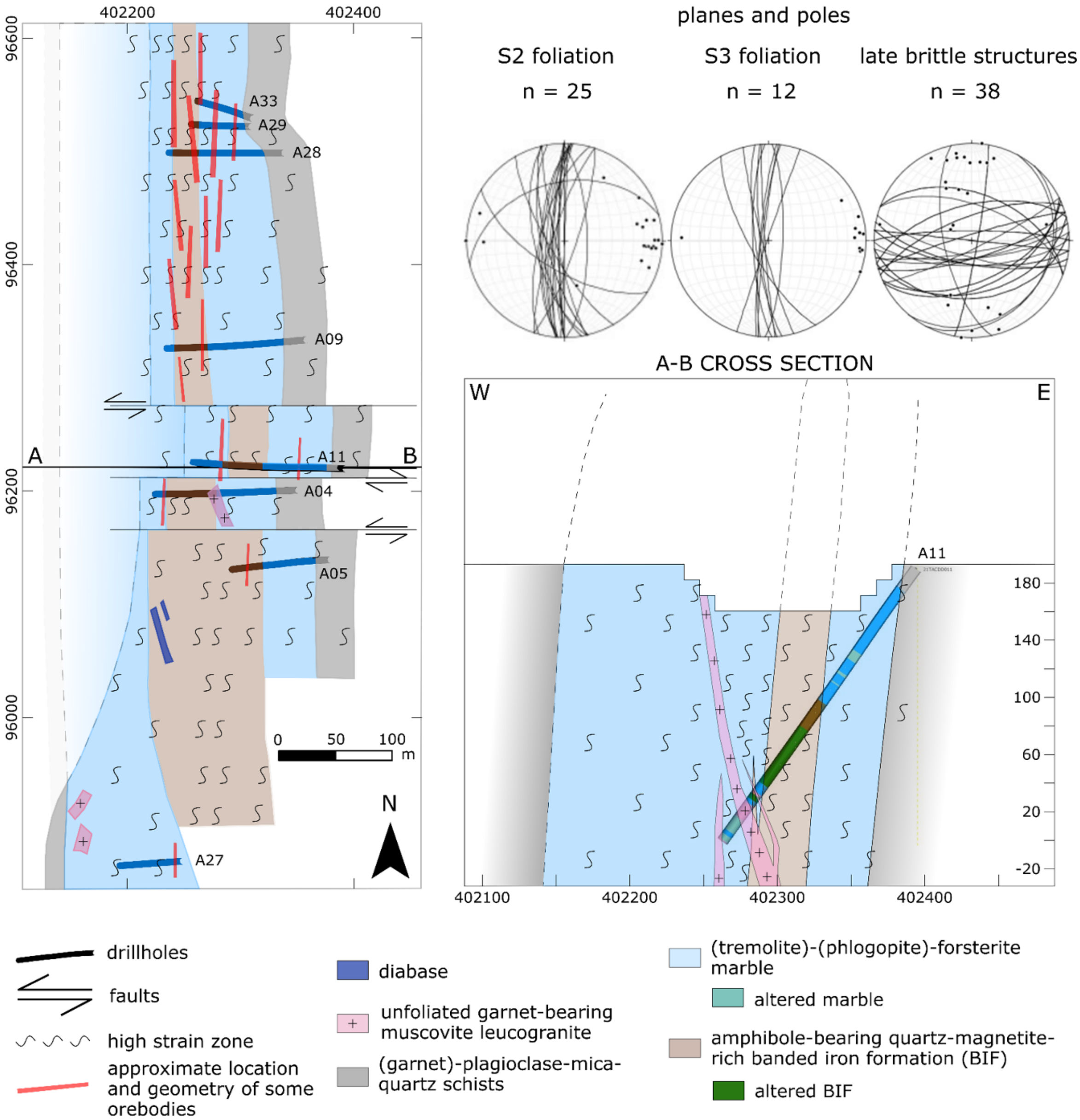


Figure 2.7. Geologic map and schematic cross section at the central part of TAP C open pit outlining the location of the drillholes logged and sampled for this study. The stereonet plots illustrate the overall steep N-S trending S2 and S3 foliation and the prevailing east-west orientation of faults and fractures. Combined surface and drillhole data indicate the metavolcano-sedimentary rocks are tightly folded against the Amapari Granite to the west.

2.6 Orebody geometry

Mining operations are assembled in three main localities along the belt, namely the southern TAP AB, the central TAP C and the northern Urucum open pits (Fig. 2.3). This work is focused on the central TAP C target (Fig. 2.8). Mineralization is made up of a series of 1 – 8 m wide, steeply dipping, subparallel ore shoots. These are aligned along a N-S direction, following the Urucum Shear Zone trend. Deposits located off the main N-S structure, such as Duckhead (Fig. 2.3), are associated with fold hinges (Great Panther, 2022).

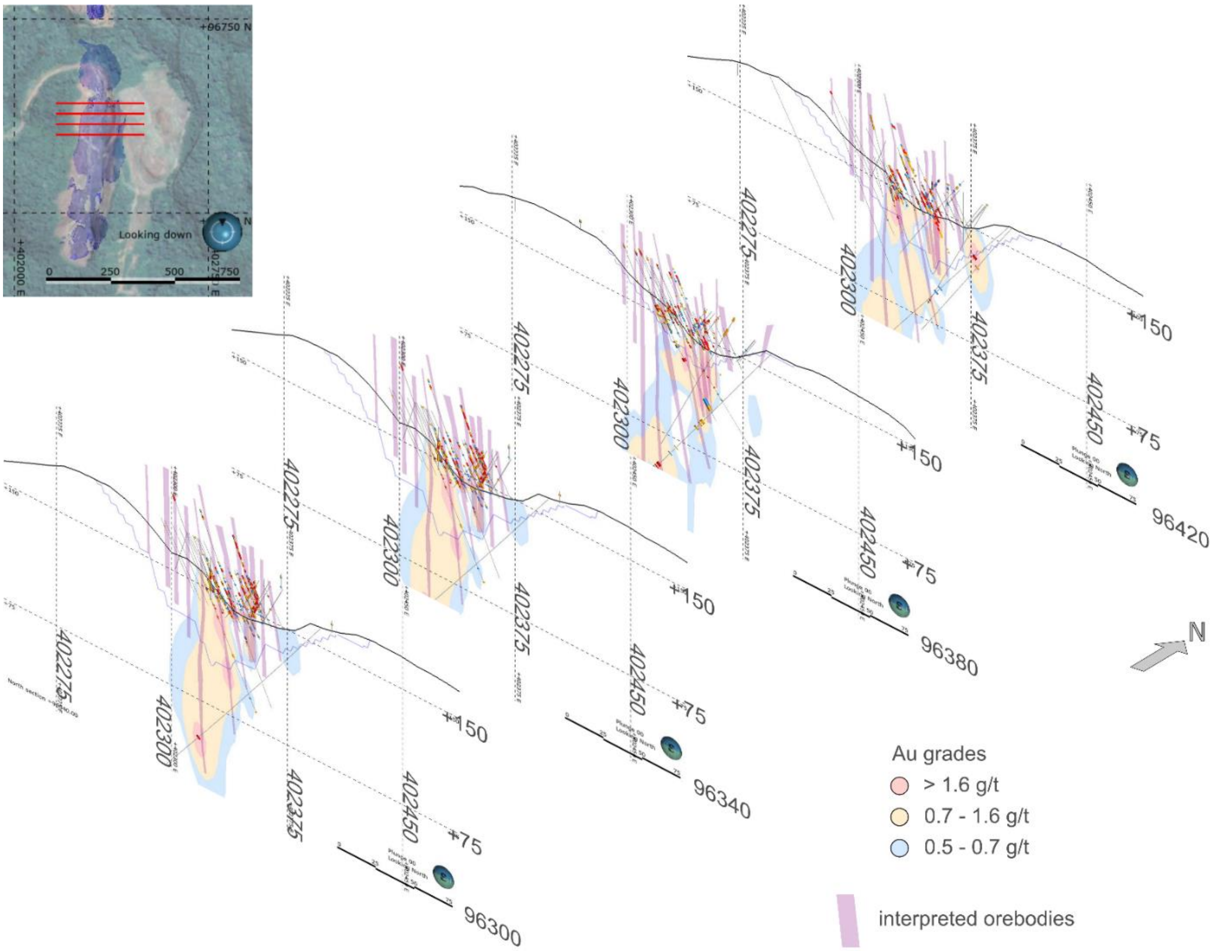


Figure 2.8. Stacked cross sections from the TAP C deposit at the Tucano gold mine, showing Au grade shells and interpreted geometry of ore shoots. Sections provided by Great Panther Mining.

2.7 Hydrothermal Alteration and Mineralization

Hydrothermal alteration related to gold mineralization is mostly constrained to the D3 event and focused on the reactive marble and BIF host rocks in the footwall as opposed to the siliciclastic units in the hanging wall of the deposit. Alteration can be segmented into three stages.

2.7.1 Early quartz-clinopyroxene-garnet hydrothermal stage (Late D2 to Early D3)

2.7.1.1 Marble

The key assemblage that defines this stage is quartz – diopside ± garnet, which is petrographically recorded as veins, and patchy blebs and lenses in the wallrocks (Fig. 2.9a, b). Diopside aggregates (1) are composed of coarse- to very coarse-grained subhedral crystals, locally featuring medium- to coarse-grained subhedral to anhedral garnet as inclusions or intergranular phase. Interstitial space between diopside crystals may contain calcite and allanite. More rarely, marble may feature tourmaline-bearing garnet-biotite-rich intervals in association with clinopyroxene-rich domains. Early hydrothermal stage biotite will be referred to as biotite-1 from now on. Ilmenite is the main opaque mineral ascribed to this early alteration stage, occurring as fine- to medium-grained, prismatic or subequant subhedral intergranular crystals. Magnetite is subordinate and sulfides are rare.

2.7.1.2 BIF

Early-stage alteration in BIF is dominated by hedenbergite, with little quartz. Other phases that are featured in marble are lacking in BIF. In textural terms, veins and lenses are prevalent.

(1) $2(Mg_{0.6}Fe_{0.35}Mn_{0.05})_2SiO_4 + 2CaCO_3 \longrightarrow Ca(Mg_{0.7}Fe_{0.3})Si_2O_6 + 2CO_2 + 2O_2 + Ca^{2+} + 1.7Mg^{2+} + 1.1Fe^{2+} + 0.2Mn^{2+}$
forsterite-rich olivine ***calcite*** ***diopside***

(2) $8(Mg_{0.6}Fe_{0.35}Mn_{0.05})_2SiO_4 + 2CaCO_3 + H_2O + 0.2Na^+ + 0.8Fe^{2+} \longrightarrow (Na_{0.2}Ca_{1.8})(Mg_{4.6}Fe_{0.4})Si_8O_{22}(OH)_2 + 2Fe_3O_4 + 2CO_2 + 0.5O_2 + 0.2Ca^{2+} + 5Mg^{2+} + 0.8Mn^{2+}$
forsterite-rich olivine ***calcite*** ***tremolite*** ***magnetite***

(3) $3K(Mg_{1.6}Fe_{0.9}Al_{0.4}Ti_{0.1})(Al_{1.3}Si_{2.7})O_{10}(OH)_2 + 0.3Fe^{2+} \longrightarrow (Mg_{0.8}Fe_{1.2})(Mg_{3.4}Fe_{1.6}Ti_{0.1})(Al_{0.2}Si_{7.8})O_{22}(OH)_2 + 0.2FeTiO_3 + 3K^+ + 4.9Al^{3+} + 4Mg^{2+} + 0.3SiO_2 + 2H_2O + 4.4O_2$
biotite ***cummingtonite*** ***ilmenite***

(4) $2Ca(Mg_{0.7}Fe_{0.3})Si_2O_6 + 3.7SiO_2 + 0.2CO_2 + H_2O + 2.5Mg^{2+} + 0.3Fe^{2+} + 0.2Na^+ + 0.5Al^{3+} + 1.9O_2 \longrightarrow (Na_{0.2}Ca_{1.8})(Mg_{3.9}Fe_{0.9}Al_{0.2})(Al_{0.3}Si_{7.7})O_{22}(OH)_2 + 0.2CaCO_3$
diopside ***quartz*** ***actinolite*** ***calcite***

(5) $6(Mg_{0.6}Fe_{0.35}Mn_{0.05})_2SiO_4 + 2CaCO_3 + H_2O + 0.5O_2 + 0.7Na^+ + 0.7Al^{3+} \longrightarrow Na_{0.7}(Fe_{0.1}Ca_{1.9})(Mg_{3.3}FeAl_{0.7})(Al_2Si_6)O_{22}(OH)_2 + Fe_3O_4 + 2CO_2 + 0.1Ca^{2+} + 3.9Mg^{2+} + 0.1Fe^{2+} + 0.6Mn^{2+}$
forsterite-rich olivine ***calcite*** ***pargasite*** ***magnetite***

(6) $K(Mg_{2.6}Fe_{0.3}Al_{0.1})(Al_{1.2}Si_{2.8})O_{10}(OH)_2 + 0.2\ Na^+ + 0.2Al^{3+} + 0.3Fe^{2+} + 0.1O_2 \longrightarrow Na_{0.2}K_{0.8}(Mg_{2.2}Fe_{0.6}Al_{0.2})(Al_{1.3}Si_{2.7})O_{10}(OH)_2 + 0.2K^+ + 0.4Mg^{2+} + 0.1SiO_2$
Na-poor phlogopite ***Na-bearing phlogopite***

(7) $6Fe_3O_4 + 31SiO_2 + 4H_2O + 0.8Na^+ + 4Ca^{2+} + 8.4Mg^{2+} + 0.4Mn^{2+} + 3O_2 \longrightarrow 2(Na_{0.2}Ca_{0.2}Mg_{0.6}Fe_{0.9}Mn_{0.1})(Mg_{1.5}Fe_{3.4}Mn_{0.1})(Al_{0.3}Si_{7.7})O_{22}(OH)_2 + 2(Na_{0.2}Ca_{1.8})(Mg_{2.1}Fe_{2.9})(Al_{0.2}Si_{7.8})O_{22}(OH)_2 + 3.6Fe^{2+}$
magnetite quartz ***grunerite*** ***ferroactinolite***

(8) $20Ca(Mg_{0.45}Fe_{0.55})Si_2O_6 + 38SiO_2 + 2CO_2 + 10H_2O + 14Mg^{2+} + 16Fe^{2+} + 3Na^+ + 2Al^{3+} + 19.5O_2 \longrightarrow 10(Na_{0.3}Ca_{1.7})(Mg_{2.3}Fe_{2.7})(Al_{0.2}Si_{7.8})O_{22}(OH)_2 + 3CaCO_3$
hedenbergite ***quartz*** ***ferroactinolite*** ***calcite***

(9) $Fe_3O_4 + 3.3H_2S \longrightarrow 3FeS_{1.1} + 3.3H_2O + 0.35O_2$
magnetite ***pyrrhotite***

(10) $FeS_{1.1} + 0.9S \longrightarrow FeS_2$
pyrrhotite ***pyrite***

(11) $FeAs_2 + 10FeS_{1.1} \longrightarrow 2FeAsS + 9FeS$
loellingite ***pyrrhotite*** ***arsenopyrite***

(12) $23Na_{0.2}K_{0.8}(Mg_{2.2}Fe_{0.6}Al_{0.2})(Al_{1.3}Si_{2.7})O_{10}(OH)_2 + 36H_2O + 6.4Mg^{2+} + 4.2Fe^{2+} \longrightarrow 15(Mg_{3.8}FeAl_{1.2})(Al_{1.1}Si_{2.9})O_{10}(OH)_8 + Fe_3O_4 + 4.6Na^+ + 18.4K^+ + 18.6SiO_2 + 1.6O_2$
Na-bearing phlogopite ***clinochlore*** ***magnetite***

(13) $2(Mg_{0.6}Fe_{0.35}Mn_{0.05})_2SiO_4 + 2H_2O + 0.4Mg^{2+} + 0.6O_2 \longrightarrow (Mg_{2.8}Fe_{0.2})Si_2O_5(OH)_4 + 0.4Fe_3O_4$
forsterite-rich olivine ***serpentine***

(14) $11(Na_{0.3}Ca_{1.7})(Mg_{2.3}Fe_{2.7})(Al_{0.2}Si_{7.8})O_{22}(OH)_2 + 1.6K^+ + Mn^{2+} \longrightarrow 2(Na_{0.2}K_{0.8})(Mg_{0.8}Fe_{6.7}Mn_{0.5})(Al_{1.1}Si_{10.9})O_{22}(OH)_3.2H_2O + 2.9Na^+ + 18.7Ca^{2+} + 23.7Mg^{2+} + 16.3Fe^{2+} + 64SiO_2 + 4H_2O + 156O_2$
ferroactinolite ***stilpnomelane***

Table 2.2. Mineral reaction formulas (numbers for reactions are referenced throughout the text).

2.7.2 Main amphibole-phlogopite-magnetite-pyrrhotite ± calcite hydrothermal stage (Syn D3)

The main hydrothermal alteration stage is distinguished by its amphibole-magnetite-pyrrhotite ± calcite assemblage. Unlike the early hydrothermal stage, main stage alteration is accompanied by substantial modification of the host rocks, with pervasive replacement of the metamorphic mineral assemblage and textures, as well as destabilization of earlier hydrothermal minerals.

2.7.2.1 Marble – distal alteration zone

The distal alteration zone is defined by the pseudomorphic replacement of metamorphic olivine (Fig. 2.10a) by tremolite-magnetite (2). Tremolite also develops interstitially within the carbonate groundmass, both individually and as aggregates (patchy texture), Light green pleochroism indicates actinolite as an important constituent of such aggregates. Locally, subparallel stringers of phlogopite flakes and irregular phlogopite aggregates are observed. Traces of ilmenite, pyrrhotite ± chalcopyrite, spinel, and apatite are also reported. Biotite 1 is replaced by randomly oriented, needle-like crystals of cummingtonite (3).

2.7.2.2 Marble – proximal alteration zone

Proximal alteration (Fig. 2.11a) is defined by amphibole-phlogopite-magnetite-pyrrhotite ± calcite. This assemblage is typically superimposed on early hydrothermal products, i.e., veins, blebs and aggregates containing diopside. As a result, this phase, as well as garnet, are out of equilibrium during this alteration stage, with pervasive replacement by tremolite-actinolite ± calcite, thereby developing sieve texture and, in more extreme cases, skeletal crystals (Fig. 2.10b) (4). Locally, fine- to medium-grained, irregular aggregates of biotite lamellae are found in equilibrium with amphibole. In rare cases, a coarse-grained olivine is in equilibrium with the hydrothermal phases. This amphibole-dominated alteration may range from thin envelopes rimming diopside to wide (up to 2 m) replacement corridors (Fig. 2.10c). Tremolite-actinolite is the prevailing amphibole type, and hornblende takes place more locally. Cummingtonite-grunerite series amphibole is much less abundant, except where main stage alteration overprints quartz-diopside veins, mostly as stockwork-style or sheeted stringers. Hydrothermal calcite is found interstitially in altered diopside and in equilibrium with amphibole aggregates, locally as euhedral, coarse-grained crystals with equally euhedral amphibole. Dolomite is rare and form exsolution lamellae in calcite.

Three varieties of proximal alteration zone rocks are distinguished. The first and more common is characterized by the near complete replacement of the metamorphic carbonate groundmass by calcic amphibole ± biotite-2 or phlogopite (proximal zone A) (Fig. 2.9a), which may be laterally associated with a quartz-clinopyroxene vein with cummingtonite-grunerite overprint (Fig. 2.9b). Magnetite is not always present (indeed always absent in overprinted quartz-diopside veins) and sulfides are usually <5 vol %. More locally, proximal alteration zone may be defined by the occurrence of calcic-sodic amphiboles (pargasite and hastingsite) and light green phlogopite (Fig. 2.10d), and texturally characterized by subparallel stringers, poorly to strongly oriented disseminated crystals or patchy irregular aggregates, locally with decussate phlogopite (proximal zone B) (Fig. 2.9c). Such rocks are characterized by few weight percent magnetite and pyrrhotite (up to 10 vol. % each), which are texturally characterized by interstitial isolated crystals or networks, irregular stringers and bands. These rocks are also distinguished from proximal zone A by significant preservation of the precursor rock's assemblages and textures. Magnetite-calcite-rich rocks, either massive or banded, and locally exceeding 50 vol. % magnetite, define the proximal zone C (Fig. 2.9d).

With regards to magnetite, two generations are reported within the time frame of the main stage alteration. Magnetite 1 is typically fine- to medium-grained, (in general <0.2 mm), subhedral, and predates sulfide formation. In contrast, magnetite 2 is, on average, coarser (locally >1,0 mm), shows complex intergrowth relationship with pyrrhotite, and typically displays interstitial nature (Fig. 2.12a). Other non-sulfide hydrothermal minerals include ilmenite, apatite, spinel, titanite, barite and scheelite, the latter three of rare occurrence. Ilmenite is often found in equilibrium with amphibole and phlogopite but is most notoriously observed in complex intergrowths with magnetite 2, locally as exsolution lamellae within the host magnetite. Apatite is one of the most abundant accessory phases, being found in equilibrium with amphibole, phlogopite, magnetite and pyrrhotite. On the contrary, green spinel is of more restricted occurrence, generally in textural equilibrium with ilmenite, phlogopite and magnetite, though outlasted by the latter as attested by interstitial magnetite between spinel crystals.

2.7.2.3 BIF – distal alteration zone

Distally altered BIF (Fig. 2.11b) is characterized by concordant amphibole replacement of the metamorphic quartz-magnetite assemblage (7), with grunerite dominating over ferroactinolite (Fig. 2.9e). The fabric of the BIF is largely preserved (Fig. 2.10e). Grunerite commonly develops as euhedral to subhedral, long prismatic to needle-like crystals, whereas ferroactinolite typically forms subhedral to anhedral, short prismatic to subequant crystals. Early alteration stage relict hedenbergite from the early hydrothermal stage, commonly in thin, boudinaged veins, is replaced by amphibole (8). Locally, thin, medium- to coarse-grained ferroactinolite veins also display pyrrhotite.

2.7.2.4 BIF – proximal alteration zone

The transition from the distal to the proximal alteration zone is marked by increasing amphibole abundance replacing metamorphic quartz, increase of pyrrhotite (9) and locally carbonate. In addition, the proximal zone is marked by partial to total destruction of the banded BIF fabric as a result of widespread amphibole development (Fig. 2.10f). Hydrothermal alteration in BIF enables the breakdown of hydrothermal amphibole formation into two substages. Amphibole 1, broadly coeval with magnetite 1, is manifested as concordant, stratiform replacement along host rock magnetite bands. Amphibole 2, on the other hand, is hosted in shear structures, crosscutting the rock fabric (including amphibole 1) and feeding networks of anastomosing veinlets and local pockets (Fig. 2.9f). The two generations of amphibole encompass both grunerite and ferroactinolite, where second generation crystals are typically coarser-grained and broadly contemporaneous with magnetite 2 and pyrrhotite.

It is worth mentioning that both metamorphic and hydrothermal minerals may locally display effects of grain boundary area reduction (GBAR) recrystallization. This is clearly observed in the carbonate groundmass of marbles, as well as lenses and patches of green calcic amphibole in the proximal alteration zone, where these minerals exhibit polygonised contacts.

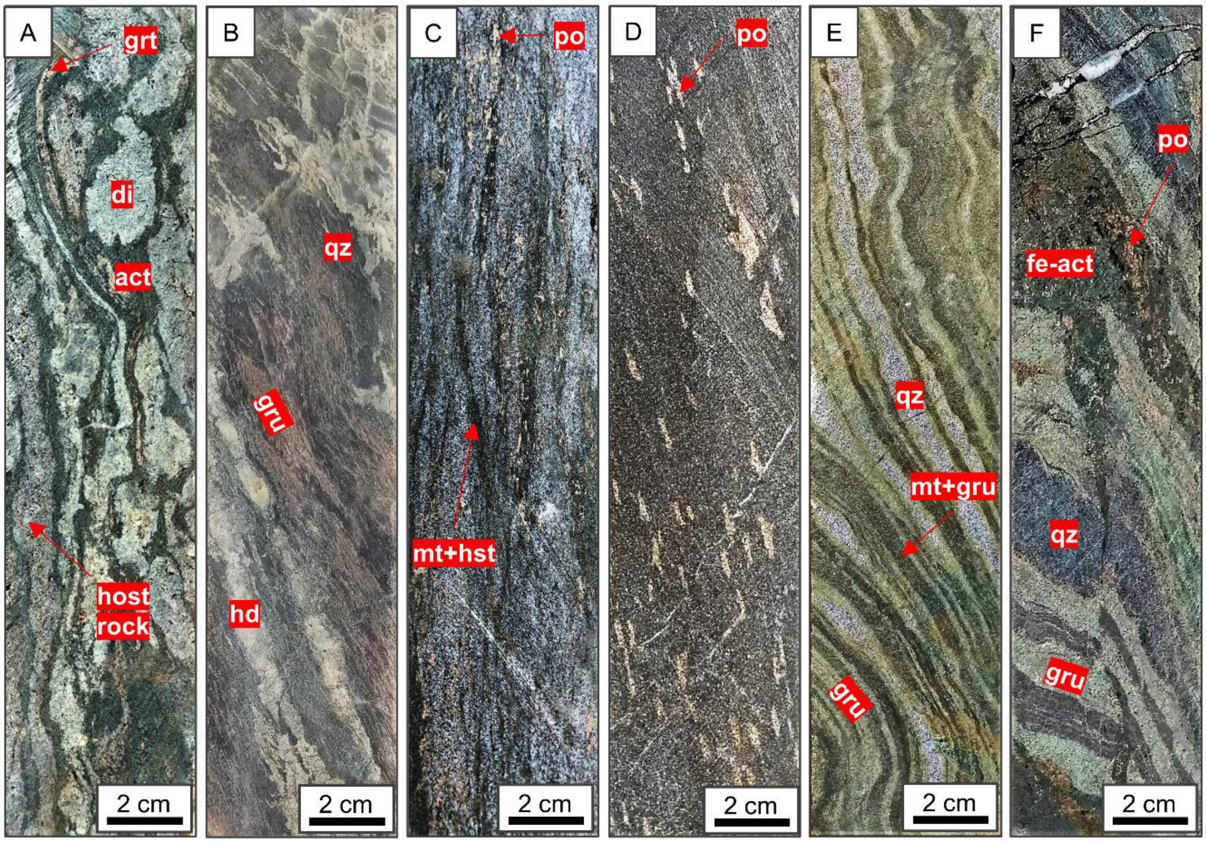


Figure 2.9. Hydrothermal alteration of marble and BIF in the Tucano gold deposit. A) Light green diopside (di) nodules enveloped by actinolite (act) with fragment of marble. B) Quartz(qz)-hedenbergite(hd) vein overprinted by fibrous grunerite (gru). C) Altered marble crosscut by composite magnetite (mt)-hastingsite (hst)-pyrrhotite stringers. D) Carbonate-magnetite rock with disseminated, elongated pyrrhotite. E) Intense concordant, stratiform replacement of BIF bands by light green grunerite. F) Ferroctinolite (fe-act)-pyrrhotite (po) shear vein offsetting strongly grunerite-altered BIF.

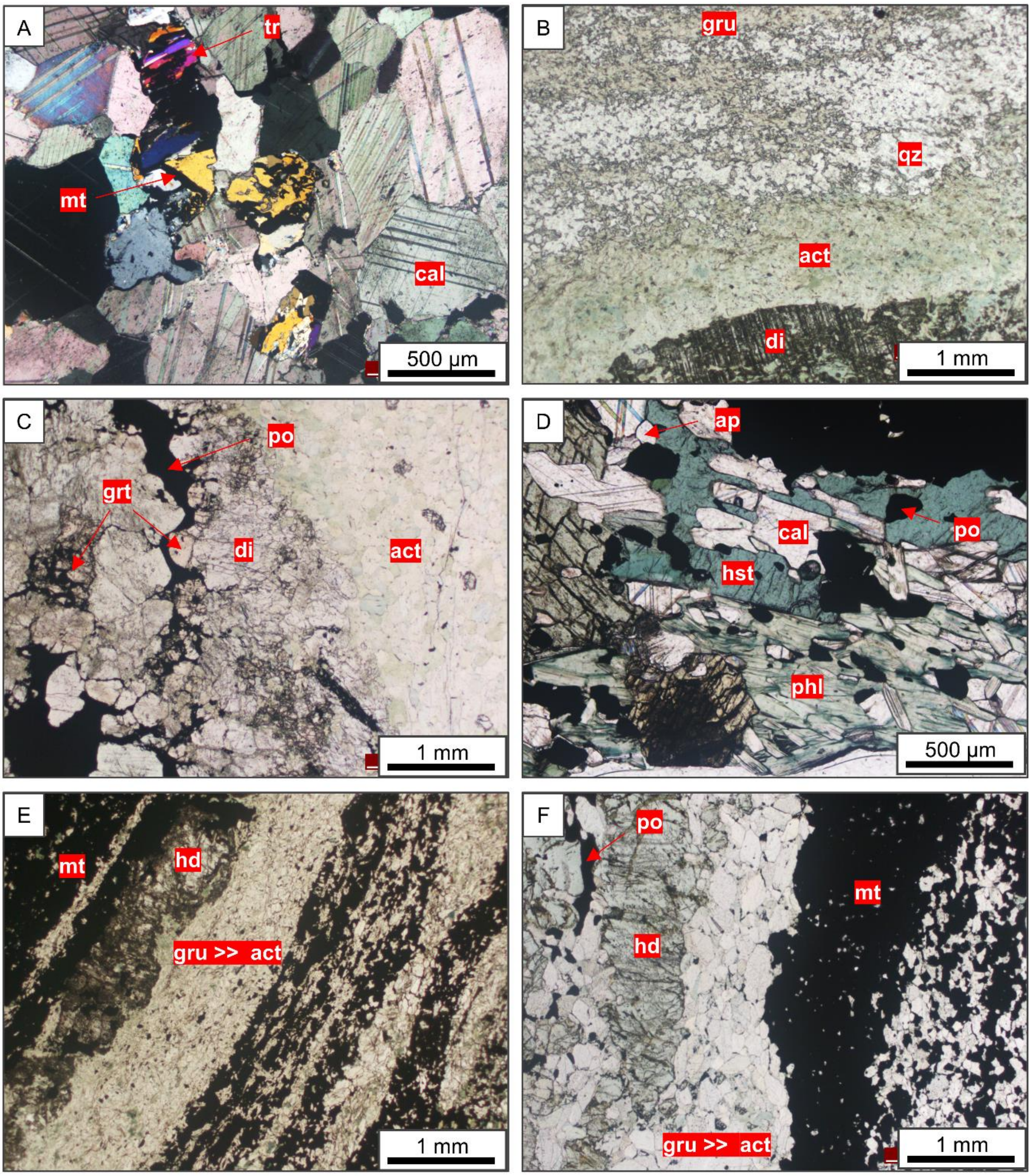


Figure 2.10. Selection of alteration features commonly observed in thin sections at the Tucano gold deposit. All photomicrographs are taken under plane-polarized, transmitted light. A) Pseudomorphism after metamorphic olivine, with formation of tremolite (tr)-magnetite (mt). B) Quartz-diopside vein overprinted by amphibole stringers and veinlets. Clinopyroxene is skeletal and surrounded by actinolite with outer zone of grunerite. C) Actinolite rims diopside-garnet (grt) aggregate, with pyrrhotite interstitial along grain boundaries and overprinting garnet. D) Bluish green hastingsite (hst) and green phlogopite in altered marble. Except for the indicated pyrrhotite, all opaque minerals are magnetite. E) Altered BIF with preserved banded fabric. Notice the partly replaced hedenbergite crystal and the complete replacement of earlier quartz bands by amphibole. F) Altered BIF with disrupted banding showing a relict magnetite (mt) slab. Opaques to the left of the elongated hedenbergite crystal are all pyrrhotite.

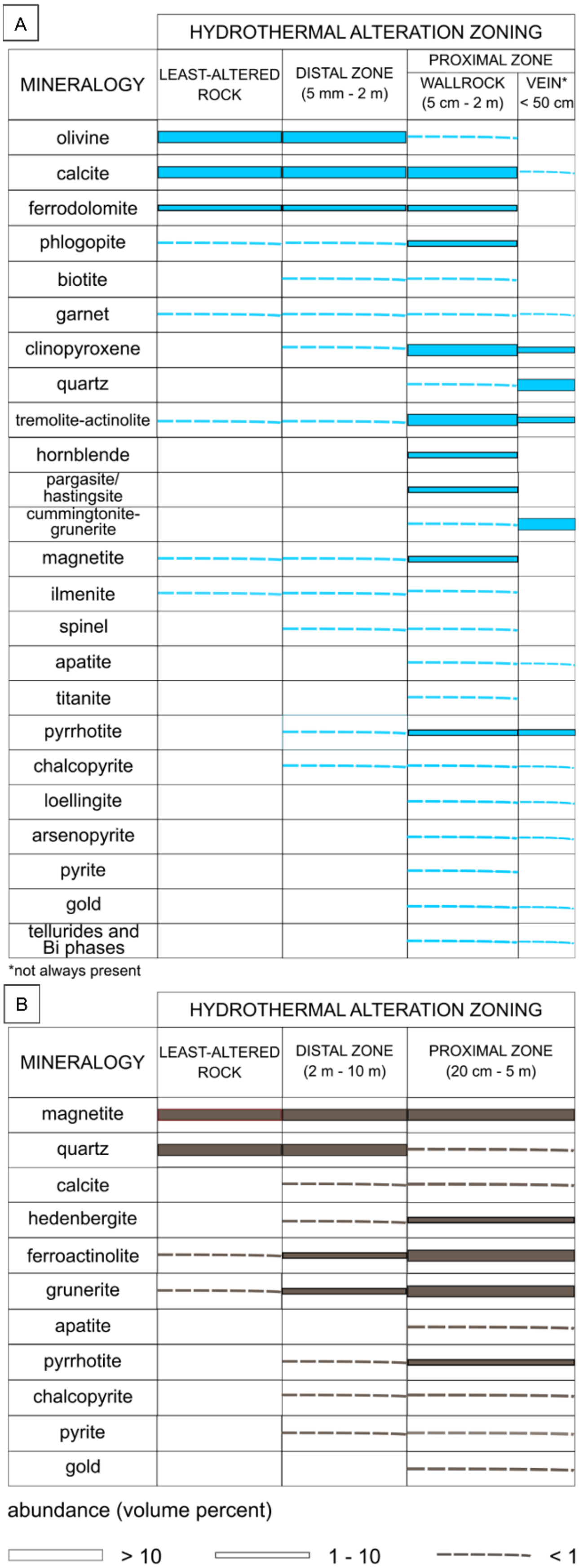


Figure 2.11. Hydrothermal alteration zoning in host rock A) Marble, and B) BIF. Note that late retrograde minerals are not included.

2.7.2.5 Ore sulfide assemblage

Irrespective of host rock, pyrrhotite is the most abundant sulfide mineral and occurs as: (i) lenses and stringers subparallel to the shear zone foliation, (ii) tension gash infill; (iii) shear structures feeding network of anastomosing veinlets, and (iv) disseminated crystals locally showing preferred growth directions parallel to shear zone foliation. Other sulfide species are rare and include chalcopyrite, pyrite (Fig. 2.12b), arsenopyrite and sphalerite, and the arsenide loellingite. The latter three are not observed in altered BIF. Chalcopyrite is observed as fine-grained, subhedral to anhedral crystals intergrown with pyrrhotite. Pyrite is almost ubiquitously found as replacement of pyrrhotite (10), either as anhedral, mottled crystals or euhedral overgrowths, ranging from fine- to coarse-grained. Sphalerite is rare and occurs as very fine (< 30 µm) rounded crystals at the margins of pyrrhotite.

Arsenopyrite and loellingite are spatially associated with one another, but in equilibrium with pyrrhotite only locally. They are typically observed intergranular in calc-silicate minerals (mostly amphibole and garnet), ranging from fine- to medium-grained, euhedral to subhedral. Arsenopyrite commonly has internal loellingite domains (Fig. 2.13a). Loellingite without arsenopyrite mantling is also recorded. (11). Both arsenopyrite and loellingite contain locally micro-inclusions of altaite.

Visible gold (Figs. 2.12c to f, and 2.13b, c, d) does not exceed 100 µm and is reported as: (i) in equilibrium with pyrrhotite and loellingite; (ii) in equilibrium with or as inclusions in arsenopyrite; (iii) in equilibrium with, enclosed by or crosscutting magnetite; (iv) interstitial or fracture-filling in silicates (amphibole, clinopyroxene, garnet); and (v) rarely in apparent equilibrium with native bismuth and Bi-Te phase, locally rimmed by bismuthinite.

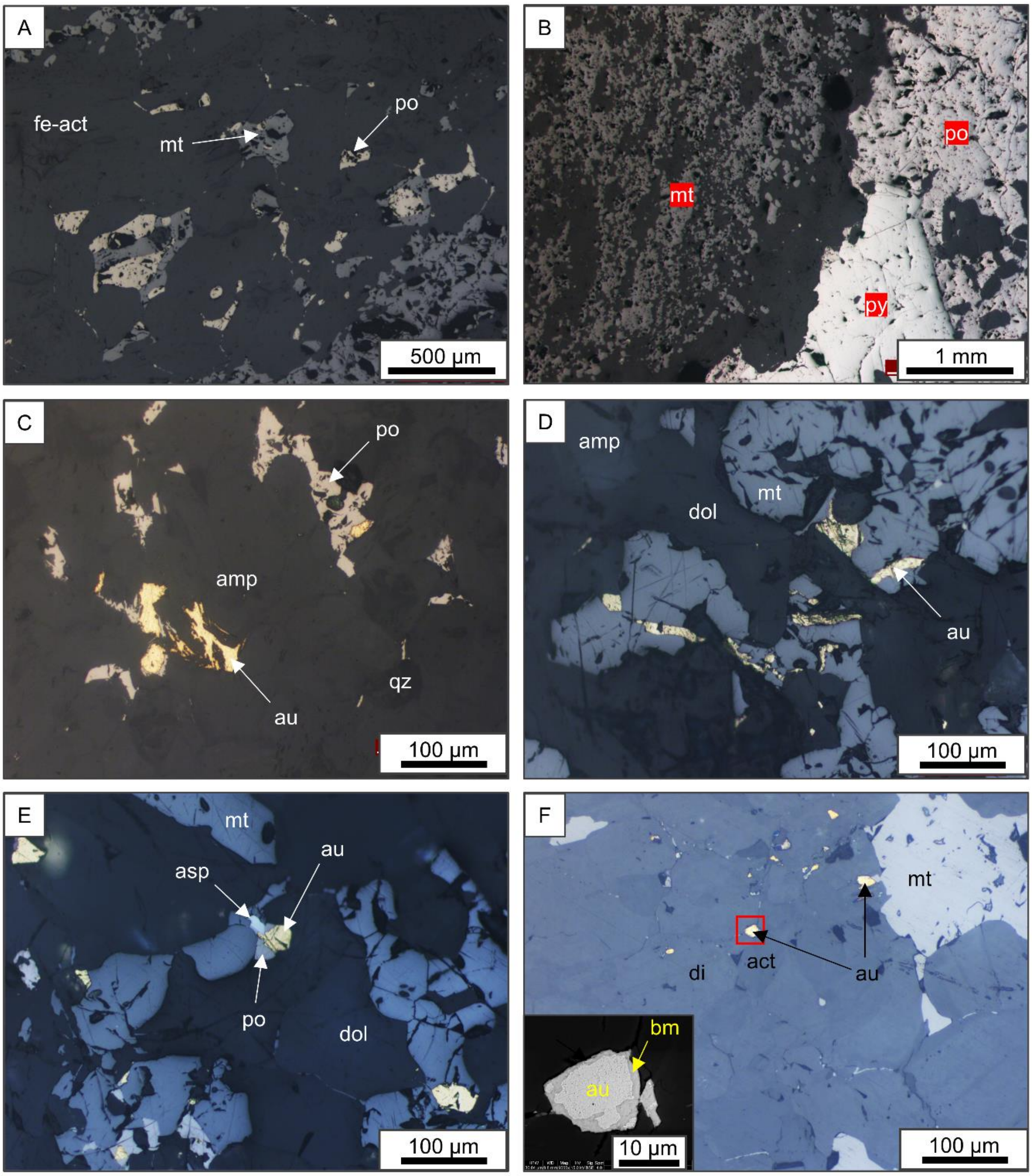


Figure 2.12. Paragenetic relationships of magnetite, sulfides and gold in the Tucano gold deposit. All photomicrographs are taken under plane-polarized, reflected light. A) Hydrothermal magnetite and pyrrhotite in BIF-hosted Fe-actinolite (fe-act) vein. B) Sulfide front (pyrrhotite and overprinting pyrite (py)) on the right against altered BIF on the left. C) Gold (au)-pyrrhotite association and gold in grain boundaries and cleavage planes in an amphibole (amp)-rich groundmass. D) Gold as anastomosed lenses crosscutting magnetite in dolomite (dol)-rich altered marble. E) Gold crystals in apparent equilibrium with pyrrhotite and arsenopyrite (asp) in a dolomite-rich, altered marble. F) Gold in equilibrium with fine-grained actinolite, the latter replacing diopside along grain boundaries and fissures. Lower left inset highlights, in backscattered electron image, a gold grain rimmed by bismuthinite (bm).

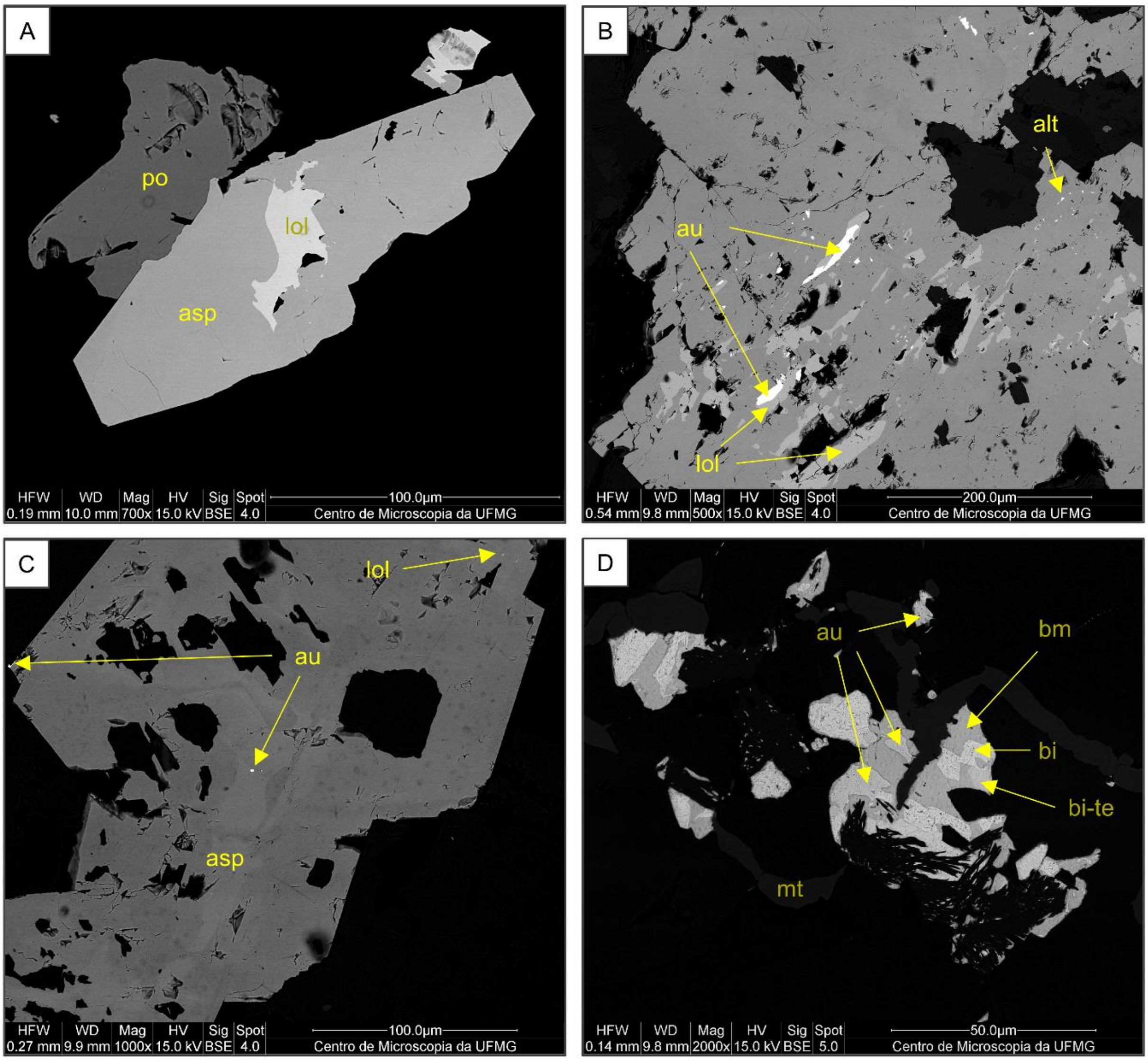


Figure 2.13. Backscattered electron (BSE) images of key paragenetic relationships involving gold, sulfides, sulfarsenide and Bi phases. A) Destabilized loellingite core to euhedral, unzoned arsenopyrite crystal next to pyrrhotite. The euhedral morphology of arsenopyrite in contrast with anhedral pyrrhotite and loellingite suggests attainment of disequilibrium between the latter two, triggering the reaction to produce arsenopyrite. B) Gold and loellingite (lol) lamellae hosted in arsenopyrite, which also contains very fine-grained altaite (alt) crystals. C) Zoned arsenopyrite showing tiny gold crystals at its center and margin, and fine-grained loellingite. D) Gold crystals and Bi phases.

2.7.3 Late (retrograde) low-temperature stage alteration (Late D3 to D4)

The high-temperature mineral assemblages show localized effects of late retrograde alteration affecting alteration zones in both host rocks. Such examples include: (i) chlorite replacing phlogopite (Fig. 2.14a) (12) and locally biotite; (ii) serpentine replacing olivine (13), accompanied by formation of very fine-grained magnetite and locally talc, chlorite and carbonate; (iii) replacement of clinopyroxene along grain boundaries and fissures, by clinozoisite, sericite and carbonate, and; (iv) conversion of amphibole to stilpnomelane (14). Locally, a second arsenopyrite generation (asp-2) (Fig. 2.15) is identified as dendritic mantling around main-stage arsenopyrite (asp-1) (Fig. 2.14b). Thin and irregular V4 veins typically contain euhedral quartz and calcite, the latter locally observed as fine-grained radial spheroids and comb-textured crystals along vein margins. Stilpnomelane is also observed and commonly make up the selvage of such veins (Fig. 2.14c). Tabular pyrrhotite is common whereas sphalerite is rare and, locally, masses of euhedral to subhedral pyrite are observed. Serpentine-dolomite veins (Fig. 2.14d) are accompanied by mottled serpentine-magnetite aggregates, after olivine, in the wallrock.

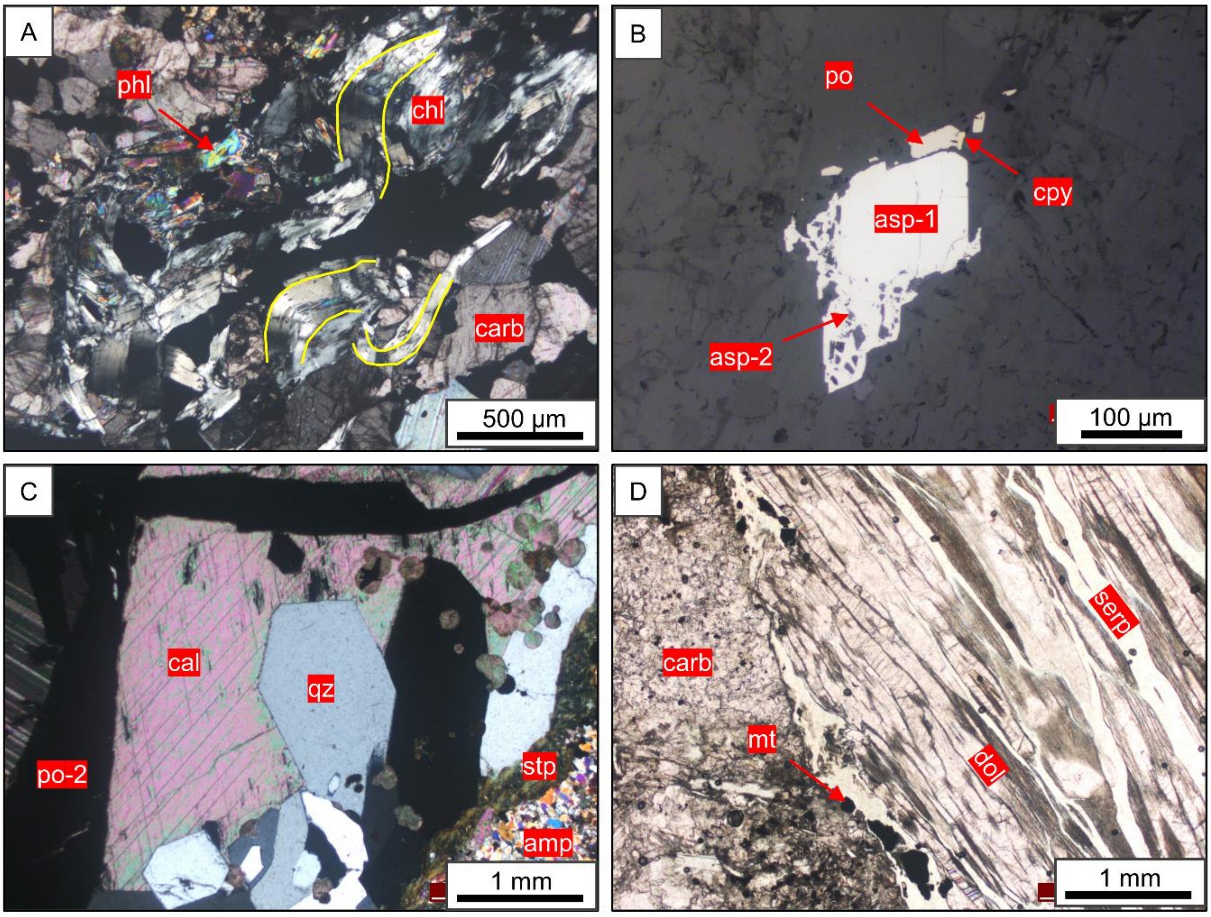


Figure 2.14. Selection of late-stage, retrograde alteration at the Tucano gold deposit. A) Openly folded pseudomorphic chlorite after hydrothermal phlogopite, in altered marble (cross-polarized transmitted light). B) Arsenopyrite-2 (asp-2) overgrowth on main stage arsenopyrite-1 (asp-1), the latter in apparent textural equilibrium with pyrrhotite (po) and chalcopyrite (cpy) (plane-polarized reflected light). C) Euhedral quartz (qz) and calcite (cal), as well as spheroidal calcite and tabular pyrrhotite (po) in vein with stilpnomelane (stp) selvage replacing wallrock amphibole (amp) (cross-polarized transmitted light). D) Serpentine-dolomite filling in E-W-trending fault (plane-polarized transmitted light).

2.7.4 Granite-related alteration

Hydrothermal alteration products are also documented along the contact between the unfoliated leucogranite dikes and their wallrocks. Metasomatic halos are thin, rarely surpassing 5 cm wide, and consist of an inner garnet wall (endoskarn) and an external clinopyroxene-amphibole wall (exoskarn). Amphiboles encompass both calcic amphiboles of the tremolite-ferroactinolite series, and calcium-poor amphiboles of the cummingtonite-grunerite series. The former typically replaces clinopyroxene along grain boundaries and intracrystalline fissures, thereby producing sieve textured crystals. In addition, fine- to medium-grained apatite and quartz occur as inclusions in the coarse-grained garnet and clinopyroxene. Some minor interstitial calcite is common.

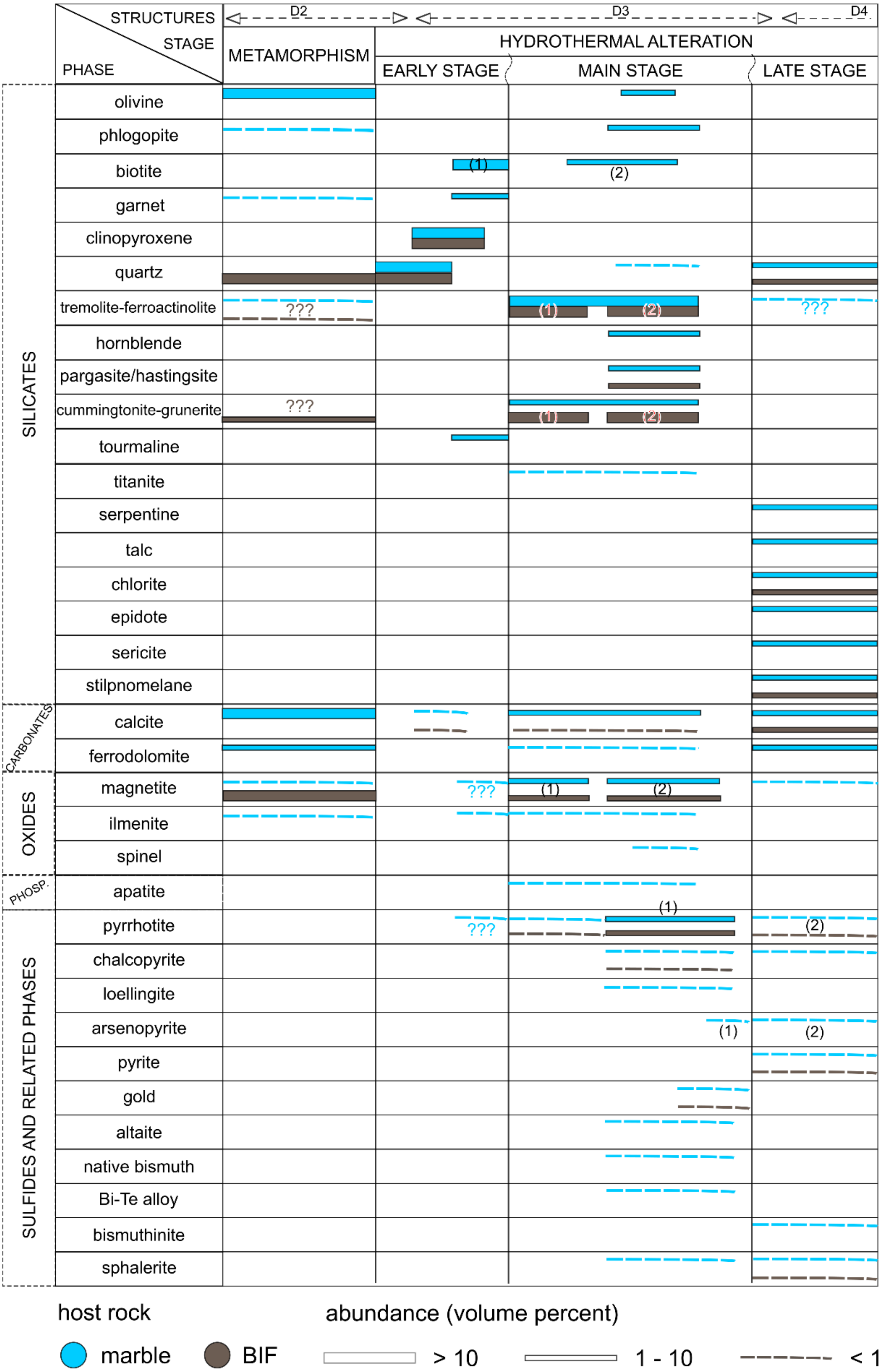


Figure 2.15. Paragenetic sequence of the hydrothermal mineral assemblages developed at the Tucano gold deposit. The metamorphic minerals are also included.

2.8 Mineral Chemistry

2.8.1 Olivine, clinopyroxene and garnet

Hydrothermal olivine in marble is forsterite (Fo)-dominated yet shows a slightly higher fayalite (Fa) component than its metamorphic counterpart (Fig. 2.16a). Average composition of selected crystals (n=5) is $Fo_{53}Fa_{43}Tf_4$. Marble-hosted clinopyroxene (n=25) falls in the diopside field (0.543 < X_{Mg} < 0.878), whereas BIF-hosted clinopyroxene (n=8) is dominantly hedenbergite (0.454 < X_{Mg} < 0.517). Clinopyroxene crystals hosted in early D3 veins alongside quartz (n=5) straddle the diopside-hedenbergite boundary (0.445 < X_{Mg} < 0.558) (Fig. 2.16b). Hydrothermal garnet shows a large compositional range (Fig. 2.16c, d), but in general it contains higher grossular (4 – 34%) and some minor andradite (up to 8%), when compared to metamorphic and magmatic ones. They are chemically homogeneous, with exception of garnet found along reaction rims on the contact of supracrustal rocks with leucogranite. EPMA data for metamorphic, magmatic and hydrothermal minerals are available in electronic Appendix Table A6.

2.8.2 Amphiboles, phlogopite, biotite and chlorite

There are three hydrothermal amphibole groups: Na-poor calcic amphiboles (Fig. 2.17a), Na-bearing calcic amphiboles (Fig. 2.17b) and Mg-Fe-Mn amphiboles (Fig. 2.17c). The first ranges from tremolite-actinolite to magnesiohornblende, for crystals hosted in marble (0.534 < X_{Mg} < 1, n=34), and from actinolite to ferroactinolite for crystals hosted in BIF (0.221 < X_{Mg} < 0.579, n=14) and quartz-clinopyroxene veins (0.383 < X_{Mg} < 0.597, n=14). The second group encompasses pargasite and magnesiohastingsite (0.745 < X_{Mg} < 0.942, and 1,71 wt. % < Na_2O < 3,03 wt. %, n=16), depending on the relative abundances of Al and Fe^{3+} in the octahedral site. As for the third compositional group, cummingtonites prevail in marble (0.792 < X_{Mg} < 1, n=7) whereas BIF (0,437 < X_{Mg} < 0,557, n=6)- and quartz-clinopyroxene-vein (0,405 < X_{Mg} < 0,653, n=13)-hosted crystals lie about the cummingtonite-grunerite transition.

Hydrothermal biotite 1 (n=4) has relatively high Al_2O_3 (18.14 – 19.25 wt. %) and MgO (0,642 < X_{Mg} < 0,672), low Ba (0.00 – 0.10 wt. %) and TiO_2 ranging from 1.22 to

1.34 wt. %. Biotite 2 (n=9) has comparatively lower Al_2O_3 (14.19 – 15,92 wt. %), a wider relative ratio between Fe and Mg (0,502 < X_{Mg} < 0,744), higher Ba (0.29 – 3.26 wt. %) and variable TiO_2 (0.20 – 2.62 wt. %). Hydrothermal phlogopite (n=23) has variable Al_2O_3 content (15.43 – 19.78 wt. %), high MgO (0,865 < X_{Mg} < 1), variable Ba (0.00 – 1.96 wt. %, with low mean value = 0.29 wt. %) and low TiO_2 (0.05 – 0.40 wt. %). It is remarkably distinguished from metamorphic phlogopite by higher Na/K ratio, hence belonging to the phlogopite-aspidolite series (Fig. 2.17d). Overall, hydrothermal amphiboles, biotites and phlogopite display a higher Fe^{3+}/Fe^{2+} ratio than their metamorphic equivalents.

Late-stage chlorite is mostly classified between sheridanite and clinochlore, with Si in atoms per formula unit ranging from 5.39 to 5.78, and X_{Mg} from 0.812 to 0.860. Other compositional types may be recorded in the deposit as attested by one outlier plotting in the diabantite field (Fig. 2.17e).

2.8.3 Carbonates, ilmenite and spinel

Two carbonate species are identified, namely calcite and ferrodolomite, both Mn-bearing (up to 5 wt. %). Hydrothermal spinel has an intermediate composition between the hercynite and spinel end members, and are hence classified as pleonaste, having ZnO content ranging between 0.4-1.4 wt. %. Ilmenites are almost ubiquitously manganoan and locally the atomic Mn/Fe ratio can exceed 1. Thus, these titanium-rich oxides range from ilmenite to ferroan pyrophanite.

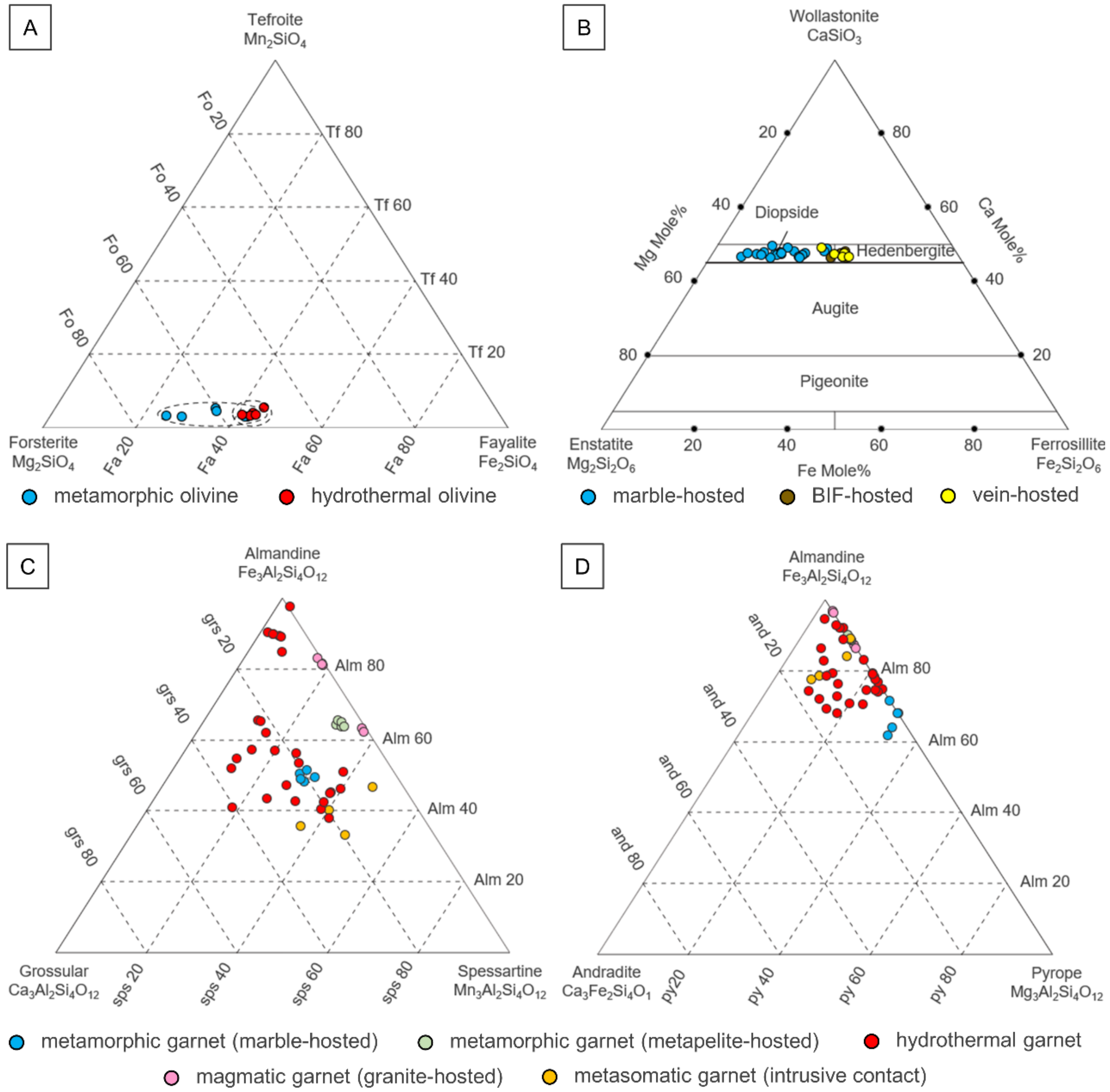


Figure 2.16. EPMA data for selected anhydrous silicate minerals. A) Metamorphic and hydrothermal olivine compositions in a forsterite-fayalite-tefroite ternary diagram. B) Composition of clinopyroxene in the pyroxene ternary diagram; color shaded according to the respective host rock. C) and D) Garnet compositions encompassing the various types of garnets identified during petrographic work.

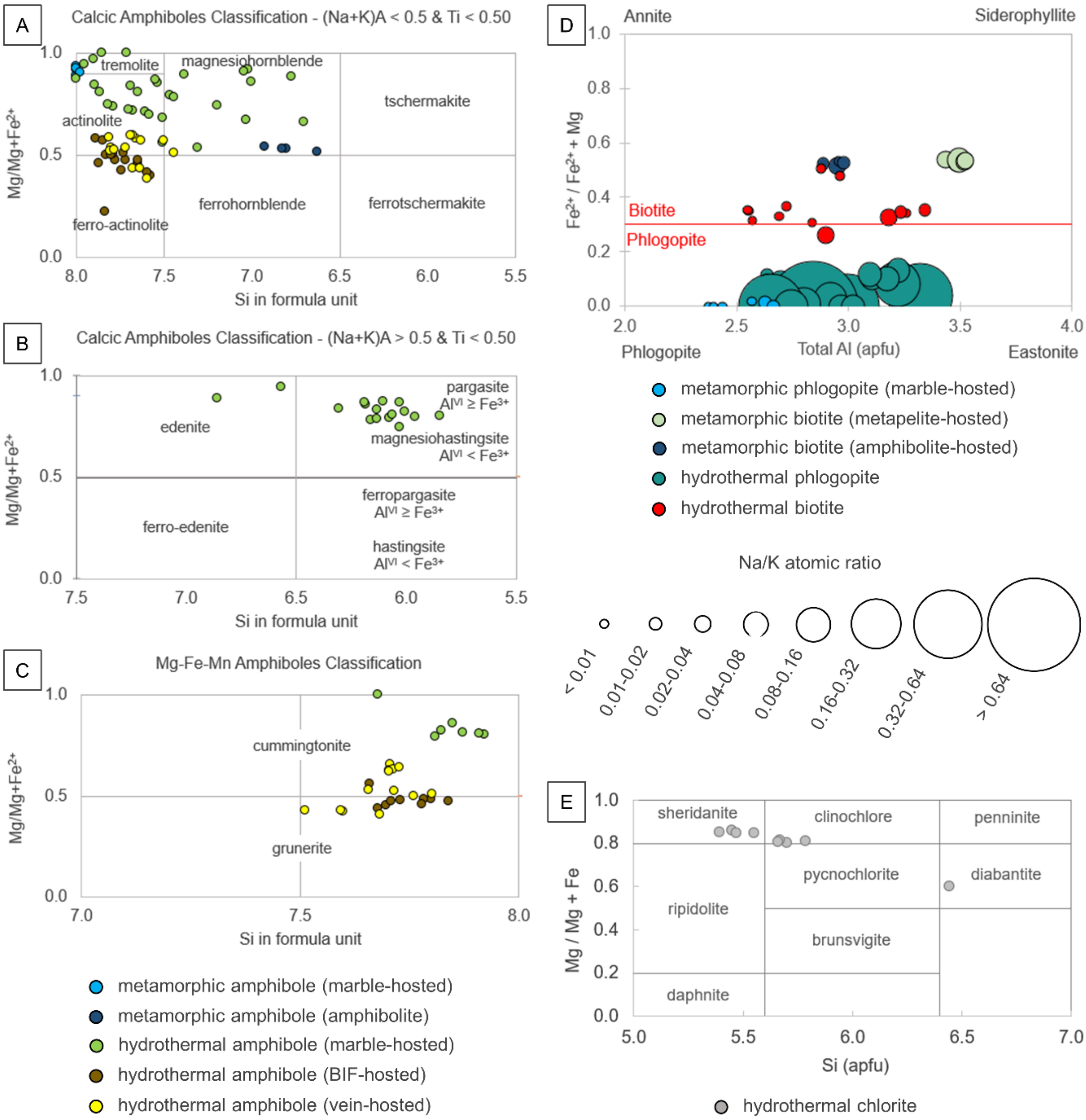


Figure 2.17. EPMA data for amphibole and biotite-phlogopite from different origins (metamorphic vs hydrothermal) and across distinct host rocks, as well as hydrothermal chlorite compositions. A) Calcic amphiboles classification diagram (after Leake et al., 1997) for compositions having $(Na+K)_A$ < 0.5 and Ti < 0.5 (apfu). B) Classification diagram of calcic amphiboles (after Leake et al., 1997) for compositions having $(Na+K)_A$ > 0.5 and Ti < 0.5 (apfu). C) Classification diagram of Mg-Fe-Mn amphiboles (after Leake et al., 1997). D) Classification diagram of Rieder et al. (1998) for biotite and phlogopite, with data point sizes indicating atomic Na/K ratios. E) Classification diagram of Hey (1954) for chlorite.

2.8.4 Arsenopyrite, loellingite and gold

SEM imaging reveals that some arsenopyrite crystals are internally zoned (Fig. 2.13c) and core-margin pairs reveal large differences in As (up to 5.5 wt. %), Co (up to 2.4 wt. %) and Ni (up to 1.7 wt. %). Total Co + Ni can exceed 5 wt. %. In contrast, unzoned arsenopyrites show < 1 wt. % difference from core to margin and Co + Ni generally < 1 wt. %. Loellingite crystals are internally homogeneous, but Co + Ni ranges significantly between individual crystals, from < 0.5 to > 6 wt. %. Gold crystals generally display significant Ag content (up to 14 wt. %) and therefore a range in fineness between 765-774.

2.8.5 Geothermometry

2.8.5.1 Early calc-silicate hydrothermal alteration

Garnet-biotite equilibrium allows for temperature determination using the geothermometer from Holdaway (2000) and yield temperature estimates at 578 ± 26 °C (1σ, n=4). This is further supported by estimation via the Ti-in-biotite geothermometer (Henry et al., 2005), through which similar values were obtained (568 ± 23 °C - 1σ, n=4).

2.8.5.2 Main stage hydrothermal alteration

Using Henry et al. (2005) equation for two biotite-2 crystals, temperature estimates at 550 and 577 °C were obtained. The calcite-dolomite solvus geothermometer of Anovitz and Essene (1987) revealed a temperature of 536 °C. Unzoned arsenopyrite crystals having low Co+Ni+Sb (< 0.4 wt. %) were used for temperature estimation (Fig. 2.18a, b), yielding value of 500 ± 17 °C (1σ, n=6), which are significantly lower than those obtained from the silicate assemblage. Conversely, it is observed that loellingite displays resorption margins within the host arsenopyrite crystal, suggesting simultaneous crystallization of pyrrhotite and loellingite at higher temperature and subsequent retrograde solid-solid reaction to produce arsenopyrite as the system crosses the pyrrhotite-loellingite-arsenopyrite equilibrium line (Fig. 2.13a). Thus, the estimated average temperature is interpreted as a minimum temperature for this phase of the main stage hydrothermal alteration and mineralization event.

2.8.5.3 Late-stage hydrothermal alteration

The Zang and Fyfe (1995) calibration was applied to the chorite compositions clustered between sheridanite and clinochlore compositions, yielding temperature of 290 ± 26 °C (1σ, n=8).

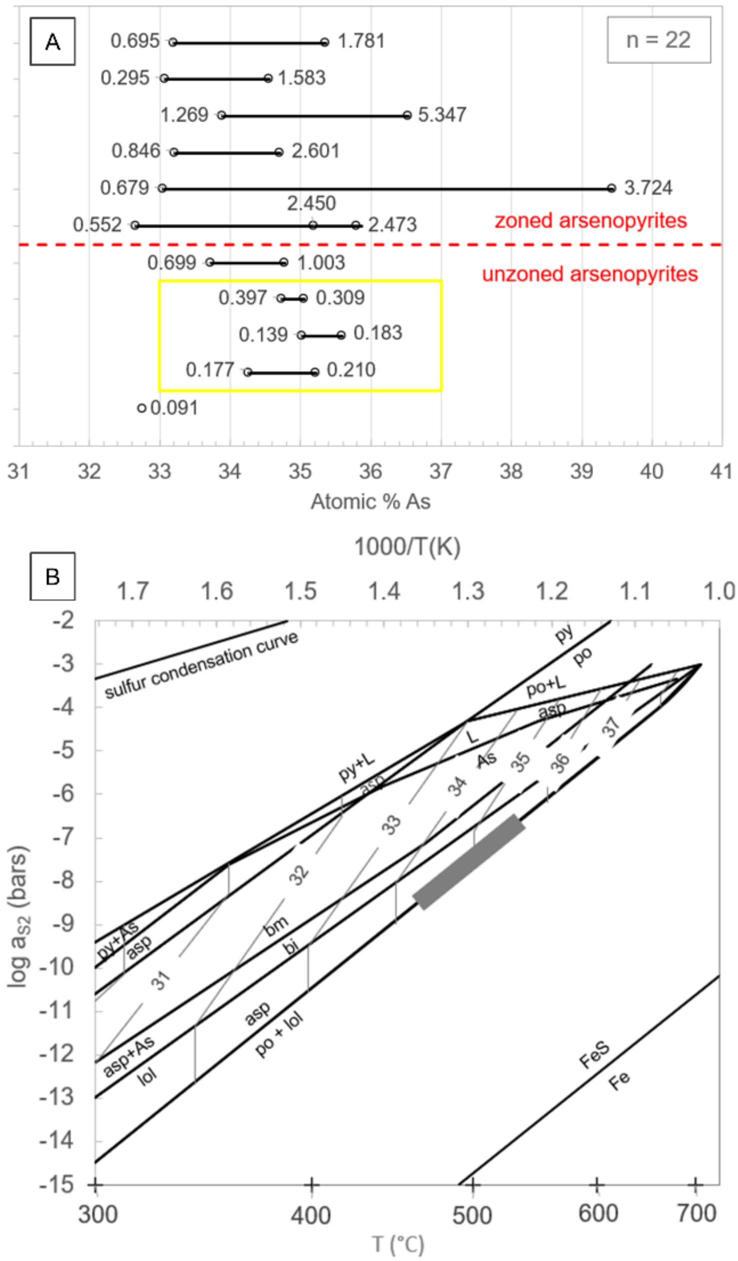


Figure 2.18. A) Atomic percent As measured in core-margin pairs of arsenopyrite in zoned and unzoned crystals. Single spot is reported for a very fine-grained, unzoned crystal. Figures beside data points indicate the weight percent sum of Co+Ni+Sb. The yellow box outlines the data points used for temperature estimates, i.e., crystals having <1 atomic percent As difference between core and margin and low trace elements. B) Arsenopyrite geothermometry (Sharp et al., 1985, after Kretschmar and Scott, 1976) showing with red lines the crystallization conditions of retrograde arsenopyrite in logaS_2 – temperature space.

2.8.6 Magnetite

LA-ICP-MS analyses have encompassed metamorphic BIF magnetite (magnetite-0) and hydrothermal magnetite 1 and 2. Figure 2.19 illustrates the chemical signature of the various magnetite groups in discrimination diagrams, binary and ternary plots, and magnetite-0-normalized spidergrams. LA-ICP-MS data for magnetite is available in electronic appendix Table A7.

Magnetite 0 has high contents of Mg (54 – 1,340 ppm), Al (223 – 484 ppm), Ti (628 – 1,246 ppm), V (39 – 46 ppm), Cr (12 – 25 ppm), Mn (316 – 1,064 ppm) and Zn (9 – 169 ppm). Ga and Ge range between 3.5 – 5 ppm and 1.6 – 2.9 ppm, respectively, and Cu values range between 0.8 – 18 ppm, with a fraction of readings below detection limit. Sc, Co and Ni, if detectable, are low, averaging 0.10, 0.46 and 1.68 ppm, respectively. Magnetite-1 in altered BIF is enriched in Al, V, Co and Zn, and depleted in Sc, Ti and Cu, when compared to magnetite-0. Magnetite-2 in altered BIF shows two distinct compositional clusters, which can be readily distinguished based on their Ti and V contents. One of them has a trace element signature relatively similar to magnetite-1, whereas the second is enriched in Ti, V and Cr, and depleted in Mn, Co, Cu, Zn, Ga and Ge, when compared to magnetite-0.

Magnetite-1 in altered marble shows highly enriched Sc contents, with substantial enrichments also in Mg, Al, V, Mn, Zn, when compared to magnetite-0. In addition, minor enrichments in Cr, Co and Ge, and depletions in Ti, Cu and Ga are reported. Three distinct compositional patterns are identified for magnetite-2 in altered marble. One shows Sc enrichment, slightly higher than that of magnetite-1, followed by a small Ti trough. It also shows a distinct Ge enrichment when compared to magnetite-0, which is not shared by other magnetite-2 subtypes. The second is enriched in Sc relative to magnetite-0 in similar magnitude as magnetite-1, displaying also distinct Cr and Zn peaks, as well as a minor V trough. The third subtype of magnetite-2 in altered marble remarkably contrasts with other hydrothermal magnetite in altered marble as it lacks the characteristic Sc enrichment, having similar values for this element to magnetite-0. Irrespective of host rock, hydrothermal magnetite is strongly depleted in Cu when compared to metamorphic magnetite-0 of BIF.

2.8.7 Pyrrhotite

No remarkable systematic differences are identified between different textural and paragenetic types of main stage alteration pyrrhotite-1 and late-stage alteration pyrrhotite-2. Nonetheless, noticeable differences are reported in Co and Ni contents between BIF-hosted (0.15-33 ppm Co; 23-51 ppm Ni) and marble-hosted (5-160 ppm Co; 22-193 ppm Ni) pyrrhotite crystals. Irrespective of host rock, the lower end of distribution for these metals is documented in pyrrhotite crystals with local pyrite overgrowth. Resolvable differences can also be observed for As and Te contents between wallrock-hosted and vein-hosted pyrrhotite crystals, with slightly higher values in the latter. Au contents are ubiquitously low, ranging from < 1 ppb to 0.3 ppm. LA-ICP-MS data for pyrrhotite is available in electronic Appendix Table A8. The electronic appendix Figure A8 shows elemental concentration boxplots for main alteration stage (BIF-, marble- and vein-hosted) and late alteration stage (vein-hosted) pyrrhotite.

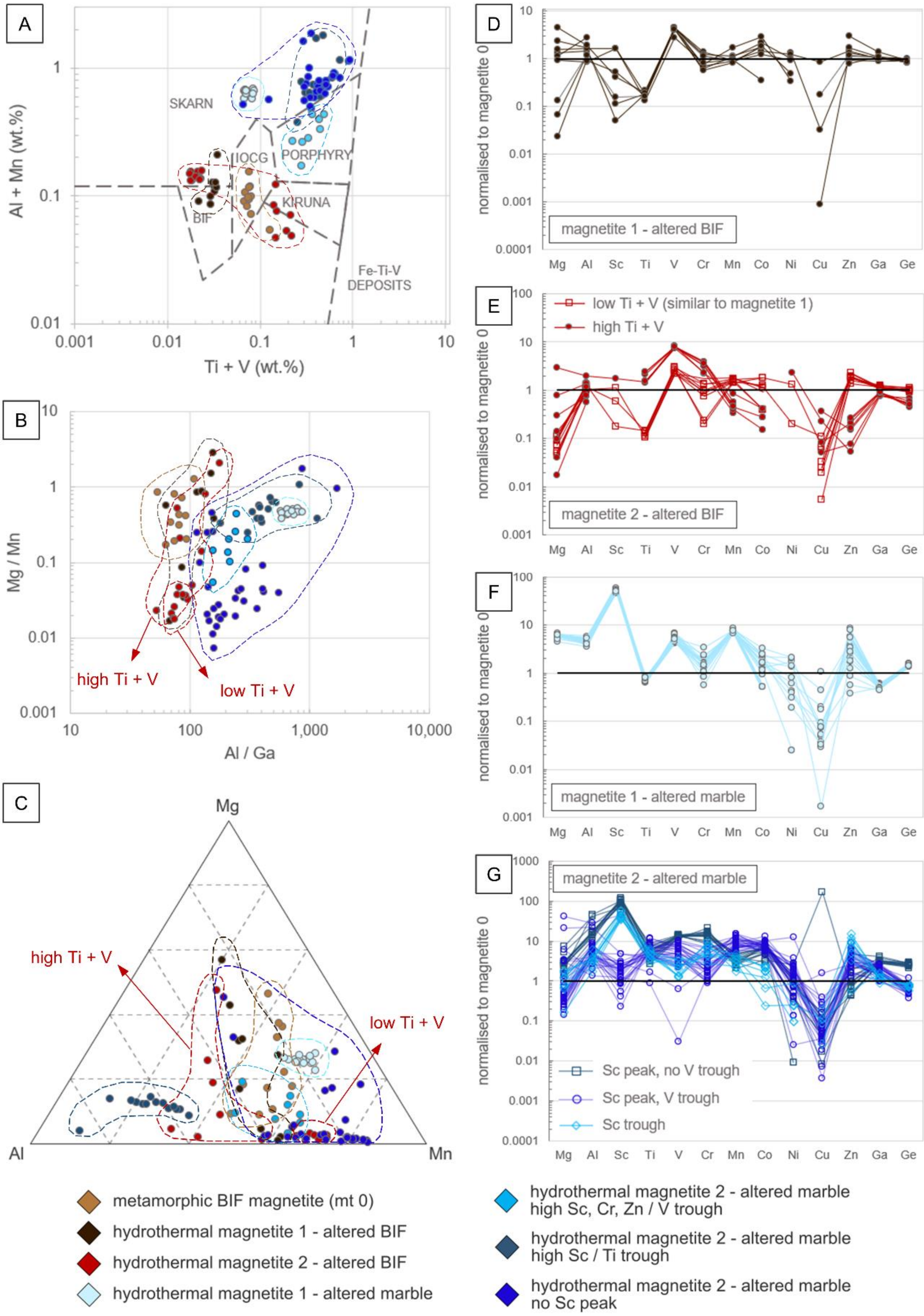


Figure 2.19. Mineral chemistry of magnetite (data obtained by LA-ICP-MS). A) Ti + V vs. Al + Mn plot with deposit fields proposed by Dupuis and Beaudoin (2011) and Nadoll (2011) – values in weight percent. BIF-hosted magnetite mostly plots outside its suggested boundary, and marble-hosted magnetite fall within compositional field indicative of magmatic-

hydrothermal origin. B) Binary plot showing Al/Ga vs. Mg/Mn. C) Ternary diagram with the major spinel elements Mg-Al-Mn. D) to G) Mineral chemistry of different generations of hydrothermal magnetite across distinct host rocks, normalized to metamorphic BIF magnetite-0.

2.9 Alteration Geochemistry

This section is focused on hydrothermal alteration, addressing the compositional changes across the distinct alteration zones for BIF and marble host rocks. Next, a more detailed overview of hydrothermal alteration will look at the internal data structure to unravel the fingerprint of the gold mineralization and elemental mass balance.

2.9.1 BIF alteration chemistry

An increase in CaO and MgO is noticed (Fig. 2.20a) from least altered rocks to the proximal alteration zone. Average CaO + MgO increases from 4.7 wt. % in least-altered BIF through 9.3 wt. % in distal alteration zone to 16.9 wt. % in proximal alteration zone. This is accompanied by a decrease in SiO2 content from average 46 wt. % in least-altered BIF through 43.1 wt. % in distal alteration zone to 31.3 wt. % in proximal alteration zone (Fig. 2.20a). Such changes reflect the progressive increase in hydrothermal amphibole content at the expense of the metamorphic quartz. The Na_2O/K_2O ratios, and CO_2 and S contents are also increased in altered BIF (Fig. 2.20b), which reflects the development of amphiboles with greater Na content as alteration advances, carbonation and sulfidation, respectively. PAAS-normalized REE+Y pattern for altered BIF is similar to that for its least-altered counterpart, with subtle HREE + Y enrichment. One sample, however, exhibits higher total REE + Y content than the range observed in least-altered BIF (Fig. 2.20e). Alongside Au, other elements that experience enrichment towards proximal alteration zone include Ag, Te, Bi, W, Se, Zn, Pb and V. This reflects the occurrence of altaite in gold-bearing zones (reservoir for Pb, Te and Se), gold-related Bi phases, scheelite, hydrothermal magnetite, and the significant Ag content in gold particles.

2.9.2 Marble alteration chemistry

Major oxide element composition changes dramatically from least-altered marble to proximal alteration zone. Overall, CaO, MgO and MnO are depleted as alteration evolves. Average CaO in least-altered marble is 27.6 wt. %, reducing to 22.2 wt. % in distal alteration zone and reaching 13.65 wt. % in the proximal alteration zone. Likewise, average MgO content reduces from 15 wt. % in least-altered marble through 12.1 wt. % in distal zone to 7.46 wt. % in the proximal zone. This reflects the progressive replacement of carbonate and olivine by amphibole and subordinately phlogopite. In contrast, Al_2O_3 and Fe_2O_{3total} show increased average concentrations with evolving alteration (Fig. 2.20c), which is a reflection of the highest concentrations of such elements in the developed hydrothermal silicates and magnetite. Mean contents for Fe_2O_{3total} in distal and proximal alteration zones are 24.09 and 44.82 wt. %, respectively, reflecting an increase in magnetite. An increase in Na_2O/K_2O, Al_2O_3/CaO and Fe_2O_{3total}/CaO ratios and a decrease in SiO_2/Al_2O_3 ratio are recorded with progressive alteration intensity (Fig. 2.20c, d). The S contents increase in similar fashion to observed in BIF, indicating increasing volume of pyrrhotite. In contrast, CO_2 is progressively depleted from least-altered rock to proximal alteration zone, indicating a systematic decarbonation. PAAS-normalized REE+Y for altered marble samples lie systematically above the range observed in their least-altered counterparts (Fig. 2.20f). In terms of trace elements, Au, Ag, Te, Bi and Cu are systematically enriched towards proximal alteration zone, with W, Se and V experiencing enrichment more locally.

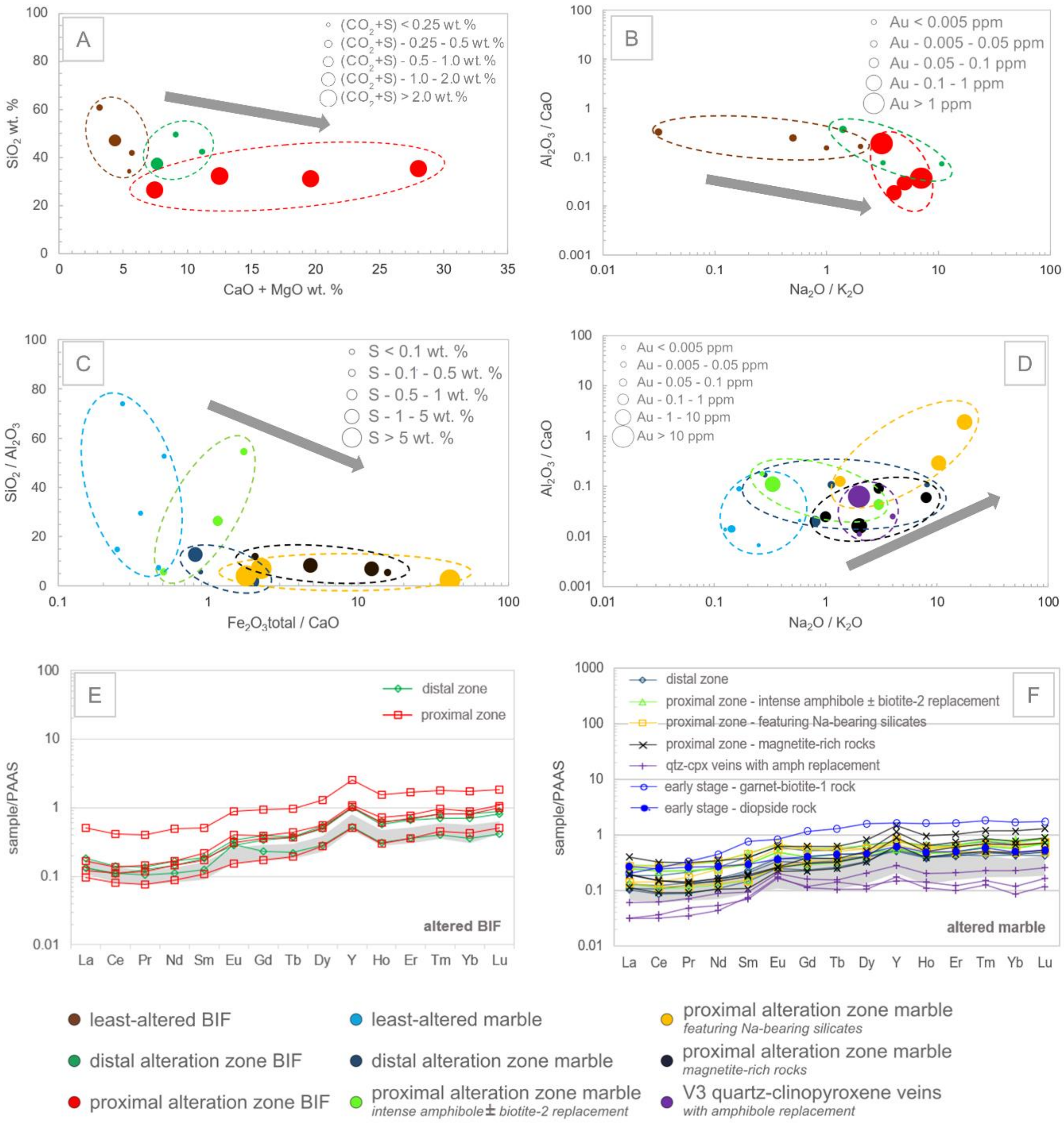


Figure 2.20. Geochemistry of hydrothermal alteration in BIF and marble from the Tucano gold deposit. A) CaO + MgO versus SiO_2 for least altered and altered BIF samples. Data point size indicates compositional range of CO_2 + S (wt. %). B) Na_2O/K_2O versus Al_2O_3/CaO for least altered and altered BIF samples. Data point size indicates compositional range of Au in ppm. C) Fe_2O_{3total}/CaO versus Al_2O_3/SiO_2 for least altered and altered marble samples. Data point size indicates compositional range of S in wt. D) Na_2O/K_2O versus Al_2O_3/CaO for least altered and altered marble samples. Data point size indicates compositional range of Au in ppm. E) PAAS-normalized REE+Y diagram for altered BIF samples, having least-altered BIF values as the shaded area for comparison. F) PAAS-normalized REE+Y diagram for altered marble and marble-hosted quartz-clinopyroxene-amphibole V3 veins, having least-altered marble values as the shaded area for comparison. Normalization values from Taylor and McLennan (1989).

2.9.3 Hydrothermal footprint of gold mineralization

Gold concentrations show weak to strong positive linear correlations with a series of elements regardless of host rock type, most notably Te (R = 0.85), Ag (R = 0.77) and S (R = 0.71) (Fig. 2.21). These reflect the occurrence of altaite in gold-bearing zones, significant Ag content in gold particles, and sulfidation (pyrrhotite), respectively. Conversely, remarkable differences are documented for gold elemental associations between BIF and marble (Fig. 2.22). On the contrary, vanadium is the strongest positively correlated element with Au in BIF (R = 0.78), showing little to no correlation with it in marble (R = -0.079). Hydrothermal magnetite is likely the main V reservoir, which is more consistently developed in BIF. In addition, Na and W show moderate to strong positive correlation with Au in BIF (R = 0.65 and 0.58, respectively), but are only very weakly correlated in marble (R = 0.07 and 0.14, respectively). These reflect the Na endowment of hydrothermal silicate minerals and the occurrence of scheelite, respectively. It is important to keep in mind that linear correlation coefficients must be looked with caution as anomalous samples may either overshadow an existing correlation or create a false sense of it (Fig. 2.22).

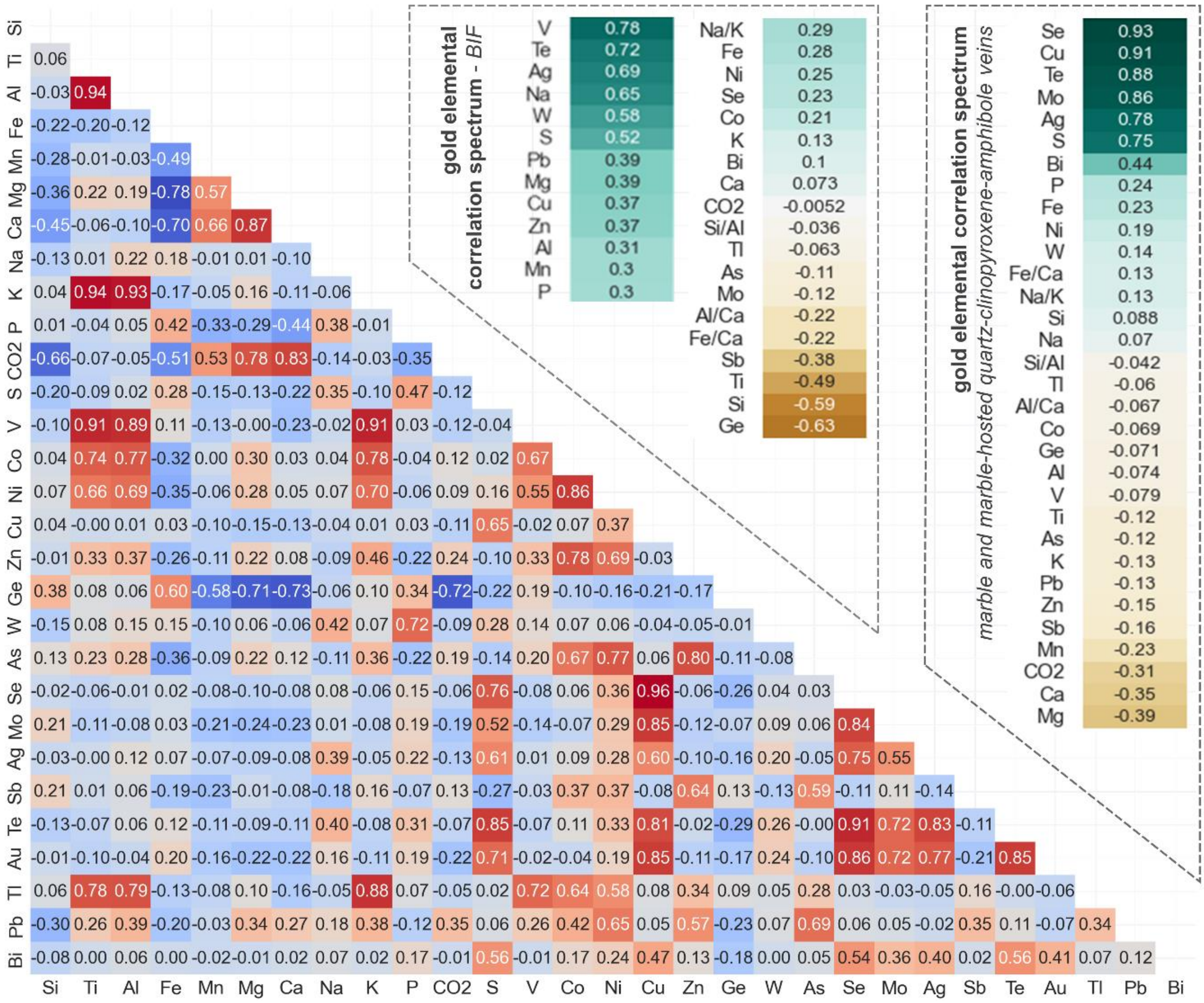


Figure 2.21. Linear correlation heatmap for a series of elements based on least altered and altered samples of both BIF and marble. Gold elemental correlation charts for BIF and marble are separately shown on the upper right corner. Values are arranged in decreasing order of linear correlation.

2.9.4 Mass balance calculations

For mass balance calculations, Ce and Pr were selected as immobile elements due to their near 1:1 ratio through all alteration zones (Fig. 2.23) across both rock types. Isocon diagrams (Grant, 1986) (Fig. 2.24) reveal that both host rocks underwent mass loss during alteration. The percent mass changes from least altered to proximal alteration zone rocks are estimated based on the inverse of the slopes of isocon lines, and these correspond to losses of 47 % for BIF and 58 % for marble (averaging across the three proximal zone types). Mass balance calculations of major and trace elements utilizing the graphical solution for the Gresens (1967) mass transfer equation proposed by Grant (1986) reveal the following (Fig. 2.25): (1) strong hydrothermal addition of Ca, Na, H_2O, CO_2 and S, and loss of Si and K in BIF; (2) significant gains of Au, W, Te, Cd, Bi and, to a lesser extent, V, Se and Pb, in BIF; (3) depletion in Ca, Mg and Mn, and remarkable S and P gains, in marble, and; (4) significant gains of Au, Ag, Te and Bi, in marble. Some differences in elemental gains are observed between the three types of proximal zone in marble: (1) proximal zone A shows Na, K, Cu, Zn and Se addition; (2) proximal zone B shows strong Fe, Na, Cu, W and Se addition, and (3) proximal zone C shows strong Fe, V and W gains. Al gain in proximal zone B likely reflects this zone to be a result of alteration developed on marble intervals with significant detrital contamination.

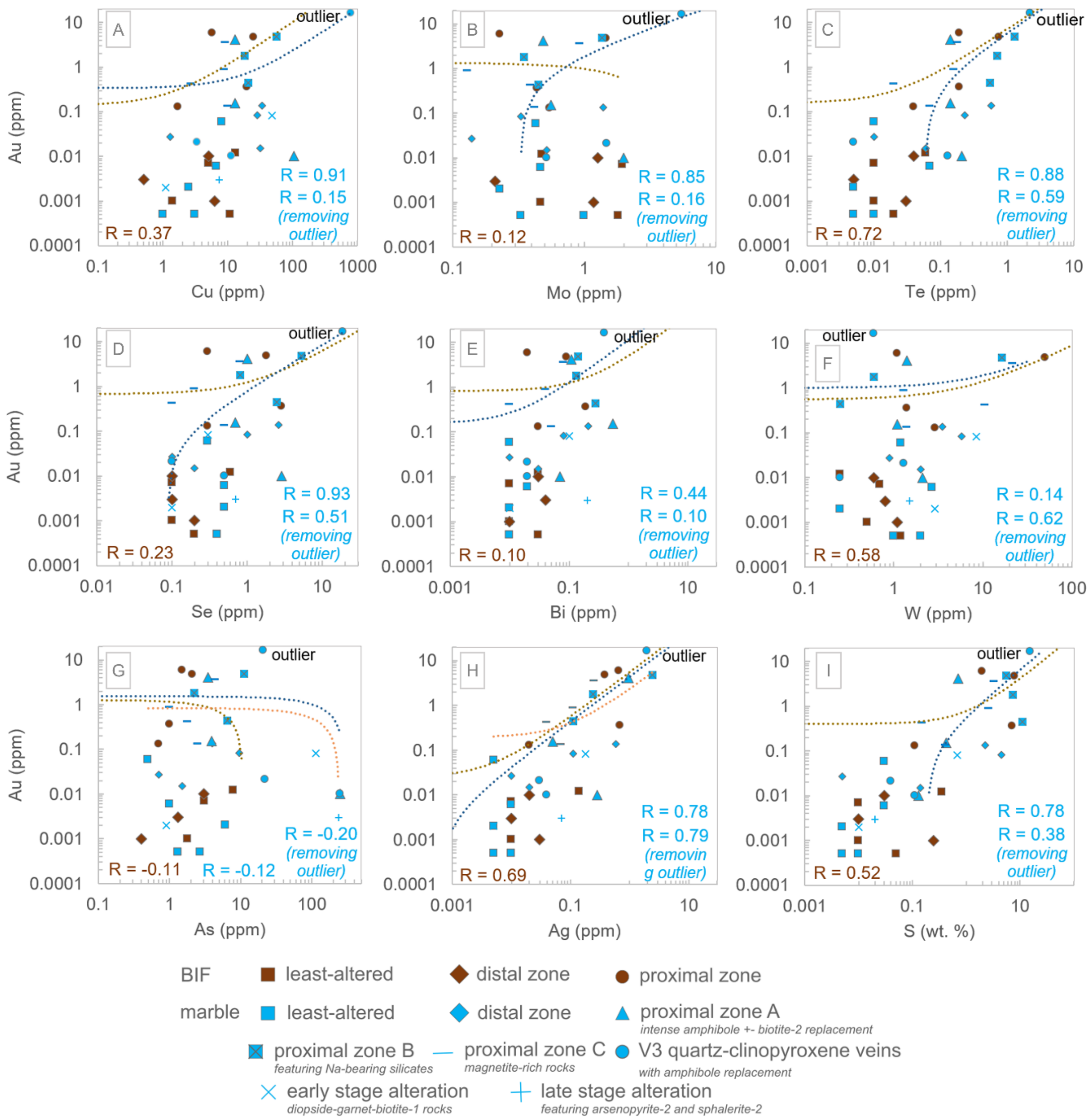


Figure 2.22. Gold linear correlation plots for both BIF and marble host rocks.

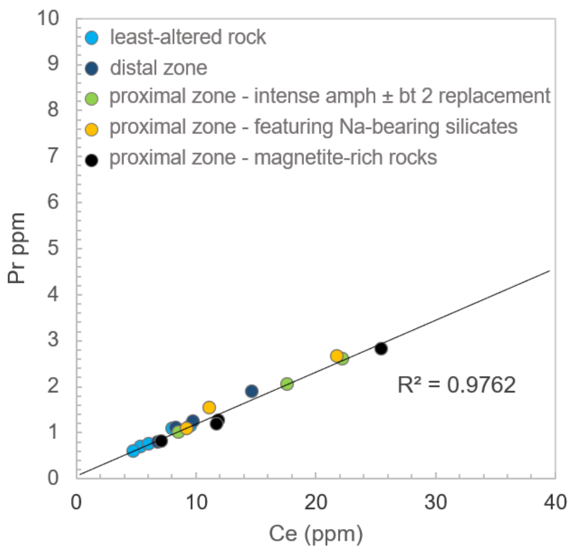


Figure 2.23. Pr versus Ce in least altered and variably altered marble. The linear trend with limited sample dispersion indicates that the ratio of these elements does not change with hydrothermal alteration.

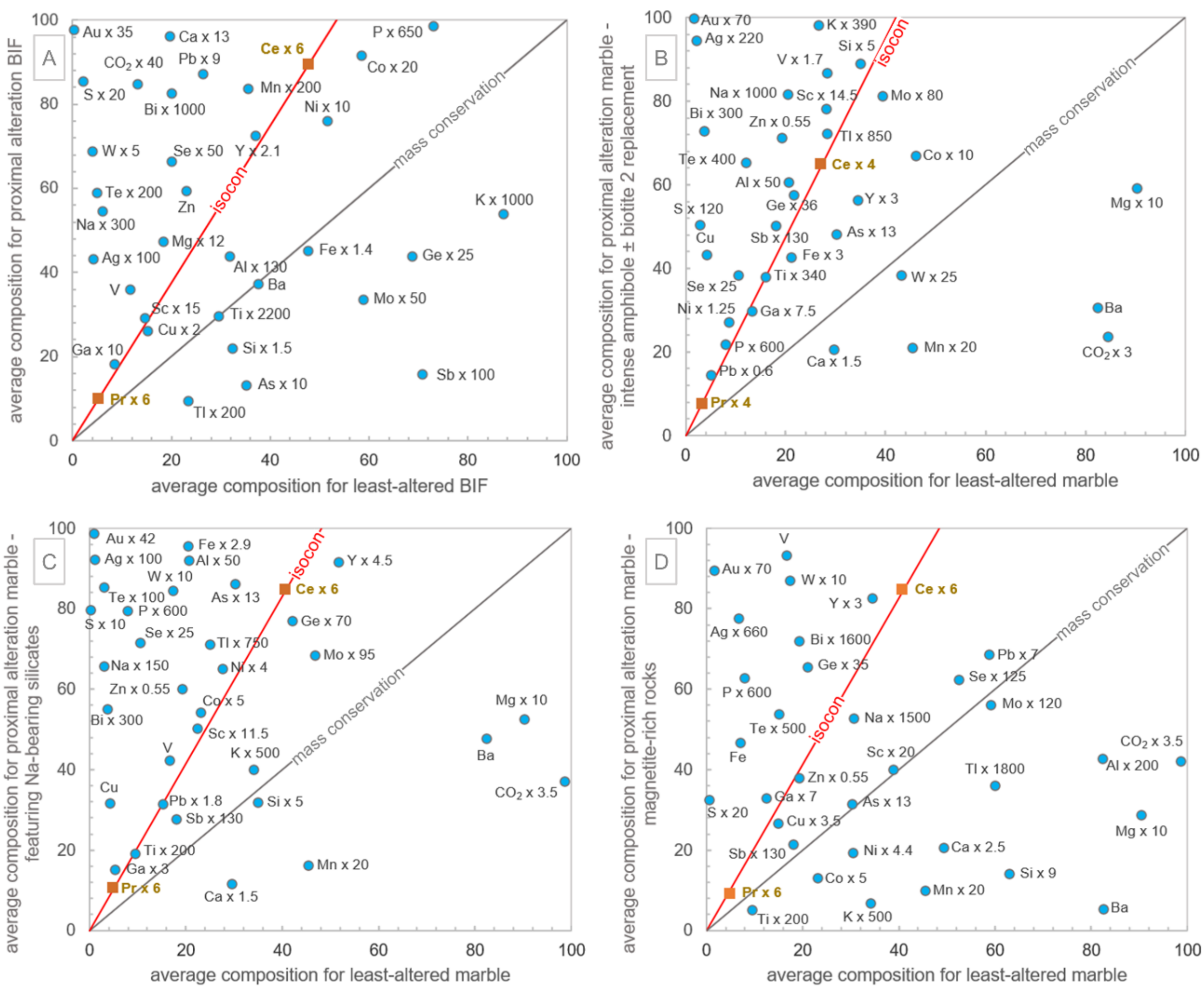


Figure 2.24. Isocon diagrams (Grant, 1986) contrasting average elemental values of least-altered rock types with corresponding average values for proximal alteration zone rocks.

Values for Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, CO_2 and S are in wt. %, and in ppm for the remaining elements. Figures beside element symbols denote multiplying concentration factors as a means to have a more even, easily readable, distribution of the elements within the plot space. Isocons are traced through the selected immobile elements – Ce, Pr.

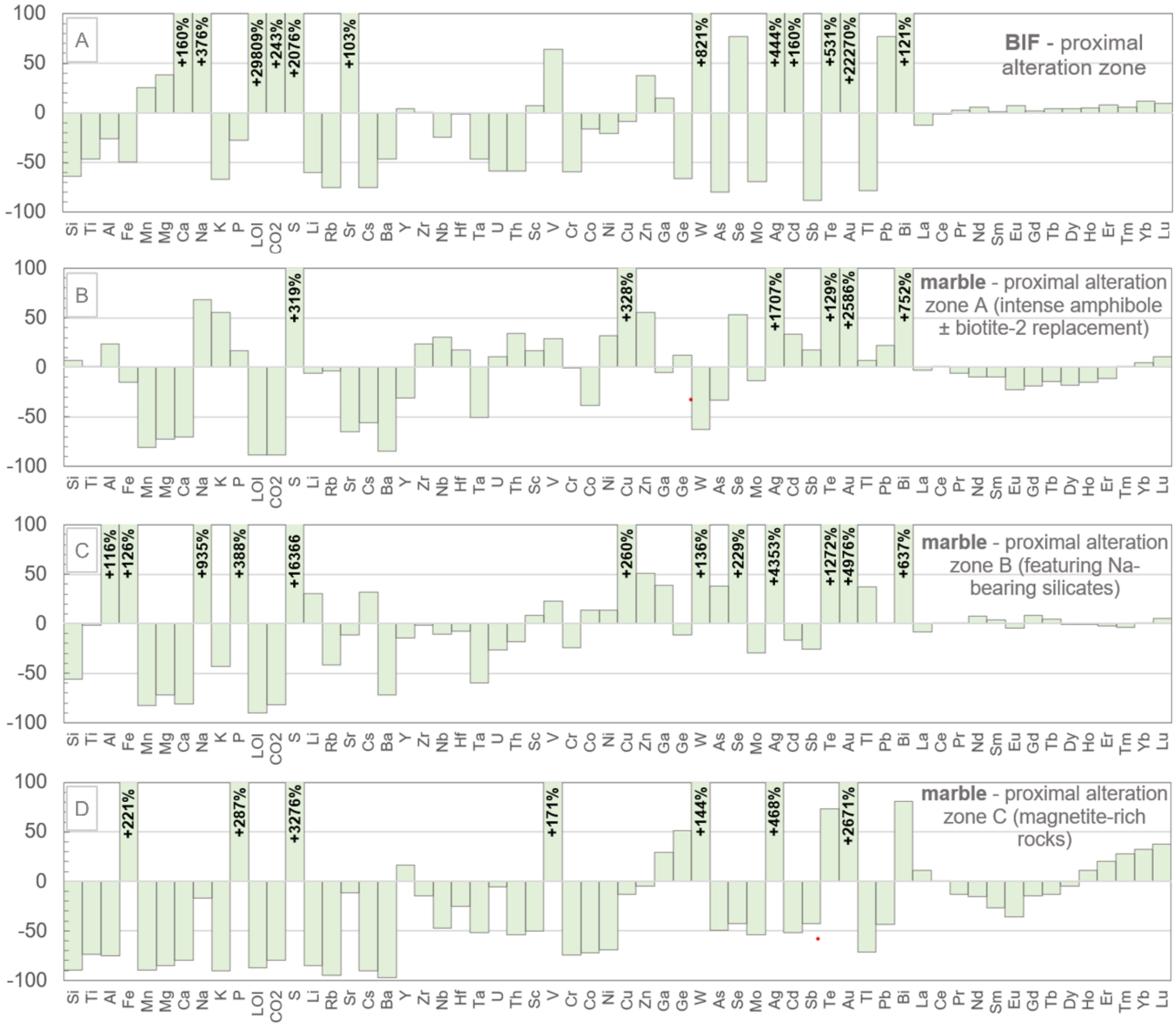


Figure 2.25. Mass balance modelling of major and trace elements utilizing the graphical solution for the Gresens (1967) mass transfer equation presented by Grant (1986).

2.10 Discussion

2.10.1 Constraints on the P-T conditions, redox state and pH of the gold-bearing fluids

Temperature estimates of 480-600 °C for combined early and main stages of alteration, and pressures of about 4 kbars, indicate a deep-seated hydrothermal system compatible with amphibolite facies conditions at mid-crustal (hypozonal) levels.

This temperature range is typical of many hypozonal orogenic gold deposits (Kolb et al., 2015).

Alteration assemblages allow some constraints on the characteristics of the ore fluids at Tucano. Wide distal alteration zones suggest a high fluid/rock ratio, which is further manifested in the alteration mineralogy – clinopyroxene-garnet-amphiboles-phlogopite-magnetite-pyrrhotite – which indicates an intense fluid-buffered composition. Mass balance modelling indicates opposite behavior for BIF and marble with respect to some major elements, particularly Ca, Mg, Mn and C (as CO_2), which are added to the first, but subtracted from the second. This not only indicates significant mobility of these elements during alteration, but also implies that to some extent they were remobilized from one host rock reservoir to the other. Irrespective of host rock, nevertheless, a noticeable hydrothermal addition of Na is attested by incorporation of minor contents of this element into the crystal lattice of hydrothermal silicates – amphiboles and phlogopite. On the other hand, Si and K are mostly subtracted. The sites of maximum Na enrichment (proximal zone B in altered marble) see substantial input of Fe (magnetite and Fe-bearing silicates) and P (apatite). Fe is possibly remobilized from BIF, where it is commonly subtracted, and added to marble, which commonly sees Fe gain. V addition is also reported and its magnitude is controlled by the amount of hydrothermal magnetite. Mass balance modelling also highlights significant trace element enrichment of Ag, S, Te, W, Bi, Se, and locally Cu and V, in addition to Au.

Evolving opaque assemblages in the chronological order (i) magnetite-1, (ii) magnetite-2 + pyrrhotite ± loellingite, (iii) pyrrhotite ± loellingite, and (iv) pyrrhotite ± loellingite ± arsenopyrite, indicate progressive sulfidation during main stage alteration (Fig. 2.26a). In addition, assemblages containing loellingite-magnetite ± ilmenite define reduced fluid conditions, constraining maximum fO_2 values to approximately 1.5 log units above the CO_2-CH_4 buffer. Minimum fO_2 values of 0.5-1.0 log units above this buffer can be inferred based on stability limits of spinel solid solutions (Mikucki and Ridley, 1993). Assemblages containing diopside, quartz and tremolite indicate nearly neutral conditions – pH = 5.0-6.0 (Mikucki and Ridley, 1993) (Fig. 2.26b).

Moderate to strong correlation of Au with S and its occurrence towards the end of the main stage of alteration coevally with increasing sulfur activity suggests that sulfidation may have been an important mechanism for Au precipitation. This can be tracked in the Au content of hydrothermal magnetite. Pre-sulfidation magnetite-1 is slightly Au-poorer in comparison with early- to syn-sulfidation magnetite-2 (BIF mt-1: 0.011-0.035 ppm, average = 0.019 ppm; BIF mt-2: 0.003-0.078 ppm, average = 0.035 ppm; marble mt-1: 0.002-0.037 ppm, average = 0.014 ppm; marble mt-2: 0.001-0.102 ppm, average = 0.019 ppm). Reduction of Fe^{3+} and the resulting precipitation of pyrrhotite decreased activity of reduced sulfur species in the fluid. This in turn destabilizes Au bisulfide complex and prompts precipitation. Nonetheless, the intimate association of some gold with Fe-bearing silicates and magnetite, with no direct contact with pyrrhotite, suggests a second mechanism for gold precipitation. The dissociation of Au bisulfide complex not prompted by sulfur extraction as sulfide mineral implies that Au solubility decrease was driven, under these circumstances, by oxygen fugacity change rather than modifications in sulfur activity in the fluid phase. Reporting of gold inclusions in magnetite possibly indicates that Au-bearing fluids were introduced into a system with slightly higher fO_2 than its own oxidation state. The subsequent search for equilibrium induced a decrease in Au solubility while maintaining sulfur in solution for a bit longer. The net result of the occurrence of such process is to undermine the otherwise stronger correlation between Au and S if sulfidation were the only Au precipitation mechanism.

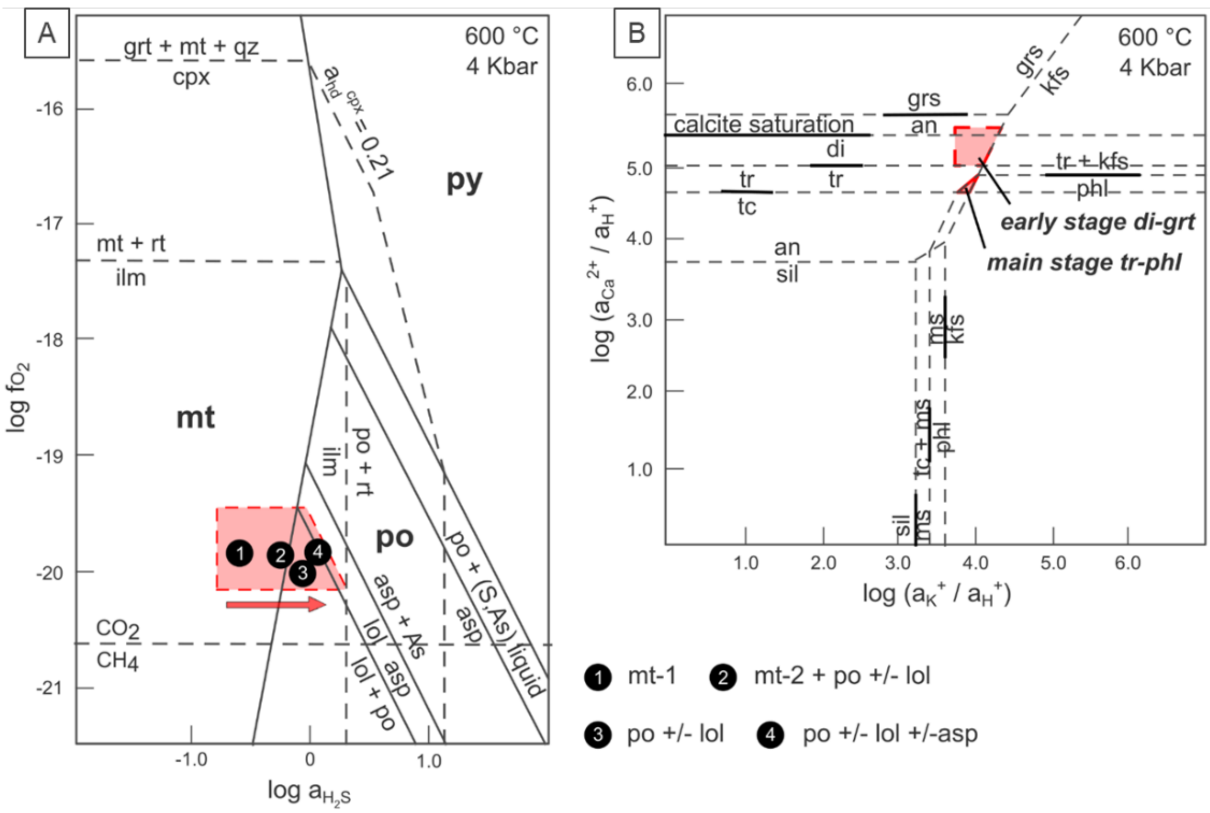


Figure 2.26. A) Stability relationships for selected minerals as a function of log fO_2 and log aH_2S at amphibolite facies conditions (600 °C and 4 Kbars) (Mikucki and Ridley, 1993). The shaded area indicates possible fluid conditions for the Tucano deposit based on observed mineral assemblages. Numbered circles indicate paragenetic succession with ongoing alteration and increasing sulfidation during the main alteration stage. B) Mineral stability relations between K-aluminosilicates, Ca-Mg silicates and carbonates with respect to calcium and potassium ion activities in an aqueous fluid at 600 °C and 4 kbar (Mikucki and Ridley, 1993). Shaded areas indicate possible fluid conditions for early stage and main stage alteration at Tucano based on observed mineral assemblages. Abbreviation: an = anorthite; asp = arsenopyrite; cpx = clinopyroxene; di = diopside; grs = grossular; grt = undistinguished garnet; hd = hedenbergite; ilm = ilmenite; kfs = K-feldspar; lol = loellingite; ms = muscovite; mt-1 = magnetite 1; mt-2 = magnetite 2; phl = phlogopite; po = pyrrhotite; qz = quartz; rt = rutile; (S,As)liquid = S- and As-rich melt; sil = sillimanite; tc = talc; tr = tremolite.

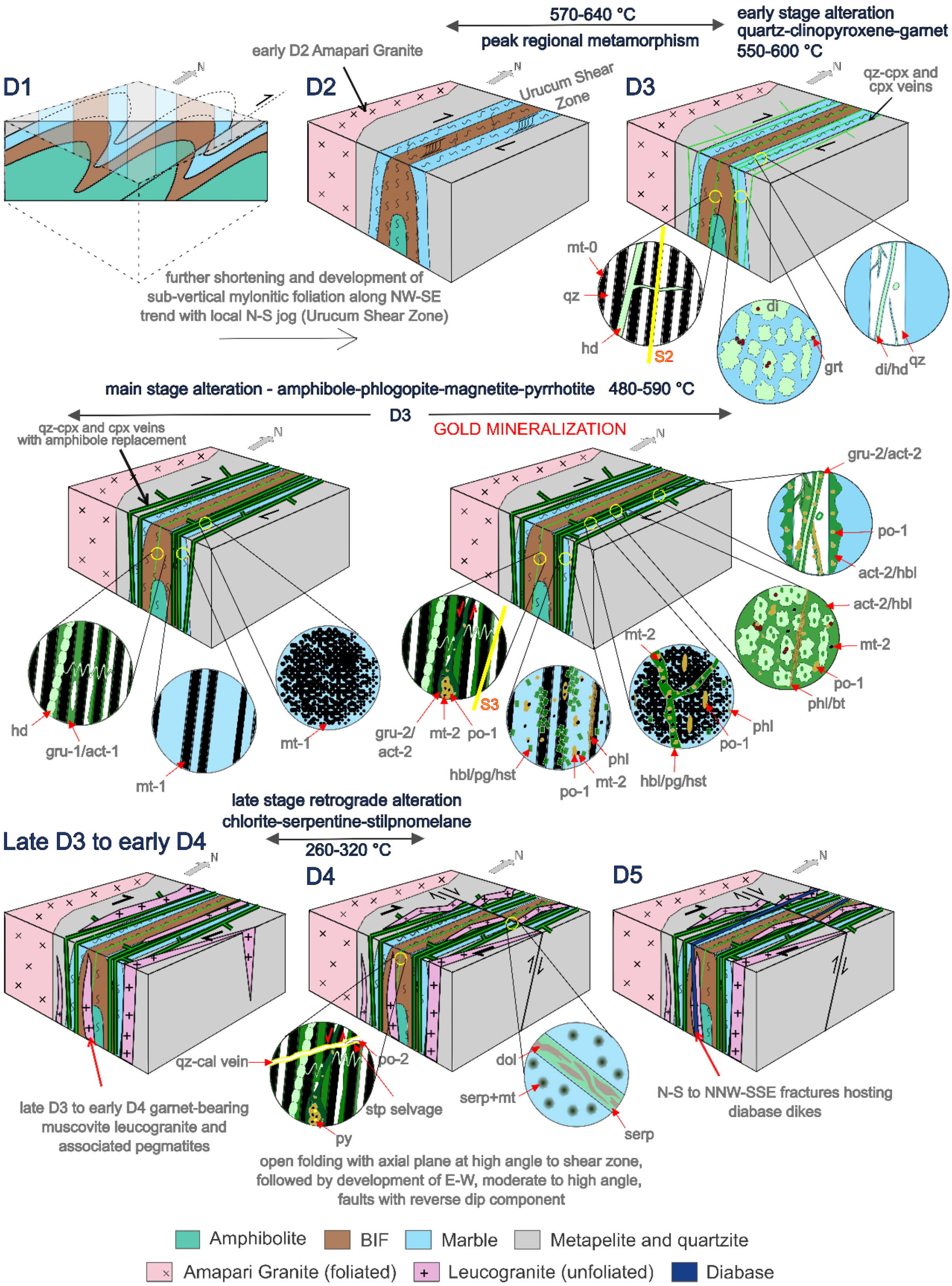
Substantial mass loss during alteration is indicated by steep isocons, especially for marble. This process is further supported by high contents of less mobile elements (especially Al, Ti, Sc and Cr) in marble-hosted hydrothermal magnetite in comparison to metamorphic BIF magnetite. Dissolution and leaching of reactive host rocks might have been an important process to generate space and create permeability channels to sustain fluid flow in a strongly compressional setting.

Hydrothermal pyrrhotite trace element composition shows significant differences in Co and Ni contents between BIF-hosted and marble-hosted crystals. Furthermore, vein-hosted crystals have slightly higher As and Te contents. Whereas the variations in Co and Ni may reflect local conditions at the site of deposition, the quoted differences in As and Te possibly result from fluid:rock ratio variations between wallrock and veins. Lower Co and Ni contents recorded in pyrrhotite experiencing pyrite overgrowth are likely due to preferential partitioning of these elements to the newly forming pyrite. In addition, negligible Au contents indicate that the bulk of this element resides in native gold particles, as opposed to chemically bound Au in pyrrhotite.

2.10.2 Evolutionary model for the Tucano gold deposit

The complex interplay between tectonics, magmatism and hydrothermal alteration at Tucano adds a significant level of difficulty in interpreting its evolution through time. Replacement of metamorphic assemblages by hydrothermal minerals without prograde overprint indicates a post-metamorphic peak timing for the gold-related hydrothermal alteration. With regards to tectonics, mineralization is hosted in a ductile shear zone affecting a sequence of metavolcano-sedimentary rocks tightly folded against the Amapari Granite to the west, with evidence for syn- to late-kinematic D3 hydrothermal activity, mostly focused on highly reactive chemical metasedimentary rocks. Early stage calc-silicate veins show evidence of non-coaxial shear strain, such as asymmetric folding and boudinage, suggesting a maximum early D3 structural age. Main stage alteration is largely comprised within the time span of the D3 event. This is evidenced by elements such as: (i) banded fabric in hydrothermal magnetite-1-carbonate rock; (ii) local development of amphibole as pressure shadows around early stage clinopyroxene; (iii) shear amphibole-2-pyrrhotite veins; (iv) pyrrhotite tension gashes; (v) elongated pyrrhotite lenses; and (vi) the common development of amphibole and phlogopite as subparallel stringers and disseminated oriented crystals. However, these same minerals may form as randomly oriented crystals, locally displaying decussate texture. This may imply that main stage alteration consists of multiple episodes of fluid flow extending up until the waning stages of D3 deformation. This is further supported by the prevailing euhedral habit of arsenopyrite crystals that form at the initial cooling path of the high-temperature alteration.

Granitic magmatism represented by leucogranite stocks and dikes outcropping in the mine pits are unmineralized and do not show evidence of D3 strain, rather exhibiting only F4 folds. Therefore, They were likely emplaced between late D3 and early D4. The role of this magmatic event with respect to contributing with hydrothermal fluids, gold upgrading or remobilization, was likely minimal. This is evidenced by the very narrow (typically <5 cm) alteration rims developed along the intrusive contacts with highly reactive country rocks, suggesting limited volumes of fluids generated upon cooling and crystallization of this magma. Conversely, this magmatic event seemingly had profound textural effects on both metamorphic and hydrothermal minerals, as they not seldom display granoblastic fabric. This may indicate that maintenance of high temperature conditions during post-kinematic time allowed for textural reequilibration in the form of grain boundary area reduction recrystallization. In addition, late- stage hydrothermal alteration does not show evidence of destabilization and conversion to higher temperature phases, implying that this magmatism was likely emplaced shortly after the main stage of alteration, preceding the retrograde, low temperature alteration stage (Fig. 2.27).



Abbreviation: act-1 = hydrothermal actinolite-1; act-2 = hydrothermal actinolite-2; bt = biotite; cal = calcite; cpx = clinopyroxene; di = diopside; dol = dolomite; gru-1 = hydrothermal grunerite 1; gru-2 = hydrothermal grunerite 2; hbl = hornblende; hd = hedenbergite; hst = hastingsite; grt = garnet; mt-0 = metamorphic BIF magnetite; mt-1 = hydrothermal magnetite 1; mt-2 = hydrothermal magnetite-2; pg = pargasite; phl = phlogopite; po-1 = main stage pyrrhotite; po-2 = late stage pyrrhotite; py = pyrite; qz = quartz

Figure 2.27. Schematic model for the evolution of hydrothermal alteration and gold mineralization at the Tucano gold deposit.

2.10.3 Implications for gold exploration

Orogenic hypozonal gold mineralization at Tucano is characterized by high-temperature hydrothermal minerals such as clinopyroxene, garnet, amphiboles, phlogopite and loellingite. Also, it is defined by an increase of amphiboles, phlogopite, magnetite and pyrrhotite towards the ore zone. Geochemically, significant Na, Te, Bi, W and Se addition is recorded, accompanied by sulfidation, plus minor carbonation specifically in BIF. As for mineral chemistry, Na/K ratio in phlogopite and Na/Ca in amphiboles are good proxies to vector gold-bearing zones.

2.10.4 Comparison with other hypozonal orogenic gold deposits

Tucano has many similarities with other hypozonal orogenic gold deposits, but also some key differences (Table 2.3). Most gold deposits of this class are hosted in ductile to brittle-ductile shear zones, such as deposits in the Southern Cross Province in the Yilgarn Craton, e.g. Marvel Loch (Mueller et al., 1991) and Transvaal (Hagemann et al., 1998). In terms of host rocks, examples of high-temperature BIF-hosted and marble-hosted orogenic gold deposits are reported at Nevoria (Mueller et al., 2004) and Navachab (Dziggel et al., 2009a, b), respectively. Replacement of peak metamorphic minerals by hydrothermal assemblages are also recorded at Hutti, Hira Buddini, Nevoria and New Consort, where gold mineralization is concentrated in retrograde amphibolite facies shear zones (Mueller et al., 2004; Otto et al., 2007; Kolb and Meyer, 2008). Skarn-type calc-silicate alteration assemblages seem to be a unifying characteristic shared by nearly all high-temperature orogenic gold deposits, implying that Ca is an important ore fluid component in these hydrothermal systems. Nonetheless, either one or both of plagioclase and K-feldspar are almost invariably featured as part of the high-temperature alteration assemblage. None of these, however, is documented in either altered BIF or altered marble at Tucano. In addition, hydrothermal magnetite and hercynite-rich spinels are also rare in this class of gold deposit, and only observed in few other deposits, such as Marvel Loch and Renco (Mueller et al., 1991; Kolb et al., 2000).

The Au-Ag-S-Te-Na ± W, Bi, Se, V, Cu, P fluid signature is similar to those determined in other deposits of this class, except for of Se, V and P, and the lack of K. Se has a very strong positive correlation with Te (R = 0.91) and is thus interpreted to accompany this element during hydrothermal fluid migration, likely sharing the same source rock. In oxidizing environments, the elemental form Se^0 prevails, which is colloidal and electrically charged, and hence adsorbed by clay minerals (Koljonen, 1973). Thus, the highest Se contents in metasedimentary rocks are found in sulfide-bearing black shales containing organic matter. Thus, this element could have possibly been sourced alongside S and Te from sulfidic metapelitic rocks. V gain is reflected in the abundance of hydrothermal magnetite, and it is relatively unusual in orogenic gold deposits, with some of the most outstanding deposits having V-bearing minerals being Golden Mile (Shackleton et al., 2003), Mother Lode (Weir and Kerrich, 1987) and Hemlo (Harris, 1989). In comparison with such deposits, however, V enrichment at Tucano is much lower, restricted as an important trace element in magnetite and minor element in ilmenite. It is worth stating that high abundances of magnetite are a unique feature of this deposit. The strong positive correlation between P (concentrated as apatite) and W (R = 0.72) suggests a common source for both elements.

Lastly, Bi-bearing assemblages are reported in some high-temperature orogenic gold deposits such as Navachab (Dziggel et al., 2009a, b) and São Sebastião (Brando Soares et al., 2018, 2022). The low melting point of native bismuth (271 °C) and Bi-bearing polymetallic assemblages (e.g. Au-Bi = 241 °C) suggests that these metals have been incorporated into a bismuth or sulfide melt (Tooth et al., 2008). Such melts are argued to be effective gold scavengers, favoring its remobilization, refining and concentration (Brando Soares et al., 2022). Nonetheless, unlike these deposits, Bi-phases are only very locally observed at Tucano, resulting in only low to moderate linear positive correlation of this element with Au (R = 0.10-0.44). Thus, if such process had taken place at Tucano, it would have been of very restricted distribution at least in the TAP C orebody. In addition, these melts are common in sulfide-rich deposits formed under high fS_2, containing pyrite, and generated by interaction of chalcophile-rich hot fluids with arsenopyrite in the absence of loellingite (Tomkins et al., 2006). Since loellingite is part of the high-temperature hydrothermal assemblage, and pyrite is only a late-stage phase as attested by petrographic studies, it is unlikely that such process has occurred to a significant extent at the TAP C zone of the Tucano gold deposit. However, other orebodies along the Urucum shear zone (e.g. TAP AB) are reported to have pyrite rather than pyrrhotite as its main sulfide. Thus, the previous statement can only be applied thus far to the studied TAP C orebody.

Deposit	Location	Age	Host structure	Host rock	Hypozonal alteration assemblages	PT conditions of mineralization	Replacement of metamorphic mineral assemblage	Geochemical footprint	References
Tucano	Serra do Navio greenstone belt, Amazon Craton, Brazil	2114 ± 65 Ma (Pb-Pb pyrrhotite)	Urucum shear zone	marble, banded iron formation	cpx, grt, qz, bt, amph, phl, cal, ap, mt, po ± ilm, sp, cpy, lol, asp, au, alt, bi, Bi-Te	~ 500-580 °C ~ 4 kbar	olivine and carbonates by clinopyroxene, garnet and amphiboles	Au, Ag, Te, S, Se, W, Bi, V, Na, P	this work Melo (2001) Galarza et al. (2006) Horikava (2008)
Salamangone	Lombarda greenstone belt, Amazon Craton, Brazil	2002 ± 61 Ma (Pb-Pb arsenopyrite)	shear zones	tonalite, granodiorite	qz, bt, chl, act, ser, ep, carb, asp, po, py, au ± lol, cpy, gn	400-565 °C	hornblende by actinolite, and biotite by chlorite	Au, Ag, As, Ca, Mg	Nogueira (2002)
São Sebastião	Pitangui greenstone belt, São Francisco Craton, Brazil	1987 ± 72 Ma (Re-Os arsenopyrite and pyrite)	tight to isoclinal folds	banded iron formation	kfs, sch, ap, asp, py, po, cpy, sph, au, bi, Bi-Te	465 - 560 °C	not determined	Au, Bi, Ag, Cu, As, Pb, Co, Ni, Te, W	Brando Soares et al. (2018, 2021, 2022)
New Consort	Barberton greenstone belt, South Africa	3027 ± 7.5 Ma (U-Pb titanite	Consort Bar shear zone	mafic-ultramafic rocks, biotite schist	(1) grt, di, kfs, qz, cal, bt, lol, po; (2) hbl, pl, kfs, bt, tit, qz, asp, lol, po	520-680 °C	hornblende and plagioclase by biotite and k-feldspar	K, Na, Si, As, S, Au	Otto et al. (2007) Dziggel et al. (2010)
Renco	Limpopo belt, Zimbabwe and Kaapval Cratons, Zimbabwe and South Africa	2560 ± 10 Ma (Pb-Pb chalcopyrite + pyrrhotite)	North Limpopo thrust zone	enderbite (orthopyroxene tonalite)	grt, bt, kfs, qz, po, cpy, au ± sd, amph, mt	610-710 °C ~ 4 kbar	orthopyroxene by biotite and amphibole	Au, S, Fe, Cu, Mo, Bi, Te, Ni, Co, H_2O	Blenkinsop and Frei (1996) Kolb et al. (2000)
Hutti/Hira Buddini	Hutti-Mask greenstone belt, Dhawar Craton, India	2580-2540 Ma (U-Pb zircon, granite)	Hutti Mask shear zones	amphibolite, felsic schist	bt, pl, qz, cal, py, asp ± kfs, act, tour	460-590 °C 3-4 kbar	hornblende by biotite + arsenopyrite	Si, K, Ca, C, S, Cu, Au ± As, B	Kolb and Meyer (2008) Krienitz et al. (2008) Rogers et al. (2013)
Navachab	Damara orogenic belt, Namibia	525-520 Ma (Re-Os molybdenite)	Karibib dome, footwall of Mon Repos thrust zone	marble, calc-silicate rock, biotite schist	(1) grt, di, qz, kfs; or (2) grt, bt; both with po, cpy, sph, asp, bi, au, bm, and Bi-Te	~ 550 °C 2 kbar	carbonates by clinopyroxene + garnet	not determined	Kisters (2005) Dziggel et al. (2009a, b) Steven et al. (2014)
Southern Cross Province (Marvel Loch, Transvaal, Frasers, Corinthia)	Southern Cross domain, Yilgarn Craton, Australia	ca. 2640 Ma (U-Pb allanite)	Frasers-Corinthia shear zone	matamorphosed komatiite, basalt, gabbro, banded iron formation and pelite	di, hbl, qtz, tr, bt, au, mt, ilm, sch, po, lol, asp, cpy, bi	~ 500-600 °C 2 - 4 kbar	not determined	Au, Ag, W, Cu, Pb, Mo, Te	Mueller (1991) Bloem et al. (1994) Hagemann et al. (1998) Ridley et al. (2000)
Faboliden	Svecofennian Orogen, Sweden	ca. 1800 Ma (U-Pb zircon, granite)	reverse shear zone	meta-greywacke and meta-volcanic rocks	di, amph, bt, pl, kfs, and, tour, au, asp, lol, stb	520-560 °C 4 kbar	not determined	Au, As, Bi, W, Se, Sb, Hg, Ag, Si, S, K, Sn	Bark and Weihed (2012)

Mineral abbreviation: act = actinolite; and = andalusite; alt = altaite; amph = undistinguished amphibole; ap = apatite; asp = arsenopyrite; au = gold; bi = native bismuth; Bi-Te = bismuth-tellurium phases; bm = bismuthinite; bt = biotite; cal = calcite; carb = undistinguished carbonate; cpx = undistinguished clinopyroxene; cpy = chalcopyrite; chl = chlorite; di = diopside; ep = epidote; grt = garnet; hbl = hornblende; ilm = ilmenite; kfs = K-feldspar; lol = loellingite; mt = magnetite; phl = phlogopite; pl = plagioclase; po = pyrrhotite; py = pyrite; qz = quartz; sch = scheelite; sd = siderite; ser = sericite; sp = spinel; sph = sphalerite; stb = stibnite; tit = titanite; tour = tourmaline; tr = tremolite

Table 2.3 Comparison of selected hypozonal orogenic gold deposits and districts with the Tucano gold deposit

Conclusions

The results of field and laboratory investigations at Tucano provided evidence that this is a shear-zone-hosted hypozonal orogenic gold deposit where the mineralization event postdates the regional metamorphic peak and is structurally constrained as syn- to late-kinematic. Leucogranite dikes and stocks did not take up shear strain and are hence interpreted as postdating the mineralization event. The ore assemblage pyrrhotite ± loellingite ± arsenopyrite complies with reduced hydrothermal fluid conditions. The abundance of magnetite in proximal alteration zone further constrains the chemistry of fluids as it indicates relatively low sulfur activities (magnetite-pyrrhotite boundary). Fe-rich host rocks were a favorable chemical trap, with their sulfidation interpreted as an important mechanism for gold deposition. However, detection of gold in sulfide-free assemblages suggests a second precipitation mechanism, possibly invoking oxygen fugacity contrast within the ore system without simultaneous sulfur destabilization. This likely diminished the correlation between Au and S in this deposit. Alteration is characterized by narrow to wide distal zone (BIF > marble) with direct transition to proximal zone without proper development of an intermediate zone. Whole-rock and mineral chemistry data reveal a significant sodic alteration, with amphiboles and phlogopite serving as reservoirs for this element. In contrast, this hydrothermal system lacks the typical K addition that is featured in many high-temperature orogenic gold deposits. Mass balance modelling supports a significant mass loss during alteration, which is reflected in the composition of hydrothermal magnetite, specifically in marble, which contains high contents of elements typically known for their low mobility in hydrothermal fluids (Al, Ti, Sc, Cr). Pyrrhotite trace element composition indicates a lack of structurally bound Au in this sulfide. An interplay between local conditions at the site of deposition and fluid:rock ratio appears to account for variations in pyrrhotite composition. The Au-Ag-S-Te-Na ± W, Bi, Se, V, Cu, P geochemical signature of the ore fluid shares some similarities with other high-temperature orogenic gold deposits. Se and V hydrothermal additions are, nonetheless, less commonly observed in other deposits of this class, the latter in particular reflecting the high proportions of hydrothermal magnetite, a characteristic that seems to be unique to this deposit. Tucano is the first documented high-temperature orogenic gold deposit in the Guiana Shield.

Acknowledgements

This paper is part of a M.Sc. project that began in May 2021 at the PPGEOL, Institute of Geosciences, Federal University of Minas (UFMG), and this research has been funded by AMIRA Global through the Project Number P1061B - South American Exploration Initiative (SAXI) Stage 2. Further financial support for analytical work, travel and on-site accommodation was provided by Great Panther Mining. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors would like to thank the Great Panther Mining staff for their support and hospitality, particularly the exploration team for their assistance throughout the site visits, invaluable discussions, and data sharing. The authors also acknowledge the Microscopy Center (UFMG) and the Isotope Geochemistry Laboratory at Federal University of Ouro Preto for the expertise of their staff with mineral chemistry analyses. We also thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the granted scholarship.

References

Almeida, F.F.M., Hasui, Y., Brito Neves, B.B., and Fuck, R.A., 1981, Brazilian structural provinces: An introduction: Earth Science Reviews, v. 17, p. 1-29.

Anovitz, L.M., and Essene, E.J., 1987, Phase Equilibria in the System CaCO3-MgCO3-FeCO3: Journal of Petrology, v. 28, p. 389-415.

Avelar, V.G., 2002, Geocronologia Pb-Pb em zircão e Sm-Nd rocha total da porção centro-norte do Amapá-Brasil: Implicações para a evolução geodinâmica do setor oriental do Escudo das Guianas: Ph.D. thesis, Belém, Brazil, Federal University of Pará, 213 p. (in Portuguese with English abs.).

Avelar, V.G., Lafon, J.M., Delor, C., Guerrot, C., and Lahondère, D., 2003, Archean crustal remnants in the easternmost part of the Guiana Shield: Pb-Pb and Sm-Nd geochronological evidence for Mesoarchean versus Neoarchean signatures: Géologie de la France, v. 2 (3-4), p. 83-100.

Barbosa, J.P.O., Costa Neto, M.C., Rosa-Costa, L.T., Anjos, G.C., and Chaves, C.L., 2015, Geologia e recursos minerais da Folha Macapá NA.22-Y-D, estado do Amapá, escala 1:250.000: Belém, Brazil, Brazilian Geological Survey – CPRM, 118 p. (in Portuguese).

Bark, G., and Weihed, P., 2012, Geodynamic settings for Paleoproterozoic gold mineralization in the Svecofennian domain: a tectonic model for the Fäboliden orogenic gold deposit, northern Sweden: Ore Geology Reviews, v. 48, p. 403-412.
Barreto, C.J., Lafon, J.M., and Rosa-Costa, L.T., 2009, Magmatismo eoriaciano (2,26 Ga) na porção norte do Bloco arqueano Amapá: nova evidência e implicações geodinâmicas [ext. abs]: Simpósio de Geologia da Amazônia, 11th, SBG Núcleo Norte, Manaus, Brazil, 2009, Anais, p. 174-176. (in Portuguese).

Barreto, C.J., Lafon, J.M., Rosa-Costa, L.T., and Dantas, E.L., 2013, Paleoproterozoic granitoids from the northern limit of the Archean Amapá block (Brazil), southeastern Guyana Shield: Pb-Pb evaporation in zircons and Sm-Nd geochronology: Journal of South American Earth Sciences, v. 45, p. 97-116.

Bau, M., and Dulski, P., 1996, Distribution of yttrium and rare-earth elements in the Penge and Kuruman Iron-Formations, Transvaal Supergroup, South Africa: Precambrian Research, v. 79, p. 37–55.

Bau, M., and Dulski, P., 1999, Comparing yttrium and rare earths in hydrothermal fluids from the Mid-Atlantic Ridge: implications for Y and REE behaviour during near-vent mixing and for the Y/Ho ratio of Proterozoic seawater: Chemical Geology, v. 155, p. 77–90.

Belousov, I., Danyushevsky, P., Olin, P., Gilbert, S., and Thompson, J., 2015, STDGL3 – A new calibration standard for sulphide analysis by LA-ICP-MS [abs.]: Goldschmidt, 25th, Prague, Czech Republic, 2015, Abstracts, p. A251.

Blenkinsop, T.G., and Frei, R., 1996, Archean and Proterozoic mineralization and tectonics at the Renco mine (Northern Marginal Zone, Limpopo Belt, Zimbabwe): Economic Geology, v. 91, p. 1225–1238.

Bloem, E.J.M., Dalstra, H.J., Groves, D.I., and Ridley, J.R., 1994, Metamorphic and structural setting of Archaean amphibolite-hosted gold deposits near Southern Cross, Southern Cross Province, Yilgarn Block, Western Australia: Ore Geology Reviews, v. 9, p. 183–208.

Bolhar, R., Kamber, B.S., Moorbath, S., Fedo, C.M., and Whitehouse, M.J., 2004, Characterization of early Archaean chemical sediments by trace element signatures: Earth and Planetary Science Letters, v. 222, p. 43–60.

Borges, A.A.S., Lafon, J.M., and Villas, R.N.N., 2002, Magmatismo tardi-transamazônico na Serra do Navio, região central do Amapá: Evidências geocronológicas [abs.]: Congresso Brasileiro de Geologia, 41th, SBG Núcleo Nordeste, João Pessoa, Brazil, 2002, Anais, p. 435. (in Portuguese).

Borghetti, C., Philipp, R.P., 2017, Geologia e geofísica do greenstone belt Vila Nova, porção NE do Cráton Amazônico, Amapá, Brasil: Geologia USP Série Científica, v. 17 (1), p. 109-127. (in Portuguese with English abs.)

Brando Soares, M., Corrêa Neto, A.V., Bertolino, L.C., Alves, F.E.A., Almeida, A.M., Silva, P.H.M., Araújo, R.O., Manduca, L.G., and Araújo, I.M.C.P., 2018, Multistage

mineralization at the hypozonal São Sebastião gold deposit, pitangui greenstone belt, minas gerais, Brazil: Ore Geology Reviews, v. 102, p. 618–638.
Brando Soares, M., Corrêa Neto, A.V., and Fabrício-Silva, W., 2020, The development of a Meso- to Neoarchean rifting-convergence collision-collapse cycle over an ancient thickened protocontinent in the south São Francisco craton, Brazil: Gondwana Research, v. 77, p. 40–66.

Brando Soares, M., Alves, F.E.A., Corrêa Neto, A.V., Bertolino, L.C., Araújo, I.M.C.P., Gopon, P., and Mozart, M.S., 2022, Gold refinement by the fractionation of Bi-enriched partial melts at the Quadrilátero Ferrífero, Brazil: Implications on the formation of hypozonal deposits: Mineralium Deposita, v. 57, p. 781-800.

Byrne, R.H., and Sholkovitz, E.R., 1996, Marine chemistry and geochemistry of lanthanides, *in* Gschneider Jr., K.A., and Eyring, L., ed., The Handbook on the Physics and Chemistry of the Rare Earths, vol. 23: Amsterdam, Elsevier, p. 497-593.

Cavalcante, G.C.G., 2009, Tectonic geometry, kinematics and modelling of the Vila Nova Group rocks in the Pedra Branca do Amapari region in AP: M.Sc. thesis, Belém, Brazil, Federal University of Pará, 168 p.

Cordani, U.G., and Brito Neves, B.B. 1982, The geologic evolution of South America during the Archean and early Proterozoic: Revista Brasileira de Geociencias, v. 12, p. 78-88. (in Portuguese with English abs.)

Cordani, U.G., Tassinari, C.C.G., Teixeira, W., Basei, M.A.S., and Kawashita, K., 1979, Evolução da Amazônia com base nos dados geocronológicos: Congresso Geologico Chileno, 2nd, Arica: Instituto de Investigaciones Geologicas, Santiago, Chile, 1979, Actas, 4, p. 137-148. (in Portuguese).

Danyushevsky, L., Robinson, P., Gilbert, S., Norman, M., Large, R., McGoldrick, P., and Shelley, M., 2011, Routine quantitative multi-element analysis of sulphide minerals by laser ablation ICP-MS: Standard development and consideration of matrix effects: Geochemistry: Exploration, Environment, Analysis, v. 11, p. 51-60.

Delor, C., Lahondère, D., Egal, E., Lafon, J. M., Cocherie, A., Guerrot, C., Rossi, P., Trufert, C., Theveniaut, H., Phillips, D., and Avelar, V. G., 2003a, Transamazonian crustal growth and reworking as revealed by the 1:500.000 scale geological map of French Guiana (2nd ed.): Géologie de la France, v. 2, p. 5-57.

Delor, C., Roever, E. W. F., Lafon, J. M., Lahondère, D., Rossi, P., Cocherie, A., Guerrot, C., and Potrel, A., 2003b, The Bakhuis ultrahigh-temperature granulite belt: Implications for late Transamazonian crustal stretching in a revised Guiana Shield framework: Géologie de la France, v. 2, p. 207-230.

Dupuis, C., Beaudoin, G., 2011, Discriminant diagrams for iron oxide trace element fingerprinting of mineral deposit types: Mineralium Deposita, v. 46, p. 319–335.

Dziggel, A., Wulff, K., Kolb, J., and Meyer, F.M., 2009a, Processes of high-T fluid–rock interaction during gold mineralization in carbonate-bearing metasediments: the Navachab gold deposit, Namibia: Mineralium Deposita, v. 44, p. 665–684.

Dziggel, A., Wulff, K., Kolb, J., Meyer, F.M., and Lahaye, Y., 2009b, Significance of oscillatory and bell-shaped growth zoning in hydrothermal garnet: evidence from the Navachab gold deposit, Namibia: Chemical Geology, v. 262, p. 278–292.

Dziggel, A., Poujol, M., Otto, A., Kisters, A.F.M., Trieloff, M., Schwarz, W., and Meyer, F.M., 2010, New U–Pb and 40Ar/39Ar ages from the northern part of the Barberton greenstone belt, South Africa: implications for the formation of Mesoarchaean gold deposits: Precambrian Research, v. 179, p. 206–220.

Faraco, M.T.L., Marinho, P.A.C., Moura, C.A.V., Macambira, M.J., and Pimentel, M.M., 2004, Novos Dados Geocronológicos no Amapá-NNW do Pará [abs.]: Brazilian Geological Congress, 42th, Araxá, Brazil, 2004. (in Portuguese).

Faraco, M.T.L., Marinho, P.A.C., Melo, L.V., Villas, R.N.N., and Soares, J.W., 2005, O campo Taperebá do depósito aurífero Amapari, Amapá: Rochas encaixantes e minerografia: Contribuições à Geologia da Amazônia, v. 4, p. 164-172. (in Portuguese with English abs.).

Galarza, M.A.T., Lafon, J.M., and Macambira, M.J.B., 2006, Idades Pb-Pb das mineralizações auríferas dos depósitos Amapari (Amapá), Igarapé Bahia (Carajás) e Mamão (Rio Maria), Amazônia Oriental [ext. abs.]: Simpósio de Geologia da Amazônia, 9th, SBG Núcleo Norte, Belém, Brazil, 2006, Anais, p. 300-303. (in Portuguese).

Gibbs, A.K., and Barron, C.N., 1993, Geology of the Guiana Shield: Oxford, Oxford University Press, p. 246.

Goldfarb, R.J., and Groves, D.I., 2015, Orogenic gold: Common vs evolving fluid and metal sources through time: Lithos, v. 223, p. 2–26.

Goldfarb, R.J., Baker, T., Dubé, B., Groves, D.I., Hart, C.J.R., and Gosselin, P., 2005, Distribution, character, and genesis of gold deposits in metamorphic terranes: Economic Geology 100th Anniversary, p. 407–450.

Goldfarb, R.J., André-Mayer, A.-S., Jowitt, S.M., and Mudd, G.M., 2017, West Africa: The world’s premier Paleoproterozoic gold province: Economic Geology, v. 112, p. 123-143.

Grant, J.A., 1986, The isocon diagram – a simple solution to Gresens’ equation for metasomatic alteration: Economic Geology, v. 81, p. 1976-1982.

Great Panther Mining, 2022, Technical report on the 2021 mineral reserves and mineral resources of the Tucano gold mine, Amapá state, Brazil, p. 247.

Gresens, R.L., 1967, Composition–volume relationships of metasomatism: Chemical Geology, v. 2, p. 47-55.

Groves, D.I., Goldfarb, R.J., Gebre-Mariam, M., Hagemann, S.G., and Robert, F., 1998, Orogenic gold deposits: A proposed classification in the context of their crustal distribution and relationship to other gold deposit types: Ore Geology Reviews, v. 13, p. 7–27.

Hagemann, S.G., and Cassidy, K.F., 2000, Archean orogenic lode gold deposits. *in* Hagemann, S.G., and Brown, P.E., ed., Gold in 2000: Reviews in Economic Geology, p. 9–68.

Hagemann, S.G., Brown, P.E., Ridley, J., Stern, P., and Fournelle, J., 1998, Ore petrology, chemistry, and timing of electrum in the Archean hypozonal Transvaal lode gold deposit, Western Australia: Economic Geology, v. 93 (3), p. 271–291.

Harris, D.C., 1989, The mineralogy and geochemistry of the Hemlo gold deposit, Ontario. Geological Survey of Canada, Economic Geology Report, 38p.

Hasui, Y., Haralyi, N.L.E., Schobbenhaus, C., 1984, Elementos geofísicos e geológicos da região amazônica: Subsídios para o modelo geotectônico [ext. abs.]: Symposium Amazonico, 2nd, Manaus, Brazil, 1984, Anais, p. 129-147. (in Portuguese).

Henry, D.J., Guidotti, C.V., and Thomson, J.A., 2005, The Ti-saturation surface for low-to-medium pressure metapelitic biotites: Implications for geothermometry and Ti-substitution mechanisms: American Mineralogist, v. 90, p. 316-328.

Hoffmann, I.B., Philipp, R.P., and Borghetti, C., 2018, Geochemistry and origin of the Rhyacian tholeiitic metabasalts and meta-andesites from the Vila Nova Greenstone Belt, Guyana Shield, Amapá, Brazil: Journal of South American Earth Sciences v. 88, p. 29-49.

Holdaway, M.J., 2000, Application of new experimental and garnet Margules data to the garnet–biotite geothermometer: American Mineralogist, v. 85, p. 881-892.

Horikava, E.H., 2008, Geoquímica de Solo e Geologia da Região do Depósito de Ouro do Amapari – AP: M.Sc thesis, Belo Horizonte, Brazil, Federal University of Minas Gerais, 2 vol.

Jochum, K.P., Willbold, M., Raczek, I., Stoll, B., and Herwig, K., 2005, Chemical characterization of the USGS reference glasses GSA-1G, GSC-1G, GSD-1G, GSE-1G, BCR-2G, BHVO-2G and BIR-1G using EPMA, ID-TIMS, ID-ICP-MS and LA-ICP-MS: Geostandards and Geoanalytical Research, v. 29 (3), p. 285-302.

Kisters, A.F.M., 2005, Controls of gold-quartz vein formation during regional folding in amphibolite-facies, marble dominated metasediments of the Navachab Gold Mine in the Pan-African Damara Belt, Namibia: South African Journal of Geology, v. 108, p. 365–380.

Kolb, J., and Meyer, F.M., 2008, Balanced mineral reactions for alteration zones developed in auriferous shear zones of the Hutti Mine, Dharwar craton, India: Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, v. 159 (2), p. 331–348.

Kolb, J., Kisters, A.F.M., Hoernes, S., and Meyer, F.M., 2000, The origin of fluids and nature of fluid-rock interaction in auriferous mylonites of the Renco Mine, southern Zimbabwe: Mineralium Deposita, v. 35 (1), p. 109–125.

Kolb, J., Dziggel, A., and Bagas, L., 2015, Hypozonal lode gold deposits: A genetic concept based on a review of the New Consort, Hutti, Hira Buddini, Navachab, Nevoria, and The Granites deposits: Precambrian Research, v. 262, p. 20-44.

Koljonen, T., 1973, Selenium in certain metamorphic rocks: Bulletin of the Geological Society of Finland, v. 45, p. 107-117.

Kretschmar, U., and Scott, S.D., 1976, Phase relations involving arsenopyrite in the system Fe-As-S and their applications: Canadian Mineralogist, v. 14, p. 364–386.

Krienitz, M.S., Trumbull, R.B., Hellmann, A., Kolb, J., Meyer, F.M., and Wiedenbeck, M., 2008, Hydrothermal gold mineralization at the Hira Buddini gold mine, India: constraints on fluid evolution and fluid sources from boron isotopic compositions of tourmaline: Mineralium Deposita, v. 43, p. 421–434.

Li, X., Zhang, C., Behrens, H., and Holtz, F., 2020a, Calculating amphibole formula from electron microprobe analysis data using a machine learning method based on principal components regression: Lithos, v. 362-363, 105469.

Li, X., Zhang, C., Behrens, H., and Holtz, F., 2020b, Calculating biotite formula from electron microprobe analysis data using a machine learning method based on principal components regression: Lithos, v. 356-357, 105371.

Leake, B.E., Woolley, A.R., Arps, C.E.S., Birch, W.D., Gilbert, M.C., Grice, J.D., Hawthorne, F.C., Kato, A., Kisch, H.J., Krivovichev, V.G., Linthout, K., Laird, J., Mandarino, J.A., Maresch, W.V., Nickel, E.H., Rock, N.M.S., Schumacher, J.C., Smith, D.C., Stephenson, N.C.N., Ungaretti, L., Whittaker, E.J.W., and Guo, Y., 1997, Nomenclature of amphiboles: report of the Subcommittee on Amphiboles of the International Mineralogical Association, Commission on New Minerals and Mineral Names: Canadian Mineralogist, v. 35, p. 219-246.

Lima, M.I.C., Montalvão, R.M.G., Issler, R.S., Oliveira, A.S., Basei, M.A.S., Araújo, J.F.V., and Silva, G.G., 1974, Folha NA/NB.22 - Macapá: Geologia, geomorfologia, solos, vegetação e uso potencial da terra: Rio de Janeiro, Brazil, National Department of Mineral Production – DNPM, Levantamento de recursos naturais, v. 6, 120 p. (in Portuguese).

McDonough, W. F., and Sun, S.S., 1995, The composition of the Earth: Chemical Geology, v. 120, p. 223–253.

McReath, I., and Faraco, M.T.L., 2006, Paleoproterozoic greenstone-granite belts in northern Brazil and the former Guyana Shield-West African craton province: Geologia USP Série Científica, v. 5(2), p. 49-63.

Melo, L.V., 2001, Estudo do campo Urucum do depósito Amapari, Amapá, com base em dados petrográficos, de química mineral e microtermométricos: M.Sc. thesis, Belém, Brazil, Federal University of Pará, 112 p. (in Portuguese with English abs.).

Middlemost, E.A.K., 1994, Naming materials in the magma/igneous rock system: Earth Science Reviews, v. 37, p. 215-224.

Mikucki, E.J., and Ridley, J.R., 1993, The hydrothermal fluid of Archaean lode-gold deposits: constraints on its composition inferred from ore and wallrock alteration assemblages over a spectrum of metamorphic grades: Mineralium Deposita, v. 28, p. 469-481.

Mueller, A.G., Groves, D.I., and Delor, C.P., 1991, The Savage Lode magnesian skarn in the Marvel Loch gold–silver mine, Southern Cross greenstone belt, Western Australia. Part 2: Pressure–temperature estimates and constraints on fluid sources: Canadian Journal of Earth Sciences, v. 28 (5), p. 686–705.

Mueller, A.G., Nemchin, A.A., and Frei, R., 2004, The Nevoria gold skarn deposit, Southern Cross greenstone belt, Western Australia: Pressure-Temperature-Time path and relationship to postorogenic granites: Economic Geology, v. 99, p. 453-478.

Nadoll, P., 2011, Geochemistry of magnetite from hydrothermal ore deposits and host rocks - Case studies from the Proterozoic Belt Supergroup, Cu-Mo-porphyry + skarn and Climax-Mo deposits in the western United States: PhD thesis, Auckland, Australia, University of Auckland, 311 p.

Nogueira, S.A.A., 2002, Contribuição ao estudo metalogenético do depósito de ouro de Salamangone, Distrito aurífero de Lourenço, Amapá: PhD thesis, São Paulo, Brazil, Universidade de São Paulo, 250 p.

Onstott, T.C., and Hargraves, R.B., 1981, Proterozoic transcurrent tectonics: Paleomagnetic evidence from Venezuela and Africa: Nature, v. 289, p. 131–136.

Otto, A., Dziggel, A., Kisters, A.F.M., and Meyer, F.M., 2007, The New Consort gold mine, Barberton greenstone belt, South Africa: orogenic gold mineralization in a condensed metamorphic profile: Mineralium Deposita, v. 42, p. 715–735.

Pearce, J.A., Harris, N.B.W., and Tindle, A.G., 1984, Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: Journal of Petrology, v. 25, p. 956-983.

Ricci, P.S.F., Carvalho, J.M.A., Rosa-Costa, L.T., Klein, E.L., Vasquez, M.L., Vale, A.G., Macambira, E.M.B., and Araújo, O.J.B., 2001, Geologia e recursos minerais do Projeto RENCA - Fase I: Brazilian Geological Survey, Belém, Brazil, 69 p. (in Portuguese).

Ridley, J.R., and Diamond, L.W., 2000, Fluid chemistry of orogenic lode gold deposits and implications for genetic models: Reviews in Economic Geology, v. 13, p. 141–162.

Rieder, M., Cavazzini, G., D'Yakonov, Y.S., Frank-Kamenetskii, V.A., Gottardi, G., Guoggenheim, S., Koval, P.V., Muller, G., Neiva, A.M.R., Radoslovich, E.W., Robert, J.L., Sassi, F.P., Takeda, H., Weiss, Z., and Wones, D.R., 1998, Nomenclature of the micas: Canadian Mineralogist, v. 36, p. 41-48.

Rogers, A.J., Kolb, J., Meyer, F.M., and Vennemann, T.W., 2013, Two stages of gold mineralization at Hutti mine, India: Mineralium Deposita, v. 48, p. 99–114.

Rosa-Costa, L.T., Ricci, P.S.F., Lafon, J.M., Vazquez, M.L., Carvalho, J.M.A., Klein, E.L., and Macambira, E.M.B., 2003, Geology and geochronology of Archean and Paleoproterozoic domains of the southeastern Amapá and northwestern Pará, Brazil–southeastern Guiana Shield: Géologie de la France, v. 2–4, p. 101-120.

Rosa-Costa, L.T., Lafon, J.M., and Delor, C., 2006, Zircon geochronology and Sm-Nd isotopic study: Further constraints for the Archean and Paleoproterozoic geodynamic evolution of the southeastern Guiana Shield, north of Brazil: Gondwana Research, v. 10, p. 277-300.

Rosa-Costa, L.T., Chaves, C.L., and Klein, E.L., 2014, Geologia e recursos minerais da folha Rio Araguari NA.22-Y-B, estado do Amapá, escala 1:250.000: Belém, Brazil, Brazilian Geological Survey – CPRM, 159 p. (in Portuguese).

Santos, J.O.S., Hartmann, L.A., Gaudette, H.E., Groves, D.I., Mcnaughton, N.J., and Fletcher, I.R., 2000, A new understanding of the provinces of the Amazonian Craton based on integration of field mapping and U–Pb and Sm–Nd geochronology: Gondwana Research, v. 3, p. 453–488.

Santos, J.O.S., Hartmann, L.A., Faria, M.S., Riker, S.R., Souza, M.M., Almeida, M.E., and McNaughton, N.J., 2006, A compartimentacao do Craton Amazônico em províncias: Avanços ocorridos no período de 2000-2006 [ext. abs.]: Simpósio de Geologia da Amazônia, 9th, SBG Núcleo Norte, Belém, Brazil, Anais, 3, p. 156-159. (in Portuguese).

Scarpelli, W., and Horikava, E.H., 2017, Gold, iron and manganese in central Amapá, Brazil: Brazilian Journal of Geology, v. 47 (4), p. 703-721.

Shackleton, J.M., Spry, P.G., and Bateman, R., 2003, Telluride mineralogy of the Golden Mile deposit, Kalgoorlie, Western Australia: The Canadian Mineralogist, v. 41, p. 1503-1524.

Shand, S.J., 1943, Eruptive rocks: their genesis, composition, and classification, with a chapter on meteorites: New York, Wiley, 444p.

Sharp, Z.D., Essene, E.J., and Kelly W.C., 1985, Reexamination of the arsenopyrite geothermometer: pressure considerations and application to natural assemblages: Canadian Mineralogist, v. 23, p. 517-534.

Steven, N., Creaser, R., Wulff, K., Kisters, A., Eglington, B., and Miller, J., 2014, Implications of high-precision Re–Os molybdenite dating of the Navachab orogenic gold deposit, Namibia: Geochemistry: Exploration, Environment, Analysis, v. 15 (2-3), p. 125-130.

Sun, S.S., McDonough, W.F., 1989, Chemical and isotopic systematics of oceanic basalts: implication for mantle composition and processes: Geological Society Special Publication, v. 42, p. 313–345.

Tassinari, C.C.G., and Macambira, M.J.B., 1999, Geochronological provinces of the Amazonian Craton: Episodes, v. 22, p. 174–182.

Tassinari, C.C.G., and Macambira, M.J.B., 2004, A evolução tectônica do Cráton Amazônico, in Mantesso-Neto, V., Bartorelli, A., Carneiro, C.D.R., and Brito Neves, B.B., eds., Geologia do Continente Sul-Americano: Evolução da Obra de Fernando Flávio Marques de Almeida: São Paulo, Beca, p. 471–485. (in Portuguese).

Tavares, R. P. S., 2009, Granitoides e anfibolitos da Serra do Navio, borda norte do bloco arqueano Amapá: caracterização petrográfica e geoquímica, geocronologia Pb-Pb em zircão e isótopos de Nd: M.Sc. thesis, Belém, Brazil, Universidade Federal do Pará, 114 p. (in Portuguese with English abs.).

Taylor, S. R., and McLennan, S.M., 1985, The Continental Crust: Its Composition and Evolution: Oxford, Blackwell, 312p.

Tomkins, A.G., Frost, B.R., and Pattison, D.R.M., 2006, Arsenopyrite melting during metamorphism of sulfide ore deposits: Canadian Mineralogist, v. 44, p. 1045–1062.

Tooth, B., Brugger, J., Ciobanu, C., and Liu, W., 2008, Modeling of gold scavenging by bismuth melts coexisting with hydrothermal fluids. Geology, v. 36, p. 815–818.

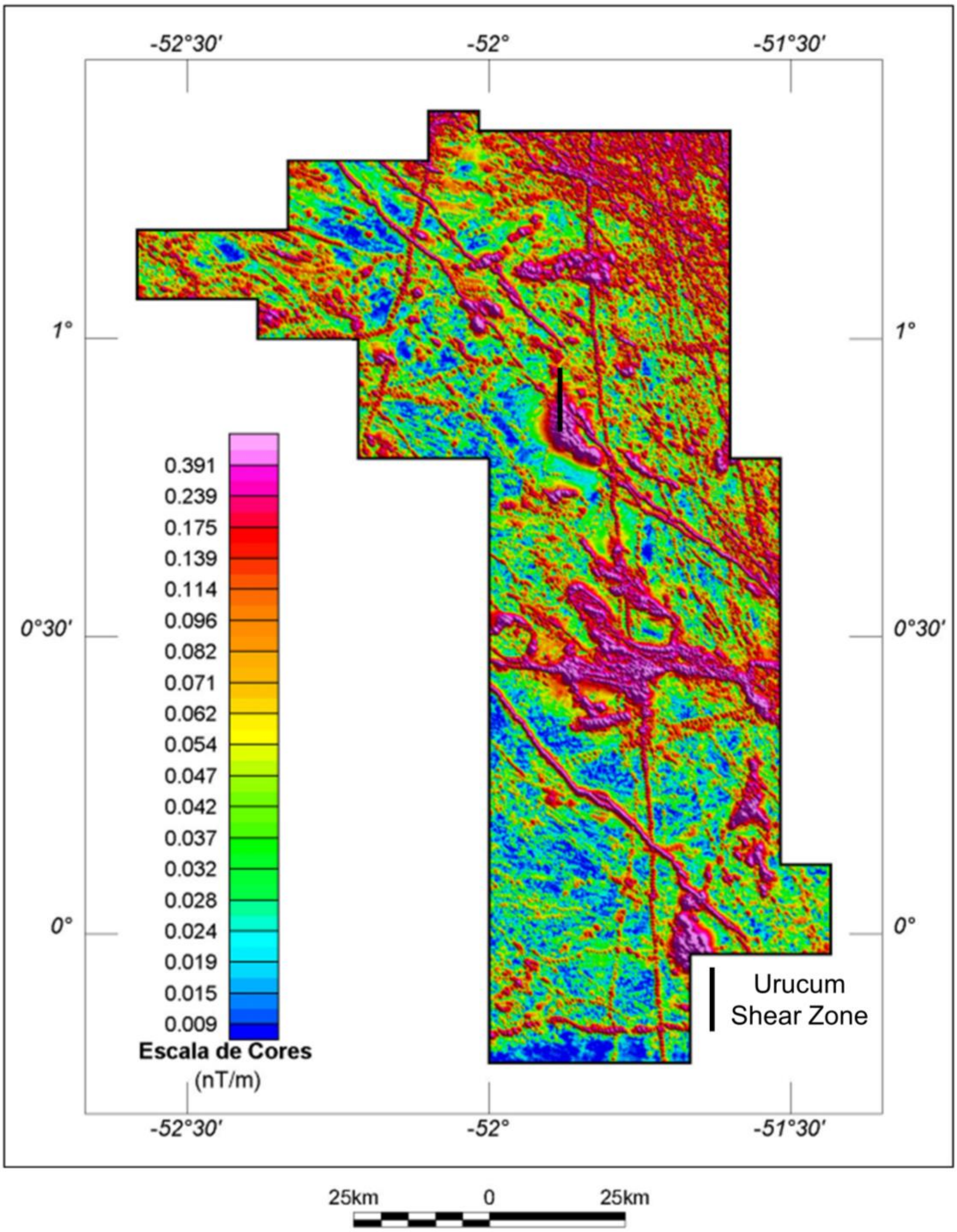
Vasquez, M.L., Rosa-Costa, L.T.R., 2008, Geologia e recursos minerais do Pará: Texto explicativo dos mapas geológico, tectônico e de recursos minerais do estado do Pará: Belém, Brazilian Geological Survey – CPRM, 328 p.

Weir Jr, R.H., and Kerrich, D.M., 1987, Mineralogic, fluid inclusion, and stable isotope studies of several gold mines in the Mother Lode, Tuolumne and Mariposa counties, California: Economic Geology, v. 82, p. 328-344.

Winter, J.D., 2010, An introduction to igneous and metamorphic petrology, 2nd edition: Upper Saddle River, Prentice Hall, 702 p.
Wu, C.M., 2019, Original calibration of a garnet geobarometer in metapelite: Minerals, v. 9, p. 540.

Zang, W., and Fyfe, W.S., 1995, Chloritization of the hydrothermally altered bedrock at the Igarapé Bahia gold deposit, Carajás, Brazil: Mineralium Deposita, v. 30, p. 30-38.

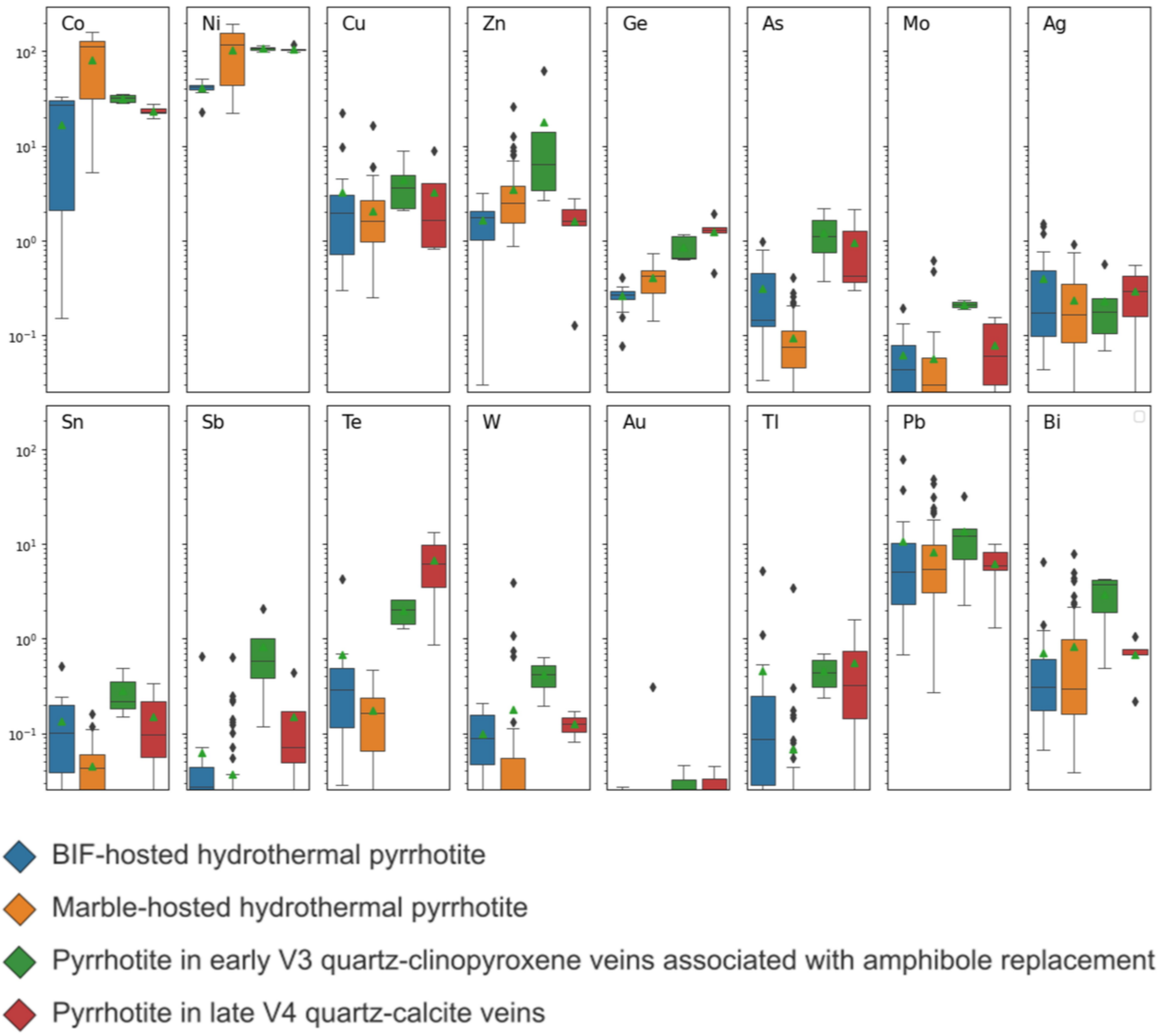
ELECTRONIC APPENDIX FIGURE A1 – Analytic signal amplitude (ASA) inversion of total field magnetic anomaly map (CPRM, 2004), showing the location of the ore-hosting Urucum Shear Zone



Reference

CPRM, 2004, Relatório final do levantamento e processamento dos dados magnetométricos e gamaespectrométricos: Projeto aerogeofísico Rio Araguari: Brazil, Brazilian Geological Survey – CPRM, 136 p. (in Portuguese).

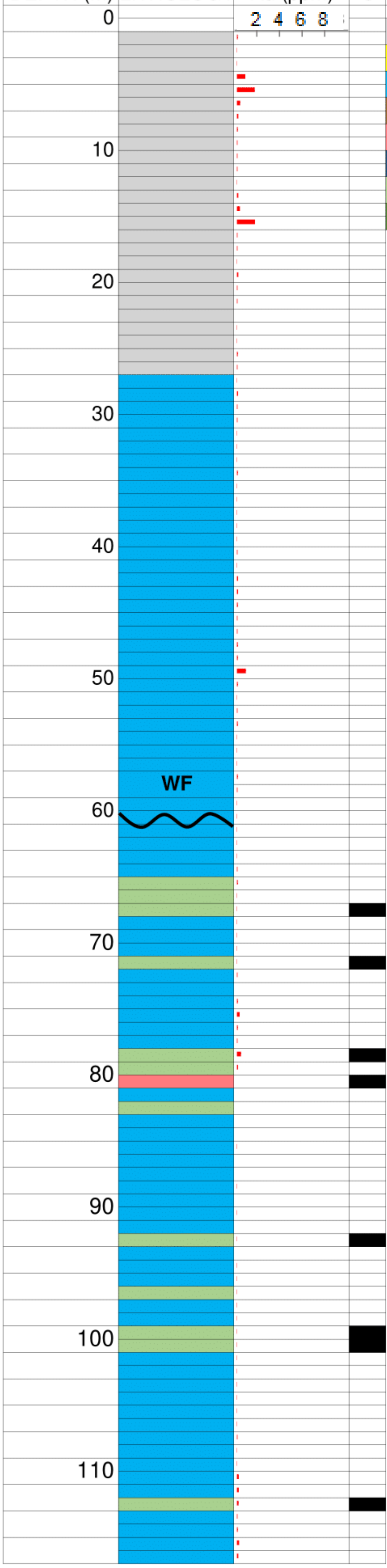
ELECTRONIC APPENDIX FIGURE A2 – Trace element composition of pyrrhotite



Boxplots for main stage (BIF- and marble-hosted, as well as quartz-clinopyroxene-amphibole vein-hosted) and late-stage (quartz-calcite vein-hosted) alteration pyrrhotite trace element composition in ppm. Data plotted on logarithmic scale. The upper and lower margins of the box represent the upper and lower quartile of the data distribution. The whiskers represent the upper and lower threshold values (95 percentile of the data). Median values are shown as solid horizontal lines, whereas green triangles indicate mean values. Black diamonds are outliers.

ELECTRONIC APPENDIX TABLE A1 – Graphic logs

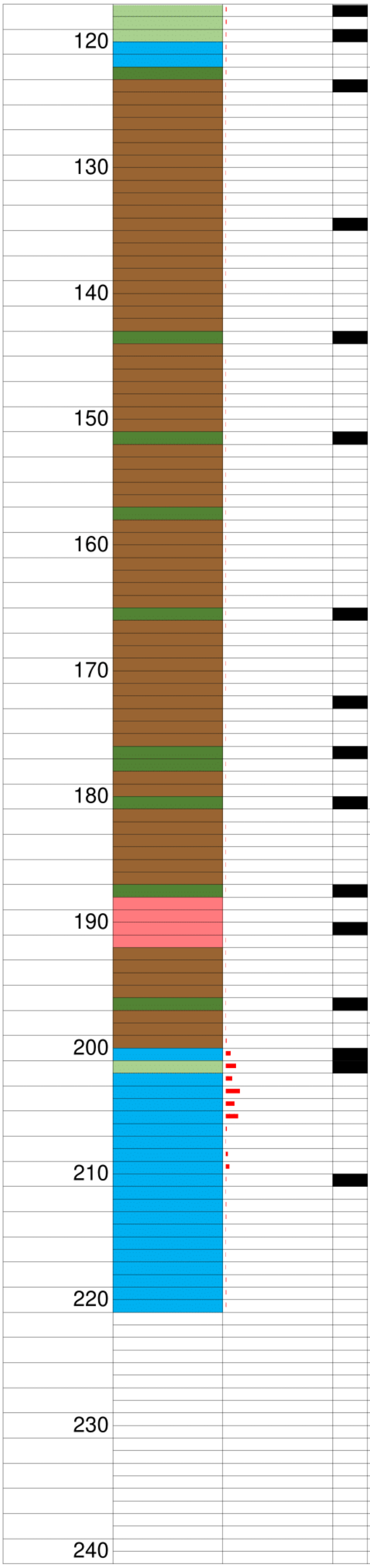
DRILLCORE LOGGING				NOTES:
DRILLHOLE ID:		A04		S = SAMPLE / WF = WEATHERING FRONT
DEPTH (m)	LITHOLOGY	Au (ppm)	S	DESCRIPTION



	(GRT)-PL-MS-BT-QZ SCHIST
	(MS) QUARTZITE
	LEAST-ALTERED (TR)-PHL-OL MARBLE
	LEAST-ALTERED OXIDE-TYPE BIF
	LEUCOGRANITE
	DIABASE
	ALTERED MARBLE
	ALTERED BIF

WHEATERED SECTION NOT LOGGED

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: hydrothermal alteration is manifested as light green blebs or lenticular coarse-grained diopside aggregates (locally as boudinaged veins), occasionally with minor garnet association. Quartz nodules and lenses may be found interspersed between diopside clots. Such features are often observed enveloped and infiltrated by dark green amphibole and possibly some biotite. Overall, the geometry of alteration features is concordant to shear zone foliation. These greenish rocks range from weakly to moderately and more rarely strongly magnetic, indicating variable magnetite concentrations. Sulfide content ranges from negligible to moderate, rarely exceeding 5-10 volume percent. Pyrrhotite is by far the most abundant sulfide, with local identification of chalcopyrite and pyrite in very minor proportions. Pyrrhotite occurs as disseminated fine- to coarse-grained aggregates, sometimes displaying preffered orientation, and more rarely as feeder/shear veins. Domains of greenish calc-silicate minerals are sometimes centered about quartz-diopside veins overrun by oriented fibrous aggregates of a light brown amphibole (grunerite). These are almost ubiquitously magnetite-free and their pyrrhotite content is variable.



Wallrock: fine- to medium-grained quartz-magnetite-dominated banded rock (BIF - BIF) with milimeter-thick regular mesobands (seldom exceeding 1 cm in thickness) that locally display internal microbands. Disseminated fine-grained light green amphibole can be found throughout the package in fairly diminute volume proportions. The BIF exhibits open folds and more rarely tight folds with development of axial plane cleavage. Bands can be locally sheared and also be offset by faults with limited displacement.
Alteration products: light green clinopyroxene veins are a common hydrothermal feature, which oftens partitions the strain displayed by its host rock. These veins, which are frequently thinner than 1 cm, are usually boudinaged and may also be offset by shear and tightly folded when oriented at high angle to the banding plane. In addition, the boudinaged clinopyroxene veins may feature amphibole lining and boudin neck amphibole filling, which can be accompanied by pyrrhotite precipitation. Amphiboles may characteristically occur as haloes around and replacement of magnetite-rich bands (lesser frequently about quartz-rich bands). This superimposed amphibole alteration front is often concordant to the banded rock structure, even when banding is folded.

Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: darker, moderately magnetic intervals are identified and coincide with higher gold grades. Other alteration features observed in this section are partial to total replacement by irregular dark green amphibole masses with accompanying minor pyrrhotite as well as dark green amphibole milimeter-thick amphibole veinlets.

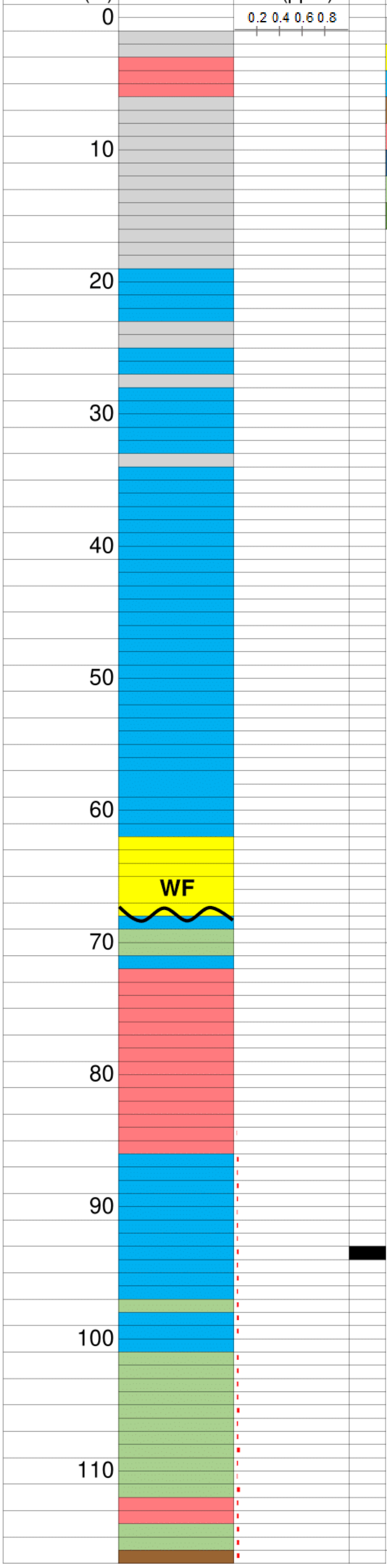
DRILLCORE LOGGING

DRILLHOLE ID: A05

NOTES:

S = SAMPLE / WF = WEATHERING FRONT

DEPTH (m) | LITHOLOGY | Au (ppm) | S | DESCRIPTION



(GRT)-PL-MS-BT-QZ SCHIST

(MS) QUARTZITE

LEAST-ALTERED (TR)-PHL-OL MARBLE

LEAST-ALTERED OXIDE-TYPE BIF

LEUCOGRANITE

DIABASE

ALTERED MARBLE

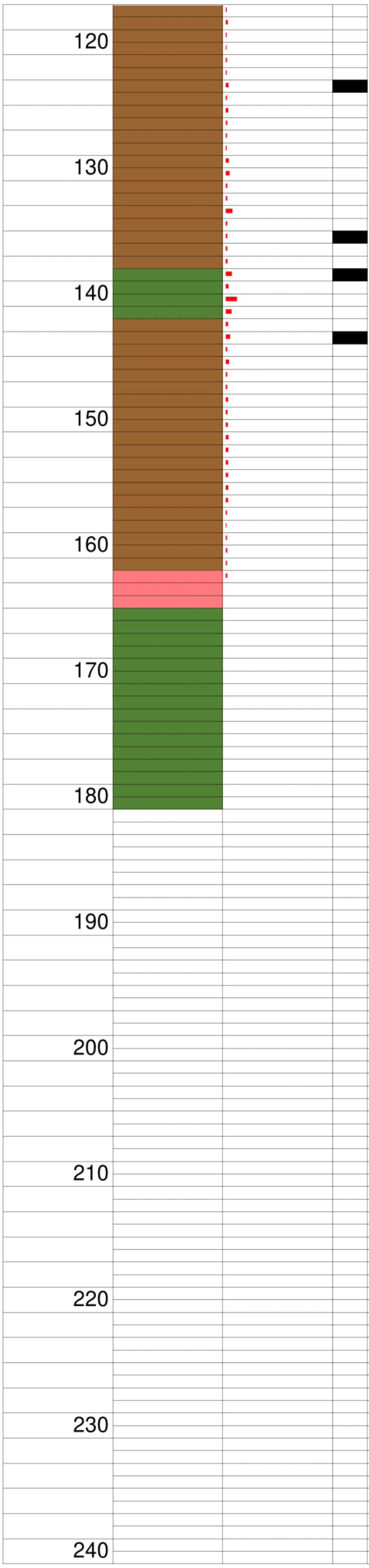
ALTERED BIF

WHEATERED SECTION NOT LOGGED

Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: hydrothermal alteration is manifested as light green blebs or preferentially oriented lenticular coarse-grained diopside aggregates, occasionally with minor garnet association. Such features are often observed enveloped and infiltrated by dark green amphibole. Overall, the geometry of alteration features is concordant to shear zone foliation. Sulfide content is negligible. Magnetism increases as amphibole volume proportion is augmented.

Wallrock: fine- to medium-grained quartz-magnetite-dominated



Wallrock: fine- to medium-grained quartz-magnetite-dominated banded rock (BIF - BIF) with milimeter- to centimeter-thick regular mesobands that locally display internal microbands. Disseminated fine-grained light green amphibole can be found throughout the package in fairly diminute volume proportions. The BIF exhibits open folds and more rarely tight folds with development of axial plane cleavage. Bands can be locally sheared and also be offset by faults with limited displacement.
Alteration products: light green clinopyroxene veins are a common alteration feature. These veins, which are frequently thinner than 2 cm, are usually boudinaged and may also be offset by shear and tightly folded when oriented at high angle to the banding plane. In addition, the boudinaged clinopyroxene veins typically display thin amphibole + pyrrhotite lining, also precipitating in boudin necks. Amphiboles also develop as haloes around and concordant replacement of magnetite-rich bands and more rarely as submilimeter-thick veinlets.

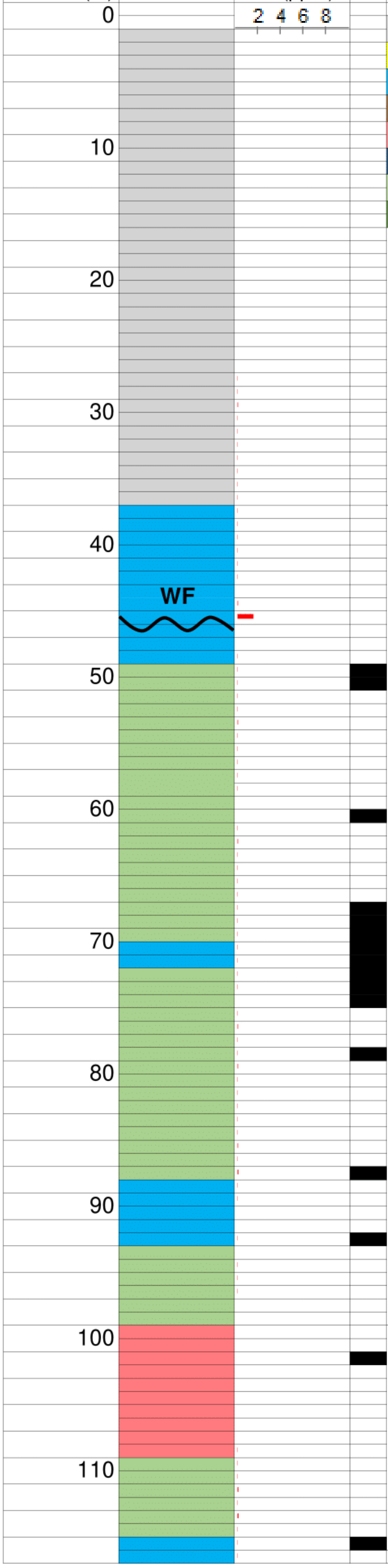
Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

DRILLCORE LOGGING

DRILLHOLE ID: A09

NOTES: S = SAMPLE / WF = WEATHERING FRONT

DEPTH (m)	LITHOLOGY	Au (ppm)	S	DESCRIPTION

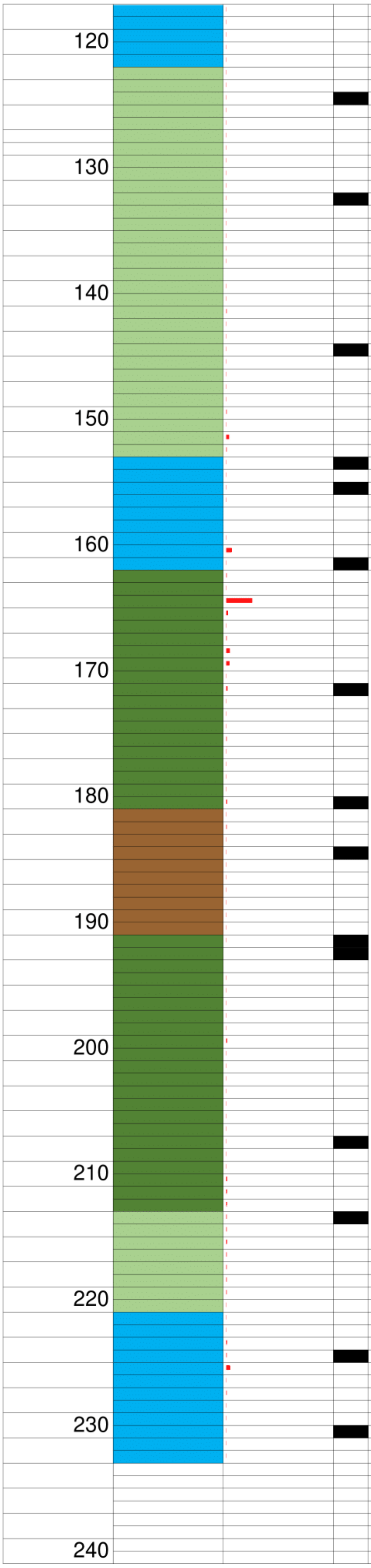


(grey)	(GRT)-PL-MS-BT-QZ SCHIST
(yellow)	(MS) QUARTZITE
(blue)	LEAST-ALTERED (TR)-PHL-OL MARBLE
(brown)	LEAST-ALTERED OXIDE-TYPE BIF
(pink)	LEUCOGRANITE
(dark blue)	DIABASE
(light green)	ALTERED MARBLE
(dark green)	ALTERED BIF

WHEATERED SECTION NOT LOGGED

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: hydrothermal alteration is manifested as light green blebs or lenticular coarse-grained diopside aggregates (locally as boudinaged veins), occasionally with minor garnet association. Quartz nodules and lenses may be found interspersed between diopside clots. Such features are often observed enveloped and infiltrated by dark green amphibole and possibly some biotite. Overall, the geometry of alteration features is concordant to shear zone foliation. In addition, alteration manifests itself as banded amphibole-quartz-garnet-biotite-diopside rocks. These usually alternate with bands of the carbonate precursor. Altered rocks range from weakly to moderately and more rarely strongly magnetic. Irregular amphibole veinlets are also reported. Sulfide content ranges from negligible to moderate, rarely exceeding 5-10 volume percent. Pyrrhotite is by far the most abundant sulfide, with local identification of chalcopyrite and pyrite in very minor proportions. Pyrrhotite occurs as disseminated fine- to coarse-grained aggregates, sometimes displaying preffered orientation, and more rarely as thin discontinuous veinlets. Moreover, alteration also takes place as replacement of olivine by serpentine-magnetite.

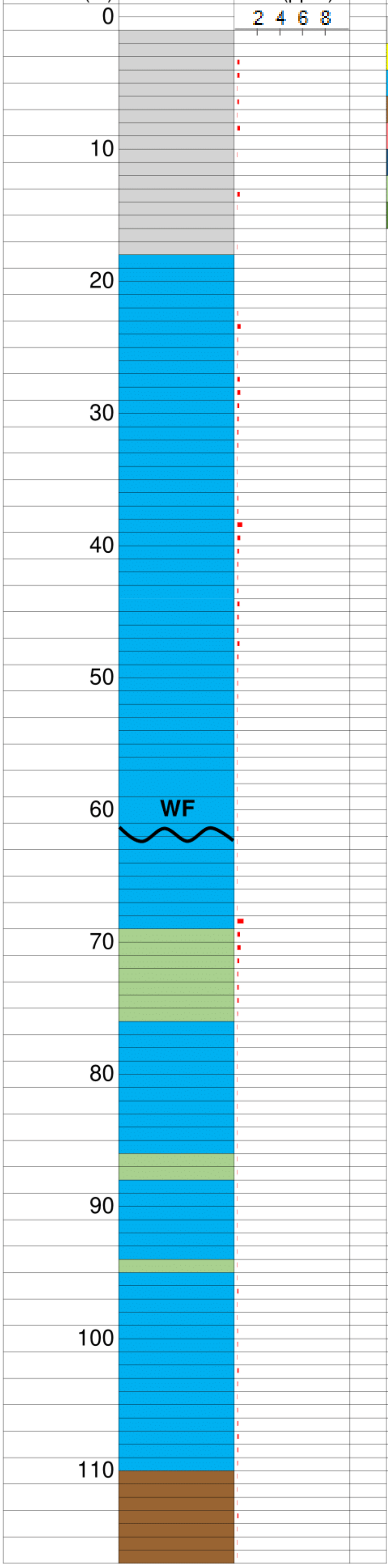
Coarse-grained garnet-bearing muscovite-rich leucogranite, locally displaying pegmatoid texture, with very coarse muscovite plates. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.



Wallrock: fine- to medium-grained quartz-magnetite-dominated banded rock (BIF - BIF) with milimeter- to centimeter-thick regular mesobands that locally display internal microbands. Disseminated fine-grained light green amphibole can be found throughout the package in fairly diminute volume proportions. The BIF exhibits open folds and more rarely tight folds with development of axial plane cleavage. Bands can be locally sheared and also be offset by faults with limited displacement.
Alteration products: light green clinopyroxene blebs and veins are a common alteration feature. These veins, which are frequently thinner than 2 cm, are usually boudinaged and may also be offset by shear and tightly folded when oriented at high angle to the banding plane. In addition, the boudinaged clinopyroxene veins typically display thin amphibole + pyrrhotite lining, also precipitating in boudin necks. Amphiboles also develop as haloes around and concordant replacement of magnetite-rich bands and more rarely as submilimeter-thick veinlets. Quartz bands are often recrystallized. Late carbonate veins are associated with retrograde replacement of hydrothermal amphiboles and pyrite precipitation as disseminations and veinlets.

DRILLCORE LOGGING		NOTES:
DRILLHOLE ID:	A11	S = SAMPLE / WF = WEATHERING FRONT

DEPTH (m) | LITHOLOGY | Au (ppm) | S | DESCRIPTION

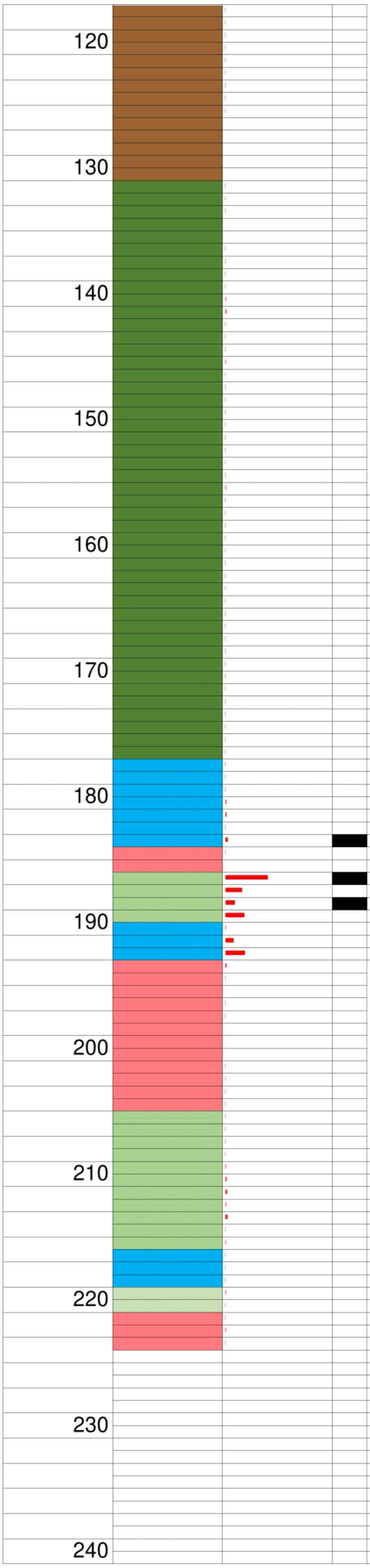


(grey)	(GRT)-PL-MS-BT-QZ SCHIST
(yellow)	(MS) QUARTZITE
(blue)	LEAST-ALTERED (TR)-PHL-OL MARBLE
(brown)	LEAST-ALTERED OXIDE-TYPE BIF
(pink)	LEUCOGRANITE
(dark blue)	DIABASE
(light green)	ALTERED MARBLE
(dark green)	ALTERED BIF

WHEATERED SECTION NOT LOGGED

<u>Wallrock</u>: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. <u>Alteration products</u>: hydrothermal alteration is manifested as light green blebs or preferentially oriented lenticular coarse-grained diopside aggregates, occasionally with minor garnet association. Such features are often observed enveloped and infiltrated by dark green amphibole. Overall, the geometry of alteration features is concordant to shear zone foliation. Sulfide content is negligible. Magnetism increases as amphibole volume proportion is augmented.

Wallrock: fine- to medium-grained quartz-magnetite-dominated banded rock (BIF - BIF) with milimeter- to centimeter-thick regular mesobands that locally display internal microbands. Disseminated



fine-grained light green amphibole can be found throughout the package in fairly diminute volume proportions. The BIF exhibits open folds and more rarely tight folds with development of axial plane cleavage. Bands can be locally sheared and also be offset by faults with limited displacement.

Alteration products: light green clinopyroxene veins are a common alteration feature. These veins, which are frequently thinner than 2 cm, are usually boudinaged and may also be offset by shear and tightly folded when oriented at high angle to the banding plane. In addition, the boudinaged clinopyroxene veins typically display thin amphibole + pyrrhotite lining, also precipitating in boudin necks. Amphiboles also develop as haloes around and concordant replacement of magnetite-rich bands and more rarely as submilimeter-thick veinlets.

Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

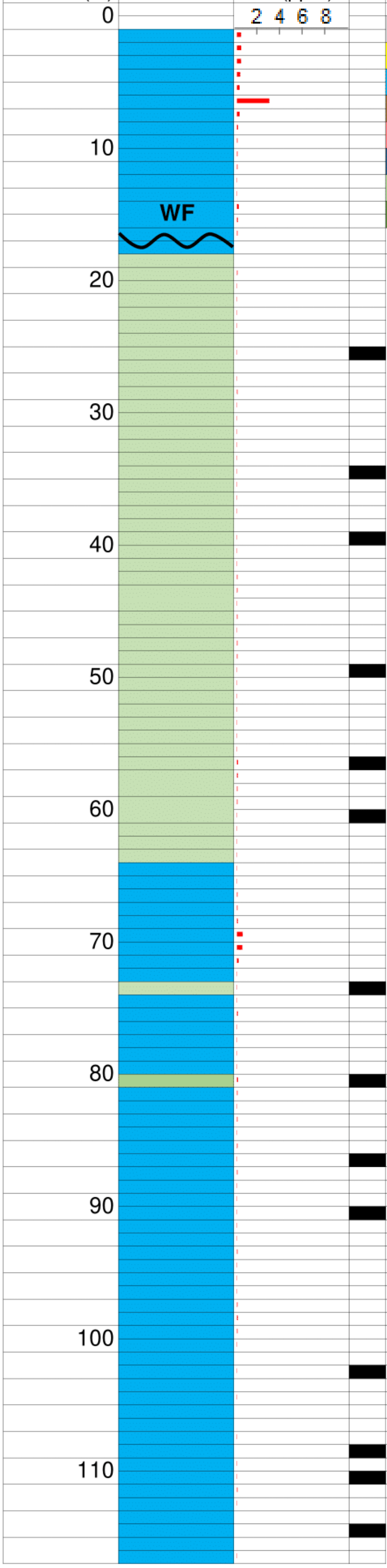
DRILLCORE LOGGING

DRILLHOLE ID: A27

NOTES:

S = SAMPLE / WF = WEATHERING FRONT

DEPTH (m)	LITHOLOGY	Au (ppm)	S	DESCRIPTION



	(GRT)-PL-MS-BT-QZ SCHIST
	(MS) QUARTZITE
	LEAST-ALTERED (TR)-PHL-OL MARBLE
	LEAST-ALTERED OXIDE-TYPE BIF
	LEUCOGRANITE
	DIABASE
	ALTERED MARBLE
	ALTERED BIF

WHEATERED SECTION NOT LOGED

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: hydrothermal alteration is manifested as light green blebs or preferentially oriented lenticular coarse-grained diopside aggregates, which are ubiquitously enveloped and infiltrated by dark green amphibole. Overall, the geometry of alteration features is concordant to shear zone foliation. Exception to this rule applies mainly to irregular white calcite nodules scattered in the metacarbonate precursor. Magnetism increases as amphibole volume proportion is augmented, implying a direct correlation between hydrothermal magnetite and amphibole. Sulfide content is generally negligible, with few exceptions in restricted intervals where disseminated medium- to coarse-grained pyrrhotite lenticular aggregates are featured within amphibole-rich domains. Such aggregates are usually oriented in accordance to shear zone foliation. Moreover, alteration also produces motted carbonate rocks with disseminated clots of fine-grained intergrown serpentine and magnetite, likely formed as a result of retrograde replacement of olivine. Such features seem to be clustered in the vicinity of highly strained serpentine-dolomite veins no thicker than 2 cm.

Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the

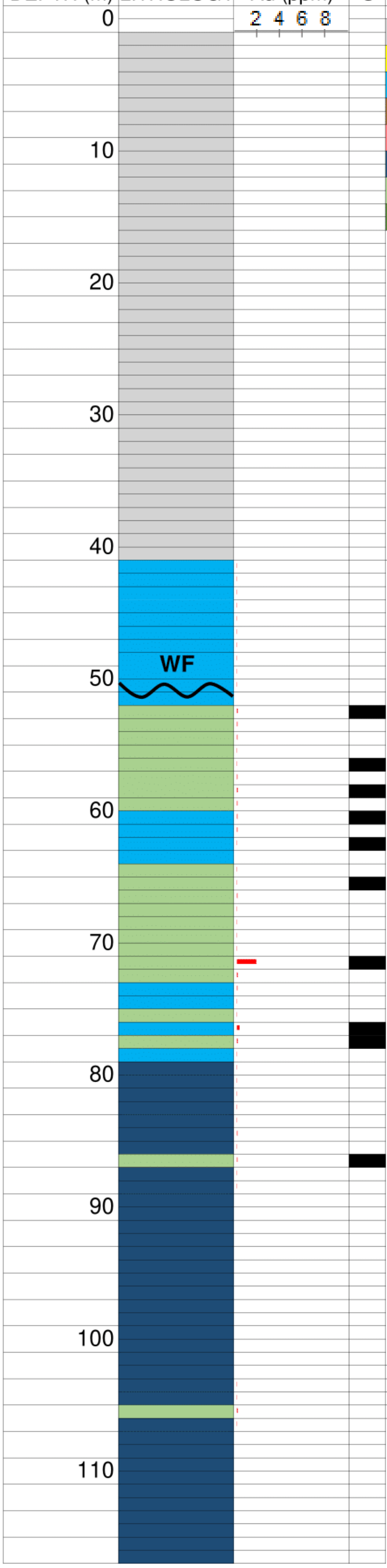
120

Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

130

DRILLCORE LOGGING		NOTES:
DRILLHOLE ID:	A28	S = SAMPLE / WF = WEATHERING FRONT

DEPTH (m) | LITHOLOGY | Au (ppm) | S | DESCRIPTION

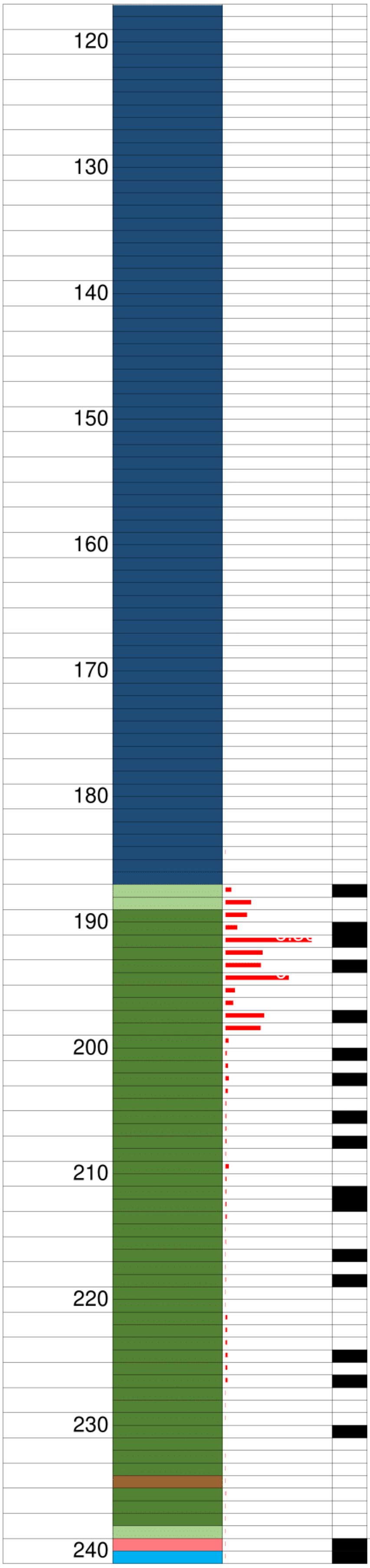


	(GRT)-PL-MS-BT-QZ SCHIST
	(MS) QUARTZITE
	LEAST-ALTERED (TR)-PHL-OL MARBLE
	LEAST-ALTERED OXIDE-TYPE BIF
	LEUCOGRANITE
	DIABASE
	ALTERED MARBLE
	ALTERED BIF

WHEATERED SECTION NOT LOGGED

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: hydrothermal alteration is manifested as light green blebs or boudinaged diopside veins. These can be part of a banded fabric, alternating with biotite-garnet and quartz-amphibole levels, as well as remnants of the precursor rock. White calcite nodules are also reported. Light green diopside blebs are typically arranged in a nebulitic-like structure, enveloped and infiltrated by dark green amphibole and possibly some biotite. Overall, the geometry of alteration features is concordant to shear zone foliation. These greenish rocks range from weakly to moderately magnetic, indicating variable magnetite concentrations. Moreover, alteration also produces motted carbonate rocks with disseminated clots of fine-grained intergrown serpentine and magnetite, likely formed as a result of retrograde replacement of olivine. Sulfide content is negligible, being represented by fine- to medium-grained anhedral pyrrhotite aggregates filling cracks and fissures in diopside and also accompanying amphibole. Domains of greenish calc-silicate minerals are sometimes centered about quartz-diopside veins overrun by oriented fibrous aggregates of a light brown amphibole (grunerite). These are almost ubiquitously magnetite-free.

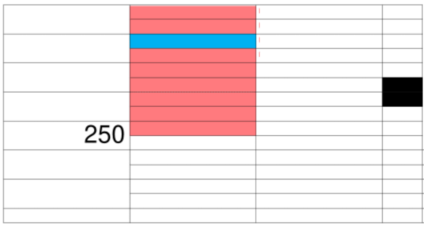
Isotropic, homogeneous, dark grey rock ranging from afanitic to fine-grained faneritic, likely dominated by plagioclase and clinopyroxene assembled in a subophitic to intergranular fabric, with accessory



magnetite identified by slight magnetism of the rock. While the inner parts of this rock unit are holocrystalline, the intrusive contacts with its country rocks are characterized by chilled margin glassy appearance (hyalocrystalline character).

Wallrock: fine- to medium-grained quartz-magnetite-dominated banded rock (BIF - BIF) with milimeter- to centimeter-thick regular mesobands that locally display internal microbands. Disseminated fine-grained light green amphibole can be found in fairly diminute volume proportions. Least altered BIF is very scarce in this drillcore. Alteration products: i) 186 - 204 / 209 - 213 / 217 - 226 m: highly magnetite-rich rocks (locally exceeding 70 volume percent) with near complete obliteration of the precursor banded fabric that, whenever preserved to some extent, is often found to be openly to tightly folded with associated shear. Dark green amphibole and calcite (as indicated by strong HCl fizzle) are also abundant, the first locally forming nearly bimineralic domains with magnetite. Sulfide abundance ranges from incipient to close to 20 volume percent within small intervals, with pyrrhotite as the only phase identified under naked eye. It can occur as follows: a) interconnected network of chaotically disseminated irregular and stringer-like aggregates defining a foliation; b) preferentially oriented clots or lenticular aggregates, in isolated clusters or pervasively disseminated, subparalell or at low angle to shear zone foliation, locally as banding replacement seams; c) small feeder/shear and tensional veins. ii) 204 - 205 / 213 - 217 / 226 - 237 m: greenish banded rocks characterized by structurally controlled (concordant to banding) pervasively amphibole replacement along magnetite-rich bands and less often along quartz-rich bands. Light green clinopyroxene veins are reported as a subordinated feature. Sulfide content is negligible, with only local banding-paralell replacement seams or lenses.

Very coarse-grained to pegmatoid pinkish leucogranite with k-

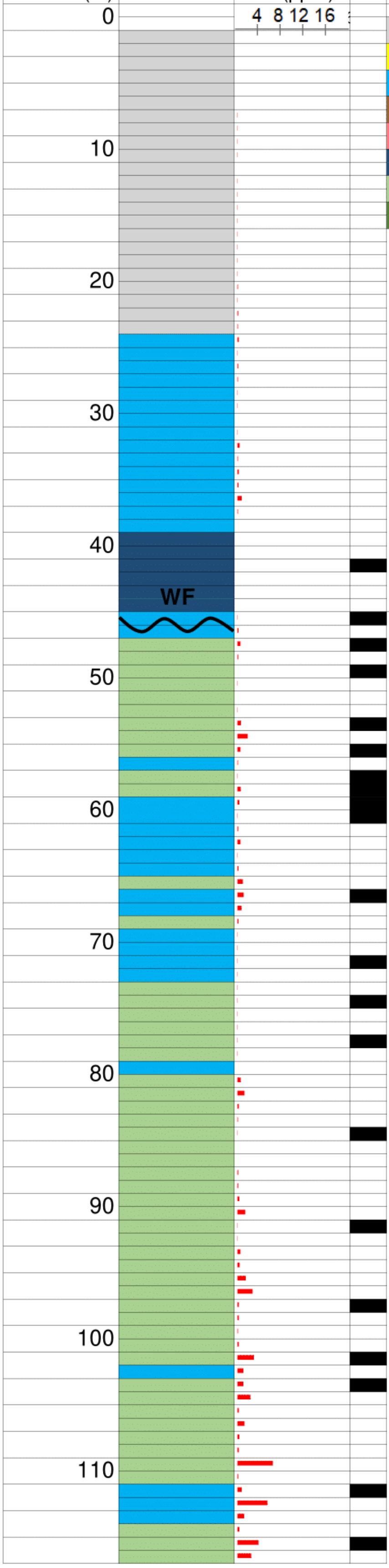


feldspar megacrysts. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

DRILLCORE LOGGING

DRILLHOLE ID: A29

DEPTH (m) | LITHOLOGY | Au (ppm) | S



NOTES:

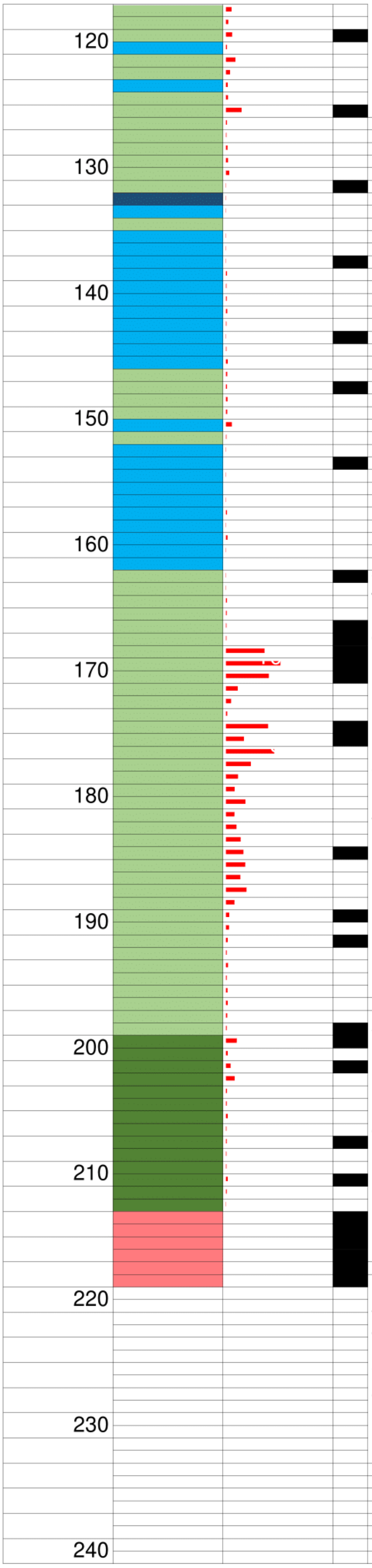
S = SAMPLE / WF = WEATHERING FRONT

DESCRIPTION

- (GRT)-PL-MS-BT-QZ SCHIST
- (MS) QUARTZITE
- LEAST-ALTERED (TR)-PHL-OL MARBLE
- LEAST-ALTERED OXIDE-TYPE BIF
- LEUCOGRANITE
- DIABASE
- ALTERED MARBLE
- ALTERED BIF

WHEATERED SECTION NOT LOGGED

<u>Wallrock</u>: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. <u>Alteration products</u>: alteration is manifested as light green blebs or boudinaged diopside veins, as well as quartz-diopside veins. Garnet-biotite rich intervals are locally associated with such structures. Light green diopside blebs are typically arranged in a nebulitic-like structure, enveloped and infiltrated by dark green amphibole and possibly some biotite. Locally, this yields a banded pattern, alternating diopside, amphibole and garnet seams. Quartz-diopside veins are usually surrounded by green amphibole. Overall, the geometry of alteration features is concordant to shear zone foliation. These greenish rocks range from weakly to moderately and more rarely strongly magnetic, indicating variable magnetite concentrations. Moreover, alteration also produces motted carbonate rocks with disseminated clots of fine-grained intergrown serpentine and magnetite, likely formed as a result of retrograde replacement of olivine. White calcite masses and veins are also reported and may be spatially associated with amphibole. Locally, stretched calcite lenses are observed. Sulfide content is variable, with intervals where it is virtually absent to others where a few volume percent can be recognized, being solely described as pyrrhotite. It is often described as a disseminated phase interspersed/intergranular within amphibole-rich rocks, although coarse to very coarse anhedral aggregates can be seen within some calcitic masses. Disseminated oriented clots are also reported in moderately to strongly magnetic carbonate-rich rocks. Discontinuous tensional veins at high angle to main foliation are rarely observed.

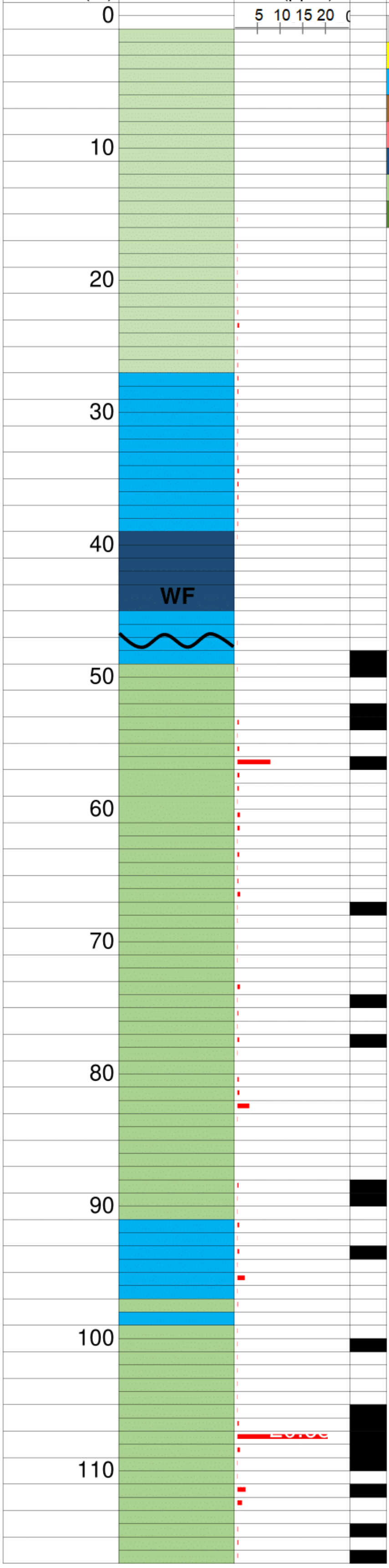


<u>Wallrock</u>: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. <u>Alteration products</u>: moderately to strongly magnetic carbonate-rich rocks with abundant interconnected (network) subparalell stringers of green amphibole and green biotite, which can locally develop massive greenish concentrations. Stringers and seams of magnetite and pyrrhotite are also featured and, together with the above mentioned silicates, define the rock foliation which is concordant to shear zone orientation. Some of the pyrrhotite seems to develop on top of former magnetite bands/seams. Disseminated irregular medium- to coarse-grained pyrrhotite aggregates are also reported.

Altered rocks apparently developed over a BIF interval from where least-altered varieties are no longer detected. When the precursor's banding fabric is preserved, microbands can be observed within the macroscopic mesobands. Notwithstanding, banding is mostly disrupted in this interval, which apparently displays the same alteration minerals as above. One distinguishing feature is that the light bands are made up of carbonate instead of quartz.

Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

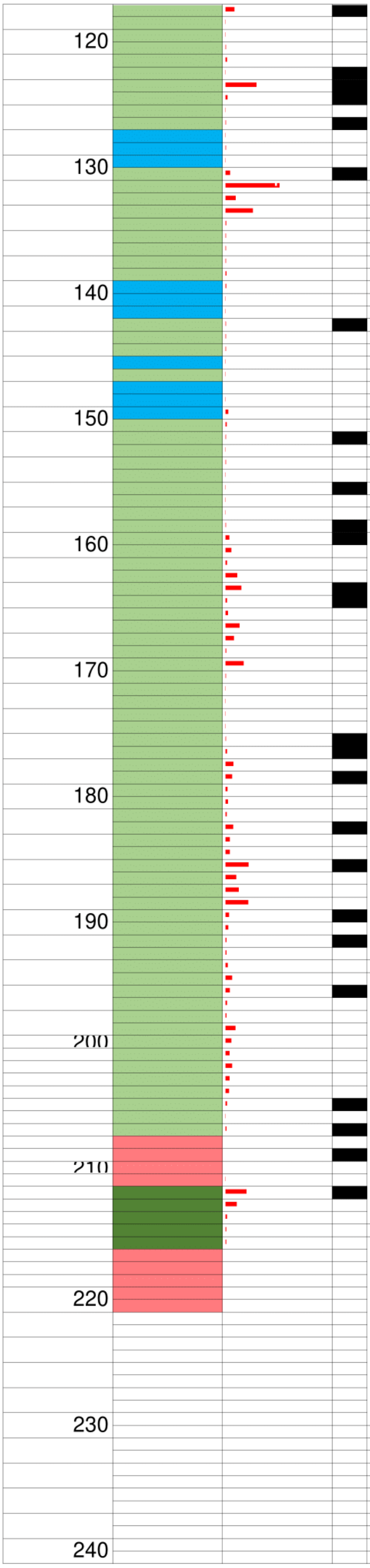
DRILLCORE LOGGING				NOTES:
DRILLHOLE ID:		A33		S = SAMPLE / WF = WEATHERING FRONT
DEPTH (m)	LITHOLOGY	Au (ppm)	S	DESCRIPTION



Grey	(GRT)-PL-MS-BT-QZ SCHIST
Yellow	(MS) QUARTZITE
Light blue	LEAST-ALTERED (TR)-PHL-OL MARBLE
Brown	LEAST-ALTERED OXIDE-TYPE BIF
Pink	LEUCOGRANITE
Dark blue	DIABASE
Light green	ALTERED MARBLE
Dark green	ALTERED BIF

WHEATERED SECTION NOT LOGGED

Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: alteration is manifested as light green blebs or boudinaged diopside veins, as well as quartz-diopside veins. Garnet-biotite rich intervals are locally associated with such structures. Light green diopside blebs are typically arranged in a nebulitic-like structure, enveloped and infiltrated by dark green amphibole and possibly some biotite. Locally, this yields a banded pattern, alternating diopside, amphibole and garnet seams. Domains of greenish calc-silicate minerals are sometimes centered about quartz-diopside veins overrun by oriented fibrous aggregates of a light brown amphibole (grunerite). Overall, the geometry of alteration features is concordant to shear zone foliation. These greenish rocks range from weakly to moderately and more rarely strongly magnetic, indicating variable magnetite concentrations. Moreover, alteration also produces motted carbonate rocks with disseminated clots of fine-grained intergrown serpentine and magnetite, likely formed as a result of retrograde replacement of olivine. White calcite masses and veins are also reported and may be spatially associated with amphibole. Locally, stretched calcite lenses are observed. Sulfide content is variable, with intervals where it is virtually absent to others where a few volume percent can be recognized, being solely described as pyrrhotite. It is often described as a disseminated phase interspersed/intergranular within amphibole-rich rocks as well as in quartz-clinopyroxene-amphibole veins, although coarse to very coarse anhedral aggregates can be seen within some calcitic masses. Disseminated oriented clots are also reported in moderately to strongly magnetic carbonate-rich rocks. Discontinuous tensional veins at high angle to main foliation are rarely observed.



Wallrock: Granoblastic, isotropic, fine- to medium-grained greyish rock with strong fizzle to HCl (carbonate-dominated composition) and disseminated subequant grains of a mafic mineral (olivine). Magnetism ranges from weak to moderate. Alteration products: moderately to strongly magnetic carbonate-rich rocks with abundant interconnected (network) subparalell stringers of green amphibole and green biotite, which can locally develop massive greenish concentrations. Stringers and seams of magnetite and pyrrhotite are also featured and, together with the above mentioned silicates, define the rock foliation which is concordant to shear zone orientation. Some of the pyrrhotite seems to develop on top of former magnetite bands/seams. Disseminated irregular medium- to coarse-grained pyrrhotite aggregates are also reported.

Altered rocks apparently developed over a BIF interval from where least-altered varieties are no longer detected. When the precursor's banding fabric is preserved, microbands can be observed within the macroscopic mesobands. Notwithstanding, banding is mostly disrupted in this interval, which apparently displays the same alteration minerals as above. One distinguishing feature is that the light bands are made up of carbonate instead of quartz.

Coarse-grained garnet-bearing muscovite-rich leucogranite. Medium- to coarse-grained tourmaline crystals are present as a minor phase. Thin reaction rims (a few centimeters at most) are recorded along the contacts between the granite dyke and its country rocks, being defined as inner garnet and outer clinopyroxene-amphibole haloes.

ELECTRONIC APPENDIX TABLE A2 - EPMA analytical conditions

Electronic Appendix Table A2. Electron microprobe analytical conditions

Silicate-Oxide-Carbonate routine

Operating conditions:
Acceleration voltage: 15kV
Beam current: 20nA
Beam diameter: 5µm
ZAF corrections were apllied for all elements

Element (X-ray line)	Standard[1]	Analyzing crystal	Channel	Counting time (s)[2]	Detection limit (ppm)
F (Kα)	fluorite	TAP	1	10	1557
Na (Kα)	jadeite	TAP	2	10	266
V (Kα)	divanadium trioxide	LIF	3	20	307
P (Kα)	apatite	PETJ	4	20	160
Si (Kα)	quartz	TAP	1	10	547
Mg (Kα)	forsterite	TAP	2	20	127
Mn (Kα)	rodonite	LIF	3	20	292
Cl (Kα)	chlorapatite	PETJ	4	20	50
Al (Kα)	corindon	TAP	2	10	333
Cr (Kα)	chromite	LIF	3	15	415
K (Kα)	sanidine	PETJ	4	20	80
Fe[3] (Kα)	magnetite	LIF	3	20	671
Ca (Kα)	apatite	PETJ	4	10	264
Ni (Kα)	Ni oxide	LIF	3	20	252
Ba (Kα)	barite	PETJ	4	10	387
Zn (Kα)	willemite	LIF	3	20	509
Ti (Kα)	rutile	PETJ	4	15	167

Sulfide-arsenide-gold routine

Operating conditions:
Acceleration voltage: 20kV
Beam current: 20nA
Beam diameter: 5µm
ZAF corrections were apllied for all elements

Element (X-ray line)	Standard[1]	Analyzing crystal	Channel	Counting time (s)[2]	Detection limit (ppm)
As (Lα)	loellingite	TAP	1	20	541
Fe (Kα)	chalcopyrite	LIF	3	10	530
S (Kα)	chalcopyrite	PETJ	4	10	189
Cu (Kα)	chalcopyrite	LIF	3	20	183
Ag (Lα)	Ag metal	PETJ	4	30	130
Zn (Kα)	Zn metal	LIF	3	10	211
Sb (Lα)	tellurantimony	PETJ	4	30	114
Co (Kα)	Co metal	LIF	3	30	132
Te (Lα)	tellurantimony	PETJ	4	30	130
Ni (Kα)	Ni metal	LIF	3	20	107
Au (Mα)	Au metal	PETJ	4	30	457
Pb (Mα)	galena	PETJ	4	20	318
Bi (Mα)	Bi metal	PETJ	4	20	269

[1]From Dr. Ian Steele's collection (The University of Chicago)

[2]At peak

[3]The total iron content obtained by the microprobe is considered as FeO

Further information

(1) Anhydrous minerals with closure below 98.5 wt. % or above 102 wt. % were discarded

(2) The structural mineral formula of biotite and amphiboles were calculated following Li et al. (2020a, b)

(3) Mineral chemistry plots were made using microsoft Excel.

References

Li, X., Zhang, C., Behrens, H., and Holtz, F., 2020a, Calculating biotite formula from electron microprobe analysis data using a machine learning method based on principal component regression: Lithos, v. 356-357, 105371.

Li, X., Zhang, C., Behrens, H., and Holtz, F., 2020b, Calculating amphibole formula from electron microprobe analysis data using a machine learning method based on principal component regression: Lithos, v. 362-363, 105469.

ELECTRONIC APPENDIX TABLE A3 - Whole-rock geochemistry – Methodology

Electronic Appendix Table A3. Whole-rock geochemistry - Methodology

Powdered samples were obtained by jaw crushing to less than 2 mm, riffle splitting off 250g and pulverizing the split to better than 85% passing 75 microns. As an effort to mitigate cross-contamination, barren material was inserted between samples to clean crushers and pulverisers. Major elements were determined by ICP-AES following fusion and acid digestion, with Loss On Ignition (LOI) quantified at 1000 °C. Total carbon and sulfur were determined by induction furnace/ IR spectroscopy. Lithium borate fusion prior to acid dissolution and ICP-MS finish was the analytical approach designed to quantify rare earth (REE), high-field strength (HFSE) and large ion lithophile (LILE) elements. As, Bi, Hg, In, Re, Sb, Se, Te and Tl were determined by ICP-MS following aqua regia digestion, whereas Ag, Cd, Co, Cu, Li, Mo, Ni, Pb, Sc and Zn quantification was conducted by ICP-MS after four acid digestion. Au determination was performed by fire assay and ICP-AES. Analytical accuracy and precision were tested with in-house standard from Laurentian University, with further support from four blind duplicates inserted in the sample sequence. Reported detection limits for the major elements are < 0.01 wt% and < 1 ppm for most of the trace elements but < 0.1 ppm for REE. Sample preparation and analyses were carried out at the ALS Geochemistry Laboratory at Lima, Peru.

Detection limits

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Cr_2O_3	TiO_2	MnO
%	%	%	%	%	%	%	%	%	%
0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,002	0,01	0,01
P_2O_5	SrO	BaO	Total	LOI	C	S	Ba	Ce	Cr
%	%	%	%	%	%	%	ppm	ppm	ppm
0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,5	0,1	5
Cs	Dy	Er	Eu	Ga	Gd	Ge	Hf	Ho	La
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0,01	0,05	0,03	0,02	0,1	0,05	0,5	0,05	0,01	0,1
Lu	Nb	Nd	Pr	Rb	Sm	Sn	Sr	Ta	Tb
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0,01	0,05	0,1	0,02	0,2	0,03	0,5	0,1	0,1	0,01
Th	Tm	U	V	W	Y	Yb	Zr	As	Bi
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0,05	0,01	0,05	5	0,5	0,1	0,03	1	0,1	0,01
Hg	In	Re	Sb	Se	Te	Tl	Ag	Cd	Co
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0,005	0,005	0,001	0,05	0,2	0,01	0,02	0,01	0,02	0,1
Cu	Li	Mo	Ni	Pb	Sc	Zn	Au		
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm		
0,2	0,2	0,05	0,2	0,5	0,1	2	0,001		

Analytical precision and accuracy

	certified reference material						
sample	run-1	run-2	mean	rv	2sd (of rv)	accuracy (% error)	precision (2sd)
Weight %							
SiO_2	67,00	65,10	66,05	66,09	0,86	0,06	2,69
TiO_2	0,52	0,52	0,52	0,55	0,02	5,45	0,00
Al_2O_3	14,55	15,00	14,78	15,15	0,54	2,48	0,64
Fe_2O_{3total}	5,45	5,61	5,53	5,70	0,09	2,98	0,23
MnO	0,07	0,07	0,07	0,07	0,00	0,00	0,00
MgO	2,40	2,50	2,45	2,52	0,08	2,78	0,14

CaO	2,36	2,40	2,38	2,35	0,12	-1,28	0,06
Na_2O	4,29	4,31	4,30	4,33	0,14	0,69	0,03
K_2O	1,98	2,07	2,03	2,11	0,12	4,03	0,13
P_2O_5	0,12	0,13	0,13	0,14	0,02	10,71	0,01
LOI	1,45	1,00	1,23	1,03	0,43	-18,93	0,64
Total	100,19	98,71	99,45	100,04		0,59	2,09
C	0,09	0,10	0,10	0,09	0,01	-5,56	0,01
S	0,22	0,23	0,23	0,23	0,02	2,17	0,01
Parts per million							
Li	22,7	21,3	22,0				1,98
Rb	58,7	64,6	61,7	59,7	5,42	-3,27	8,34
Sr	504	538	521	520	52	-0,19	48,08
Cs	2,55	2,71	2,63	2,72	0,22	3,31	0,23
Ba	755	768	762	818	61	6,91	18,38
Y	12,7	13	12,9	12,1	1,2	-6,20	0,42
Zr	153	158	156	147	23	-5,78	7,07
Nb	5,99	6,11	6,05	4,95	1,24	-22,22	0,17
Hf	3,92	3,86	3,89	3,97	0,66	2,02	0,08
Ta	0,5	0,3	0,4	0,46	0,14	13,04	0,28
U	2,17	2,28	2,23	2,37	0,32	6,12	0,16
Th	6,57	7,13	6,85	7,28	0,76	5,91	0,79
Sc	11	11,2	11,1	11,2	1,46	0,89	0,28
V	103	102	103	92	15	-11,41	1,41
Cr	196	195	195,5	193	19	-1,30	1,41
Co	20,9	18,9	19,9	20,4	2	2,45	2,83
Ni	73,6	74,3	74,0	74,5	5,6	0,74	0,99
Cu	50,2	53,3	51,8	52,6	3,9	1,62	4,38
Zn	78	84	81	80	4	-1,25	8,49
Ga	18,6	18,8	18,7	17,89	2,4	-4,53	0,28
Ge	1,2	1	1,1				0,28
Sn	<0.5	0,9	0,9	0,8	0,1	-12,50	
W	0,8	1	0,9	0,4	0,1	-125,00	0,28
As	0,2	1,1	0,7	0,3	0,2	-116,67	1,27
Se	0,2	1,1	0,7	0,5	0,4	-30,00	1,27
Mo	1,84	1,87	1,86	1,63	0,17	-13,80	0,04
Ag	0,04	0,08	0,06	0,06	0,01	0,00	0,06
Cd	0,11	0,12	0,12	0,08	0,02	-43,75	0,01
In	0,023	0,028	0,026				0,01
Sb	<0.05	<0.05		0,03	0,01		
Te	0,02	0,14	0,08	0,02	0,02	-300,00	0,17
Re	0,001	0,001	0,001				0,00
Au	0,002	0,001	0,002	0,001	0,002	-50,00	0,001
Hg	<0.005	<0.005					
Tl	0,32	0,31	0,32				0,01
Pb	20,4	22,9	21,7	7,02	0,72	-208,40	3,54
Bi	0,16	0,17	0,17	0,16	0,02	-3,13	0,01
La	25,5	27,1	26,3	26,8	2,5	1,87	2,26
Ce	51,6	52,7	52,2	52,8	5,1	1,23	1,56
Pr	5,83	6,16	6,00	6,15	0,53	2,52	0,47
Nd	21,5	22,7	22,1	22,7	2	2,64	1,70
Sm	3,48	3,64	3,56	3,93	0,51	9,41	0,23
Eu	0,95	1,03	0,99	1,02	0,15	2,94	0,11
Gd	2,88	2,9	2,89	3,06	0,38	5,56	0,03
Tb	0,41	0,38	0,40	0,42	0,05	5,95	0,04

Dy	2,28	2,21	2,25	2,32	0,26	3,23	0,10
Ho	0,44	0,46	0,45	0,46	0,05	2,17	0,03
Er	1,24	1,22	1,23	1,31	0,17	6,11	0,03
Tm	0,2	0,18	0,19	0,19	0,03	0,00	0,03
Yb	1,2	1,22	1,21	1,27	0,13	4,72	0,03
Lu	0,2	0,19	0,20	0,18	0,03	-8,33	0,01

Notes:
rv = reference value; 2sd = two standard deviation

Further information

(1) The PAAS (Post-Archean Australian Shale) (Taylor and McLennan, 1989) is used for REE and Y normalization. $(La/La^*)_{SN} = La_{SN}/(3Pr_{SN} - 2Nd_{SN})$, $(Ce/Ce^*)_{SN} = Ce_{SN}/(0.5La_{SN} + 0.5Pr_{SN})$, $(Pr/Pr^*)_{SN} = Pr_{SN}/(0.5Ce_{SN} + 0.5Nd_{SN})$, $(Eu/Eu^*)_{SN} = Eu_{SN}/(0.67Sm_{SN} + 0.33Tb_{SN})$ and $(Y/Y^*)_{SN} = 2Y_{SN}/(Dy_{SN} + Ho_{SN})$ (Bau & Dulski, 1996; Bolhar et al., 2004) are used to evaluate elements abnormal values

(2) Provided that main ore-hosting rocks (BIF and marble) are graphite-free, it is fair to assume that all C occurs in the carbonate form. Thus, C was stoichiometrically converted to CO_2 for mass balance calculations

(3) For mass balance modelling purposes, censored values (i.e. below detection limit) were replaced by half the detection limit

(4) Mass balance modelling was conducted based on the construction of isocon diagrams (Grant, 1986). Such method consists in a graphical solution for the Gresens mass transfer equation (Gresens, 1967) and compares an altered sample to its precursor to estimate bulk rock mass (or volume) changes necessary to the calculation of elemental gains and losses the equation (Grant, 1986):

$$\frac{\Delta C_i^A}{C_i^0} = \frac{C_i^A - \frac{M^0}{M^A} C_i^0}{\frac{M^0}{M^A} C_i^0}$$

where:

- $\frac{\Delta C_i^A}{C_i^0}$: concentration factor of component i (< 0 for net loss; > 0 for net gain);
- C_i^0 and C_i^A: concentration of component i in the precursor (0) and in the altered rock (A);
- $\frac{M^0}{M^A}$: slope of the best-fit isocon and mathematically the inverse of relative mass change.

On a binary diagram, the immobile elements align along the isocon line, which passes through the origin, and the mass change () equals the inverse of the slope of this line.

(5) All plots regarding whole-rock geochemical data were made using microsoft Excel, except for correlation heatmap, which was made using Jupyter Notebook.

References

Bau, M, and Dulski, P., 1996, Distribution of yttrium and rare-earth elements in the Penge and Kuruman iron-formations, Transvaal Supergroup, South Africa: Precambrian Research, v. 79 (1-2), p. 37-55.

Bolhar, R., Kamber, B.S., Moorbath, S., Fedo, C.M., and Whitehouse, M.J., 2004, Characterization of early

Arhean chemical sediments by trace element signatures: Precambrian Research, v. 315, p. 92-102.

Grant, J.A., 1986, The isocon diagram – a simple solution to Gresens' equation for metasomatic alteration: Economic Geology, v. 81, p. 1976-1982.

Gresens, R.L., 1967, Composition–volume relationships of metasomatism: Chemical Geology, v. 2, p. 47-55.

ELECTRONIC APPENDIX TABLE A4 - LA-ICP-MS – Methodology and analytical conditions

Electronic appendix Table A4. LA-ICP-MS - Methodology and analytical conditions

In situ LA-ICP-MS analyses of magnetite and pyrrhotite were conducted at the Isotope Geochemistry Laboratory of the Geology Department of Federal University of Ouro Preto using a Thermofinigan Element II ICP-MS coupled with a CETAC-213 nm Laser Ablation system. See electronic appendix Table A3 for details of the methodology and analytical conditions. Laser was operated at constant 10 Hz pulse rate and 40% power level, with laser energy density for mineral ablation at 8 J/cm². A spot size of 40 µm diameter was used, and the analysis time for each sample was 60 s - 20 s background measurement with the laser off (gas blank), and 40 s analysis with laser on (signal). The ICP-MS operated with a plasma power of 1200 W. He (0.3 L/min) was used as ablation carrier gas and mixed with Ar (1.1 L/min) before entering the plasma torch. For magnetite analyses, the analyzed isotopes were ^{24}Mg, ^{27}Al, ^{29}Si, ^{45}Sc, ^{47}Ti, ^{49}Ti, ^{51}V, ^{52}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{65}Cu, ^{66}Zn, ^{69}Ga, ^{74}Ge, ^{75}As, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{91}Zr, ^{93}Nb, ^{95}Mo, ^{107}Ag, ^{109}Ag, ^{114}Cd, ^{118}Sn, ^{121}Sb, ^{137}Ba, ^{139}La, ^{140}Ce, ^{153}Eu, ^{175}Lu, ^{180}Hf, ^{182}W, ^{183}W, ^{195}Pt, ^{197}Au, ^{205}Tl, ^{208}Pb, ^{209}Bi, ^{232}Th and ^{238}U. The USGS MACS-3 standard (Wilson et al., 2008) was used as the external calibration standard to correct for instrumental drift and fractionation. As for pyrrhotite, the analyzed isotopes were ^{24}Mg, ^{27}Al, ^{33}S, ^{34}S, ^{47}Ti, ^{49}Ti, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{65}Cu, ^{66}Zn, ^{74}Ge, ^{75}As, ^{88}Sr, ^{90}Zr, ^{91}Zr, ^{95}Mo, ^{107}Ag, ^{109}Ag, ^{114}Cd, ^{118}Sn, ^{121}Sb, ^{130}Te, ^{180}Hf, ^{182}W, ^{183}W, ^{195}Pt, ^{197}Au, ^{205}Tl, ^{208}Pb, ^{209}Bi, ^{232}Th and ^{238}U. The sulfide reference material STDGL-3 (Belousov et al., 2015; Danyushevsky and Belousov, 2018) was used as the external standard for calibration and drift correction. Irrespective of the mineral analyzed, Fe, determined during electron microprobe analyses, was used as the normalizing element (or internal calibration). The BHVO-2 microanalysis reference material glass (Hawaiian Basalt) and the NIST SRM 610 glass were used as quality control standards. Data treatment was done using Saturn software, developed by the Isotope Geochemistry Laboratory, Federal University of Ouro Preto. While conducting spot analyses, multiple spots were obtained from single grains if the grains were large enough. Edges of grains were avoided to ensure no contamination occurred due to accidental ablation of adjacent minerals. Whenever possible effects of microinclusions were detected, these were subtracted during the calculation of the net signal. All plots regarding LA-ICP-MS data were made using microsoft Excel.

Average detection limits (ppm)

Mg^{24}	Al^{27}	Si^{29}	S^{33}	S^{34}	Sc^{45}	Ti^{47}	Ti^{49}	V^{51}	Cr^{52}
0,0841	0,3595	206,35	499,48	205,855	0,0612	1,79	0,953	0,0273	0,22
Mn^{55}	Fe^{57}	Co^{59}	Ni^{60}	Cu^{63}	Cu^{65}	Zn^{66}	Ga^{69}	Ge^{74}	As^{75}
0,127	17,975	0,2795	0,7665	0,0438	0,0718	0,2545	0,1904	0,0379	0,0539
Sr^{88}	Y^{89}	Zr^{90}	Zr^{91}	Nb^{93}	Mo^{95}	Ag^{107}	Ag^{109}	Cd^{114}	Sn^{118}
0,06915	0,0252	0,2855	0,558	0,00163	0,01535	0,117	0,0548	0,0535	0,04155
Sb^{121}	Te^{130}	Ba^{137}	La^{139}	Ce^{140}	Eu^{153}	Lu^{175}	Hf^{180}	W^{182}	W^{183}
0,003015	0,0007	0,0065	0,00271	0,00305	0,00151	0,00522	0,01475	0,04	0,0603
Pt^{195}	Au^{197}	Tl^{205}	Pb^{208}	Bi^{209}	Th^{232}	U^{238}			
0,0218	0,0189	0,000875	0,009465	0,003495	0,002465	0,000725			

References

Belousov, I., Danyushevsky, P., Olin, P., Gilbert, S., and Thompson, J., 2015, STDGL3 – A new calibration standard for sulphide analysis by LA-ICP-MS [abs.]: Goldschmidt, 25th, Prague, Czech Republic, 2015, Abstracts, p. A251.

Danyushevsky, L., Robinson, P., Gilbert, S., Norman, M., Large, R., McGoldrick, P., and Shelley, M., 2011, Routine quantitative multi-element analysis of sulphide minerals by laser ablation ICP-MS: Standard development and consideration of matrix effects: Geochemistry: Exploration, Environment, Analysis, v. 11, p. 51-60.

ELECTRONIC APPENDIX TABLE A5 - Whole-rock geochemistry – Results

TABLE A5-1 - Whole-rock geochemical data for least-altered and altered metasedimentary rocks

Table A1-1. Whole-rock geochemical data for least-altered and altered metasedimentary rocks

	least-altered BIF				BIF - distal zone alteration			BIF - proximal zone alteration			
sample	009-17	004-12	005-03	URS-033-05	005-02	004-21	028-22	009-16	028-14	028-15	029-38
Weight %											
SiO_2	42	47.1	60.8	34.3	37.3	42.5	49.5	35.5	31.1	26.4	32.3
TiO_2	0.03	0.02	0.02	0.02	0.06	0.04	0.03	0.04	0.02	0.01	0.02
Al_2O_3	0.4	0.82	0.21	0.42	0.98	0.56	0.33	0.38	1.8	0.15	0.22
Fe_2O_{3total}	52.6	45.3	34.6	62.5	53.5	44.8	41.4	30.3	41.4	62.5	50.5
MnO	0.22	0.16	0.13	0.41	0.4	0.62	0.33	0.34	0.36	0.65	0.81
MgO	3.07	1.84	2.3	2.93	4.98	3.84	4.5	7.54	10.15	3.4	5.11
CaO	2.6	2.51	0.85	2.55	2.67	7.31	4.58	20.5	9.47	4.05	7.41
Na_2O	0.04	0.01	0.02	0.04	0.07	0.16	0.32	0.08	0.59	0.21	0.1
K_2O	0.04	0.32	0.04	0.02	0.05	0.05	0.03	0.02	0.19	0.03	0.02
P_2O_5	0.26	0.19	0.32	0.26	0.25	0.35	0.2	0.05	0.85	0.08	0.41
LOI	-0.87	-0.05	-0.99	-1.93	-1.1	-0.64	-0.9	5.57	3.39	0.01	2.21
Total	100.39	98.22	98.3	101.52	99.16	99.59	100.32	100.32	99.32	97.49	99.11
C	0.07	0.18	0.07	0.04	0.29	0.09	0.03	1.7	0.22	0.3	0.09
S	0.01	0.35	0.01	0.05	0.03	0.01	0.25	0.11	7.85	1.97	7.15
Parts per million											
Li	12.2	21.4	42.7	8.3	52.7	10.3	6.4	16.9	9	21.1	16.5
Rb	4.3	49.9	3.1	0.8	4.7	7.1	4	2.5	23	0.6	0.4
Sr	34.1	50.3	18	31.7	13.6	50.7	34.2	193.5	154.5	41.1	119.5
Cs	1.04	11.7	1.66	0.61	3.77	7.75	3.2	1.84	4.3	0.66	0.17
Ba	14.2	85.7	46.1	4.1	179	40.6	3.1	43.9	103	0.6	1.7
Y	19.9	12.8	21.5	16.5	14	27	26.5	29.2	67.5	13.9	27.3
Zr	8	4	5	7	11	12	8	8	22	7	8
Nb	0.76	0.72	0.36	0.44	0.76	0.87	0.6	0.54	1.54	0.72	0.43
Hf	0.2	0.12	0.07	0.12	0.25	0.29	0.12	0.2	0.4	0.16	0.19
Ta	0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1
U	0.56	0.96	0.09	0.11	0.18	0.73	3.19	0.67	0.32	0.11	0.22
Th	1.55	0.82	0.21	0.33	0.68	0.43	1.92	0.82	0.97	0.29	0.17
Sc	1.3	0.9	0.9	0.8	2.1	2.3	1.4	1.5	3.6	1.1	1.6
V	14	13	8	12	20	18	19	9	20	87	28
Cr	9	7	28	12	21	45	21	7	20	5	<5
Co	3.8	2.3	2.2	3.4	4.1	4.8	2.2	2.5	7	2.3	6.5
Ni	3.4	3	5.4	8.8	6.5	4.9	6.5	3.3	13.4	3.4	10.3
Cu	1.4	13.2	5.1	10.9	5.1	0.5	6.2	1.7	25	5.7	19.8
Zn	20	22	21	29	30	18	42	55	45	56	81
Ga	0.8	0.9	0.5	1.2	1.8	1.2	1.1	0.5	1.9	3.8	1.1
Ge	3.5	2.2	2.4	2.9	3.2	2.4	2.1	2	1.3	1.7	2
Sn	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.4
W	0.5	<0.5	0.7	1.2	0.6	0.8	1.1	2.9	49.7	1.1	1.4
As	1.8	7.9	3.1	1.3	3	1.3	0.4	0.7	2.1	1.5	1
Se	<0.2	0.6	<0.2	0.2	<0.2	<0.2	0.2	0.3	1.8	0.3	2.9
Mo	0.47	0.48	1.95	1.81	1.27	0.21	1.18	0.55	1.47	0.23	0.44
Ag	0.01	0.14	0.01	0.01	0.02	0.01	0.03	0.02	0.38	0.65	0.68
Cd	0.06	0.07	0.02	0.06	0.09	0.05	0.13	0.18	0.33	0.18	0.33
In	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Sb	0.25	0.71	1.35	0.52	1.06	0.14	0.06	0.36	0.14	0.07	0.06
Te	0.01	0.06	0.01	0.02	0.04	<0.01	0.03	0.04	0.76	0.19	0.19
Re	<0.001	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Au	0.001	0.012	0.007	<0.001	0.01	0.003	0.001	0.13	4.74	5.92	0.359
Hg	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
Tl	0.02	0.31	0.02	<0.02	0.04	0.03	0.03	0.03	0.09	<0.02	0.02
Pb	3.7	3.8	1.2	3	1.8	5	4.7	14.2	16.1	4.1	4.3
Bi	0.01	0.03	0.01	0.03	0.03	0.04	0.01	0.03	0.09	0.02	0.19
La	6.6	4.1	5.1	4.8	5	6.9	5.1	6.4	19.2	3.6	4.6
Ce	10.9	6.6	7.5	6.9	8.8	11.3	8.7	10.9	33.4	6.5	8.8
Pr	1.07	0.66	0.88	0.84	0.94	1.2	1.12	1.29	3.63	0.68	1.04
Nd	4.3	2.6	3.8	3.6	3.6	5.3	4.6	5.3	15.6	2.8	4.6
Sm	0.89	0.5	0.83	0.77	0.69	1.05	1.02	1.22	2.86	0.61	0.96
Eu	0.24	0.17	0.26	0.29	0.32	0.37	0.31	0.44	0.98	0.17	0.34
Gd	1.3	0.8	1.35	1.18	1.08	1.84	1.57	1.81	4.47	0.82	1.7
Tb	0.23	0.14	0.22	0.19	0.17	0.29	0.28	0.34	0.75	0.15	0.28
Dy	1.69	1.01	1.63	1.58	1.24	2.36	2.18	2.46	5.63	1.22	2.23
Ho	0.47	0.28	0.45	0.41	0.31	0.62	0.57	0.73	1.52	0.3	0.61
Er	1.47	0.87	1.48	1.22	1.03	2	1.94	2.25	4.86	1.04	2.02
Tm	0.24	0.14	0.24	0.19	0.16	0.32	0.28	0.39	0.71	0.18	0.32
Yb	1.56	0.86	1.57	1.13	0.99	2.25	1.98	2.48	4.81	1.18	2.24
Lu	0.27	0.18	0.27	0.21	0.18	0.38	0.35	0.46	0.79	0.22	0.43
Σ LREE	23.76	14.46	18.11	16.91	19.03	25.75	20.54	25.11	74.69	14.19	20
Σ HREE	7.23	4.28	7.21	6.11	5.16	10.06	9.15	10.92	23.54	5.11	9.83
Σ REE	31.23	18.91	25.58	23.31	24.51	36.18	30	36.47	99.21	19.47	30.17
$(La/Sm)_{SN}$	1.093	1.208	0.906	0.919	1.068	0.968	0.737	0.773	0.989	0.870	0.706
$(Gd/Yb)_{SN}$	0.496	0.554	0.512	0.622	0.650	0.487	0.472	0.435	0.554	0.414	0.452
$(La/Yb)_{SN}$	0.312	0.351	0.239	0.313	0.372	0.226	0.190	0.190	0.294	0.225	0.151
$(La/La^*)_{SN}$	1.889	1.799	2.270	2.172	1.432	2.479	1.491	1.626	2.032	1.747	1.920
$(Ce/Ce^*)_{SN}$	0.927	0.906	0.804	0.782	0.927	0.893	0.836	0.870	0.914	0.950	0.925
$(Pr/Pr^*)_{SN}$	0.888	0.906	0.931	0.950	0.949	0.879	0.997	0.960	0.901	0.906	0.921
$(Eu/Eu^*)_{SN}$	1.064	1.290	1.221	1.519	1.872	1.346	1.164	1.371	1.343	1.126	1.316
$(Y/Y^*)_{SN}$	1.726	1.861	1.941	1.589	1.752	1.730	1.842	1.678	1.786	1.784	1.811
Y/Ho	42.340	45.714	47.778	40.244	45.161	43.548	46.491	40.000	44.408	46.333	44.754
Sm/Yb	0.571	0.581	0.529	0.681	0.697	0.467	0.515	0.492	0.595	0.517	0.429

Table A1-1. (Cont)

	least-altered marble					marble - distal zone alteration			
sample	009-03d	005-01	011-01	009-22	009-03e	004-22b	029-26	029-27	009-12
Weight %									
SiO_2	5.91	17.1	20	17.7	14.05	7.3	20.4	3.63	30.1
TiO_2	0.02	0.26	0.03	0.05	0.03	0.04	0.47	0.25	0.27
Al_2O_3	0.4	2.32	0.38	0.6	0.19	0.57	3.6	2.02	2.24
Fe_2O_{3total}	7.18	12	13.45	10.1	7.58	23.2	19	36.6	17.55
MnO	1.16	2.03	5.35	5	1.12	1.82	2.4	2	2.47
MgO	16.6	15.8	12.1	14.1	16.25	10.35	13.75	11.15	13.15
CaO	29	25.7	26.4	28.5	28.2	28.3	21.3	18.65	20.7
Na_2O	0.01	<0.01	0.02	0.07	0.01	0.08	0.22	0.09	0.57
K_2O	0.08	0.03	0.14	0.12	0.04	0.1	0.77	0.08	0.07
P_2O_5	0.01	0.06	0.04	0.02	0.02	0.2	0.1	0.2	0.09
LOI	38.4	24	21.7	24	31.4	23	17.85	17.05	13.1
Total	98.77	99.3	99.61	100.26	98.89	94.96	99.86	91.72	100.31
C	10.9	6.67	6.41	6.89	7.51	7.76	5.11	7.29	3.75
S	<0.01	0.03	0.03	<0.01	0.01	2.24	<0.01	4.47	0.14
Parts per million									
Li	3.9	12	9.5	4.6	1.1	3.9	14.4	7.5	5.2
Rb	2.9	3.1	5.1	6.5	2	4	41.5	2.3	0.8
Sr	37.8	73.1	121.5	144.5	41.8	255	135.5	187.5	76.3
Cs	0.68	0.76	1.3	0.63	1.4	2.24	9.8	0.82	0.3
Ba	15.6	241	49.9	93.9	11.7	53.3	237	23.3	23.1
Y	13.9	13.5	8.9	5.6	15.4	15.7	20.5	14.6	13.5
Zr	6	33	7	10	9	12	67	36	36
Nb	0.43	1.77	0.51	0.49	0.42	0.88	3.94	1.99	2.28
Hf	0.17	0.79	0.12	0.27	0.29	0.3	1.7	0.92	0.9
Ta	0.2	<0.1	<0.1	<0.1	0.2	0.2	0.4	0.3	<0.1
U	0.24	0.38	0.48	0.31	0.15	0.22	0.42	0.31	0.36
Th	0.26	0.61	0.4	0.48	1.03	0.26	0.71	0.61	0.55
Sc	0.9	5.7	1	1.5	0.6	2.8	7.4	4.3	5.3
V	9	50	10	7	7	11	63	69	44
Cr	10	20	10	15	<5	10	23	15	22
Co	2.2	8.1	5	5.2	2.5	7.2	11.7	11.8	9.8
Ni	5.1	12	6	5.5	5.9	8.3	14.3	15.2	14.4
Cu	2.5	6.6	8	3.1	1	33.4	1.3	28.6	31.4
Zn	31	23	58	21	42	59	50	81	45
Ga	0.9	3.7	1.6	2.1	0.5	1.3	6.8	5.4	4.3
Ge	<0.5	0.6	<0.5	<0.5	<0.5	0.5	1.3	0.9	1.1
Sn	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7
W	<0.5	2.7	1.2	2	1	3.5	0.9	5.8	2
As	6.1	1	0.5	2.7	1.3	4	0.7	9.5	1.5
Se	0.5	0.5	0.3	0.4	0.4	2.6	<0.2	1	0.2
Mo	0.23	0.47	0.43	0.33	1	1.39	0.14	0.33	0.52
Ag	<0.01	0.01	<0.01	<0.01	0.01	0.58	0.01	0.11	0.02
Cd	0.23	0.06	0.36	0.06	0.28	0.21	0.12	0.2	0.21
In	0.014	0.014	<0.005	<0.005	0.019	0.009	0.023	0.026	0.006

Sb	0.27	0.09	0.09	0.15	0.09	0.26	0.07	0.15	0.16
Te	<0.01	0.07	0.01	0.01	<0.01	0.58	0.01	0.23	0.06
Re	0.001	0.001	<0.001	<0.001	0.001	0.003	<0.001	<0.001	0.001
Au	0.002	0.006	0.059	<0.001	<0.001	0.136	0.027	0.083	0.015
Hg	0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tl	<0.02	0.03	0.03	0.04	<0.02	0.05	0.27	0.02	<0.02
Pb	9.5	9.2	10.3	3.6	9.4	10.2	9.2	4.9	9.4
Bi	0.01	0.02	0.01	0.01	0.01	0.21	0.01	0.08	0.03
La	3.1	4.1	3.6	2.5	5	3.9	7	4.9	4.1
Ce	5.4	8.1	6.1	4.8	9.6	6.9	14.7	9.8	8.4
Pr	0.68	1.08	0.74	0.58	1.13	0.78	1.89	1.23	1.1
Nd	2.8	4.8	2.7	2.2	4.7	3.5	8.5	5.2	4.9
Sm	0.73	1.25	0.49	0.52	0.99	0.81	2.19	1.28	1.15
Eu	0.31	0.49	0.18	0.12	0.3	0.27	0.65	0.41	0.37
Gd	0.96	1.68	0.69	0.47	1.26	1.1	2.46	1.76	1.48
Tb	0.16	0.27	0.1	0.08	0.23	0.2	0.41	0.29	0.26
Dy	1.04	1.79	0.77	0.59	1.5	1.46	2.85	1.82	1.72
Ho	0.26	0.39	0.2	0.13	0.37	0.39	0.64	0.4	0.38
Er	0.74	1.12	0.65	0.44	1.14	1.26	1.87	1.18	1.27
Tm	0.14	0.15	0.08	0.07	0.17	0.2	0.3	0.19	0.17
Yb	0.77	1.02	0.63	0.48	1.02	1.26	1.89	1.25	1.2
Lu	0.15	0.15	0.09	0.08	0.18	0.21	0.29	0.21	0.18
Σ LREE	12.71	19.33	13.63	10.6	21.42	15.89	34.28	22.41	19.65
Σ HREE	4.22	6.57	3.21	2.34	5.87	6.08	10.71	7.1	6.66
Σ REE	17.24	26.39	17.02	13.06	27.59	22.24	45.64	29.92	26.68
$(La/Sm)_{SN}$	0.626	0.483	1.083	0.709	0.744	0.710	0.471	0.564	0.525
$(Gd/Yb)_{SN}$	0.743	0.981	0.652	0.583	0.736	0.520	0.775	0.839	0.735
$(La/Yb)_{SN}$	0.297	0.296	0.421	0.384	0.361	0.228	0.273	0.289	0.252
$(La/La^*)_{SN}$	1.505	1.685	1.174	1.134	1.510	2.323	1.741	1.439	1.672
$(Ce/Ce^*)_{SN}$	0.855	0.883	0.857	0.916	0.928	0.907	0.927	0.917	0.907
$(Pr/Pr^*)_{SN}$	0.986	0.966	1.035	1.012	0.952	0.896	0.945	0.970	0.958
$(Eu/Eu^*)_{SN}$	1.808	1.679	1.612	1.130	1.257	1.344	1.350	1.344	1.351
$(Y/Y^*)_{SN}$	2.074	1.255	1.758	1.571	1.605	1.611	1.179	1.329	1.297
Y/Ho	53.462	34.615	44.500	43.077	41.622	40.256	32.031	36.500	35.526
Sm/Yb	0.948	1.225	0.778	1.083	0.971	0.643	1.159	1.024	0.958

Table A1-1. (Cont)

	marble - proximal zone alteration									
	intense amph ± bt-2 replacement			featuring Na-bearing silicates			magnetite-rich rocks			
sample	004-22d	009-03b	029-18	028-12	029-30	033-19	029-36	028-13	028-16	011-03
Weight %										
SiO_2	40.3	24.3	49.7	8.71	12.4	19.8	1.74	2.66	2.62	6.41
TiO_2	0.11	0.34	0.11	0.06	0.12	0.3	0.11	0.02	0.01	0.03
Al_2O_3	0.74	4.25	1.88	3.77	1.77	4.9	0.21	0.49	0.38	0.54
Fe_2O_{3total}	29.2	12.05	19.75	79.9	31.8	29.8	62.1	83.4	77.7	43.9
MnO	1.78	1.12	1.16	0.35	1.22	1.58	0.89	0.34	0.36	0.98
MgO	7.23	12.35	9.84	1.73	13.7	10.7	5.75	3.47	3.23	6.62
CaO	16.95	23.8	17.05	1.96	14.1	16.65	12.95	5.34	6.32	21.4
Na_2O	0.09	0.22	0.02	0.71	0.23	0.83	0.01	0.09	0.08	0.01
K_2O	0.03	0.82	0.06	0.04	0.17	0.08	<0.01	0.03	0.01	0.01
P_2O_5	0.15	0.06	0.04	0.1	0.42	0.39	0.28	0.34	0.11	0.23
LOI	1.93	19.45	1.22	1.62	11.8	3.88	7.13	2.94	0.66	18.15
Total	98.51	98.76	100.83	98.95	87.73	88.91	91.17	99.12	91.48	98.28
C	0.83	5.37	0.28	0.08	5.31	3.28	4.26	1.29	2.04	5.57
S	0.42	0.13	0.71	7.29	11	5.61	3.31	0.15	2.65	0.41
Parts per million										
Li	22.9	11.8	7.2	22.5	16.9	11	0.6	0.6	2.4	4.3
Rb	1.5	24.5	1	1.4	11.8	1	0.3	<0.2	0.5	0.5
Sr	120	32	58.2	50.3	249	162.5	185.5	72.9	127	230
Cs	1.6	1.24	0.18	2.93	4.8	0.11	0.07	0.04	0.25	0.43
Ba	25.4	54.2	12.2	17.1	86.3	39.9	7.3	2.5	7.2	4.5
Y	21	20.6	14.7	22.5	20.6	18	38.9	29.9	24.2	17.2
Zr	17	60	38	10	40	30	53	9	19	11
Nb	1.04	4.13	1.59	0.54	1.23	2.26	1.3	0.96	0.28	0.61
Hf	0.46	1.55	0.74	0.22	0.99	0.67	1.16	0.26	0.47	0.15
Ta	0.1	0.4	0.2	0.2	0.2	0.1	0.3	0.1	0.2	<0.1
U	0.28	1.43	0.75	0.17	0.88	0.38	1	0.21	0.2	1.03
Th	0.62	3.23	1.49	0.49	1.68	0.67	0.83	0.44	0.42	0.44
Sc	2.6	9.5	4.1	1	7.3	4.8	2.7	1.5	1.8	2
V	28	80	45	55	20	52	110	96	118	49
Cr	12	60	26	6	37	22	7	6	6	10
Co	5.6	10.9	3.6	6.2	9.9	16.4	3.1	1.3	2.9	3.2
Ni	6.5	51.2	7.4	8.4	12.9	27.6	4.1	3.3	4.2	6
Cu	12.8	104	12.8	18.2	20.7	56	9.2	2.7	8.8	9.9
Zn	45	256	88	264	51	13	68	82	48	78
Ga	2	6.4	3.5	8	1.8	5.4	2.4	6.8	7.7	1.9
Ge	1.8	1.4	1.6	1.2	0.9	1.2	1.8	2.2	2	1.5
Sn	<0.5	2	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	0.6
W	1.1	2.1	1.4	0.6	<0.5	16.3	21.5	10.6	1.3	1.4
As	3.9	>250	3.5	2.2	6.5	11.2	4.4	1.8	1	2.5
Se	0.7	2.9	1	0.8	2.5	5.3	0.8	<0.2	0.2	0.5
Mo	0.56	2	0.49	0.35	0.45	1.36	0.93	0.39	0.13	0.42
Ag	0.05	0.28	0.96	0.24	0.11	2.42	0.25	0.04	0.11	0.07
Cd	0.21	1.28	0.4	0.41	0.33	0.29	0.19	0.18	0.14	0.28
In	<0.005	0.07	<0.005	0.008	<0.005	0.038	0.008	0.013	0.006	0.007

Sb	0.32	0.76	0.08	0.15	0.13	0.36	0.1	0.19	0.08	0.29
Te	0.14	0.21	0.14	0.71	0.55	1.3	0.18	0.02	0.16	0.07
Re	0.003	0.015	0.001	0.001	0.001	0.005	0.001	0.001	<0.001	<0.001
Au	0.154	0.01	4.12	1.79	0.442	4.82	3.65	0.43	0.905	0.137
Hg	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.012	0.005	0.005	<0.005
Tl	0.02	0.15	<0.02	0.03	0.16	<0.02	<0.02	<0.02	<0.02	0.02
Pb	3.5	65.2	4.3	23.4	19.7	9.4	9.2	5.2	16	8.8
Bi	0.55	0.07	0.11	0.13	0.28	0.14	0.08	0.01	0.04	0.05
La	5	10.9	9.5	5.2	10.3	5.4	15	7.4	7.2	4.2
Ce	8.6	22.3	17.7	9.3	21.8	11.2	25.5	11.9	11.8	7.2
Pr	1	2.6	2.04	1.07	2.65	1.52	2.8	1.26	1.18	0.8
Nd	4	10.2	7.9	4.3	11	7.7	10.9	5.2	4.7	3.4
Sm	0.87	2.61	1.65	0.85	2.49	1.81	2.16	1.07	1.01	0.6
Eu	0.3	0.71	0.53	0.29	0.76	0.61	0.68	0.29	0.28	0.24
Gd	1.36	2.64	1.85	1.54	2.6	2.68	2.88	1.8	1.42	1.05
Tb	0.24	0.45	0.34	0.27	0.43	0.39	0.48	0.29	0.25	0.19
Dy	1.82	2.8	2.03	2.05	2.51	2.48	3.54	2.23	1.8	1.42
Ho	0.54	0.64	0.46	0.55	0.6	0.52	0.95	0.64	0.5	0.39
Er	1.92	1.84	1.41	1.78	1.79	1.4	2.95	2.13	1.74	1.32
Tm	0.32	0.31	0.25	0.26	0.27	0.2	0.47	0.34	0.28	0.2
Yb	2.28	2	1.56	1.68	1.86	1.37	3.27	2.15	1.84	1.32
Lu	0.37	0.36	0.3	0.32	0.31	0.22	0.56	0.38	0.31	0.23
Σ LREE	19.47	48.61	38.79	20.72	48.24	27.63	56.36	26.83	25.89	16.2
Σ HREE	8.85	11.04	8.2	8.45	10.37	9.26	15.1	9.96	8.14	6.12
Σ REE	28.62	60.36	47.52	29.46	59.37	37.5	72.14	37.08	34.31	22.56
$(La/Sm)_{SN}$	0.847	0.615	0.848	0.902	0.610	0.440	1.023	1.019	1.051	1.032
$(Gd/Yb)_{SN}$	0.355	0.786	0.706	0.546	0.833	1.165	0.525	0.499	0.460	0.474
$(La/Yb)_{SN}$	0.162	0.402	0.449	0.228	0.408	0.290	0.338	0.254	0.288	0.234
$(La/La^*)_{SN}$	1.511	1.201	1.289	1.489	1.317	4.568	1.503	1.953	1.822	1.934
$(Ce/Ce^*)_{SN}$	0.881	0.963	0.923	0.904	0.958	0.895	0.899	0.885	0.916	0.898
$(Pr/Pr^*)_{SN}$	0.967	0.978	0.979	0.959	0.966	0.897	0.954	0.910	0.901	0.916
$(Eu/Eu^*)_{SN}$	1.318	1.278	1.404	1.213	1.433	1.445	1.332	1.045	1.117	1.424
$(Y/Y^*)_{SN}$	1.631	1.196	1.182	1.641	1.304	1.230	1.642	1.931	1.972	1.788
Y/Ho	38.889	32.188	31.957	40.909	34.333	34.615	40.947	46.719	48.400	44.103
Sm/Yb	0.382	1.305	1.058	0.506	1.339	1.321	0.661	0.498	0.549	0.455

Table A1-1. (Cont)

	quartz-clinopyroxene veins with amphibole replacement			marble-hosted early stage alteration products		marble-hosted late stage alteration product
sample	004-03	028-06	033-11b	009-03h (cpx rock)	029-04 (grt-bt rock)	028-05 (mylonitic carbonate)
Weight %						
SiO_2	77.4	68.3	35.5	51.3	38.6	9.05
TiO_2	0.01	0.01	0.02	0.53	2.18	0.09
Al_2O_3	0.08	0.11	0.32	0.9	16.75	1.72
Fe_2O_{3total}	14.4	12.5	41.4	8.96	25.6	4.99
MnO	0.55	0.71	0.44	1.13	0.43	1.06
MgO	4.09	7.09	3.25	12.6	9.48	16.25
CaO	3.17	9.76	5.07	23	1.38	26.8
Na_2O	0.04	0.01	0.02	0.02	0.04	0.02
K_2O	0.01	<0.01	0.01	0.12	3.96	0.6
P_2O_5	0.1	0.09	0.2	0.02	0.22	0.02
LOI	0.82	1	5.85	1.55	2.16	38
Total	100.67	99.58	92.08	100.13	100.8	98.6
C	0.33	0.21	0.48	0.3	0.07	11.3
S	0.04	0.11	15.35	0.01	0.68	0.02
Parts per million						
Li	3.8	4.4	3.9	42.6	164	10.2
Rb	0.4	0.5	1.9	7.3	86.1	17.1
Sr	10.8	15.6	33.7	30.1	11.4	52.5
Cs	0.38	0.03	1.22	0.21	13.9	0.43
Ba	10.9	2.2	2.4	27	183	73.6
Y	4	4.7	7.5	16.7	43.5	7.5
Zr	2	2	8	156	158	19
Nb	0.31	0.27	0.3	21.4	8.89	1.73
Hf	0.8	0.08	0.15	3.64	4.33	0.48
Ta	0.3	0.1	<0.1	0.8	0.1	0.3
U	0.54	0.19	1.41	2.01	0.37	0.63
Th	0.24	0.1	0.45	3.69	0.93	1.47
Sc	0.3	0.3	0.9	3.1	51.6	3.4
V	10	5	12	17	537	26
Cr	12	7	13	91	79	26
Co	1.5	27.4	8.6	6.5	49.8	33.3
Ni	6	33.9	37.3	19	64.1	44.6
Cu	3.4	11.3	785	1.1	48.2	7.4
Zn	111	492	52	118	550	1115
Ga	0.6	0.4	1.1	2	24.3	3
Ge	1	1.6	0.5	1.2	2.3	<0.5
Sn	<0.5	<0.5	<0.5	3.2	0.8	0.6
W	1.3	<0.5	0.6	2.9	8.4	1.5
As	22	>250	20.9	0.9	113.5	240
Se	<0.2	0.5	18.8	<0.2	0.3	0.7
Mo	1.48	0.52	5.49	0.17	0.46	0.31
Ag	0.03	0.04	1.98	<0.01	0.18	0.07
Cd	0.17	0.74	0.39	0.71	0.31	4.4
In	<0.005	<0.005	<0.005	<0.005	0.084	0.142

Sb	0.53	0.66	0.11	0.11	0.46	1.98
Te	<0.01	0.13	2.2	<0.01	0.06	0.25
Re	<0.001	0.002	0.001	<0.001	0.002	0.002
Au	0.021	0.01	16.45	0.002	0.082	0.003
Hg	<0.005	<0.005	0.013	0.006	0.012	0.021
Tl	<0.02	<0.02	0.08	<0.02	0.57	0.11
Pb	2	5.8	7.1	6.6	23.8	42
Bi	0.02	0.02	0.39	0.01	0.1	0.2
La	1.2	1.2	2.3	10.1	7.7	5
Ce	2.9	2.5	4.9	19.6	20.3	10
Pr	0.43	0.31	0.63	2.3	2.95	1.17
Nd	1.7	1.4	2.8	8.6	14.1	4.3
Sm	0.39	0.42	0.52	1.66	4.25	0.89
Eu	0.18	0.19	0.22	0.4	0.9	0.36
Gd	0.55	0.53	0.75	1.9	5.44	1.02
Tb	0.11	0.08	0.12	0.34	1	0.16
Dy	0.53	0.46	0.9	2.02	6.94	0.99
Ho	0.14	0.11	0.2	0.48	1.6	0.23
Er	0.35	0.29	0.6	1.46	4.74	0.66
Tm	0.06	0.05	0.09	0.23	0.72	0.11
Yb	0.33	0.24	0.63	1.38	4.71	0.67
Lu	0.07	0.05	0.11	0.23	0.74	0.12
Σ LREE	6.62	5.83	11.15	42.26	49.3	21.36
Σ HREE	2.14	1.81	3.4	8.04	25.89	3.96
Σ REE	8.94	7.83	14.77	50.7	76.09	25.68
$(La/Sm)_{SN}$	0.453	0.421	0.652	0.897	0.267	0.442
$(Gd/Yb)_{SN}$	0.993	1.316	0.709	0.820	0.688	1.787
$(La/Yb)_{SN}$	0.268	0.368	0.269	0.539	0.120	0.553
$(La/La^*)_{SN}$	0.816	1.858	1.620	1.118	1.791	0.565
$(Ce/Ce^*)_{SN}$	0.907	0.941	0.933	0.935	0.950	1.025
$(Pr/Pr^*)_{SN}$	1.081	0.929	0.952	1.006	0.955	1.269
$(Eu/Eu^*)_{SN}$	1.744	2.043	1.760	1.056	0.873	1.870
$(Y/Y^*)_{SN}$	1.138	1.623	1.373	1.317	1.014	1.221
Y/Ho	28.571	42.727	37.500	34.792	27.188	32.609
Sm/Yb	1.182	1.750	0.825	1.203	0.902	1.328

TABLE A5-2 - Whole-rock geochemical data for granite and altered amphibolite samples

Table A1-2. Whole-rock geochemical data for granite and altered amphibolite samples

	leucogranite				altered amphibolite	
	albite-rich		k-feldspar-rich			
sample	029-39a	963-13a	963-03	028-33a	963-22	020-01a
Weight %						
SiO_2	75.7	71.9	71.8	69.8	49.5	39.8
TiO_2	0.01	<0.01	<0.01	<0.01	1.35	1.38
Al_2O_3	14.2	15.25	14.75	15.95	13.15	19.15
Fe_2O_{3total}	1.2	1.1	1.2	0.62	14.2	11.7
MnO	0.07	0.06	0.03	0.02	0.26	0.16
MgO	0.1	0.05	0.08	0.4	6.1	7.75
CaO	0.36	0.4	0.24	0.8	10	10.55
Na_2O	4.02	5.81	2.54	3.51	0.93	0.77
K_2O	3.88	3.79	8.16	8.03	1.65	1.58
P_2O_5	0.24	0.77	0.52	0.68	0.13	0.13
LOI	0.98	0.49	0.71	1.35	1.3	3.93
Total	100.76	99.62	100.03	101.16	98.57	96.9
C	0.03	0.02	0.05	0.25	0.05	0.03
S	0.03	0.02	0.02	0.01	0.05	0.05
Parts per million						
Li	50.2	179	92.9	62.7	109.5	327
Rb	476	705	1235	1000	178	73.6
Sr	2.3	37.1	18.2	18.4	100	217
Cs	15.85	45	39.6	211	37.8	8.15
Ba	2.4	34	14.8	23.9	469	312
Y	2.9	2.6	0.6	0.6	32.1	20.4
Zr	22	16	7	4	99	99
Nb	20.4	21.5	23.5	16.35	5.29	7.39
Hf	1.45	1.28	0.42	0.4	2.76	2.7
Ta	3	7.9	4	25.6	0.4	0.4
U	16.65	9.72	28	3.45	0.34	0.3
Th	2.88	0.74	1	0.31	0.48	0.85
Sc	1	0.3	0.4	0.2	46.9	44
V	<5	<5	<5	<5	409	319
Cr	5	12	11	12	97	519
Co	0.2	0.2	0.2	0.1	49	67.8
Ni	0.9	0.9	1.1	0.6	52.8	199.5
Cu	1	1.4	0.9	0.7	104	7.4
Zn	32	33	41	13	108	88
Ga	29.2	31	23.5	25.8	21.5	24.2
Ge	2.9	4.1	3.6	3.5	1.5	0.6
Sn	15.6	20.8	19.2	14.6	1.7	1.4
W	3.2	2.7	1.7	2.7	4.4	2.2
As	1	3.3	2.4	1.9	1.1	>250
Se	<0.2	<0.2	<0.2	<0.2	0.5	0.6
Mo	0.27	0.26	0.31	0.12	0.44	0.27
Ag	0.11	0.21	0.16	0.11	0.24	0.04
Cd	0.1	0.14	0.04	0.02	0.14	0.12
In	<0.005	<0.005	0.005	<0.005	0.033	0.009

Sb	<0.05	0.14	0.13	0.4	0.11	0.09
Te	<0.01	0.02	0.01	<0.01	0.03	0.28
Re	<0.001	<0.001	<0.001	<0.001	0.002	0.001
Au	0.001	0.01	<0.001	0.002	0.003	0.004
Hg	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tl	0.17	0.18	0.59	0.17	1	0.07
Pb	21	37.1	24.6	29.3	18.5	9.4
Bi	0.2	1.69	0.09	0.31	0.07	0.09
La	1.4	0.4	0.3	0.2	6	9.7
Ce	3.2	0.7	0.6	0.4	15.3	22.2
Pr	0.36	0.1	0.06	0.07	2.3	2.93
Nd	1.3	0.4	0.1	0.2	11.3	13
Sm	0.64	0.37	0.1	0.13	3.31	3.35
Eu	<0.02	<0.02	<0.02	<0.02	1.32	1.08
Gd	0.53	0.57	0.12	0.6	4.89	3.84
Tb	0.1	0.14	0.02	0.03	0.84	0.59
Dy	0.55	0.63	0.11	0.13	5.54	3.84
Ho	0.07	0.06	0.01	0.03	1.18	0.74
Er	0.22	0.12	0.03	<0.03	3.43	2.09
Tm	0.05	0.03	0.02	0.02	0.53	0.31
Yb	0.34	0.14	0.04	0.09	3.36	1.92
Lu	0.06	0.02	0.02	0.02	0.52	0.31
Σ LREE	6.9	1.97	1.16	1	38.21	51.18
Σ HREE	1.92	1.71	0.37	0.92	20.29	13.64
Σ REE	8.82	3.68	1.53	1.92	59.82	65.9
$(La/Sm)_{CN}$	1.366	0.675	1.873	0.961	1.132	1.808
$(Gd/Yb)_{CN}$	1.261	3.294	2.427	5.394	1.177	1.618
$(La/Yb)_{CN}$	2.797	1.941	5.095	1.510	1.213	3.432
A/CNK	1.238	1.060	1.097	1.002	0.612	0.864
A/NK	1.313	1.116	1.134	1.103	3.966	6.433
Nb+Y	23.300	24.100	24.100	16.950	37.390	27.790

TABLE A5-3 - Summary statistics of whole-rock geochemical data

Table A1-3. Summary statistics of whole-rock geochemical data

	least-altered BIF				BIF - distal zone alteration				BIF - proximal zone alteration			
sample	mean	min	max	n	mean	min	max	n	mean	min	max	n
Weight %												
SiO_2	46.05	34.30	60.80	4	43.10	37.30	49.50	3	31.33	26.40	35.50	4
TiO_2	0.02	0.02	0.03	4	0.04	0.03	0.06	3	0.02	0.01	0.04	4
Al_2O_3	0.46	0.21	0.82	4	0.62	0.33	0.98	3	0.64	0.15	1.80	4
Fe_2O_{3total}	48.75	34.60	62.50	4	46.57	41.40	53.50	3	46.18	30.30	62.50	4
MnO	0.23	0.13	0.41	4	0.45	0.33	0.62	3	0.54	0.34	0.81	4
MgO	2.54	1.84	3.07	4	4.44	3.84	4.98	3	6.55	3.40	10.15	4
CaO	2.13	0.85	2.60	4	4.85	2.67	7.31	3	10.36	4.05	20.50	4
Na_2O	0.03	0.01	0.04	4	0.18	0.07	0.32	3	0.25	0.08	0.59	4
K_2O	0.11	0.02	0.32	4	0.04	0.03	0.05	3	0.07	0.02	0.19	4
P_2O_5	0.26	0.19	0.32	4	0.27	0.20	0.35	3	0.35	0.05	0.85	4
LOI	-0.96	-1.93	-0.05	4	-0.88	-1.10	-0.64	3	2.80	0.01	5.57	4
Total	99.61	98.22	101.52	4	99.69	99.16	100.32	3	99.06	97.49	100.32	4
C	0.09	0.04	0.18	4	0.14	0.03	0.29	3	0.58	0.09	1.70	4
S	0.11	0.01	0.35	4	0.10	0.01	0.25	3	4.27	0.11	7.85	4
Parts per million												
Li	21.15	8.30	42.70	4	23.13	6.40	52.70	3	15.88	9.00	21.10	4
Rb	14.53	0.80	49.90	4	5.27	4.00	7.10	3	6.63	0.40	23.00	4
Sr	33.53	18.00	50.30	4	32.83	13.60	50.70	3	127.15	41.10	193.50	4
Cs	3.75	0.61	11.70	4	4.91	3.20	7.75	3	1.74	0.17	4.30	4
Ba	37.53	4.10	85.70	4	74.23	3.10	179.00	3	37.30	0.60	103.00	4
Y	17.68	12.80	21.50	4	22.50	14.00	27.00	3	34.48	13.90	67.50	4
Zr	6.00	4.00	8.00	4	10.33	8.00	12.00	3	11.25	7.00	22.00	4
Nb	0.57	0.36	0.76	4	0.74	0.60	0.87	3	0.81	0.43	1.54	4
Hf	0.13	0.07	0.20	4	0.22	0.12	0.29	3	0.24	0.16	0.40	4
Ta	0.10	0.10	0.10	2	0.10	0.10	0.10	1	0.10	0.10	0.10	1
U	0.43	0.09	0.96	4	1.37	0.18	3.19	3	0.33	0.11	0.67	4
Th	0.73	0.21	1.55	4	1.01	0.43	1.92	3	0.56	0.17	0.97	4
Sc	0.98	0.80	1.30	4	1.93	1.40	2.30	3	1.95	1.10	3.60	4
V	11.75	8.00	14.00	4	19.00	18.00	20.00	3	36.00	9.00	87.00	4
Cr	14.00	7.00	28.00	4	29.00	21.00	45.00	3	10.67	5.00	20.00	3
Co	2.93	2.20	3.80	4	3.70	2.20	4.80	3	4.58	2.30	7.00	4
Ni	5.15	3.00	8.80	4	5.97	4.90	6.50	3	7.60	3.30	13.40	4
Cu	7.65	1.40	13.20	4	3.93	0.50	6.20	3	13.05	1.70	25.00	4
Zn	23.00	20.00	29.00	4	30.00	18.00	42.00	3	59.25	45.00	81.00	4
Ga	0.85	0.50	1.20	4	1.37	1.10	1.80	3	1.83	0.50	3.80	4
Ge	2.75	2.20	3.50	4	2.57	2.10	3.20	3	1.75	1.30	2.00	4
Sn	0.60	0.60	0.60	1	#DIV/0!	0.00	0.00	0	1.40	1.40	1.40	1
W	0.80	0.50	1.20	3	0.83	0.60	1.10	3	13.78	1.10	49.70	4
As	3.53	1.30	7.90	4	1.57	0.40	3.00	3	1.33	0.70	2.10	4
Se	0.40	0.20	0.60	2	0.20	0.20	0.20	1	1.33	0.30	2.90	4
Mo	1.18	0.47	1.95	4	0.89	0.21	1.27	3	0.67	0.23	1.47	4
Ag	0.04	0.01	0.14	4	0.02	0.01	0.03	3	0.43	0.02	0.68	4
Cd	0.05	0.02	0.07	4	0.09	0.05	0.13	3	0.26	0.18	0.33	4
In	#DIV/0!	0.00	0.00	0	#DIV/0!	0.00	0.00	0	#DIV/0!	0.00	0.00	0

Sb	0.71	0.25	1.35	4	0.42	0.06	1.06	3	0.16	0.06	0.36	4
Te	0.03	0.01	0.06	4	0.04	0.03	0.04	2	0.30	0.04	0.76	4
Re	0.001	0.001	0.001	2	0.001	0.001	0.001	1	0.002	0.002	0.002	1
Au	0.007	0.001	0.012	3	0.005	0.001	0.010	3	2.787	0.130	5.920	4
Hg	0.005	0.005	0.005	1	#DIV/0!	0.000	0.000	0	0.006	0.006	0.006	1
Tl	0.12	0.02	0.31	3	0.03	0.03	0.04	3	0.05	0.02	0.09	3
Pb	2.93	1.20	3.80	4	3.83	1.80	5.00	3	9.68	4.10	16.10	4
Bi	0.02	0.01	0.03	4	0.03	0.01	0.04	3	0.08	0.02	0.19	4
La	5.15	4.10	6.60	4	5.67	5.00	6.90	3	8.45	3.60	19.20	4
Ce	7.98	6.60	10.90	4	9.60	8.70	11.30	3	14.90	6.50	33.40	4
Pr	0.86	0.66	1.07	4	1.09	0.94	1.20	3	1.66	0.68	3.63	4
Nd	3.58	2.60	4.30	4	4.50	3.60	5.30	3	7.08	2.80	15.60	4
Sm	0.75	0.50	0.89	4	0.92	0.69	1.05	3	1.41	0.61	2.86	4
Eu	0.24	0.17	0.29	4	0.33	0.31	0.37	3	0.48	0.17	0.98	4
Gd	1.16	0.80	1.35	4	1.50	1.08	1.84	3	2.20	0.82	4.47	4
Tb	0.20	0.14	0.23	4	0.25	0.17	0.29	3	0.38	0.15	0.75	4
Dy	1.48	1.01	1.69	4	1.93	1.24	2.36	3	2.89	1.22	5.63	4
Ho	0.40	0.28	0.47	4	0.50	0.31	0.62	3	0.79	0.30	1.52	4
Er	1.26	0.87	1.48	4	1.66	1.03	2.00	3	2.54	1.04	4.86	4
Tm	0.20	0.14	0.24	4	0.25	0.16	0.32	3	0.40	0.18	0.71	4
Yb	1.28	0.86	1.57	4	1.74	0.99	2.25	3	2.68	1.18	4.81	4
Lu	0.23	0.18	0.27	4	0.30	0.18	0.38	3	0.48	0.22	0.79	4

Table A1-3. (Cont)

	least-altered marble				marble - distal zone alteration				marble - proximal zone alteration intense amphibole ± biotite 2 replacem			
sample	mean	min	max	n	mean	min	max	n	mean	min	max	n
Weight %												
SiO_2	14.95	5.91	20.00	5	15.36	3.63	30.10	4	38.10	24.30	49.70	3
TiO_2	0.08	0.02	0.26	5	0.26	0.04	0.47	4	0.19	0.11	0.34	3
Al_2O_3	0.78	0.19	2.32	5	2.11	0.57	3.60	4	2.29	0.74	4.25	3
Fe_2O_{3total}	10.06	7.18	13.45	5	24.09	17.55	36.60	4	20.33	12.05	29.20	3
MnO	2.93	1.12	5.35	5	2.17	1.82	2.47	4	1.35	1.12	1.78	3
MgO	14.97	12.10	16.60	5	12.10	10.35	13.75	4	9.81	7.23	12.35	3
CaO	27.56	25.70	29.00	5	22.24	18.65	28.30	4	19.27	16.95	23.80	3
Na_2O	0.03	0.01	0.07	4	0.24	0.08	0.57	4	0.11	0.02	0.22	3
K_2O	0.08	0.03	0.14	5	0.26	0.07	0.77	4	0.30	0.03	0.82	3
P_2O_5	0.03	0.01	0.06	5	0.15	0.09	0.20	4	0.08	0.04	0.15	3
LOI	27.90	21.70	38.40	5	17.75	13.10	23.00	4	7.53	1.22	19.45	3
Total	99.37	98.77	100.26	5	96.71	91.72	100.31	4	99.37	98.51	100.83	3
C	7.68	6.41	10.90	5	5.98	3.75	7.76	4	2.16	0.28	5.37	3
S	0.02	0.01	0.03	3	2.28	0.14	4.47	3	0.42	0.13	0.71	3
Parts per million												
Li	6.22	1.10	12.00	5	7.75	3.90	14.40	4	13.97	7.20	22.90	3
Rb	3.92	2.00	6.50	5	12.15	0.80	41.50	4	9.00	1.00	24.50	3
Sr	83.74	37.80	144.50	5	163.58	76.30	255.00	4	70.07	32.00	120.00	3
Cs	0.95	0.63	1.40	5	3.29	0.30	9.80	4	1.01	0.18	1.60	3
Ba	82.42	11.70	241.00	5	84.18	23.10	237.00	4	30.60	12.20	54.20	3
Y	11.46	5.60	15.40	5	16.08	13.50	20.50	4	18.77	14.70	21.00	3
Zr	13.00	6.00	33.00	5	37.75	12.00	67.00	4	38.33	17.00	60.00	3
Nb	0.72	0.42	1.77	5	2.27	0.88	3.94	4	2.25	1.04	4.13	3
Hf	0.33	0.12	0.79	5	0.96	0.30	1.70	4	0.92	0.46	1.55	3
Ta	0.20	0.20	0.20	2	0.30	0.20	0.40	3	0.23	0.10	0.40	3
U	0.31	0.15	0.48	5	0.33	0.22	0.42	4	0.82	0.28	1.43	3
Th	0.56	0.26	1.03	5	0.53	0.26	0.71	4	1.78	0.62	3.23	3
Sc	1.94	0.60	5.70	5	4.95	2.80	7.40	4	5.40	2.60	9.50	3
V	16.60	7.00	50.00	5	46.75	11.00	69.00	4	51.00	28.00	80.00	3
Cr	13.75	10.00	20.00	4	17.50	10.00	23.00	4	32.67	12.00	60.00	3
Co	4.60	2.20	8.10	5	10.13	7.20	11.80	4	6.70	3.60	10.90	3
Ni	6.90	5.10	12.00	5	13.05	8.30	15.20	4	21.70	6.50	51.20	3
Cu	4.24	1.00	8.00	5	23.68	1.30	33.40	4	43.20	12.80	104.00	3
Zn	35.00	21.00	58.00	5	58.75	45.00	81.00	4	129.67	45.00	256.00	3
Ga	1.76	0.50	3.70	5	4.45	1.30	6.80	4	3.97	2.00	6.40	3
Ge	0.60	0.60	0.60	1	0.95	0.50	1.30	4	1.60	1.40	1.80	3
Sn	#DIV/0!	0.00	0.00	0	0.70	0.70	0.70	1	2.00	2.00	2.00	1
W	1.73	1.00	2.70	4	3.05	0.90	5.80	4	1.53	1.10	2.10	3
As	2.32	0.50	6.10	5	3.93	0.70	9.50	4	3.70	3.50	3.90	2
Se	0.42	0.30	0.50	5	1.27	0.20	2.60	3	1.53	0.70	2.90	3
Mo	0.49	0.23	1.00	5	0.60	0.14	1.39	4	1.02	0.49	2.00	3
Ag	0.01	0.01	0.01	2	0.18	0.01	0.58	4	0.43	0.05	0.96	3
Cd	0.20	0.06	0.36	5	0.19	0.12	0.21	4	0.63	0.21	1.28	3
In	0.02	0.01	0.02	3	0.02	0.01	0.03	4	0.07	0.07	0.07	1

Sb	0.138	0.09	0.27	5	0.16	0.07	0.26	4	0.38667	0.08	0.76	3
Te	0.03	0.01	0.07	3	0.22	0.01	0.58	4	0.16	0.14	0.21	3
Re	0.001	0.001	0.001	3	0.002	0.001	0.003	2	0.006	0.001	0.015	3
Au	0.022	0.002	0.059	3	0.065	0.015	0.136	4	1.428	0.010	4.120	3
Hg	0.005	0.005	0.005	2	#DIV/0!	0.000	0.000	0	0.005	0.005	0.005	1
Tl	0.03	0.03	0.04	3	0.11	0.02	0.27	3	0.09	0.02	0.15	2
Pb	8.40	3.60	10.30	5	8.43	4.90	10.20	4	24.33	3.50	65.20	3
Bi	0.01	0.01	0.02	5	0.08	0.01	0.21	4	0.24	0.07	0.55	3
La	3.66	2.50	5.00	5	4.98	3.90	7.00	4	8.47	5.00	10.90	3
Ce	6.80	4.80	9.60	5	9.95	6.90	14.70	4	16.20	8.60	22.30	3
Pr	0.84	0.58	1.13	5	1.25	0.78	1.89	4	1.88	1.00	2.60	3
Nd	3.44	2.20	4.80	5	5.53	3.50	8.50	4	7.37	4.00	10.20	3
Sm	0.80	0.49	1.25	5	1.36	0.81	2.19	4	1.71	0.87	2.61	3
Eu	0.28	0.12	0.49	5	0.43	0.27	0.65	4	0.51	0.30	0.71	3
Gd	1.01	0.47	1.68	5	1.70	1.10	2.46	4	1.95	1.36	2.64	3
Tb	0.17	0.08	0.27	5	0.29	0.20	0.41	4	0.34	0.24	0.45	3
Dy	1.14	0.59	1.79	5	1.96	1.46	2.85	4	2.22	1.82	2.80	3
Ho	0.27	0.13	0.39	5	0.45	0.38	0.64	4	0.55	0.46	0.64	3
Er	0.82	0.44	1.14	5	1.40	1.18	1.87	4	1.72	1.41	1.92	3
Tm	0.12	0.07	0.17	5	0.22	0.17	0.30	4	0.29	0.25	0.32	3
Yb	0.78	0.48	1.02	5	1.40	1.20	1.89	4	1.95	1.56	2.28	3
Lu	0.13	0.08	0.18	5	0.22	0.18	0.29	4	0.34	0.30	0.37	3

Table A1-3. (Cont)

ient sample	marble - proximal zone alteration featuring Na-bearing silicates mean	 min	 max	 n	magnetite-rich rocks mean	 min	 max	 n	quartz-clinopyroxene veins with amphibole replacement mean	 min	 max	 n
Weight %												
SiO_2	13.64	8.71	19.80	3	3.36	1.74	6.41	4	60.40	35.50	77.40	3
TiO_2	0.16	0.06	0.30	3	0.04	0.01	0.11	4	0.01	0.01	0.02	3
Al_2O_3	3.48	1.77	4.90	3	0.41	0.21	0.54	4	0.17	0.08	0.32	3
Fe_2O_{3total}	47.17	29.80	79.90	3	66.78	43.90	83.40	4	22.77	12.50	41.40	3
MnO	1.05	0.35	1.58	3	0.64	0.34	0.98	4	0.57	0.44	0.71	3
MgO	8.71	1.73	13.70	3	4.77	3.23	6.62	4	4.81	3.25	7.09	3
CaO	10.90	1.96	16.65	3	11.50	5.34	21.40	4	6.00	3.17	9.76	3
Na_2O	0.59	0.23	0.83	3	0.05	0.01	0.09	4	0.02	0.01	0.04	3
K_2O	0.10	0.04	0.17	3	0.02	0.01	0.03	3	0.01	0.01	0.01	2
P_2O_5	0.30	0.10	0.42	3	0.24	0.11	0.34	4	0.13	0.09	0.20	3
LOI	5.77	1.62	11.80	3	7.22	0.66	18.15	4	2.56	0.82	5.85	3
Total	91.86	87.73	98.95	3	95.01	91.17	99.12	4	97.44	92.08	100.67	3
C	2.89	0.08	5.31	3	3.29	1.29	5.57	4	0.34	0.21	0.48	3
S	7.97	5.61	11.00	3	1.63	0.15	3.31	4	5.17	0.04	15.35	3
Parts per million												
Li	16.80	11.00	22.50	3	1.98	0.60	4.30	4	4.03	3.80	4.40	3
Rb	4.73	1.00	11.80	3	0.43	0.30	0.50	3	0.93	0.40	1.90	3
Sr	153.93	50.30	249.00	3	153.85	72.90	230.00	4	20.03	10.80	33.70	3
Cs	2.61	0.11	4.80	3	0.20	0.04	0.43	4	0.54	0.03	1.22	3
Ba	47.77	17.10	86.30	3	5.38	2.50	7.30	4	5.17	2.20	10.90	3
Y	20.37	18.00	22.50	3	27.55	17.20	38.90	4	5.40	4.00	7.50	3
Zr	26.67	10.00	40.00	3	23.00	9.00	53.00	4	4.00	2.00	8.00	3
Nb	1.34	0.54	2.26	3	0.79	0.28	1.30	4	0.29	0.27	0.31	3
Hf	0.63	0.22	0.99	3	0.51	0.15	1.16	4	0.34	0.08	0.80	3
Ta	0.17	0.10	0.20	3	0.20	0.10	0.30	3	0.20	0.10	0.30	2
U	0.48	0.17	0.88	3	0.61	0.20	1.03	4	0.71	0.19	1.41	3
Th	0.95	0.49	1.68	3	0.53	0.42	0.83	4	0.26	0.10	0.45	3
Sc	4.37	1.00	7.30	3	2.00	1.50	2.70	4	0.50	0.30	0.90	3
V	42.33	20.00	55.00	3	93.25	49.00	118.00	4	9.00	5.00	12.00	3
Cr	21.67	6.00	37.00	3	7.25	6.00	10.00	4	10.67	7.00	13.00	3
Co	10.83	6.20	16.40	3	2.63	1.30	3.20	4	12.50	1.50	27.40	3
Ni	16.30	8.40	27.60	3	4.40	3.30	6.00	4	25.73	6.00	37.30	3
Cu	31.63	18.20	56.00	3	7.65	2.70	9.90	4	266.57	3.40	785.00	3
Zn	109.33	13.00	264.00	3	69.00	48.00	82.00	4	218.33	52.00	492.00	3
Ga	5.07	1.80	8.00	3	4.70	1.90	7.70	4	0.70	0.40	1.10	3
Ge	1.10	0.90	1.20	3	1.88	1.50	2.20	4	1.03	0.50	1.60	3
Sn	1.20	1.20	1.20	1	0.60	0.60	0.60	1	#DIV/0!	0.00	0.00	0
W	8.45	0.60	16.30	2	8.70	1.30	21.50	4	0.95	0.60	1.30	2
As	6.63	2.20	11.20	3	2.43	1.00	4.40	4	21.45	20.90	22.00	2
Se	2.87	0.80	5.30	3	0.50	0.20	0.80	3	9.65	0.50	18.80	2
Mo	0.72	0.35	1.36	3	0.47	0.13	0.93	4	2.50	0.52	5.49	3
Ag	0.92	0.11	2.42	3	0.12	0.04	0.25	4	0.68	0.03	1.98	3
Cd	0.34	0.29	0.41	3	0.20	0.14	0.28	4	0.43	0.17	0.74	3
In	0.02	0.01	0.04	2	0.01	0.01	0.01	4	#DIV/0!	0.00	0.00	0

Sb	0.21	0.13	0.36	3	0.17	0.08	0.29	4	0.43	0.11	0.66	3
Te	0.85	0.55	1.30	3	0.11	0.02	0.18	4	1.17	0.13	2.20	2
Re	0.002	0.001	0.005	3	0.001	0.001	0.001	2	0.002	0.001	0.002	2
Au	2.351	0.442	4.820	3	1.281	0.137	3.650	4	5.494	0.010	16.450	3
Hg	#DIV/0!	0.000	0.000	0	0.007	0.005	0.012	3	0.013	0.013	0.013	1
Tl	0.10	0.03	0.16	2	0.02	0.02	0.02	1	0.08	0.08	0.08	1
Pb	17.50	9.40	23.40	3	9.80	5.20	16.00	4	4.97	2.00	7.10	3
Bi	0.18	0.13	0.28	3	0.05	0.01	0.08	4	0.14	0.02	0.39	3
La	6.97	5.20	10.30	3	8.45	4.20	15.00	4	1.57	1.20	2.30	3
Ce	14.10	9.30	21.80	3	14.10	7.20	25.50	4	3.43	2.50	4.90	3
Pr	1.75	1.07	2.65	3	1.51	0.80	2.80	4	0.46	0.31	0.63	3
Nd	7.67	4.30	11.00	3	6.05	3.40	10.90	4	1.97	1.40	2.80	3
Sm	1.72	0.85	2.49	3	1.21	0.60	2.16	4	0.44	0.39	0.52	3
Eu	0.55	0.29	0.76	3	0.37	0.24	0.68	4	0.20	0.18	0.22	3
Gd	2.27	1.54	2.68	3	1.79	1.05	2.88	4	0.61	0.53	0.75	3
Tb	0.36	0.27	0.43	3	0.30	0.19	0.48	4	0.10	0.08	0.12	3
Dy	2.35	2.05	2.51	3	2.25	1.42	3.54	4	0.63	0.46	0.90	3
Ho	0.56	0.52	0.60	3	0.62	0.39	0.95	4	0.15	0.11	0.20	3
Er	1.66	1.40	1.79	3	2.04	1.32	2.95	4	0.41	0.29	0.60	3
Tm	0.24	0.20	0.27	3	0.32	0.20	0.47	4	0.07	0.05	0.09	3
Yb	1.64	1.37	1.86	3	2.15	1.32	3.27	4	0.40	0.24	0.63	3
Lu	0.28	0.22	0.32	3	0.37	0.23	0.56	4	0.08	0.05	0.11	3

TABLE A5-4 - Quality control tools for whole-rock analyses

Table A1-4. Quality control tools for whole-rock analyses

	certified reference material				field duplicates							
					028-14		033-19		029-26		004-22b	
sample	run-1	run-2	rv	2sd								
Weight %												
SiO_2	67.00	65.10	66.09	0.86	31.10	29.50	19.80	19.45	20.40	19.75	7.30	4.90
TiO_2	0.52	0.52	0.55	0.02	0.02	0.02	0.30	0.30	0.47	0.47	0.04	0.08
Al_2O_3	14.55	15.00	15.15	0.54	1.80	1.32	4.90	4.19	3.60	3.55	0.57	0.35
Fe_2O_{3total}	5.45	5.61	5.70	0.09	41.40	38.90	29.80	29.80	19.00	19.25	23.20	25.60
MnO	0.07	0.07	0.07	0.00	0.36	0.38	1.58	1.76	2.40	2.40	1.82	1.64
MgO	2.40	2.50	2.52	0.08	10.15	9.46	10.70	11.10	13.75	14.75	10.35	10.20
CaO	2.36	2.40	2.35	0.12	9.47	8.72	16.65	18.35	21.30	21.00	28.30	28.60
Na_2O	4.29	4.31	4.33	0.14	0.59	0.53	0.83	0.69	0.22	0.21	0.08	0.08
K_2O	1.98	2.07	2.11	0.12	0.19	0.08	0.08	0.05	0.77	0.55	0.10	0.05
P_2O_5	0.12	0.13	0.14	0.02	0.85	0.41	0.39	0.41	0.10	0.09	0.20	0.21
LOI	1.45	1.00	1.03	0.43	3.39	4.53	3.88	4.58	17.85	18.15	23.00	27.00
Total	100.19	98.71	100.04		99.32	93.85	88.91	90.68	99.86	100.17	94.96	98.71
C	0.09	0.10	0.09	0.01	0.22	0.21	3.28	3.82	5.11	5.16	7.76	8.36
S	0.22	0.23	0.23	0.02	7.85	10.85	5.61	4.25	<0.01	<0.01	2.24	1.05
Parts per million												
Li	22.7	21.3			9	9.1	11	10.7	14.4	12.6	3.9	2
Rb	58.7	64.6	59.7	5.42	23	2.4	1	1.2	41.5	30.3	4	1.5
Sr	504	538	520	52	154.5	115	162.5	181.5	135.5	124	255	236
Cs	2.55	2.71	2.72	0.22	4.3	0.64	0.11	0.23	9.8	7.07	2.24	0.59
Ba	755	768	818	61	103	11.4	39.9	33.3	237	237	53.3	34.1
Y	12.7	13	12.1	1.2	67.5	49.1	18	18.2	20.5	20.1	15.7	16
Zr	153	158	147	23	22	17	30	32	67	67	12	18
Nb	5.99	6.11	4.95	1.24	1.54	1.06	2.26	1.94	3.94	3.48	0.88	1.21
Hf	3.92	3.86	3.97	0.66	0.4	0.28	0.67	0.75	1.7	2.09	0.3	0.5
Ta	0.5	0.3	0.46	0.14	<0.1	<0.1	0.1	0.1	0.4	0.4	0.2	0.2
U	2.17	2.28	2.37	0.32	0.32	0.2	0.38	0.36	0.42	0.5	0.22	0.19
Th	6.57	7.13	7.28	0.76	0.97	0.63	0.67	0.67	0.71	0.86	0.26	0.3
Sc	11	11.2	11.2	1.46	3.6	2.8	4.8	4.9	7.4	7.8	2.8	2.7
V	103	102	92	15	20	17	52	46	63	58	11	12
Cr	196	195	193	19	20	16	22	22	23	32	10	11
Co	20.9	18.9	20.4	2	7	8.4	16.4	12.8	11.7	11.8	7.2	5.4
Ni	73.6	74.3	74.5	5.6	13.4	12.3	27.6	21.2	14.3	15.8	8.3	6.8
Cu	50.2	53.3	52.6	3.9	25	27.1	56	51.8	1.3	0.7	33.4	22.4
Zn	78	84	80	4	45	38	13	17	50	46	59	44
Ga	18.6	18.8	17.89	2.4	1.9	1.4	5.4	5.6	6.8	8.5	1.3	1.1
Ge	1.2	1			1.3	1.2	1.2	1.3	1.3	0.8	0.5	0.5
Sn	<0.5	0.9	0.8	0.1	<0.5	<0.5	1.2	0.9	<0.5	0.8	<0.5	2.2
W	0.8	1	0.4	0.1	49.7	40.8	16.3	15.4	0.9	2.1	3.5	0.7
As	0.2	1.1	0.3	0.2	2.1	2.1	11.2	7	0.7	6.6	4	3.4
Se	0.2	1.1	0.5	0.4	1.8	2.1	5.3	3.5	<0.2	<0.2	2.6	1.3
Mo	1.84	1.87	1.63	0.17	1.47	0.64	1.36	0.88	0.14	0.09	1.39	1.57
Ag	0.04	0.08	0.06	0.01	0.38	2.21	2.42	1.5	0.01	0.01	0.58	0.33
Cd	0.11	0.12	0.08	0.02	0.33	0.36	0.29	0.26	0.12	0.13	0.21	0.19
In	0.023	0.028			<0.005	<0.005	0.038	0.029	0.023	0.021	0.009	0.008

Sb	<0.05	<0.05	0.03	0.01	0.14	0.09	0.36	0.28	0.07	0.31	0.26	0.26
Te	0.02	0.14	0.02	0.02	0.76	1.02	1.3	0.93	0.01	0.01	0.58	0.31
Re	0.001	0.001			0.002	0.002	0.005	0.004	<0.001	<0.001	0.003	0.002
Au	0.002	0.001	0.001	0.002	4.74	18.3	4.82	3.18	0.027	0.027	0.136	0.082
Hg	<0.005	<0.005			<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	0.005
Tl	0.32	0.31			0.09	0.05	<0.02	<0.02	0.27	0.2	0.05	<0.02
Pb	20.4	22.9	7.02	0.72	16.1	15	9.4	8.2	9.2	7.5	10.2	9.6
Bi	0.16	0.17	0.16	0.02	0.09	0.15	0.14	0.13	0.01	0.01	0.21	0.15
La	25.5	27.1	26.8	2.5	19.2	12.6	5.4	5.4	7	7.6	3.9	3.8
Ce	51.6	52.7	52.8	5.1	33.4	22.8	11.2	11.6	14.7	16.4	6.9	7
Pr	5.83	6.16	6.15	0.53	3.63	2.6	1.52	1.58	1.89	1.88	0.78	0.83
Nd	21.5	22.7	22.7	2	15.6	10.7	7.7	7.6	8.5	9.1	3.5	3.7
Sm	3.48	3.64	3.93	0.51	2.86	2.08	1.81	1.91	2.19	2.13	0.81	0.78
Eu	0.95	1.03	1.02	0.15	0.98	0.66	0.61	0.57	0.65	0.6	0.27	0.29
Gd	2.88	2.9	3.06	0.38	4.47	3.06	2.68	2.55	2.46	2.77	1.1	1.1
Tb	0.41	0.38	0.42	0.05	0.75	0.54	0.39	0.39	0.41	0.46	0.2	0.21
Dy	2.28	2.21	2.32	0.26	5.63	4.37	2.48	2.4	2.85	3.03	1.46	1.49
Ho	0.44	0.46	0.46	0.05	1.52	1.1	0.52	0.5	0.64	0.66	0.39	0.42
Er	1.24	1.22	1.31	0.17	4.86	3.63	1.4	1.42	1.87	1.99	1.26	1.24
Tm	0.2	0.18	0.19	0.03	0.71	0.53	0.2	0.2	0.3	0.3	0.2	0.19
Yb	1.2	1.22	1.27	0.13	4.81	3.56	1.37	1.25	1.89	2.11	1.26	1.24
Lu	0.2	0.19	0.18	0.03	0.79	0.59	0.22	0.18	0.29	0.28	0.21	0.22

Notes:
rv = reference value; 2sd = two standard deviation

ELECTRONIC APPENDIX TABLE A6 - EPMA – Results

TABLE A6-1 - Olivine compositional data

Table A2-1. Electron microprobe data for selected metamorphic and hydrothermal olivine grains

Sample	009-03f	009-03f	029-07	029-07	033-19	033-19	009-03d	029-07	029-07
Drillhole	A09	A09	A29	A29	A33	A33	A09	A29	A29
Depth (m)	71.55	71.55	55.9	55.9	177	177	69.85	55.9	55.9
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	met	hyd	hyd
Spot ID	C4-1	C4-2	C2-1	C2-3	C1-3	C4-3	C3-1	C1-1	C3-1
SiO_2	38.17	38.04	35.97	36.08	35.13	36.26	38.74	36.33	35.85
TiO_2	0.01	0.00	0.00	0.02	0.07	0.00	0.03	0.02	0.01
Al_2O_3	0.02	0.00	0.02	0.00	0.02	0.01	0.01	0.00	0.00
Cr_2O_3	0.05	0.10	0.00	0.00	0.00	0.05	0.06	0.00	0.00
FeO_t	25.28	26.18	35.90	35.32	30.75	30.59	22.88	36.70	35.46
MnO	2.69	2.66	2.47	2.55	4.57	3.95	2.89	3.28	2.76
MgO	34.39	35.60	25.82	26.01	29.95	29.43	36.88	25.07	24.96
CaO	0.05	0.02	0.05	0.02	0.06	0.03	0.04	0.06	0.03
NiO	0.00	0.02	0.04	0.03	0.01	0.00	0.00	0.00	0.00
Na_2O	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Total	100.65	102.63	100.28	100.02	100.56	100.32	101.54	101.46	99.07
Mineral formula based on 4 oxygens									
Si	1.010	0.992	1.012	1.008	1.011	1.018	1.007	1.005	0.971
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Al	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
Cr	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Fe	0.559	0.571	0.855	0.842	0.828	0.842	0.815	0.874	0.711
Mn	0.060	0.059	0.077	0.059	0.060	0.066	0.068	0.070	0.107
Mg	1.356	1.383	1.041	1.079	1.087	1.056	1.101	1.044	1.234
Ca	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.000	0.002
Ni	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
Na	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	2.989	3.008	2.988	2.991	2.988	2.982	2.993	2.994	3.027
Olivine composition (molar %)									
Forsterite	68.64	68.73	52.76	54.52	55.02	53.77	55.47	52.53	60.14
Fayalite	28.31	28.35	43.32	42.52	41.92	42.85	41.09	43.97	34.65
Tefroite	3.05	2.91	3.92	2.96	3.06	3.38	3.44	3.50	5.21

Notes:

met = metamorphic; hyd = hydrothermal

Table A2-1. (Cont)

Sample	029-07	029-07	033-37
Drillhole	A29	A29	A33
Depth (m)	55.9	55.9	158.45
Host Rock	marble	marble	marble
Type	hyd	hyd	hyd
Spot ID	C3-7	C4-5	C1-1
SiO_2	36.31	35.56	35.90
TiO_2	0.02	0.02	0.00
Al_2O_3	0.00	0.00	0.00
Cr_2O_3	0.00	0.05	0.02
FeO_t	35.17	36.97	36.80
MnO	2.91	2.91	4.53
MgO	26.64	24.78	22.89
CaO	0.05	0.00	0.03
NiO	0.00	0.00	0.00
Na_2O	0.00	0.00	0.06
Total	101.09	100.28	100.22
Mineral formula based on 4 oxygens			
Si	0.997	1.005	1.021
Ti	0.000	0.001	0.000
Al	0.000	0.000	0.000
Cr	0.001	0.001	0.000
Fe	0.704	0.496	0.875
Mn	0.092	0.063	0.109
Mg	1.207	1.426	0.971
Ca	0.001	0.001	0.001
Ni	0.000	0.000	0.000
Na	0.000	0.000	0.003
Total	3.002	2.994	2.980
Olivine composition (molar %)			
Forsterite	60.27	71.81	49.65
Fayalite	35.14	25.00	44.77
Tefroite	4.60	3.19	5.58

Notes:
met = metamorphic; hyd = hydrothermal

TABLE A6-2 - Clinopyroxene compositional data

Table A2-2. Electron microprobe data for selected hydrothermal clinopyroxene grains

Sample	004-15	004-15	004-15	004-15	029-20	033-17b	033-04b	033-04b	033-11b
Drillhole	A04	A04	A04	A04	A29	A33	A33	A33	A33
Depth (m)	164.05	164.05	164.05	164.05	110.1	162.1	55.75	55.75	106.5
Host Rock	marble	marble	marble	marble	marble	marble	qz-cpx vein	qz-cpx vein	qz-cpx vein
Spot ID	C1-5	C2-6	C3-2	C4-3	C1-1	C2-1	C1-2	C2-3	C1-1
SiO_2	52.10	52.06	52.14	52.35	52.14	52.47	49.90	51.73	49.49
TiO_2	0.03	0.01	0.01	0.04	0.00	0.05	0.00	0.02	0.02
Al_2O_3	0.63	0.43	0.39	0.43	0.11	0.33	0.29	0.23	0.38
Cr_2O_3	0.00	0.00	0.06	0.05	0.02	0.00	0.08	0.04	0.00
FeO_t	8.68	9.24	10.82	9.58	9.59	8.87	15.88	14.04	17.28
MnO	0.94	1.19	1.01	1.24	1.36	2.08	1.12	1.06	0.62
MgO	14.20	13.68	12.23	13.59	12.51	13.73	8.94	9.93	8.33
CaO	24.02	24.20	23.78	23.94	24.01	23.23	22.34	24.05	22.84
Na_2O	0.06	0.00	0.00	0.02	0.02	0.04	0.03	0.00	0.05
K_2O	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Total	100.66	100.79	100.45	101.24	99.77	100.80	98.58	101.11	99.02
Mineral formula based on 6 oxygens									
Si	1.949	1.953	1.972	1.956	1.979	1.966	1.971	1.975	1.959
Ti	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.001
Al	0.028	0.019	0.017	0.019	0.005	0.015	0.013	0.010	0.018
Cr	0.000	0.000	0.002	0.001	0.001	0.000	0.002	0.001	0.000
Fe	0.272	0.290	0.342	0.299	0.305	0.278	0.525	0.448	0.572
Mn	0.030	0.038	0.032	0.039	0.044	0.066	0.038	0.034	0.021
Mg	0.792	0.765	0.690	0.757	0.708	0.766	0.526	0.565	0.491
Ca	0.963	0.973	0.963	0.958	0.977	0.933	0.945	0.984	0.969
Na	0.004	0.000	0.000	0.002	0.002	0.003	0.002	0.000	0.004
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.038	4.037	4.019	4.033	4.019	4.027	4.022	4.019	4.034
X_{Mg}	0.745	0.725	0.668	0.717	0.699	0.734	0.501	0.558	0.462
Classification	di	di	di	di	di	di	di	di	hd

Notes:
cpx = clinopyroxene; di = diopside; hd = hedenbergite; qz = quartz

Table A2-2. (Cont)

Sample	009-16	009-16	009-16	009-16	009-16	009-16	009-16	009-16	028-06a
Drillhole	A09	A09	A09	A09	A09	A09	A09	A09	A28
Depth (m)	179.35	179.35	179.35	179.35	179.35	179.35	179.35	179.35	64.5
Host Rock	marble	marble	marble	marble	marble	BIF	BIF	BIF	qz-cpx vein
Spot ID	C2-4	C2-6	C2-7	C2-10-1	C2-10-2	C3-1	C3-5	C3-7	C2-2
SiO_2	54.70	53.72	54.62	55.15	53.89	51.92	51.94	51.85	51.63
TiO_2	0.00	0.00	0.02	0.06	0.00	0.00	0.01	0.03	0.02
Al_2O_3	0.11	0.39	0.09	0.13	0.56	0.23	0.12	0.09	0.08
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO_t	6.18	8.32	7.04	4.90	7.01	17.42	17.21	17.14	17.12
MnO	0.22	0.36	0.29	0.20	0.23	0.54	0.55	0.58	1.26
MgO	15.63	14.73	15.11	16.60	15.40	8.41	8.44	8.08	8.51
CaO	24.04	23.46	24.48	24.56	24.01	22.36	22.59	22.92	22.19
Na_2O	0.07	0.08	0.08	0.00	0.08	0.32	0.32	0.33	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.96	101.05	101.73	101.59	101.18	101.19	101.17	101.02	100.81
Mineral formula based on 6 oxygens									
Si	2.000	1.983	1.994	1.994	1.977	1.996	1.997	1.998	1.995
Ti	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000
Al	0.005	0.017	0.004	0.006	0.024	0.010	0.005	0.004	0.004
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.189	0.257	0.215	0.148	0.215	0.560	0.553	0.553	0.553
Mn	0.007	0.011	0.009	0.006	0.007	0.018	0.018	0.019	0.041
Mg	0.852	0.811	0.822	0.895	0.842	0.482	0.484	0.464	0.490
Ca	0.942	0.928	0.957	0.951	0.943	0.921	0.931	0.947	0.919
Na	0.005	0.006	0.006	0.000	0.006	0.024	0.024	0.025	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.012	4.007	4.002	4.014	4.011	4.012	4.011	4.003
X_{Mg}	0.818	0.759	0.793	0.858	0.797	0.462	0.466	0.457	0.470
Classification	di	di	di	di	di	hd	hd	hd	hd

Notes:
cpx = clinopyroxene; di = diopside; hd = hedenbergite; qz = quartz

Table A2-2. (Cont)

Sample	028-06a	033-11	033-11	HS-10	HS-10	HS-10	HS-10	HS-10
Drillhole	A28	A33	A33	surface	surface	surface	surface	surface
Depth (m)	64.5	99.2	99.2	n/a	n/a	n/a	n/a	n/a
Host Rock	qz-cpx vein	marble	marble	marble	marble	marble	marble	marble
Spot ID	C2-4	C1-3	C1-4	C1-1	C1-2	C1-3	C5-1	C5-2
		(core)	(margin)	(core)		(margin)	(core)	(margin)
SiO_2	50.38	51.84	51.64	52.31	51.79	52.30	51.87	53.20
TiO_2	0.00	0.04	0.06	0.00	0.00	0.00	0.00	0.00
Al_2O_3	0.06	0.37	0.43	0.31	0.15	0.25	0.25	0.23
Cr_2O_3	0.00	0.00	0.07	0.03	0.07	0.07	0.01	0.00
FeO_t	17.61	14.75	14.54	11.95	12.37	11.92	11.69	11.88
MnO	1.34	0.74	0.82	2.12	2.03	2.09	2.28	2.01
MgO	7.91	9.48	9.71	11.51	11.43	11.53	11.97	11.95
CaO	21.73	23.58	23.05	22.60	23.27	22.67	22.54	22.55
Na_2O	0.00	0.00	0.00	0.01	0.00	0.07	0.03	0.03
K_2O	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Total	99.03	100.80	100.31	100.84	101.10	100.90	100.65	101.86
Mineral formula based on 6 oxygens								
Si	1.991	1.984	1.983	1.982	1.967	1.981	1.971	1.989
Ti	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000
Al	0.003	0.017	0.020	0.014	0.007	0.011	0.011	0.010
Cr	0.000	0.000	0.002	0.001	0.002	0.002	0.000	0.000
Fe	0.582	0.472	0.467	0.378	0.393	0.377	0.371	0.372
Mn	0.045	0.024	0.027	0.068	0.065	0.067	0.073	0.064
Mg	0.466	0.541	0.556	0.650	0.647	0.651	0.678	0.666
Ca	0.920	0.967	0.948	0.917	0.947	0.920	0.918	0.903
Na	0.000	0.000	0.000	0.000	0.000	0.005	0.002	0.002
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.007	4.006	4.004	4.011	4.028	4.015	4.025	4.007
X_{Mg}	0.445	0.534	0.543	0.632	0.622	0.633	0.646	0.642
Classification	hd	di	di	di	di	di	di	di

Notes:
cpx = clinopyroxene; di = diopside; hd = hedenbergite; qz = quartz

Table A2-2. (Cont)

Sample	011-01	011-01	011-01	028-29	028-29	028-29	028-29	028-29
Drillhole	A11	A11	A11	A28	A28	A28	A28	A28
Depth (m)	183	183	183		199.1	199.1	199.1	199.1
Host Rock	marble	marble	marble	BIF	BIF	BIF	BIF	BIF
Spot ID	C1-1	C3-1	C3-2	C1-1	C1-4	C1-6	C2-1	C2-2
		(core)	(margin)		(core)	(margin)	(core)	(margin)
SiO_2	54.14	53.02	53.10	52.55	52.55	53.27	52.60	53.06
TiO_2	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Al_2O_3	0.29	0.18	0.21	0.13	0.14	0.16	0.13	0.18
Cr_2O_3	0.09	0.00	0.06	0.01	0.05	0.00	0.03	0.08
FeO_t	4.06	7.22	9.04	16.23	16.61	15.49	16.31	17.25
MnO	3.41	3.30	2.86	0.84	0.78	0.64	0.79	1.05
MgO	16.44	13.34	12.88	8.09	8.23	9.31	8.36	8.05
CaO	22.94	23.83	22.78	21.62	21.40	21.66	22.26	21.38
Na_2O	0.03	0.04	0.06	0.77	0.81	0.56	0.55	0.58
K_2O	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Total	101.43	100.93	101.01	100.23	100.57	101.10	101.04	101.64
Mineral formula based on 6 oxygens								
Si	1.977	1.980	1.987	2.027	2.022	2.024	2.015	2.024
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.013	0.008	0.009	0.006	0.006	0.007	0.006	0.008
Cr	0.002	0.000	0.002	0.000	0.001	0.000	0.001	0.003
Fe	0.124	0.225	0.283	0.523	0.534	0.492	0.523	0.550
Mn	0.106	0.104	0.091	0.027	0.025	0.021	0.026	0.034
Mg	0.895	0.743	0.719	0.465	0.472	0.527	0.477	0.457
Ca	0.897	0.954	0.914	0.893	0.882	0.882	0.913	0.874
Na	0.002	0.003	0.004	0.057	0.061	0.042	0.041	0.043
K	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001
Total	4.016	4.017	4.010	3.999	4.004	3.994	4.002	3.993
X_{Mg}	0.878	0.767	0.717	0.471	0.469	0.517	0.477	0.454
Classification	di	di	di	hd	hd	di	hd	hd

Notes:
cpx = clinopyroxene; di = diopside; hd = hedenbergite; qz = quartz

TABLE A6-3 - Garnet compositional data

Table A2-3. Electron microprobe data for selected igneous, metamorphic and hydrothermal garnet grains

Sample	029-39a	029-39a	029-39a	029-39a	011-01	011-01	057-03	057-03
Drillhole	A29	A29	A29	A29	A11	A11	B57	B57
Depth (m)	213.15	213.15	213.15	213.15	183	183	83.8	83.8
Host Rock	granite	granite	granite	granite	granite	granite	pelitic schist	pelitic schist
Type	mag	mag	mag	mag	mag	mag	met	met
Spot ID	C1-7a	C3-1b	C3-1a	C3-3a	C5-1	C5-2	C2-1	C3-1
		(margin)	(core)	(margin)	(core)	(margin)		
SiO_2	37.42	36.85	37.35	36.84	35.20	36.64	38.21	37.19
P_2O_5	0.21	0.26	0.21	0.25	0.53	0.25	0.00	0.00
TiO_2	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Al_2O_3	21.69	21.13	21.48	20.66	21.71	21.45	21.04	21.51
Cr_2O_3	0.01	0.01	0.00	0.00	0.04	0.00	0.00	0.00
FeO_t	33.86	34.93	33.44	33.45	26.07	25.07	26.31	26.81
MnO	7.31	6.73	7.45	7.34	13.96	14.65	12.00	11.87
MgO	0.64	0.67	0.61	0.68	2.02	2.21	1.90	1.95
CaO	0.18	0.22	0.20	0.22	0.37	0.31	1.92	1.60
Na_2O	0.03	0.03	0.00	0.00	0.00	0.01	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Total	101.36	100.83	100.75	99.44	99.89	100.59	101.39	100.94
Mineral formula based on 8 cations (iron as Fe^{2+} and Fe^{3+} based on charge balance)								
Si	3.027	3.003	3.041	3.043	2.864	2.956	3.055	2.985
P	0.014	0.018	0.014	0.018	0.037	0.017	0.000	0.000
Ti	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Al^{IV}	0.000	0.000	0.000	0.000	0.136	0.044	0.000	0.015
Al^{VI}	2.068	2.029	2.061	2.011	1.947	1.996	1.983	2.020
Cr	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000
Fe^{3+}	0.000	0.000	0.000	0.000	0.077	0.000	0.000	0.000
Fe^{2+}	2.291	2.380	2.277	2.311	1.697	1.692	1.759	1.800
Mn	0.501	0.465	0.514	0.514	0.962	1.001	0.812	0.807
Mg	0.077	0.081	0.074	0.084	0.244	0.265	0.226	0.234
Ca	0.016	0.019	0.017	0.019	0.032	0.027	0.165	0.138
Na	0.005	0.005	0.001	0.000	0.000	0.002	0.000	0.000
K	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Garnet composition (molar %)								
Pyrope	2.676	2.759	2.569	2.856	8.327	8.892	7.633	7.843
Almandine	79.418	80.818	79.016	78.934	57.809	56.669	59.379	60.425
Spessartine	17.365	15.776	17.822	17.548	32.777	33.538	27.425	27.103
Uvarovite	0.015	0.035	0.000	0.013	0.110	0.000	0.000	0.000
Andradite	0.000	0.000	0.000	0.000	0.080	0.000	0.000	0.000
Grossular	0.525	0.611	0.593	0.649	0.900	0.901	5.564	4.629
Fe^{3+}/Fe_{total}	0.000	0.000	0.000	0.000	0.043	0.000	0.000	0.000

Notes:

mag = magmatic; met = metamorphic; hyd = hydrothermal; hyd* = granite contact aureoles

cpx = clinopyroxene; qz = quartz

Table A2-3. (Cont)

Sample	057-03	057-03	057-03	029-27	029-27	029-27	029-27	029-27	029-04
Drillhole	B57	B57	B57	A29	A29	A29	A29	A29	A29
Depth (m)	83.8	83.8	83.8	146.7	146.7	146.7	146.7	146.7	48.25
Host Rock	pelitic schist	pelitic schist	pelitic schist	marble	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	met	met	hyd
Spot ID	C4-1	C5-1	C6-1	C1-1	C1-3	C2-1	C2-2	C4-3	C1-12a
SiO_2	38.13	37.83	37.57	38.30	38.29	38.42	37.96	38.68	37.97
P_2O_5	0.00	0.01	0.02	0.00	0.00	0.00	0.02	0.00	0.00
TiO_2	0.03	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.08
Al_2O_3	21.42	21.10	21.29	22.71	22.50	22.59	22.72	21.49	22.06
Cr_2O_3	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.09	0.00
FeO_t	25.75	26.70	26.22	18.45	19.43	18.02	18.22	18.18	31.09
MnO	12.40	12.34	12.91	10.34	11.02	10.92	11.07	10.80	2.72
MgO	1.80	1.77	1.60	4.88	4.31	4.99	5.11	4.76	4.84
CaO	1.56	1.42	1.43	5.99	5.58	6.62	6.10	6.31	2.24
Na_2O	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.01	0.02
K_2O	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01
Total	101.09	101.18	101.04	100.69	101.17	101.58	101.27	100.32	101.03
Mineral formula based on 8 cations (iron as Fe^{2+} and Fe^{3+} based on charge balance)									
Si	3.057	3.037	3.022	2.975	2.979	2.957	2.931	3.025	2.979
P	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Ti	0.002	0.000	0.000	0.001	0.000	0.000	0.002	0.000	0.005
Al^{IV}	0.000	0.000	0.000	0.025	0.021	0.043	0.069	0.000	0.021
Al^{VI}	2.023	1.996	2.018	2.055	2.042	2.006	1.998	1.981	2.018
Cr	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.006	0.000
Fe^{3+}	0.000	0.000	0.000	0.000	0.000	0.041	0.072	0.000	0.000
Fe^{2+}	1.727	1.793	1.764	1.199	1.264	1.119	1.104	1.189	2.040
Mn	0.842	0.839	0.880	0.681	0.726	0.712	0.724	0.715	0.180
Mg	0.215	0.212	0.191	0.565	0.500	0.572	0.588	0.555	0.565
Ca	0.134	0.122	0.123	0.499	0.465	0.546	0.505	0.529	0.188
Na	0.000	0.000	0.000	0.000	0.001	0.004	0.005	0.001	0.002
K	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.001
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Garnet composition (molar %)									
Pyrope	7.377	7.147	6.466	19.202	16.909	19.402	20.143	18.569	19.013
Almandine	59.174	60.455	59.627	40.731	42.786	37.941	37.808	39.797	68.588
Spessartine	28.853	28.282	29.742	23.124	24.578	24.140	24.771	23.945	6.068
Uvarovite	0.000	0.000	0.000	0.000	0.107	0.000	0.000	0.289	0.000
Andradite	0.000	0.000	0.000	0.000	0.000	1.957	3.353	0.000	0.000
Grossular	4.595	4.116	4.164	16.944	15.620	16.560	13.925	17.400	6.331
Fe^{3+}/Fe_{total}	0.000	0.000	0.000	0.000	0.000	0.035	0.061	0.000	0.000

Notes:

mag = magmatic; met = metamorphic; hyd = hydrothermal; hyd* = granite contact aureoles

cpx = clinopyroxene; qz = quartz

Table A2-3. (Cont)

Sample	029-04	029-04	029-04	029-04	029-04	029-04	004-15	004-15
Drillhole	A29	A29	A29	A29	A29	A29	A04	A04
Depth (m)	48.25	48.25	48.25	48.25	48.25	48.25	164.05	164.05
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C2-8a	C2-1	C2-7a	C3-1b	C3-7b	C4-1b	C1-2	C1-7
	(core)		(margin)					
SiO_2	37.92	38.05	38.11	37.48	38.04	36.04	38.51	38.28
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
TiO_2	0.01	0.00	0.04	0.06	0.06	0.00	0.07	0.00
Al_2O_3	22.22	22.30	22.25	22.11	21.38	23.95	21.27	21.63
Cr_2O_3	0.00	0.00	0.00	0.10	0.00	0.06	0.13	0.02
FeO_t	31.47	31.40	31.42	31.78	32.55	31.88	22.36	22.63
MnO	1.78	1.04	1.60	0.54	1.08	0.85	9.77	7.77
MgO	5.53	5.89	5.75	5.33	5.22	5.42	3.27	3.37
CaO	2.12	1.98	2.07	2.36	2.03	2.00	5.95	7.17
Na_2O	0.00	0.00	0.01	0.00	0.00	0.08	0.00	0.00
K_2O	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01
Total	101.05	100.66	101.24	99.76	100.36	100.28	101.33	100.89
Mineral formula based on 8 cations (iron as Fe^{2+} and Fe^{3+} based on charge balance)								
Si	2.961	2.973	2.966	2.963	3.002	2.825	3.022	3.002
P	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Ti	0.001	0.000	0.002	0.003	0.003	0.000	0.004	0.000
Al^{IV}	0.039	0.027	0.034	0.037	0.000	0.175	0.000	0.000
Al^{VI}	2.005	2.027	2.006	2.024	1.988	2.037	1.967	1.999
Cr	0.000	0.000	0.000	0.006	0.000	0.003	0.008	0.001
Fe^{3+}	0.033	0.000	0.025	0.001	0.002	0.147	0.000	0.000
Fe^{2+}	2.022	2.052	2.020	2.101	2.146	1.943	1.467	1.484
Mn	0.118	0.069	0.105	0.036	0.072	0.056	0.649	0.516
Mg	0.643	0.686	0.667	0.629	0.614	0.633	0.383	0.394
Ca	0.177	0.166	0.173	0.200	0.171	0.168	0.500	0.603
Na	0.000	0.000	0.001	0.000	0.000	0.011	0.000	0.000
K	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.001
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Garnet composition (molar %)								
Pyrope	21.726	23.087	22.507	21.196	20.450	22.607	12.760	13.136
Almandine	68.309	69.033	68.118	70.838	71.434	69.389	48.926	49.528
Spessartine	3.973	2.309	3.552	1.213	2.409	2.008	21.643	17.227
Uvarovite	0.000	0.000	0.000	0.290	0.000	0.144	0.421	0.046
Andradite	1.598	0.000	1.207	0.040	0.090	6.229	0.000	0.000
Grossular	4.394	5.571	4.616	6.423	5.617	-0.378	16.250	20.063
Fe^{3+}/Fe_{total}	0.016	0.000	0.012	0.000	0.001	0.070	0.000	0.000

Notes:

mag = magmatic; met = metamorphic; hyd = hydrothermal; hyd* = granite contact aureoles

cpx = clinopyroxene; qz = quartz

Table A2-3. (Cont)

Sample	004-15	004-15	004-15	004-15	029-20	033-17b	033-11b	033-11b
Drillhole	A04	A04	A04	A04	A29	A33	A33	A33
Depth (m)	164.05	164.05	164.05	164.05	110.1	162.1	106.5	106.5
Host Rock	marble	marble	marble	marble	marble	marble	qz-cpx vein	qz-cpx vein
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C2-2	C2-4	C3-4	C4-1	C4-3	C5-1	C6-1	C6-4
SiO_2	38.04	38.44	37.69	38.08	37.41	38.05	41.32	36.75
P_2O_5	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.04
TiO_2	0.04	0.04	0.05	0.01	0.21	0.04	0.02	0.02
Al_2O_3	21.17	21.26	21.04	21.50	21.00	20.74	19.20	21.74
Cr_2O_3	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
FeO_t	21.69	19.21	18.88	18.10	18.04	16.59	26.98	27.83
MnO	10.75	10.60	9.86	12.03	6.92	16.18	4.80	5.05
MgO	2.49	3.05	1.49	2.60	1.98	1.87	0.84	0.90
CaO	6.25	8.61	11.52	9.46	14.67	8.24	7.23	8.36
Na_2O	0.05	0.04	0.04	0.00	0.00	0.04	0.05	0.01
K_2O	0.00	0.01	0.00	0.01	0.00	0.00	0.03	0.00
Total	100.53	101.28	100.62	101.78	100.22	101.76	100.46	100.69
Mineral formula based on 8 cations (iron as Fe^{2+} and Fe^{3+} based on charge balance)								
Si	3.019	3.002	2.975	2.964	2.936	2.990	3.315	2.932
P	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.003
Ti	0.002	0.002	0.003	0.001	0.013	0.002	0.001	0.001
Al^{IV}	0.000	0.000	0.025	0.036	0.064	0.010	0.000	0.068
Al^{VI}	1.980	1.956	1.933	1.937	1.879	1.911	1.815	1.976
Cr	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
Fe^{3+}	0.000	0.040	0.088	0.098	0.159	0.101	0.000	0.084
Fe^{2+}	1.439	1.214	1.158	1.080	1.025	0.989	1.810	1.773
Mn	0.723	0.701	0.659	0.793	0.460	1.077	0.326	0.342
Mg	0.294	0.355	0.175	0.302	0.231	0.219	0.100	0.107
Ca	0.531	0.721	0.974	0.789	1.233	0.694	0.621	0.715
Na	0.007	0.006	0.006	0.000	0.000	0.007	0.007	0.001
K	0.000	0.001	0.000	0.001	0.000	0.000	0.003	0.000
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Garnet composition (molar %)								
Pyrope	9.845	11.880	5.915	10.186	7.840	7.354	3.495	3.642
Almandine	48.179	40.588	39.043	36.433	34.752	33.209	63.346	60.379
Spessartine	24.195	23.444	22.212	26.764	15.588	36.147	11.421	11.633
Uvarovite	0.000	0.000	0.158	0.000	0.000	0.000	0.000	0.000
Andradite	0.000	2.004	4.306	4.752	7.564	5.008	0.000	3.942
Grossular	17.781	22.084	28.366	21.865	34.255	18.282	21.738	20.404
Fe^{3+}/Fe_{total}	0.000	0.032	0.071	0.084	0.134	0.093	0.000	0.045

Notes:

mag = magmatic; met = metamorphic; hyd = hydrothermal; hyd* = granite contact aureoles

cpx = clinopyroxene; qz = quartz

Table A2-3. (Cont)

Sample	033-11	033-11	033-11	033-11	HS-10	HS-10	HS-10
Drillhole	A33	A33	A33	A33	surface	surface	surface
Depth (m)	99.2	99.2	99.2	99.2	n/a	n/a	n/a
Host Rock	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-1	C1-2	C2-3	C2-4	C3-1	C3-3	C3-4
	(core)	(margin)	(core)	(margin)		(core)	(margin)
SiO_2	39.17	39.17	38.07	37.89	37.24	37.32	37.33
P_2O_5	0.02	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.27	0.08	0.03	0.08	0.14	0.00	0.01
Al_2O_3	21.15	21.07	21.12	21.28	20.98	20.75	21.06
Cr_2O_3	0.00	0.12	0.00	0.11	0.00	0.02	0.06
FeO_t	23.34	24.36	24.81	26.39	21.92	18.30	19.83
MnO	5.61	5.46	6.28	6.24	14.18	14.52	14.83
MgO	1.13	1.18	1.02	1.51	1.72	1.24	1.19
CaO	12.34	11.50	9.54	8.36	6.12	9.40	7.37
Na_2O	0.01	0.00	0.08	0.02	0.00	0.02	0.04
K_2O	0.00	0.00	0.00	0.02	0.01	0.00	0.01
Total	103.04	102.94	100.95	101.89	102.31	101.57	101.73
Mineral formula based on 8 cations (iron as Fe^{2+} and Fe^{3+} based on charge balance)							
Si	3.027	3.036	3.017	2.979	2.934	2.946	2.954
P	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.016	0.005	0.002	0.004	0.008	0.000	0.001
Al^{IV}	0.000	0.000	0.000	0.021	0.066	0.054	0.046
Al^{VI}	1.926	1.924	1.973	1.951	1.882	1.876	1.918
Cr	0.000	0.007	0.000	0.007	0.000	0.001	0.004
Fe^{3+}	0.000	0.000	0.003	0.059	0.170	0.181	0.130
Fe^{2+}	1.508	1.579	1.641	1.676	1.275	1.027	1.182
Mn	0.367	0.359	0.421	0.416	0.946	0.971	0.994
Mg	0.130	0.136	0.120	0.177	0.201	0.146	0.141
Ca	1.022	0.955	0.810	0.704	0.516	0.795	0.625
Na	0.002	0.000	0.013	0.003	0.001	0.003	0.006
K	0.000	0.000	0.000	0.002	0.001	0.000	0.001
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Garnet composition (molar %)							
Pyrope	4.304	4.491	4.010	5.965	6.854	4.979	4.784
Almandine	49.819	52.136	54.839	56.379	43.371	34.947	40.188
Spessartine	12.129	11.840	14.076	13.977	32.199	33.020	33.783
Uvarovite	0.010	0.368	0.000	0.339	0.009	0.044	0.176
Andradite	0.000	0.000	0.138	2.909	8.020	8.566	6.191
Grossular	33.739	31.165	26.936	20.432	9.547	18.444	14.878
Fe^{3+}/Fe_{total}	0.000	0.000	0.002	0.034	0.118	0.150	0.099

Notes:

mag = magmatic; met = metamorphic; hyd = hydrothermal; hyd* = granite contact aureoles

cpx = clinopyroxene; qz = quartz

Table A2-3. (Cont)

Sample	HS-10	HS-10	HS-10	011-01	011-01	011-01	011-01
Drillhole	surface	surface	surface	A11	A11	A11	A11
Depth (m)	n/a	n/a	n/a	183	183	183	183
Host Rock	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd*	hyd*	hyd*	hyd*
Spot ID	C4-2	C4-3	C6-2	C4-1	C4-2	C4-3	C4-4
	(core)	(margin)	Grt	(core)	(margin)	(core)	(margin)
SiO_2	36.96	37.75	37.45	37.34	38.19	37.54	36.87
P_2O_5	0.00	0.00	0.00	0.04	0.02	0.00	0.02
TiO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al_2O_3	21.25	20.69	20.89	21.65	20.03	21.44	21.63
Cr_2O_3	0.00	0.00	0.02	0.00	0.00	0.07	0.00
FeO_t	19.33	18.48	20.03	19.74	17.52	16.13	15.17
MnO	14.54	15.45	15.11	18.87	17.26	14.58	18.77
MgO	1.53	1.36	1.68	1.64	1.21	0.98	0.78
CaO	7.27	7.34	6.73	2.71	6.63	10.80	8.05
Na_2O	0.01	0.00	0.01	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	100.88	101.08	101.93	101.99	100.85	101.53	101.32
Mineral formula based on 8 cations (iron as Fe^{2+} and Fe^{3+} based on charge balance)							
Si	2.940	3.003	2.956	2.966	3.055	2.952	2.927
P	0.000	0.000	0.000	0.003	0.001	0.000	0.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al^{IV}	0.060	0.000	0.044	0.034	0.000	0.048	0.073
Al^{VI}	1.933	1.940	1.898	1.992	1.889	1.940	1.951
Cr	0.000	0.000	0.001	0.000	0.000	0.004	0.000
Fe^{3+}	0.126	0.054	0.146	0.033	0.000	0.104	0.119
Fe^{2+}	1.159	1.175	1.176	1.278	1.172	0.957	0.888
Mn	0.979	1.041	1.010	1.270	1.170	0.971	1.262
Mg	0.181	0.162	0.197	0.194	0.145	0.114	0.093
Ca	0.619	0.625	0.569	0.230	0.568	0.910	0.685
Na	0.001	0.000	0.001	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Garnet composition (molar %)							
Pyrope	6.173	5.378	6.682	6.526	4.733	3.872	3.161
Almandine	39.440	39.134	39.824	43.004	38.377	32.418	30.327
Spessartine	33.320	34.661	34.216	42.724	38.293	32.888	43.115
Uvarovite	0.000	0.000	0.054	0.000	0.010	0.196	0.000
Andradite	5.969	2.712	6.999	1.595	0.000	4.952	5.557
Grossular	15.098	18.115	12.226	6.151	18.586	25.674	17.840
Fe^{3+}/Fe_{total}	0.098	0.044	0.111	0.025	0.000	0.098	0.118

Notes:

mag = magmatic; met = metamorphic; hyd = hydrothermal; hyd* = granite contact aureoles

cpx = clinopyroxene; qz = quartz

TABLE A6-4 - Amphibole compositional data

Table A2-4. Electron microprobe data for selected metamorphic and hydrothermal amphibole grains

Sample	963-22	963-22	963-22	963-22	009-03d	009-03d	009-03d	009-03d	009-03d
Drillhole	A963	A963	A963	A963	A09	A09	A09	A09	A09
Depth (m)	57.7	57.7	57.7	57.7	69.85	69.85	69.85	69.85	69.85
Host Rock	amphibolite	amphibolite	amphibolite	amphibolite	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	met	met	met
Spot ID	C1-1	C1-2	C2-2	C2-5	C1-1	C1-2	C1-3	C1-4	C2-1
Mineral	mag-hbl	mag-hbl	mag-hbl	mag-hbl	tre	tre	tre	tre	tre
SiO_2	46.64	47.12	44.35	46.54	58.35	58.02	57.95	58.44	57.44
TiO_2	0.74	0.74	1.03	0.83	0.00	0.00	0.00	0.03	0.00
Al_2O_3	10.36	8.54	10.68	9.55	0.06	0.35	0.34	0.14	0.70
Cr_2O_3	0.00	0.01	0.00	0.00	0.00	0.00	0.08	0.04	0.00
V_2O_3	0.09	0.15	0.12	0.16	0.04	0.05	0.01	0.00	0.04
FeO_t	18.05	17.84	18.45	18.75	2.63	4.59	4.50	3.08	5.25
MnO	0.40	0.45	0.42	0.43	0.48	0.36	0.48	0.34	0.54
MgO	9.66	10.08	8.94	9.67	22.05	20.95	21.39	22.04	20.61
CaO	12.51	12.56	12.16	12.10	13.41	13.42	12.80	13.51	12.72
BaO	0.13	0.05	0.13	0.04	0.00	0.03	0.04	0.01	0.00
NiO	0.03	0.03	0.04	0.00	0.00	0.04	0.00	0.02	0.00
ZnO	0.05	0.04	0.06	0.00	0.05	0.00	0.00	0.00	0.00
Na_2O	0.56	0.55	0.73	0.66	0.01	0.08	0.08	0.00	0.10
K_2O	0.76	0.74	1.02	0.85	0.04	0.04	0.04	0.03	0.06
F	0.33	0.00	0.00	0.00	0.51	0.21	0.10	0.31	0.00
Cl	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
–O=F+Cl	0.14	0.00	0.00	0.00	0.22	0.09	0.04	0.13	0.00
Total (init)	100.42	98.90	98.14	99.59	97.85	98.23	97.85	98.13	97.46
H_2O (calc)	1.77	1.99	1.86	1.89	2.17	2.17	2.17	2.17	2.16
Total (calc)	102.19	100.89	100.01	101.48	100.02	100.40	100.02	100.31	99.62
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	6.803	6.924	6.629	6.825	8.058	8.024	8.010	8.052	7.973
T.Al	1.193	1.073	1.376	1.171	0.000	0.000	0.000	0.000	0.003
T.Ti	0.000	0.002	0.000	0.001	0.000	0.000	0.000	0.003	0.000
T.sum	7.996	7.998	8.005	7.997	8.059	8.024	8.010	8.055	7.976
C.Al	0.588	0.406	0.506	0.480	0.010	0.057	0.056	0.023	0.111
C.Ti	0.081	0.080	0.124	0.091	0.000	0.000	0.000	0.000	0.000
C.Fe3	0.356	0.379	0.431	0.429	0.059	0.052	0.147	0.019	0.180
C.Cr	0.000	0.001	0.000	0.000	0.000	0.000	0.008	0.004	0.000
C.Ni	0.003	0.003	0.005	0.000	0.000	0.004	0.000	0.002	0.000
C.Zn	0.005	0.004	0.006	0.000	0.005	0.000	0.000	0.000	0.000
C.Mn2	0.039	0.044	0.043	0.042	0.028	0.018	0.028	0.014	0.036
C.Mg	2.095	2.208	1.992	2.100	4.540	4.320	4.408	4.526	4.266
C.Fe2	1.854	1.863	1.879	1.860	0.308	0.546	0.386	0.379	0.462
C.sum	5.021	4.989	4.985	5.002	4.951	4.998	5.033	4.967	5.054
B.Mn2	0.011	0.012	0.010	0.012	0.028	0.024	0.028	0.026	0.028
B.Fe2	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000
B.Mg	0.006	0.000	0.000	0.014	0.000	0.000	0.000	0.000	0.000
B.Ca	1.959	1.983	1.947	1.906	1.995	2.001	1.901	2.005	1.898
B.Na	0.028	0.062	0.050	0.050	0.184	0.175	0.172	0.000	0.191
B.sum	2.004	2.056	2.006	1.992	2.207	2.200	2.102	2.030	2.117
A.Ca	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.129	0.094	0.163	0.138	0.000	0.000	0.000	0.000	0.000
A.K	0.141	0.139	0.197	0.159	0.000	0.000	0.000	0.000	0.000
A.sum	0.270	0.232	0.360	0.297	0.000	0.000	0.000	0.000	0.000
W.OH	1.722	1.948	1.858	1.853	2.000	2.000	2.000	2.000	2.000
W.F	0.135	0.000	0.000	0.000	0.201	0.066	0.009	0.112	0.000
W.Cl	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.O2-	0.142	0.050	0.142	0.147	0.000	0.000	0.000	0.000	0.000
W.sum	2.000	2.000	2.000	2.000	2.201	2.066	2.009	2.113	2.000
X_{Mg}	0.531	0.542	0.515	0.530	0.936	0.888	0.919	0.923	0.902
calc.tot.Fe^{3+}	0.356	0.379	0.431	0.429	0.059	0.052	0.147	0.019	0.180
calc.tot.Fe^{2+}	1.854	1.863	1.879	1.870	0.308	0.546	0.386	0.379	0.462
calc.Fe^{3+}/Fe_{tot}	0.161	0.169	0.186	0.187	0.162	0.088	0.276	0.047	0.280

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	029-04	029-04	029-04	029-04	029-04	029-04	029-07	029-07	029-07
Drillhole	A29	A29	A29	A29	A29	A29	A29	A29	A29
Depth (m)	48.25	48.25	48.25	48.25	48.25	48.25	55.9	55.9	55.9
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-2a	C1-5	C1-8a	C1-13a	C1-16a	C2-14a	C1-2	C1-3	C3-5
Mineral	cum	cum	cum	cum	cum	cum	act	act	act
SiO_2	55.03	56.39	55.41	55.98	55.86	55.02	58.14	56.05	54.20
TiO_2	0.09	0.05	0.07	0.02	0.01	0.04	0.03	0.03	0.11
Al_2O_3	0.66	0.69	0.55	0.65	0.57	1.44	0.99	1.97	4.67
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.04
V_2O_3	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.06
FeO_t	21.39	21.96	21.44	20.18	20.17	22.07	6.71	6.59	7.91
MnO	0.53	0.50	0.53	0.43	0.45	0.43	0.51	0.64	0.60
MgO	19.54	19.32	19.22	21.12	19.06	18.68	20.19	18.24	18.27
CaO	0.38	0.45	0.40	0.28	1.84	0.43	12.69	12.28	12.62
BaO	0.04	0.08	0.05	0.06	0.10	0.02	0.10	0.05	0.01
NiO	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.00
ZnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02
Na_2O	0.00	0.04	0.09	0.06	0.00	0.01	0.09	0.32	0.38
K_2O	0.05	0.01	0.01	0.02	0.01	0.02	0.06	0.08	0.25
F	0.41	0.34	0.22	0.16	0.09	0.18	0.20	0.14	0.61
Cl	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02
–O=F+Cl	0.17	0.14	0.09	0.07	0.04	0.08	0.09	0.06	0.26
Total (init)	98.29	100.07	98.09	99.04	98.21	98.42	99.79	96.54	100.03
H_2O (calc)	0.74	0.77	0.88	0.83	1.11	0.87	2.18	2.13	1.97
Total (calc)	99.03	100.84	98.97	99.87	99.32	99.29	101.97	98.66	102.00
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.822	7.921	7.871	7.849	7.909	7.809	7.996	7.891	7.535
T.Al	0.234	0.121	0.180	0.202	0.131	0.242	0.000	0.090	0.450
T.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.012
T.sum	8.056	8.042	8.051	8.051	8.040	8.051	7.999	7.985	7.997
C.Al	0.000	0.000	0.000	0.000	0.000	0.000	0.160	0.237	0.316
C.Ti	0.096	0.075	0.087	0.079	0.062	0.083	0.000	0.000	0.000
C.Fe3	1.645	1.585	1.608	1.633	1.417	1.580	0.174	0.175	0.262
C.Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.005
C.Ni	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.002	0.000
C.Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.002
C.Mn2	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.050	0.044
C.Mg	3.519	3.439	3.462	3.803	3.494	3.341	4.138	3.827	3.787
C.Fe2	0.000	0.000	0.000	0.000	0.070	0.000	0.584	0.716	0.642
C.sum	5.260	5.102	5.158	5.516	5.044	5.005	5.089	5.014	5.059
B.Mn2	0.064	0.059	0.064	0.051	0.054	0.052	0.027	0.026	0.027
B.Fe2	0.897	0.994	0.940	0.733	0.902	1.040	0.013	0.000	0.015
B.Mg	0.623	0.606	0.607	0.611	0.530	0.612	0.000	0.000	0.000
B.Ca	0.028	0.012	0.030	0.000	0.247	0.032	1.872	1.860	1.886
B.Na	0.000	0.037	0.059	0.000	0.000	0.033	0.159	0.302	0.101
B.sum	1.613	1.709	1.700	1.396	1.733	1.768	2.072	2.188	2.029
A.Ca	0.030	0.056	0.031	0.042	0.032	0.033	0.000	0.000	0.000
A.Na	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000
A.K	0.026	0.014	0.018	0.016	0.012	0.019	0.000	0.002	0.034
A.sum	0.056	0.070	0.049	0.073	0.044	0.052	0.000	0.002	0.035
W.OH	0.703	0.723	0.833	0.775	1.049	0.822	2.000	2.000	1.827
W.F	0.069	0.033	0.000	0.000	0.000	0.000	0.048	0.032	0.241
W.Cl	0.008	0.000	0.008	0.011	0.008	0.008	0.002	0.000	0.004
W.O2-	1.219	1.244	1.159	1.214	0.943	1.170	0.000	0.000	0.000
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.050	2.032	2.072
X_{Mg}	0.822	0.803	0.812	0.858	0.806	0.792	0.874	0.842	0.852
calc.tot.Fe^{3+}	1.645	1.585	1.608	1.633	1.417	1.580	0.174	0.175	0.262
calc.tot.Fe^{2+}	0.897	0.994	0.940	0.733	0.971	1.040	0.598	0.716	0.657
calc.Fe^{3+}/Fe_{tot}	0.647	0.614	0.631	0.690	0.593	0.603	0.226	0.196	0.285

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	029-07	004-15	004-15	004-15	004-15	029-20	029-20	029-27	033-17b
Drillhole	A29	A04	A04	A04	A04	A29	A29	A29	A33
Depth (m)	55.9	164.05	164.05	164.05	164.05	110.1	110.1	147.7	162.1
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C4-9	C1-4	C2-3	C3-7	C3-8	C1-2	C3-2	C4-1	C1-3
Mineral	act	mag-hbl	mag-hbl	act	act	act	mag-hbl	pgs	mag-hbl
SiO_2	53.80	45.67	48.36	53.20	53.49	55.18	53.30	42.07	47.75
TiO_2	0.09	0.31	0.17	0.04	0.01	0.02	0.24	0.06	0.21
Al_2O_3	3.69	9.52	7.03	2.84	3.06	1.57	5.06	14.94	8.28
Cr_2O_3	0.02	0.03	0.00	0.00	0.00	0.01	0.01	0.03	0.14
V_2O_3	0.00	0.02	0.05	0.02	0.01	0.00	0.00	0.00	0.00
FeO_t	8.41	15.74	16.49	14.73	15.83	13.11	6.65	11.69	9.80
MnO	0.54	0.53	0.79	0.77	0.80	0.88	0.37	0.86	1.00
MgO	18.91	12.42	12.83	14.70	14.48	15.78	20.05	12.84	17.33
CaO	11.92	12.28	11.62	11.95	12.20	12.58	12.82	11.89	12.11
BaO	0.07	0.07	0.03	0.00	0.00	0.00	0.06	0.07	0.07
NiO	0.05	0.00	0.00	0.01	0.00	0.00	0.03	0.03	0.02
ZnO	0.05	0.08	0.04	0.00	0.00	0.02	0.06	0.00	0.00
Na_2O	0.20	0.38	0.33	0.00	0.00	0.06	0.24	1.71	1.46
K_2O	0.17	0.83	0.47	0.02	0.01	0.02	0.29	0.54	0.29
F	0.19	0.12	0.00	0.00	0.01	0.00	0.05	0.43	0.15
Cl	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.03	0.01
–O=F+Cl	0.08	0.05	0.00	0.00	0.00	0.00	0.02	0.19	0.06
Total (init)	98.21	98.07	98.22	98.30	99.90	99.23	99.26	97.37	98.66
H_2O (calc)	2.10	1.88	1.98	2.10	2.11	2.12	2.16	1.77	1.99
Total (calc)	100.32	99.95	100.20	100.39	102.01	101.35	101.42	99.14	100.65
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.546	6.702	7.030	7.604	7.583	7.785	7.381	6.160	6.773
T.Al	0.453	1.319	0.991	0.400	0.416	0.202	0.612	1.894	1.258
T.Ti	0.007	0.000	0.000	0.000	0.001	0.002	0.017	0.000	0.000
T.sum	8.006	8.021	8.021	8.004	8.001	7.990	8.009	8.054	8.031
C.Al	0.157	0.328	0.214	0.079	0.095	0.059	0.215	0.684	0.125
C.Ti	0.003	0.061	0.046	0.007	0.000	0.000	0.009	0.069	0.057
C.Fe3	0.382	0.557	0.657	0.513	0.540	0.435	0.286	0.633	0.691
C.Cr	0.002	0.003	0.000	0.000	0.000	0.001	0.001	0.004	0.016
C.Ni	0.006	0.000	0.000	0.001	0.000	0.000	0.004	0.004	0.003
C.Zn	0.005	0.009	0.004	0.000	0.000	0.002	0.006	0.000	0.000
C.Mn2	0.033	0.045	0.068	0.063	0.067	0.076	0.016	0.081	0.087
C.Mg	3.940	2.667	2.709	3.089	3.012	3.318	4.139	2.768	3.632
C.Fe2	0.527	1.318	1.289	1.264	1.334	1.188	0.367	0.743	0.394
C.sum	5.054	4.987	4.986	5.016	5.047	5.079	5.044	4.986	5.004
B.Mn2	0.031	0.021	0.029	0.030	0.029	0.029	0.027	0.025	0.033
B.Fe2	0.078	0.058	0.059	0.000	0.003	0.000	0.117	0.055	0.078
B.Mg	0.014	0.051	0.071	0.043	0.048	0.000	0.000	0.035	0.031
B.Ca	1.798	1.936	1.818	1.840	1.861	1.910	1.912	1.865	1.849
B.Na	0.057	0.000	0.000	0.000	0.000	0.132	0.000	0.005	0.000
B.sum	1.977	2.066	1.978	1.914	1.942	2.071	2.056	1.986	1.991
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.000	0.107	0.094	0.000	0.000	0.000	0.064	0.479	0.402
A.K	0.022	0.160	0.091	0.000	0.000	0.000	0.040	0.107	0.053
A.sum	0.022	0.267	0.185	0.000	0.000	0.000	0.104	0.587	0.455
W.OH	1.969	1.841	1.917	2.000	2.000	2.000	2.000	1.728	1.888
W.F	0.052	0.041	0.000	0.000	0.000	0.000	0.000	0.188	0.041
W.Cl	0.005	0.004	0.004	0.004	0.001	0.000	0.000	0.007	0.001
W.O2-	0.000	0.114	0.079	0.000	0.000	0.000	0.000	0.077	0.070
W.sum	2.026	2.000	2.000	2.004	2.001	2.000	2.000	2.000	2.000
X_{Mg}	0.867	0.664	0.673	0.712	0.696	0.736	0.895	0.778	0.886
calc.tot.Fe^{3+}	0.382	0.557	0.657	0.513	0.540	0.435	0.286	0.633	0.691
calc.tot.Fe^{2+}	0.604	1.376	1.348	1.264	1.337	1.188	0.484	0.799	0.472
calc.Fe^{3+}/Fe_{tot}	0.387	0.288	0.328	0.289	0.288	0.268	0.371	0.442	0.594

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	033-17b	033-17b	033-17b	033-04b	033-04b	033-04b	033-04b	033-04b	033-04b
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	162.1	162.1	162.1	55.75	55.75	55.75	55.75	55.75	55.75
Host Rock	marble	marble	marble	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C2-2	C3-2	C5-2	C1-3	C1-4	C2-2	C3-1	C3-2	C3-3
Mineral	mag-hbl	act	mag-hbl	mag-hbl	act	mag-hbl	cum	cum	cum
SiO_2	49.04	53.79	51.88	50.10	52.63	50.76	51.67	51.08	52.76
TiO_2	0.06	0.03	0.07	0.08	0.01	0.05	0.01	0.00	0.00
Al_2O_3	6.42	1.40	2.13	2.94	1.21	2.28	0.25	0.24	0.26
Cr_2O_3	0.00	0.09	0.01	0.05	0.00	0.00	0.00	0.08	0.04
V_2O_3	0.00	0.04	0.07	0.04	0.00	0.00	0.01	0.00	0.04
FeO_t	12.00	14.75	15.91	21.40	20.80	20.24	32.99	32.97	33.06
MnO	1.62	2.45	2.51	0.92	0.77	0.92	1.27	1.24	1.25
MgO	15.80	14.83	13.94	9.71	10.74	11.10	10.63	10.83	10.32
CaO	11.86	11.29	11.14	11.75	11.51	11.59	0.59	0.69	0.93
BaO	0.00	0.04	0.08	0.01	0.00	0.00	0.06	0.00	0.00
NiO	0.03	0.02	0.00	0.00	0.00	0.01	0.05	0.03	0.01
ZnO	0.00	0.05	0.09	0.00	0.00	0.06	0.05	0.06	0.07
Na_2O	1.01	0.32	0.48	0.10	0.04	0.04	0.00	0.00	0.04
K_2O	0.30	0.04	0.04	0.22	0.04	0.17	0.02	0.01	0.02
F	0.00	0.00	0.00	0.00	0.03	0.52	0.05	0.18	0.00
Cl	0.02	0.00	0.00	0.03	0.00	0.02	0.01	0.01	0.01
–O=F+Cl	0.00	0.00	0.00	0.01	0.01	0.22	0.02	0.08	0.00
Total (init)	98.17	99.12	98.35	97.36	97.79	97.99	97.68	97.49	98.80
H_2O (calc)	2.10	2.11	2.08	2.02	2.04	1.83	0.97	0.90	1.04
Total (calc)	100.27	101.23	100.43	99.38	99.83	99.81	98.65	98.39	99.84
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.004	7.645	7.467	7.441	7.719	7.498	7.715	7.657	7.803
T.Al	1.031	0.376	0.570	0.572	0.284	0.520	0.357	0.420	0.255
T.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	8.034	8.021	8.037	8.013	8.003	8.018	8.072	8.077	8.058
C.Al	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Ti	0.050	0.039	0.064	0.031	0.007	0.035	0.118	0.000	0.000
C.Fe3	0.890	1.088	1.197	0.670	0.591	0.702	1.970	1.987	1.877
C.Cr	0.000	0.010	0.001	0.006	0.000	0.000	0.000	0.010	0.004
C.Ni	0.004	0.002	0.000	0.000	0.000	0.001	0.006	0.003	0.002
C.Zn	0.000	0.005	0.010	0.000	0.000	0.006	0.006	0.007	0.007
C.Mn2	0.153	0.236	0.243	0.088	0.069	0.082	0.076	0.073	0.077
C.Mg	3.322	3.071	2.911	2.122	2.309	2.382	1.773	1.814	1.700
C.Fe2	0.538	0.742	0.791	2.072	2.047	1.853	1.224	1.205	1.344
C.sum	5.006	5.194	5.217	4.987	5.023	5.061	5.172	5.099	5.011
B.Mn2	0.044	0.059	0.063	0.028	0.027	0.033	0.084	0.085	0.080
B.Fe2	0.006	0.000	0.000	0.000	0.000	0.000	0.925	0.941	0.868
B.Mg	0.041	0.070	0.080	0.029	0.040	0.063	0.594	0.606	0.574
B.Ca	1.819	1.716	1.719	1.884	1.826	1.848	0.158	0.179	0.190
B.Na	0.059	0.195	0.172	0.126	0.177	0.093	0.000	0.000	0.158
B.sum	1.969	2.041	2.035	2.066	2.069	2.038	1.762	1.811	1.870
A.Ca	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.220	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.K	0.060	0.013	0.018	0.049	0.010	0.040	0.037	0.036	0.032
A.sum	0.281	0.016	0.018	0.049	0.010	0.040	0.037	0.036	0.032
W.OH	2.000	2.000	2.000	2.000	2.000	1.800	0.963	0.900	1.025
W.F	0.000	0.000	0.000	0.000	0.000	0.210	0.000	0.000	0.000
W.Cl	0.004	0.002	0.000	0.005	0.000	0.003	0.008	0.010	0.009
W.O2-	0.000	0.000	0.000	0.000	0.000	0.000	1.028	1.090	0.966
W.sum	2.004	2.002	2.000	2.005	2.000	2.013	2.000	2.000	2.000
X_{Mg}	0.861	0.809	0.791	0.509	0.534	0.569	0.524	0.530	0.507
calc.tot.Fe^{3+}	0.890	1.088	1.197	0.670	0.591	0.702	1.970	1.987	1.877
calc.tot.Fe^{2+}	0.544	0.742	0.791	2.072	2.047	1.853	2.149	2.146	2.212
calc.Fe^{3+}/Fe_{tot}	0.621	0.595	0.602	0.244	0.224	0.275	0.478	0.481	0.459

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	033-04b	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-19
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	55.75	106.5	106.5	106.5	106.5	106.5	106.5	106.5	177
Host Rock	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C4-1	C2-1	C2-2	C3-1	C3-2	C4-1	C6-2	C6-3	C3-6
Mineral	cum	gru	ferro-act	gru	ferro-act	gru	gru	ferro-act	pgs
SiO_2	52.11	49.71	51.47	50.60	49.81	48.70	49.45	51.12	42.85
TiO_2	0.00	0.02	0.09	0.06	0.07	0.07	0.00	0.04	0.18
Al_2O_3	0.18	0.42	0.90	0.37	0.34	0.43	0.30	1.22	15.29
Cr_2O_3	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.08
V_2O_3	0.03	0.01	0.00	0.01	0.00	0.00	0.02	0.09	0.00
FeO_t	34.04	35.50	23.97	35.98	25.42	35.60	35.59	24.27	8.95
MnO	1.07	1.31	0.54	1.29	0.39	1.30	1.27	0.49	0.73
MgO	10.37	8.22	8.66	7.87	7.62	8.31	8.34	8.69	15.43
CaO	0.27	1.01	11.83	0.91	12.12	1.11	0.70	11.54	12.13
BaO	0.00	0.00	0.03	0.01	0.02	0.00	0.00	0.04	0.06
NiO	0.05	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01
ZnO	0.07	0.10	0.10	0.01	0.00	0.00	0.06	0.00	0.00
Na_2O	0.05	0.06	0.03	0.00	0.00	0.02	0.00	0.03	2.37
K_2O	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.27
F	0.17	0.00	0.18	0.00	0.00	0.00	0.06	0.11	0.47
Cl	0.00	0.01	0.00	0.02	0.02	0.01	0.01	0.02	0.02
–O=F+Cl	0.07	0.00	0.07	0.00	0.00	0.00	0.03	0.05	0.20
Total (init)	98.49	96.45	97.89	97.16	95.81	95.56	95.81	97.76	99.04
H_2O (calc)	0.87	1.04	2.01	1.02	1.96	1.01	0.99	2.01	1.75
Total (calc)	99.36	97.49	99.89	98.18	97.78	96.57	96.80	99.76	100.79
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.759	7.599	7.676	7.684	7.597	7.511	7.594	7.634	6.102
T.Al	0.307	0.482	0.329	0.389	0.419	0.581	0.493	0.373	1.949
T.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	8.066	8.081	8.004	8.073	8.016	8.092	8.087	8.007	8.051
C.Al	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.618
C.Ti	0.000	0.130	0.020	0.125	0.029	0.148	0.136	0.017	0.074
C.Fe3	1.934	1.992	0.559	1.956	0.566	2.046	2.026	0.578	0.586
C.Cr	0.001	0.007	0.000	0.000	0.000	0.000	0.000	0.005	0.009
C.Ni	0.006	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.001
C.Zn	0.007	0.011	0.011	0.001	0.000	0.000	0.006	0.000	0.000
C.Mn2	0.054	0.086	0.049	0.085	0.035	0.084	0.080	0.042	0.065
C.Mg	1.690	1.340	1.915	1.251	1.734	1.377	1.364	1.904	3.261
C.Fe2	1.345	1.636	2.533	1.714	2.788	1.600	1.595	2.515	0.366
C.sum	5.038	5.202	5.087	5.133	5.153	5.255	5.207	5.062	4.979
B.Mn2	0.080	0.083	0.019	0.081	0.014	0.086	0.085	0.019	0.023
B.Fe2	0.960	0.911	0.000	0.899	0.000	0.946	0.949	0.000	0.114
B.Mg	0.612	0.533	0.011	0.531	0.000	0.533	0.545	0.030	0.015
B.Ca	0.103	0.267	1.909	0.239	2.000	0.298	0.228	1.867	1.859
B.Na	0.121	0.131	0.152	0.000	0.000	0.083	0.000	0.131	0.000
B.sum	1.876	1.925	2.092	1.751	2.014	1.946	1.807	2.047	2.011
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.654
A.K	0.000	0.041	0.007	0.038	0.000	0.042	0.043	0.008	0.050
A.sum	0.000	0.041	0.007	0.038	0.000	0.042	0.043	0.008	0.704
W.OH	0.864	1.059	2.000	1.038	2.000	1.041	1.011	2.000	1.661
W.F	0.000	0.000	0.062	0.000	0.000	0.000	0.000	0.032	0.204
W.Cl	0.000	0.009	0.000	0.010	0.001	0.008	0.007	0.004	0.005
W.O2-	1.136	0.931	0.000	0.952	0.000	0.951	0.982	0.000	0.130
W.sum	2.000	2.000	2.062	2.000	2.001	2.000	2.000	2.036	2.000
X_{Mg}	0.500	0.424	0.432	0.405	0.383	0.429	0.429	0.435	0.872
calc.tot.Fe^{3+}	1.934	1.992	0.559	1.956	0.566	2.046	2.026	0.578	0.586
calc.tot.Fe^{2+}	2.305	2.546	2.533	2.613	2.788	2.546	2.544	2.515	0.480
calc.Fe^{3+}/Fe_{tot}	0.456	0.439	0.181	0.428	0.169	0.446	0.443	0.187	0.550

Notes:
met = metamorphic; hyd = hydrothermal; "---" = not determined
act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	033-19	033-20	033-20	033-20	033-20	033-20	033-20	009-03f	009-03f
Drillhole	A33	A33	A33	A33	A33	A33	A33	A09	A09
Depth (m)	177	188.5	188.5	188.5	188.5	188.5	188.5	71.55	71.55
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C4-2	C1-5	C2-5	C3-1	C3-1b	C3-2	C4-2	C2-8	C3-1
Mineral	pgs	mag-hst	mag-hst	mag-hst	mag-hst	mag-hst	mag-hst	tre	tre
SiO_2	42.32	42.19	39.92	37.46	41.01	40.59	45.10	56.25	55.77
TiO_2	0.11	0.05	0.06	0.05	0.08	0.09	0.12	0.12	0.04
Al_2O_3	16.12	13.04	13.91	12.69	12.61	13.71	7.79	1.89	1.41
Cr_2O_3	0.05	0.00	0.00	0.02	0.00	0.00	0.02	---	---
V_2O_3	0.03	0.05	0.04	0.03	0.00	0.03	0.06	---	---
FeO_t	9.12	11.74	12.90	13.74	14.23	14.79	9.24	4.63	4.21
MnO	0.72	0.67	0.83	1.05	1.19	1.02	0.92	0.45	0.40
MgO	15.09	15.12	13.35	12.79	13.25	12.19	18.20	22.10	22.02
CaO	12.07	11.63	11.54	11.38	11.49	11.21	11.20	12.71	13.06
BaO	0.04	0.00	0.01	0.00	0.00	0.03	0.00	---	---
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	---	---
ZnO	0.07	0.00	0.00	0.09	0.07	0.06	0.00	---	---
Na_2O	2.40	2.74	2.88	2.81	2.72	3.03	2.37	0.30	0.24
K_2O	0.21	0.16	0.20	0.22	0.18	0.17	0.14	0.11	0.09
F	0.34	0.10	0.06	0.00	0.40	0.08	0.01	---	---
Cl	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01
–O=F+Cl	0.15	0.04	0.03	0.00	0.17	0.03	0.01	0.00	0.00
Total (init)	98.85	97.53	95.73	92.31	97.40	97.02	95.19	98.56	97.23
H_2O (calc)	1.81	1.90	1.91	1.92	1.72	1.88	2.03	2.18	2.16
Total (calc)	100.66	99.43	97.63	94.23	99.12	98.90	97.22	100.74	99.39
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	6.030	6.130	5.959	5.844	6.075	6.030	6.568	7.737	7.741
T.Al	2.026	1.935	2.121	2.265	2.004	2.044	1.496	0.247	0.249
T.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.004
T.sum	8.056	8.065	8.081	8.110	8.080	8.074	8.065	7.997	7.993
C.Al	0.682	0.297	0.326	0.067	0.198	0.355	0.000	0.060	0.000
C.Ti	0.071	0.074	0.095	0.131	0.102	0.094	0.083	0.000	0.000
C.Fe3	0.597	0.769	0.851	1.050	0.994	0.912	0.882	0.266	0.233
C.Cr	0.006	0.000	0.000	0.003	0.000	0.000	0.003	0.000	0.000
C.Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Zn	0.007	0.000	0.000	0.010	0.008	0.007	0.000	0.000	0.000
C.Mn2	0.065	0.058	0.079	0.101	0.114	0.100	0.077	0.022	0.018
C.Mg	3.190	3.221	2.913	2.872	2.851	2.646	3.875	4.532	4.556
C.Fe2	0.364	0.542	0.693	0.702	0.698	0.859	0.163	0.171	0.227
C.sum	4.982	4.961	4.956	4.936	4.965	4.973	5.082	5.052	5.035
B.Mn2	0.022	0.024	0.026	0.038	0.036	0.028	0.037	0.030	0.029
B.Fe2	0.127	0.116	0.067	0.041	0.070	0.065	0.081	0.094	0.028
B.Mg	0.016	0.053	0.059	0.101	0.076	0.054	0.077	0.000	0.000
B.Ca	1.850	1.818	1.845	1.885	1.825	1.785	1.761	1.880	1.955
B.Na	0.000	0.000	0.008	0.000	0.000	0.067	0.024	0.052	0.058
B.sum	2.015	2.011	2.005	2.065	2.006	1.999	1.978	2.056	2.070
A.Ca	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000
A.Na	0.664	0.771	0.824	0.849	0.781	0.805	0.645	0.028	0.005
A.K	0.040	0.035	0.049	0.064	0.046	0.044	0.034	0.001	0.000
A.sum	0.704	0.806	0.873	0.929	0.828	0.849	0.679	0.029	0.005
W.OH	1.718	1.840	1.903	1.996	1.700	1.869	1.973	2.000	2.000
W.F	0.144	0.041	0.034	0.000	0.173	0.033	0.000	0.000	0.000
W.Cl	0.003	0.003	0.002	0.000	0.001	0.000	0.000	0.000	0.000
W.O2-	0.135	0.116	0.062	0.004	0.126	0.098	0.027	0.000	0.000
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.867	0.833	0.797	0.800	0.792	0.745	0.942	0.945	0.947
calc.tot.Fe^{3+}	0.597	0.769	0.851	1.050	0.994	0.912	0.882	0.266	0.233
calc.tot.Fe^{2+}	0.490	0.658	0.759	0.743	0.768	0.925	0.244	0.266	0.255
calc.Fe^{3+}/Fe_{tot}	0.549	0.539	0.529	0.586	0.564	0.496	0.783	0.500	0.478

Notes:
met = metamorphic; hyd = hydrothermal; "---" = not determined
act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	009-03f	009-03f	028-18	028-18	028-18	028-18	028-18	028-18	028-18
Drillhole	A09	A09	A28	A28	A28	A28	A28	A28	A28
Depth (m)	71.55	71.55	206.6	206.6	206.6	206.6	206.6	206.6	206.6
Host Rock	marble	marble	BIF	BIF	BIF	BIF	BIF	BIF	BIF
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C3-4	C3-5	C1-1	C1-2	C1-3	C1-4	C1-8	C1-9	C2-1
Mineral	tre	tre	ferro-act	ferro-act	gru	ferro-act	gru	ferro-act	ferro-act
SiO_2	54.22	55.68	51.86	50.62	51.28	52.22	51.35	51.11	51.64
TiO_2	0.09	0.07	0.01	0.03	0.00	0.00	0.06	0.02	0.00
Al_2O_3	2.24	1.81	0.04	2.09	0.42	0.90	0.18	2.19	1.65
Cr_2O_3	---	---	---	---	---	---	---	---	---
V_2O_3	---	---	---	---	---	---	---	---	---
FeO_t	4.59	4.46	28.85	26.85	35.12	24.78	35.48	25.00	24.02
MnO	0.43	0.47	1.88	0.78	1.79	0.67	1.86	0.54	0.58
MgO	22.07	21.71	3.77	7.41	8.22	8.36	8.53	8.02	8.96
CaO	12.45	12.86	11.30	8.77	1.70	10.57	0.84	10.32	10.25
BaO	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---
ZnO	---	---	---	---	---	---	---	---	---
Na_2O	0.24	0.23	0.20	1.22	0.18	0.67	0.11	0.99	0.89
K_2O	0.21	0.10	0.04	0.07	0.00	0.04	0.00	0.08	0.07
F	---	---	---	---	---	---	---	---	---
Cl	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
–O=F+Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (init)	96.55	97.41	97.96	97.84	98.70	98.21	98.42	98.27	98.07
H_2O (calc)	2.14	2.16	1.98	1.94	1.10	2.02	1.01	2.02	2.02
Total (calc)	98.69	99.57	99.95	99.78	99.80	100.23	99.43	100.28	100.09
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.575	7.723	7.836	7.578	7.678	7.741	7.697	7.596	7.647
T.Al	0.427	0.267	0.169	0.435	0.391	0.257	0.377	0.405	0.355
T.Ti	0.008	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	8.010	7.997	8.005	8.012	8.069	7.998	8.074	8.000	8.001
C.Al	0.000	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Ti	0.002	0.000	0.024	0.027	0.000	0.000	0.131	0.007	0.006
C.Fe3	0.354	0.257	0.907	0.868	2.035	0.650	2.139	0.641	0.658
C.Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Mn2	0.018	0.026	0.198	0.071	0.139	0.063	0.142	0.050	0.052
C.Mg	4.597	4.489	0.850	1.567	1.320	1.813	1.347	1.741	1.927
C.Fe2	0.093	0.221	2.989	2.431	1.572	2.495	1.441	2.506	2.350
C.sum	5.064	5.021	4.969	4.963	5.065	5.021	5.200	4.945	4.992
B.Mn2	0.032	0.030	0.042	0.027	0.088	0.021	0.094	0.018	0.020
B.Fe2	0.089	0.040	0.000	0.062	0.790	0.000	0.867	0.000	0.000
B.Mg	0.000	0.000	0.000	0.087	0.515	0.035	0.560	0.036	0.052
B.Ca	1.874	1.922	1.847	1.438	0.331	1.701	0.200	1.667	1.649
B.Na	0.010	0.068	0.415	0.355	0.172	0.298	0.168	0.302	0.291
B.sum	2.006	2.060	2.304	1.970	1.896	2.054	1.889	2.022	2.013
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.K	0.027	0.002	0.022	0.024	0.000	0.012	0.037	0.020	0.017
A.sum	0.083	0.002	0.022	0.024	0.000	0.012	0.037	0.020	0.017
W.OH	2.000	2.000	2.000	1.936	1.098	2.000	1.011	2.000	2.000
W.F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.Cl	0.000	0.000	0.001	0.000	0.000	0.000	0.009	0.000	0.000
W.O2-	0.000	0.000	0.000	0.064	0.902	0.000	0.980	0.000	0.000
W.sum	2.000	2.000	2.001	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.962	0.945	0.221	0.399	0.437	0.425	0.452	0.415	0.457
calc.tot.Fe^{3+}	0.354	0.257	0.907	0.868	2.035	0.650	2.139	0.641	0.658
calc.tot.Fe^{2+}	0.182	0.261	2.989	2.493	2.362	2.495	2.308	2.506	2.350
calc.Fe^{3+}/Fe_{tot}	0.661	0.496	0.233	0.258	0.463	0.207	0.481	0.204	0.219

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	028-18	028-18	028-18	009-16	009-16	009-16	009-16	009-16	028-06a
Drillhole	A28	A28	A28	A09	A09	A09	A09	A09	A28
Depth (m)	206.6	206.6	206.6	179.35	179.35	179.35	179.35	179.35	64.5
Host Rock	BIF	BIF	BIF	marble	marble	BIF	BIF	BIF	qz-cpx vein
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C2-2	C2-6	C2-7	C2-2	C2-8	C3-2	C3-4	C3-6	C1-1
Mineral	gru	cum	ferro-act	act	act	act	act	act	act
SiO_2	51.76	51.13	51.87	56.35	54.65	53.30	52.96	53.41	53.46
TiO_2	0.00	0.00	0.02	0.00	0.02	0.03	0.00	0.03	0.00
Al_2O_3	0.13	0.39	1.82	0.60	0.78	0.56	1.07	0.66	0.20
Cr_2O_3	---	---	---	---	---	---	---	---	---
V_2O_3	---	---	---	---	---	---	---	---	---
FeO_t	34.64	31.29	23.50	10.43	9.80	22.05	22.43	21.78	20.46
MnO	2.26	3.01	0.61	0.22	0.22	0.33	0.41	0.42	0.99
MgO	8.62	9.06	9.27	19.00	19.68	10.68	10.67	10.54	10.99
CaO	0.90	1.78	10.25	12.40	12.66	11.76	11.38	11.66	12.19
BaO	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---
ZnO	---	---	---	---	---	---	---	---	---
Na_2O	0.11	0.29	0.95	0.09	0.19	0.09	0.17	0.18	0.11
K_2O	0.00	0.01	0.06	0.06	0.00	0.00	0.04	0.00	0.00
F	---	---	---	---	---	---	---	---	---
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
–O=F+Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (init)	98.41	96.95	98.36	99.13	97.99	98.80	99.13	98.68	98.40
H_2O (calc)	1.06	1.24	2.03	2.15	2.13	2.05	2.05	2.05	2.05
Total (calc)	99.47	98.20	100.39	101.28	100.11	100.85	101.18	100.73	100.45
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.729	7.659	7.647	7.925	7.809	7.968	7.967	7.802	7.801
T.Al	0.347	0.428	0.353	0.040	0.158	0.000	0.000	0.188	0.197
T.Ti	0.000	0.000	0.000	0.000	0.002	0.004	0.000	0.004	0.000
T.sum	8.076	8.087	8.000	7.964	7.969	7.971	7.967	7.993	7.997
C.Al	0.000	0.000	0.000	0.059	0.000	0.098	0.189	0.000	0.000
C.Ti	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000
C.Fe3	2.216	2.309	0.655	0.100	0.000	0.000	0.000	0.471	0.601
C.Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Mn2	0.184	0.266	0.055	0.006	0.009	0.038	0.049	0.034	0.094
C.Mg	1.366	1.535	1.983	3.944	4.099	2.250	2.210	2.264	2.379
C.Fe2	1.297	0.962	2.276	1.099	1.155	2.916	3.048	2.278	2.058
C.sum	5.063	5.073	4.976	5.207	5.263	5.301	5.496	5.047	5.132
B.Mn2	0.101	0.115	0.021	0.021	0.018	0.004	0.003	0.018	0.028
B.Fe2	0.813	0.649	0.000	0.028	0.016	0.000	0.000	0.000	0.000
B.Mg	0.552	0.488	0.056	0.039	0.093	0.131	0.184	0.032	0.012
B.Ca	0.200	0.339	1.640	1.877	1.949	1.899	1.849	1.843	1.920
B.Na	0.215	0.300	0.298	0.000	0.000	0.000	0.000	0.184	0.193
B.sum	1.881	1.891	2.014	1.965	2.076	2.034	2.035	2.076	2.153
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.000	0.000	0.000	0.024	0.052	0.026	0.050	0.000	0.000
A.K	0.038	0.043	0.015	0.009	0.000	0.040	0.062	0.000	0.001
A.sum	0.038	0.043	0.015	0.033	0.052	0.065	0.112	0.000	0.001
W.OH	1.059	1.244	2.000	1.880	1.638	1.384	1.097	2.000	2.000
W.F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.Cl	0.010	0.008	0.000	0.260	0.521	0.783	1.046	0.000	0.001
W.O2-	0.931	0.748	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.sum	2.000	2.000	2.000	2.140	2.159	2.168	2.143	2.000	2.001
X_{Mg}	0.476	0.557	0.472	0.780	0.782	0.449	0.440	0.502	0.538
calc.tot.Fe^{3+}	2.216	2.309	0.655	0.100	0.000	0.000	0.000	0.471	0.601
calc.tot.Fe^{2+}	2.110	1.611	2.276	1.126	1.171	2.916	3.048	2.278	2.058
calc.Fe^{3+}/Fe_{tot}	0.512	0.589	0.224	0.082	0.000	0.000	0.000	0.171	0.226

Notes:
met = metamorphic; hyd = hydrothermal; "---" = not determined
act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	028-06a	028-06a	028-06a	028-06a	028-06a	028-06a	028-06a	028-06a	028-06a
Drillhole	A28	A28	A28	A28	A28	A28	A28	A28	A28
Depth (m)	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5
Host Rock	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-3	C1-5	C1-8	C1-9	C2-1	C2-2	C2-3	C2-4	C2-6
Mineral	act	act	act	cum	act	cum	act	cum	act
SiO_2	53.30	52.91	54.06	52.33	52.86	52.40	52.19	52.48	52.90
TiO_2	0.03	0.00	0.07	0.05	0.10	0.03	0.12	0.04	0.14
Al_2O_3	0.14	0.38	0.48	0.11	1.98	0.29	2.25	0.20	1.87
Cr_2O_3	---	---	---	---	---	---	---	---	---
V_2O_3	---	---	---	---	---	---	---	---	---
FeO_t	21.36	20.96	19.75	29.47	20.01	30.82	19.50	30.70	19.17
MnO	1.12	1.09	0.75	1.74	0.75	2.25	0.78	2.43	0.81
MgO	10.44	10.40	12.24	13.10	11.80	11.79	11.32	11.74	12.04
CaO	11.80	11.76	11.66	0.65	11.36	0.86	11.44	0.81	11.38
BaO	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---
ZnO	---	---	---	---	---	---	---	---	---
Na_2O	0.00	0.00	0.01	0.00	0.02	0.05	0.04	0.00	0.00
K_2O	0.01	0.02	0.01	0.01	0.04	0.00	0.06	0.00	0.05
F	---	---	---	---	---	---	---	---	---
Cl	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.02
–O=F+Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (init)	98.20	97.53	99.04	97.47	98.92	98.49	97.71	98.41	98.37
H_2O (calc)	2.05	2.04	2.07	1.00	2.07	1.02	2.05	1.03	2.06
Total (calc)	100.24	99.56	101.11	98.47	100.98	99.51	99.76	99.44	100.44
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.807	7.781	7.813	7.706	7.660	7.703	7.629	7.714	7.676
T.Al	0.194	0.224	0.181	0.373	0.341	0.376	0.376	0.368	0.326
T.Ti	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	8.001	8.004	7.998	8.079	8.001	8.079	8.005	8.081	8.002
C.Al	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000
C.Ti	0.011	0.000	0.003	0.131	0.015	0.133	0.022	0.137	0.020
C.Fe3	0.676	0.661	0.574	2.100	0.611	2.224	0.582	2.275	0.599
C.Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Mn2	0.107	0.104	0.064	0.121	0.064	0.176	0.069	0.196	0.070
C.Mg	2.252	2.259	2.581	2.259	2.477	1.983	2.418	1.971	2.540
C.Fe2	2.082	2.065	1.873	0.625	1.826	0.716	1.859	0.660	1.759
C.sum	5.127	5.089	5.096	5.236	4.993	5.231	4.961	5.238	4.989
B.Mn2	0.032	0.032	0.027	0.097	0.028	0.103	0.028	0.107	0.029
B.Fe2	0.000	0.000	0.000	0.904	0.000	0.849	0.000	0.839	0.000
B.Mg	0.027	0.021	0.056	0.616	0.072	0.600	0.049	0.601	0.064
B.Ca	1.866	1.869	1.818	0.137	1.775	0.162	1.806	0.153	1.782
B.Na	0.000	0.000	0.142	0.000	0.114	0.139	0.154	0.000	0.000
B.sum	1.926	1.922	2.043	1.754	1.990	1.853	2.036	1.700	1.876
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.K	0.005	0.007	0.000	0.035	0.008	0.000	0.012	0.037	0.010
A.sum	0.005	0.007	0.000	0.035	0.008	0.000	0.012	0.037	0.010
W.OH	2.000	2.000	2.000	0.984	2.000	1.003	2.000	1.007	2.000
W.F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.Cl	0.001	0.002	0.000	0.009	0.001	0.011	0.003	0.013	0.004
W.O2-	0.000	0.000	0.000	1.007	0.000	0.986	0.000	0.980	0.000
W.sum	2.001	2.002	2.000	2.000	2.001	2.000	2.003	2.000	2.004
X_{Mg}	0.523	0.525	0.585	0.653	0.583	0.623	0.570	0.632	0.597
calc.tot.Fe^{3+}	0.676	0.661	0.574	2.100	0.611	2.224	0.582	2.275	0.599
calc.tot.Fe^{2+}	2.082	2.065	1.873	1.529	1.826	1.565	1.859	1.499	1.759
calc.Fe^{3+}/Fe_{tot}	0.245	0.242	0.234	0.579	0.251	0.587	0.238	0.603	0.254

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	028-06a	028-06a	028-06a	029-30	029-30	029-30	029-30	029-30	033-11
Drillhole	A28	A28	A28	A29	A29	A29	A29	A29	A33
Depth (m)	64.5	64.5	64.5	167.8	167.8	167.8	167.8	167.8	99.2
Host Rock	qz-cpx vein	qz-cpx vein	qz-cpx vein	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C2-7	C2-9	C2-10	C1-1	C1-3	C1-5	C2-5	C3-1	C2-1
Mineral	cum	cum	act	cum	tre	mag-hbl	mag-hbl	mag-hst	act
SiO_2	52.57	52.51	53.19	55.17	57.43	49.88	50.18	48.75	51.43
TiO_2	0.05	0.07	0.13	0.03	0.07	0.18	0.15	0.25	0.20
Al_2O_3	0.28	0.28	1.81	0.22	1.05	6.56	6.49	7.95	3.27
Cr_2O_3	---	---	---	---	---	---	---	---	0.00
V_2O_3	---	---	---	---	---	---	---	---	0.00
FeO_t	30.82	29.83	18.85	11.88	5.03	9.18	9.58	10.38	19.69
MnO	2.25	2.28	0.77	3.71	0.96	0.91	1.04	0.88	0.47
MgO	11.76	11.93	12.24	24.03	21.65	18.48	18.16	17.54	11.32
CaO	1.27	0.91	11.77	1.10	11.27	10.30	10.62	10.45	11.77
BaO	---	---	---	---	---	---	---	---	0.03
NiO	---	---	---	---	---	---	---	---	0.01
ZnO	---	---	---	---	---	---	---	---	0.08
Na_2O	0.00	0.06	0.00	0.09	0.81	2.52	2.40	2.77	0.08
K_2O	0.00	0.01	0.05	0.00	0.02	0.06	0.06	0.07	0.08
F	---	---	---	---	---	---	---	---	0.03
Cl	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00
–O=F+Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total (init)	99.01	97.88	98.83	96.22	98.30	98.08	98.68	99.04	98.49
H_2O (calc)	1.04	1.07	2.07	1.18	2.18	2.08	2.10	2.03	2.05
Total (calc)	100.05	98.95	100.90	97.40	100.48	100.16	100.78	101.07	100.54
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.704	7.726	7.688	7.679	7.899	7.022	7.042	6.857	7.505
T.Al	0.372	0.352	0.309	0.428	0.087	1.004	0.981	1.170	0.498
T.Ti	0.000	0.000	0.001	0.000	0.008	0.000	0.000	0.000	0.000
T.sum	8.076	8.078	7.998	8.107	7.993	8.026	8.024	8.027	8.003
C.Al	0.000	0.000	0.000	0.000	0.084	0.084	0.093	0.148	0.065
C.Ti	0.130	0.136	0.013	0.163	0.000	0.043	0.039	0.052	0.027
C.Fe3	2.196	2.186	0.553	2.518	0.447	0.740	0.754	0.750	0.497
C.Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C.Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
C.Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
C.Mn2	0.178	0.180	0.066	0.308	0.074	0.075	0.090	0.075	0.038
C.Mg	1.981	2.033	2.587	4.462	4.439	3.843	3.773	3.641	2.414
C.Fe2	0.757	0.666	1.779	0.000	0.047	0.217	0.267	0.339	1.930
C.sum	5.243	5.200	4.998	7.451	5.090	5.002	5.016	5.005	4.980
B.Mn2	0.102	0.104	0.027	0.129	0.037	0.033	0.034	0.030	0.021
B.Fe2	0.824	0.819	0.000	0.000	0.085	0.124	0.104	0.132	0.000
B.Mg	0.588	0.585	0.051	0.523	0.000	0.036	0.027	0.037	0.048
B.Ca	0.220	0.172	1.835	0.080	1.651	1.556	1.598	1.578	1.855
B.Na	0.000	0.177	0.000	0.104	0.248	0.211	0.200	0.184	0.084
B.sum	1.733	1.856	1.913	0.836	2.022	1.960	1.962	1.961	2.008
A.Ca	0.000	0.000	0.000	0.084	0.009	0.000	0.000	0.000	0.000
A.Na	0.000	0.000	0.000	0.000	0.000	0.478	0.453	0.572	0.000
A.K	0.000	0.036	0.007	0.000	0.000	0.007	0.006	0.009	0.015
A.sum	0.000	0.036	0.007	0.084	0.009	0.484	0.459	0.581	0.015
W.OH	1.015	1.047	2.000	1.099	2.000	1.956	1.968	1.903	2.000
W.F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.Cl	0.011	0.009	0.004	0.000	0.001	0.000	0.001	0.001	0.000
W.O2-	0.974	0.943	0.000	0.901	0.000	0.044	0.032	0.096	0.000
W.sum	2.000	2.000	2.004	2.000	2.001	2.000	2.000	2.000	2.000
X_{Mg}	0.619	0.638	0.597	1.000	0.971	0.919	0.911	0.887	0.561
calc.tot.Fe^{3+}	2.196	2.186	0.553	2.518	0.447	0.740	0.754	0.750	0.497
calc.tot.Fe^{2+}	1.581	1.485	1.779	0.000	0.132	0.341	0.370	0.471	1.930
calc.Fe^{3+}/Fe_{tot}	0.581	0.595	0.237	1.000	0.773	0.684	0.671	0.614	0.205

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	033-11	HS-10	HS-10	HS-10	HS-10	011-01	011-01	011-01	011-01
Drillhole	A33	surface	surface	surface	surface	A11	A11	A11	A11
Depth (m)	99.2	n/a	n/a	n/a	n/a	183	183	183	183
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C2-2	C2-1	C2-2	C6-3	C6-4	C1-5	C2-2	C3-3	C4-5
Mineral	mag-hbl	act	act	mag-hbl	mag-hbl	tre	tre	act	act
SiO_2	50.16	52.43	53.77	50.15	52.01	56.31	56.85	54.66	53.70
TiO_2	0.24	0.02	0.04	0.07	0.00	0.01	0.00	0.00	0.06
Al_2O_3	5.43	2.68	0.99	5.04	3.04	0.61	0.07	0.75	1.90
Cr_2O_3	0.03	0.00	0.04	0.00	0.04	0.00	0.03	0.00	0.00
V_2O_3	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO_t	20.16	18.24	17.10	16.56	14.88	6.29	5.14	12.67	13.79
MnO	0.53	1.81	1.71	1.72	1.82	2.23	2.13	1.38	1.31
MgO	10.38	12.80	14.09	13.67	14.75	22.39	21.53	15.23	14.43
CaO	11.90	11.52	11.57	11.27	11.33	11.60	12.25	12.43	12.20
BaO	0.00	0.00	0.07	0.05	0.06	0.00	0.00	0.00	0.00
NiO	0.01	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.00
ZnO	0.11	0.06	0.00	0.05	0.00	0.00	0.08	0.04	0.05
Na_2O	0.18	0.28	0.15	0.47	0.44	0.02	0.05	0.05	0.06
K_2O	0.18	0.19	0.06	0.40	0.22	0.07	0.02	0.02	0.08
F	0.41	0.00	0.27	0.33	0.37	0.26	0.43	0.00	0.13
Cl	0.02	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00
–O=F+Cl	0.18	0.00	0.12	0.14	0.16	0.11	0.18	0.00	0.05
Total (init)	100.02	100.02	99.99	99.92	99.12	99.93	98.80	97.25	97.74
H_2O (calc)	1.81	2.09	2.00	1.83	1.94	2.04	2.15	2.09	2.09
Total (calc)	101.83	102.11	101.98	101.76	101.07	101.97	100.95	99.35	99.83
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.309	7.507	7.678	7.196	7.441	7.711	7.850	7.817	7.699
T.Al	0.695	0.507	0.333	0.830	0.581	0.309	0.161	0.184	0.305
T.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	8.004	8.014	8.011	8.026	8.022	8.020	8.010	8.001	8.004
C.Al	0.238	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.016
C.Ti	0.036	0.028	0.027	0.049	0.000	0.031	0.000	0.000	0.014
C.Fe3	0.495	0.951	0.900	0.985	0.943	1.031	0.819	0.576	0.595
C.Cr	0.004	0.000	0.005	0.000	0.005	0.000	0.003	0.000	0.000
C.Ni	0.001	0.000	0.000	0.000	0.000	0.001	0.004	0.001	0.000
C.Zn	0.012	0.006	0.000	0.005	0.000	0.000	0.008	0.004	0.005
C.Mn2	0.045	0.173	0.159	0.161	0.170	0.198	0.193	0.129	0.121
C.Mg	2.201	2.658	2.919	2.827	3.067	4.551	4.432	3.246	3.072
C.Fe2	1.972	1.276	1.189	0.968	0.863	0.000	0.000	1.108	1.189
C.sum	5.004	5.091	5.199	5.017	5.047	5.812	5.458	5.065	5.013
B.Mn2	0.020	0.046	0.047	0.048	0.050	0.061	0.056	0.038	0.037
B.Fe2	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.000	0.000
B.Mg	0.054	0.074	0.081	0.097	0.079	0.019	0.000	0.000	0.011
B.Ca	1.868	1.770	1.774	1.735	1.739	1.688	1.807	1.913	1.883
B.Na	0.052	0.122	0.114	0.049	0.124	0.007	0.131	0.219	0.188
B.sum	1.995	2.013	2.016	1.963	1.992	1.775	1.993	2.170	2.119
A.Ca	0.000	0.000	0.000	0.000	0.000	0.014	0.006	0.000	0.000
A.Na	0.000	0.000	0.000	0.082	0.000	0.000	0.000	0.000	0.000
A.K	0.033	0.039	0.014	0.082	0.046	0.010	0.000	0.002	0.013
A.sum	0.033	0.039	0.014	0.164	0.046	0.024	0.006	0.002	0.013
W.OH	1.761	2.000	1.903	1.756	1.854	1.864	1.981	2.000	2.000
W.F	0.160	0.000	0.067	0.100	0.113	0.038	0.126	0.000	0.016
W.Cl	0.003	0.000	0.003	0.005	0.004	0.003	0.000	0.000	0.000
W.O2-	0.076	0.000	0.027	0.140	0.030	0.094	0.000	0.000	0.000
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.107	2.000	2.016
X_{Mg}	0.534	0.682	0.716	0.745	0.785	1.000	1.000	0.746	0.722
calc.tot.Fe^{3+}	0.495	0.951	0.900	0.985	0.943	1.031	0.819	0.576	0.595
calc.tot.Fe^{2+}	1.972	1.276	1.189	1.002	0.863	0.000	0.000	1.108	1.189
calc.Fe^{3+}/Fe_{tot}	0.201	0.427	0.431	0.496	0.522	1.000	1.000	0.342	0.333

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	028-29	028-29	028-29	028-29	028-29	028-29	028-29	029-32	029-32
Drillhole	A28	A28	A28	A28	A28	A28	A28	A29	A29
Depth (m)	199.1	199.1	199.1	199.1	199.1	199.1	199.1	173.65	173.65
Host Rock	BIF	BIF	BIF	BIF	BIF	BIF	BIF	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-2	C1-3	C1-5	C2-3	C3-1	C3-2	C3-3	C1-1	C1-2
Mineral	ferro-act	act	ferro-act	act	ferro-act	gru	gru	tre	mag-hst
SiO_2	53.79	54.64	53.66	53.78	52.16	52.62	52.16	57.72	43.62
TiO_2	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Al_2O_3	0.57	0.65	1.06	0.68	1.42	0.11	0.21	0.36	12.79
Cr_2O_3	0.00	0.00	0.06	0.00	0.00	0.00	0.02	0.00	0.02
V_2O_3	0.00	0.03	0.00	0.00	0.04	0.00	0.10	0.03	0.00
FeO_t	23.84	18.93	21.94	19.04	23.44	34.42	33.55	3.99	10.15
MnO	0.81	0.63	0.83	0.74	0.83	1.81	2.00	0.46	0.54
MgO	9.15	12.11	9.91	11.60	9.10	9.23	8.91	22.32	15.25
CaO	10.42	11.01	10.59	10.78	9.99	0.81	0.89	12.74	11.63
BaO	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.01
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02
ZnO	0.02	0.02	0.03	0.11	0.07	0.10	0.10	0.03	0.05
Na_2O	0.43	0.56	0.59	0.56	0.66	0.02	0.14	0.25	2.54
K_2O	0.01	0.03	0.02	0.03	0.03	0.00	0.00	0.00	0.11
F	0.15	0.16	0.02	0.14	0.11	0.00	0.00	0.21	0.10
Cl	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.01
–O=F+Cl	0.06	0.07	0.01	0.06	0.05	0.00	0.00	0.09	0.04
Total (init)	99.27	98.86	98.81	97.53	97.91	99.12	98.10	98.23	97.01
H_2O (calc)	2.03	2.07	2.05	2.05	2.02	1.03	1.11	2.17	1.98
Total (calc)	101.30	100.93	100.86	99.58	99.94	100.16	99.21	100.40	98.99
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	7.871	7.889	7.829	7.849	7.715	7.799	7.783	7.952	6.306
T.Al	0.120	0.095	0.161	0.145	0.290	0.266	0.286	0.027	1.746
T.Ti	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	7.994	7.985	7.990	7.994	8.005	8.065	8.069	7.979	8.053
C.Al	0.000	0.015	0.022	0.000	0.000	0.000	0.000	0.031	0.433
C.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.117	0.000	0.067
C.Fe3	0.645	0.484	0.600	0.539	0.718	2.070	2.077	0.202	0.594
C.Cr	0.000	0.000	0.007	0.000	0.000	0.000	0.002	0.000	0.002
C.Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003
C.Zn	0.002	0.002	0.004	0.012	0.008	0.011	0.011	0.003	0.006
C.Mn2	0.074	0.054	0.077	0.065	0.076	0.136	0.158	0.023	0.046
C.Mg	1.932	2.566	2.107	2.488	1.942	1.468	1.443	4.585	3.262
C.Fe2	2.335	1.894	2.167	1.893	2.218	1.351	1.317	0.223	0.558
C.sum	4.989	5.015	4.984	4.998	4.962	5.036	5.126	5.071	4.970
B.Mn2	0.026	0.023	0.025	0.026	0.028	0.091	0.095	0.031	0.020
B.Fe2	0.000	0.000	0.000	0.000	0.000	0.845	0.793	0.034	0.076
B.Mg	0.063	0.042	0.049	0.037	0.065	0.571	0.540	0.000	0.024
B.Ca	1.651	1.717	1.671	1.703	1.606	0.174	0.199	1.886	1.810
B.Na	0.300	0.298	0.325	0.326	0.312	0.189	0.253	0.131	0.054
B.sum	2.041	2.079	2.070	2.092	2.010	1.870	1.880	2.082	1.985
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.658
A.K	0.004	0.002	0.005	0.006	0.012	0.000	0.036	0.000	0.021
A.sum	0.004	0.002	0.005	0.006	0.012	0.000	0.036	0.000	0.679
W.OH	1.983	2.000	2.000	2.000	1.997	1.021	1.102	2.000	1.910
W.F	0.027	0.040	0.000	0.031	0.016	0.000	0.000	0.061	0.041
W.Cl	0.000	0.003	0.000	0.000	0.000	0.008	0.010	0.000	0.002
W.O2-	0.000	0.000	0.000	0.000	0.000	0.970	0.888	0.000	0.047
W.sum	2.011	2.043	2.000	2.031	2.013	2.000	2.000	2.061	2.000
X_{Mg}	0.461	0.579	0.499	0.571	0.475	0.481	0.484	0.947	0.838
calc.tot.Fe^{3+}	0.645	0.484	0.600	0.539	0.718	2.070	2.077	0.202	0.594
calc.tot.Fe^{2+}	2.335	1.894	2.167	1.893	2.218	2.196	2.110	0.257	0.634
calc.Fe^{3+}/Fe_{tot}	0.217	0.203	0.217	0.222	0.244	0.485	0.496	0.441	0.484

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

Table A2-4. (Cont)

Sample	029-32	029-32	033-37	033-37	033-37	URS-033-05	URS-033-05	URS-033-05	URS-033-05
Drillhole	A29	A29	A33	A33	A33	C33	C33	C33	C33
Depth (m)	173.65	173.65	158.45	158.45	158.45	256.85	256.85	256.85	256.85
Host Rock	marble	marble	marble	marble	marble	BIF	BIF	BIF	BIF
Type	hyd	hyd	hyd	hyd	hyd	met?	met?	met?	met?
Spot ID	C2-5	C3-2	C1-3	C2-3	C3-2	C1-1	C1-2	C1-4	C1-5
Mineral	mag-hst	mag-hst	pgs	pgs	pgs	gru	gru	gru	ferro-act
SiO_2	42.80	42.76	41.61	42.69	41.12	52.70	52.26	51.26	52.67
TiO_2	0.15	0.12	0.13	0.18	0.16	0.00	0.00	0.00	0.00
Al_2O_3	13.15	13.13	15.74	16.02	15.67	0.04	0.17	0.47	1.07
Cr_2O_3	0.00	0.05	0.06	0.06	0.03	0.00	0.01	0.00	0.00
V_2O_3	0.00	0.04	0.08	0.00	0.06	0.06	0.00	0.00	0.05
FeO_t	10.29	9.88	10.55	10.94	10.56	34.06	34.74	31.34	22.26
MnO	0.68	0.75	0.75	0.78	0.78	1.20	1.35	1.19	0.43
MgO	15.40	15.46	13.50	13.18	13.63	9.55	9.12	9.20	9.64
CaO	11.72	11.68	12.12	12.11	11.89	0.65	1.09	3.25	11.15
BaO	0.04	0.03	0.03	0.02	0.04	0.00	0.00	0.00	0.05
NiO	0.00	0.01	0.00	0.00	0.06	0.01	0.00	0.00	0.00
ZnO	0.00	0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Na_2O	2.86	2.89	1.89	2.00	2.50	0.04	0.05	0.07	0.14
K_2O	0.13	0.13	0.62	0.46	0.59	0.00	0.00	0.03	0.09
F	0.00	0.00	0.38	0.63	0.77	0.03	0.18	0.00	0.00
Cl	0.01	0.01	0.03	0.02	0.02	0.01	0.00	0.00	0.01
–O=F+Cl	0.00	0.00	0.17	0.27	0.33	0.02	0.08	0.00	0.00
Total (init)	97.21	96.95	97.64	99.35	98.21	98.36	99.05	96.81	97.56
H_2O (calc)	2.01	2.03	1.79	1.66	1.60	1.02	0.95	1.31	2.03
Total (calc)	99.22	98.99	99.43	101.01	99.81	99.38	100.00	98.12	99.59
mineral formula based on $O_{22}(OH,F,Cl,O)_2$									
T.Si	6.185	6.188	6.060	6.131	6.003	7.840	7.779	7.707	7.778
T.Al	1.873	1.871	1.991	1.912	2.052	0.219	0.282	0.350	0.216
T.Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T.sum	8.058	8.059	8.051	8.043	8.055	8.058	8.061	8.057	7.994
C.Al	0.366	0.368	0.710	0.799	0.644	0.000	0.000	0.000	0.000
C.Ti	0.075	0.073	0.070	0.068	0.080	0.000	0.000	0.000	0.000
C.Fe3	0.687	0.693	0.583	0.539	0.632	1.875	1.924	1.640	0.488
C.Cr	0.000	0.006	0.006	0.006	0.004	0.000	0.001	0.000	0.000
C.Ni	0.000	0.001	0.000	0.000	0.007	0.001	0.000	0.000	0.000
C.Zn	0.000	0.004	0.000	0.000	0.003	0.000	0.000	0.000	0.000
C.Mn2	0.061	0.069	0.071	0.074	0.074	0.072	0.089	0.083	0.036
C.Mg	3.295	3.313	2.907	2.804	2.938	1.549	1.465	1.636	2.094
C.Fe2	0.477	0.439	0.637	0.702	0.607	1.484	1.544	1.654	2.345
C.sum	4.962	4.965	4.985	4.992	4.989	4.982	5.023	5.013	4.964
B.Mn2	0.022	0.023	0.022	0.021	0.022	0.079	0.081	0.069	0.018
B.Fe2	0.079	0.064	0.065	0.073	0.050	0.878	0.857	0.647	0.000
B.Mg	0.022	0.021	0.024	0.018	0.027	0.568	0.559	0.425	0.028
B.Ca	1.824	1.819	1.893	1.867	1.861	0.160	0.229	0.586	1.785
B.Na	0.038	0.058	0.000	0.009	0.032	0.191	0.156	0.186	0.235
B.sum	1.985	1.985	2.004	1.987	1.993	1.876	1.882	1.914	2.066
A.Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A.Na	0.763	0.753	0.535	0.547	0.674	0.000	0.000	0.000	0.000
A.K	0.026	0.027	0.120	0.088	0.116	0.000	0.000	0.033	0.018
A.sum	0.788	0.780	0.655	0.635	0.790	0.000	0.000	0.033	0.018
W.OH	1.937	1.965	1.743	1.594	1.557	1.012	0.943	1.315	2.000
W.F	0.000	0.000	0.167	0.275	0.349	0.000	0.000	0.000	0.000
W.Cl	0.001	0.002	0.007	0.006	0.004	0.010	0.008	0.000	0.000
W.O2-	0.062	0.033	0.083	0.125	0.090	0.977	1.049	0.685	0.000
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.856	0.869	0.807	0.785	0.819	0.473	0.457	0.472	0.475
calc.tot.Fe^{3+}	0.687	0.693	0.583	0.539	0.632	1.875	1.924	1.640	0.488
calc.tot.Fe^{2+}	0.557	0.503	0.702	0.774	0.657	2.362	2.401	2.302	2.345
calc.Fe^{3+}/Fe_{tot}	0.552	0.580	0.454	0.411	0.490	0.442	0.445	0.416	0.172

Notes:

met = metamorphic; hyd = hydrothermal; "---" = not determined

act = actinolite; cpx = clinopyroxene; cum = cummingtonite; ferro-act = ferroactinolite; gru = grunerite; mag-hbl = magnesiohornblende; mag-hst = magnesiohastingsite; pgs = pargasite; qz = quartz; tre = tremolite

TABLE A6-5 - Biotite and phlogopite compositional data

Table A2-5. Electron microprobe data for selected metamorphic and hydrothermal biotite and phlogopite grains

Sample	963-22	963-22	963-22	963-22	057-03	057-03	057-03	057-03	057-03
Drillhole	A963	A963	A963	A963	B57	B57	B57	B57	B57
Depth (m)	57.7	57.7	57.7	57.7	83.8	83.8	83.8	83.8	83.8
Host Rock	amphibolite	amphibolite	amphibolite	amphibolite	pelitic schist	pelitic schist	pelitic schist	pelitic schist	pelitic schist
Type	met	met	met	met	met	met	met	met	met
Spot ID	C1-4	C1-5	C2-3	C2-4	C2-2	C3-2	C4-2	C5-2	C6-2
Mineral	bt	bt	bt	bt	bt	bt	bt	bt	bt
SiO_2	36.42	36.52	36.40	36.94	35.55	35.80	35.76	35.63	35.85
TiO_2	3.81	3.61	3.83	3.80	1.93	2.01	2.53	1.92	1.89
Al_2O_3	16.52	16.54	16.74	16.27	19.09	19.46	19.43	19.52	19.61
Cr_2O_3	0.02	0.04	0.07	0.00	0.11	0.06	0.09	0.00	0.00
V_2O_3	0.11	0.05	0.06	0.10	0.05	0.02	0.01	0.05	0.03
FeO_t	22.02	22.48	22.60	22.85	20.69	19.96	19.76	19.44	19.37
MnO	0.20	0.28	0.25	0.20	0.43	0.40	0.25	0.35	0.29
MgO	9.43	9.08	9.20	9.14	8.76	8.94	8.64	8.87	8.88
CaO	0.08	0.02	0.05	0.04	0.02	0.02	0.00	0.02	0.02
BaO	0.46	0.52	0.57	0.63	0.02	0.10	0.06	0.01	0.15
NiO	0.04	0.01	0.00	0.00	0.04	0.04	0.00	0.02	0.04
ZnO	0.02	0.00	0.00	0.02	0.24	0.30	0.20	0.24	0.15
Na_2O	0.15	0.05	0.09	0.10	0.15	0.13	0.23	0.19	0.22
K_2O	9.31	9.32	9.06	9.25	9.09	8.19	8.31	9.04	9.21
F	0.18	0.43	0.47	0.08	0.34	0.66	0.53	0.16	0.49
Cl	0.01	0.00	0.01	0.01	0.02	0.00	0.01	0.01	0.01
–O=F+Cl	0.08	0.18	0.20	0.04	0.15	0.28	0.22	0.07	0.21
Total (init)	98.86	99.12	99.61	99.46	96.67	96.39	96.01	95.52	96.43
H_2O (calc)	2.96	2.95	2.87	3.03	3.26	3.09	3.02	3.32	3.22
Total (calc)	101.82	102.08	102.48	102.49	99.93	99.48	99.03	98.84	99.64
mineral formula based on $O_{10}(OH, F, Cl,O)_2$									
T.Si	2.759	2.767	2.748	2.780	2.714	2.719	2.727	2.723	2.730
T.Al	1.136	1.118	1.148	1.082	1.231	1.269	1.261	1.257	1.259
T.Fe3+	0.106	0.115	0.104	0.139	0.055	0.012	0.012	0.020	0.011
T.sum	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Oc.Al	0.340	0.359	0.341	0.362	0.487	0.472	0.485	0.501	0.501
Oc.Mg	1.038	1.005	1.008	1.000	0.986	0.989	0.971	0.998	0.994
Oc.Fe2+	1.137	1.169	1.152	1.130	1.168	1.121	1.137	1.141	1.153
Oc.Fe3+	0.153	0.140	0.171	0.170	0.099	0.134	0.112	0.082	0.069
Oc.Ti	0.211	0.200	0.211	0.209	0.114	0.119	0.149	0.115	0.113
Oc.Cr	0.001	0.002	0.004	0.000	0.007	0.003	0.005	0.000	0.000
Oc.Mn	0.013	0.018	0.016	0.013	0.028	0.026	0.016	0.023	0.019
Oc.Ni	0.003	0.001	0.000	0.000	0.002	0.002	0.000	0.001	0.002
Oc.sum	2.895	2.894	2.904	2.882	2.890	2.868	2.875	2.860	2.852
Oc.vacancy	0.105	0.106	0.096	0.118	0.110	0.132	0.125	0.140	0.148
inter.K	0.901	0.902	0.878	0.886	0.888	0.819	0.825	0.887	0.896
inter.Na	0.022	0.007	0.014	0.014	0.022	0.019	0.034	0.028	0.033
inter.Ba	0.014	0.015	0.017	0.019	0.001	0.003	0.002	0.000	0.004
inter.Ca	0.006	0.002	0.004	0.003	0.002	0.002	0.000	0.001	0.002
inter.sum	0.943	0.926	0.913	0.923	0.913	0.843	0.860	0.917	0.935
inter.vacancy	0.057	0.074	0.087	0.077	0.087	0.157	0.140	0.083	0.065
W.F	0.028	0.089	0.091	0.006	0.075	0.129	0.110	0.033	0.110
W.Cl	0.001	0.000	0.001	0.001	0.003	0.000	0.001	0.001	0.001
W.OH	1.499	1.494	1.448	1.525	1.663	1.564	1.538	1.694	1.636
W.O2-	0.472	0.417	0.461	0.468	0.259	0.306	0.351	0.272	0.253
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.477	0.462	0.467	0.469	0.458	0.469	0.461	0.467	0.463
calc.tot.Fe^{3+}	0.258	0.255	0.275	0.308	0.153	0.147	0.123	0.101	0.080
calc.tot.Fe^{2+}	1.137	1.169	1.152	1.130	1.168	1.121	1.137	1.141	1.153
calc.Fe^{3+}/Fe_{tot}	0.185	0.179	0.193	0.214	0.116	0.116	0.098	0.082	0.065

Notes:

met = metamorphic; hyd = hydrothermal

apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

Table A2-5. (Cont)

Sample	009-03f	009-03f	009-03f	009-03f	009-03f	009-03f	029-04	029-04	029-04
Drillhole	A09	A09	A09	A09	A09	A09	A29	A29	A29
Depth (m)	71.55	71.55	71.55	71.55	71.55	71.55	48.25	48.25	48.25
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	hyd	hyd	hyd
Spot ID	C4-2	C4-3	C4-4	C4-8	C4-9	C4-10	C2-2a	C3-2	C3-8
Mineral	phl	phl	phl	phl	phl	phl	bt	bt	bt
SiO_2	39.73	39.73	39.65	40.65	41.10	43.10	37.15	36.65	36.10
TiO_2	0.47	0.66	0.48	0.69	0.56	0.60	1.22	1.33	1.34
Al_2O_3	14.84	15.81	16.22	15.57	14.38	15.03	18.14	18.65	18.34
Cr_2O_3	0.01	0.07	0.07	0.03	0.00	0.06	0.04	0.03	0.01
V_2O_3	0.07	0.03	0.00	0.11	0.04	0.01	0.26	0.06	0.11
FeO_t	6.01	6.63	6.20	6.46	5.92	6.31	14.20	14.88	15.75
MnO	0.14	0.15	0.12	0.16	0.12	0.14	0.00	0.02	0.01
MgO	26.21	23.40	24.44	23.52	24.54	25.14	14.42	14.43	14.06
CaO	0.11	0.06	0.21	0.02	0.03	0.00	0.01	0.00	0.05
BaO	0.21	0.31	0.26	0.29	0.24	0.19	0.00	0.09	0.10
NiO	0.04	0.01	0.03	0.00	0.00	0.00	0.04	0.03	0.00
ZnO	0.00	0.04	0.05	0.05	0.07	0.00	0.18	0.18	0.10
Na_2O	0.04	0.07	0.08	0.03	0.03	0.00	0.14	0.05	0.09
K_2O	9.14	8.81	8.30	9.14	9.11	6.47	9.49	9.75	9.06
F	0.70	0.30	0.66	0.51	0.30	0.45	0.28	0.39	0.40
Cl	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02
–O=F+Cl	0.30	0.13	0.28	0.22	0.13	0.19	0.12	0.17	0.17
Total (init)	98.03	96.21	97.06	97.45	96.56	97.71	95.68	96.70	95.70
H_2O (calc)	3.57	3.60	3.45	3.55	3.63	3.44	3.53	3.57	3.48
Total (calc)	101.60	99.81	100.51	101.00	100.19	101.15	99.21	100.27	99.18
mineral formula based on $O_{10}(OH, F, Cl,O)_2$									
T.Si	2.765	2.799	2.762	2.844	2.877	2.916	2.763	2.718	2.700
T.Al	1.182	1.158	1.241	1.107	1.026	0.995	1.192	1.257	1.253
T.Fe3+	0.052	0.043	0.000	0.049	0.097	0.090	0.045	0.025	0.047
T.sum	4.000	4.000	4.003	4.000	4.000	4.000	4.000	4.000	4.000
Oc.Al	0.035	0.154	0.090	0.177	0.160	0.204	0.398	0.373	0.363
Oc.Mg	2.747	2.464	2.532	2.468	2.584	2.568	1.581	1.577	1.547
Oc.Fe2+	0.000	0.036	0.000	0.047	0.000	0.000	0.773	0.830	0.826
Oc.Fe3+	0.298	0.311	0.361	0.282	0.250	0.267	0.065	0.068	0.112
Oc.Ti	0.010	0.028	0.015	0.028	0.022	0.018	0.072	0.074	0.076
Oc.Cr	0.001	0.004	0.004	0.002	0.000	0.003	0.002	0.001	0.000
Oc.Mn	0.008	0.009	0.007	0.009	0.007	0.008	0.000	0.001	0.001
Oc.Ni	0.002	0.001	0.002	0.000	0.000	0.000	0.002	0.002	0.000
Oc.sum	3.100	3.007	3.010	3.014	3.023	3.068	2.894	2.925	2.925
Oc.vacancy	0.000	0.000	0.000	0.000	0.000	0.000	0.106	0.075	0.075
inter.K	0.834	0.814	0.779	0.829	0.827	0.580	0.900	0.918	0.870
inter.Na	0.006	0.010	0.011	0.004	0.004	0.000	0.020	0.007	0.013
inter.Ba	0.006	0.009	0.007	0.008	0.007	0.005	0.000	0.003	0.003
inter.Ca	0.008	0.005	0.016	0.002	0.002	0.000	0.001	0.000	0.004
inter.sum	0.853	0.837	0.812	0.843	0.839	0.585	0.920	0.927	0.890
inter.vacancy	0.147	0.163	0.188	0.157	0.161	0.415	0.080	0.073	0.110
W.F	0.098	0.016	0.062	0.073	0.025	0.005	0.059	0.084	0.079
W.Cl	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.003
W.OH	1.658	1.693	1.606	1.659	1.696	1.554	1.751	1.768	1.736
W.O2-	0.243	0.291	0.331	0.267	0.278	0.439	0.189	0.147	0.183
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	1.000	0.985	1.000	0.981	1.000	1.000	0.672	0.655	0.652
calc.tot.Fe^{3+}	0.350	0.354	0.361	0.331	0.347	0.357	0.110	0.093	0.159
calc.tot.Fe^{2+}	0.000	0.036	0.000	0.047	0.000	0.000	0.773	0.830	0.826
calc.Fe^{3+}/Fe_{tot}	1.000	0.907	1.000	0.876	1.000	1.000	0.125	0.101	0.162

Notes:

met = metamorphic; hyd = hydrothermal

apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

Table A2-5. (Cont)

Sample	029-04	004-15	004-15	004-15	004-15	HS-10	HS-10	HS-10	HS-10
Drillhole	A29	A04	A04	A04	A04	surface	surface	surface	surface
Depth (m)	48.25	164.05	164.05	164.05	164.05	n/a	n/a	n/a	n/a
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C4-3	C1-1	C1-6	C2-1	C2-5	C3-2	C3-5	C4-1	C5-3
Mineral	bt	bt	bt	bt	phl	bt	bt	bt	bt
SiO_2	36.97	30.06	31.05	34.74	33.31	36.69	35.29	34.14	36.06
TiO_2	1.26	1.80	1.87	2.62	2.47	0.43	0.57	0.61	0.34
Al_2O_3	19.25	15.81	15.16	15.74	15.92	14.29	14.19	14.96	15.15
Cr_2O_3	0.05	0.14	0.05	0.06	0.02	0.01	0.00	0.01	0.04
V_2O_3	0.23	0.11	0.01	0.01	0.01	0.02	0.00	0.00	0.00
FeO_t	15.05	30.80	28.82	20.56	20.40	21.29	23.39	24.03	20.73
MnO	0.03	1.30	0.97	0.70	0.54	1.06	1.70	1.92	0.76
MgO	13.94	9.07	8.28	11.27	12.14	12.83	12.74	11.92	13.75
CaO	0.05	0.10	0.00	0.01	0.03	0.04	0.08	0.00	0.07
BaO	0.08	1.38	1.88	2.97	3.26	0.33	0.25	0.29	0.50
NiO	0.00	0.05	0.00	0.01	0.00	0.06	0.00	0.00	0.00
ZnO	0.11	0.06	0.14	0.09	0.00	0.00	0.00	0.00	0.12
Na_2O	0.07	0.00	0.00	0.03	0.10	0.02	0.05	0.01	0.00
K_2O	9.62	4.68	6.84	7.64	7.50	9.02	7.78	7.04	8.72
F	0.26	0.02	0.00	0.38	0.07	0.22	0.45	0.43	0.50
Cl	0.01	0.03	0.05	0.07	0.09	0.11	0.09	0.10	0.09
–O=F+Cl	0.11	0.01	0.01	0.17	0.05	0.12	0.21	0.20	0.23
Total (init)	97.09	95.39	95.11	97.09	95.90	96.53	96.78	95.66	97.05
H_2O (calc)	3.61	3.12	3.21	2.94	3.10	3.48	3.22	3.19	3.48
Total (calc)	100.70	98.51	98.32	100.03	99.00	100.00	100.00	98.84	100.54
mineral formula based on $O_{10}(OH, F, Cl,O)_2$									
T.Si	2.722	2.389	2.500	2.656	2.573	2.780	2.689	2.634	2.716
T.Al	1.272	1.331	1.173	1.116	1.178	0.912	1.040	1.103	1.020
T.Fe3+	0.006	0.280	0.327	0.228	0.249	0.307	0.272	0.263	0.264
T.sum	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Oc.Al	0.398	0.150	0.265	0.302	0.271	0.363	0.234	0.258	0.324
Oc.Mg	1.499	1.044	1.026	1.305	1.429	1.447	1.413	1.356	1.531
Oc.Fe2+	0.837	0.984	1.019	0.569	0.493	0.782	0.791	0.799	0.765
Oc.Fe3+	0.083	0.783	0.595	0.517	0.576	0.260	0.428	0.489	0.276
Oc.Ti	0.069	0.095	0.106	0.146	0.136	0.025	0.029	0.032	0.018
Oc.Cr	0.003	0.009	0.003	0.004	0.001	0.000	0.000	0.000	0.003
Oc.Mn	0.002	0.087	0.066	0.045	0.035	0.068	0.109	0.125	0.049
Oc.Ni	0.000	0.003	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Oc.sum	2.892	3.155	3.080	2.890	2.942	2.949	3.004	3.059	2.965
Oc.vacancy	0.108	0.000	0.000	0.110	0.058	0.051	0.000	0.000	0.035
inter.K	0.905	0.580	0.739	0.754	0.741	0.865	0.789	0.731	0.841
inter.Na	0.009	0.000	0.000	0.005	0.016	0.002	0.007	0.001	0.000
inter.Ba	0.002	0.043	0.059	0.089	0.099	0.010	0.007	0.009	0.015
inter.Ca	0.004	0.008	0.000	0.001	0.002	0.004	0.006	0.000	0.005
inter.sum	0.920	0.631	0.799	0.849	0.857	0.880	0.809	0.742	0.861
inter.vacancy	0.080	0.369	0.201	0.151	0.143	0.120	0.191	0.258	0.139
W.F	0.041	0.000	0.000	0.105	0.046	0.066	0.084	0.092	0.111
W.Cl	0.001	0.004	0.006	0.010	0.012	0.014	0.011	0.013	0.012
W.OH	1.776	1.657	1.727	1.498	1.597	1.759	1.636	1.641	1.752
W.O2-	0.182	0.340	0.267	0.388	0.344	0.160	0.268	0.253	0.126
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.642	0.515	0.502	0.696	0.744	0.649	0.641	0.629	0.667
calc.tot.Fe^{3+}	0.089	1.063	0.922	0.745	0.825	0.567	0.700	0.752	0.540
calc.tot.Fe^{2+}	0.837	0.984	1.019	0.569	0.493	0.782	0.791	0.799	0.765
calc.Fe^{3+}/Fe_{tot}	0.096	0.519	0.475	0.567	0.626	0.421	0.470	0.485	0.414

Notes:
met = metamorphic; hyd = hydrothermal
apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

Table A2-5. (Cont)

Sample	HS-10	033-17b	033-17b	033-17b	033-04b	029-07	029-07	029-20	029-27
Drillhole	surface	A33	A33	A33	A33	A29	A29	A29	A29
Depth (m)	n/a	162.1	162.1	162.1	55.75	55.9	55.9	110.1	110.1
Host Rock	marble	marble	marble	marble	qz-cpx vein	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C6-1	C4-2	C4-3	C4-4	C2-1	C4-3	C4-4	C3-1	C4-2
Mineral	bt	bt --> chl	bt --> chl	bt --> chl	bt --> chl	phl	phl	phl --> chl	phl
SiO_2	36.29	28.60	29.06	30.17	30.34	40.59	40.33	36.43	38.28
TiO_2	0.20	0.12	0.23	0.41	2.17	0.40	0.35	0.50	0.24
Al_2O_3	14.43	15.16	14.52	12.14	16.61	15.68	15.74	15.29	16.89
Cr_2O_3	0.09	0.06	0.00	0.00	0.09	0.04	0.08	0.02	0.05
V_2O_3	0.02	0.01	0.00	0.03	0.05	0.05	0.02	0.00	0.00
FeO_t	20.73	28.75	28.63	29.64	28.54	9.18	9.81	7.54	10.27
MnO	0.96	3.58	3.70	5.15	0.99	0.19	0.21	0.21	0.41
MgO	13.89	12.89	13.75	11.93	9.16	20.15	20.34	26.53	20.48
CaO	0.03	0.12	0.01	0.07	0.07	0.03	0.10	0.07	0.11
BaO	0.49	0.02	0.14	0.31	0.92	0.07	0.16	1.23	0.34
NiO	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00
ZnO	0.03	0.09	0.00	0.06	0.01	0.00	0.00	0.00	0.00
Na_2O	0.01	0.05	0.00	0.00	0.01	0.09	0.05	0.06	0.10
K_2O	8.70	0.34	0.61	1.40	4.51	9.50	9.41	6.30	8.67
F	0.64	0.13	0.00	0.12	0.00	0.57	0.14	0.00	0.58
Cl	0.11	0.01	0.01	0.02	0.06	0.05	0.06	0.02	0.03
–O=F+Cl	0.30	0.06	0.00	0.05	0.01	0.25	0.07	0.00	0.25
Total (init)	96.92	89.99	90.66	91.51	93.56	96.83	96.87	94.17	96.70
H_2O (calc)	3.39	2.78	2.88	2.45	3.08	3.52	3.71	3.72	3.54
Total (calc)	100.31	92.77	93.54	93.96	96.63	100.35	100.57	97.90	100.24
mineral formula based on $O_{10}(OH, F, Cl,O)_2$									
T.Si	2.742	2.285	2.301	2.420	2.422	2.895	2.863	2.571	2.736
T.Al	0.954	1.530	1.483	1.338	1.340	0.999	1.017	1.332	1.219
T.Fe3+	0.304	0.185	0.216	0.242	0.239	0.105	0.120	0.097	0.045
T.sum	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Oc.Al	0.331	0.000	0.000	0.000	0.222	0.318	0.299	0.000	0.204
Oc.Mg	1.565	1.403	1.502	1.296	1.081	2.141	2.145	2.827	2.162
Oc.Fe2+	0.720	0.531	0.466	0.449	0.984	0.277	0.244	0.000	0.266
Oc.Fe3+	0.287	1.205	1.213	1.297	0.682	0.166	0.218	0.348	0.303
Oc.Ti	0.012	0.001	0.003	0.018	0.119	0.020	0.014	0.010	0.006
Oc.Cr	0.005	0.004	0.000	0.000	0.005	0.002	0.005	0.001	0.003
Oc.Mn	0.061	0.242	0.248	0.350	0.067	0.011	0.013	0.013	0.025
Oc.Ni	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
Oc.sum	2.980	3.386	3.433	3.410	3.162	2.936	2.939	3.199	2.968
Oc.vacancy	0.020	0.000	0.000	0.000	0.000	0.064	0.061	0.000	0.032
inter.K	0.836	0.287	0.293	0.390	0.557	0.862	0.856	0.617	0.815
inter.Na	0.002	0.008	0.000	0.000	0.002	0.012	0.006	0.008	0.014
inter.Ba	0.015	0.000	0.004	0.010	0.029	0.002	0.004	0.034	0.010
inter.Ca	0.002	0.010	0.001	0.006	0.006	0.003	0.007	0.005	0.008
inter.sum	0.854	0.305	0.298	0.406	0.594	0.879	0.874	0.664	0.847
inter.vacancy	0.146	0.695	0.702	0.594	0.406	0.121	0.126	0.336	0.153
W.F	0.160	0.000	0.000	0.000	0.000	0.111	0.001	0.000	0.082
W.Cl	0.014	0.002	0.001	0.002	0.008	0.006	0.007	0.002	0.004
W.OH	1.712	1.483	1.521	1.313	1.639	1.674	1.756	1.753	1.688
W.O2-	0.113	0.515	0.478	0.685	0.354	0.209	0.236	0.245	0.226
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.685	0.725	0.763	0.743	0.524	0.885	0.898	1.000	0.891
calc.tot.Fe^{3+}	0.591	1.390	1.430	1.540	0.921	0.271	0.338	0.445	0.348
calc.tot.Fe^{2+}	0.720	0.531	0.466	0.449	0.984	0.277	0.244	0.000	0.266
calc.Fe^{3+}/Fe_{tot}	0.451	0.724	0.754	0.774	0.483	0.494	0.581	1.000	0.567

Notes:

met = metamorphic; hyd = hydrothermal

apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

Table A2-5. (Cont)

Sample	029-27	029-27	033-19	033-19	033-20	033-20	033-20	033-20	033-20
Drillhole	A29	A29	A33	A33	A33	A33	A33	A33	A33
Depth (m)	110.1	110.1	177	177	188.5	188.5	188.5	188.5	188.5
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C4-4	C4-5	C1-1	C1-2	C1-3	C1-4	C2-4	C2-6	C2-6b
Mineral	phl	phl	phl	phl	phl --> chl	phl	phl	phl	phl
SiO_2	39.40	40.11	37.38	36.55	28.59	35.52	36.45	35.55	35.93
TiO_2	0.18	0.18	0.21	0.23	0.09	0.10	0.19	0.14	0.05
Al_2O_3	17.18	16.16	17.73	17.90	13.42	17.16	19.78	18.52	18.71
Cr_2O_3	0.00	0.00	0.03	0.00	0.00	0.08	0.00	0.00	0.00
V_2O_3	0.00	0.02	0.00	0.01	0.10	0.02	0.00	0.00	0.01
FeO_t	10.31	10.34	7.49	7.57	18.60	7.46	10.44	10.07	9.40
MnO	0.30	0.27	0.21	0.26	0.71	0.29	0.37	0.33	0.28
MgO	20.23	20.29	22.31	22.19	24.13	21.73	20.17	19.39	19.95
CaO	0.09	0.06	0.03	0.04	0.32	0.30	0.13	0.11	0.17
BaO	0.42	0.32	1.74	1.96	0.00	0.11	0.00	0.00	0.01
NiO	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.00
ZnO	0.00	0.04	0.11	0.00	0.00	0.01	0.05	0.00	0.10
Na_2O	0.20	0.31	0.26	0.40	0.02	2.62	1.75	1.32	0.41
K_2O	8.10	8.09	8.29	8.30	0.16	6.71	5.64	6.50	8.53
F	0.47	0.80	0.33	0.57	0.05	0.00	0.19	0.11	0.08
Cl	0.04	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.01
–O=F+Cl	0.20	0.34	0.14	0.24	0.02	0.00	0.08	0.05	0.04
Total (init)	97.10	97.34	96.29	96.22	86.21	92.10	95.26	92.15	93.67
H_2O (calc)	3.55	3.34	3.65	3.50	3.28	2.65	3.04	3.18	3.68
Total (calc)	100.65	100.69	99.94	99.72	89.49	94.76	98.30	95.32	97.35
mineral formula based on $O_{10}(OH, F, Cl,O)_2$									
T.Si	2.780	2.839	2.653	2.614	2.213	2.628	2.596	2.621	2.625
T.Al	1.168	1.072	1.319	1.376	1.577	1.412	1.484	1.410	1.416
T.Fe3+	0.053	0.090	0.028	0.009	0.210	0.000	0.000	0.000	0.000
T.sum	4.000	4.000	4.000	4.000	4.000	4.040	4.080	4.031	4.041
Oc.Al	0.261	0.276	0.164	0.133	0.000	0.084	0.177	0.199	0.195
Oc.Mg	2.109	2.127	2.379	2.380	2.634	2.310	2.087	2.078	2.130
Oc.Fe2+	0.211	0.206	0.000	0.000	0.000	0.000	0.087	0.192	0.333
Oc.Fe3+	0.344	0.317	0.417	0.443	0.994	0.461	0.535	0.429	0.242
Oc.Ti	0.002	0.005	0.002	0.004	0.000	0.019	0.008	0.014	0.001
Oc.Cr	0.000	0.000	0.002	0.000	0.000	0.005	0.000	0.000	0.000
Oc.Mn	0.018	0.016	0.013	0.016	0.046	0.018	0.022	0.020	0.017
Oc.Ni	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.000
Oc.sum	2.945	2.947	2.976	2.977	3.675	2.898	2.917	2.935	2.918
Oc.vacancy	0.055	0.053	0.024	0.023	0.000	0.102	0.083	0.065	0.082
inter.K	0.749	0.744	0.764	0.771	0.245	0.667	0.546	0.655	0.829
inter.Na	0.027	0.042	0.035	0.055	0.003	0.376	0.242	0.189	0.059
inter.Ba	0.012	0.009	0.048	0.055	0.000	0.003	0.000	0.000	0.000
inter.Ca	0.007	0.004	0.003	0.003	0.026	0.024	0.010	0.009	0.013
inter.sum	0.795	0.799	0.850	0.884	0.275	1.069	0.797	0.852	0.901
inter.vacancy	0.205	0.201	0.150	0.116	0.725	0.000	0.203	0.148	0.099
W.F	0.049	0.133	0.043	0.101	0.000	0.000	0.000	0.000	0.000
W.Cl	0.004	0.004	0.003	0.002	0.001	0.001	0.001	0.000	0.001
W.OH	1.672	1.580	1.729	1.671	1.694	1.311	1.445	1.564	1.795
W.O2-	0.276	0.283	0.225	0.225	0.305	0.689	0.554	0.436	0.203
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.909	0.912	1.000	1.000	1.000	1.000	0.960	0.916	0.865
calc.tot.Fe^{3+}	0.397	0.406	0.445	0.453	1.204	0.461	0.535	0.429	0.242
calc.tot.Fe^{2+}	0.211	0.206	0.000	0.000	0.000	0.000	0.087	0.192	0.333
calc.Fe^{3+}/Fe_{tot}	0.653	0.664	1.000	1.000	1.000	1.000	0.860	0.691	0.421

Notes:

met = metamorphic; hyd = hydrothermal

apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

Table A2-5. (Cont)

Sample	029-32	029-32	029-32	029-32	029-32	029-32	029-32	029-32	029-32
Drillhole	A29	A29	A29	A29	A29	A29	A29	A29	A29
Depth (m)	173.65	173.65	173.65	173.65	173.65	173.65	173.65	173.65	173.65
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-3	C1-4	C1-5	C2-1	C2-2	C2-3	C2-4	C3-1	C3-3
Mineral	phl	phl	phl	phl	apd	phl	phl	phl	phl
SiO_2	39.34	38.91	38.38	38.98	40.71	38.65	39.44	36.38	39.68
TiO_2	0.31	0.31	0.33	0.30	0.24	0.27	0.22	0.23	0.21
Al_2O_3	15.97	17.35	16.91	17.63	17.42	17.35	16.83	15.43	16.38
Cr_2O_3	0.02	0.05	0.00	0.00	0.03	0.00	0.00	0.01	0.05
V_2O_3	0.00	0.00	0.06	0.02	0.01	0.00	0.00	0.02	0.05
FeO_t	9.17	6.52	6.44	6.83	6.61	6.40	7.21	13.32	5.59
MnO	0.32	0.17	0.20	0.13	0.16	0.15	0.21	0.68	0.31
MgO	21.47	22.68	22.92	22.48	22.86	22.23	22.60	20.40	22.74
CaO	0.06	0.06	0.06	0.05	0.10	0.02	0.04	0.09	0.06
BaO	0.04	0.02	0.04	0.07	0.17	0.05	0.06	0.02	0.07
NiO	0.00	0.03	0.00	0.00	0.01	0.02	0.00	0.04	0.00
ZnO	0.01	0.00	0.02	0.00	0.00	0.05	0.04	0.00	0.00
Na_2O	0.62	1.22	1.08	1.01	2.93	0.69	0.66	1.18	0.64
K_2O	5.69	6.48	6.96	6.96	4.29	8.37	7.93	2.19	7.88
F	0.58	0.00	0.31	0.16	0.31	0.11	0.25	0.00	0.09
Cl	0.01	0.06	0.06	0.00	0.00	0.00	0.02	0.00	0.00
–O=F+Cl	0.25	0.01	0.14	0.07	0.13	0.05	0.11	0.00	0.04
Total (init)	93.85	93.88	93.90	94.70	95.98	94.41	95.62	89.97	93.77
H_2O (calc)	3.10	3.23	3.18	3.32	2.31	3.53	3.47	2.89	3.42
Total (calc)	96.95	97.11	97.08	98.02	98.29	97.94	99.09	92.86	97.19
mineral formula based on $O_{10}(OH, F, Cl,O)_2$									
T.Si	2.799	2.756	2.744	2.750	2.816	2.760	2.782	2.654	2.820
T.Al	1.136	1.218	1.230	1.267	1.207	1.245	1.193	1.225	1.163
T.Fe3+	0.065	0.026	0.026	0.000	0.000	0.000	0.025	0.121	0.017
T.sum	4.000	4.000	4.000	4.016	4.023	4.005	4.000	4.000	4.000
Oc.Al	0.203	0.230	0.194	0.199	0.214	0.215	0.207	0.102	0.209
Oc.Mg	2.253	2.398	2.446	2.352	2.318	2.362	2.374	2.156	2.399
Oc.Fe2+	0.001	0.000	0.000	0.000	0.000	0.064	0.022	0.000	0.000
Oc.Fe3+	0.479	0.361	0.359	0.403	0.382	0.318	0.379	0.692	0.315
Oc.Ti	0.017	0.017	0.018	0.014	0.018	0.014	0.007	0.017	0.012
Oc.Cr	0.001	0.003	0.000	0.000	0.002	0.000	0.000	0.000	0.003
Oc.Mn	0.019	0.010	0.012	0.008	0.009	0.009	0.012	0.042	0.019
Oc.Ni	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.002	0.000
Oc.sum	2.973	3.021	3.030	2.976	2.944	2.982	3.001	3.011	2.957
Oc.vacancy	0.027	0.000	0.000	0.024	0.056	0.018	0.000	0.000	0.043
inter.K	0.565	0.596	0.646	0.649	0.381	0.775	0.728	0.311	0.741
inter.Na	0.085	0.167	0.150	0.139	0.393	0.095	0.090	0.167	0.088
inter.Ba	0.001	0.001	0.001	0.002	0.005	0.001	0.002	0.001	0.002
inter.Ca	0.004	0.005	0.004	0.004	0.007	0.002	0.003	0.007	0.004
inter.sum	0.656	0.768	0.802	0.793	0.786	0.873	0.823	0.485	0.834
inter.vacancy	0.344	0.232	0.198	0.207	0.214	0.127	0.177	0.515	0.166
W.F	0.049	0.000	0.031	0.000	0.000	0.000	0.005	0.000	0.000
W.Cl	0.002	0.007	0.007	0.000	0.000	0.000	0.002	0.000	0.000
W.OH	1.474	1.527	1.516	1.562	1.066	1.683	1.634	1.406	1.624
W.O2-	0.475	0.466	0.446	0.438	0.933	0.317	0.360	0.594	0.376
W.sum	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
X_{Mg}	0.999	1.000	1.000	1.000	1.000	0.974	0.991	1.000	1.000
calc.tot.Fe^{3+}	0.544	0.386	0.385	0.403	0.382	0.318	0.403	0.813	0.332
calc.tot.Fe^{2+}	0.001	0.000	0.000	0.000	0.000	0.064	0.022	0.000	0.000
calc.Fe^{3+}/Fe_{tot}	0.998	1.000	1.000	1.000	1.000	0.832	0.948	1.000	1.000

Notes:

met = metamorphic; hyd = hydrothermal

apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

Table A2-5. (Cont)

Sample	033-37	033-37	033-37
Drillhole	A33	A33	A33
Depth (m)	158.45	158.45	158.45
Host Rock	marble	marble	marble
Type	hyd	hyd	hyd
Spot ID	C1-2	C2-1	C2-2
Mineral	phl	phl	phl
SiO_2	37.14	37.00	38.45
TiO_2	0.19	0.21	0.20
Al_2O_3	18.22	18.73	18.38
Cr_2O_3	0.00	0.00	0.07
V_2O_3	0.01	0.00	0.03
FeO_t	8.93	10.59	9.86
MnO	0.10	0.32	0.31
MgO	20.39	19.60	19.14
CaO	0.02	0.03	0.00
BaO	0.35	0.24	0.45
NiO	0.00	0.00	0.00
ZnO	0.00	0.00	0.00
Na_2O	0.34	0.30	0.23
K_2O	8.10	6.76	8.07
F	0.68	0.31	0.50
Cl	0.01	0.02	0.02
–O=F+Cl	0.29	0.14	0.21
Total (init)	94.78	94.25	95.92
H_2O (calc)	3.49	3.56	3.54
Total (calc)	98.26	97.81	99.46
mineral formula based on $O_{10}(OH, F, Cl,O)_2$			
T.Si	2.685	2.658	2.746
T.Al	1.320	1.341	1.242
T.Fe3+	0.000	0.001	0.012
T.sum	4.005	4.000	4.000
Oc.Al	0.232	0.245	0.305
Oc.Mg	2.191	2.083	2.025
Oc.Fe2+	0.257	0.237	0.271
Oc.Fe3+	0.283	0.399	0.306
Oc.Ti	0.008	0.007	0.008
Oc.Cr	0.000	0.000	0.004
Oc.Mn	0.006	0.020	0.019
Oc.Ni	0.000	0.000	0.000
Oc.sum	2.978	2.989	2.938
Oc.vacancy	0.022	0.011	0.062
inter.K	0.767	0.657	0.754
inter.Na	0.047	0.042	0.032
inter.Ba	0.010	0.007	0.012
inter.Ca	0.001	0.002	0.000
inter.sum	0.825	0.707	0.799
inter.vacancy	0.175	0.293	0.201
W.F	0.122	0.014	0.075
W.Cl	0.002	0.003	0.002
W.OH	1.683	1.706	1.690
W.O2-	0.193	0.277	0.234
W.sum	2.000	2.000	2.000
X_{Mg}	0.895	0.898	0.882
calc.tot.Fe^{3+}	0.283	0.399	0.318
calc.tot.Fe^{2+}	0.257	0.237	0.271
calc.Fe^{3+}/Fe_{tot}	0.525	0.628	0.540

Notes:

met = metamorphic; hyd = hydrothermal

apd = aspidolite; bt = biotite; bt --> chl = biotite partly converted to chlorite; cpx = clinopyroxene; phl = phlogopite; phl --> chl = phlogopite partly converted to chlorite; qz = quartz

TABLE A6-6 - Chlorite compositional data

Table A2-6. Electron microprobe data for selected hydrothermal chlorite grains

Sample	029-04	029-07	029-07	029-07	029-07	029-20	029-20	029-20	029-20
Drillhole	A29	A29	A29	A29	A29	A29	A29	A29	A29
Depth (m)	48.25	55.9	55.9	55.9	55.9	110.1	110.1	110.1	110.1
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Spot ID	C1-7	C1-4	C1-5	C3-4	C4-7	C2-6	C3-3	C5-4	C5-5
SiO_2	32.05	29.31	29.54	29.49	30.19	29.12	29.38	28.11	28.72
TiO_2	0.00	0.01	0.01	0.03	0.04	0.03	0.03	0.05	0.07
Al_2O_3	14.04	20.38	21.21	21.38	20.59	20.97	19.80	21.45	21.43
Cr_2O_3	0.00	0.05	0.04	0.00	0.04	0.00	0.10	0.00	0.00
V_2O_3	0.00	0.06	0.00	0.02	0.06	0.04	0.02	0.00	0.03
FeO_t	22.90	11.34	10.88	11.27	10.82	8.57	8.74	8.74	8.79
MnO	0.15	0.26	0.22	0.27	0.28	0.20	0.22	0.18	0.19
MgO	19.31	26.14	26.64	26.20	26.34	30.19	30.52	28.73	29.17
CaO	0.18	0.02	0.00	0.02	0.05	0.04	0.09	0.06	0.03
BaO	0.00	0.10	0.03	0.00	0.00	0.00	0.00	0.01	0.00
NiO	0.02	0.01	0.03	0.05	0.05	0.00	0.01	0.00	0.04
ZnO	0.00	0.07	0.06	0.08	0.06	0.03	0.13	0.03	0.02
Na_2O	0.04	0.00	0.00	0.00	0.06	0.01	0.05	0.00	0.00
K_2O	0.02	0.00	0.00	0.01	0.11	0.02	0.01	0.01	0.01
F	0.39	0.08	0.00	0.00	0.00	0.49	0.00	0.41	0.00
Cl	0.01	0.00	0.01	0.00	0.00	0.02	0.01	0.01	0.01
–O=F+Cl	0.16	0.03	0.00	0.00	0.00	0.21	0.00	0.17	0.00
Total (init)	89.10	87.82	88.67	88.82	88.69	89.73	89.09	87.77	88.51
H_2O (calc)	11.39	12.22	12.48	12.48	12.48	12.19	12.60	12.00	12.55
Total (calc)	100.49	100.04	101.15	101.29	101.17	101.92	101.69	99.77	101.05
mineral formula based on $O_{20}(OH,F,Cl)_{16}$									
Si	6.444	5.700	5.667	5.658	5.784	5.451	5.550	5.392	5.470
Al^{IV}	1.556	2.300	2.333	2.342	2.216	2.549	2.450	2.608	2.530
Al^{VI}	1.804	2.382	2.471	2.504	2.449	2.110	1.990	2.266	2.298
Ti	0.000	0.002	0.002	0.005	0.005	0.004	0.004	0.007	0.009
Cr	0.000	0.008	0.007	0.000	0.006	0.000	0.015	0.000	0.000
Fe^{3+}	0.301	0.086	0.085	0.095	0.118	0.000	0.000	0.000	0.000
Fe^{2+}	3.549	1.758	1.661	1.713	1.616	1.376	1.565	1.415	1.489
Mn	0.025	0.042	0.035	0.043	0.045	0.032	0.036	0.029	0.030
Mg	5.787	7.576	7.616	7.494	7.524	8.426	8.594	8.215	8.284
Ni	0.004	0.001	0.005	0.008	0.008	0.000	0.001	0.000	0.007
Zn	0.000	0.011	0.008	0.011	0.009	0.004	0.019	0.004	0.003
Ca	0.039	0.003	0.000	0.004	0.009	0.009	0.019	0.012	0.005
Na	0.032	0.002	0.000	0.000	0.043	0.005	0.034	0.000	0.000
K	0.008	0.000	0.000	0.002	0.052	0.008	0.004	0.003	0.005
Ba	0.000	0.015	0.004	0.000	0.000	0.000	0.000	0.002	0.000
F	0.491	0.100	0.000	0.000	0.000	0.580	0.000	0.496	0.000
Cl	0.003	0.002	0.008	0.000	0.002	0.011	0.008	0.005	0.006
OH	15.506	15.898	15.992	16.000	15.998	15.409	15.992	15.499	15.994
X_{Mg}	0.620	0.812	0.821	0.814	0.823	0.860	0.846	0.853	0.848
calc.Fe^{3+}/Fe_{tot}	0.078	0.046	0.049	0.052	0.068	0.000	0.000	0.000	0.000
Classification	diabantite	clinochlore	clinochlore	clinochlore	clinochlore	sheridanite	sheridanite	sheridanite	sheridanite

TABLE A6-7 - Carbonate compositional data

Table A2-7. Electron microprobe data for selected metamorphic and hydrothermal carbonate grains

Sample	009-03f	009-03f	009-03f	009-03f	029-07	029-07	029-07	029-20	029-27
Drillhole	A09	A09	A09	A09	A29	A29	A29	A29	A29
Depth (m)	71.55	71.55	71.55	71.55	55.9	55.9	55.9	110.1	146.7
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	met	met	met
Spot ID	C2-4	C2-9	C4-5	C4-6	C2-2	C2-4	C2-6	C2-5	C1-2
Mineral	calcite	dolomite	dolomite	calcite	calcite	calcite	dolomite	calcite	dolomite
CaO	54.72	29.79	30.43	54.35	52.31	54.02	29.49	54.90	27.75
MgO	1.82	16.48	20.36	1.46	2.45	2.28	18.11	0.00	20.10
FeOt	1.10	3.52	3.91	0.79	1.44	1.52	5.13	0.44	7.30
MnO	1.11	1.43	1.57	1.12	1.24	1.31	1.51	2.40	3.06
Total	58.75	51.21	56.29	57.80	57.53	59.36	54.37	57.74	58.24
atoms per formula unit									
Ca	0.976	0.531	0.543	0.969	0.933	0.963	0.526	0.979	0.495
Mg	0.045	0.409	0.505	0.036	0.061	0.057	0.449	0.000	0.499
Fe	0.015	0.049	0.054	0.011	0.020	0.021	0.071	0.006	0.102
Mn	0.016	0.020	0.022	0.016	0.018	0.018	0.021	0.034	0.043
Total	1.052	1.009	1.124	1.032	1.031	1.060	1.068	1.019	1.138
Carbonate composition (molar %)									
$CaCO_3$	0.928	0.526	0.483	0.939	0.905	0.909	0.493	0.961	0.435
$MgCO_3$	0.043	0.405	0.449	0.035	0.059	0.053	0.421	0.000	0.438
$FeCO_3$	0.015	0.049	0.048	0.011	0.019	0.020	0.067	0.006	0.089
$MnCO_3$	0.015	0.020	0.020	0.015	0.017	0.017	0.020	0.033	0.038

Sample	029-27	029-27	033-17b	033-17b	033-19	033-19	033-19	033-20	033-20
Drillhole	A29	A29	A33	A33	A33	A33	A33	A33	A33
Depth (m)	146.7	146.7	162.1	162.1	177	177	177	188.5	188.5
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	met	met	met
Spot ID	C2-4	C3-1	C1-2	C3-3	C1-4	C1-5	C2-4	C1-2	C2-1
Mineral	dolomite	dolomite	calcite	calcite	dolomite	calcite	calcite	calcite	calcite
CaO	28.77	27.31	50.64	51.18	27.67	51.62	51.04	52.09	50.06
MgO	17.81	20.29	2.03	0.40	20.46	1.89	1.52	2.02	1.33
FeOt	6.36	7.72	1.60	1.45	5.48	0.92	1.10	1.63	0.93
MnO	2.13	2.96	4.88	4.98	2.59	2.19	1.99	2.78	2.01
Total	55.07	58.27	59.18	58.02	56.25	56.71	55.67	58.56	54.40
atoms per formula unit									
Ca	0.513	0.487	0.903	0.913	0.493	0.921	0.910	0.929	0.893
Mg	0.442	0.503	0.050	0.010	0.508	0.047	0.038	0.050	0.033
Fe	0.089	0.107	0.022	0.020	0.076	0.013	0.015	0.023	0.013
Mn	0.030	0.042	0.069	0.070	0.037	0.031	0.028	0.039	0.028
Total	1.073	1.140	1.044	1.013	1.114	1.011	0.991	1.041	0.967
Carbonate composition (molar %)									
$CaCO_3$	0.478	0.427	0.865	0.901	0.443	0.910	0.918	0.892	0.923
$MgCO_3$	0.412	0.442	0.048	0.010	0.456	0.046	0.038	0.048	0.034
$FeCO_3$	0.082	0.094	0.021	0.020	0.068	0.013	0.015	0.022	0.013
$MnCO_3$	0.028	0.037	0.066	0.069	0.033	0.031	0.028	0.038	0.029

Notes: met = metamorphic; hyd = hydrothermal / cpx = clinopyroxene; qz = quartz

Table A2-7. (Cont)

Sample	033-20	033-20	009-16	009-16	009-16	009-16	029-30	009-03f	009-03f
Drillhole	A33	A33	A09	A09	A09	A09	A29	A09	A09
Depth (m)	188.5	188.5	179.35	179.35	179.35	179.35	167.8	71.55	71.55
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	met	met	met	met	met	met	met	hyd	hyd
Spot ID	C2-7	C4-1	C1-1	C1-4	C2-5	C2-9	C1-4	C3-2	C3-3
Mineral	calcite	calcite	calcite	dolomite	calcite	calcite	dolomite	calcite	calcite
CaO	50.51	51.95	55.26	30.24	53.55	49.41	29.92	54.00	53.20
MgO	1.50	1.84	1.60	19.75	0.39	0.52	17.79	0.51	1.37
FeOt	1.42	1.61	0.41	2.31	0.54	0.75	3.23	0.58	0.79
MnO	2.81	2.72	0.31	0.45	0.39	0.52	2.03	1.24	1.08
Total	56.26	58.21	57.58	52.75	54.86	51.19	52.96	56.33	56.44
atoms per formula unit									
Ca	0.901	0.926	0.985	0.539	0.955	0.881	0.534	0.963	0.949
Mg	0.037	0.046	0.040	0.490	0.010	0.013	0.441	0.013	0.034
Fe	0.020	0.022	0.006	0.032	0.008	0.010	0.045	0.008	0.011
Mn	0.040	0.038	0.004	0.006	0.005	0.007	0.029	0.017	0.015
Total	0.997	1.033	1.035	1.068	0.977	0.912	1.048	1.001	1.009
Carbonate composition (molar %)									
$CaCO_3$	0.903	0.897	0.952	0.505	0.977	0.966	0.509	0.962	0.940
$MgCO_3$	0.037	0.044	0.038	0.459	0.010	0.014	0.421	0.013	0.034
$FeCO_3$	0.020	0.022	0.005	0.030	0.008	0.011	0.043	0.008	0.011
$MnCO_3$	0.040	0.037	0.004	0.006	0.006	0.008	0.027	0.017	0.015

Sample	029-07	029-07	029-07	029-07	004-15	029-20	033-17b	033-11b	033-11b
Drillhole	A29	A29	A29	A29	A04	A29	A33	A33	A33
Depth (m)	55.9	55.9	55.9	55.9	164.05	110.1	162.1	106.5	106.5
Host Rock	marble	marble	marble	marble	marble	marble	marble	qz-cpx vein	qz-cpx vein
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C3-2	C3-6	C4-6	C4-7	C2-7	C1-3	C5-3	C5-1	C5-3
Mineral	calcite	dolomite	dolomite	calcite	calcite	calcite	calcite	calcite	calcite
CaO	53.93	29.93	28.65	54.86	54.26	53.98	52.81	56.65	55.17
MgO	2.45	17.01	17.99	1.21	0.24	0.07	0.35	0.00	0.00
FeOt	1.81	5.17	5.34	0.86	1.15	0.56	1.63	0.12	0.62
MnO	1.63	1.85	1.80	1.58	1.23	1.29	5.28	0.97	0.80
Total	59.95	54.08	53.86	58.82	56.92	55.93	60.06	57.76	56.64
atoms per formula unit									
Ca	0.962	0.534	0.511	0.978	0.968	0.963	0.942	1.010	0.984
Mg	0.061	0.422	0.446	0.030	0.006	0.002	0.009	0.000	0.000
Fe	0.025	0.072	0.074	0.012	0.016	0.008	0.023	0.002	0.009
Mn	0.023	0.026	0.025	0.022	0.017	0.018	0.074	0.014	0.011
Total	1.071	1.054	1.057	1.043	1.007	0.990	1.047	1.025	1.004
Carbonate composition (molar %)									
$CaCO_3$	0.898	0.507	0.483	0.938	0.961	0.972	0.899	0.985	0.980
$MgCO_3$	0.057	0.400	0.422	0.029	0.006	0.002	0.008	0.000	0.000
$FeCO_3$	0.024	0.068	0.070	0.012	0.016	0.008	0.022	0.002	0.009
$MnCO_3$	0.022	0.025	0.024	0.021	0.017	0.018	0.071	0.013	0.011

Notes: met = metamorphic; hyd = hydrothermal / cpx = clinopyroxene; qz = quartz

Table A2-7. (Cont)

Sample	033-04b	033-20	028-18	028-18	009-16	028-06a	029-30	029-30	033-37
Drillhole	A33	A33	A28	A28	A09	A28	A29	A29	A33
Depth (m)	55.75	188.5	206.6	206.6	179.35	64.5	167.8	167.8	158.45
Host Rock	qz-cpx vein	marble	BIF	BIF	BIF	qz-cpx vein	marble	marble	marble
Type	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-1	C3-3	C2-5	C3-2	C3-3	C1-10	C2-4	C2-5	C1-4
Mineral	calcite	calcite	calcite	calcite	calcite	calcite	calcite	dolomite	calcite
CaO	56.44	48.53	53.95	57.82	54.03	53.72	49.01	29.39	50.31
MgO	0.00	1.46	0.00	0.00	0.10	0.12	2.21	16.61	1.99
FeOt	0.09	2.47	1.14	0.77	1.49	1.94	1.39	4.45	1.59
MnO	0.43	4.49	2.57	0.70	0.54	1.21	2.15	2.14	2.28
Total	57.07	56.98	57.66	59.30	56.14	56.99	54.75	52.58	56.17
atoms per formula unit									
Ca	1.007	0.865	0.962	1.031	0.963	0.958	0.874	0.524	0.897
Mg	0.000	0.036	0.000	0.000	0.002	0.003	0.055	0.412	0.049
Fe	0.001	0.034	0.016	0.011	0.021	0.027	0.019	0.062	0.022
Mn	0.006	0.063	0.036	0.010	0.008	0.017	0.030	0.030	0.032
Total	1.014	0.999	1.014	1.052	0.994	1.005	0.978	1.028	1.001
Carbonate composition (molar %)									
$CaCO_3$	0.993	0.866	0.949	0.980	0.969	0.953	0.893	0.510	0.896
$MgCO_3$	0.000	0.036	0.000	0.000	0.002	0.003	0.056	0.401	0.049
$FeCO_3$	0.001	0.034	0.016	0.010	0.021	0.027	0.020	0.060	0.022
$MnCO_3$	0.006	0.063	0.036	0.009	0.008	0.017	0.031	0.029	0.032

Sample	033-37
Drillhole	A33
Depth (m)	158.45
Host Rock	marble
Type	hyd
Spot ID	C1-5
Mineral	dolomite
CaO	32.82
MgO	15.95
FeOt	5.34
MnO	2.85
Total	56.96
atoms per formula unit	
Ca	0.585
Mg	0.396
Fe	0.074
Mn	0.040
Total	1.096
Carbonate composition (molar %)	
$CaCO_3$	0.534
$MgCO_3$	0.361
$FeCO_3$	0.068
$MnCO_3$	0.037

Notes: met = metamorphic; hyd = hydrothermal / cpx = clinopyroxene; qz = quartz

TABLE A6-8 - Ilmenite compositional data

Table A2-8. Electron microprobe data for selected hydrothermal ilmenite grains

Sample	029-04	029-04	029-04	029-07	004-15	029-20	029-20
Drillhole	A29	A29	A29	A29	A04	A29	A29
Depth (m)	48.25	48.25	48.25	55.9	164.05	110.1	110.1
Host Rock	marble	marble	marble	marble	marble	marble	marble
Spot ID	C1-6	C3-4	C4-2	C4-1	C3-6	C4-1	C4-4
SiO_2	0.19	0.33	0.95	0.75	0.13	0.04	0.18
TiO_2	52.30	53.52	53.07	52.41	54.67	56.02	53.98
Al2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	0.02	0.07	0.00	0.02	0.00	0.04	0.02
V_2O_3	0.56	0.62	0.56	0.63	0.47	0.52	0.52
FeO_t	44.02	43.67	41.70	35.72	27.90	11.56	24.41
MnO	2.99	3.05	4.58	10.67	17.00	32.15	22.74
MgO	0.07	0.05	0.07	0.13	0.04	0.01	0.09
CaO	0.12	0.11	0.12	0.02	0.09	0.10	0.13
NiO	0.01	0.01	0.00	0.02	0.00	0.00	0.00
ZnO	0.00	0.00	0.12	0.03	0.02	0.03	0.00
Total	100.27	101.43	101.15	100.41	100.31	100.47	102.06
Mineral formula based on 3 oxygens							
Si	0.005	0.008	0.023	0.019	0.003	0.001	0.004
Ti	0.989	0.996	0.986	0.983	1.020	1.036	0.997
Al	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.000	0.001	0.000	0.000	0.000	0.001	0.000
V	0.011	0.012	0.011	0.013	0.009	0.010	0.010
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	0.925	0.903	0.861	0.745	0.579	0.238	0.501
Mn	0.064	0.064	0.096	0.225	0.357	0.669	0.473
Mg	0.003	0.002	0.002	0.005	0.001	0.000	0.003
Ca	0.003	0.003	0.003	0.001	0.002	0.003	0.003
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.002	0.001	0.000	0.001	0.000
Total	2.000	1.989	1.985	1.992	1.972	1.958	1.993
$Fe^{2+}/Mn+Fe^{2-}$	0.936	0.934	0.900	0.768	0.618	0.262	0.514
Classification	ilmenite	ilmenite	ilmenite	Mn-ilmenite	Mn-ilmenite	Fe-pyrophanite	Mn-ilmenite

TABLE A6-9 - Spinel compositional data

Table A2-9. Electron microprobe data for selected spinel grains

Sample	029-39a	029-27	033-19	033-19	033-19	033-19
Drillhole	A29	A29	A33	A33	A33	A33
Depth (m)	213.15	146.7	177	177	177	177
Host Rock	granite	marble	marble	marble	marble	marble
Type	mag?	hyd	hyd	hyd	hyd	hyd
Spot ID	C1-1	C3-4	C1-7	C2-2	C3-5	C4-1
SiO_2	0.08	0.06	0.02	0.94	0.36	0.15
TiO_2	0.00	0.00	0.03	0.00	0.00	0.00
Al_2O_3	57.66	58.83	62.04	62.08	61.49	62.52
Cr_2O_3	0.03	0.00	0.07	0.02	0.04	0.00
V_2O_3	0.00	0.00	0.02	0.00	0.07	0.01
FeO_t	16.54	30.72	25.92	25.02	26.04	25.31
MnO	0.18	1.74	1.62	1.69	1.81	1.69
MgO	0.59	8.70	11.62	11.04	10.90	11.25
CaO	0.00	0.01	0.06	0.02	0.00	0.02
ZnO	25.38	1.42	0.45	0.71	0.78	0.74
Total	100.46	101.47	101.85	101.53	101.48	101.69
Mineral formula based on 3 cations (iron as Fe^{2+} and Fe^{3+})						
Si	0.002	0.002	0.001	0.025	0.010	0.004
Ti	0.000	0.000	0.001	0.000	0.000	0.000
Al	2.005	1.881	1.924	1.934	1.923	1.943
Cr	0.001	0.000	0.001	0.000	0.001	0.000
V	0.000	0.000	0.000	0.000	0.001	0.000
Fe^{3+}	0.000	0.116	0.071	0.016	0.055	0.049
Fe^{2+}	0.408	0.581	0.499	0.537	0.522	0.509
Mn	0.004	0.040	0.036	0.038	0.041	0.038
Mg	0.026	0.352	0.456	0.435	0.431	0.442
Ca	0.000	0.000	0.002	0.001	0.000	0.001
Zn	0.553	0.028	0.009	0.014	0.015	0.014
Total	3.000	3.000	3.000	3.000	3.000	3.000
$Fe^{2+}/Mg+Fe^{2+}$	0.940	0.623	0.523	0.552	0.548	0.535
Classification	gahnite	pleonaste	pleonaste	pleonaste	pleonaste	pleonaste

Notes:
mag? = likely magmatic origin; hyd = hydrothermal

TABLE A6-10 - Arsenopyrite compositional data

Table A2-10. Electron microprobe data for selected arsenopyrite grains

Sample	033-11	033-11	033-11	033-11	033-11	033-11	033-11	033-11
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	99.2	99.2	99.2	99.2	99.2	99.2	99.2	99.2
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble
Type	asp-1-zo	asp-1-zo	asp-1-zo	asp-1-zo	asp-1-zo	asp-1-zo	asp-1-zo	asp-1-zo
Spot ID	C2-1	C2-2	C2-3	C2-4	C2-5	C2-6	C3-1	C3-2
	core	margin	core	margin	core	margin	core	margin
S	18.64	20.16	19.67	20.78	17.90	19.81	19.46	20.46
Fe	31.45	32.98	31.93	33.45	27.34	31.93	30.36	32.89
Co	1.30	0.43	1.38	0.15	3.25	0.87	2.01	0.41
Ni	0.45	0.22	0.16	0.15	2.10	0.36	0.58	0.41
Cu	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Zn	0.01	0.00	0.00	0.05	0.00	0.03	0.00	0.00
As	48.15	45.85	47.93	46.41	49.13	46.54	47.61	46.25
Ag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sb	0.03	0.04	0.05	0.00	0.00	0.04	0.01	0.03
Te	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Au	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pb	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Bi	0.04	0.00	0.00	0.04	0.09	0.00	0.11	0.00
Total	100.09	99.72	101.12	101.02	99.81	99.58	100.15	100.44
atoms per formula unit								
S	0.320	0.341	0.331	0.346	0.311	0.337	0.332	0.343
Fe	0.310	0.320	0.309	0.320	0.273	0.312	0.297	0.317
Co	0.012	0.004	0.013	0.001	0.031	0.008	0.019	0.004
Ni	0.004	0.002	0.001	0.001	0.020	0.003	0.005	0.004
Cu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As	0.354	0.332	0.346	0.331	0.365	0.339	0.347	0.332
Ag	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Te	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Au	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As (atomic %)	35.357	33.204	34.555	33.081	36.534	33.899	34.715	33.216
Fe/(As+S)	0.460	0.476	0.456	0.473	0.403	0.461	0.438	0.469
Co+Ni+Sb (wt.%)	1.78	0.70	1.58	0.30	5.35	1.27	2.60	0.85

Notes:

asp-1-zo = zoned arsenopyrite from the main stage hydrothermal alteration

asp-1-un = unzoned arsenopyrite from the main stage hydrothermal alteration

asp-2 = late arsenopyrite, likely from the late stage hydrothermal alteration stage

Table A2-10. (Cont)

Sample	033-11	033-11	033-11	033-11	033-11	033-11	033-11
Drillhole	A33	A33	A33	A33	A33	A33	A33
Depth (m)	99.2	99.2	99.2	99.2	99.2	99.2	99.2
Host Rock	marble	marble	marble	marble	marble	marble	marble
Type	asp-1-zo	asp-1-zo	asp-1-un	asp-1-un	asp-1-zo	asp-1-zo	asp-1-zo
Spot ID	C3-5	C3-6	C4-1	C4-2	C5-1	C5-2	C5-3
	core	margin	core	margin	margin	core	margin
S	15.57	20.52	19.14	20.26	20.48	18.32	18.50
Fe	28.18	32.92	32.14	33.06	33.23	30.77	30.64
Co	2.57	0.40	0.58	0.44	0.13	1.99	2.22
Ni	1.14	0.28	0.42	0.26	0.41	0.46	0.23
Cu	0.00	0.01	0.00	0.01	0.01	0.01	0.00
Zn	0.01	0.00	0.03	0.00	0.00	0.00	0.02
As	51.40	45.91	47.57	47.13	45.20	48.66	47.53
Ag	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sb	0.02	0.00	0.01	0.00	0.01	0.03	0.00
Te	0.00	0.00	0.00	0.00	0.04	0.01	0.00
Au	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pb	0.00	0.00	0.01	0.00	0.01	0.01	0.04
Bi	0.00	0.03	0.15	0.11	0.00	0.02	0.10
Total	98.88	100.07	100.03	101.26	99.51	100.28	99.27
atoms per formula unit							
S	0.279	0.345	0.327	0.339	0.346	0.315	0.320
Fe	0.290	0.318	0.315	0.317	0.322	0.304	0.304
Co	0.025	0.004	0.005	0.004	0.001	0.019	0.021
Ni	0.011	0.003	0.004	0.002	0.004	0.004	0.002
Cu	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As	0.394	0.331	0.348	0.337	0.327	0.358	0.352
Ag	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Te	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Au	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As (atomic %)	39.438	33.053	34.781	33.726	32.666	35.800	35.194
Fe/(As+S)	0.431	0.471	0.467	0.469	0.479	0.451	0.453
Co+Ni+Sb (wt.%)	3.72	0.68	1.00	0.70	0.55	2.47	2.45

Notes:

asp-1-zo = zoned arsenopyrite from the main stage hydrothermal alteration

asp-1-un = unzoned arsenopyrite from the main stage hydrothermal alteration

asp-2 = late arsenopyrite, likely from the late stage hydrothermal alteration stage

Table A2-10. (Cont)

Sample	033-04b	033-04b	033-04b	033-04b	033-04b	033-04b	033-04b	029-30
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	55.75	55.75	55.75	55.75	55.75	55.75	55.75	167.8
Host Rock	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	marble
Type	asp-1-un	asp-1-un	asp-2	asp-1-un	asp-1-un	asp-1-un	asp-1-un	asp-2?
Spot ID	C2-1	C2-S2	C2-S3	C4-1	C4-2	C5-1	C5-2	C1-2
	core	margin		core	margin	core	margin	
S	19.33	18.81	19.96	18.51	18.99	19.45	18.61	20.99
Fe	33.09	32.78	32.74	33.06	33.20	33.76	33.48	34.45
Co	0.08	0.13	0.00	0.12	0.07	0.05	0.02	0.01
Ni	0.18	0.21	0.53	0.03	0.05	0.11	0.16	0.01
Cu	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.03
Zn	0.01	0.03	0.00	0.00	0.00	0.01	0.00	0.00
As	47.92	47.75	47.08	48.57	48.07	47.42	48.19	46.45
Ag	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01
Sb	0.05	0.06	0.28	0.03	0.03	0.02	0.02	0.07
Te	0.00	0.01	0.00	0.00	0.05	0.00	0.04	0.00
Au	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pb	0.09	0.00	0.00	0.02	0.01	0.01	0.00	0.00
Bi	0.00	0.07	0.00	0.15	0.07	0.00	0.00	0.01
Total	100.79	99.84	100.59	100.51	100.56	100.82	100.52	102.03
atoms per formula unit								
S	0.327	0.323	0.337	0.317	0.323	0.328	0.318	0.346
Fe	0.322	0.323	0.317	0.325	0.325	0.327	0.328	0.326
Co	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.000
Ni	0.002	0.002	0.005	0.000	0.000	0.001	0.002	0.000
Cu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As	0.347	0.351	0.340	0.356	0.350	0.343	0.352	0.328
Ag	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Te	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Au	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As (atomic %)	34.738	35.057	33.997	35.592	35.026	34.272	35.213	32.754
Fe/(As+S)	0.477	0.480	0.469	0.483	0.482	0.488	0.490	0.484
Co+Ni+Sb (wt.%)	0.31	0.40	0.82	0.18	0.14	0.18	0.21	0.09

Notes:

asp-1-zo = zoned arsenopyrite from the main stage hydrothermal alteration

asp-1-un = unzoned arsenopyrite from the main stage hydrothermal alteration

asp-2 = late arsenopyrite, likely from the late stage hydrothermal alteration stage

TABLE A6-11 - Loellingite compositional data

Table A2-11. Electron microprobe data for selected loellingite grains

Sample	033-19	033-19	033-04b	033-04b	033-04b	033-04b	033-04b	033-11	033-11	033-11
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth	177	177	55.75	55.75	55.75	55.75	55.75	99.2	99.2	99.2
Host Rock	marble	marble	marble	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	marble	marble	marble
Spot ID	C4-S3	C5-S1	C1-S4	C3-S2	C3-S3	C4-S3	C4-S5	C3-4	C4-3	C4-4
S	0.99	0.79	2.38	1.78	1.62	1.71	1.72	1.46	0.98	1.10
Fe	25.15	24.51	23.78	29.38	29.27	29.22	28.78	20.29	21.80	21.65
Co	3.72	3.30	2.07	0.13	0.11	0.12	0.21	2.47	2.40	2.42
Ni	1.29	1.31	4.38	0.23	0.24	0.17	0.59	4.23	2.99	2.94
Cu	0.00	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.02	0.02
Zn	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.01	0.00	0.03
As	70.51	70.05	68.59	68.42	68.76	69.38	68.80	71.61	72.48	72.83
Ag	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.03
Sb	0.00	0.03	0.01	0.06	0.03	0.04	0.05	0.00	0.01	0.02
Te	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Au	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Pb	0.08	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.01	0.02
Bi	0.04	0.00	0.06	0.08	0.03	0.00	0.08	0.07	0.00	0.05
Total	101.78	100.00	101.26	100.19	100.11	100.68	100.26	100.15	100.69	101.09
atoms per formula unit										
S	0.020	0.017	0.049	0.037	0.034	0.035	0.036	0.031	0.021	0.023
Fe	0.299	0.297	0.279	0.350	0.350	0.347	0.343	0.246	0.264	0.261
Co	0.042	0.038	0.023	0.001	0.001	0.001	0.002	0.028	0.028	0.028
Ni	0.015	0.015	0.049	0.003	0.003	0.002	0.007	0.049	0.034	0.034
Cu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As	0.624	0.633	0.600	0.608	0.612	0.614	0.611	0.646	0.653	0.654
Ag	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Te	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Au	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
(Co+Ni)/(Co+Ni+Fe)	0.159	0.151	0.205	0.011	0.011	0.009	0.026	0.239	0.190	0.190

Note:
cpx = clinopyroxene; qz = quartz

TABLE A6-12 - Gold compositional data

Table A2-12. Electron microprobe data for selected gold grains

Sample	033-11b	033-11b	033-11b	033-11b	033-17b	033-11	029-30	029-30
Drillhole	A33	A33	A33	A33	A33	A33	A29	A29
Depth (m)	106.5	106.5	106.5	106.5	162.1	99.2	167.8	167.8
Host Rock	qtz-cpx vein	qtz-cpx vein	qtz-cpx vein	qtz-cpx vein	marble	marble	marble	marble
Spot	C6-S1	C6-S3	C6-S4	C6-S6	C5-S4	C3-3	C1-1	C1-3
S	0.06	0.12	0.09	0.06	0.07	0.17	0.04	0.05
Fe	0.10	0.06	0.33	0.49	0.07	0.46	0.20	0.31
Co	0.02	0.00	0.00	0.03	0.01	0.03	0.02	0.00
Ni	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.03
Cu	0.13	0.05	0.05	0.03	0.07	0.06	0.06	0.08
Zn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
As	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag	5.76	14.36	14.04	13.92	13.77	13.82	1.30	2.08
Sb	0.00	0.00	0.01	0.00	0.04	0.00	0.00	0.00
Te	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Au	92.01	85.32	83.99	84.06	85.94	85.89	98.89	98.83
Pb	0.02	0.01	0.00	0.05	0.00	0.00	0.05	0.00
Bi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	98.09	99.93	98.50	98.65	99.96	100.51	100.58	101.37
Fineness	897	765	766	768	774	773	977	963

Note:
cpx = clinopyroxene; qz = quartz

ELECTRONIC APPENDIX TABLE A7 - LA-ICP-MS – Magnetite

TABLE A7-1 - Magnetite compositional data

Table A3-1 Mineral chemistry data for magnetite obtained by LA-ICP-MS

Sample	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15
Drillhole	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28
Depth (m)	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65
Host Rock	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF
Type	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 2	mt 2	mt 2	mt 2
Spot ID	C1-1	C1-2	C1-3	C1-4	C1-5	C1-6	C2-1	C2-2	C2-3	C2-4	C2-5	C2-6	C3-3
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	902	509	25	603	430	1680	347	50	9	35	44	43	28
Al^{27}	590	503	423	564	971	679	296	412	319	468	378	374	366
Sc^{45}	0.01	0.01	b.d.l.	0.17	b.d.l.	0.04	0.17	0.02	0.06	b.d.l.	b.d.l.	b.d.l.	0.12
Ti^{49}	138	144	146	133	165	145	102	127	124	98	88	88	81
V^{51}	187	182	191	177	181	186	118	166	172	113	94	93	93
Cr^{52}	27	22	24	12	15	14	16	23	11	17	19	34	26
Mn^{55}	603	589	733	697	1117	584	612	585	534	1090	934	1157	1120
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	b.d.l.	0.67	0.82	0.99	1.35	0.57	0.17	0.82	0.83	0.83	0.57	0.43	0.54
Ni^{60}	2.27	2.06	b.d.l.	1.71	0.57	1.57	b.d.l.	b.d.l.	0.82	2.26	b.d.l.	b.d.l.	0.33
Cu^{65}	0.15	3.97	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.00	0.84	b.d.l.	0.31	0.12	0.12	0.51
Zn^{66}	62	98	115	89	206	68	77	79	54	130	122	147	129
Ga^{69}	3.92	4.34	4.69	4.50	6.09	4.33	4.69	4.82	4.66	4.85	4.59	4.79	4.94
Ge^{74}	2.37	2.45	2.73	2.38	2.52	2.28	2.21	2.18	2.32	2.43	2.70	2.54	2.56
As^{75}	0.22	0.16	0.03	0.15	0.37	0.06	b.d.l.	0.01	b.d.l.	0.08	0.14	0.09	0.04
Sr^{88}	2.25	0.83	b.d.l.	0.50	2.16	0.51	0.03	b.d.l.	0.03	b.d.l.	b.d.l.	b.d.l.	0.00
Y^{89}	0.98	0.38	0.00	0.46	1.32	0.41	0.06	0.04	b.d.l.	0.02	0.02	0.00	b.d.l.
Nb^{93}	0.33	0.20	0.02	0.27	2.25	0.24	0.03	0.17	0.00	0.12	0.12	0.16	0.12
Sn^{118}	1.22	1.13	1.29	1.11	1.32	1.15	1.04	1.03	1.04	1.20	1.15	1.18	1.25
Ba^{137}	0.93	1.41	b.d.l.	0.03	12.03	0.50	0.03	1.47	0.05	b.d.l.	0.01	0.06	b.d.l.
W^{183}	0.06	b.d.l.	0.03	0.07	0.54	0.15	b.d.l.	0.02	b.d.l.	0.01	0.03	b.d.l.	0.13
Au^{197}	b.d.l.	0.0114	0.0346	b.d.l.	0.0182	0.0145	b.d.l.	b.d.l.	0.0169	0.0089	b.d.l.	0.0244	b.d.l.
Pb^{208}	0.33	0.42	0.00	0.17	0.64	0.22	0.05	0.16	0.04	0.03	0.13	0.09	0.06
Al/Ga	151	116	90	125	159	157	63	86	68	96	82	78	74
Mg/Mn	1.50	0.86	0.03	0.87	0.39	2.88	0.57	0.09	0.02	0.03	0.05	0.04	0.03
Ni/Co	---	3.08	---	1.72	0.42	2.73	---	---	0.99	2.74	---	---	0.62

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	028-15	028-15	028-15	028-15	028-15	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36
Drillhole	A28	A28	A28	A28	A28	A29	A29	A29	A29	A29	A29	A29	A29
Depth (m)	192.65	192.65	192.65	192.65	192.65	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2
Host Rock	BIF	BIF	BIF	BIF	BIF	marble	marble	marble	marble	marble	marble	marble	marble
Type	mt 2	mt 2	mt 2	mt 2	mt 2	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1
Spot ID	C3-4	C4-1	C4-2	C4-3	C4-4	C1-1	C1-2	C1-3	C1-4	C1-5	C1-6	C2-1	C2-2
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	20	34	43	19	16	2103	2208	2221	2169	2519	2270	2332	2277
Al^{27}	349	442	435	379	408	1401	1419	1469	1510	1278	1407	1791	1788
Sc^{45}	b.d.l.	0.02	b.d.l.	b.d.l.	0.06	5.03	5.71	5.54	5.95	5.69	5.48	5.64	5.90
Ti^{49}	86	108	110	99	106	484	523	500	502	520	527	519	522
V^{51}	93	121	126	105	115	258	281	268	264	276	273	187	177
Cr^{52}	15	27	19	5	4	29	42	30	11	21	35	33	24
Mn^{55}	956	924	1131	1031	942	4904	4773	4850	4618	5220	4989	4792	4936
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	b.d.l.	0.83	0.52	0.18	0.18	0.59	0.80	0.78	1.01	1.12	1.52	0.71	0.49
Ni^{60}	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	2.85	2.28	0.70	3.47	2.38	3.52	1.04	0.04
Cu^{65}	0.09	0.27	b.d.l.	0.03	0.15	0.01	2.07	0.22	b.d.l.	0.36	0.25	0.92	b.d.l.
Zn^{66}	92	128	152	110	122	115	291	390	226	139	255	303	170
Ga^{69}	4.97	4.80	5.00	5.20	5.45	2.14	2.36	2.37	2.39	2.20	2.40	2.15	2.17
Ge^{74}	2.72	2.74	2.77	3.03	3.03	4.08	4.01	3.99	4.07	3.78	4.02	3.67	3.79
As^{75}	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.10	0.01	0.04	0.47	b.d.l.	0.09	0.03	0.00	b.d.l.
Sr^{88}	b.d.l.	b.d.l.	0.01	b.d.l.	b.d.l.	0.03	b.d.l.	0.01	0.12	0.11	0.20	0.03	b.d.l.
Y^{89}	b.d.l.	b.d.l.	0.01	0.03	b.d.l.	0.50	0.24	0.18	0.03	2.37	0.28	0.10	0.06
Nb^{93}	0.08	0.02	0.14	0.05	0.08	0.04	0.01	0.01	0.05	0.51	0.07	0.20	0.04
Sn^{118}	1.26	1.46	1.37	1.48	1.22	1.56	1.86	1.53	1.72	1.55	1.86	2.05	1.70
Ba^{137}	0.07	b.d.l.	0.05	0.12	0.10	b.d.l.	0.12	0.10	0.01	0.15	0.08	b.d.l.	0.08
W^{183}	0.03	0.04	0.24	b.d.l.	b.d.l.	0.90	b.d.l.	0.13	b.d.l.	4.76	0.05	0.13	0.21
Au^{197}	b.d.l.	b.d.l.	b.d.l.	0.0250	b.d.l.	0.0108	0.0023	0.0366	b.d.l.	0.0102	0.0179	0.0092	0.0339
Pb^{208}	0.20	0.11	0.10	0.34	0.10	0.09	0.22	0.18	0.16	0.30	0.25	0.30	0.21
Al/Ga	70	92	87	73	75	654	601	620	632	580	585	835	826
Mg/Mn	0.02	0.04	0.04	0.02	0.02	0.43	0.46	0.46	0.47	0.48	0.45	0.49	0.46
Ni/Co	---	---	---	---	---	4.83	2.84	0.90	3.43	2.13	2.32	1.46	0.08

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	028-19	028-19	028-19
Drillhole	A29	A29	A29	A29	A29	A29	A29	A29	A29	A29	A28	A28	A28
Depth (m)	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	210.8	210.8	210.8
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	BIF	BIF	BIF
Type	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 1	mt 0	mt 0	mt 0
Spot ID	C2-3	C3-1	C3-2	C3-3	C3-4	C3-5	C4-1	C4-2	C4-3	C4-4	C1-1	C1-2	C1-3
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	2339	1709	2390	2308	2369	2303	2349	2259	1935	2370	206	577	304
Al^{27}	1931	1244	2027	1672	1590	1761	1492	1822	1415	1364	416	371	337
Sc^{45}	5.65	5.73	5.78	5.94	5.91	6.19	5.64	5.43	4.89	5.19	0.30	b.d.l.	0.02
Ti^{49}	510	495	504	504	520	517	614	641	593	624	628	731	651
V^{51}	179	187	174	179	183	188	225	213	219	216	335	351	335
Cr^{52}	25	17	26	37	21	32	31	29	47	65	12	25	24
Mn^{55}	4655	4540	4549	4832	4663	4892	5440	4860	4338	4940	498	804	717
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	0.43	1.05	0.98	0.57	0.53	0.24	1.08	0.73	0.74	1.12	b.d.l.	b.d.l.	b.d.l.
Ni^{60}	b.d.l.	0.66	0.32	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.52	1.36	b.d.l.	0.74	b.d.l.	b.d.l.
Cu^{65}	0.17	0.14	0.15	0.83	b.d.l.	b.d.l.	4.91	0.43	0.34	0.35	0.92	0.96	0.82
Zn^{66}	567	25	520	230	84	376	59	122	186	38	48	43	33
Ga^{69}	2.64	2.12	2.52	2.29	2.42	2.19	2.00	2.09	2.11	1.90	4.45	4.30	4.15
Ge^{74}	3.72	3.86	4.18	3.69	4.03	3.62	3.71	3.68	3.73	3.80	2.81	2.70	2.91
As^{75}	0.05	b.d.l.	0.04	0.15	0.09	0.23	0.31	0.21	0.28	0.15	0.59	0.31	b.d.l.
Sr^{88}	0.07	0.16	b.d.l.	b.d.l.	0.03	0.09	0.17	0.04	0.03	0.09	5.64	3.13	1.70
Y^{89}	0.09	0.03	0.09	0.17	0.22	0.32	1.19	0.06	0.42	1.16	4.83	3.59	3.32
Nb^{93}	0.20	0.01	0.07	0.23	0.19	0.12	0.16	0.09	0.06	0.19	0.57	0.34	0.17
Sn^{118}	1.79	1.65	1.74	1.47	1.80	1.59	1.59	1.83	1.41	1.58	1.30	2.28	1.84
Ba^{137}	2.77	0.15	0.10	0.03	0.07	0.07	0.15	0.08	0.11	0.09	4.50	3.77	1.54
W^{183}	0.26	0.78	0.03	0.07	b.d.l.	b.d.l.	4.38	0.11	3.42	5.95	0.32	0.58	b.d.l.
Au^{197}	b.d.l.	b.d.l.	0.0092	b.d.l.	0.0024	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.0029	b.d.l.	0.0245	0.0856
Pb^{208}	0.19	0.07	0.31	0.17	0.32	0.12	1.22	0.44	0.11	0.25	1.21	0.99	0.16
Al/Ga	731	588	804	730	657	803	748	870	671	716	93	86	81
Mg/Mn	0.50	0.38	0.53	0.48	0.51	0.47	0.43	0.46	0.45	0.48	0.41	0.72	0.42
Ni/Co	---	0.63	0.33	---	---	---	---	0.72	1.83	---	---	---	---

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19
Drillhole	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28
Depth (m)	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8
Host Rock	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF
Type	mt 0	mt 0	mt 0	mt 0	mt 0	mt 0	mt 0	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2
Spot ID	C1-4	C1-5	C1-6	C2-1	C2-2	C2-3	C2-4	C3-1	C3-2	C3-3	C3-6	C3-7	C3-8
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	251	98	1340	118	551	498	151	1103	37	295	111	52	6
Al^{27}	353	467	484	370	276	247	272	681	497	485	258	277	202
Sc^{45}	b.d.l.	b.d.l.	0.03	b.d.l.	b.d.l.	0.08	b.d.l.	0.18	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Ti^{49}	715	727	726	761	697	696	751	1131	1182	1079	1174	1603	1843
V^{51}	330	340	349	324	348	318	357	343	319	320	305	333	329
Cr^{52}	16	16	23	17	19	20	24	43	62	77	45	62	75
Mn^{55}	807	478	1064	619	693	586	444	536	266	364	213	252	284
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.02	b.d.l.	0.19	b.d.l.	b.d.l.	b.d.l.	0.07	0.13
Ni^{60}	2.62	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	3.87	b.d.l.	b.d.l.
Cu^{65}	b.d.l.	7.70	b.d.l.	1.40	b.d.l.	6.19	18.09	b.d.l.	0.39	0.23	1.04	1.69	b.d.l.
Zn^{66}	74	169	81	143	19	84	32	16	14	5	4	10	11
Ga^{69}	4.36	4.93	4.47	4.96	3.72	4.61	3.92	3.83	3.93	3.56	3.28	3.36	3.85
Ge^{74}	2.73	2.77	2.89	2.56	2.75	2.78	2.65	1.30	1.19	1.37	1.81	1.46	1.54
As^{75}	b.d.l.	b.d.l.	0.02	b.d.l.	0.52	b.d.l.	b.d.l.	0.36	0.14	b.d.l.	0.13	0.12	b.d.l.
Sr^{88}	0.94	0.67	1.48	0.46	2.74	2.37	1.28	0.64	0.01	1.00	0.40	0.07	b.d.l.
Y^{89}	2.56	1.55	5.28	3.48	7.53	6.17	3.40	0.76	0.16	4.70	0.75	0.27	0.05
Nb^{93}	0.22	0.10	0.40	0.11	0.30	0.57	0.12	0.01	0.00	0.16	0.03	0.04	0.00
Sn^{118}	1.55	1.71	2.07	2.00	1.53	0.80	0.98	1.24	0.74	0.67	0.47	0.68	1.01
Ba^{137}	3.48	1.34	2.70	0.16	0.21	19.59	1.08	0.11	0.67	0.54	0.92	0.27	0.11
W^{183}	0.10	b.d.l.	0.35	0.20	b.d.l.	b.d.l.	b.d.l.	0.12	0.05	b.d.l.	0.01	0.08	0.03
Au^{197}	0.2250	b.d.l.	0.1415	b.d.l.	b.d.l.	b.d.l.	0.0597	0.0032	0.0075	0.0114	0.0780	0.0781	0.0536
Pb^{208}	0.35	0.30	0.46	0.11	0.15	1.02	0.08	0.11	0.03	0.06	0.40	0.60	b.d.l.
Al/Ga	81	95	108	75	74	53	69	178	127	136	79	82	52
Mg/Mn	0.31	0.21	1.26	0.19	0.79	0.85	0.34	2.06	0.14	0.81	0.52	0.21	0.02
Ni/Co	---	---	---	---	---	---	---	---	---	---	---	---	---

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	028-19	028-19	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15
Drillhole	A28	A28	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	210.8	210.8	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5
Host Rock	BIF	BIF	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	mt 2	mt 0	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2
Spot ID	C3-9	C3-10	C1-1	C1-2	C1-3	C1-4	C1-5	C2-1	C2-2	C2-3	C2-4	C2-5	C2-6
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	15	54	453	1156	919	580	1041	930	906	1104	2766	1036	1956
Al^{27}	413	223	2394	5957	4819	3656	5648	4404	4893	5524	14397	5470	8421
Sc^{45}	b.d.l.	b.d.l.	5.68	10.99	9.14	11.25	11.64	10.13	11.37	12.59	7.44	8.62	9.23
Ti^{49}	1806	1246	2037	2295	2550	3936	5803	2817	4455	5409	3494	3138	6689
V^{51}	331	382	490	510	506	528	558	581	560	597	588	576	588
Cr^{52}	71	18	410	285	307	324	281	259	343	329	285	272	252
Mn^{55}	300	316	1362	1819	1635	2333	3072	1976	2408	2896	2573	1946	3134
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	b.d.l.	0.90	1.54	2.41	2.29	2.50	3.08	3.13	1.44	3.23	3.02	2.20	2.97
Ni^{60}	b.d.l.	b.d.l.	4.20	0.60	0.70	1.56	b.d.l.	b.d.l.	b.d.l.	1.29	0.02	0.69	2.13
Cu^{65}	b.d.l.	0.81	757.47	0.21	0.19	0.43	b.d.l.	0.08	b.d.l.	0.71	b.d.l.	0.04	0.54
Zn^{66}	18	9	46	63	64	30	61	29	51	79	318	50	128
Ga^{69}	3.92	3.52	13.35	12.13	12.63	12.05	14.09	13.15	13.42	14.14	17.45	14.10	15.95
Ge^{74}	1.34	1.56	6.34	5.71	6.58	6.41	7.77	6.73	7.41	6.95	7.45	6.96	7.54
As^{75}	0.03	b.d.l.	0.05	0.09	0.10	b.d.l.	b.d.l.	0.11	b.d.l.	0.09	0.10	b.d.l.	0.09
Sr^{88}	0.01	0.19	0.18	b.d.l.	0.08	0.17	0.08	0.16	0.01	b.d.l.	0.15	0.11	0.08
Y^{89}	b.d.l.	0.69	0.11	b.d.l.	0.03	0.01	0.02	0.01	b.d.l.	0.01	0.04	0.01	0.02
Nb^{93}	0.02	0.11	0.71	0.02	0.03	0.02	0.02	b.d.l.	0.02	0.03	0.04	0.01	0.03
Sn^{118}	0.94	0.85	3.49	8.58	7.81	8.65	13.68	8.83	10.65	12.57	10.48	10.97	12.99
Ba^{137}	0.06	0.62	0.66	b.d.l.	0.25	0.07	0.00	b.d.l.	0.15	b.d.l.	0.27	0.00	b.d.l.
W^{183}	b.d.l.	0.30	6.12	0.02	b.d.l.	0.03	b.d.l.	1.92	0.12	0.08	0.23	0.00	b.d.l.
Au^{197}	b.d.l.	0.0407	b.d.l.	b.d.l.	0.0083	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.0074	b.d.l.	0.0217
Pb^{208}	0.04	0.18	0.30	0.14	0.05	0.10	0.11	0.11	0.25	0.31	b.d.l.	b.d.l.	0.07
Al/Ga	105	63	179	491	381	303	401	335	365	391	825	388	528
Mg/Mn	0.05	0.17	0.33	0.64	0.56	0.25	0.34	0.47	0.38	0.38	1.07	0.53	0.62
Ni/Co	---	---	2.72	0.25	0.31	0.62	---	---	---	0.40	0.01	0.31	0.72

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	033-15	033-15	033-15	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	141.5	141.5	141.5	162.1	162.1	162.1	162.1	162.1	162.1	162.1	162.1	162.1	162.1
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2
Spot ID	C3-1	C3-2	C3-3	C1-3	C1-4	C1-5	C2-1	C2-2	C2-3	C2-4	C2-5	C3-1	C3-2
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	1175	749	1093	293	8002	15630	124	172	139	135	96	264	1275
Al^{27}	5640	15903	5550	2600	7758	9745	1252	1542	1547	1624	1293	1487	1350
Sc^{45}	11.65	11.10	8.42	0.29	0.51	4.84	0.20	0.04	0.14	0.18	b.d.l.	0.24	0.09
Ti^{49}	4596	4264	4124	3282	2867	3450	3872	4881	6055	8768	3934	5084	3921
V^{51}	567	569	539	91	91	97	312	313	328	272	271	376	349
Cr^{52}	183	166	198	131	162	87	32	40	62	59	34	127	62
Mn^{55}	2294	1936	1535	7374	8394	8947	6066	6402	7450	9591	5781	5684	5145
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	3.16	2.97	4.01	3.31	3.49	3.27	3.61	4.18	3.88	4.30	3.68	3.84	3.35
Ni^{60}	2.62	1.75	1.78	0.50	0.04	2.52	1.24	1.26	2.10	1.23	1.63	1.95	2.14
Cu^{65}	b.d.l.	0.19	0.55	0.50	0.17	0.41	0.26	0.33	0.36	0.77	0.03	0.25	1.36
Zn^{66}	34	89	131	606	223	202	244	273	312	409	217	204	347
Ga^{69}	12.32	13.73	11.80	4.70	4.53	11.09	8.85	8.79	8.94	9.64	8.88	10.46	9.65
Ge^{74}	6.12	6.16	7.08	0.97	1.28	1.40	1.91	1.89	2.10	1.95	1.77	2.13	3.13
As^{75}	b.d.l.	0.05	1.40	b.d.l.	0.12	0.22	0.11	0.11	0.04	0.42	0.01	0.08	0.15
Sr^{88}	b.d.l.	0.11	44.47	0.20	3.72	10.27	0.10	0.09	0.06	0.25	0.23	0.03	0.32
Y^{89}	0.03	0.52	26.46	0.02	0.50	6.19	0.04	0.05	0.00	0.03	0.02	0.28	1.61
Nb^{93}	b.d.l.	0.03	0.23	0.13	0.50	1.06	0.01	0.01	0.01	0.37	0.00	0.05	0.03
Sn^{118}	14.06	13.25	9.71	1.24	1.44	1.65	1.86	2.06	2.20	2.32	1.91	2.33	2.29
Ba^{137}	b.d.l.	0.09	0.50	1.02	1.00	68.26	4.39	3.36	0.00	0.97	4.59	0.50	0.90
W^{183}	b.d.l.	17.89	1.91	b.d.l.	1.57	1.07	0.10	0.17	0.10	0.00	0.04	0.61	0.79
Au^{197}	0.0009	0.0201	b.d.l.	b.d.l.	0.0231	0.0125	b.d.l.	b.d.l.	0.0250	b.d.l.	0.0024	0.0167	0.0288
Pb^{208}	0.21	0.54	0.73	0.21	0.22	2.06	0.12	0.14	0.20	0.17	0.20	0.18	0.44
Al/Ga	458	1158	470	553	1714	879	141	175	173	168	146	142	140
Mg/Mn	0.51	0.39	0.71	0.04	0.95	1.75	0.02	0.03	0.02	0.01	0.02	0.05	0.25
Ni/Co	0.83	0.59	0.44	0.15	0.01	0.77	0.34	0.30	0.54	0.29	0.44	0.51	0.64

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	HS-10	HS-10	HS-10	HS-10	HS-10
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	surface	surface	surface	surface	surface
Depth (m)	162.1	162.1	162.1	162.1	162.1	162.1	162.1	162.1	n/a	n/a	n/a	n/a	n/a
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2
Spot ID	C3-3	C4-1	C4-3	C4-4	C4-5	C5-1	C6-4	C6-5	C1-1	C1-2	C2-1	C2-2	C2-3
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	73	2238	1169	151	54	172	1238	589	200	95	85	135	108
Al^{27}	1774	698	471	1649	1270	1767	1075	1335	1619	934	1476	2369	1746
Sc^{45}	0.06	0.30	0.13	0.16	0.02	0.19	0.10	0.32	0.28	0.22	0.21	0.25	0.50
Ti^{49}	6820	1231	657	5993	5886	9001	3673	4811	3872	3454	3337	4187	3256
V^{51}	409	26	1	249	218	316	197	419	168	152	153	153	212
Cr^{52}	98	40	26	59	35	74	45	135	17	36	19	22	57
Mn^{55}	6555	4907	4715	7486	7435	9788	4829	6027	4851	3892	4430	5516	3284
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	4.59	4.65	3.21	3.16	2.10	2.78	3.02	6.03	3.38	3.05	2.76	2.67	4.05
Ni^{60}	1.71	21.48	6.22	2.18	0.66	3.90	3.44	3.25	1.18	3.71	1.99	0.69	0.86
Cu^{65}	b.d.l.	1.18	0.16	0.16	0.14	0.50	0.40	0.91	7.32	0.22	0.12	0.09	0.02
Zn^{66}	356	105	112	290	406	454	81	369	179	196	188	166	216
Ga^{69}	11.42	4.52	4.12	8.42	7.91	9.76	6.85	11.08	6.39	5.85	6.05	6.51	7.28
Ge^{74}	2.10	2.26	1.34	1.80	1.60	2.00	1.98	1.86	1.37	1.28	1.60	1.57	1.69
As^{75}	0.11	2.31	0.25	b.d.l.	b.d.l.	0.12	0.16	b.d.l.	0.43	0.01	b.d.l.	b.d.l.	0.27
Sr^{88}	b.d.l.	0.35	0.00	b.d.l.	0.03	0.12	0.30	0.22	0.08	0.04	0.08	b.d.l.	b.d.l.
Y^{89}	0.01	1.54	0.10	0.02	0.02	0.03	0.83	0.32	0.02	0.02	b.d.l.	0.00	0.02
Nb^{93}	0.02	1.08	0.46	0.04	0.01	0.03	0.12	0.01	0.07	0.02	0.01	0.02	b.d.l.
Sn^{118}	2.25	0.98	0.89	2.35	1.59	2.10	1.28	2.44	13.94	12.14	12.99	15.67	15.09
Ba^{137}	0.10	6.33	1.49	0.08	0.50	0.11	7.60	2.06	0.53	b.d.l.	b.d.l.	0.01	0.03
W^{183}	0.02	3.05	0.50	b.d.l.	b.d.l.	0.07	1.16	0.89	0.12	b.d.l.	0.02	0.12	0.24
Au^{197}	0.0021	0.0208	0.0314	b.d.l.	b.d.l.	0.0139	b.d.l.	b.d.l.	0.0096	b.d.l.	0.0240	0.0049	b.d.l.
Pb^{208}	0.09	1.18	0.54	b.d.l.	0.14	0.01	0.18	0.28	0.54	0.00	0.06	0.03	0.14
Al/Ga	155	154	114	196	161	181	157	120	253	160	244	364	240
Mg/Mn	0.01	0.46	0.25	0.02	0.01	0.02	0.26	0.10	0.04	0.02	0.02	0.02	0.03
Ni/Co	0.37	4.62	1.94	0.69	0.31	1.40	1.14	0.54	0.35	1.22	0.72	0.26	0.21

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont.)

Sample	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10	029-30	029-30	029-30	029-30	029-30	029-30	029-30
Drillhole	surface	surface	surface	surface	surface	surface	A29	A29	A29	A29	A29	A29	A29
Depth (m)	n/a	n/a	n/a	n/a	n/a	n/a	167.8	167.8	167.8	167.8	167.8	167.8	167.8
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Type	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2	mt 2
Spot ID	C2-4	C2-5	C3-1	C3-2	C3-3	C3-4	C1-1	C1-2	C1-3	C1-4	C3-1	C3-2	C3-4
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Mg^{24}	360	191	184	191	526	116	306	61	238	461	453	260	686
Al^{27}	2182	1951	3062	2808	2758	1824	1337	592	1053	2075	1099	789	1250
Sc^{45}	0.25	0.11	0.11	0.22	b.d.l.	0.09	5.80	3.77	4.51	6.10	4.75	4.21	3.65
Ti^{49}	4287	4803	3074	2915	3215	2849	4895	2717	3232	3567	4410	2792	4264
V^{51}	202	198	114	109	121	154	51	85	55	57	98	99	135
Cr^{52}	46	19	36	49	19	31	122	163	138	190	89	82	90
Mn^{55}	4406	4335	4476	4268	5721	3779	3016	1125	1777	2249	2227	1836	2697
Fe^{57}	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177	720177
Co^{59}	3.63	4.41	3.98	4.53	2.55	2.57	0.95	0.56	0.11	0.30	1.09	0.78	1.03
Ni^{60}	0.23	3.77	2.32	4.07	1.86	4.75	0.41	0.16	0.43	1.47	b.d.l.	b.d.l.	b.d.l.
Cu^{65}	b.d.l.	0.23	1.79	b.d.l.	0.26	0.17	b.d.l.	b.d.l.	0.52	0.40	0.12	b.d.l.	0.94
Zn^{66}	186	271	104	155	219	204	787	222	442	39	655	590	1018
Ga^{69}	7.33	7.18	7.34	6.86	6.74	6.47	6.17	3.79	5.02	6.81	5.12	5.08	5.16
Ge^{74}	1.75	1.76	1.26	1.26	1.37	1.50	1.97	1.86	1.55	1.94	2.24	2.12	2.00
As^{75}	0.30	0.16	b.d.l.	0.05	0.06	0.14	b.d.l.	0.02	0.06	b.d.l.	b.d.l.	b.d.l.	0.05
Sr^{88}	0.07	0.07	b.d.l.	0.05	0.35	0.03	0.11	b.d.l.	b.d.l.	b.d.l.	0.07	b.d.l.	0.16
Y^{89}	0.07	b.d.l.	0.02	0.02	0.82	0.01	b.d.l.	0.03	b.d.l.	0.01	b.d.l.	0.01	0.01
Nb^{93}	0.07	0.11	0.83	0.47	1.01	0.05	b.d.l.	0.00	b.d.l.	b.d.l.	0.01	b.d.l.	b.d.l.
Sn^{118}	16.28	17.31	12.37	11.85	12.31	11.51	2.53	1.26	1.53	2.28	2.31	2.39	2.41
Ba^{137}	0.16	b.d.l.	b.d.l.	0.04	0.18	b.d.l.	0.03	0.03	0.01	b.d.l.	b.d.l.	0.08	0.09
W^{183}	0.14	0.09	0.11	b.d.l.	0.43	b.d.l.	b.d.l.	b.d.l.	0.16	0.14	0.03	0.01	0.20
Au^{197}	0.0077	0.0326	b.d.l.	b.d.l.	0.0031	b.d.l.	b.d.l.	0.0153	0.1016	0.0207	0.0173	b.d.l.	b.d.l.
Pb^{208}	0.11	0.19	0.05	0.10	0.63	0.13	0.26	0.15	0.13	0.09	0.20	0.11	0.15
Al/Ga	298	272	417	409	409	282	217	156	210	305	215	155	242
Mg/Mn	0.08	0.04	0.04	0.04	0.09	0.03	0.10	0.05	0.13	0.21	0.20	0.14	0.25
Ni/Co	0.06	0.85	0.58	0.90	0.73	1.85	0.43	0.29	3.94	4.86	---	---	---

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

Table A3-1. (Cont)

Sample	029-30
Drillhole	A29
Depth (m)	167.8
Host Rock	marble
Type	mt 2
Spot ID	C3-5
IS	Fe^{57}
Mg^{24}	633
Al^{27}	1218
Sc^{45}	4.01
Ti^{49}	2102
V^{51}	154
Cr^{52}	54
Mn^{55}	1448
Fe^{57}	720177
Co^{59}	b.d.l.
Ni^{60}	b.d.l.
Cu^{65}	b.d.l.
Zn^{66}	338
Ga^{69}	4.94
Ge^{74}	2.16
As^{75}	0.09
Sr^{88}	0.00
Y^{89}	0.06
Nb^{93}	0.01
Sn^{118}	1.67
Ba^{137}	0.11
W^{183}	0.30
Au^{197}	b.d.l.
Pb^{208}	0.14
Al/Ga	247
Mg/Mn	0.44
Ni/Co	---

Notes: IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm; b.d.l. = below detection limit; mt 0 = metamorphic BIF magnetite; mt 1 = hydrothermal magnetite 1 (pre-main stage pyrrhotite); mt 2 = hydrothermal magnetite 2 (early- to syn-main stage pyrrhotite)

TABLE A7-2 - Quality control

Table A3-2. LA-ICP-MS quality control spreadsheet for magnetite analyses (external standard = MACS-3)

Statistics and comparison with certified values

BHVO-2						NISTSRM610					
	rv	2sd	ma	2sd	n		rv	2sd	ma	2sd	n
Mg^{24}	43600	420	32701	3293	22	Mg^{24}	432	29	412	116	15
Al^{27}	71600	600	54880	7443	22	Al^{27}	10323	212	8248	2176	15
Sc^{45}	31.83	0.34	37.27	1.94	22	Sc^{45}	455	10	613	181	15
Ti^{49}	16310	180	15902	798	22	Ti^{49}	452	10	522	152	15
V^{51}	318.2	2.3	350.9	33.1	22	V^{51}	450	9	550	162	15
Cr^{52}	287.2	3.1	218.2	17.1	22	Cr^{52}	408	10	388	116	15
Mn^{55}	1309	19	1267	110	22	Mn^{55}	444	13	461	121	15
Fe^{57}			IS			Fe^{57}			IS		
Co^{59}	44.89	0.32	52.76	3.50	22	Co^{59}	410	10	490	145	15
Ni^{60}	119.8	1.2	122.3	11.4	22	Ni^{60}	458.7	4	481.5	136.4	15
Cu^{65}	129.3	1.4	139.2	13.8	22	Cu^{65}	441	15	521	147	15
Zn^{66}	103.9	1	240.1	21.3	22	Zn^{66}	460	18	920	286	15
Ga^{69}	21.37	0.2	21.87	1.56	22	Ga^{69}	433	13	267	9	15
Ge^{74}	1.623	0.039	1.634	0.180	22	Ge^{74}	447	78	445	152	15
As^{75}	0.7	0.11	0.65	0.21	22	As^{75}	325	18	308	102	15
Sr^{88}	394.1	1.7	321.0	28.7	22	Sr^{88}	515.5	1	501.2	141.0	15
Y^{89}	25.91	0.28	21.49	1.62	22	Y^{89}	462	11	576	172	15
Zr^{90}	171.2	1.3	113.6	8.9	22	Zr^{90}	448	9	418	133	15
Nb^{93}	18.1	0.2	12.8	1.2	22	Nb^{93}	465	34	375	124	15
Mo^{95}	4.07	0.16	4.00	0.82	22	Mo^{95}	417	21	447	139	15
Ag^{109}						Ag^{109}	251	9	337	116	15
Sn^{118}	1.776	0.059	1.850	0.269	22	Sn^{118}	430	29	547	186	15
Sb^{121}	0.1034	0.0079	0.1143	0.0249	22	Sb^{121}	396	19	388	137	15
Ba^{137}	130.9	1	106.4	11.3	22	Ba^{137}	452	9	391	119	15
La^{139}	15.2	0.08	12.90	2.30	22	La^{139}	440	10	458	150	15
Ce^{140}	37.53	0.19	40.24	8.38	22	Ce^{140}	453	8	545	167	15
Eu^{153}	2.043	0.012	2.181	0.181	22	Eu^{153}	447	12	544	157	15
Lu^{175}	0.2754	0.0024	0.2644	0.0328	22	Lu^{175}	439	8	570	163	15
Hf^{180}	4.47	0.025	3.342	0.277	22	Hf^{180}	435	12	455	129	15
W^{183}	0.251	0.035	0.272	0.144	22	W^{183}	444	29	639	189	15
Pt^{195}	8.9	1.6	1.0	0.6	22	Pt^{195}	3.12	0.08	3.67	0.89	15
Au^{197}						Au^{197}	23.6	1.7	32.7	10.0	15
Tl^{205}	0.0224	0.0015	0.0113	0.0038	22	Tl^{205}	59.6	2.8	58.3	17.5	15
Pb^{208}	1.653	0.038	1.763	0.166	22	Pb^{208}	426	1	434	133	15
Bi^{209}	0.0148	0.0043	0.0326	0.0190	22	Bi^{209}	384	26	337	110	15
Th^{232}	1.224	0.016	1.269	0.180	22	Th^{232}	457.2	1	611.9	182.4	15
U^{238}	0.412	0.035	0.711	0.122	22	U^{238}	461.5	1	762.5	265.2	15

Notes:

rv = reference value (Jochum et al., 2005); 2sd = two standard deviations; ma = mean value for runs in this work; n = number of run analyses; IS = internal standard for matrix correction

ELECTRONIC APPENDIX TABLE A8 - LA-ICP-MS – Pyrrhotite

TABLE A8-1 - Pyrrhotite compositional data

Table A4-1. Mineral chemistry data for pyrrhotite obtained by LA-ICP-MS

Sample	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	028-15	029-36	029-36
Drillhole	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A28	A29	A29
Depth (m)	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	192.65	198.2	198.2
Host Rock	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF	marble	marble
Po type	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2
Spot ID	C2-7	C2-8	C2-9	C3-5	C3-6	C3-7	C3-8	C3-9	C3-10	C4-5	C4-6	C3-5	C3-6
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	28	27	27	31	32	31	31	33	30	31	29	29	32
Ni^{60}	41	39	37	42	44	46	41	37	42	49	43	167	117
Cu^{65}	3.3	3.0	22.3	2.9	2.6	9.7	1.9	2.5	3.1	1.4	4.6	0.8	0.8
Zn^{66}	2.8	1.0	1.8	2.4	2.3	3.2	1.9	2.0	2.7	1.2	1.4	1.5	3.3
Ge^{74}	0.29	0.27	0.29	0.27	0.31	0.30	0.27	0.28	0.29	0.24	0.20	0.28	0.28
As^{75}	0.13	b.d.l.	0.03	0.07	0.14	0.14	0.11	0.21	b.d.l.	0.14	b.d.l.	b.d.l.	0.01
Mo^{95}	b.d.l.	0.02	0.00	0.13	0.08	0.00	0.02	b.d.l.	b.d.l.	b.d.l.	0.02	b.d.l.	b.d.l.
Ag^{109}	0.19	0.15	0.13	0.07	0.08	0.21	0.10	0.09	0.12	0.05	0.04	0.04	0.13
Cd^{114}	0.07	0.03	0.07	0.00	b.d.l.	0.11	b.d.l.	0.02	0.01	b.d.l.	0.06	b.d.l.	b.d.l.
Sn^{118}	0.10	b.d.l.	0.11	0.08	0.03	0.04	0.01	0.04	b.d.l.	b.d.l.	0.11	0.02	0.07
Sb^{121}	0.03	0.02	0.04	0.00	0.06	0.03	0.01	0.07	0.01	0.01	0.00	0.00	0.01
Te^{130}	4.24	0.16	b.d.l.	b.d.l.	0.10	0.51	b.d.l.	0.03	0.70	b.d.l.	b.d.l.	b.d.l.	b.d.l.
W^{183}	b.d.l.	0.03	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.00	0.18	b.d.l.	b.d.l.	b.d.l.
Pt^{195}	0.01	0.01	b.d.l.	0.01	0.04	b.d.l.	b.d.l.	b.d.l.	0.01	0.01	b.d.l.	b.d.l.	0.04
Au^{197}	0.0031	b.d.l.	b.d.l.	0.0089	b.d.l.	0.0075	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.0078	0.0042
Tl^{205}	0.09	0.03	0.19	0.01	0.03	0.22	0.01	0.08	0.03	0.07	0.01	b.d.l.	0.01
Pb^{208}	78.8	13.3	11.5	4.5	10.3	17.5	4.8	7.1	6.5	5.1	2.4	1.3	4.5
Bi^{209}	0.64	0.34	0.17	0.20	0.21	0.53	0.11	0.18	0.31	0.08	0.07	0.14	0.47

Notes:

IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm

1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2

1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)

1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement

1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite

1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)

1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes

1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)

2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein

cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36	029-36
Drillhole	A29	A29	A29	A29	A29	A29	A29	A29	A29	A29	A29	A29	A29
Depth (m)	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2	198.2
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Po type	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2
Spot ID	C3-7	C3-8	C3-9	C3-10	C4-5	C4-6	C4-7	C4-8	C4-9	C4-10	C4-11	C4-12	C4-13
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	32	32	34	34	32	32	32	34	35	35	36	36	33
Ni^{60}	119	121	123	125	47	40	43	46	50	55	55	58	61
Cu^{65}	1.1	1.2	1.2	1.2	1.4	1.0	1.2	0.7	1.2	0.6	0.7	1.0	1.9
Zn^{66}	3.5	4.3	6.1	2.1	2.1	2.5	2.5	2.1	2.4	1.1	1.8	3.2	5.1
Ge^{74}	0.32	0.39	0.32	0.31	0.31	0.38	0.30	0.37	0.27	0.37	0.26	0.25	0.31
As^{75}	0.07	0.06	0.11	0.08	b.d.l.	0.13	0.12	b.d.l.	0.22	0.15	0.07	0.11	0.13
Mo^{95}	0.06	0.01	0.11	0.03	b.d.l.	b.d.l.	0.00	0.01	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Ag^{109}	0.23	0.74	0.48	0.17	0.17	0.10	0.07	0.51	0.23	0.20	0.21	0.44	0.10
Cd^{114}	0.01	b.d.l.	b.d.l.	0.03	b.d.l.	b.d.l.	0.05	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.02	0.04
Sn^{118}	0.04	0.09	0.02	0.05	b.d.l.	0.01	0.02	0.03	0.16	0.12	0.03	0.06	0.03
Sb^{121}	0.01	0.02	0.01	0.01	0.01	b.d.l.	0.02	0.07	0.01	0.01	0.00	0.01	0.02
Te^{130}	b.d.l.	0.36	0.04	0.09	b.d.l.	0.05	b.d.l.	0.15	0.01	0.13	0.06	0.21	b.d.l.
W^{183}	0.05	b.d.l.	0.01	b.d.l.	0.02	0.00	0.02	0.04	b.d.l.	0.02	0.13	0.03	b.d.l.
Pt^{195}	0.01	b.d.l.	b.d.l.	0.00	0.01	b.d.l.	0.00	b.d.l.	b.d.l.	b.d.l.	0.00	b.d.l.	0.03
Au^{197}	b.d.l.	0.0190	0.0054	b.d.l.	b.d.l.	0.0070	b.d.l.	0.0156	0.0016	0.0093	0.0003	b.d.l.	b.d.l.
Tl^{205}	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.01	b.d.l.	0.01	0.01	0.01
Pb^{208}	9.1	21.0	12.0	3.5	7.3	1.3	1.3	31.3	8.6	1.9	8.0	11.3	7.2
Bi^{209}	0.53	2.16	0.46	0.29	0.71	0.16	0.17	2.30	1.11	0.19	0.73	0.98	0.72

Notes:

IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm

1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2

1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)

1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement

1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite

1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)

1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes

1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)

2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein

cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	029-36	029-36	029-36	029-36	029-36	028-19	028-19	028-19	028-19	028-19	028-19	028-19	028-19
Drillhole	A29	A29	A29	A29	A29	A28	A28	A28	A28	A28	A28	A28	A28
Depth (m)	198.2	198.2	198.2	198.2	198.2	210.8	210.8	210.8	210.8	210.8	210.8	210.8	210.8
Host Rock	marble	marble	marble	marble	marble	BIF	BIF	BIF	BIF	BIF	BIF	BIF	BIF
Po type	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-eqmt2	1-deqmt2	1-deqmt2	1-deqmt2	1-deqmt2	1-deqmt2	1-deqmt2	1-deqmt2	1-deqmt2
Spot ID	C4-14	C4-15	C4-16	C4-17	C4-18	C2-5	C2-6	C2-7	C2-8	C2-9	C3-11	C3-12	C3-13
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	34	32	34	34	34	2	0.15	3	4	2	3	1	2
Ni^{60}	54	52	55	54	50	45	43	37	48	23	51	41	44
Cu^{65}	2.8	1.0	1.2	0.8	1.0	0.7	0.3	1.4	0.7	0.7	0.6	0.7	1.3
Zn^{66}	7.9	2.0	5.6	3.6	3.1	0.8	1.5	1.3	0.9	1.9	0.8	1.0	0.0
Ge^{74}	0.29	0.28	0.26	0.14	0.27	0.26	0.22	0.41	0.27	0.33	0.15	0.30	0.08
As^{75}	b.d.l.	0.10	b.d.l.	b.d.l.	0.41	0.46	b.d.l.	0.24	b.d.l.	0.80	0.60	b.d.l.	b.d.l.
Mo^{95}	b.d.l.	0.02	b.d.l.	b.d.l.	0.04	b.d.l.	b.d.l.	0.04	0.04	b.d.l.	0.05	0.19	0.08
Ag^{109}	0.01	0.15	0.08	0.11	0.53	1.42	0.29	0.38	0.77	0.13	1.19	0.40	b.d.l.
Cd^{114}	0.02	b.d.l.	0.01	0.01	0.03	0.78	3.55	b.d.l.	b.d.l.	b.d.l.	0.08	b.d.l.	b.d.l.
Sn^{118}	0.11	0.07	b.d.l.	b.d.l.	0.04	b.d.l.	b.d.l.	0.22	0.20	b.d.l.	b.d.l.	0.51	0.24
Sb^{121}	0.03	0.00	0.01	b.d.l.	0.01	0.00	b.d.l.	0.03	0.03	b.d.l.	0.04	b.d.l.	0.05
Te^{130}	0.23	b.d.l.	b.d.l.	0.02	0.15	0.15	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.42	0.08
W^{183}	0.00	b.d.l.	0.08	b.d.l.	b.d.l.	b.d.l.	0.09	b.d.l.	0.21	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Pt^{195}	0.03	0.02	0.00	b.d.l.	0.01	b.d.l.	b.d.l.	0.03	0.01	b.d.l.	0.02	0.08	0.07
Au^{197}	0.0021	b.d.l.	b.d.l.	0.0218	b.d.l.	b.d.l.	b.d.l.	0.0270	b.d.l.	0.0234	b.d.l.	b.d.l.	b.d.l.
Tl^{205}	b.d.l.	0.00	0.01	0.00	0.01	0.04	0.31	1.09	0.27	b.d.l.	0.53	0.17	0.19
Pb^{208}	2.0	3.3	2.4	4.7	21.5	2.3	0.7	2.0	5.1	1.3	9.0	2.8	1.8
Bi^{209}	0.23	0.27	0.28	0.59	2.00	0.77	0.22	0.60	1.23	0.28	1.41	0.38	0.38

Notes:
IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm
1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2
1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)
1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement
1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite
1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)
1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes
1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)
2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein
cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	028-19	028-19	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-11b	033-15
Drillhole	A28	A28	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	210.8	210.8	106.5	106.5	106.5	106.5	106.5	106.5	106.5	106.5	106.5	106.5	141.5
Host Rock	BIF	BIF	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	qz-cpx vein	marble
Po type	1-deqmt2	1-deqmt2	2	2	2	1-nomt	1-nomt	1-nomt	1-nomt	1-nomt	2	2	1-mt2-ilm2
Spot ID	C3-14	C3-15	C1-3	C1-4	C1-5	C1-6	C2-1	C2-2	C2-3	C2-4	C3-1	C3-2	C1-6
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	4	0.43	25	23	28	28	34	33	35	29	22	20	131
Ni^{60}	40	38	103	103	118	110	115	108	102	100	98	106	163
Cu^{65}	3.0	1.2	b.d.l.	2.4	8.8	2.2	3.7	8.9	4.9	2.1	0.8	0.9	1.8
Zn^{66}	2.1	1.8	2.8	1.4	2.1	62.0	3.4	6.5	14.2	2.7	0.1	1.6	2.1
Ge^{74}	0.26	0.18	1.37	1.93	1.29	1.17	0.64	0.63	1.12	0.66	0.45	1.21	0.40
As^{75}	0.98	b.d.l.	b.d.l.	b.d.l.	2.12	b.d.l.	0.37	1.12	2.18	b.d.l.	0.42	0.30	0.05
Mo^{95}	0.12	b.d.l.	0.13	0.06	0.16	0.19	b.d.l.	0.24	0.21	b.d.l.	0.02	0.03	0.05
Ag^{109}	1.50	0.72	b.d.l.	b.d.l.	0.56	0.11	0.17	0.56	0.07	0.25	0.02	b.d.l.	0.73
Cd^{114}	b.d.l.	b.d.l.	2.08	5.09	b.d.l.	0.48	0.23	0.36	0.33	0.37	0.43	0.28	0.01
Sn^{118}	0.08	b.d.l.	0.10	b.d.l.	0.34	0.15	0.49	b.d.l.	0.22	b.d.l.	0.02	b.d.l.	0.02
Sb^{121}	0.66	0.01	0.44	0.06	0.08	1.01	0.12	2.09	0.38	0.58	0.02	b.d.l.	0.00
Te^{130}	0.45	b.d.l.	b.d.l.	0.86	6.14	1.48	1.29	2.55	2.57	b.d.l.	13.41	b.d.l.	b.d.l.
W^{183}	b.d.l.	0.09	b.d.l.	b.d.l.	0.17	b.d.l.	0.20	b.d.l.	0.63	b.d.l.	b.d.l.	0.08	0.05
Pt^{195}	b.d.l.	b.d.l.	b.d.l.	0.12	0.01	b.d.l.	b.d.l.	0.02	b.d.l.	0.10	0.04	0.00	b.d.l.
Au^{197}	b.d.l.	b.d.l.	b.d.l.	0.0454	0.0294	0.0002	0.0109	b.d.l.	0.0280	0.0458	0.0039	0.0059	0.0032
Tl^{205}	5.25	b.d.l.	b.d.l.	0.01	1.59	0.56	b.d.l.	0.24	0.33	0.70	0.19	0.46	0.01
Pb^{208}	37.1	0.7	1.3	8.2	5.3	6.9	2.2	31.8	14.4	12.2	10.1	5.9	13.5
Bi^{209}	6.46	0.16	0.22	0.77	0.67	1.90	0.49	4.14	4.31	3.72	1.04	0.68	1.00

Notes:

IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm

1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2

1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)

1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement

1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite

1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)

1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes

1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)

2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein

cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15	033-15
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5	141.5
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Po type	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2
Spot ID	C1-7	C1-8	C1-9	C1-10	C1-11	C1-12	C1-13	C2-8	C2-9	C2-10	C2-11	C2-12	C3-5
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	126	128	132	126	129	126	128	130	131	138	128	131	123
Ni^{60}	153	148	158	153	153	145	155	152	161	161	157	157	145
Cu^{65}	1.5	1.2	1.6	2.0	2.0	2.0	1.7	3.3	2.8	3.3	2.7	2.3	0.8
Zn^{66}	1.5	1.6	6.7	2.4	1.1	3.0	2.9	3.5	3.7	4.3	1.1	1.0	2.9
Ge^{74}	0.44	0.47	0.45	0.45	0.45	0.49	0.43	0.48	0.48	0.44	0.48	0.47	0.40
As^{75}	0.05	0.02	0.06	0.06	0.07	b.d.l.	0.02	0.08	b.d.l.	0.11	b.d.l.	0.07	0.16
Mo^{95}	0.04	0.03	0.04	0.01	b.d.l.	0.04	0.06	0.07	0.00	0.05	0.03	0.03	0.01
Ag^{109}	0.27	0.41	0.30	0.32	0.35	0.26	0.27	0.46	0.11	0.23	0.18	0.40	0.60
Cd^{114}	0.00	b.d.l.	0.02	0.00	0.00	b.d.l.	b.d.l.	0.01	b.d.l.	0.00	b.d.l.	0.01	0.00
Sn^{118}	0.03	0.04	0.04	0.00	0.02	0.02	0.05	b.d.l.	0.07	b.d.l.	b.d.l.	b.d.l.	0.05
Sb^{121}	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	b.d.l.	0.01
Te^{130}	b.d.l.	b.d.l.	b.d.l.	0.19	b.d.l.	0.17	0.18	b.d.l.	b.d.l.	0.07	b.d.l.	0.15	b.d.l.
W^{183}	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.01	0.74	b.d.l.	0.03	b.d.l.	b.d.l.	b.d.l.	0.04	0.65
Pt^{195}	0.01	0.00	b.d.l.	0.02	0.01	0.01	0.01	b.d.l.	0.02	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Au^{197}	b.d.l.	0.0115	b.d.l.	b.d.l.	0.0157	0.0085	b.d.l.	b.d.l.	0.0016	b.d.l.	b.d.l.	0.0134	0.0085
Tl^{205}	0.01	0.00	0.00	0.01	0.00	0.17	0.01	0.01	0.01	0.00	0.00	0.00	0.02
Pb^{208}	5.2	5.9	1.8	4.7	7.7	3.6	6.6	9.5	4.5	6.0	3.4	9.9	7.8
Bi^{209}	0.18	0.21	0.06	0.29	0.25	0.17	0.44	0.48	0.14	1.01	0.18	0.25	0.35

Notes:

IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm

1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2

1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)

1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement

1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite

1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)

1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes

1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)

2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein

cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	033-15	033-15	033-15	033-15	033-15	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b	033-17b
Drillhole	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33	A33
Depth (m)	141.5	141.5	141.5	141.5	141.5	162.1	162.1	162.1	162.1	162.1	162.1	162.1	162.1
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Po type	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b
Spot ID	C3-6	C3-7	C3-8	C3-9	C3-10	C1-1	C1-2	C3-4	C3-5	C5-2	C5-3	C5-4	C6-1
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	127	127	136	126	129	160	144	131	140	141	144	135	137
Ni^{60}	156	148	162	147	143	181	141	170	175	177	172	163	167
Cu^{65}	0.8	1.0	0.9	0.6	0.9	5.0	3.4	2.4	3.0	16.3	3.2	3.7	3.2
Zn^{66}	1.7	3.2	2.8	1.5	1.3	3.0	b.d.l.	9.6	12.7	4.2	3.8	5.8	8.9
Ge^{74}	0.49	0.48	0.50	0.44	0.46	0.43	0.40	0.46	0.44	0.43	0.48	0.48	0.48
As^{75}	0.07	0.08	0.28	0.09	0.12	0.11	b.d.l.	b.d.l.	0.02	b.d.l.	0.04	0.04	0.21
Mo^{95}	0.00	0.07	0.06	0.03	0.04	0.04	b.d.l.	0.03	0.06	b.d.l.	0.06	0.04	0.09
Ag^{109}	0.51	0.48	0.91	0.34	0.50	0.02	b.d.l.	0.04	0.07	0.59	0.11	0.11	0.08
Cd^{114}	0.01	b.d.l.	0.02	b.d.l.	b.d.l.	0.01	b.d.l.	b.d.l.	0.01	0.06	0.01	0.05	0.07
Sn^{118}	b.d.l.	0.02	b.d.l.	0.02	0.05	b.d.l.	0.01	0.01	0.07	0.02	0.05	b.d.l.	b.d.l.
Sb^{121}	0.00	0.00	0.01	0.02	b.d.l.	b.d.l.	0.01	0.02	0.04	0.23	0.03	0.01	0.01
Te^{130}	0.20	b.d.l.	0.26	0.24	0.07	0.13	0.24	b.d.l.	0.20	0.43	0.05	0.31	0.45
W^{183}	0.03	1.07	b.d.l.	3.92	b.d.l.	b.d.l.	b.d.l.	0.03	0.05	b.d.l.	0.08	0.02	b.d.l.
Pt^{195}	b.d.l.	b.d.l.	0.03	0.00	0.02	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.00	b.d.l.	0.01	b.d.l.
Au^{197}	0.0003	b.d.l.	0.0194	0.0093	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.0011	0.3056	0.0029	0.0141	0.0141
Tl^{205}	0.01	0.00	0.03	0.00	0.02	0.00	3.39	0.00	0.02	0.30	0.08	0.01	0.01
Pb^{208}	7.2	4.7	17.7	5.8	3.7	2.5	5.1	4.9	17.9	48.6	13.6	14.9	16.0
Bi^{209}	0.42	0.21	0.99	0.28	0.25	0.30	1.15	1.08	4.95	7.86	1.87	2.43	2.84

Notes:

IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm

1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2

1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)

1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement

1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite

1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)

1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes

1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)

2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein

cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	033-17b	033-17b	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10	HS-10
Drillhole	A33	A33	surface	surface	surface	surface	surface	surface	surface	surface	surface	surface	surface
Depth (m)	162.1	162.1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Po type	1-mt2-ilm2-b	1-mt2-ilm2-b	1-mt2-ilm2-b	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg
Spot ID	C6-2	C6-3	C1-3	C1-4	C1-5	C1-6	C1-7	C1-8	C1-9	C1-10	C2-6	C2-7	C2-8
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	136	140	115	119	117	129	113	137	120	112	122	104	114
Ni^{60}	179	173	67	170	39	135	90	146	22	39	70	82	74
Cu^{65}	2.7	3.3	0.6	2.2	0.2	1.6	1.3	0.7	1.2	0.6	0.7	0.9	1.1
Zn^{66}	7.0	8.2	2.4	3.9	1.5	5.6	2.4	3.4	2.9	1.8	2.3	1.9	3.9
Ge^{74}	0.45	0.44	0.62	0.60	0.58	0.62	0.62	0.61	0.62	0.57	0.71	0.63	0.63
As^{75}	0.08	0.05	0.03	b.d.l.	0.08	0.07	0.11	0.04	0.04	b.d.l.	0.26	0.10	0.01
Mo^{95}	0.01	0.06	0.47	b.d.l.	0.01	b.d.l.	0.61	0.01	0.05	b.d.l.	0.02	0.02	0.07
Ag^{109}	0.03	0.12	0.21	0.04	0.01	0.15	0.15	0.10	0.21	0.06	0.50	0.05	0.15
Cd^{114}	0.02	b.d.l.	0.04	b.d.l.	b.d.l.	b.d.l.	0.03	0.00	0.02	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Sn^{118}	0.05	0.06	0.05	0.08	0.08	0.03	0.07	0.11	0.01	0.02	0.04	0.01	b.d.l.
Sb^{121}	0.02	0.10	0.64	0.04	0.12	0.02	0.22	0.02	0.01	0.00	0.05	0.00	0.02
Te^{130}	0.20	0.46	b.d.l.	0.23	b.d.l.	b.d.l.	0.04	0.06	0.02	b.d.l.	b.d.l.	b.d.l.	0.30
W^{183}	0.03	0.02	b.d.l.	b.d.l.	0.00	0.01	0.01	0.05	0.01	b.d.l.	b.d.l.	b.d.l.	0.11
Pt^{195}	b.d.l.	0.01	0.00	0.01	0.02	0.01	b.d.l.	b.d.l.	0.01	b.d.l.	0.00	b.d.l.	b.d.l.
Au^{197}	0.0106	0.0016	b.d.l.	0.0069	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.0062	b.d.l.	0.0001	0.0069
Tl^{205}	0.00	0.04	0.08	0.01	0.07	0.01	0.02	0.03	0.01	0.00	0.03	b.d.l.	0.01
Pb^{208}	6.1	24.2	4.9	0.7	3.1	2.7	11.2	1.1	2.2	0.4	11.3	0.3	2.7
Bi^{209}	1.17	4.10	0.70	0.07	0.35	0.64	2.19	0.24	0.34	0.08	4.41	0.15	1.24

Notes:
IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm
1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2
1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)
1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement
1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite
1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)
1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes
1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)
2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein
cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	HS-10	HS-10	HS-10	029-30	029-30	029-30	029-30	029-30	029-30	029-30	029-30	029-30	029-30
Drillhole	surface	surface	surface	A29	A29	A29	A29	A29	A29	A29	A29	A29	A29
Depth (m)	n/a	n/a	n/a	167.8	167.8	167.8	167.8	167.8	167.8	167.8	167.8	167.8	167.8
Host Rock	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble	marble
Po type	1-eqmt2tg	1-eqmt2tg	1-eqmt2tg	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over
Spot ID	C3-5	C3-6	C3-7	C2-1	C2-2	C2-3	C2-4	C3-6	C3-7	C3-8	C3-9	C4-3	C4-4
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	106	111	108	8	12	8	9	22	22	9	9	5	6
Ni^{60}	98	193	123	34	40	39	25	36	34	31	31	33	34
Cu^{65}	1.5	6.0	1.1	2.4	6.0	3.5	2.2	1.8	1.4	1.7	1.8	2.3	3.2
Zn^{66}	4.8	25.9	3.2	1.9	1.3	2.8	2.2	2.6	1.4	1.3	1.3	1.1	1.2
Ge^{74}	0.56	0.64	0.73	0.30	0.25	0.21	0.26	0.22	0.21	0.22	0.22	0.24	0.25
As^{75}	0.10	b.d.l.	0.01	b.d.l.	0.11	0.02	0.07	b.d.l.	b.d.l.	0.16	0.02	0.01	b.d.l.
Mo^{95}	b.d.l.	b.d.l.	b.d.l.	0.09	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.01	0.02	0.03
Ag^{109}	0.03	0.10	0.38	0.10	0.67	0.05	0.07	0.18	0.04	0.01	0.08	0.17	0.23
Cd^{114}	0.00	0.05	0.02	0.02	0.11	0.01	0.02	0.05	b.d.l.	0.01	b.d.l.	b.d.l.	b.d.l.
Sn^{118}	0.05	b.d.l.	0.05	0.05	b.d.l.	0.02	0.09	0.04	b.d.l.	0.00	b.d.l.	0.03	0.05
Sb^{121}	0.01	0.13	0.03	0.02	0.25	0.01	0.01	0.01	0.00	0.01	0.00	b.d.l.	0.14
Te^{130}	b.d.l.	b.d.l.	0.03	b.d.l.	b.d.l.	0.41	0.19	0.00	b.d.l.	b.d.l.	0.07	0.13	0.33
W^{183}	0.05	0.01	0.01	0.02	b.d.l.	0.08	b.d.l.	b.d.l.	0.01	0.02	0.04	b.d.l.	b.d.l.
Pt^{195}	b.d.l.	0.03	0.01	0.01	0.00	b.d.l.	0.01	b.d.l.	b.d.l.	0.01	b.d.l.	b.d.l.	0.00
Au^{197}	b.d.l.	0.0103	0.0105	0.0009	0.0009	b.d.l.	0.0072	0.0154	0.0007	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Tl^{205}	0.00	0.03	0.05	0.00	0.15	0.03	0.01	0.16	0.00	0.00	0.00	0.01	0.03
Pb^{208}	0.4	5.8	3.2	5.6	43.5	7.6	5.0	17.9	1.2	1.8	2.5	4.3	22.7
Bi^{209}	0.07	1.71	0.81	0.14	0.80	0.19	0.09	0.09	0.04	0.07	0.08	0.06	0.20

Notes:
IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm
1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2
1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)
1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement
1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite
1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)
1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes
1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)
2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein
cpx = clinopyroxene; qz = quartz

Table A4-1. (Cont.)

Sample	029-30	029-30	029-30	029-30	029-30
Drillhole	A29	A29	A29	A29	A29
Depth (m)	167.8	167.8	167.8	167.8	167.8
Host Rock	marble	marble	marble	marble	marble
Po type	1-py-over	1-py-over	1-py-over	1-py-over	1-py-over
Spot ID	C4-5	C4-6	C4-7	C4-9	C4-10
IS	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}	Fe^{57}
Co^{59}	7	5	5	6	5
Ni^{60}	33	32	31	36	33
Cu^{65}	2.7	2.6	2.6	2.4	2.6
Zn^{66}	1.3	1.0	1.1	0.9	1.3
Ge^{74}	0.29	0.25	0.25	0.27	0.21
As^{75}	b.d.l.	b.d.l.	0.22	0.06	b.d.l.
Mo^{95}	0.02	b.d.l.	0.01	0.03	b.d.l.
Ag^{109}	0.11	0.07	0.41	0.11	0.23
Cd^{114}	b.d.l.	b.d.l.	0.06	0.01	0.00
Sn^{118}	0.03	0.00	0.05	b.d.l.	b.d.l.
Sb^{121}	0.00	0.00	0.03	0.01	0.00
Te^{130}	0.17	0.20	0.31	0.07	0.10
W^{183}	0.02	0.02	b.d.l.	0.01	b.d.l.
Pt^{195}	0.02	0.01	b.d.l.	b.d.l.	0.02
Au^{197}	0.0050	0.0153	0.0006	0.0014	0.0032
Tl^{205}	0.01	0.00	0.02	0.00	0.01
Pb^{208}	5.9	4.4	16.7	6.1	3.2
Bi^{209}	0.13	0.08	0.13	0.12	0.08

Notes:

IS = internal standard for matrix correction (normalization values obtained by EPMA measurements); elemental concentrations are in ppm

1-eqmt2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2

1-deqmt2 = main alteration stage pyrrhotite aggregates encapsulating hydrothermal magnetite 2 (with pyrite overgrowth)

1-nomt = main alteration stage pyrrhotite in magnetite-free early V3 quartz-clinopyroxene vein with amphibole replacement

1-mt2-ilm2 = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equilibrium with ilmenite

1-mt2-ilm2-b = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in equiibrium with ilmenite (gold-bearing rock)

1 -eqmt2tg = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 in tension gashes

1-py-over = main alteration stage pyrrhotite co-precipitating with hydrothermal magnetite 2 (with pyrite overgrowth)

2 - late alteration stage pyrrhotite in V4 quartz-carbonate vein

cpx = clinopyroxene; qz = quartz

TABLE A8-2 - Quality control

Table A4-2. LA-ICP-MS quality control spreadsheet for pyrrhotite analyses (external standard = STDGL-3)

Statistics and comparison with certified values

	BHVO-2						NISTSRM610				
	rv	2sd	ma	2sd	n		rv	2sd	ma	2sd	n
Ti^{49}	16310	180	10497	690	22	Ti^{49}	452	10	338	95	15
Mn^{55}	1309	19	1015	80	22	Mn^{55}	444	13	367	116	15
Fe^{57}			IS			Fe^{57}			IS		
Co^{59}	44.89	0.32	45.13	3.38	22	Co^{59}	410	10	419	146	15
Ni^{60}	119.8	1.2	122.6	13.5	22	Ni^{60}	458.7	4	492.8	157	15
Cu^{65}	129.3	1.4	120.17	15.2	22	Cu^{65}	441	15	451	151	15
Zn^{66}	103.9	1	124.8	9	22	Zn^{66}	460	18	478	160	15
Ge^{74}	1.623	0.039	1.154	0.184	22	Ge^{74}	447	78	307	85	15
As^{75}	0.7	0.11	0.720	0.28	22	As^{75}	325	18	330	93	15
Mo^{95}	4.07	0.16	4.30	1.06	22	Mo^{95}	417	21	472	128	15
Ag^{109}			1.18	0.38		Ag^{109}	251	9	230	71	15
Cd^{114}	0.152	0.049	0.120	0.043	22	Cd^{114}	270	16	293	95	15
Sn^{118}	1.776	0.059	1.9247	0.2993	22	Sn^{118}	430	29	563	168	15
Sb^{121}	0.1034	0.0079	0.155	0.033	22	Sb^{121}	396	19	523	172	15
Te^{130}			0.50	0.28	22	Te^{130}	302		336	101	15
W^{183}	0.251	0.035	0.2453	0.1223	22	W^{183}	444	29	566	184	15
Pt^{195}	8.9	1.6	0.67	0.447	22	Pt^{195}	3.12	0.08	2.46	0.53	15
Au^{197}			1.7264	0.8791	22	Au^{197}	23.6	1.7	17.5	4.9	15
Tl^{205}	0.0224	0.0015	0.0156	0.0053	22	Tl^{205}	59.6	2.8	78.9	20.0	15
Pb^{208}	1.653	0.038	2.0246	0.2281		Pb^{208}	426	1	482	124	15
Bi^{209}	0.0148	0.0043	0.0454	0.0278	22	Bi^{209}	384	26	454	129	15

Notes:
rv = reference value (Jochum et al., 2005); 2sd = two standard deviations; ma = mean value for runs in this work; n = number of run analyses; IS = internal standard for matrix correction

3 CONCLUSÃO

Os resultados de estudos de campo e laboratório indicam que a mineralização aurífera no depósito Tucano é do tipo orogênico hipozonal controlado por zona de cisalhamento dúctil a dúctil-rúptil. Evidências petrográficas indicam que a mineralização sucede o pico metamórfico regional. Ademais, as texturas exibidas por minerais hidrotermais sugerem que a janela de alteração compreendeu praticamente todo o período de reativação da zona de cisalhamento Urucum. Nestes termos, à fase cedo hidrotermal, tendo em vista as estruturas comumente exibidas, seria atribuída uma idade estrutural máxima cedo-cinemática. A fase principal de alteração, associada à introdução de fluidos auríferos, exibe estruturas indicativas de um prolongado período de atividade hidrotermal compreendendo desde o estágio de intensa deformação até o período declinante tardi-cinemático. Este último é notavelmente representado por cristais de arsenopirita euédricos e agregados de flogopita aleatoriamente orientados. Diques e stocks de leucogranito aflorantes na área da mina são estéreis e não exibem deformação associada à zona de cisalhamento, sendo interpretados como pós-cinemáticos e também mais jovens que o evento mineralizador. Todavia, alteração hidrotermal associada ao granito é registrada. Trata-se de auréolas de reação de largura < 5 cm, sugestivas portanto de limitado volume de fluidos hidrotermais produzidos mediante sua cristalização. A fase tardia de alteração hidrotermal se manifesta através da subtituição retrógrada de fases metamórficas e hidrotermais hipozonais, possivelmente situada em tempo posterior ao magmatismo. Essa interpretação decorre da ausência de evidências de transformações mineralógicas que do contrário seriam observadas caso essa paragênese retrógrada fosse afetada por metamorfismo de contato. Além disso, o referido evento magmático aparentemente gerou importantes efeitos de caráter textural em ambas as tramas metamórfica e hidrotermal. A despeito dos eventos deformacionais associados à zona de cisalhamento, em particular aquele no qual a alteração hidrotermal de alta temperatura se insere, verifica-se um marcante processo de reequilíbrio textural sob a forma de desenvolvimento de texturas granoblásticas e decussadas. Isto indica que altas temperaturas foram registradas em período pós-cinemático, permitindo assim recristalização do tipo redução de área de limite de grão. A proximidade temporal de granitos tipo S sugere que a alteração hidrotermal e mineralização de ouro ocorreu em uma fase da evolução orogênica dada por espessamento crustal e anatexia.

O zoneamento da alteração hidrotermal é tal que a transição entre zonas distal e proximal se dá de forma súbita, sem definição de uma zona intermediária, e com formação de sulfetos mais concentrada na zona proximal. A paragênese pirrotita ± loellingita ± arsenopirita indica condições relativamente baixas de fugacidade de oxigênio para os fluidos auríferos. A abundância de magnetita em zona proximal sugere ainda condições de atividade de enxofre relativamente baixas. Rochas hospedeiras ricas em ferro (mármore enriquecido em ferro e formação ferrífera) consistiram em uma trapa química favorável à mineralização, com sua sulfetação interpretada como um importante mecanismo para precipitação de Au. Contudo, a ocorrência de ouro visível em paragêneses sem contato direto com sulfetos, especialmente inclusões em magnetita, sugere um segundo mecanismo para deposição de Au. A contemporaneidade de formação de magnetita hidrotermal com a precipitação de ouro sugere que a disponibilidade de ferro trivalente no sistema possa ter desencadeado pequenas diferenças de fugacidade de oxigênio com respeito ao fluido, suficientes para reduzir a solubilidade do Au, porém ainda limitadas para desestabilizar de imediato o enxofre no fluido. Essa pode ser a razão pela qual a correlação linear entre Au e S não é tão alta ($R = 0.71$).

Dados litogeoquímicos e de química mineral indicam significativa adição de Na durante a alteração, com anfibólios e flogopita consistindo nos principais repositórios desse elemento. Em contraste, a adição hidrotermal de K comumente documentada em depósitos orogênicos de alta temperatura não é identificada no depósito Tucano. Cálculos de balanço de massa sugerem significativa perda de massa durante a alteração, refletida principalmente na composição de magnetita hidrotermal, particularmente aquela hospedada em mármores alterados, que contém alto conteúdo em elementos de baixa mobilidade em fluidos hidrotermais (Al, Ti, Sc, Cr). Não são identificadas variações sistemáticas no conteúdo de elementos traços entre diferentes tipos texturais e paragenéticos de pirrotita hidrotermal. Não obstante, algumas diferenças significativas podem ser apontadas de acordo com a natureza da rocha hospedeira. Enquanto variações em Ni e Co com relação aos tipos de hospedeira mármore > BIF) podem sugerir diferentes condições locais entre sítios de deposição, as variações de As e Te (veio > hospedeiras alteradas) estão possivelmente associadas a distintas razões fluido:rocha entre veios e hospedeiras alteradas.

Ademais, conteúdo de Au insignificante indica carência de ouro na estrutura desse sulfeto, seja ocupando sítios cristalinos específicos ou vacâncias.

A assinatura geoquímica Au-Ag-S-Te-Na ± W, Bi, Se, V, Cu, P do fluido hidrotermal aurífero no depósito Tucano compartilha semelhanças com outros depósitos de ouro orogênico hipozonais. Diferenças importantes são apontadas pela indicação de adição hidrotermal de Se, V e P. Se têm comportamento geoquímico semelhante a S e Te, podendo possivelmente ser extraído de uma rocha fonte comum. O enriquecimento em V é diretamente refletido na abundância de magnetita hidrotermal, cujas significativos volumes são aparentemente característica singular desse depósito. A incorporação de P, por sua vez, é manifestada pela ocorrência de apatita, localmente em proporções significativas.

REFERÊNCIAS

Almeida F.F.M., Hasui Y., Brito Neves B.B., Fuck R.A. 1981. Brazilian structural provinces: An introduction. *Earth Science Reviews*, 17:1-29.

Anovitz L.M. and Essene E.J. 1987. Phase Equilibria in the System $CaCO_3$-$MgCO_3$-$FeCO_3$. *Journal of Petrology*, 28:389-415.

Avelar V.G. 2002. *Geocronologia Pb-Pb em zircão e Sm-Nd rocha total da porção centro-norte do Amapá-Brasil: Implicações para a evolução geodinâmica do setor oriental do Escudo das Guianas*. Tese de Doutorado, Universidade Federal do Pará, Belém, 213 p.

Avelar V.G., Lafon J.M., Delor C., Guerrot C., Lahondère D. 2003. Archean crustal remnants in the easternmost part of the Guiana Shield: Pb-Pb and Sm-Nd geochronological evidence for Mesoarchean versus Neoarchean signatures. *Géologie de la France*, 2(3-4):83-100.

Barbosa J.P.O., Costa Neto M.C., Rosa-Costa, L.T., Anjos G.C., Chaves, C.L. 2015. Geologia e recursos minerais da Folha Macapá NA.22-Y-D, estado do Amapá, escala 1:250.000. Texto explicativo. Belém, Serviço Geológico do Brasil – CPRM, 118 p.

Bark G. and Weihed P. 2012. Geodynamic settings for Paleoproterozoic gold mineralization in the Svecofennian domain: a tectonic model for the Fäboliden orogenic gold deposit, northern Sweden. *Ore Geology Reviews*, 48:403-412.

Barreto C.J., Lafon J.M., Rosa-Costa L.T. 2009. Magmatismo eoriaciano (2,26 Ga) na porção norte do Bloco arqueano Amapá: nova evidência e implicações geodinâmicas. In: 11° Simpósio de Geologia da Amazônia. Manaus, Anais, p. 174-176.

Barreto C.J., Lafon J.M., Rosa-Costa L.T. Dantas E.L. 2013. Paleoproterozoic granitoids from the northern limit of the Archean Amapá block (Brazil), southeastern Guyana Shield: Pb-Pb evaporation in zircons and Sm-Nd geochronology. *Journal of South American Earth Sciences*, 45:97-116.

Bau M. and Dulski P. 1996. Distribution of yttrium and rare-earth elements in the Penge and Kuruman Iron-Formations, Transvaal Supergroup, South Africa. *Precambrian Research*, 79:37–55.

Bau M. and Dulski P. 1999. Comparing yttrium and rare earths in hydrothermal fluids from the Mid-Atlantic Ridge: implications for Y and REE behaviour during near-vent mixing and for the Y/Ho ratio of Proterozoic seawater. *Chemical Geology*, 155:77–90.

Belousov I., Danyushevsky P. Olin P., Gilbert S., Thompson J. 2015. STDGL3 – A new calibration standard for sulphide analysis by LA-ICP-MS. In: 25th Goldschmidt. Prague, Abstracts, p. A251.

Blenkinsop T.G. and Frei R. 1996. Archean and Proterozoic mineralization and tectonics at the Renco mine (Northern Marginal Zone, Limpopo Belt, Zimbabwe). *Economic Geology*, 91:1225–1238.

Bloem E.J.M., Dalstra H.J., Groves D.I., Ridley J.R. 1994. Metamorphic and structural setting of Archaean amphibolite-hosted gold deposits near Southern Cross, Southern Cross Province, Yilgarn Block, Western Australia. *Ore Geology Reviews*, 9:183–208.

Bolhar R., Kamber B.S., Moorbath S., Fedo C.M., Whitehouse M.J. 2004. Characterization of early Archaean chemical sediments by trace element signatures. *Earth and Planetary Science Letters*, 222:43–60.

Borges A.A.S., Lafon J.M., Villas R.N.N. 2002. Magmatismo tardi-transamazônico na Serra do Navio, região central do Amapá: Evidências geocronológicas. In: 41° Congresso Brasileiro de Geologia. João Pessoa, Anais, p. 435.

Borghetti C. and Philipp R.P. 2017. Geologia e geofísica do greenstone belt Vila Nova, porção NE do Cráton Amazônico, Amapá, Brasil. *Geologia USP Série Científica*, 17(1):109-127.

Brando Soares M., Corrêa Neto A.V., Bertolino L.C., Alves F.E.A., Almeida A.M., Silva P.H.M., Araújo R.O., Manduca L.G., Araújo I.M.C.P. 2018. Multistage mineralization at the hypozonal São Sebastião gold deposit, pitangui greenstone belt, minas gerais, Brazil. *Ore Geology Reviews*, 102:618–638.

Brando Soares M., Corrêa Neto A.V., Fabrício-Silva W. 2020. The development of a Meso- to Neoarchean rifting-convergence collision-collapse cycle over an ancient thickened protocontinent in the south São Francisco craton, Brazil. *Gondwana Research*, 77:40–66.

Brando Soares M., Alves F.E.A., Corrêa Neto A.V., Bertolino L.C., Araújo I.M.C.P., Gopon P., Mozart M.S. 2022. Gold refinement by the fractionation of Bi-enriched partial melts at the Quadrilátero Ferrífero, Brazil: Implications on the formation of hypozonal deposits. *Mineralium Deposita*, 57:781-800.

Byrne R.H. and Sholkovitz E.R. 1996. Marine chemistry and geochemistry of lanthanides. In: Gschneider Jr. K.A. and Eyring L. (eds.). The Handbook on the Physics and Chemistry of the Rare Earths. 23, Amsterdam, Elsevier, p. 497-593.

Cavalcante G.C.G. 2009. *Tectonic geometry, kinematics and modelling of the Vila Nova Group rocks in the Pedra Branca do Amapari region in AP*. Dissertação de Mestrado, Universidade Federal do Pará, Belém, 168 p.

Cordani U.G. and Brito Neves B.B. 1982. The geologic evolution of South America during the Archean and early Proterozoic. *Revista Brasileira de Geociencias*, 12:78-88.

Cordani U.G., Tassinari C.C.G., Teixeira W., Basei M.A.S. Kawashita K. 1979. Evolução da Amazônia com base nos dados geocronológicos. In: 2° Congresso Geologico Chileno. Santiago, Actas, v. 4, p. 137-148.

Companhia de Pesquisa de Recursos Minerais (CPRM). 2004. *Relatório final do levantamento e processamento dos dados magnetométricos e gamaespectrométricos* - Projeto aerogeofísico Rio Araguari. LASA Engenharia e Prospecções S.A., Relatório Técnico, 136 p.

Danyushevsky L., Robinson P., Gilbert S., Norman M., Large R., McGoldrick P., Shelley M. 2011. Routine quantitative multi-element analysis of sulphide minerals by laser ablation ICP-MS: Standard development and consideration of matrix effects. *Geochemistry: Exploration, Environment, Analysis*, 11:51-60.

Delor C., Lahondère D., Egal E., Lafon J.M., Cocherie A., Guerrot C., Rossi P., Trufert C., Theveniaut H., Phillips D., Avelar V.G. 2003a. Transamazonian crustal growth and reworking as revealed by the 1:500.000 scale geological map of French Guiana (2nd ed.). *Géologie de la France*, 2:5-57.

Delor C., Roever E.W.F., Lafon J. M., Lahondère D., Rossi P., Cocherie A., Guerrot C., Potrel, A. 2003b. The Bakhuis ultrahigh-temperature granulite belt: Implications for late Transamazonian crustal stretching in a revised Guiana Shield framework. *Géologie de la France*, 2:207-230.

Dupuis C., Beaudoin G. 2011. Discriminant diagrams for iron oxide trace element fingerprinting of mineral deposit types. *Mineralium Deposita*, 46:319–335.

Dziggel A., Wulff K., Kolb J., Meyer F.M. 2009a. Processes of high-T fluid–rock interaction during gold mineralization in carbonate-bearing metasediments: the Navachab gold deposit, Namibia. *Mineralium Deposita*, 44:665–684.

Dziggel A., Wulff K., Kolb J., Meyer F.M., Lahaye Y. 2009b. Significance of oscillatory and bell-shaped growth zoning in hydrothermal garnet: evidence from the Navachab gold deposit, Namibia. *Chemical Geology*, 262:278–292.

Dziggel A., Poujol M., Otto A., Kisters A.F.M., Trieloff M., Schwarz W., Meyer F.M. 2010. New U–Pb and 40Ar/39Ar ages from the northern part of the Barberton greenstone belt, South Africa: implications for the formation of Mesoarchaean gold deposits. *Precambrian Research*, 179:206–220.

Faraco M.T.L., Marinho P.A.C., Moura C.A.V., Macambira M.J., Pimentel M.M. 2004. Novos Dados Geocronológicos no Amapá-NNW do Pará. In: 42° Congresso Brasileiro de Geologia. Araxá, Anais, CD ROM.

Faraco M.T.L., Marinho P.A.C., Melo L.V., Villas R.N.N., Soares J.W. 2005. O campo Taperebá do depósito aurífero Amapari, Amapá: Rochas encaixantes e minerografia. *Contribuições à Geologia da Amazônia*, 4:164-172.

Galarza M.A.T., Lafon J.M., Macambira M.J.B. 2006. Idades Pb-Pb das mineralizações auríferas dos depósitos Amapari (Amapá), Igarapé Bahia (Carajás) e Mamão (Rio Maria), Amazônia Oriental. In: 9° Simpósio de Geologia da Amazônia. Belém, Anais, p. 300-303.

Gibbs A.K. and Barron C.N. 1993. Geology of the Guiana Shield. Oxford, Oxford University Press, 246 p.

Goldfarb R.J. and Groves D.I. 2015. Orogenic gold: Common vs evolving fluid and metal sources through time. *Lithos*, 223:2–26.

Goldfarb R.J., Baker T., Dubé B., Groves D.I., Hart C.J.R., Gosselin P. 2005. Distribution, character, and genesis of gold deposits in metamorphic terranes. *Economic Geology 100th Anniversary*, 407–450.

Goldfarb R.J., André-Mayer A.-S., Jowitt S.M., Mudd G.M. 2017. West Africa: The world's premier Paleoproterozoic gold province. *Economic Geology*, 112:123-143.

Grant J.A. 1986. The isocon diagram – a simple solution to Gresens' equation for metasomatic alteration. *Economic Geology*, 81:1976-1982.

Great Panther Mining. 2022. Technical report on the 2021 mineral reserves and mineral resources of the Tucano gold mine, Amapá state, Brazil, 247 p.

Gresens R.L. 1967. Composition–volume relationships of metasomatism. *Chemical Geology*, 2:47-55.

Groves D.I., Goldfarb R.J., Gebre-Mariam M., Hagemann S.G., Robert, F. 1998. Orogenic gold deposits: A proposed classification in the context of their crustal distribution and relationship to other gold deposit types. *Ore Geology Reviews*, 13:7–27.

Hagemann S.G. and Cassidy K.F. 2000. Archean orogenic lode gold deposits. In: Hagemann S.G. and Brown P.E. (eds.). Gold in 2000. Reviews in Economic Geology, p. 9–68.

Hagemann S.G., Brown P.E., Ridley J., Stern P., Fournelle J. 1998. Ore petrology, chemistry, and timing of electrum in the Archean hypozonal Transvaal lode gold deposit, Western Australia. *Economic Geology*, 93(3):271–291.

Harris D.C. 1989. The mineralogy and geochemistry of the Hemlo gold deposit, Ontario. Geological Survey of Canada, Economic Geology Report, 38 p.

Hasui Y., Haralyi N.L.E., Schobbenhaus C. 1984. Elementos geofísicos e geológicos da região amazônica: Subsídios para o modelo geotectônico. In: 2° Symposium Amazonico. Manaus, Anais, p. 129-147.

Henry D.J., Guidotti C.V., Thomson J.A. 2005. The Ti-saturation surface for low-to-medium pressure metapelitic biotites: Implications for geothermometry and Ti-substitution mechanisms. *American Mineralogist*, 90:316-328.

Hoffmann I.B., Philipp R.P., Borghetti C. 2018. Geochemistry and origin of the Rhyacian tholeiitic metabasalts and meta-andesites from the Vila Nova Greenstone Belt, Guyana Shield, Amapá, Brazil. *Journal of South American Earth Sciences*, 88: 29-49.

Holdaway M.J. 2000. Application of new experimental and garnet Margules data to the garnet–biotite geothermometer. *American Mineralogist*, 85:881-892.

Horikava E.H. 2008. *Geoquímica de Solo e Geologia da Região do Depósito de Ouro do Amapari – AP*. MS Dissertation, Universidade Federal de Minas Gerais, Belo Horizonte, 2 vol.

Jochum K.P., Willbold M., Raczek I., Stoll B., Herwig K. 2005. Chemical characterization of the USGS reference glasses GSA-1G, GSC-1G, GSD-1G, GSE-1G, BCR-2G, BHVO-2G and BIR-1G using EPMA, ID-TIMS, ID-ICP-MS and LA-ICP-MS. *Geostandards and Geoanalytical Research*, 29(3):285-302.

Kisters A.F.M. 2005. Controls of gold-quartz vein formation during regional folding in amphibolite-facies, marble dominated metasediments of the Navachab Gold Mine in the Pan-African Damara Belt, Namibia. *South African Journal of Geology*, 108:365–380.

Kolb J. and Meyer F.M. 2008. Balanced mineral reactions for alteration zones developed in auriferous shear zones of the Hutti Mine, Dharwar craton, India. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, 159(2):331–348.

Kolb J., Kisters A.F.M. Hoernes S., Meyer F.M. 2000. The origin of fluids and nature of fluid-rock interaction in auriferous mylonites of the Renco Mine, southern Zimbabwe. *Mineralium Deposita*, 35(1):109–125.

Kolb J., Dziggel A., Bagas L. 2015. Hypozonal lode gold deposits: A genetic concept based on a review of the New Consort, Hutti, Hira Buddini, Navachab, Nevoria, and The Granites deposits. *Precambrian Research*, 262:20-44.

Koljonen T. 1973. Selenium in certain metamorphic rocks. *Bulletin of the Geological Society of Finland*, 45:107-117.

Kretschmar U. and Scott S.D. 1976. Phase relations involving arsenopyrite in the system Fe-As-S and their applications. *Canadian Mineralogist*, 14:364–386.

Krienitz M.S., Trumbull R.B., Hellmann A., Kolb J., Meyer F.M., Wiedenbeck M. 2008. Hydrothermal gold mineralization at the Hira Buddini gold mine, India: constraints on fluid evolution and fluid sources from boron isotopic compositions of tourmaline. *Mineralium Deposita*, 43:421–434.

Li X., Zhang C., Behrens H., Holtz F. 2020a. Calculating biotite formula from electron microprobe analysis data using a machine learning method based on principal components regression. *Lithos*, 356-357:105371.

Li X., Zhang C., Behrens H., Holtz F. 2020b. Calculating amphibole formula from electron microprobe analysis data using a machine learning method based on principal components regression. *Lithos*, 362-363:105469.

Leake B.E., Woolley A.R., Arps C.E.S., Birch W.D., Gilbert M.C., Grice J.D., Hawthorne F.C., Kato A., Kisch H.J., Krivovichev V.G., Linthout K., Laird J., Mandarino J.A., Maresch W.V., Nickel E.H., Rock N.M.S., Schumacher J.C., Smith D.C., Stephenson N.C.N., Ungaretti L., Whittaker E.J.W., Guo Y. 1997. Nomenclature of amphiboles: report of the Subcommittee on Amphiboles of the International Mineralogical Association, Commission on New Minerals and Mineral Names. *Canadian Mineralogist*, 35:219-246.

Lima M.I.C., Montalvão R.M.G., Issler R.S., Oliveira A.S., Basei M.A.S., Araújo J.F.V., Silva G.G. 1974. Folha NA/NB.22 - Macapá: Geologia, geomorfologia, solos, vegetação e uso potencial da terra. Rio de Janeiro, Departamento Nacional de Produção Mineral – DNPM, Levantamento de recursos naturais, v. 6, 120 p.

McDonough W. F. and Sun S.S. 1995. The composition of the Earth. *Chemical Geology*, 120:223–253.

McReath I. and Faraco M.T.L. 2006. Paleoproterozoic greenstone-granite belts in northern Brazil and the former Guyana Shield-West African craton province. *Geologia USP Série Científica*, 5(2):49-63.

Melo L.V. 2001. *Estudo do campo Urucum do depósito Amapari, Amapá, com base em dados petrográficos, de química mineral e microtermométricos*. MS Dissertation, Universidade Federal do Pará, Belém, 112 p.

Middlemost E.A.K. 1994. Naming materials in the magma/igneous rock system. *Earth Science Reviews*, 37:215-224.

Mikucki E.J. and Ridley J.R. 1993. The hydrothermal fluid of Archaean lode-gold deposits: constraints on its composition inferred from ore and wallrock alteration assemblages over a spectrum of metamorphic grades. *Mineralium Deposita*, 28:469-481.

Mueller A.G., Groves D.I., Delor C.P. 1991. The Savage Lode magnesian skarn in the Marvel Loch gold–silver mine, Southern Cross greenstone belt, Western Australia. Part 2: Pressure–temperature estimates and constraints on fluid sources. *Canadian Journal of Earth Sciences*, 28(5):686–705.

Mueller A.G., Nemchin A.A., Frei R. 2004. The Nevoria gold skarn deposit, Southern Cross greenstone belt, Western Australia: Pressure-Temperature-Time path and relationship to postorogenic granites. *Economic Geology*, 99:453-478.

Nadoll P. 2011. *Geochemistry of magnetite from hydrothermal ore deposits and host rocks - Case studies from the Proterozoic Belt Supergroup, Cu-Mo-porphyry + skarn and Climax-Mo deposits in the western United States*. PhD Thesis, University of Auckland, Auckland, 311 p.

Nogueira S.A.A. 2002. *Contribuição ao estudo metalogenético do depósito de ouro de Salamangone, Distrito aurífero de Lourenço, Amapá*. PhD Thesis, Universidade de São Paulo, São Paulo, 250 p.

Onstott T.C. and Hargraves R.B. 1981. Proterozoic transcurrent tectonics: Paleomagnetic evidence from Venezuela and Africa. *Nature*, 289:131–136.

Otto A., Dziggel A., Kisters A.F.M., Meyer F.M. 2007. The New Consort gold mine, Barberton greenstone belt, South Africa: orogenic gold mineralization in a condensed metamorphic profile. *Mineralium Deposita*, 42:715–735.

Pearce J.A., Harris N.B.W., Tindle A.G. 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *Journal of Petrology*, 25:956-983.

Ricci P.S.F., Carvalho J.M.A., Rosa-Costa L.T., Klein E.L., Vasquez M.L., Vale A.G., Macambira E.M.B., Araújo O.J.B. 2001. Geologia e recursos minerais do Projeto RENCA - Fase I. Companhia de Pesquisa de Recursos Minerais - CPRM, Belém, Brazil, 69 p.

Ridley J.R., Diamond L.W. 2000. Fluid chemistry of orogenic lode gold deposits and implications for genetic models. *Reviews in Economic Geology*, 13:141–162.

Rieder M., Cavazzini G., D'Yakonov Y.S., Frank-Kamenetskii V.A., Gottardi G., Guoggenheim S., Koval P.V., Muller G., Neiva A.M.R., Radoslovich E.W., Robert J.L., Sassi, F.P., Takeda, H., Weiss, Z., and Wones, D.R., 1998, Nomenclature of the micas. *Canadian Mineralogist*, 36:41-48.

Rogers A.J., Kolb J., Meyer F.M., Vennemann T.W. 2013. Two stages of gold mineralization at Hutti mine, India. *Mineralium Deposita*, 48:99–114.

Rosa-Costa L.T., Ricci P.S.F., Lafon J.M., Vazquez M.L., Carvalho J.M.A., Klein E.L., Macambira E.M.B. 2003. Geology and geochronology of Archean and Paleoproterozoic domains of the southeastern Amapá and northwestern Pará, Brazil – southeastern Guiana Shield. *Géologie de la France*, 2–4:101-120.

Rosa-Costa L.T., Lafon J.M., Delor C. 2006. Zircon geochronology and Sm-Nd isotopic study: Further constraints for the Archean and Paleoproterozoic geodynamic evolution of the southeastern Guiana Shield, north of Brazil. *Gondwana Research*, 10:277-300.

Rosa-Costa L.T., Chaves C.L., Klein E.L. 2014. Geologia e recursos minerais da folha Rio Araguari NA.22-Y-B, estado do Amapá, escala 1:250.000. Belém, Serviço Geológico do Brasil - CPRM, 159 p.

Santos J.O.S., Hartmann L.A., Gaudette H.E., Groves D.I., Mcnaughton N.J., Fletcher I.R. 2000. A new understanding of the provinces of the Amazonian Craton based on integration of field mapping and U–Pb and Sm–Nd geochronology. *Gondwana Research*, 3:453–488.

Santos J.O.S., Hartmann L.A., Faria M.S., Riker S.R., Souza M.M., Almeida M.E., McNaughton N.J. 2006. A compartimentacao do Craton Amazônico em províncias: Avanços ocorridos no período de 2000-2006. In: 9° Simpósio de Geologia da Amazônia. Belém, Anais, 3, p. 156-159.

Scarpelli W. and Horikava E.H. 2017. Gold, iron and manganese in central Amapá, Brazil. *Brazilian Journal of Geology*, 47(4):703-721.

Shackleton J.M., Spry P.G., Bateman R. 2003. Telluride mineralogy of the Golden Mile deposit, Kalgoorlie, Western Australia. *The Canadian Mineralogist*, 41:1503-1524.

Shand S.J. 1943. Eruptive rocks: their genesis, composition, and classification, with a chapter on meteorites. New York, Wiley, 444 p.

Sharp Z.D., Essene E.J., Kelly W.C. 1985. Reexamination of the arsenopyrite geothermometer: pressure considerations and application to natural assemblages. *Canadian Mineralogist*, 23:517-534.

Steven N., Creaser R., Wulff K., Kisters A., Eglington B., Miller J. 2014. Implications of high-precision Re–Os molybdenite dating of the Navachab orogenic gold deposit, Namibia. *Geochemistry: Exploration, Environment, Analysis*, 15 (2-3):125-130.

Sun S.S., McDonough W.F. 1989. Chemical and isotopic systematics of oceanic basalts: implication for mantle composition and processes. *Geological Society Special Publication*, 42:313–345.

Tassinari C.C.G. and Macambira M.J.B. 1999. Geochronological provinces of the Amazonian Craton. *Episodes*, 22:174–182.

Tassinari C.C.G. and Macambira M.J.B. 2004. A evolução tectônica do Cráton Amazônico. In: Mantesso-Neto V., Bartorelli A., Carneiro C.D.R., Brito Neves, B.B. (eds.). Geologia do Continente Sul-Americano: Evolução da Obra de Fernando Flávio Marques de Almeida. São Paulo, Beca, p. 471–485.

Tavares R. P. S. 2009. *Granitoides e anfibolitos da Serra do Navio, borda norte do bloco arqueano Amapá: caracterização petrográfica e geoquímica, geocronologia Pb-Pb em zircão e isótopos de Nd*. MS Dissertation, Universidade Federal do Pará, Belém, 114 p.

Taylor S. R. and McLennan S.M. 1985. The Continental Crust: Its Composition and Evolution. Oxford, Blackwell, 312 p.

Tomkins A.G., Frost B.R., Pattison D.R.M. 2006. Arsenopyrite melting during metamorphism of sulfide ore deposits. *Canadian Mineralogist*, 44:1045–1062.

Tooth B., Brugger J., Ciobanu C., Liu W. 2008. Modeling of gold scavenging by bismuth melts coexisting with hydrothermal fluids. *Geology*, 36:815–818.

Vasquez M.L., Rosa-Costa L.T.R. 2008. Geologia e recursos minerais do Pará: Texto explicativo dos mapas geológico, tectônico e de recursos minerais do estado do Pará. Belém, Serviço Geológico do Brasil – CPRM, 328 p.

Voicu G., Bardoux M., Stevenson R. 2001. Lithostratigraphy, geochronology and gold metallogeny in the northern Guiana Shield, South America: a review..*Ore Geology Reviews*, 18:211–236.

Weir Jr R.H. and Kerrich D.M. 1987. Mineralogic, fluid inclusion, and stable isotope studies of several gold mines in the Mother Lode, Tuolumne and Mariposa counties, California. *Economic Geology*, 82:328-344.

Winter J.D. 2010. An introduction to igneous and metamorphic petrology, 2nd edition. Upper Saddle River, Prentice Hall, 702 p.

Wu C.M. 2019. Original calibration of a garnet geobarometer in metapelite. Minerals, v. 9, 540 p.

Zang W. and Fyfe W.S. 1995. Chloritization of the hydrothermally altered bedrock at the Igarapé Bahia gold deposit, Carajás, Brazil. *Mineralium Deposita*, 30:30-38.

APÊNDICE 1 - Fichas de descrição petrográfica

Lista de abreviações de minerais

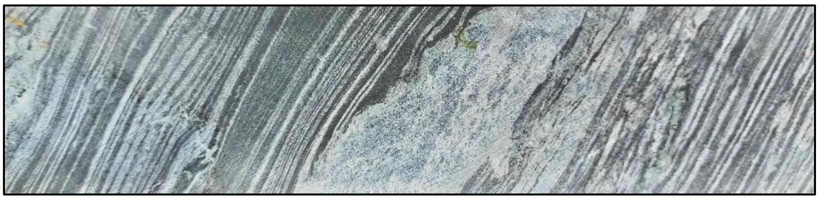
act = actinolita
ap = apatita
asp = arsenopirita
au = ouro
aug = augita
bt = biotita
bi phases = minerais portadores de bismuto
carb = carbonato indistinto
chl = clorita
cpy = calcopirita
cum = cummingtonita
di = diopsídio
dol = dolomita
ep = epidoto
fe-act = ferroactinolita
grt = granada
gru = grunerita
hbl = hornblenda
hd = hedenbergita
hst = hastingsita
ilm = ilmenita
lol = loellingita
ms = muscovita
mt = magnetita
ol = olivina
phl = flogopita
pgs = pargassita
pl = plagioclásio
po = pirrotita
py = pirita
qz = quartzo
serp = serpentina
sp = espinélio
sph = esfalerita
spm = espodumênio
stp = stilpnomelano
tc = talco
tit = titanita
tour = turmalina
tr = tremolita

Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: URS-033-05	Drillhole ID: URS033	Profundidade: 256,8 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N:	UTM E:



Descrição Microscópica

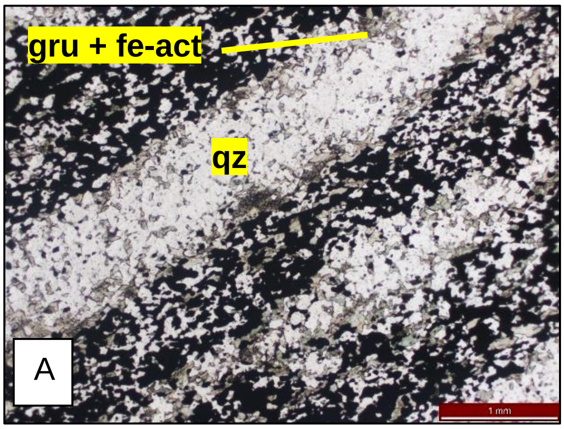
Rocha granonematoblástica de granulação média, com bandamento definido pela alternância de níveis a quartzo e anfibólio, e magnetita e anfibólio, de espessura desde submilimétrica até 2 mm (A ,B). Enquanto o quartzo é volumetricamente significativo no interior das bandas a magnetita, a magnetita é pouco abundante nos níveis onde o quartzo predomina.

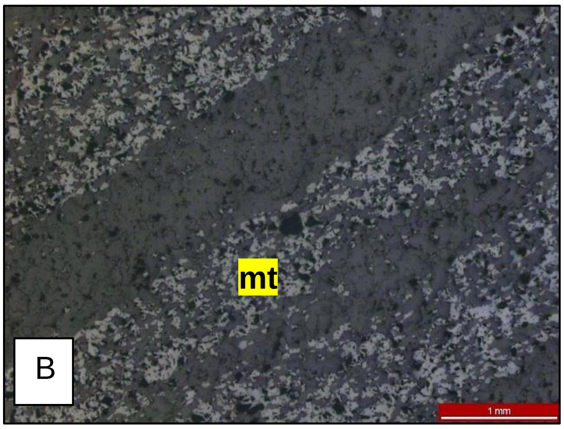
A magnetita é predominantemente subédrica, com tamanho de grão compreendido entre 0,01 e 0,15 mm. Localmente, alinhamentos de cristais de magnetita definem microbandas no interior das mesobandas. Os espaços intergranulares nas bandas a magnetita são preenchidos por quartzo e anfibólio, com distinção de anfibólio pobre em cálcio de cor castanho claro (grunerita) e anfibólio cálcico verde (actinolita). Nas bandas onde o quartzo é o principal mineral, este ocorre como cristais de fração média (0,1-0,3 mm) em relativa homogeneidade granulométrica, onde a vasta maioria dos cristais está compreendida entre 0,1 e 0,2 mm. Predominam contatos retos a suavizados, definindo uma trama granoblástica poligonizada. Devido à limitação de espaço imposta pelo arcabouço de cristais de magnetita, o quartzo é ligeiramente mais fino como fase intergranular nas bandas a magnetita, apenas esporadicamente acima de 0,1 mm.

Quanto ao anfibólio, trata-se uma fase mineral abundante e disseminada de forma irrestrita. Não obstante, sua concentração é maior nas bandas a magnetita. Seu modo de ocorrência inclui preenchimento intergranular, tanto em domínio quartzoso quanto em magnetítico, alinhamento de cristais formando feixes subparalelos descontínuos e de espessura irregular, e ocorrências intersticiais, especialmente em quartzo. Observa-se que seu desenvolvimento se dá preferencialmente nas bandas a magnetita, se projetando a partir destas em direção às bandas quartzosas. Localmente, verificam-se feições semelhantes a halos de anfibólio em torno das bandas a magnetita, localmente largas o suficiente para se conectarem a halos adjacentes, substituindo assim a banda de quartzosa intercalada. A actinolita tipicamente tem hábito subequante a prismático curto, subédrico a anédrico, ao passo que grunerita se desenvolve comumente como cristais prismáticos longos, subédricos a anédricos, sendo localmente observados cristais com intercrescimento das duas fases. Quanto a sua granulação, observa-se que cristais de natureza intergranular e intersticial, isto é, excluindo-se os feixes, são quase sempre <0,25 mm. Por outro lado, quando formam feixes e *stringers*, esses agregados de anfibólio contém cristais mais grossos, podendo medir até 0,6 mm em seu comprimento maior, principalmente grunerita.

Localmente, observam-se raros níveis/microveios de hedenbergita de espessura submilimétrica (0,2 mm), e orientados em baixo ângulo a partir do bandamento. Destaca-se na rocha a presença de um veio de actinolita oblíquo em baixo ângulo à foliação definida pelo bandamento. Sua espessura é variável, desde < 0,5 mm em porções mais finas a cerca de 3 mm em lentes de espessamento. Nele podem ser observados raros cristais de hedenbergita parcialmente consumidos, completamente envoltos por actinolita e com algum carbonato associado. A granulação média do anfibólio no veio é superior ao do restante da amostra, com a maior parte dos cristais entre 0,2 e 0,6 mm, com raros cristais alcançando até 1,0 mm, alguns dos quais geminados. Os contatos entre cristais são predominantemente retos. Magnetita intersticial é observada nesse veio, podendo alcançar até 0,3 mm, substancialmente mais grossa que aquela contida no bandamento. Vale ressaltar que a mesma se encontra em aparente equilíbrio textural com pirrotita, dada por relações de intercrescimento. A pirrotita é de granulação fina a média (<0,05-0,3 mm), e assume a geometria dos espaços intergranulares no veio de actinolita e, por esse motivo, pode apresentar uma ou mais faces retas. Com exceção desse veio, sulfetos são extremamente escassos na amostra, sendo identificados particularmente nos níveis de maior concentração de anfibólio relativamente mais grosso, onde cristais anédricos a subédricos de até 0,15 mm ocorrem em relação intergranular a intersticial com respeito aos cristais de anfibólio, e notavelmente substituindo a magnetita metamórfica da rocha.

Mineralogia Modal Semiquantitativa
QUARTZO (42%), MAGNETITA (25%), GRUNERITA (18%), FERROACTINOLITA (14,9%), HEDENBERGITA (0,1%)
Nome da rocha: **anfibólio-quartzo-magnetita formação ferrífera bandada com alteração a grunerita-ferroactinolita ± hedenbergita**
Fotomicrografias



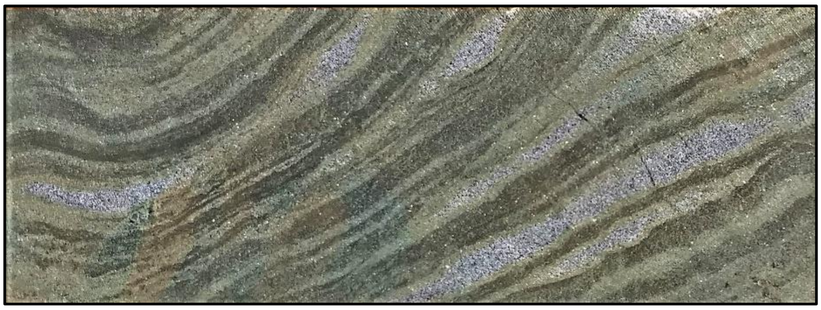


Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-004-21	Drillhole ID: A04	Profundidade: 195,2 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96201	UTM E: 402351



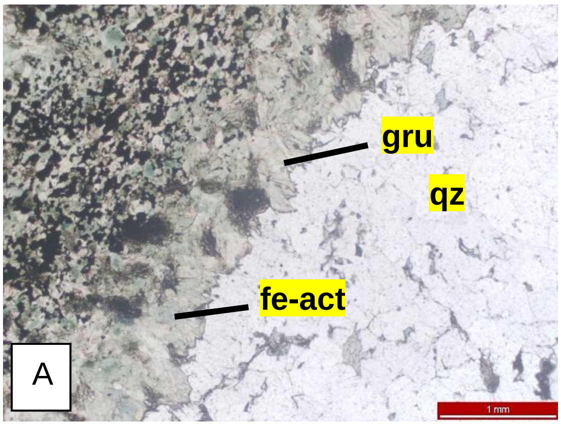
Descrição Microscópica

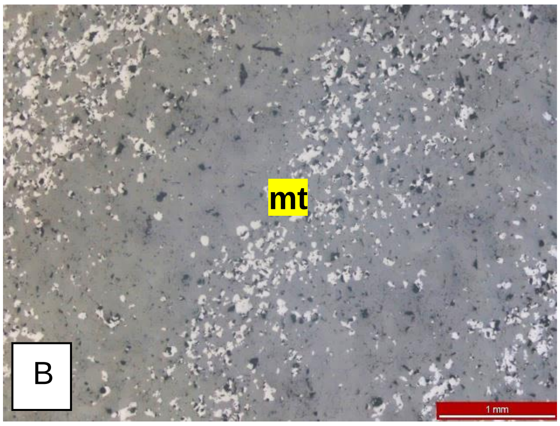
Rocha granonematoblástica de granulação média, com bandamento definido pela alternância de níveis ricos em quartzo e magnetita, de espessura entre 1 e 5 mm, com marcante proporção de anfibólio desenvolvido no interior dos níveis a magnetita e formando halos em seu entorno (A), por vezes, se estendendo lateralmente ao ponto de coalescer com halo de banda adjacente, neste caso obliterando parcial ou totalmente a banda a quartzo intermediária.

A magnetita é de granulação predominantemente fina (0,01-0,1 mm) e subédrica, com fração diminuta dos cristais excedendo essa faixa e podendo alcançar até 0,2 mm. As bandas a magnetita (B) são constituídas, na verdade, por menos de 50% em volume desse mineral, de modo que são raras massas amalgamadas relativamente contínuas. Do contrário, observam-se cristais em geral individualizados separados por anfibólio, este sendo a fase mais abundante nessas bandas. O quartzo é de granulação média a grossa (0,2-1,3 mm) e seus cristais definem um arranjo dominantemente granoblástico poligonizado. A despeito disso, observam-se frequentemente cristais com extinção ondulante e, em menor frequência, contatos indicativos de recristalização por migração de limite de grão.

Os anfibólios constituem a fase mais abundante da rocha e, como citado anteriormente, desenvolvem-se principalmente sobre e no entorno de bandas a magnetita. Não obstante,

anfibólio intersticial é observado no interior das bandas a quartzo, sendo localmente observado um alinhamento de cristais prismáticos oblíquo à foliação principal dada pelo bandamento. Em termos texturais, a granulação do anfibólio é fina a média (0,05 – 0,6 mm), com a maioria <0,2 mm, com cristais subequantes a prismáticos subédricos. De modo geral, não se observa um alinhamento preferencial dos cristais de anfibólio, salvo em casos localizados conforme descrito anteriormente. Localmente, observa-se inclusive o desenvolvimento de arranjos decussados em agregados de anfibólio. Vale frisar que o contato entre halos anfibolíticos e bandas quartzosas evidencia cristais de anfibólio orientados em alto ângulo a superfície de contato, indicando avanço do primeiro sobre o segundo. Sob o ponto de vista composicional, descrevem-se dois tipos de anfibólio, quais sejam, actinolita e grunerita, sendo distinguidos pela cor a nicóis paralelos (actinolita é verde pleocróica) e pela geminação múltipla típica da grunerita. Esta via de regra se desenvolve como cristais mais longos.
Mineralogia Modal Semiquantitativa
FERROACTINOLITA (45%), QUARTZO (22%), MAGNETITA (25%), GRUNERITA (8%)
Nome da rocha: **quartzo-magnetita formação ferrífera bandada com alteração a ferroactinolita-grunerita**
Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-005-02	Drillhole ID: A05	Profundidade: 122,6 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96140	UTM E: 402380

Descrição Microscópica

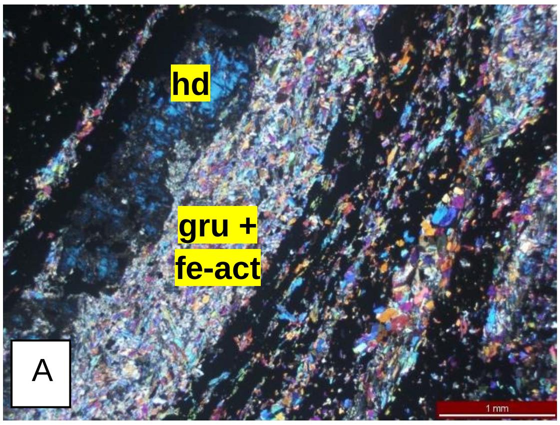
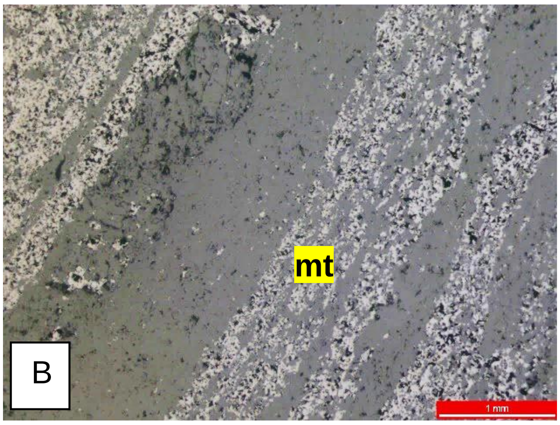
Rocha granonematoblástica de granulação fina a média, anisotrópica, de estrutura bandada, e cuja constituição mineralógica compreende magnetita, anfibólios das séries tremolita-ferroactinolita e cummingtonita-grunerita, hedenbergita, quartzo e carbonato. São definidas mesobandas de magnetita fina (0,01-0,1 mm) subédrica de espessura variando de 0,5 a 2,0 mm, com microbandas internas. Estas se encontram alternadas com bandas a anfibólio de espessura variando de 0,4 a 2,5 mm (A, B). O anfibólio predominante é a grunerita, sendo tipicamente documentada como cristais prismáticos geminados com orientação preferencial paralela ao bandamento apenas pobremente definida. A maioria dos cristais não excede 0,25 mm. Não obstante, localmente se observam concentrações de cristais mais grossos, podendo alcançar 1,0 mm. Cristais com pleocroísmo verde mais intenso (actinolita) são observados em meio à grunerita, tipicamente pouco pleocróica, com relação de aparente equilíbrio. A actinolita ocorre sob a forma de cristais prismáticos curtos subédricos geralmente <0,2 mm. A relação textural dos anfibólios com a magnetita é de superposição, com ligeira perturbação do bandamento. Em um dos locais de ocorrência de grunerita mais grossa, nota-se que os cristais prismáticos dessa fase truncam bandas a magnetita. Onde a trama anfibolítica não é contínua, domínios quartzosos são descritos. Predominam cristais finos a médios (0,05 – 0,2 mm principalmente) com extinção ondulante e localmente formação de lamelas de deformação. Os contatos entre cristais de quartzo são frequentemente povoados por anfibólio intersticial. Quando em contato direto, todavia, predominam superfícies retas a levemente curvilíneas, e subordinadamente limites de grão com *bulging*. Vale frisar que os espaços intergranulares entre os cristais de magnetita nas bandas de óxido de ferro são ocupados por anfibólios, tanto grunerita quanto actinolita.

Níveis ou veios *boudinados* de hedenbergita são documentados na amostra e sua orientação é paralela ao bandamento. Um deles tem espessura variando de 0,5-1,0 mm, com *boudins* individualmente estirados a comprimentos de 1,5-3,0 mm. O segundo é representado por dois grandes *boudins* de espessura aproximada de 5 mm e comprimento de até 1,2 cm. Esses megacristais de hedenbergita se encontram intensamente alterados, sendo substituídos ao longo de suas margens, bem como em seu interior, por actinolita e subordinadamente carbonato. Destaca-se a presença de um cristal de actinolita de 1,5 mm desenvolvido no interior da hedenbergita. Actinolita e carbonato se desenvolvem através de uma rede interconectada de microfissuras no piroxênio hospedeiro, em parte condicionada pela sua própria clivagem, com granulação e geometria condicionadas a sua ocorrência em pequenas fissuras sob forma de vênulas ou em cavidades mais amplas. Disto resulta que o aspecto do clinopiroxênio tende a uma textura esquelética. A actinolita se distingue ainda por formar mantos alongados em torno dos cristais de hedenbergita, semelhantes a sombras de pressão. Nelas, essa fase ocorre como massas monominerálicas de cristais subequantes a prismáticos subédricos quase que invariavelmente < 0,2 mm. Vale frisar que esse anfibólio cálcico é variedade abundante apenas nas imediações dos cristais de clinopiroxênio. Em outros locais, a grunerita é amplamente dominante. Vale ressaltar que tanto o piroxênio quanto os anfibólios, estes de forma bem mais restrita, encontram-se localmente substituídos por agregados de baixa cristalina de cor verde musgo.

Sobre os cristais corroídos de clinopiroxênio também se identifica magnetita, desde cristais finos (<0,05 mm) até agregados anédricos mais grossos (<0,3 mm). Localmente, observa-se que tais agregados se projetam a partir da banda de magnetita fina adjacente. Como fase acessória, relata-se a ocorrência localizada de apatita subédrica arredondada com tamanho aproximado de 0,15 mm.

Observa-se uma falha de baixa persistência rompendo uma banda de magnetita.

Mineralogia Modal Semiquantitativa
GRUNERITA (55%), MAGNETITA (25%), HEDENBERGITA (12%), FERROACTINOLITA (5,5%), QUARTZO (2,5%)
Nome da rocha: **quartzo-magnetita formação ferrífera bandada com veio de hedenbergita e intensa alteração a grunerita-ferroactinolita**

Fotomicrografias	
	

Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-029-38	Drillhole ID: A29	Profundidade: 209,7 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310

Descrição Microscópica

Rocha granonematoblástica de granulação média com bandamento composicional relicto intensamente perturbado e constituída por magnetita, grunerita, ferroactinolita, hedenbergita e pirrotita.

A trama da rocha é definida pela ocorrência de bandas rompidas de magnetita fina (em geral <0,1 mm) subédrica, em geral com cristais amalgamados, separados por domínios constituídos principalmente por agregados de grunerita prismática euédrica a subédrica de granulação fina a média (<0,1-0,6 mm) (A, B). Seus cristais são dispostos segundo arranjo decussado (sem orientação preferencial), apenas localmente observando-se cristais alinhados. Tais massas anfibolíticas truncam o antigo bandamento, e contém ainda hedenbergita e pirrotita. De forma um pouco mais localizada, observa-se também um conteúdo significativo de ferroactinolita, exibindo relação de equilíbrio com a grunerita, por vezes através de texturas de intercrescimento complexas. Enquanto a grunerita exibe mais comumente hábito prismático longo com geminação múltipla característica, a ferroactinolita possui forma prismática mais curta até subequante. Os contatos entre cristais de ferroactinolita são geralmente retos, resultando em trama local poligonizada.

A hedenbergita é uma fase disseminada pela massa anfibolítica e de distinta cor verde clara, com cristais prismáticos desde curtos até bastante elongados, subédricos a anédricos, e com tamanho de grão compreendido entre 0,1-2,0 mm. Ele se apresenta como uma fase em aparente desequilíbrio, com alteração ao longo de contatos e redes de fraturas intragranulares. Os produtos de alteração são deveras finos e de difícil identificação.

Entretanto, onde a granulação é um pouco mais grossa, constata-se que o próprio anfibólio que o engloba é um deles.

Ainda a respeito das bandas a magnetita, seus interstícios são ocupados por grunerita e ferroactinolita que, limitados pelos cristais de magnetita adjacentes, assumem uma granulação final tal qual a dos cristais de magnetita.

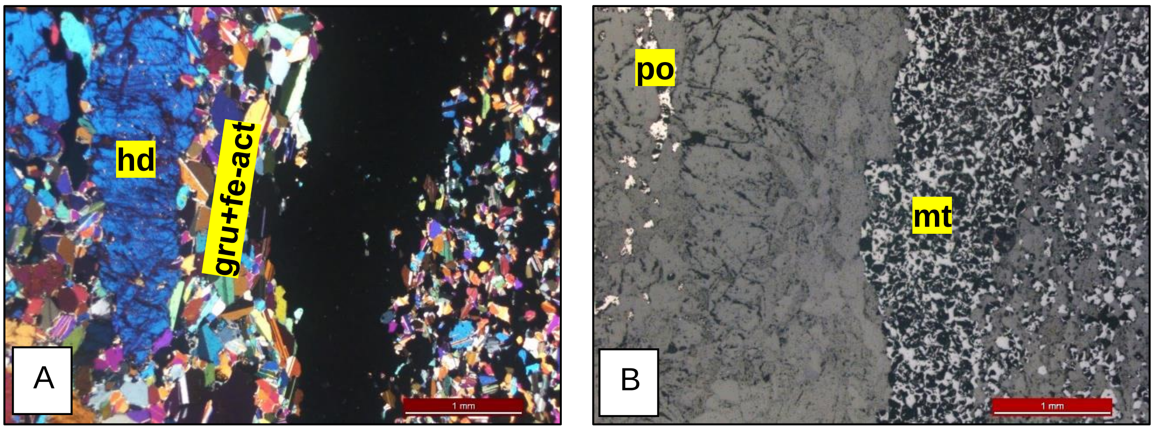
Pirrotita é uma fase que ocorre em proporção significativa, porém não se distribui de forma homogênea pela amostra, estando ausente nas bandas relictas de magnetita. Há porções da massa anfibolítica onde a pirrotita é escassa, com apenas alguns poucos cristais subequantes a elongados, subédricos ou anédricos, medindo entre 0,1-0,2 mm, de natureza essencialmente intersticial com respeito ao anfibólio. Outros locais, em contrapartida, podem conter cristais mais grossos (<1,0 mm) em maior abundância. Destaca-se aqui a ocorrência de uma massa de pirrotita com >1,0 cm de extensão formada a partir de precipitação intersticial ao ponto de encapsular por completo muitos cristais de hedenbergita e anfibólios. Nota-se que a pirrotita se concentra principalmente nos locais onde ao conteúdo de hedenbergita é maior, precipitando-se em suas fraturas ou se posicionando ao longo de limites de grão.

Mineralogia Modal Semiquantitativa

GRUNERITA (63%), MAGNETITA (13%), FERROACTINOLITA (8,8%), HEDENBERGITA (8%), PIRROTITA (7%), MATERIAL DE ALTERAÇÃO DE HEDENBERGITA DE GRANULAÇÃO MUITO FINA (0,2%)

Nome da rocha: **hedenbergita-ferroactinolita-magnetita-grunerita xisto sulfetado a pirrotita**

Fotomicrografias



Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-028-15b	Drillhole ID: A28	Profundidade: 192,6 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96499	UTM E: 402339

Descrição Microscópica

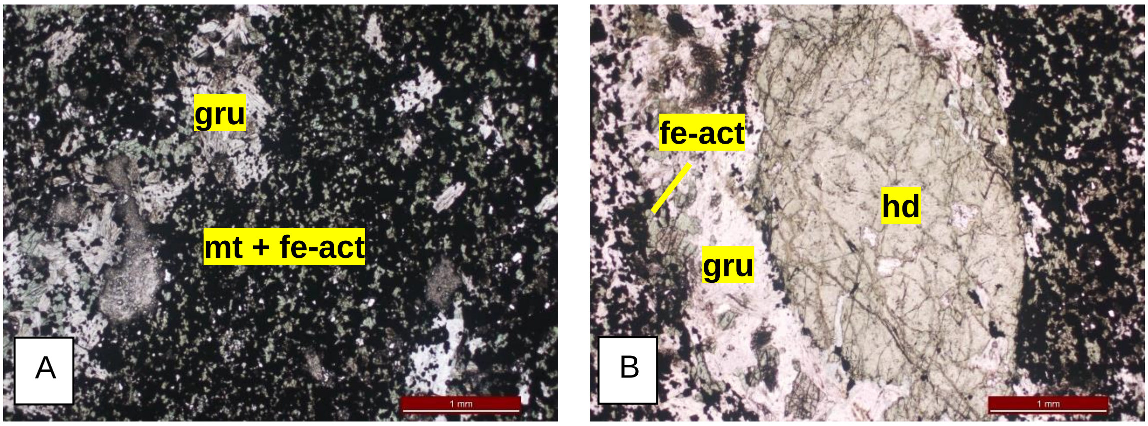
Rocha granonematoblástica, de granulação média e heterogênea, constituída por dois domínios bandados e dobrados composicionalmente distintos.

i) Rocha de granulação média alternando bandas quartzosas com níveis de magnetita muito delgados. Trata-se na verdade de filmes descontínuos de espessura submilimétrica (0,1-0,2 mm) definindo microdobras abertas. Esses níveis estão separados entre si por distâncias aproximadas de 0,8 a 1,0 mm. O quartzo é principalmente de granulação média (0,1-0,4 mm), com extinção ondulante e contatos suturados a semipoligonizados. Associados aos filmes de magnetita e intersticialmente ao quartzo, ocorrem cristais prismáticos aciculares subédricos de grunerita e, em menor proporção, cristais prismáticos curtos subédricos de anfibólio verde (ferroactinolita?), ambos medindo de 0,1-0,25 mm. Cristais disseminados de carbonato ocorrem de forma subordinada. *Clots* de composição dominantemente carbonática de cerca de 5 mm de extensão são reportados nesse domínio. Neles são observados agregados de filossilicatos de granulação fina que se formam, pelo menos em parte, por desestabilização e substituição dos anfibólios, principalmente grunerita. Devido à granulação muito fina, não é possível determinar todas as fases com exatidão, sendo inferida a presença de stilpnomelano, sericita e clorita, os quais se desenvolvem entremeados a um carbonato muito fino. O anfibólio verde exibe menor grau de desequilíbrio na presença dessas fases.

ii) Rocha de granulação média pobre em quartzo e rica em magnetita e anfibólios, com bandas em geral pobremente definidas. Alternam-se bandas de espessura em geral inferior a 1,0 mm de magnetita + anfibólio verde ± grunerita e grunerita ± anfibólio verde ± magnetita (A). Magnetita e o anfibólio verde são geralmente granulares e subédricos, de granulação fina a média, variando desde <0,1-0,2 mm, enquanto a grunerita é levemente mais grossa (0,2-0,3 mm) e de hábito prismático subédrico. Apesar do bandamento se apresentar dobrado, os cristais de grunerita não exibem orientação preferencial, nem nos flancos nem em zona de charneira, ao ponto de localmente exibir textura decussada (radial). O dobramento está integrado a uma estrutura de arrasto (cisalhamento simples) delimitada em ambos os lados por paredes de magnetita e centrada em um nível (lente/veio?) *boudinado* de clinopiroxênio verde (hedenbergita) de granulação média a grossa (o maior dos *boudins* tem 4 mm de extensão) (B). Esses cristais de hedenbergita são circundados por cristais prismáticos subédricos a euédricos de grunerita aleatoriamente orientados, que ocupam também as regiões de *neck* (pinçamento) dos *boudins*. A ocorrência de sulfetos é bastante restrita na rocha como um todo, estando condicionada espacialmente à presença dessa estrutura – (i) no interior dos *boudins*; (ii) nas margens dos *boudins* e; (iii) principalmente nas regiões de pinçamento. Uma estrutura semelhante (vênula/lente estirada? de hedenbergita), porém não boudinada, com espessura de 0,3 mm, é identificada paralelamente à primeira.

Mineralogia Modal Semiquantitativa
GRUNERITA (35%), MAGNETITA (25%), ACTINOLITA (18%), HEDENBERGITA (6%), QUARTZO (12%), CARBONATO (2%), FILOSSILICATOS FINOS (STILPNOMELANO + SERICITA + CLORITA) (1,9%), PIRROTITA (0,1%)
Nome da rocha: **quartzo-actinolita-magnetita-grunerita xisto com veio de hedenbergita alterado a grunerita**

Fotomicrografias



Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

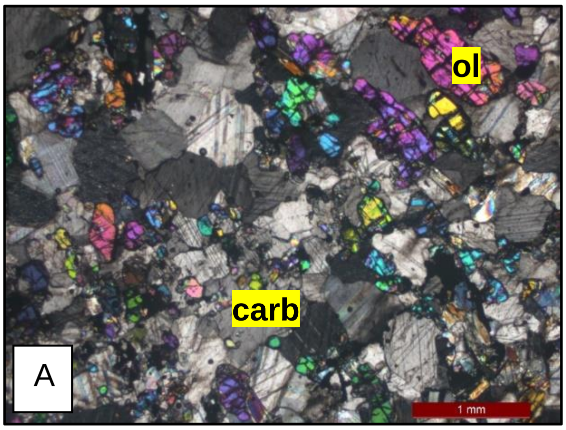
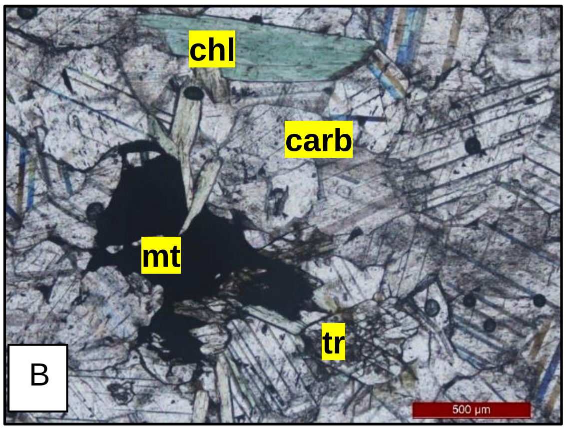
Código da amostra: TUC-DD-009-03d	Drillhole ID: A09	Profundidade: 69,8 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96334	UTM E: 402358

Descrição Microscópica

Rocha granoblástica de granulação média, isotrópica e com matriz de composição carbonática com cristais compreendidos principalmente entre 0,2-0,7 mm, cujos contatos são predominantemente retos definindo uma trama poligonizada. Nota-se também localmente cristais com alto grau de arredondamento. A rocha não é homogênea, sendo dominana por uma matriz carbonática quase pura manchada por domínios de geometria irregular com maior concentração de fases silicáticas. Olivina é a fase silicática mais abundante, ocorrendo sob a forma de cristais prismáticos curtos a subequantes subarredondados, variando de 0,1-1,0 mm (A). Tremolita é uma fase bastante subordinada, sendo identificada como cristais prismáticos curtos a longos, preferencialmente subédricos, medindo de 0,2-1,0 mm. Lamelas de clorita medindo entre 0,2-1,0 mm ocorrem de forma disseminada e carecem de orientação preferencial. Variações internas de birrefringência, com remanescentes de cores de maior ordem, sugerem se tratar de uma fase retrógrada após flogopita. Magnetita fina (<0,1 mm) ocorre como preenchimento intersticial na matriz carbonática e, sobretudo, em íntima associação espacial com as fases silicáticas, seja preenchendo fraturas, envolvendo-as ou como fase sobrecrescente. Localmente, cristais mais grossos (<0,4 mm) são identificados (B). Igualmente de forma localizada, pseudomorfos de clinohumita (?) após olivina são identificados.

Mineralogia Modal Semiquantitativa

CARBONATO (91%), OLIVINA (6%), CLORITA (2%), MAGNETITA (0,5%), TREMOLITA (0,4%), CLINOHUMITA? (0,1%)

Nome da rocha: **olivina mármore com flogopita cloritizada**	
Fotomicrografias	
	

Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-011-01	Drillhole ID: A11	Profundidade: 183,0 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96220	UTM E: 402393

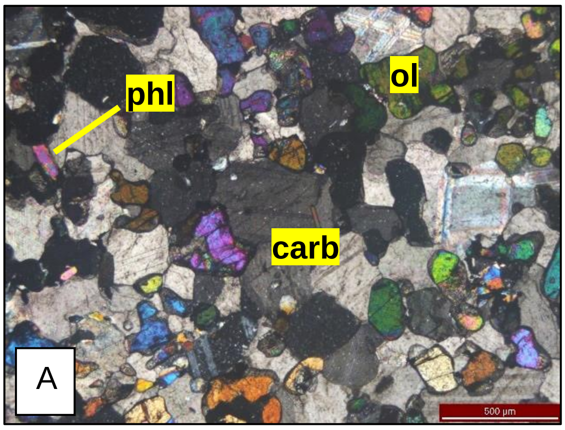
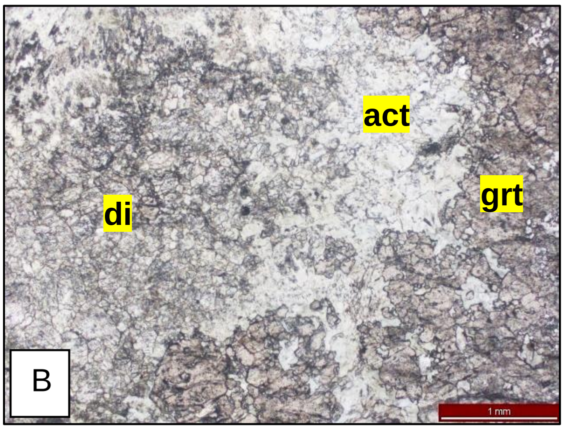
Descrição Microscópica

Rocha granoblástica de granulação fina a média, isotrópica, constituída por matriz de composição carbonática com cristais medindo de 0,1-0,5 mm e cujos contatos são definidos por superfícies retilíneas a curvilíneas suaves, localmente com pontos tríplices indicativos de redução de área de limite de grão (poligonização). Essa rocha contém proporções significativas de olivina, sob a forma de cristais subequantes a prismáticos, anédricos a subédricos, e ocupando a mesma faixa granulométrica da matriz carbonática. De ocorrência bastante subordinada, a flogopita é identificada como lamelas de granulação fina a média (0,08-0,2 mm) e aleatoriamente orientadas (A). Cristais subédricos de ilmenita de granulação fina (0,04-0,06 mm) são localmente identificados em aparente equilíbrio com olivina ou inclusas na mesma, podendo exibir intercrescimento com magnetita.

Essa rocha se encontra em contato com um dique de leucogranito com granada de granulação grossa. Este granito é de composição hololeucocrática dada sua carência de minerais máficos. Sua mineralogia principal consiste em quartzo, albita, K-feldspato e uma mica de cor verde pálida. O quartzo é de natureza intersticial anédrica, embora também forme lentes e bolsões irregulares. Seu tamanho é variável, desde <0,1 a >1,5 mm, com as frações mais grossas geralmente alocadas nesses bolsões. Os feldspatos ocorrem como cristais tabulares com margens intensamente recristalizadas, com frequente perda de faces cristalográficas. Sua granulação varia de média a grossa (0,3-3,5 mm), com as frações mais finas em equilíbrio com o quartzo intersticial. Albita é amplamente prevalente em comparação com o K-feldspato, sendo distinguidos pela identificação de geminação da albita na primeira, e geminação da albita e da periclina no segundo (microclina). A granada ocorre como cristais subédricos a anédricos, intactos ou fragmentados, de tamanho de grão compreendido entre 0,5 e 3,0 mm. Ademais, proporções subordinadas de uma mica verde de alta birrefringência (biotita?) Suas lamelas são invariavelmente < 0,2 mm e sua relação textural com as demais fases indica que se formou após os feldspatos mais grossos, por vezes, atravessando seus limites de grão. Localmente, pode-se observar uma mica incolor fina (<0,1 mm) – muscovita/sericita? – em equilíbrio com essa mica verde.

O contato entre essa rocha ígnea e a encaixante carbonática se dá por um halo de alteração constituído por um nível interno (tomando como referência o granito) a granada e um envelope externo de diopsídio (B). O primeiro tem espessura entre 1 e 2 mm, enquanto o segundo entre 4 e 6 mm. Rara ilmenita fina (<0,1 mm) intergranular pode ser identificada nessa zona. A franja de granada é contínua, sem limites de grão evidentes em seu interior, com exceção de um fragmento isolado de cerca de 1,5 mm. Em contrapartida, a zona piroxenítica externa é constituída por mosaico de cristais subequantes médios a grossos (0,3-1,5 mm) em textura *interlocking.* Ambos os níveis, especialmente a zona externa piroxenítica, se encontram desestabilizados na presença de anfibólio (tremolita-actinolita), com elevado grau de decomposição dos cristais de diopsídio em face do desenvolvimento daquela fase ao longo de limites de grão e em redes de fissuras interconectadas. Disto resulta a ocorrência de cristais de diopsídio exibindo textura do tipo peneira. O anfibólio exibe grande variação morfológica e granulométrica, com cristais sub-equantes, prismáticos curtos e longos, subédricos a anédricos, e tamanho variando de muito fino (0.025 mm) a médio (0,8 mm). Os tipos prismáticos mais grossos se concentram na margem do nível granatífero. Os espaços intersticiais entre cristais de anfibólio são ocupados por fase carbonática. A granada, comparativamente ao diopsídio, exibe menor grau de alteração resultando em anfibólio e carbonato. Contudo, as fraturas internas nesse granada costumam ser sítios de formação de apatita, cujos cristais localmente se assemelham a inclusões. A margem interna da franja de granada exibe intensa sericitização, a qual avança sobre a matriz quartzo-feldspática do granito.

A rocha encaixante do granito, já descrita em linhas gerais anteriormente, testemunha uma gradual transformação mineralógica com a aproximação dessa auréola de contato. Isso se dá através da intensificação da substituição pseudomórfica da olivina metamórfica por tremolita + magnetita. Esse anfibólio tem amplitude granulométrica semelhante a da olivina, podendo ser prismático subédrico a anédrico, ocorrendo também como preenchimento intersticial da matriz carbonática. A magnetita resultante desse processo também tem caráter intersticial, sendo anédrica e fina (<0,1 mm), frequentemente com hábito vermiforme. Sulfetos são extremamente raros, com identificação de poucos cristais de

pirrotita incrustados em olivina, podendo ou não estar associado à paragênese tremolita + magnetita. Localmente, observa-se ainda transformação retrógrada de olivina para ora serpentina ora clinohumita.
Mineralogia Modal Semiquantitativa
ROCHA ENCAIXANTE: CARBONATO (75%), OLIVINA (21%), TREMOLITA (2%), MAGNETITA (1,5%), CLINOHUMITA? (0,2%), SERPENTINA (0,1%), FLOGOPITA (0,1%), ILMENITA (0,1%) AURÉOLA DE CONTATO: DIOPSÍDIO (63%), ACTINOLITA (20%), GRANADA (15%), CARBONATO (1,8%), APATITA (0,2%) GRANITO: QUARTZO (32%), ALBITA (32%), K-FELDSPATO (13%), SERICITA (12,5%), GRANADA (10%), BIOTITA (0,4%), MUSCOVITA (0,1%)
Nome da rocha: **olivina mármore em contato intrusivo com granada leucogranito, resultando em alteração do tipo granada-diopsídio superimposta por anfibólio-carbonato-magnetita**
Fotomicrografias
 

Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

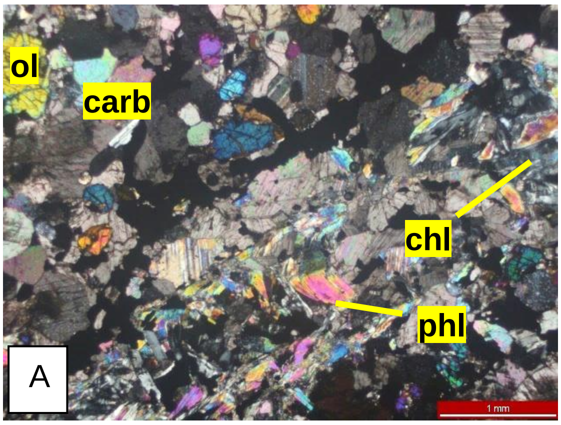
Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

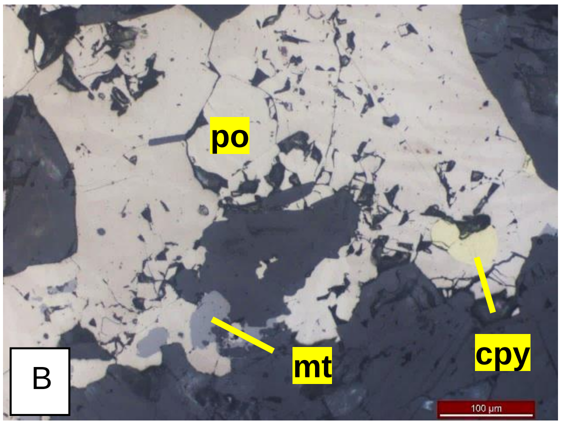
Código da amostra: TUC-DD-004-22b	Drillhole ID: A04	Profundidade: 200,0 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96201	UTM E: 402351

Descrição Microscópica

Rocha granoblástica de granulação média, isotrópica, constituída por uma matriz carbonática de arranjo textural dominantemente poligonizado com tamanho de grão compreendido principalmente entre 0,2-0,8 mm. Sua feição diagnóstica é a abundância de olivina, sob a forma de cristais subequantes a prismáticos curtos amplamente disseminados e de granulação média a grossa (0,1-1,3 mm). Destaca-se ainda a ocorrência de um feixe/agregado planar irregular de flogopita quase que inteiramente cloritizado (A). As lamelas medem de 0,1-0,7 mm de comprimento, com apenas uma fração dos cristais orientada segundo a disposição espacial do feixe/agregado. Todavia, ressalta-se que alguns cristais tanto de flogopita intacta quanto de clorita se apresentam dobrados, com uma proporção menor exibindo *kink bands*. Outra fase silicática reportada é a tremolita, que ocorre em proporção de mineral acessório. Seu modo de ocorrência é como produto de alteração da olivina, sob a forma de agregados granulares finos (<0,05 mm) em coroas de reação envolvendo cristais corroídos daquela fase, com alguns cristais, todavia, de granulação um pouco mais grossa (<0,3 mm), sendo prismáticos subédricos, por vezes geminados.

Quanto aos opacos, esta rocha exibe concentração significativa de magnetita e pirrotita. Inicialmente destaca-se uma *stringer* irregular de pirrotita e subordinamente magnetita, em relação textural indicativa de contemporaneidade entre as fases. Esta estrutura ocorre adjacente e paralela ao nível de flogopita + clorita anteriormente descrito. Dada sua natureza de preenchimento intersticial, sua geometria é bastante irregular, com locais de espessamento e pinçamento. Não obstante, magnetita e pirrotita são fases de distribuição disseminada pela rocha e de caráter essencialmente intersticial, formando localmente redes interconectadas de cristais anédricos a subédricos. Quanto ao tamanho de grão, ambas as fases exibem semelhante range granulométrico, desde partículas muito finas (<0,04 mm) até cerca de 1,0 mm no comprimento maior. A desestabilização de olivina com formação de tremolita é acompanhada pela formação de uma ou ambas as fases. Sua contemporaneidade é verificada pela presença de pirrotita no interior de ou parcialmente envolvida por magnetita e vice-versa. Além destes, aponta-se a ocorrência rara de calcopirita, arsenopirita e pirita. A primeira se desenvolve como fase fina (<0,08 mm) subédrica em equilíbrio com pirrotita (B), enquanto a segunda foi identificada através de um único espécime fragmentado de cerca de 0,04 mm compartilhando limite de grão com magnetita e clorita dobrada. A pirita foi identificada como um grão subédrico de 0,06 mm ao longo de limite de grão da matriz carbonática, em proximidade à pirrotita e calcopirita.
Mineralogia Modal Semiquantitativa
CARBONATO (76%), OLIVINA (20%), MAGNETITA (1,7%), PIRROTITA (1%), CLORITA (0,8%), FLOGOPITA (0,4%), TREMOLITA (0,1%)
Nome da rocha: **olivina mármore com alteração a magnetita-pirrotita**
Fotomicrografias



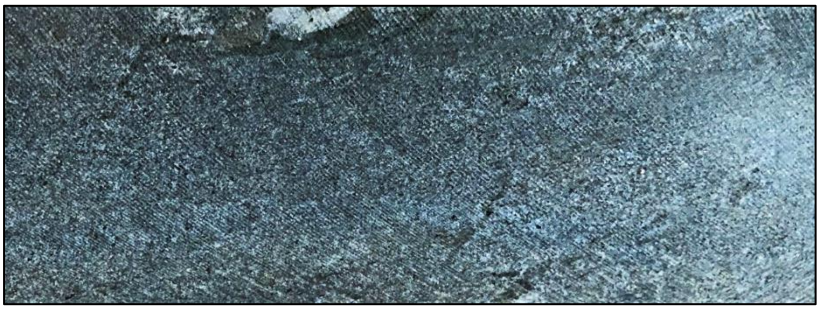


Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-029-26	Drillhole ID: A29	Profundidade: 142,6 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310

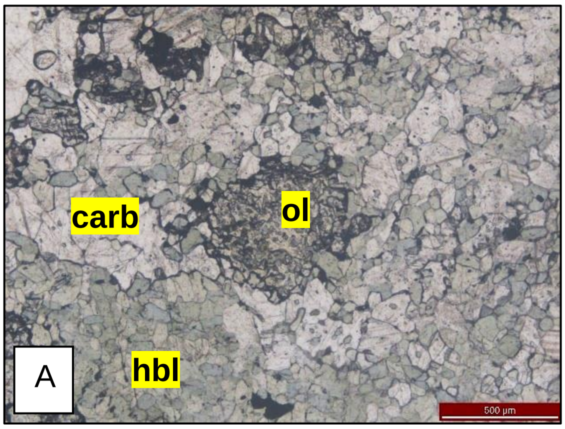


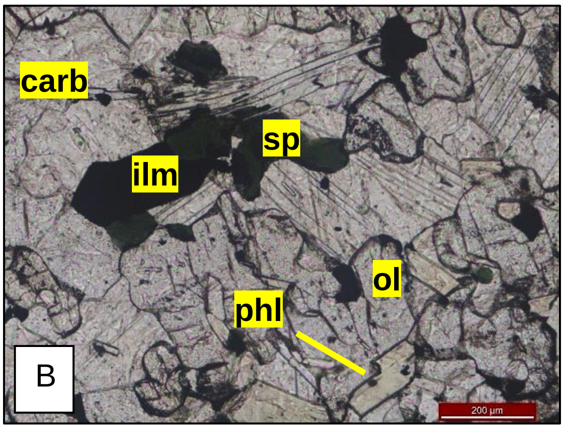
Descrição Microscópica

Rocha granolepidoblástica de granulação média, com foliação incipiente, constituída por matriz de composição carbonática com tamanho de grão compreendido entre 0,1 e 1,0 mm e contatos frequentemente poligonizados. Olivina ocorre como fase amplamente disseminada e exibe grande amplitude granulométrica, desde <0,1 mm a 2,5 mm. Seus cristais são prismáticos ou subequantes, subédricos a preferencialmente anédricos. Outros silicatos de proporção modal significativa são flogopita e actinolita/hornblenda. A flogopita se desenvolve como lamelas delgadas a espessas de comprimento variando entre <0,1 a 0,5 mm, com identificação de um cristal anomalamente grosso (1,2 mm). Sua relação textural com as demais fases é diversa. Cristais isolados exibem comumente caráter intergranular com respeito à matriz carbonática, alguns aparentemente em equilíbrio também com a olivina. Em sua ampla maioria, todavia, formam agregados irregulares ou feixes planares com cristais preferencialmente orientados. Não obstante, tal orientação é pobremente definida vista a ocorrência de fração significativa de cristais aleatoriamente dispostos, resultando em uma foliação apenas incipiente. Quando em feixes ou agregados, sua natureza é do tipo intersticial, englobando parcialmente ou mesmo incluindo cristais de olivina e carbonato. Localmente, observam-se cristais parcial a totalmente cloritizados, sendo mais frequentes na região de maior concentração de espinélio. Quanto ao anfibólio, seu hábito é preferencialmente prismático curto a subequante, subédrico a anédrico, com cristais prismáticos longos de ocorrência mais localizada. Sua granulação é fina a média, com a vasta maioria dos cristais <0,2 mm, com notória exceção de um cristal prismático subédrico de 0,9 mm. Apesar de sua ocorrência disseminada, ele se destaca por formar

agregados irregulares de natureza intersticial na matriz carbonática, comumente circundando cristais de olivina em relação de nítido desequilíbrio (A). Ressalta-se a ocorrência de um cristal de olivina com textura do tipo peneira, com incrustações de anfibólio ao longo de suas margens, as quais exibem indícios de corrosão. Vale frisar que, em sua maioria, esses agregados de anfibólio exibem textura poligonizada. Outras fases identificadas, embora em menor proporção modal, ainda que significativas, incluem ilmenita, magnetita e espinélio verde (B). Ilmenita e magnetita são os opacos mais abundantes e ocorrem de forma disseminada pela rocha. A primeira exibe hábito subequante a prismático, preferencialmente subédrico, com tamanho de grão compreendido principalmente entre 0,02-0,15 mm, com raros cristais prismáticos podendo alcançar 0,5 mm. Embora possa ocorrer em associação intergranular com a matriz carbonática, ele está principalmente associado com anfibólio e flogopita intersticiais, bem como com o espinélio. Pode ser observado também compartilhando limite de grão com a olivina, bem como aparentemente incluso na mesma. Em constraste, a magnetita é, em média, mais fina, apesar de ocupar o mesmo intervalo granulométrico da ilmenita. É relativamente comum a identificação de zonas de ilmenita no interior ou nas margens de cristais e agregados de magnetita, em relação de aparente intercrescimento. Distingue-se da ilmenita pela sua natureza intersticial em relação à olivina e subordinadamente ao espinélio. Forma cristais irregulares manteando parcial a totalmente a olivina ou em interstícios na matriz carbonática. Cristais muito finos (<0,01-0,05 mm) podem ser identificados como incrustações em olivina, ou mesmo desenvolvidos em fissuras naquele mineral, podendo estar associado com carbonato e tremolita igualmente finos. O espinélio é comparativamente menos abundante que as fases anteriormente mencionadas, com ocorrências clusterizadas na rocha. É identificado por sua cor verde e seu hábito subequante subédrico em semelhança à olivina, sendo comum a presença de halos de alteração com formação de mineral de alta birrefringência de difícil discriminação. Seu tamanho de grão varia entre 0,05 e 0,25 mm.
Mineralogia Modal Semiquantitativa
CARBONATO (56%), OLIVINA (19%), FLOGOPITA (10%), ACTINOLITA-HORNBLENDA (9,5%), CLORITA (1,9%), ILMENITA (1,7%), MAGNETITA (1,4%), ESPINÉLIO (0,3%), TREMOLITA (0,1%), CARBONATO MUITO FINO (0,1%)
Nome da rocha: **olivina mármore com alteração a flogopita-hornblenda com ilmenita e magnetita**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-009-03a	Drillhole ID: A09	Profundidade: 66,9 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96334	UTM E: 402358

Descrição Microscópica

Rocha granonematoblástica bandada com banda granoblástica dominada por carbonato de granulação muito fina, outra com abundante anfibólio (tremolita-actinolita) e subordinadamente biotita, e uma terceira onde prevalecem porfiroblastos de diopsídio bastante alterados (A).

A zona carbonática, a despeito de granulação muito fina, contém bolsões de granulação mais grossa, por vezes associados a anfibólio incolor (tremolita?), embora este mineral ocorra amplamente disseminado nesse domínio, geralmente subédrico a anédrico e medindo menos de 0,25 mm. Há uma grande proporção de cristais de anfibólio facetados, semelhantes a clastos em rocha brechada. Esta zona está em contato com uma faixa carbonática microcristalina de aproximadamente 2 mm de espessura e coloração marrom (aspecto turvo), sendo atravessada por *stringers* de material preto amorfo paralelas ao bandamento. Contém ainda bolsões de carbonato tabular (0,3-0,7 mm) separados por cristais de quartzo praticamente isentos de deformação, como evidenciado pela frequência de cristais sem extinção ondulante. Vênulas irregulares com carbonato acicular (0,2-0,5 mm) separados por quartzo facetado (0,1-0,4 mm) (B) atravessam ambos os níveis carbonáticos, sendo defletidos nessa zona e adotando a orientação do bandamento. Nessa zona microcristalina são ainda identificados fragmentos de anfibólio (tremolita?) subédricos em geral <0,1 mm, biotita subordinada (lamelas <0,1 mm) e cristais subequantes de quartzo euédricos a subédricos (<0,1 mm).

Subsequentemente, segue-se um domínio constituído essencialmente por anfibólio verde (tremolita-actinolita) de granulação fina (<0,1 mm) sob a forma de cristais prismáticos curtos, com proporção significativa de fase intersticial de alto relevo, subequante ou prismática, subédrica a anédrica, convertida em carbonato. Lamelas e agregados de biotita (<0,15 mm) ocorrem de modo subordinado, sendo preferencialmente orientados, aparentemente se desenvolvendo, pelo menos em parte, às expensas do mineral de alto relevo alterado para carbonato. Lentes e vênulas de carbonato tabular com quartzo também são comuns nessa zona. Acumulações lenticulares de cristais finos (<0,1 mm) anédricos de alto relevo e superfície turva ocorrem de forma localizada, com algumas porções isotrópicas (granada alterada?).

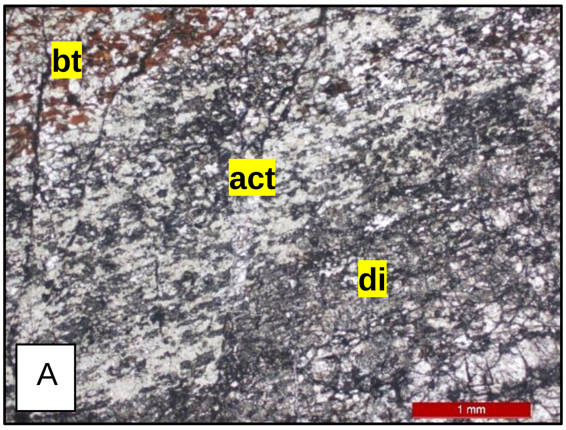
Domínio carbonático exibe aspecto textural indicativo de processo de cominuição mecânica, com fragmentos angulosos de anfibólio incolor (tremolita?) imersos em matriz muito fina (<0,05 mm) contendo anfibólio incolor a verde pálido (tremolita-actinolita?), carbonato, filossilicatos (talco e/ou muscovita) e subordinadamente quartzo. Os filossilicatos de granulação um pouco mais grossa (>0,1 mm) frequentemente exibem kink bands.

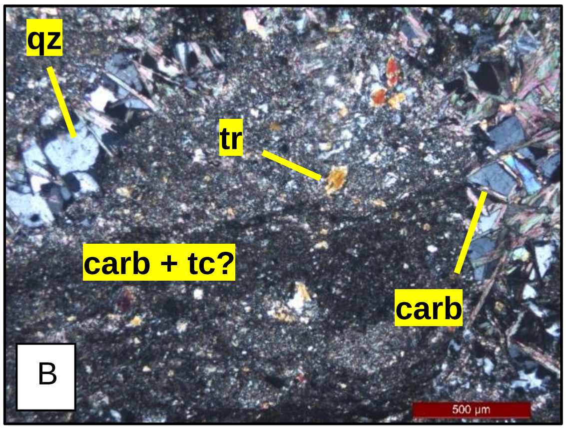
A rocha é atravessada por enxames de vênulas de espessura submilimétrica preenchidas por material escuro de baixo grau de cristalinidade.

Em termos de minerais acessórios, destaca-se a presença de ilmenita e titanita. Raramente excedendo 0,1 mm, a ilmenita, apesar de disseminada pela rocha, encontra-se particularmente concentrada nos domínios a biotita e anfibólio, e subordinadamente no domínio piroxenítico. Seus cristais variam de anédricos a prismáticos subédricos, comumente exibindo evidências de transformação em titanita ao longo de suas bordas. A titanita tende a seguir a mesma regra de distribuição espacial da ilmenita, frequentemente exibindo seções losangulares subédricas. Pirita é o único sulfeto identificado, sendo igualmente de granulação fina (<0,1 mm). Sua ocorrência é restrita ao domínio a biotita e anfibólio, sendo identificada por cristais cúbicos euédricos a subédricos. Em termos modais, é deveras menos abundante que ilmenita e titanita.

Mineralogia Modal Semiquantitativa
CARBONATO (36%), ACTINOLITA (30%), DIOPSÍDIO (15%), TREMOLITA (8%), BIOTITA (5%), EPIDOTO (2%), TALCO? (2%), MUSCOVITA (1%), QUARTZO (1%)
Nome da rocha: **biotita-tremolita-diopsídio-actinolita-carbonato xisto milonítico**

Fotomicrografias





Ficha de Descrição Petrográfica South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico		
Código da amostra: TUC-DD-028-03	Drillhole ID: A28	Profundidade: 56,9 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96499	UTM E: 402339

Descrição Microscópica

Rocha bandada de granulação média alternando níveis milimétricos a centimétricos de:

i) Rocha granolepidoblástica com porfiroblastos de granada (1-4 mm) sem bastante fragmentados, envoltos por uma matriz constituída dominantemente por biotita e anfibólio da série cummingtonita-grunerita (A). A biotita se desenvolve como lamelas delgadas <0,4 mm enquanto o anfibólio forma prismas aciculares medindo entre 0,3-0,6 mm, ambos com orientação preferencial fracamente definida. Cristais prismáticos subédricos a anédricos de turmalina verde, em geral <0,25 mm, ocorrem de forma disseminada em pequenas proporções. Cristais anédricos de quartzo ocupam os espaços intersticiais. Interpreta-se que o anfibólio não está em equilíbrio com as demais fases, sendo uma fase desenvolvida posteriormente. Quanto às fases opacas, estas ocorrem como minerais acessórios de granulação fina (<0,1 mm) disseminados. Dentre eles, são registrados cristais prismáticos euédricos a subédricos de ilmenita, cristais subequantes subédricos de magnetita e cristais anédricos de calcopirita e subordinamente pirrotita, estando os sulfetos associados sobretudo ao anfibólio.

ii) Rocha granoblástica de granulação média cuja composição modal é dominada por anfibólio verde (hornblenda), exibindo cristais prismáticos (alguns em seções basais exibindo planos de clivagem típicos) subédricos em sua maioria compreendidos entre 0,2-0,6 mm (B). Todavia, cristais mais grossos (<1,0 mm) são também identificados. Porfiroblastos de granada (1-4 mm) bastante fraturados e fragmentados são abundantes. Quartzo é intersticial à matriz anfibolítica, assumindo formas frequentemente poligonizadas condicionadas pela geometria dos interstícios. Frequentemente <0,2 mm, os cristais de quartzo podem localmente ser mais grossos (<0,8 mm). Bolsões de quartzo também são comuns. Fases opacas compreendem essencialmente óxidos (ilmenita e magnetita), com amplo predomínio de ilmenita sobre magnetita. A ilmenita ocorre sob a forma de cristais prismáticos curtos ou subequantes subédricos de granulação fina a muito fina, em geral <0,05 mm.

A lâmina petrográfica amostrou ainda um veio de quartzo intrabanda de menos de 1,0 cm de espessura. Tanto o veio quanto as bandas supracitadas exibem dobramento aberto. Na banda a biotita-granada, o conteúdo de anfibólio aumenta tanto quanto maior for a proximidade do veio. Nota-se a ocorrência de agregados irregulares de anfibólio que avançam a partir da parede do veio em direção ao seu interior.

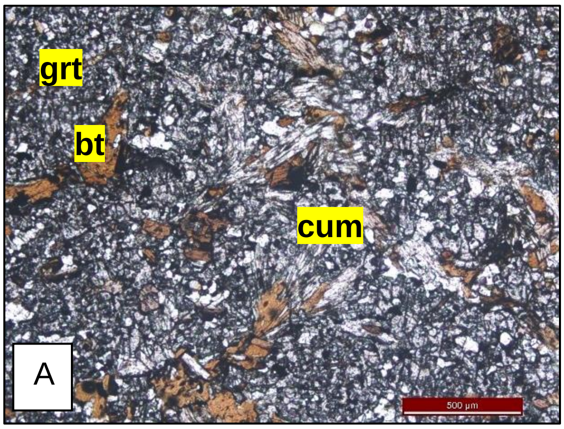
Mineralogia Modal Semiquantitativa

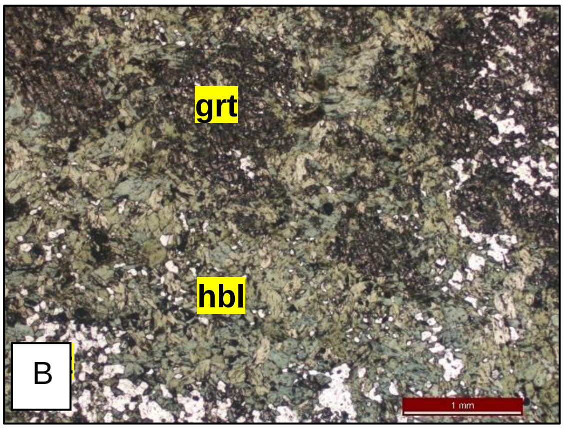
*HORNBLENDA (40%), GRANADA (21%), CUMMINGTONITA (15%), BIOTITA (11,5%), QUARTZO (9%), TURMALINA (1%), ILMENITA (1%), CLORITA (0,8%), CALCOPIRITA (0,4%), PIRROTITA (0,3%)

*excluindo o veio de quartzo

Nome da rocha: **rocha bandada alternando granada anfibolito com quartzo-biotita-granada xisto, este último com alteração a cummingtonita**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-029-18	Drillhole ID: A29	Profundidade: 100,1 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310

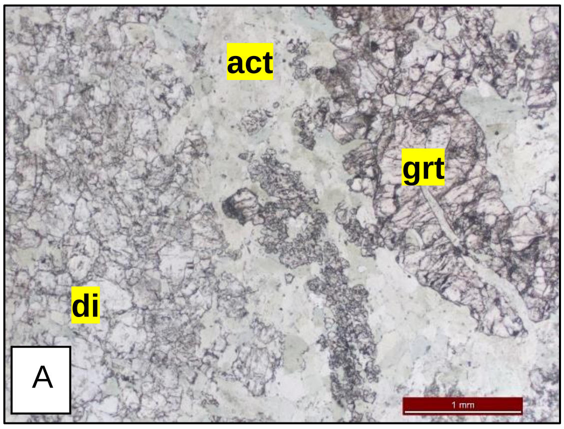
Descrição Microscópica

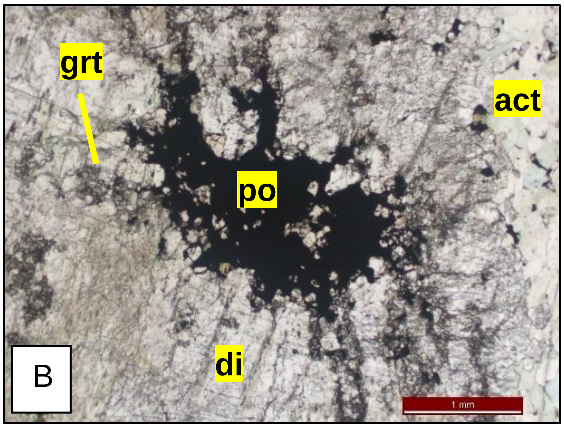
Rocha nematoblástica caracterizada pela alternância irregular de lentes/bandas descontínuas de cristais grossos de diopsídio separados por níveis delgados (1-3 mm) de actinolita (A). O diopsídio se distingue por sua granulação dominantemente grossa, cujos cristais prismáticos subédricos podem ser localmente elongados e medir até cerca de 4 cm ao longo do eixo maior. São cristais usualmente fraturados, com preenchimento e ocupação intersticial por actinolita e subordinadamente carbonato. O aspecto textural predominante dos anfibólios é aquele observado nos níveis que separam as faixas piroxeníticas, qual seja, cristais subequantes de granulação média (0,1-0,3 mm) delimitados por contatos principalmente retos definindo um arranjo poligonizado. Não obstante, cristais prismáticos também são documentados, podendo localmente atingir 0,6 mm. Cristais subédricos finos a médios (<0,2 mm) de diopsídio são observados no interior das faixas anfibolíticas, bem como carbonato intersticial fino a médio (<0,2 mm).

Feixes delgados, irregulares e descontínuos de granada ocorrem de modo subordinado e paralelamente à estrutura definida pelas bandas de diopsídio e actinolita, com predomínio de cristais anédricos finos a médios (<0,5 mm), com exceção de um único cristal grosso (2 mm) identificado em faixa anfibolítica. Este contém preenchimento de fraturas por actinolite e carbonato, além de um filossilicato fino não identificado.

Pirrotita é a principal fase opaca identificada na amostra, exibindo íntima associação espacial com a granada, comumente acompanhando-a ao longo de seus feixes e se desenvolvendo como agregados anédricos médios a grossos, podendo também exibir caráter intersticial com respeito ao diopsídio (B). Ademais, cristais subédricos a anédricos finos (<0,1 mm) são identificados de forma disseminada pela amostra em pequenas

concentrações, exibindo relação variando desde intergranular à intersticial com respeito ao anfibólio e intersticial ao diopsídio. Quantidades diminutas de ilmenita fina a média (<0,2 mm) subédrica a anédrica são reportadas, preferencialmente em equilíbrio com os feixes granatíferos.
Mineralogia Modal Semiquantitativa
DIOPSÍDIO (55%), ACTINOLITA (40%), GRANADA (3%), PIRROTITA (1,8%), CARBONATO (0,2%)
Nome da rocha: **diopsídio-actinolita xisto com granada e pirrotita**
Fotomicrografias



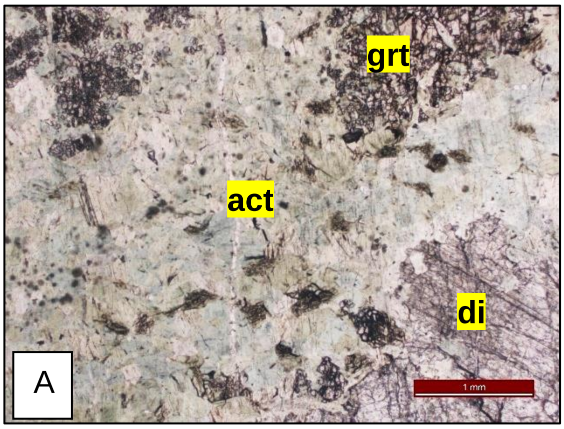
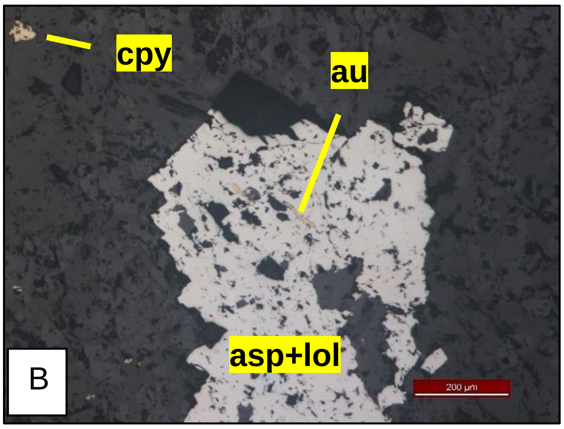


<table>
<tr><td colspan="3">Ficha de Descrição Petrográfica
South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG
Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico</td></tr>
<tr><td>Código da amostra: TUC-DD-033-11</td><td>Drillhole ID: A33</td><td>Profundidade: 99,2 m</td></tr>
<tr><td>Coordenadas SIRGAS 2000 UTM 22N</td><td>UTM N: 96529</td><td>UTM E: 402311</td></tr>
<tr><td colspan="3"> </td></tr>
<tr><td colspan="3">Descrição Microscópica</td></tr>
<tr><td colspan="3">Rocha granoblástica de granulação fina a média e caracterizada por complexo arranjo de fases silicáticas portadoras de cálcio. Destacam-se cristais grossos sub-equantes de clinopiroxênio (até 8 mm) parcialmente consumidos ao longo de suas bordas e fraturas em meio a um amplo domínio anfibolítico-granatífero (A).
O anfibólio apresenta cor verde pleocróica, hábito sub-equante a prismático, frequentemente exibindo seção basal 001 com planos de clivagem bem definidos. Ocupando principalmente o intervalo granulométrico entre 0,1-0,4 mm, com a ocorrência localizada de cristais mais grossos (<0,8 mm), o anfibólio forma acumulações monominerálicas não-foliadas em arranjo parcialmente poligonizado. A relação deste com o clinopiroxênio é de desequilíbrio, avançando sobre a fase anterior.
A granada ocorre como cristais anédricos finos a grossos (<0,1-5,0 mm) distribuídos em faixas no interior das massas de actinolita. Esses cristais se encontram bastante fragmentados, semelhantes a agregados de cristais finos amalgamados. Sua relação textural com o anfibólio envolvente é complexa, ora exibindo feições de equilíbrio (contemporaneidade) ora sendo sobreposto pelo mesmo. Cristais de granada e clinopiroxênio parcialmente alterados podem conter além do anfibólio uma fase carbonática fina os sucedendo. O carbonato pode ocorrer ainda intersticialmente em equilíbrio textural com a actinolita. Cristais subédricos de granada (0,1-0,5 mm) são identificados no interior do cristal mais grosso de clinopiroxênio, estando lateralmente associado a ao anfibólio anédrico que sucede ao piroxênio.</td></tr>
</table>

Na porção sul da amostra verifica-se a ocorrência de massas quartzosas em contato com o domínio anfibolítico-granatífero, sendo identificada a presença de um carbonato fino (<0,2 mm) anédrico a subédrico na região de interface entre os dois domínios composicionais, podendo ser intersticial ao quartzo e ao anfibólio, ou mesmo envolver parcial ou completamente o último. O quartzo é de granulação média (0,1-0,4 mm), frequentemente com extinção ondulante e distribuído segundo um arranjo parcialmente poligonizado, localmente com contatos lobados. Agregados isolados de anfibólio (actinolita), por vezes formando vênulas irregulares e descontínuas, são observadas no interior do domínio quartzoso. Ao longo do contato entre esses dois domínios composicionais são registrados cristais grossos de clinopiroxênio. Ambos, clinopiroxênio e anfibólio, encontram-se alterados ao longo de suas margens ora para o carbonato fino supracitado ora para um filossilicato fino (<0,1 mm) e fibroso (sericita?), ou mesmo para os dois. Mais raramente, identifica-se uma clorita retrógrada.

Uma fase de carbonato está representada por uma rede de vênulas delgadas (<0,05 mm) sub-paralelas e descontínuas que atravessam toda a rocha. Esses veios sempre atravessam clinopiroxênio e granada, podendo atravessar ou ser interrompidos ao entrar em contato com actinolita. Esta fase também está presente como um constituinte subordinado desses veios. Paralelamente, observam-se também vênulas igualmente delgadas e de pequena persistência constituídas essencialmente por titanita, sendo observadas exclusivamente em relação de corte com a granada, sendo interrompida na actinolita.

Quanto aos minerais opacos, são identificados pirrotita, calcopirita, arsenopirita, pirita, ilmenita e titanita. A pirrotita é o mais abundante dentre os listados, com destaque para a ocorrência de cristais prismáticos subédricos a anédricos grossos (1-3 mm) ao longo do contato entre o domínio cálcio-silicático e o quartzoso. Vale frisar que tais cristais enconstram-se parcialmente manteados por carbonato muito fino. Com exceção destes, a pirrotita tende a ocorrer como cristais predominantemente finos (<0,2 mm, maioria <0,1 mm) disseminados entre cristais de anfibólio e granada, podendo neste último preencher suas fraturas. É comum a associação deste mineral com a calcopirita, que frequentemente ocorre intercrescida às margens da pirrotita, quase invariavelmente como cristais finos (<0,1 mm) anédricos, embora cristais isolados igualmente finos sejam encontrados de forma disseminada. A arsenopirita é o segundo sulfeto mais abundante e o mais amplamente distribuído pela amostra, frequentemente formando cristais losangulares euédricos a subédricos finos a médios (<0,1-0,8 mm) e exibindo associação paragenética semelhante à pirrotita. Cristais finos de ouro (<0,03 mm) foram identificados como inclusões alinhadas no interior de um cristal de arsenopirita (B). Pirita é um sulfeto raro, sendo identificado

apenas um único grão fino (<0,1 mm) ocupando interstício carbonático entre cristais de anfibólio. Ilmenita e titanita são fases disseminadas que ocorrem em proporções muito diminutas, invariavelmente finos (<0,1 mm), e com formas arredondadas. Ocorrem intersticialmente ao anfibólio e à granada. Vale ressaltar a identificação de uma trilha de cristais de titanita preenchendo uma fratura em granada. Apesar de muito fina, a titanita pode ser identificada por sua reflectância muito baixa e por não ser totalmente opaca. Localmente verifica-se que a titanita é um produto de transformação da ilmenita. As fases opacas supracitadas se concentram nas porções onde anfibólio e granada estão presentes, sendo raros em meio a cristais de quartzo ou no interior de cristais grossos de clinopiroxênio.
Mineralogia Modal Semiquantitativa
ACTINOLITA (60%), GRANADA (18%), DIOPSÍDIO (10%), QUARTZO (8,5%), PIRROTITA (1,4%), CARBONATO MATRIZ (1%), ARSENOPIRITA + LOELLINGITE (0,4%), CARBONATO VEIO (0,2%), ILMENITA (0,2%), SERICITA (0,1%), TITANITA (0,1%), CALCOPIRITA (0,1%)
Nome da rocha: **alteração a granada-diopsídio-quartzo com superposição de actinolita com pirrotita e carbonato**
Fotomicrografias
 

Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: HS-10	Drillhole ID: n/a	Profundidade: surface
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96032	UTM E: 402241

Descrição Microscópica

Rocha granoblástica de granulação grossa a muito grossa, sem foliação aparente, dominada por minerais cálcio-silicáticos e atravessada por uma zona de infiltração a pirrotita + magnetita com geometria semelhante a veio anastomosado irregular (A), porém descrito em escala de mão como *tension gash*.

A principal fase mineral é o diopsídio, que constitui o arcabouço da rocha. Destaca a ocorrência frequente de cristais de dimensão milimétrica, o maior deles medindo 8 mm. Esses cristais são geralmente subequantes a prismáticos curtos e exibem bordas irregulares. Cristais menores são observados entre os megacristais ao longo de seus limites de grão, com registro inclusive de cristais <0,1 mm. Agregados de granada definem uma feição análoga a uma estrutura de infiltração, formando massas amalgamadas lineares, com alguns poucos cristais individualizados ao longo de suas margens, os quais podem variar desde finos (<0,1 mm) a grossos (2,0 mm). Esses cristais compreendem formas subédricas a anédricas, localmente subarredondados. Além de diopsídio e granada, outros silicatos reportados são anfibólio e biotita.

Cristais de anfibólio são de ocorrência disseminada e ocorrem aparentemente às custas da desestabilização do diopsídio. São identificados como agregados intersticiais na matriz piroxenítica ou mesmo ao longo de redes de fissuras interconectadas no interior dos megacristais de diopsídio. Constistem de cristais prismáticos subédricos a anédricos variando desde muito finos (<0,05 mm) até médios (<0,3 mm). Destaca-se a ocorrência de uma estrutura que transecta um cristal grosso de diopsídio, contendo um núcleo constituído por anfibólio e carbonato finos e margens povoadas por cristais prismáticos de granulação média dispostos ortogonalmente (ou em alto ângulo) à superfície de contato com o diopsídio truncado. Essa estrutura aparentemente está integrada à zona de infiltração sulfetada a pirrotita + magnetita que transecta a seção por completo. Distinguem-se duas diferentes fases de anfibólio, quais sejam, actinolita e hornblenda. O primeiro é o mais abundante e largamente disseminado, sendo verde pálido e de relevo relativamente baixo. A hornblenda é discriminada do anterior pela sua cor verde mais profunda e relevo relativamente mais alto, com hábito comumente mais equidimensional. Esta última é de distribuição mais restrita, embora compartilhe com a actinolita seu modo de ocorrência intersticial e em desequilíbrio com o clinopiroxênio. A biotita é uma fase comparativamente menos abundante que os anfibólios, exibindo relação de aparente equilíbrio textural com eles, porém de desequilíbrio com diopsídio e granada. Ocorre como agregados lamelares cujos cristais individuais variam desde muito finos (<0,05 mm) até médios (<0,7 mm). Com pleocroísmo variando de verde oliva a castanho, a biotita assemelha-se aos anfibólios quanto ao seu modo de ocorrência intersticial entre cristais de clinopiroxênio, inclusive como produto de alteração destes ao longo de microfissuras. Tanto anfibólios quanto biotita são frequentemente acompanhados por carbonato. Este é geralmente muito fino e anédrico, porém localmente agregados carbonáticos mais grossos (<0,5 mm) são registrados, principalmente ao longo das margens da estrutura de infiltração de pirrotita, onde se associam à biotita e preenchem fraturas em granada.

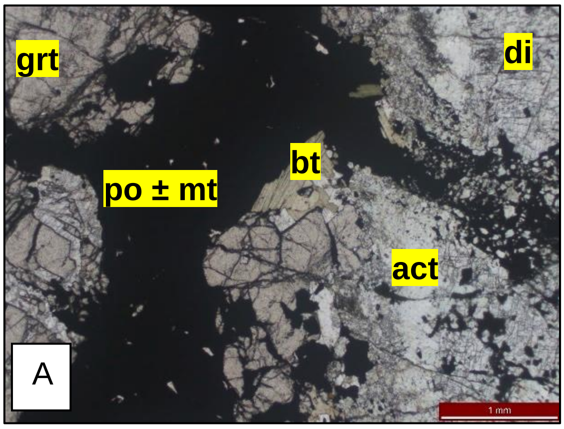
Quanto aos opacos, magnetita e pirrotita são as fases mais abundantes, rivalizando alguns silicatos em termos de proporção modal. Proporções menores de calcopirita também são documentadas, além de conteúdo traço de ouro e fases de bismuto (bismuto nativo, Bi-Te alloy e bismutinita) (B). Magnetita é amplamente disseminada pela amostra, compartilhando o mesmo modo de ocorrência de anfibólios e biotita. Seus cristais variam desde muito finos (<0,05 mm) a médios (<0,5 mm), sendo subédricos a preferencialmente anédricos. Eles têm caráter intersticial e de preenchimento de fissuras em relação ao diopsídio e granada, e intergranular ou intersticial com respeito aos anfibólios e biotita. Ocorrência notável de magnetita reside na estrutura de sulfeto maciço, onde cristais arredondados mais grossos são reportados em aparente equilíbrio com a pirrotita, alguns dos quais excedendo 1,0 mm. A referida estrutura consiste em uma espécie de vênula de geometria irregular contendo pirrotita maciça e a supracitada magnetita. Estruturas subsidiárias são emanadas a partir dessa, onde pirrotita, calcopirita e magnetita ocorrem em associação textural de aparente contemporaneidade. Uma dessas, por exemplo, é a supracitada estrutura a anfibólio + carbonato que transecta um megacristal de diopsídio. Se interior contém um rastro de magnetita e pirrotita finas (<0,1 mm). De modo geral, com o afastamento da estrutura principal, observa-se uma gradual fragmentação da pirrotita e magnetita, com desenvolvimento de cristais anédricos e intersticiais de granulação fina a média (em geral <0,2 mm). A calcopirita se desenvolve tipicamente como *patches* anédricos (<0,15 mm) no interior ou margens da pirrotita, sendo mais frequente nas disseminações do que na estrutura alimentadora principal. Cristais de ouro livre são muito finos, sempre <0,03 mm, exibindo tanto formas facetadas quanto arredondadas e apresenta-se tipicamente associada a fases de bismuto em preenchimento intersticial de limites de grão de diopsídio alterados a actinolita. As fases de bismuto são igualmente finas e anédricas, ajustando-se à geometria dos interstícios. Nota-se que uma dessas fases, a bismutinita, comumente manteia algumas partículas de ouro.

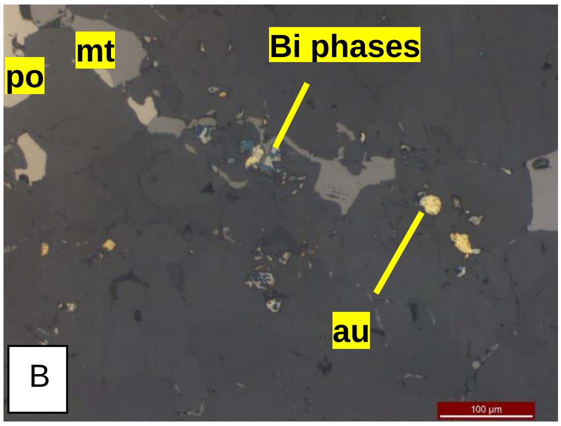
Mineralogia Modal Semiquantitativa

DIOPSÍDIO (65%), ACTINOLITA (14,5%), PIRROTITA (7%), GRANADA (5%), MAGNETITA (4%), BIOTITA (2,5%), HORNBLENDA (1,9%), CALCOPIRITA (0,1%)

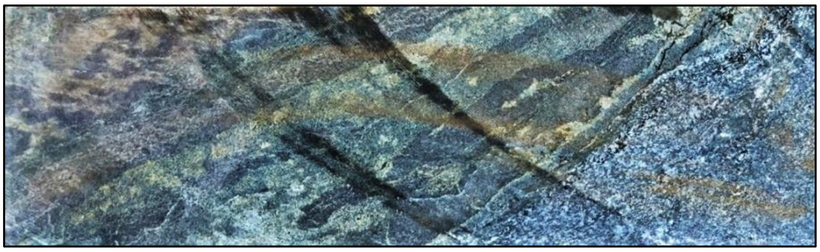
Nome da rocha: **granada-pirrotita-actinolita-diopsídio granoblastito com magnetita, biotita e hornblenda**

Fotomicrografias





<table>
<tr><td colspan="3">Ficha de Descrição Petrográfica
South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG
Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico</td></tr>
<tr><td>Código da amostra: TUC-DD-029-05</td><td>Drillhole ID: A29</td><td>Profundidade: 52,8 m</td></tr>
<tr><td>Coordenadas SIRGAS 2000 UTM 22N</td><td>UTM N: 96522</td><td>UTM E: 402310</td></tr>
</table>



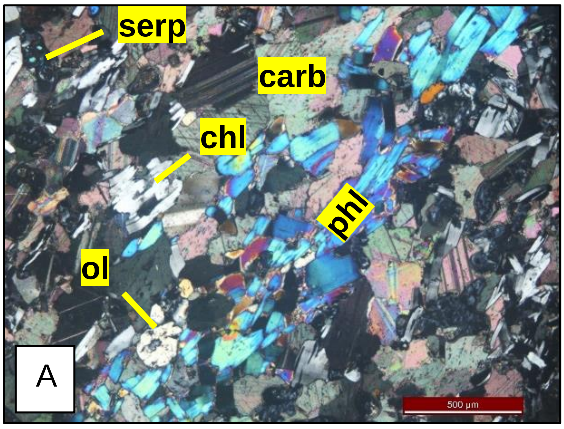
Descrição Microscópica

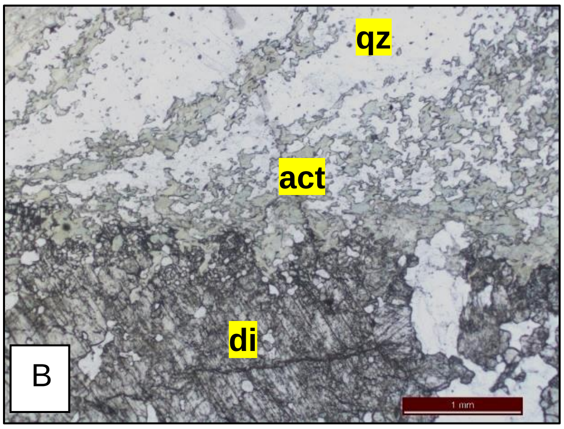
A rocha ora descrita compreende a transição entre diferentes domínios correspondentes ao zoneamento da alteração hidrotermal.

A zona mais distal corresponde a uma rocha granolepidoblástica de granulação média com matriz de composição carbonática. Os cristais de carbonato medem individualmente cerca de 0.3-0.6 mm e seus contatos variam desde suturados a localmente poligonizados. São observados cristais prismáticos a sub-equantes, subédricos a anédricos, de olivina de granulação média a grossa (0,1 - >1,0 mm). Esses cristais se encontram frequentemente alterados (pseudomorfos), sendo identificados duas principais tipologias de substituição. Enquanto alguns representam em grande medida pseudomorfos de anfibólio verde (tremolita-actinolita) após olivina, outros se mostram parcial ou totalmente serpentinizados. A serpentinização também afeta pseudomorfos de anfibólio. Feixes sub-paralelos de cristais lamelares de flogopita são documentados (A), com palhetas estando compreendidas principalmente entre 0,1-0,25 mm. Lamelas isoladas também são identificadas. Um desses feixes define a fronteira entre esta zona distal e a zona de alteração proximal. Nota-se que uma proporção significativa dos cristais de flogopita encontra-se substituída por clorita, em um processo aparentemente contemporâneo à serpentinização. Nota-se um padrão na distribuição de opacos no que concerne ao tipo de substituição mineralógica, qual seja, a substituição de olivina por anfibólio é normalmente acompanhada por pirrotita ao passo que magnetita está mais condicionada aos processos de serpentinização e cloritização. Ambos os minerais opacos supracitados tendem a se desenvolver como cristais anédricos finos (<0,1 mm), porém a magnetita adicionalmente é identificada como cristais alongados desenvolvidos ao longo dos planos de clivagem de serpentina e clorita. Magnetita é particularmente abundante ao longo de microvênulas de serpentina dispostas segundo orientação preferencial semelhante àquela observada nos feixes de flogopita. Outra fase opaca identificada é a ilmenita, com cristais prismáticos subédricos a anédricos <0,1 mm de ocorrência disseminada, embora em proporção bastante subordinada.

A zona proximal da alteração hidrotermal é constituída essencialmente por anfibólios, diopsídio e quartzo. Trata-se de uma rocha bandada onde alternam-se níveis irregulares de anfibólios e quartzo cuja espessura varia de 3-7 mm, com cristais grossos de diopsídio (um inclusive <1 cm) no interior da banda quartzosa e ao longo de contatos entre bandas. A associação textural entre essas fases indica uma sucessão paragenética quartzo > diopsídio > anfibólios. O quartzo é principalmente de granulação média e seus contatos indicam a formação de novos cristais por recristalização por migração de limites de grão. Cristais alongados no sentido da foliação costumam apresentar lamelas de deformação. O diopsídio frequentemente contém inclusões deste quartzo e sua relação com o anfibólio é de desequilíbrio, com desestabilização do primeiro e formação de anfibólio às suas custas, ao longo de limites de cristais (B) e redes interconectadas de fissuras. Vênulas finas de carbonato são observadas localmente. Carbonato e sericita finos são localmente identificados envolvendo parcialmente cristais corroídos de diopsídio. Apesar de seu hábito prismático curto típico, o diopsídio apresenta localmente indícios de estiramento. Quanto aos anfibólios, são identificados dois tipos, um verde da série tremolita-actinolita e um verde-amarelado da série cummingtonita-grunerita. O primeiro ocorre como bandas/massas monominerálicas na fronteira com a zona distal, via de regra <0,4 mm e localmente exibindo recristalização por redução de área de limite de grão (poligonização). Em direção ao interior da zona proximal são observados feixes de cristais prismáticos que atravessam as regiões quartzosas e que tem sua orientação alterada para contornar os cristais grossos de diopsídio. Por outro lado, a cummingtonita-grunerita se encontra na porção mais interna desse domínio, formando agregados de espessura milimétrica contendo cristais prismáticos longos parcialmente orientados segundo a foliação principal e medindo até 0,25 mm. Essa zona proximal é relativamente mais empobrecida em minerais opacos, porém proporcionalmente mais rica em pirrotita. Observa-se uma nítida segregação entre minerais opacos, de tal modo que ilmenita prismática subédrica fina (<0,1 mm) é identificada como fase intergranular na massa de tremolita-actinolita, ao passo que pirrotita é descrita exclusivamente como fase anédrica fina a média intersticial em cummingtonita-grunerita.

Mineralogia Modal Semiquantitativa
ZONA DISTAL: CARBONATO (60%), SERPENTINA (15%), OLIVINA (10%), CLORITA (6%), FLOGOPITA (5%), ACTINOLITA (2%), MAGNETITA (1,2%), PIRROTITA (0,6%), ILMENITA (0,2%) ZONA PROXIMAL: QUARTZO (30%), DIOPSÍDIO (30%), ACTINOLITA (27%), GRUNERITA (12%), PIRROTITA (0,5%), SERICITA (0,2%), CARBONATO (0,2%), ILMENITA (0,1%)
Nome da rocha: **zona de transição distal (olivina mármore com alteração a flogopita e tremolita-actinolita, com serpentinização e cloritização) e proximal (veio de quartzo-clinopiroxênio com superposição a actinolita e grunerita)**
Fotomicrografias





<table>
<tr><td colspan="3">Ficha de Descrição Petrográfica
South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG
Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico</td></tr>
<tr><td>Código da amostra: TUC-DD-029-30</td><td>Drillhole ID: A29</td><td>Profundidade: 167,8 m</td></tr>
<tr><td>Coordenadas SIRGAS 2000 UTM 22N</td><td>UTM N: 96522</td><td>UTM E: 402310</td></tr>
<tr><td colspan="3"> </td></tr>
<tr><td colspan="3">Descrição Microscópica</td></tr>
<tr><td colspan="3">Rocha granolepidoblástica de granulação média constituída por matriz carbonática com cristais de tamanho variando principalmente entre 0,1-0,5 mm, cujos contatos retos a levemente abaulados definem uma trama poligonizada. Destaca-se a ocorrência de acumulações (textura decussada) e feixes (definindo foliação) de flogopita pleocróica de castanho claro a verde claro (A). Suas lamelas têm comprimento <0,6 mm. De modo mais subordinado, reporta-se a ocorrência de pargassita-hastingsita, sob a forma de cristais prismáticos euédricos a subédricos em aparente equilíbrio com a flogopita e espacialmente associado aos opacos (principalmente pirrotita) (B). Localmente observa-se intercrescimento deste anfibólio com outro incolor (tremolita).
Magnetita é uma fase abundante, cujo principal modo de ocorrência é sob a forma de cristais <0,2 mm subédricos a anédricos disseminados intersticialmente à matriz carbonática, com concentração heterogênea ao longo da rocha. Trilhas de cristais também são definidas, estando integradas àquelas observadas a partir da paragênese silicática. Ademais, dada sua natureza intersticial, ela pode localmente formar redes interconectadas englobando parcialmente cristais de carbonato. Pirrotita é relativamente abundante, frequentemente adotando modo de ocorrência intersticial em semelhança à magnetita, e frequentemente compartilhando limite de grão com esta. Pode ainda formar agregados de dimensão >1 mm. Na porção NE da lâmina, destacam-se agregados interconectados de pirrotita, desde submilimétricos até >1,0 mm encapsulando parcial ou totalmente cristais de anfibólio (0,1-1,0 mm), tanto tremolita quanto pargassita-hastingsita, com texturas de intercrescimento entre ambas as variedades. Observa-se também nessa porção da amostra</td></tr>
</table>

cristais prismáticos a aciculares de cummingtonita em aparente equilíbrio com as demais variedades de anfibólio.

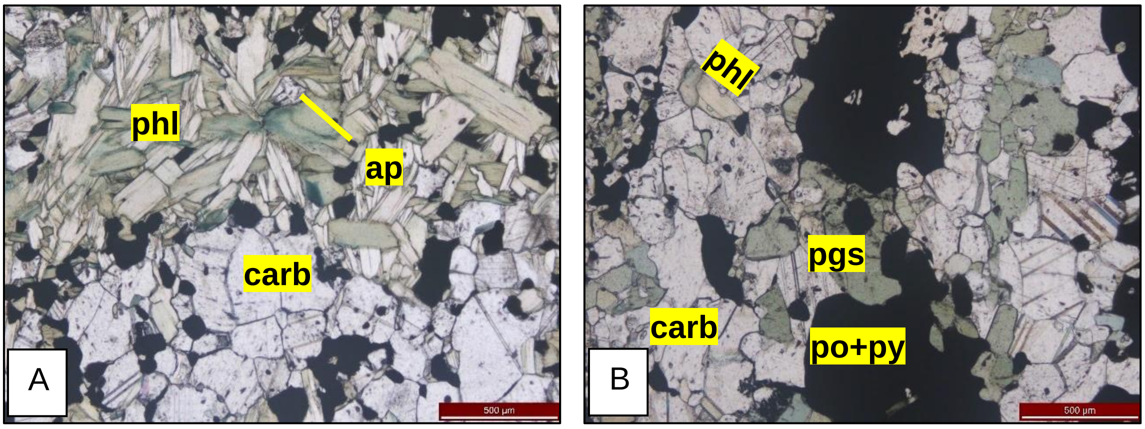
A principal fase em aparente equilíbrio com a pirrotita é a flogopita, com frequente desenvolvimento de cristais elongados subédricos a anédricos entremeados entre palhetas do referido filossilicato, principalmente onde este forma acumulações ou feixes. Na porção SW da lâmina destaca-se a ocorrência de uma grande lente/leito de flogopita com lamelas pobremente orientadas. Esta acumulação equivale a 25% da área da lâmina. A despeito de proporções insignificantes de anfibólio e carbonato, ressalta-se na verdade a ocorrência de volume relevante de apatita subédrica a euédrica fina (<0,1 mm) como fase intergranular à flogopita. Esse domínio de acumulação de flogopita equivale ao local de maior concentração de sulfetos na amostra, com magnetita ausente. A pirrotita se desenvolve sobretudo como agregados em forma de feixes e trilhas subparalelas de espessura variável entre 0,2-1,0 mm, semelhantes a redes interconectadas de estruturas de infiltração. Localmente, observa-se a superposição de pirrotita por pirita comumente anédrica.

Mineralogia Modal Semiquantitativa

CARBONATO (70%), FLOGOPITA (20%), PIRROTITA (5%), PARGASSITA-HASTINGSITA (2%), MAGNETITA (1,9%), APATITA (0,4%), CUMMINGTONITA (0,3%), TREMOLITA (0,2%), PIRITA (0,2%)

Nome da rocha: **mármore com alteração a flogopita-pirrotita com pargassita e magnetita**

Fotomicrografias



Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-033-19	Drillhole ID: A33	Profundidade: 177,0 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96529	UTM E: 402311

Descrição Microscópica

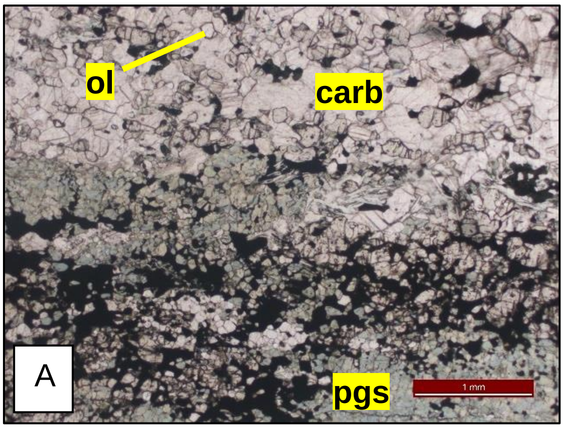
Rocha granoblástica de granulação fina a média com foliação dada pela alternância de níveis composicionais carbonáticos e anfibolíticos de espessura irregular (1-6 mm), estes últimos exibindo maior abundância em minerais opacos (A).

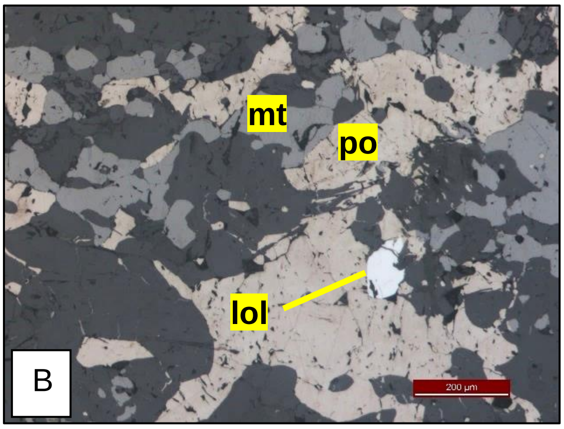
No domínio eminentemente carbonático destaca-se a ocorrência de proporções significativas de olivina, sob a forma de cristais sub-equantes a prismáticos com limites arredondados e dimensões variando desde <0,1-0,7 mm. Os cristais de carbonato exibem variação granulométrica semelhante, definindo um arranjo localmente poligonizado. Lamelas de flogopita intergranulares medindo <0,25 mm ocorrem de modo disseminado, porém em quantidades diminutas. Outra fase a ser destacada é o espinélio verde, que ocorre como cristais cúbicos <0,15 mm euédricos a subédricos, frequentemente arredondados, e que apesar de se distribuírem por toda a amostra como uma fase disseminada, estão tipicamente concentrados em clusters em associação à magnetita e pirrotita. Ademais, podem ocorrer em associação intergranular à matriz carbonática ou compartilhando limites de grão com a olivina. Anfibólio verde claro (pargassita) fino a médio (<0,2 mm), sub-equante a prismático subédrico, tem distribuição heterogênea, tanto mais abundante quanto maior a aproximação aos níveis anfibolíticos, podendo localmente ser considerada apenas uma fase acessória. Seu modo de ocorrência é intergranular aos cristais carbonáticos ou envolvendo parcial ou totalmente a olivina. Pode ainda compartilhar limites de grão com magnetita e pirrotita.

Magnetita e pirrotita são fases disseminadas e de modo de ocorrência intergranular ou intersticial. A magnetita está representada por cristais sub-equantes arredondados ou anédricos de dimensões não superiores a 0,2 mm, intergranulares na matriz carbonática, incrustados em cristais de olivina ou em associação com o espinélio. Mais raramente podem formar filamentos acompanhando limites de grão. Comparada à magnetita, a pirrotita é uma fase bem mais subordinada, mostrando semelhante associação ao espinélio ou adjacente à cristais de olivina e pargassita. Notadamente, observa-se uma frequente associação entre este sulfeto e clorita, com destaque para a ocorrência de clorita penetrando a pirrotita. A clorita é uma fase distinta pelo seu hábito lamelar longo e delgado, por vezes assemelhando-se a uma textura acicular. As lamelas, que podem ter comprimento variando desde <0,1-0,5 mm, ocorrem isoladas ou em agregados. Quando em contato com olivina e opacos, sua relação textural é de aparente desequilíbrio, estabilizando-se posteriormente às fases supracitadas.

Com o aumento em proporção de pargassita, verifica-se um concomitante enriquecimento em opacos, especialmente pirrotita. Os leitos ricos em anfibólio são irregulares em espessura e tendem a variar também em orientação, embora possam ser ainda considerados sub-paralelos. Seu aspecto remete a estruturas de infiltração, percolando através da rocha carbonática. Nesse sentido, cristais de olivina e carbonato podem ainda ser observados no interior dos leitos anfibolíticos, sendo envolvidos pelos cristais de pargassita. Apesar de ser um inossilicato, a textura geral nesse domínio ainda é granoblástica, dado a geometria sub-equante dos cristais de anfibólio arranjados em uma trama poligonal fina em que cristais individuais em sua ampla maioria não excedem 0,1 mm. Cristais de magnetita e pirrotita assumem um modo de ocorrência intersticial na matriz anfibolítica, assumindo a geometria resultante do compartilhamento de limites de grão com o anfibólio. Não obstante, cristais e agregados mais grossos podem resultar da interconexão entre interstícios adjacentes. Cristais de magnetita podem variar desde cristais muito finos (em alguns casos <0,05 mm), isolados ou em agregados amalgamados, associados ou não com pirrotita, até cristais mais grossos (<0,35 mm), sub-equantes subédricos, estes invariavelmente associados a pirrotita. A pirrotita também se desenvolve como cristais muito finos em semelhança à magnetita. Não obstante, ela se distingue pela ocorrência frequente de agregados irregulares médios a grossos (podendo alcançar até 5 mm), geralmente alongados segundo à orientação dos leitos anfibolíticos. Tais agregados grossos podem exibir extremidades semelhantes a ramificações, com precipitação de pirrotita ao longo dos contatos entre cristais de anfibólio, por vezes englobando-os por completo. Vale frisar que a magnetita também pode se desenvolver de forma intersticial (como filamentos) acompanhando limites de cristais. Arsenopirita e loellingita são raras, sendo mapeados alguns poucos cristais subédricos (0,05 mm) em contato com pirrotita e magnetita (B). Localmente são observadas concentrações de espinélio e clorita. De modo

análogo ao descrito para o domínio carbonático, a clorita aparenta se formar às expensas das demais fases descritas, sendo essa relação textural mais evidente com a olivina e a pirrotita. Apatita é uma fase acessória de distribuição disseminada, descrita como cristais sub-equantes arredondados de granulação fina a média (<0,1-0,4 mm) de modo de ocorrência intergranular.
Mineralogia Modal Semiquantitativa
CARBONATO (42 %), PARGASSITA-HASTINGSITA (32 %), OLIVINA (10 %), PIRROTITA (10 %), MAGNETITA (4 %), CLORITA (0,9 %), ESPINÉLIO (0,8 %), FLOGOPITA (0,2 %), APATITA (0,1 %)
Nome da rocha: **olivina mármore com flogopita, com alteração a pargassita-pirrotita-magnetita**
Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-033-20	Drillhole ID: A33	Profundidade: 188,5 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96529	UTM E: 402311

Descrição Microscópica

Rocha granoblástica de granulação média e isotrópica, com matriz de composição carbonática dada por cristais dominantemente sub-equantes e de dimensões variando entre 0,2-0,9 mm e distribuídas segundo um arranjo poligonal. Outras fases essenciais presentes incluem anfibólio, flogopita, pirrotita e magnetita (A).

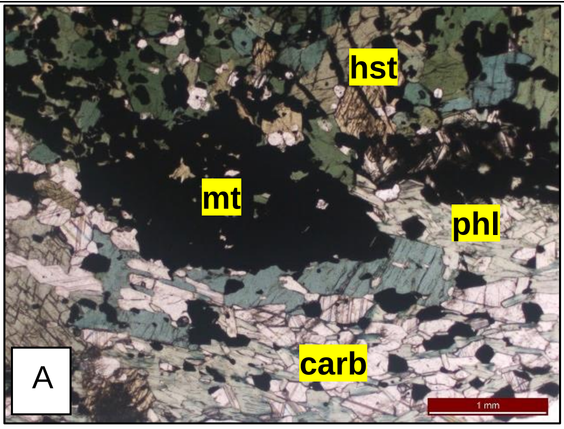
O anfibólio exibe forte pleocroísmo verde (hastingsita), sendo subédrico a anédrico e de granulação média (0,1-1,0 mm), frequentemente com planos de clivagem visíveis e cujo de modo de ocorrência é intergranular à matriz carbonática. A flogopita também apresenta pleocroísmo verde, sendo tipicamente lamelar e com tamanho de grão compreendido principalmente entre 0,1-0,4 mm. Ocorre em palhetas isoladas ou agregados, exibindo em sua maioria orientação preferencial. Magnetita e pirrotita são fases intergranulares disseminadas, formando cristais sub-arredondados, subédricos a anédricos, onde a magnetita ocupa um intervalo granulométrico entre <0,1-0,4 mm, enquanto a pirrotita pode alcançar até 0,6 mm. Cristais finos (<0,1 mm) de magnetita podem ocorrer ainda inclusos em carbonato. A relação textural entre magnetita e pirrotita sugere contemporaneidade.

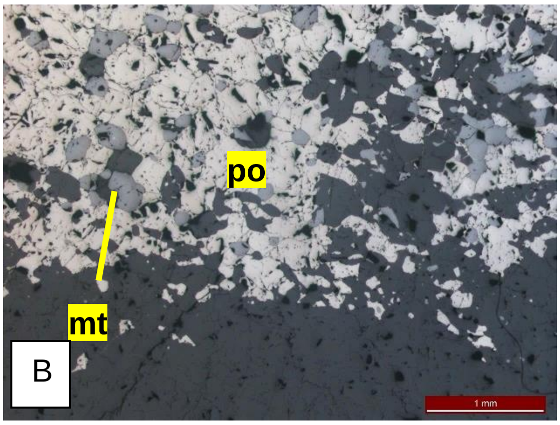
Esse domínio carbonático poligonizado transiciona abruptamente para um domínio de geometria irregular de composição a anfibólio-magnetita-pirrotita e com pequenas quantidades de quartzo. O anfibólio ocorre ao longo de toda sua extensão, porém se concentra principalmente ao longo de suas margens, formando um envoltório irregular e descontínuo de espessura variando de 1 a 4 mm. Nele o anfibólio, que é semelhante àquele do domínio carbonático, exibe ampla variação de tamanho de grão, desde <0,1-2,0 mm, podendo exibir hábito prismático ou sub-equante, onde os cristais se distribuem em arranjo localmente poligonizado. O interior desse domínio é dominado por massas extensas de cristais amalgamados de pirrotita e magnetita (as quais podem exceder 1 cm em extensão) (B), engolfando cristais isolados e agregados de anfibólio, flogopita, quartzo e apatita. A apatita ocorre tipicamente como uma fase acessória disseminada. Seus cristais são sub-equantes, com faces arredondadas e medindo entre 0,05-0,2 mm, sendo de ocorrência frequente ao longo das massas anfibolíticas, aparentemente em equilíbrio textural com o anfibólio. Ocorre menos comumente no domínio carbonático. Não obstante, lentes ou bolsões de cristais equigranulares (aproximadamente 0,1 mm) de apatita com arranjo marcadamente poligonizado são identificados no interior da massa de pirrotita + magnetita, onde podem estar associados tanto à flogopita quanto ao anfibólio.

Como citado anteriormente, magnetita e pirrotita consistem nas principais fases dentro dessa zona não carbonática. No interior dessa massa coalescida de opacos, verifica-se que a magnetita se desenvolve como cristais sub-equantes arredondados de granulação média, variando principalmente entre 0,1-0,4 mm, ora como cristais individualizados ora amalgamados. A pirrotita pode exibir hábito semelhante ao da magnetita ou desenvolver cristais anédricos, os quais podem alcançar até 0,8 mm. A despeito da textura dominantemente granoblástica que define a associação pirrotita-magnetita, com compartilhamento de limites de grão, verifica-se localmente, especialmente nas bordas desse domínio, que a pirrotita exibe feições indicativas de produto de infiltração e substituição. Em outras palavras, ela percola (ao longo de limites de grão) ou atravessa (cortando) tanto anfibólio quanto magnetita sob a forma de uma rede de microvênulas que se espalham a partir das massas amalgamadas.

Mineralogia Modal Semiquantitativa
CARBONATO (30%), HASTINGSITA (35%), PIRROTITA (20%), MAGNETITA (12 %), FLOGOPITA (1,5%), QUARTZO (1,5%)
Nome da rocha: **magnetita-pirrotita-hastinsita-carbonato granoblastito com flogopita e apatita**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

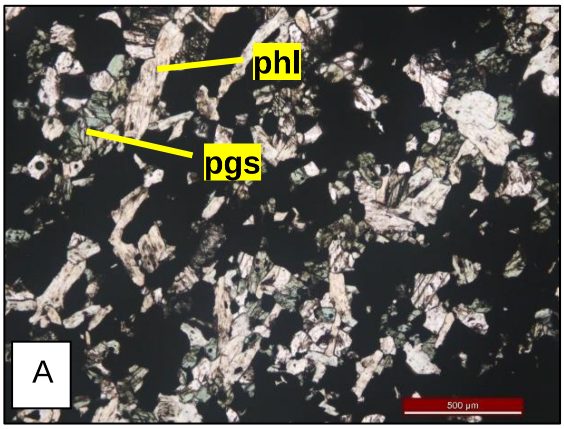
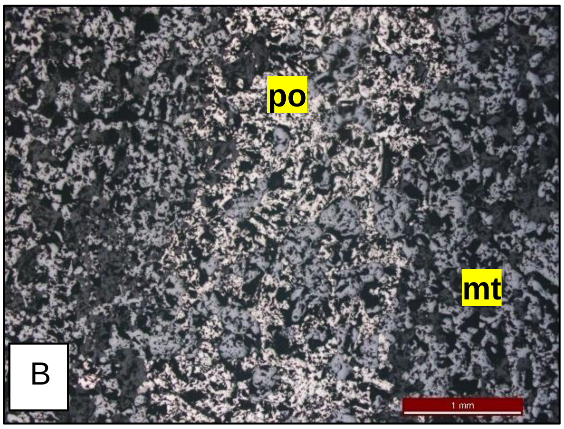
Código da amostra: TUC-DD-028-16	Drillhole ID: A28	Profundidade: 196,1 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96499	UTM E: 402339

Descrição Microscópica

Rocha granoblástica de granulação fina a média, anisotrópica, cuja constituição mineralógica é dominada por magnetita e carbonato, com proporções subordinadas de pirrotita, anfibólio e flogopita (parcialmente cloritizada) (A). O arcabouço estrutural anisotrópico é dado pela (i) orientação preferencial de agregados alongados de magnetita e carbonato, (ii) lentes de substituição de óxido por sulfeto de ferro (pirrotita), e (iii) orientação preferencial de filossilicatos e, em menor intensidade, anfibólios.

O carbonato ocorre sob a forma de cristais poligonizados com tamanho de grão variando principalmente entre 0,1-0,2 mm. A flogopita se desenvolve como palhetas com comprimento maior variando de 0,1-0,3 mm, cujo pleocroísmo varia de verde a marrom claro/castanho. A ocorrência frequente de palhetas com birrefringência em cores de primeira ordem (parcial ou totalmente) ou ainda cores azuis anômalas indica transformação retrógrada para clorita. São identificados dois tipos de anfibólios, um incolor (cummingtonita-grunerita) e outro verde pleocróico (hornblenda/pargasita?). Os cristais de anfibólio são prismáticos, subédricos a anédricos, e com tamanho de grão raramente excedendo 0,2 mm. Ambos, flogopita e anfibólios, ocorrem de forma disseminada, embora seu conteúdo seja maior onde a pirrotita está presente. Apatita intergranular disseminada ocorre de forma bastante subordinada.

A magnetita se apresenta como o arcabouço da rocha, definindo uma rede de cristais coalescidos interconectados (*framework*), onde cristais individuais variam em tamanho entre 0,1-0,3 mm, predominantemente subédricos. Espaços intersticiais nesta estrutura construída pela magnetita são preenchidos por carbonato. A pirrotita ocorre como cristais

anédricos disseminados (0,1-0,3 mm) ou ainda como pseudomorfos após magnetita. Não obstante, esse modo de ocorrência é bastante subordinado, com o maior volume deste mineral desenvolvendo lentes alongadas cujo comprimento varia de 0,6-1,0 cm. A constituição dessas lentes/ agregados de pirrotita se dá pelo encapsulamento e substituição de cristais de magnetita da matriz da rocha (B).
Mineralogia Modal Semiquantitativa
MAGNETITA (45%), CARBONATO (45%), PIRROTITA (4,5%), CUMMINGTONITA-GRUNERITA (2,5%), FLOGOPITA + CLORITA (2,5%), PARGASSITA/HASTINGSITA (0,5%)
Nome da rocha: **carbonato magnetitito com pirrotita-cummingtonita-flogopita**
Fotomicrografias
 

Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-029-36	Drillhole ID: A29	Profundidade: 198,2 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310

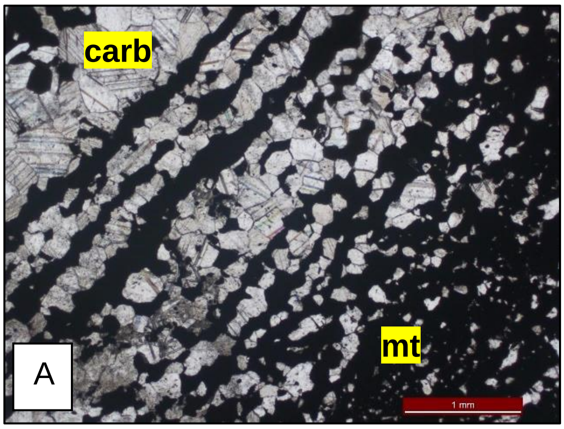
Descrição Microscópica

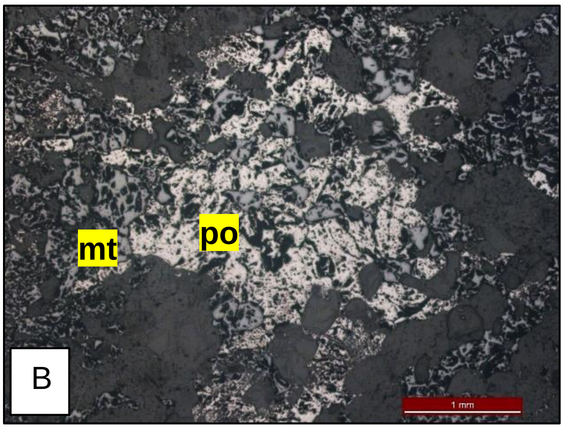
Rocha granoblástica de granulação média, bandada e constituída por matriz carbonática com cristais compreendidos entre 0,1-1,4 mm, com contatos predominantemente retos, definindo assim uma trama poligonizada. Os níveis carbonáticos se alternam com bandas a magnetita. Apesar do bandamento se apresentar fortemente perturbado, com dobras e rupturas, ainda é plenamente possível a identificação de uma trama textural com mesobandas de 3 a 6 mm de espessura (A). As bandas a magnetita são constituídas pelo empilhamento de microbandas. Em sua maioria, os cristais de magnetita são compreendidos entre <0,1-0,3 mm, com alguns raros cristais mais grossos (0,3-0,8 mm). Não obstante, a aferição da granulação nem sempre é possível em virtude da coalescência de cristais adjacentes nas bandas a magnetita.

O domínio carbonático é quase monominerálico, salvo por ocorrências localizadas de pseudomorfos de serpentina (± clorita) após olivina, frequentemente com magnetita fina como envelopamento delgado. A magnetita pode também se desenvolver de forma confinada aos planos de clivagem da serpentina. Uma fase de carbonato de aspecto turvo pode também estar vinculado a esse processo de serpentinização. Raras lamelas finas (< 0,1 mm) são também observadas como produto de alteração retrógrada. São identificadas manchas isoladas de carbonato de superfície turva, com frequente ocorrência de intercrescimento de cristais lamelares/aciculares de carbonato e serpentina subordinada.

A pirrotita é o único sulfeto registrado na amostra, exibindo hábito subequante a elongado, subédrico a anédrico, com tamanho de grão predominante no intervalo 0,1-0,4 mm, porém com alguns agregados excedendo 1,0 mm (B). Trata-se de uma fase de ocorrência

disseminada, intersticial na matriz carbonática (isolada) ou em associação à magnetita, em relação de aparente substituição. Localmente, verifica-se um horizonte de pirrotita que resulta aparentemente da substituição completa de uma banda de magnetita. Ademais, os agregados mais grossos de pirrotita se localizam onde há maior conteúdo de olivina serpentinizada. Pirrotita e magnetita muito finas (<0,05 mm) são identificadas nas áreas de carbonato sujo com serpentina subordinada.
Mineralogia Modal Semiquantitativa
CARBONATO LIMPO (60%), MAGNETITA (34%), PIRROTITA (2%), CARBONATO SUJO (1,5%), SERPENTINA (1,3%), OLIVINA (1%), CLORITA (0,2%)
Nome da rocha: **magnetita-carbonato xisto com olivina alterada a serpentina-carbonato e incipiente alteração a pirrotita**
Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-028-06a	Drillhole ID: A28	Profundidade: 64,5 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96499	UTM E: 402339

Descrição Microscópica

Rocha granonematoblástica de granulação média cujas fases minerais dominantes são quartzo e anfibólio da série cummingtonita-grunerita.

Quartzo é a fase mais abundante e se constitui em uma matriz semipoligonizada com cristais <0,2 mm. Associado ao quartzo como uma fase intersticial ou sobretudo sob a forma de *stringers* (pobremente orientados como em padrão *stockwork*) de espessura submilimétrica, o anfibólio exibe hábito prismático desde curto a longo acicular, principalmente subédrico e raramente excedendo 0,3 mm. Seus cristais possuem clivagem e geminação múltipla típicas. Observações mais detalhadas revelam a ocorrência de um anfibólio cálcico (actinolita) como um componente intersticial envolvendo os cristais de cummingtonita-grunerita.

Esses feixes de anfibólio podem ser rastreados a uma zona de infiltração a anfibólio e pirrotita de alguns milímetros de espessura que atravessa a rocha (A, B). Nela os anfibólios ocorrem como agregados de cristais finos a médios desprovidos de orientação preferencial. Seu hábito e dimensões assemelham-se àqueles dos anfibólios em outras porções da amostra, embora lentes e acumulações de cristais euédricos mais grossos (0,3-0,5 mm) sejam reportados, principalmente ao longo de suas margens. Ademais, verifica-se a ocorrência de um veio irregular de hedenbergita de <0,4 mm de espessura com actinolita de granulação fina a média (<0,2 mm) e preferencialmente subédrica se desenvolvendo ao longo de suas margens (como sobrecrescimento) ou em fraturas intracristalinas e limites intergranulares.

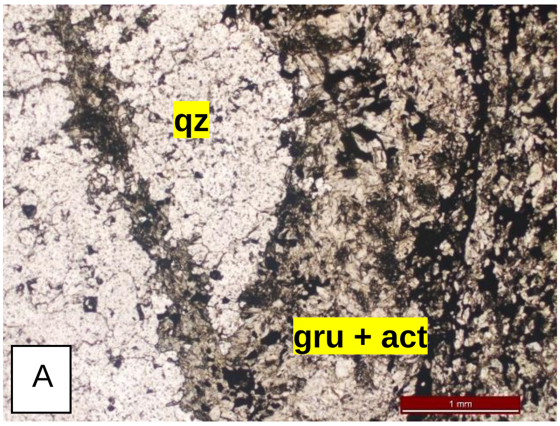
A pirrotita é a única fase opaca identificada, invariavelmente associada aos anfibólios, tanto nas stringers delgadas quanto na estrutura portadora de anfibólios mais espessa, estando mais concentrada na última. Seu modo de ocorrência é disseminado, embora esteja mais concentrado em uma das margens dessa estrutura, formando inclusive um feixe contínuo paralelo às suas margens. A pirrotita é principalmente anédrica e fina (< 0,1 mm), com raros cristais mais grossos, podendo exceder localmente 0,5 mm.

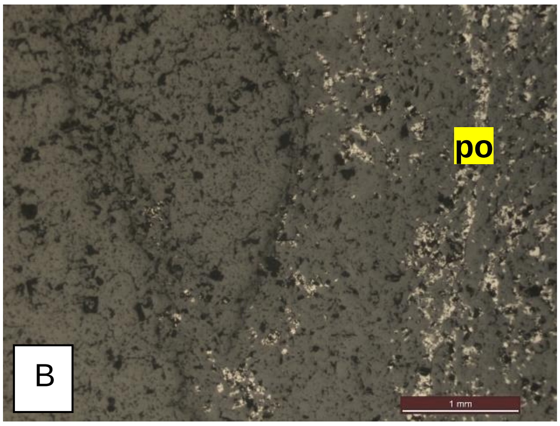
Mineralogia Modal Semiquantitativa

QUARTZO (55%), CUMMINGTONITA-GRUNERITA (35%), ACTINOLITA (7,8%), PIRROTITA (2%), HEDENBERGITA (0,2%)

Nome da rocha: **veio de quartzo-grunerita-actinolita com pirrotita**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-033-04b	Drillhole ID: A33	Profundidade: 55,7 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96529	UTM E: 402311

Descrição Microscópica

Rocha granonematoblástica de granulação fina a média e marcadamente foliada, constituída dominantemente por quartzo e anfibólio pobre em cálcio da série cummingtonita-grunerita.

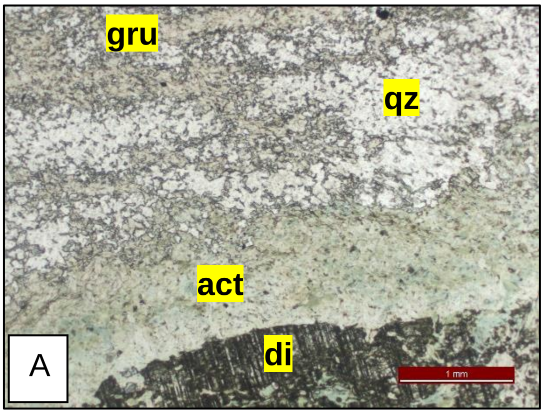
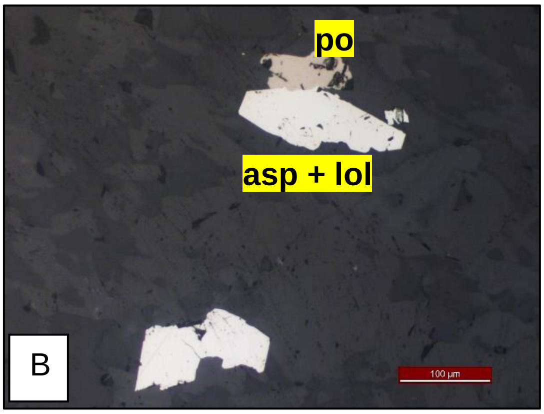
Quartzo é a fase mineral mais abundante, sendo responsável pelo caráter granoblástico da rocha. Sua trama textural é definida por cristais sub-equantes em geral <0,2 mm (maioria se situa abaixo de 0,1 mm), distribuídos em um arranjo poligonizado, onde uma proporção significativa dos cristais exibe extinção normal. Apesar de sua homogeneidade granulométrica, esporadicamente observam-se cristais mais grossos, podendo atingir até 0,6 mm. Estes exibem frequentemente extinção ondulante com formação de subgrão. Destaca-se a presença de uma vênula de quartzo delgado (espessura inferior a 0,5 mm) levemente oblíquo à foliação e com granulação ligeiramente mais grossa que o quartzo da encaixante.

A cummingtonita-grunerita se apresenta ao longo de acumulações em forma de leitos/feixes interconectados e sub-paralelos de espessura irregular sempre inferior a 1,5 mm. Essa rede de stringers confere à rocha seu caráter nematoblástico e define sua foliação. Não obstante, cristais ou agregados desse anfibólio podem também ser observados de modo intergranular aos cristais de quartzo. Quanto ao seu hábito, os cristais de grunerita são dominantemente prismáticos subédricos, medindo desde <0,1-0,4 mm. Cristais mais finos predominam no interior dos níveis quartzosos, ao passo que cristais ocupando o extremo mais grosso da distribuição granulométrica são observados nos leitos anfibolíticos, especialmente naqueles de espessura mais pujante. Dentro desses feixes, os cristais via de regra se apresentam pobremente orientados.

Na porção central da amostra destaca-se a ocorrência de uma faixa constituída por cristais prismáticos de clinopiroxênio esqueléticos de dimensão milimétrica (<8 mm). Estes encontram-se sobrepostos e revestidos por um manto de anfibólio de espessura variando entre 1 e 3 mm (A). Em contraste ao restante da rocha, nesse halo predomina anfibólio cálcico do tipo actinolita, cuja granulação varia entre <0,1-0,6 mm. Tais cristais podem variar de sub-equantes a prismáticos, com predominância de cristais prismáticos mais grossos quanto maior a aproximação do clinopiroxênio.

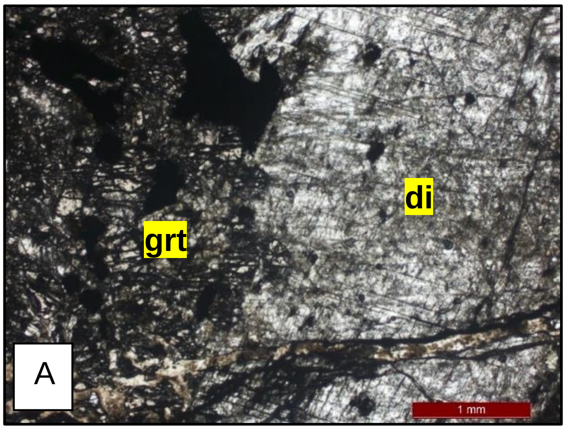
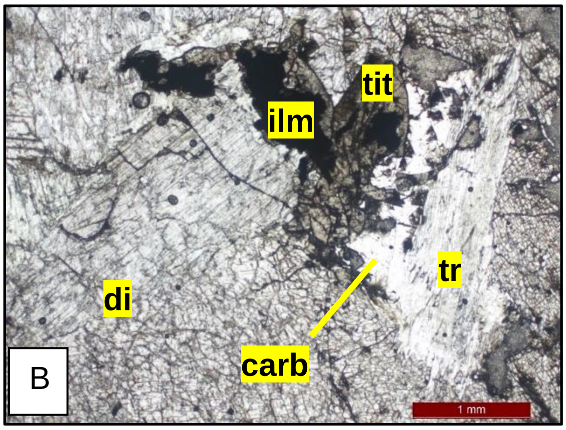
Em equilíbrio textural com este anfibólio, porém em proporções modais muito inferiores, ocorrem biotita e carbonato, essencialmente restritos ao interior dos cristais esqueléticos de clinopiroxênio. Ambos os minerais são de granulação fina (<0,15 mm), com hábito definido pelo espaço intersticial preenchido, sendo reconhecidos por sua cor, clivagem e birrefringência, no caso da biotita, e por sua clivagem e birrefringência, no caso do carbonato.

Quanto às fases acessórias, listam-se essencialmente os sulfetos, dominantemente arsenopirita e pirrotita (B) com calcopirita rara. Cristais de ouro livre são identificados, embora igualmente raros. A arsenopirita ocorre sob a forma de cristais de seção losangular subédricos a raramente euédricos, com tamanho de grão variando principalmente entre < 0,1-0,3 mm. A pirrotita é frequentemente anédrica, sendo ligeiramente mais fina que a arsenopirita (<0,2 mm), com exceção de um agregado irregular encrustado em clinopiroxênio esqueletal que excede 0,5 mm. Arsenopirita e pirrotita ocorrem disseminados pela amostra em quantidades diminutas, quase sempre isolados ou pequenos clusters de cristais individualizados, raramente compartilhando limites de grão um com outro. A calcopirita é rara e sempre muito fina (<0,05 mm), anédrica, isolada ou em associação com a pirrotita. Cristais de ouro nativo muito finos (<0,05 mm) são identificados em associação ao agregado de pirrotita mais grosso registrado na amostra, ocorrendo ao longo de margens e terminações desse sulfeto. Observa-se uma condição de equilíbrio textural na relação dos supracitados sulfetos com os dois tipos composicionais de anfibólio bem como o carbonato.

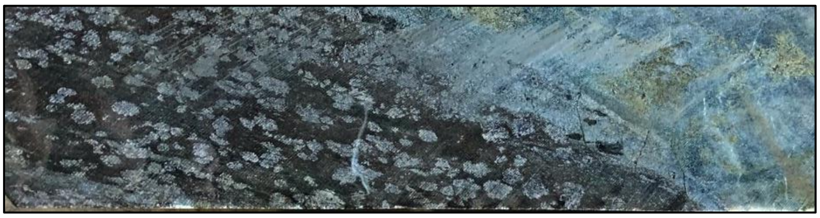
Mineralogia Modal Semiquantitativa
QUARTZO (49%), CUMMINGTONITA-GRUNERITA (30%), ACTINOLITA (10%), CLINOPIROXÊNIO (9,5%), CARBONATO (0,25%), BIOTITA (0,25%), PIRROTITA (0,5%), ARSENOPIRITA (0,5%)
Nome da rocha: **veio de quartzo-clinopiroxênio com alteração a grunerita-actinolita**
Fotomicrografias
 

Ficha de Descrição Petrográfica South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico		
Código da amostra: TUC-DD-009-03h	Drillhole ID: A09	Profundidade: 73,4 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96334	UTM E: 402358

Descrição Microscópica
Rocha granoblástica de granulação grossa a muito grossa constituída essencialmente por cristais prismáticos curtos milimétricos a >1,0cm de diopsídio dispostos sem orientação preferencial. Localmente, agregados anédricos e irregulares de granada se fazem presentes (A) e esta fase mineral ocorre acompanhada por agregados finos (<0,1 mm) contendo epidoto (clinozoisita), lamelas de muscovita ou sericita, anfibólio e quartzo subordinado. Intersticialmente aos megacristais de diopsídio, pode ser identificado preenchimento por carbonato e subordinadamente epidoto (principalmente clinozoisita e mais raramente allanita). Fases opacas ocorrem de forma disseminada, embora clusters de maior concentração sejam observados. Tais fases compreendem magnetita e ilmenita, com predominância da segunda. A ilmenita ocorre como cristais prismáticos, subédricos a anédricos, de granulação fina a média (0,1-1,0 mm), enquanto a magnetita é geralmente equidimensional, subédrica a anédrica, e fina, raramente excedendo 0,2 mm. A ilmenita frequentemente exibe bordas de reação demonstrando conversão para titanita. Um cristal euédrico de titanita de aproximadamente 1,5 mm, com núcleo de ilmenita, ocorre lateralmente associado a carbonato e a um cristal prismático de tremolita de 2 mm (B). A rocha é ainda atravessada por veios submilimétricos de quartzo.
Mineralogia Modal Semiquantitativa
DIOPSÍDIO (92%), GRANADA (3%), ILMENITA (2%), MAGNETITA (1%), TITANITA (0,5%), QUARTZO (0,5%), CARBONATO (0,4%), CLINOZOISITA (0,2%), MUSCOVITA (0,2%), TREMOLITA (0,2%)

Nome da rocha: **rocha a diopsídio com granada e ilmenita**	
Fotomicrografias	
	

Ficha de Descrição Petrográfica South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico		
Código da amostra: TUC-DD-029-04	Drillhole ID: A29	Profundidade: 48,2 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310



Descrição Microscópica
Rocha porfiroblástica de matriz de granulação fina a média e isotrópica, constituída dominantemente por biotita e granada, com proporções significativas de anfibólio e quantidades menores de turmalina e ilmenita, com traços de pirrotita (A). Porfiroblastos euédricos a subédricos de granada não rotacionados e em geral pouco fraturados são amplamente distribuídos pela amostra e medem de 2-6 mm. A matriz que os envolve é constituída essencialmente por biotita, sob a forma de massas contínuas de cristais lamelares variando de 0,1-0,4 mm e, via de regra, pobremente orientados. Cristais prismáticos subédricos de turmalina verde se destacam em meio à matriz rica em biotita, com tamanho de grão podendo alcançar 2 mm. Quartzo e muscovita de granulação predominantemente fina ocorrem como fases intersticiais a biotita, embora em proporções diminutas. Alguns dos cristais incolores e de baixa birrefringência têm superfície turva, o que sugere a ocorrência de feldspato, mas nenhuma geminação é identificada. A rocha pode ser subdividida em dois segmentos em resposta à progressiva substituição da biotita e da granada por um anfibólio da série cummingtonita-grunerita (B). Onde o anfibólio está ausente, tanto biotita quanto granada se apresentam intactos. Contudo, à medida que se verifica um aumento gradual de anfibólio, ambas as fases supracitadas são afetadas. Enquanto a biotita é totalmente substituída, ao ponto de não mais ser observada no interior do domínio rico em anfibólio, a granada permanece, embora com formação de anfibólio ao longo de suas bordas e em seu interior por meio de redes de fissuras, frequentemente resultando em cristais esqueléticos e com margens parcialmente consumidas. Os cristais de anfibólio têm hábito prismático longo acicular, variando em

comprimento de 0,2-0,5 mm, e carecem de orientação preferencial, sendo localmente observado o desenvolvimento de arranjo textural decussado. Ademais, ambos anfibólio e biotita são localmente transformados em clorita, a qual se desenvolve principalmente ao longo da interface entre os domínios a biotita e a anfibólio. Não obstante, vênulas de espessura submilimétrica (<0,2 mm) de clorita são documentadas atravessando ambos os domínios, com terminações sendo identificadas na zona onde biotita é estável. Associado à clorita, identifica-se epidoto e sericita de granulação fina.

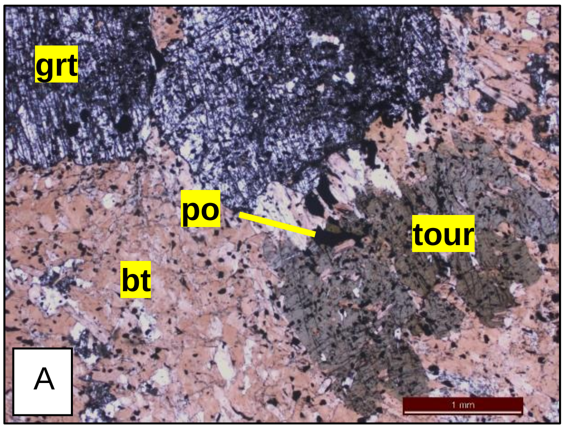
Uma das características diagnósticas dessa rocha é a relevante abundância de ilmenita disseminada. Trata-se de cristais finos (<0,1 mm) de hábito prismático a aproximadamente sub-equante. Outra fase opaca identificada é a pirrotita, porém esta não é disseminada por toda a amostra. Sua ocorrência está condicionada à distribuição de turmalina e de pequenos nódulos irregulares de sericita + epidoto, sendo notavelmente mais presente no domínio onde biotita não foi afetada por substituição de anfibólio. A pirrotita é em geral anédrica variando de 0,1-0,3 mm. Rara esfalerita fina pode ser identificada incrustada em alguns cristais de pirrotita.

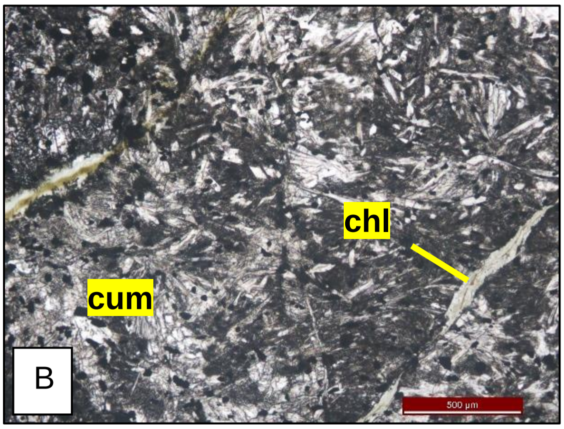
Mineralogia Modal Semiquantitativa

BIOTITA (49%), GRANADA (25%), CUMMINGTONITA (8%), CLORITA (5%), TURMALINA (3%), SERICITA (2,2%), EPIDOTO (2,2%), QUARTZO (2%), ILMENITA (2%), K-FELDSPATO? (1%), PIRROTITA (0,5%), MAGNETITA (0,1%)

Nome da rocha: **granada-biotita granoblastito com turmalina e ilmenita, com alteração a cummingtonita, sucedida por alteração a clorita-sericita-epidoto**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-029-21	Drillhole ID: A29	Profundidade: 114,0 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310

Descrição Microscópica

Rocha granoblástica de granulação média e matriz de composição carbonática constituída por cristais com tamanho de grão entre 0,1-0,4 mm, e texturalmente caracterizada por apresentar contatos extremamente irregulares, quase serrilhados, muito em virtude da intensa ocupação intersticial por minerais fibrosos (A), quais sejam, clorita, talco, serpentina e actinolita, de granulação fina a média (<0,25 mm). Além de seu hábito fibroso mais fino, o talco pode ocorrer como lamelas bem desenvolvidas aleatoriamente dispostas e dominantemente finas (<0,1 mm), embora localmente possa alcançar 0,3 mm. A actinolita se desenvolve tipicamente como cristais prismáticos subédricos de até 0,5 mm, comumente com instalação de fibras de talco ao longo de suas margens, indicando desequilíbrio e transição de fase. Do mesmo modo, a clorita também pode desenvolver lamelas mais grossas (<0,5 mm) e bem desenvolvidas, levemente dobradas, e sob a forma de cristais individuais ou em agregados, estando intimamente associada a massas de serpentina fina que frequentemente encapsulam por completo cristais de carbonato da matriz, as quais comumente exibem textura mesh.

Quanto aos opacos, predomina pirrotita, com rara magnetita associada. São cristais finos (<0,15 mm), subédricos a anédricos, distribuídos de maneira disseminada, localmente clusterizados ou formando trilhas descontínuas.

Essa rocha transiciona lateralmente para uma faixa de composição anfibolítica com restos de cristais esqueléticos de clinopiroxênio de granulação grossa (2-6 mm). OS cristais de actinolita são subequantes a prismáticos e com contatos dominantemente retos (trama poligonizada), sendo de granulação média (0,1-0,4 mm).

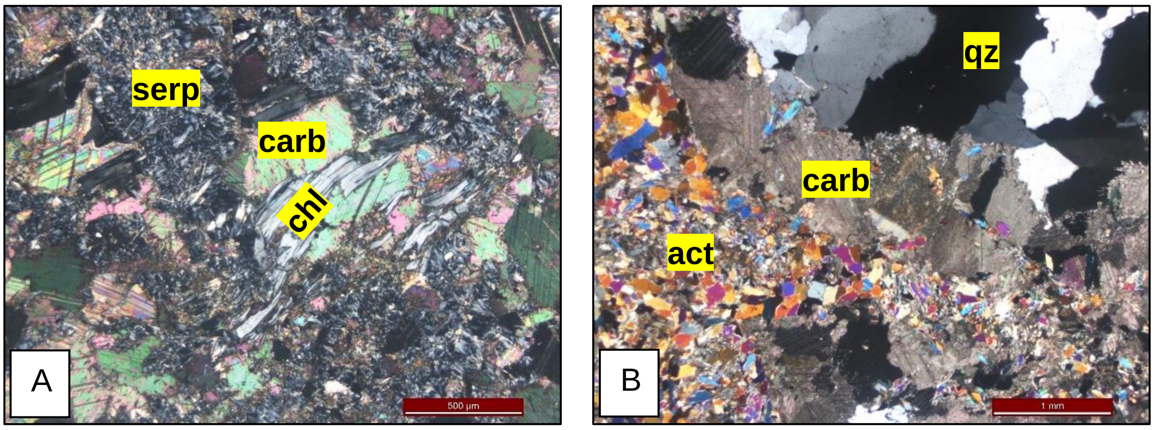
O domínio anfibolítico por sua vez dá lugar a um veio de composição quartzo-carbonática texturalmente caracterizado por desequilíbrio entre seus principais constituintes. Bolsões de quartzo de granulação média a grossa (0,2-1,5 mm) exibem cristais anédricos e com contatos ora retos ora com abaulamentos convexos típicos de recristalização por migração de limite de grão, com frequente extinção ondulante e mais raramente lamelas de deformação. Esses bolsões são englobados por agregados de carbonato de superfície turva de granulação média (<0,8 mm), porém com sobrecrescimento (franjas) de agregados de granulação muito fina e hábito acicular, projetando-se para o interior dos bolsões de quartzo. Essas porções carbonáticas intersticiais com respeito ao quartzo se desenvolvem principalmente ao redor de redes de vênulas submilimétricas em stockwork constituídas de actinolita prismática euédrica a subédrica (0,1-0,4 mm principalmente) que emanam a partir do domínio anfibolítico supracitado e se projetam para o interior do veio (B). Cristais individualizados de actinolita também ocorrem disseminados em meio ao carbonato. Tanto o domínio anfibolítico quanto o referido veio são desprovidos de minerais opacos.

Mineralogia Modal Semiquantitativa

TREMOLITA-ACTINOLITA (35%), CARBONATO MATRIZ (21%), CARBONATO VEIO (20%), QUARTZO VEIO (8%), CLINOPIROXÊNIO (7%), SERPENTINA (4%), TALCO (2,8%), CLORITA (2%), PIRROTITA (0,2%)

Nome da rocha: **mármore com veio de quartzo-clinopiroxênio, com alteração a actinolita-carbonato-talco-serpentina-clorita**

Fotomicrografias



Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-009-18a	Drillhole ID: A09	Profundidade: 190,4 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96334	UTM E: 402358

Descrição Microscópica

Rocha de cor verde constituída por pseudomorfos após cristais de granulação grossa a muito grossa de anfibólio (?) prismático. A substituição dos cristais pretéritos de anfibólio se dá principalmente por agregados de granulação fina (<0,1 mm) a microcristalina contendo possivelmente mais de um dentre epidoto, stilpnomelano, clorita, carbonato e talvez prehnita (difícil distinção devido à natureza microcristalina dessas fases). Por vezes, massas de quartzo de granulação fina a média (<0,1-0,4 mm) exibem limites facetados sugerindo substituição de uma fase pretérita, preservando apenas seu hábito (A). Localmente, a trama fina que caracteriza em grande medida esta rocha revela a presença de uma fase lamelar de pleocroísmo variando entre tonalidades de verde e marrom que, combinado com sua birrefringência anômala, são indicativos do mineral stilpnomelano.

A amostra é atravessada por um veio carbonático de cerca de 5 mm de espessura e granulação média (0,1-0,7 mm). Microestruturas subsidiárias emanando a partir deste veio evidenciam um caráter essencialmente rúptil do sistema quando de sua colocação. Ademais, as margens do veio exibem textura do tipo pente (*comb texture*), com crescimento de cristais prismáticos a aciculares ortogonalmente à parede do veio (B). Fragmentos oxidados e parcialmente consumidos de anfibólio (?) também se encontram no interior do veio. Enquanto o litotipo descrito no primeiro parágrafo representa o *footwall* do veio, o *hanging wall* consiste em uma matriz quartzosa fina com cristais em arranjo suturado pontilhada por *clots* de um mineral oxidado não identificado, cuja relação com os cristais de quartzo envolventes se dá por preenchimento de espaços intergranulares. Pirita euédrica a subédrica fina ocorre sobre esta fase.

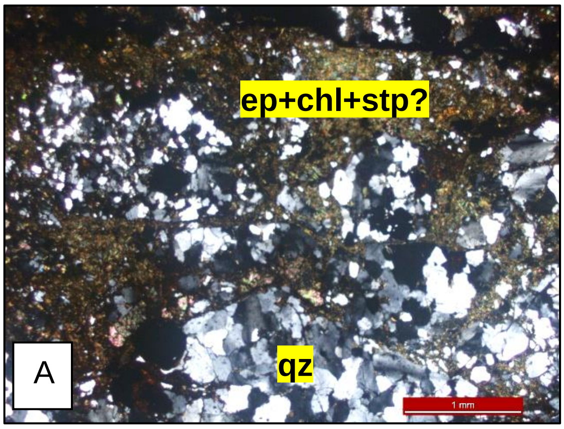
A pirita é o único sulfeto identificado nesta amostra, sendo tipicamente descrita como massas e agregados irregulares de até 5 mm, podendo formar vênulas em stockwork. Os cristais individuais são euédricos a subédricos com granulação desde fina a média (<0,1-0,9 mm). Esta fase se apresenta em equilíbrio com o carbonato de veio, seja por emanar a partir dele ou por se desenvolver como *selvage*.

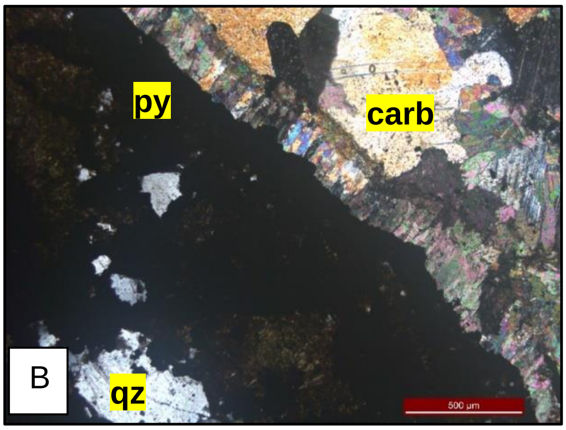
Mineralogia Modal Semiquantitativa

QUARTZO (45%), MINERAIS DE GRANULAÇÃO MUITO FINA (CLORITA-CARBONATO-EPIDOTO-STILPNOMELANO) (25%), CARBONATO (18%), PIRITA (12%)

Nome da rocha: **alteração a quartzo-carbonato-pirita sobre rocha a anfibólio(?), com agregados muito finos de clorita-carbonato-epidoto-stilpnomelano**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

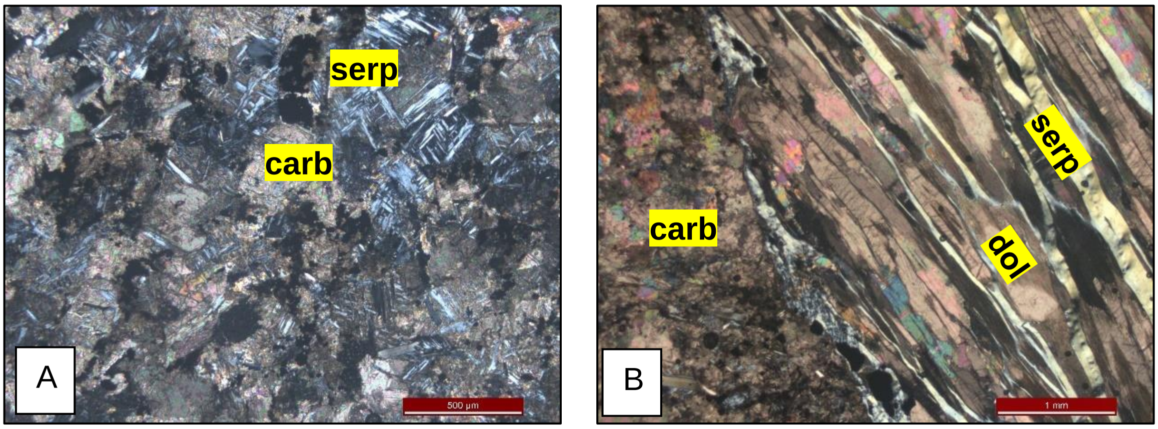
Código da amostra: TUC-DD-027-14	Drillhole ID: A27	Profundidade: 113,0 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 95873	UTM E: 402249

Descrição Microscópica

Rocha granoblástica, isotrópica, de granulação fina a média, constituída dominantemente por fases carbonáticas com tamanho de grão raramente excedendo 0,25 mm e distribuídas segundo um arranjo textural semipoligonizado. São identificados ainda cristais prismáticos subédricos de anfibólio incolor (tremolita) com tamanho médio inferior aos cristais carbonáticos, bem como lamelas delgadas de clorita (<0,4 mm). Essas fases encontram-se disseminadas e exibem relação intergranular com a matriz carbonática

Uma das feições diagnósticas dessa rocha é a presença disseminada de clots milimétricos contendo uma fase carbonática de superfície turva (em oposição ao mineral carbonático mais límpido da matriz), serpentina fibrosa (0,1-0,5 mm) exibindo típica textura *mesh*, e magnetita subédrica fina (<0,1 mm) (A). Localmente, identifica-se a ocorrência de veio irregular de espessura variando entre 1,0 e 1,5 mm, cuja composição mineralógica é análoga a sua encaixante. Contudo, distingue-se dela pela ocorrência de cristais carbonáticos mais grossos, frequentemente >0,5 mm, bem como pela maior proporção modal de tremolita. Cristais intersticiais de quartzo são registrados em quantidades diminutas.

Essa rocha é atravessada por um veio de poucos centímetros de espessura que pode ser descrito como uma estrutura altamente deformada constituída por faixas alongadas/estiradas de serpentina e dolomita (B). A dolomita é identificada por sua natureza fibrosa, típica dessa fase quando sujeita a stress diferencial, estando a mesma envolvida por serpentina em um arranjo textural semelhante a um padrão entrelaçado. A orientação geral das faixas de serpentina e dolomita é levemente oblíqua à margem do veio. Em

contraste à região mais externa do veio, nas zonas mais internas são frequentes cristais carbonáticos sub-equantes com pouca ou nenhuma evidência de estiramento.
Mineralogia Modal Semiquantitativa
*CARBONATO LÍMPIDO (80%), CARBONATO TURVO (14%), SERPENTINA (2,5%), TREMOLITA (2%), MAGNETITA (1%), CLORITA (0,5%) *excluindo o veio serpentina-dolomita
Nome da rocha: **mármore com tremolita com alteração a serpentina cortado por veio de serpentina-dolomita**
Fotomicrografias


Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

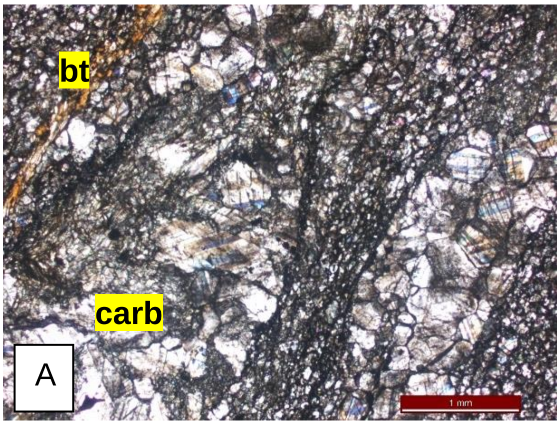
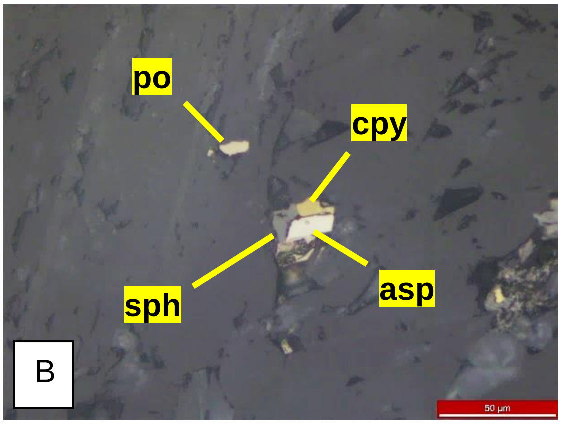
Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-028-05	Drillhole ID: A28	Profundidade: 61,6 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96499	UTM E: 402339

Descrição Microscópica

Rocha granoblástica de granulação fina constituída por matriz carbonática com tamanho de grão <0,15 mm e texturalmente caracterizada por apresentar foliação milonítica dada por porfiroclastos estirados de carbonato mais grosso, bem como por cristais inequidimensionais. Esses clastos com carbonato recristalizado variam ao longo da direção de estiramento entre 1-6 mm. É comum a interconexão entre clastos mais alongados dando origem a níveis/bandas contínuas. A foliação é dada ainda pela orientação preferencial de cristais de carbonato inequidimensionais da matriz. Ao carbonato na matriz, adiciona-se uma proporção menor, porém significativa, de lamelas de biotita preferencialmente orientadas e tamanho de grão entre 0,1-0,4 mm. A biotita apresenta-se ora em relação intergranular com a fase carbonática da matriz ora em agregados alongados de espessura submilimétrica circundando alguns os clastos supracitados (A).

Fases opacas ocorrem disseminadas por toda a amostra, porém em proporções insignificantes. Contudo, verifica-se uma grande variedade mineralógica, contemplando arsenopirita, esfalerita, calcopirita, pirrotita e pirita. Com exceção da arsenopirita, que é frequentemente subédrica com hábito losangular característico, as demais fases são normalmente anédricas. Sua granulação é muito fina, de modo que a vasta maioria dos cristais é <0,05 mm (B). Além dos sulfetos, destaca-se também a ocorrência de ilmenita como cristais prismáticos longos de granulação semelhante e orientados segundo a foliação principal.

Mineralogia Modal Semiquantitativa
CARBONATO (90%), BIOTITA (9,95%), SULFETOS TOTAIS (0,05%)
Nome da rocha: **mármore milonítico**
Fotomicrografias
 

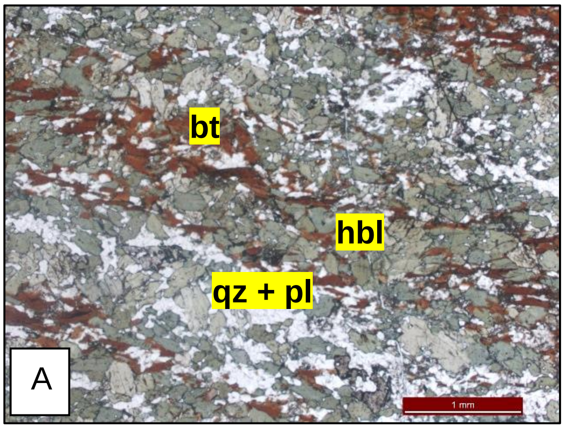
Ficha de Descrição Petrográfica South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico		
Código da amostra: TUC-DD-963-22	Drillhole ID: A957	Profundidade: 207,6 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96076	UTM E: 402184

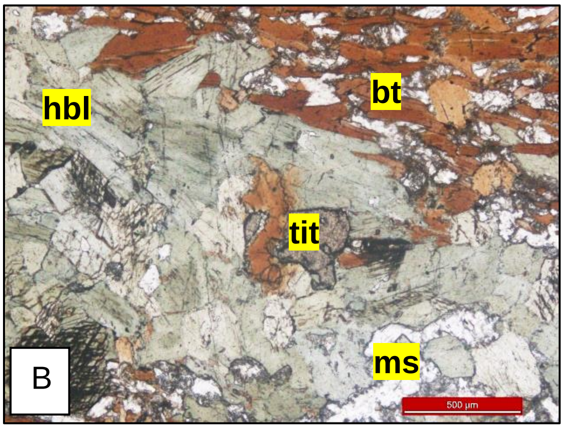
Descrição Microscópica
Rocha de granulação média, anisotrópica, alternando níveis a anfibólio e a biotita (A). Sua foliação é dada não somente pelo seu bandamento composicional relativamente bem desenvolvido, mas também pela orientação preferencial de cristais lamelares de biotita. Os leitos de biotita têm espessura compreendida entre 0,5-2,0 mm, cujos cristais constituintes raramente excedem 0,5 mm ao longo do comprimento. A hornblenda é a fase dominante da rocha, tipicamente sob a forma de cristais prismáticos curtos subédricos, com tamanho de grão médio compreendido entre 0,2-0,3 mm, raramente com cristais excedendo 0,5 mm. Ao contrário da biotita, os cristais de anfibólio não exibem orientação preferencial definida, permitindo assim a categorização da trama da rocha como granolepidoblástica. Outras fases reportadas são quartzo, plagioclásio, muscovita e titanita. Quartzo e plagioclásio são descritos como cristais subequantes, principalmente anédricos, e de granulação fina a média (<0,2 mm), e ocupam espaços intergranulares na matriz anfibolítica. São ligeiramente mais abundantes nos níveis s biotita. A muscovita ocorre como palhetas de granulação fina (<0,1 mm) de distribuição e modo de ocorrência semelhantes àqueles de quartzo e plagioclásio. Destaca-se, todavia, maior concentração de mica branca ao longo de um horizonte delgado (espessura <1,5 mm) onde predomina hornblenda de granulação mais grossa que sua média, com alta proporção de cristais medindo de 0,5-1,0 mm. A titanita ocorre como fase acessória disseminada por toda a amostra (B). Predominam cristais subédricos a anédricos <0,2 mm, com alguns poucos cristais podendo atingir até 0,7 mm. Esse mineral se encontra parcialmente transformado em leucoxênio, sendo possível distinguir cristais alterados de inalterados com base na

maior reflectância da titanita intacta. Esse processo de alteração da titanita aparenta ser maiis pronunciado nos domínios ais ricos em biotita.

Fases opacas são relativamente escassas, ocorrendo de forma disseminada como cristais invariavelmente finos (<0,1 mm). Incluem-se nessa relação pirrotita e calcopirita anédricas, pirita euédrica e ilmenita prismática. Os sulfetos são de caráter ora intergranular isolado ora intersticial, especialmente com relação ao anfibólio. A ilmenita ocorre principalmente associada à biotita.

Mineralogia Modal Semiquantitativa
HORNBLENDA (58%), BIOTITA (18%), QUARTZO (12%), PLAGIOCLÁSIO (8,5%), MUSCOVITA (2%), TITANITA (1,5%)
Nome da rocha: **quartzo-biotita anfibolito**
Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: URN-057-03	Drillhole ID: URN057	Profundidade: 83,8 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N:	UTM E:

Descrição Microscópica

Rocha granolepidoblástica de granulação média a grossa, anisotrópica, com foliação dada pelo alinhamento preferencial de cristais lamelares de biotita e, subordinamente, muscovita. O quartzo é o mineral mais abundante da rocha, e seus cristais definem uma trama predominantemente granoblástica, com apenas uma pequena fração de cristais alongados. Os cristais são em geral anédricos e com tipos de contato variados, incluindo retos, suavizados, e com embaiamento (recristalização por migração de limite de grão), sendo frequente a observação de pontos tríplices típicos de arranjo poligonizado. Seu tamanho de grão está compreendido principalmente na faixa granulométrica 0,2-0,7 mm.

Lamelas de biotita ocorrem de forma disseminada por toda a amostra, com distribuição e orientação definindo dois planos de foliação em trama de cisalhamento SC. Os cristais de biotita que definem a xistosidade (S) consistem em lamelas delgadas a espessas de comprimento compreendido entre 0,1-0,5 mm, sendo localmente defletidas nos planos de cisalhamento (C). Seus cristais se distribuem de forma relativamente homogênea pela matriz, seja como lamelas individuais ou agregados de poucos cristais. Em contrapartida, nos planos C, verifica-se uma maior acumulação desse mineral, com lamelas delgadas, porém significativamente mais longas (<2,0 mm) (A). De modo semelhante, a muscovita também está inserida nesse contexto estrutural de trama SC, exibindo faixas granulométricas similares à biotita tanto em planos S quanto em C. Distingue-se da anterior pela menor proporção modal ao longo dos planos S e significativa abundância comparativa nos planos C, sendo localmente mais volumosa que a biotita nestes planos.

Mesmo afastando-se dos planos C, observam-se alguns cristais isolados tanto de biotita quanto de muscovita alinhados segundo esta foliação, truncando cristais orientados segundo a xistosidade.

Independente de sua localização na amostra, a granada apresenta-se sempre elongada ou estirada segundo o plano C (B). Em termos de distribuição modal, a maior fração dos cristais de granada são subédricos a anédricos com granulação média a grossa (0,6 – 2,5 mm), contendo frequentemente trilhas de inclusões de quartzo alongado. Não obstante, alguns raros cristais finos (<0,15 mm) são documentados. Cristais anédricos a subédricos de plagioclásio intergranular são disseminados pela amostra.

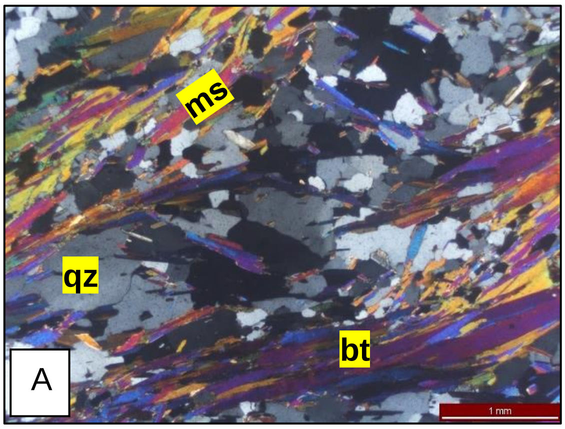
Quanto às fases acessórias, destaca-se a ocorrência de raros cristais de pirrotita anédricos ou subarredondados intergranulares na matriz quartzosa ou compartilhando limites de grão com biotita. Medem em geral até 0,1 mm, podendo localmente atingir 0,25 mm. Cristais muito finos de zircão e monazita (<0,03 mm) são identificados através de halos pleocróicos em biotita.

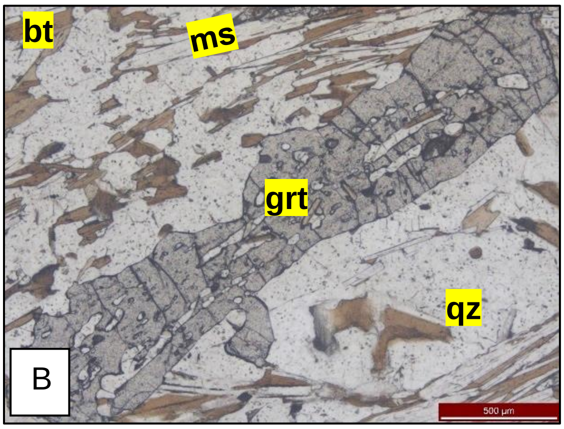
Mineralogia Modal Semiquantitativa

QUARTZO (62%), BIOTITA (21%), MUSCOVITA (12%), PLAGIOCLÁSIO (4,6%), GRANADA (0,4%)

Nome da rocha: **muscovita-biotita-quartzo xisto com plagioclásio e granada**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: URN-005-01	Drillhole ID: URN005	Profundidade: 120,4 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N:	UTM E:

Descrição Microscópica

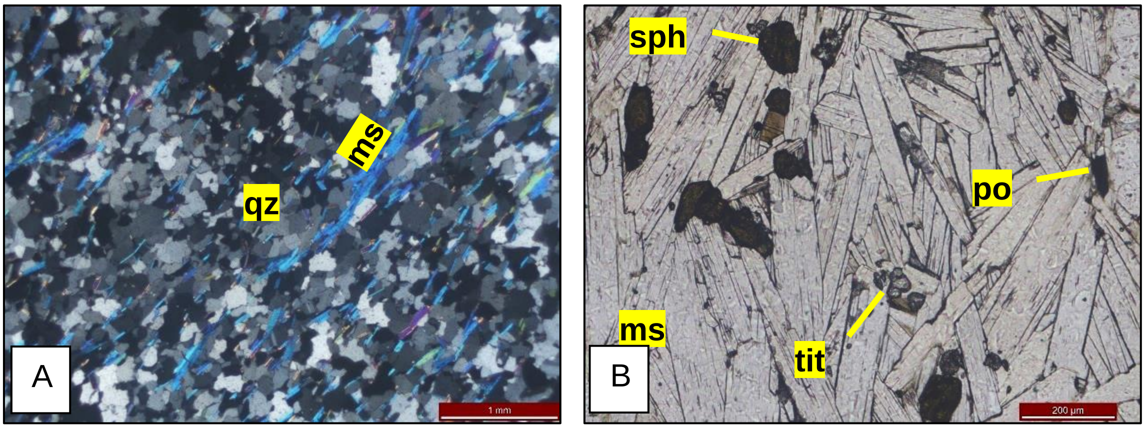
Rocha granolepidoblástica de granulação média, anisotrópica, com matriz quartzosa e foliação dada pelo alinhamento preferencial de cristais lamelares de muscovita e, subordinamente, biotita (A). O quartzo é o mineral mais abundante da rocha, perfazendo a maior parte de sua composição modal. Seus cristais definem uma trama granoblástica com forte tendência à poligonização e, apenas de forma subordinada, reportam-se contatos irregulares (em bainha) característicos de recristalização por migração de limite de grão. Em sua ampla maioria, os cristais estão compreendidos na faixa granulométrica 0,1-0,3 mm e com grande proporção com extinção normal. Bolsões e lentes de quartzo médio a grosso orientados subparalelamente à foliação são frequentes, com cristais medindo até 3 mm. Comparativamente à matriz, extinção ondulante é mais comum nesses cristais mais grossos. Cristais subédricos de plagioclásio, com macla polissintética característica, são documentados ao longo de toda a amostra, em relação de equilíbrio textural com o quartzo. Seu tamanho de grão varia entre 0,1-0,3 mm, com cristais ligeiramente mais grossos nas regiões de quartzo grosso, podendo alcançar até 0,6 mm.

Filossilicatos são disseminados pela rocha, com ampla dominância de muscovita sobre biotita. A muscovita se desenvolve como lamelas muito delgadas de comprimento variando principalmente entre 0,1-0,6 mm, e geralmente sob a forma de cristais individuais ou pequenos agregados planares. Exceção a regra aplica-se à borda de um dos domínios de quartzo mais grosso, o qual é delimitado por agregados de muscovita (± biotita) mais extensos e que contém lamelas mais grossas, podendo ultrapassar 1,0 mm. Estes agregados não estão orientados segundo a foliação principal, mas assumem a disposição do contorno da lente de quartzo-plagioclásio. Todavia, seus prolongamentos estão alinhados àquela foliação. Tal agregado de muscovita representa um dos poucos locais da amostra em que foi identificada a presença de titanita, sob a forma de cristais arredondados <0,05 mm. Em contraste com a muscovita, as lamelas de biotita têm razão de forma menor (isto é, menor razão comprimento/espessura) e seu comprimento é geralmente <0,3 mm. A despeito de seu modo de ocorrência semelhante a da muscovita, identificam-se alguns poucos agregados dessa fase contendo lamelas mais grossas (<0,6 mm), pobremente orientadas e em associação textural com plagioclásio. Estas ocorrem tanto na matriz quanto nos domínios contendo quartzo mais grosso.

Quanto aos opacos, destaca-se a ocorrência de pirrotita e esfalerita. A primeira ocorre como fase acessória por toda a amostra e texturalmente descrita como cristais subequantes a elongados, com certo grau de arredondamento, e ocupando a faixa granulométrica entre 0,1-0,5 mm. Apesar da identificação de cristais isolados em meio a cristais de quartzo, este é um modo de ocorrência bastante subordinado. Via de regra, os cristais e agregados de pirrotita compartilham limites de grão com ambos filossilicatos, com notável concentração, inclusive de cristais mais grossos, no bolsão de quartzo-plagioclásio delimitado por feixes de muscovita. Mais raramente observam-se cristais elongados de pirrotita dispostos ao longo de planos de clivagem de filossilicatos. Quanto à esfalerita, seu modo de ocorrência e distribuição é semelhante ao da pirrotita, distinguindo-se principalmente no que concerne ao tamanho de grão, sendo quase invariavelmente <0,1 mm. Ademais, seus cristais de concentram principalmente no interior dos agregados de muscovita (B). Verifica-se uma aparente contemporaneidade entre essa esfalerita e a titanita. Por último, relata-se a rara ocorrência de calcopirita fina (<0,15 mm) como fase em intercrescimento com pirrotita.

Mineralogia Modal Semiquantitativa
QUARTZO (85%), MUSCOVITA (8%), PLAGIOCLÁSIO (4,5%), BIOTITA (1,5%), PIRROTITA (0,7%), ESFALERITA (0,3%)
Nome da rocha: **biotita-plagioclásio-muscovita quartzito com pirrotita e esfalerita**

Fotomicrografias



Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-028-27	Drillhole ID: A28	Profundidade: 237,9 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96499	UTM E: 402339

Descrição Microscópica

Rocha ígnea fanerítica, isotrópica e de textura pegmatóide inequigranular, constituída por quartzo, albita, k-feldspato, biotita, granada e espodumênio (A).

Os feldspatos são as fases mais abundantes, com leve predomínio do feldspato sódico sobre o potássico (B). A albita sempre exibe geminação polissintética segundo a Lei da Albita e ocasionalmente geminação segundo a Lei de Carlsbad. O tamanho de grão varia de 0,4-1,2 cm para os cristais que constituem o arcabouço da rocha, com cristais menores ocupando interstícios. Contém frequentemente inclusões de quartzo, em geral <0,2 mm e cristais anédricos e vênulas descontínuas de carbonato secundário, bem como palhetas de sericita. Raros cristais euédricos de zircão (<0,1 mm) se encontram inclusos na albita. O feldspato potássico, do mesmo modo, contém inclusões diminutas de quartzo e fases acessórias muito finas de difícil distinção, com detecção adicional de sericita e carbonato secundário muito finos pintalgando os cristais hospedeiros. Via de regra este feldspato não mostra geminação. Lamelas de exsolução (pertita) são de fácil identificação, porém pouco expressivas em termos de volume. Sua granulação é semelhante àquela da albita, com destaque para um cristal de 1,4 cm. Quanto ao hábito, ambos os feldspatos são relativamente equidimensionais e subédricos.

O quartzo exibe distribuição granulométrica bimodal. Cristais finos a médios (<0,1-0,3 mm) com extinção ondulante ocupam espaços intersticiais entre os cristais grossos de feldspato, em equilíbrio com cristais mais finos de feldspato e biotita também intersticiais, segundo um arranjo textural *interlocking*. Em adição, bolsões de quartzo grosso (<2,0 mm) são mapeados entre cristais de feldspato, estando suas margens povoadas por cristais mais finos (<0,2 mm), formando assim uma interface de separação com os feldspatos. Esses cristais grossos de quartzo exibem contatos suturados e extinção ondulante. Cristais prismáticos euédricos a subédricos de apatita (<0,2 mm) ocorrem inclusos em feldspatos grossos ou em relação intergranular com quartzo fino intersticial aos cristais de feldspato grosso.

A biotita é a principal fase ferro-magnesiana, sendo descrita como lamelas de granulação fina a grossa (<0,1-10mm). As frações mais finas ocupam os interstícios entre os cristais grossos de feldspato, junto com quartzo e feldspato finos. Cristais euédricos a subédricos de granada, de granulação média a grossa (0,1-1,5 mm) ocorrem em íntima associação espacial com a biotita. Seus extremos mais grossos são muito fraturados e fragmentados, enquanto os cristais mais finos são frequentemente euédricos e intactos.

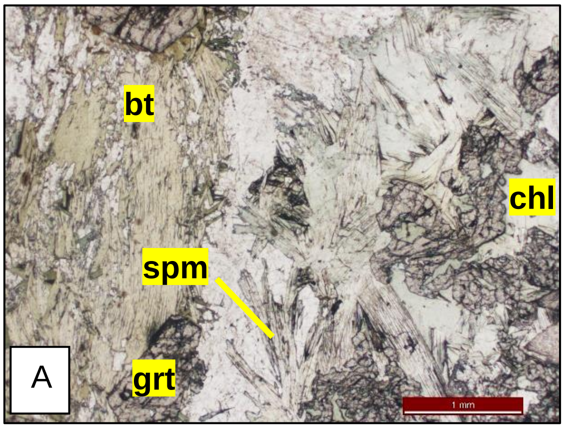
Localmente, verifica-se a ocorrência de um anfibólio prismático longo a acicular, subédrico, incolor, e de tamanho de grão variando de 0,2-1,3 mm, com cristais distribuídos segundo um padrão textural decussado (radial). Suas propriedades de hábito, cor e birrefringência, aliados ao seu contexto paragenético, indicam se tratar de espodumênio. Nota-se uma íntima associação espacial desta fase com granada e um filossilicato verde de granulação média (0,2-0,8 mm) e birrefringência baixa (cores de primeira ordem), provavelmente clorita resultado de alteração deutérica da biotita.

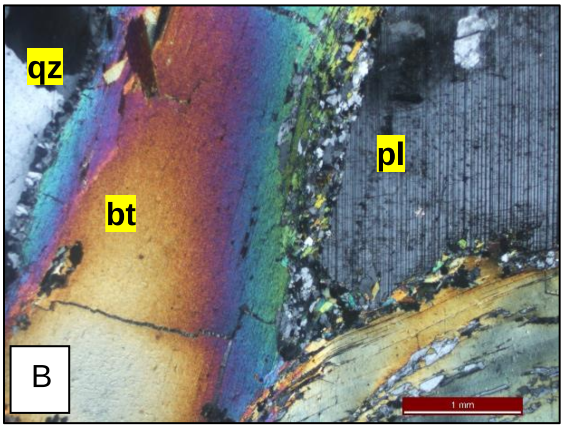
Mineralogia Modal Semiquantitativa

ALBITA (40%), QUARTZO (20%), K-FELDSPATO (18%), BIOTITA (14%), GRANADA (4%), ESPODUMÊNIO (2%), CLORITA (2%)

Nome da rocha: **biotita-álcali-feldspato granito pegmatítico com granada e espodumênio**

Fotomicrografias





Ficha de Descrição Petrográfica

South American Exploration Initiative – Projeto de Mestrado PPGEOL-IGC-UFMG

Geologia e Alteração Hidrotermal do Depósito Aurífero Tucano, NE do Cráton Amazônico

Código da amostra: TUC-DD-029-01	Drillhole ID: A29	Profundidade: 40,0 m
Coordenadas SIRGAS 2000 UTM 22N	UTM N: 96522	UTM E: 402310

Descrição Microscópica

Rocha ígnea fanerítica, de granulação fina a média, inequigranular, isotrópica e de arranjo textural sub-ofítico (A). Seus constituintes minerais principais são plagioclásio e augita. O primeiro é descrito sob a forma de ripas euédricas a subédricas, exibindo macla polissintética típica e mais raramente zoneamento concêntrico (B), com tamanho de grão compreendido principalmente entre 0,4-2,0 mm ao longo de seu eixo maior. Seu ângulo de extinção indica se tratar de andesina. Frequentemente, os cristais maiores exibem sericitização incipiente. A augita, por sua vez, é desenvolvida como cristais prismáticos curtos (sub-equantes) subédricos com tamanho de grão entre 0,1-0,5 mm, cuja moda se posiciona em torno de 0,2 mm. Localmente observa-se a degradação de alguns cristais produzindo material microcristalino amarronzado, que ocorre ainda como fase intersticial. Em outros casos, nota-se substituição (pseudomorfismo) por material verde de granulação muito fina aparentemente constituído por clorita principalmente. Minerais opacos são representados dominantemente por magnetita e subordinadamente ilmenita. Variam desde finos (<0,1 mm) a médios (0,5 mm) e se distribuem de forma disseminada com hábitos de caráter desde sub-equante (granular) até prismáticos e aciculares.

Mineralogia Modal Semiquantitativa

PLAGIOCLÁSIO (54.5%), AUGITA (45%), MAGNETITA (1.9%), CLORITA (1%), SERICITA (0.5%), ILMENITA (0.1%)

Nome da rocha: **microgabro**

Fotomicrografias