



UNIVERSIDADE DE BRASÍLIA - UNB  
INSTITUTO DE GEOCIÊNCIAS - IG

***GEOQUÍMICA E QUÍMICA MINERAL DE CARBONATITOS E ISÓTOPOS  
ESTÁVEIS EM CARBONATITOS DA PROVÍNCIA ÍGNEA DO ALTO  
PARANAÍBA***

Tese de Doutorado  
Nº 127

**CAROLINE SIQUEIRA GOMIDE**

**Orientador:** JOSÉ AFFONSO BROD  
**Co-Orientadora:** LUCIETH CRUZ VIEIRA

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2015

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PARANAÍBA***

Tese de doutorado apresentada ao Programa de Pós Graduação em Geoquímica do Instituto de Geociências, Universidade de Brasília, como requisito básico para obtenção de título de doutora em Geologia.

Orientador: José Affonso Brod

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Não há saber mais ou menos: há saberes diferentes.  
Paulo Freire

Quem não se movimenta, não sente as correntes que o prendem.  
Rosa Luxemburgo

## RESUMO

A Província Ígnea do Alto Paranaíba (APIP), resultado de intenso magmatismo alcalino que gerou corpos intrusivos e extrusivos de afinidade kamafugítica, é uma das maiores províncias ultramáficas-ultrapotássicas mundiais. Os complexos carbonatíticos presentes na APIP são intrusões multifásicas formadas por rochas das séries bebedourítica, carbonatítica e foscorítica.

Esta tese aborda a composição isotópica de carbonatos e sulfetos presentes em carbonatitos da província e inclui, além das análises isotópicas, a obtenção de novos dados petrográficos, imagens de microscopia eletrônica, análises de química mineral e geoquímica de rocha total. No trabalho investiga-se a relação entre a geoquímica de rocha total e composição de isótopos estáveis de carbonatitos pertencentes aos complexos Tapira, Araxá, Salitre, Serra Negra, Catalão I e Catalão II da APIP e, para efeito de comparação, do Complexo Jacupiranga (afiliação sódica), na província Grossa Ponta. Os dados de litogeoquímica aliados a critérios mineralógicos permitiram classificar os carbonatitos em cinco grupos (C1 a C5) e definir um índice de evolução ( $BaO/(BaO+SrO)$ ) para rochas carbonatíticas.

Os carbonatitos evoluem de calciocarbonatitos enriquecidos em apatita para magnesiocarbonatitos enriquecidos em Ba, Sr e REE. Esta evolução é marcada principalmente pelo fracionamento de apatita, flogopita, dolomita, calcita e enriquecimento em monazita, norsethita, e estroncianita. Os dados de isótopos estáveis registram uma ampla variação nos complexos da APIP, em comparação com Jacupiranga, tendo em vista que as intrusões da APIP se estabeleceram em níveis mais rasos, permitindo a atuação de uma diversidade muito maior de processos petrogenéticos, incluindo cristalização fracionada, imiscibilidade de líquidos, desgaseificação e interação com sistemas hidrotermais e carbohidrotermais.

Uma diversidade de carbonatos foi encontrada na província incluindo, além de calcita e dolomita (os dois carbonatos mais comuns), estroncianita, olekminskita, burbankita, ancylita, norsethita, baritocalcita, basnaesita, parisita e benstonita. Calciocarbonatitos e magnesiocarbonatitos pouco evoluídos são tipicamente compostos de calcita e dolomita de alta temperatura, com exsoluções de burbankita, olekminskita e ancylita, e com microinclusões de nyerereita e gregoryita/zemkorita tipos de carbonato descritos pela primeira vez na Província. Carbonatitos intermediários apresentam estroncianita, norsethita e baritocalcita como fases *liquidus*, além de calcita e dolomita. Carbonatitos tardios podem apresentar, além desses, carbonatos de terras raras (ancylita, bastnaesita e parisita). Estudos texturais, mineralógicos e de composição ajudaram a entender processos como evolução magmática por cristalização fracionada, desgaseificação e processos fluidos tardios.

## ABSTRACT

The Alto Parnaíba Igneous Province (APIP) results from an intense alkaline magmatism that generated intrusive and extrusive bodies of kamafugitic affinity, and it is one of the largest ultramafic-ultrapotassic provinces in the world. Carbonatite complexes present in the APIP are multiphase intrusions formed by rocks derived from the bebedourite, carbonatite and foscrite series.

This thesis discusses the APIP carbonatites on the basis of the stable isotope composition of their carbonates and sulphides, petrographic data, high-resolution electron images, mineral chemistry and whole rock geochemistry. The relationship between whole rock geochemistry and stable isotope composition of carbonatites belonging to the Tapira, Araxá, Salitre, Serra Negra, Catalão I and Catalão II complexes of APIP is investigated, and compared with the Jacupiranga Complex, an example of sodic complex from the Ponta Grossa Province. The geochemical and mineralogical criteria were used to divide the carbonatites into five groups (C1 to C5), and to propose a chemical index ( $BaO/(BaO+SrO)$ ) to gauge the evolution of the carbonatite magma.

The APIP carbonatites evolve from apatite-rich calciocarbonatite to magnesiocarbonatite enriched in Ba, Sr and REE, mostly as a result of the fractionation of apatite, phlogopite, dolomite, calcite and enrichment in monazite, norsethite, strontianite. Data from stable isotopes record a wide variety of evolution processes in the APIP magmas, fractional crystallization, such as liquid immiscibility, degassing and interaction with hydrothermal and carbohydrothermal systems, resulting from their emplacement at shallower depths than Jacupiranga.

A variety of carbonates is reported from the APIP carbonatites in addition to the essential calcite and dolomite, including strontianite, olekminskite, burbankite, ancylite, norsethite, barytocalcite, basnaesite, parisite and benstonite. Early-stage calciocarbonatites and magnesiocarbonatites are typically composed of high temperature calcite and dolomite which contain exsolutions of burbankite, olekminskite and ancylite, as well as microinclusions of nyerereite and gregoryite/zemkorite a type of carbonate identified for the first time in the Province. Intermediate carbonatites have strontianite, norsethite and barytocalcite as *liquidus* phases, in addition to calcite and dolomite. In late-stage carbonatites REE carbonates (ancylite, basnaesite and parisite) also crystallize as *liquidus* phases. Textural, mineralogical and compositional evidence helped to understand processes such as magma evolution by fractional crystallization, degassing processes and interaction with late-stage fluids in the studied complexes.



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Lista de abreviaturas e convenções

Amp	Anfibólio		Amphibole
Anc	Ancylita	$(\text{Sr,Ca})_2\text{REE}_2(\text{CO}_3)_4(\text{OH})_2 \cdot 2\text{H}_2\text{O}$	Ancylite
Ap	Apatita		Apatite
APIP	Província Ígnea do Alto Paranaíba		Alto Paranaíba Igneous Province
Bacc	Baritocalcita	$\text{BaCa}(\text{CO}_3)_2$	Barytocalcite
Bast	Bastnaesita	$\text{REE}_2(\text{CO}_3)_2\text{F}_2$	Bastnaesite
Bens	Benstonita	$(\text{Ba,Sr})_6(\text{Ca,Mn})_6\text{Mg}(\text{CO}_3)_{13}$	Benstonite
Bkt	Burbankita	$(\text{Na,Ca})_3(\text{Sr,Ba,Ce})_3(\text{CO}_3)_5$	Burbankite
Br	Barita		Barite
Cal	Calcita	$(\text{Ca}(\text{CO}_3))_2$	Calcite
Cb	Carbonato		Carbonate
Ccp	Calcopirita		Chalcopyrite
Dol	Dolomita	$\text{CaMg}(\text{CO}_3)_2$	Dolomite
EDS	espectrometro de dispersão de energia		Energy dispersive spectrometer
Gre	Gregoryita	$(\text{Na}_2,\text{K}_2,\text{Ca})\text{CO}_3$	Gregoryite
Ilm	Ilmenita		Ilmenite
Mag	Magnetita		Magnetite
MEV	Microscópio eletrônico de varredura		Scanning Electron Microscope
Mnz	Monazita		Monazite
Mrc	Marcassita		Marcasite
Nor	Norsethita	$\text{BaMg}(\text{CO}_3)_2$	Norsethite
Nye	Nyerereita	$\text{Na}_2\text{Ca}(\text{CO}_3)_2$	Nyerereite
Oi	Olivina		Olivine
Olk	Olekminskita	$\text{Sr}(\text{Sr,Ca,Ba})(\text{CO}_3)_2$	Olekminskite
Par	Parisita	$\text{Ca}(\text{Ce,La})_2(\text{CO}_3)_3\text{F}_2$	Parisite
Pcl	Pirocloro		Pyrochlore
Phl	Flogopita		Phlogopite
Pn	Pentlandita		Pentlandite
Po	Pirrotita		Pyrrhotite
Prv	Perovskita		Perovskite
Py	Pirita		Pyrite
SEM	Microscópio eletrônico de varredura		Scanning Electron Microscope
Str	Estroncianita	$\text{SrCO}_3$	Strontianite
Tfp	Tetraferriphlogopita		Tetraferriphlogopite
WDS	espectrometro de dispersão por comprimento de onda		wavelength-dispersive spectrometer
Zem	Zemkorita	$\text{Na}_2\text{Ca}(\text{CO}_3)_2$	Zemkorite



## CAPÍTULO 1

### 1.1 Introdução

A Província Ígnea do Alto Paranaíba (APIP), localizada entre o oeste de Minas Gerais e sul de Goiás, resulta de intenso magmatismo alcalino que gerou corpos intrusivos (diques, condutos, diatremas e complexos carbonatíticos) e extrusivos (lavas e piroclásticas) de afinidade kamafugítica (Almeida & Svisero, 1991; Brod *et al.*, 2000; Brod *et al.*, 2004; Carlson *et al.*, 2007; Carlson *et al.*, 1996; Comin-Chiaramonti *et al.*, 2005; Gibson *et al.*, 1995; Leonardos *et al.*, 1991). É uma das maiores províncias ultramáficas-ultrapotássicas mundiais (Gibson *et al.*, 1995), e uma das poucas associações kamafugíticas-carbonatíticas conhecidas (Brod *et al.*, 2000). Os complexos carbonatíticos da APIP são intrusões multifásicas formadas por rochas das séries bebedourítica, carbonatítica e foscorítica.

Diversos estudos geoquímicos, mineralógicos, de isótopos estáveis (principalmente C, O) e radiogênicos (Sr, Nd, Pb, além dos sistemas Re-Os e Lu-Hf) tem sido realizados na APIP (Barbosa, 2009; Cordeiro *et al.*, 2011; Grasso, 2010; Ribeiro, 2008) e outras províncias alcalinas da borda da Bacia do Paraná (Comin-Chiaramonti *et al.*, 2001, 2005; Ruberti *et al.*, 2008, Santos & Clayton, 1995). Recentemente foram realizados estudos de isótopos de S (Gomide *et al.*, 2013), que permitiram estabelecer importantes parâmetros indicadores de evolução magmática dos complexos da APIP, evidenciando a necessidade de aprofundar os estudos da dinâmica da fugacidade de oxigênio dos magmas que geraram estas rochas.

O presente trabalho aborda a composição isotópica de carbonatos e sulfetos presentes em diversos litotipos dos complexos alcalino-carbonatíticos da província e inclui, além das análises isotópicas, a obtenção de novos dados petrográficos, imagens de microscopia eletrônica, análises de química mineral e geoquímica de rocha total.

Esse trabalho é dividido em seis capítulos. O primeiro aborda a geologia regional, complexos alcalino-carbonatíticos e uma revisão sobre análises

isotópicas de C, O e S, seguido de um capítulo onde são descritos os materiais e métodos utilizados durante o trabalho de doutorado. O capítulo 3 é destinado à discussão de carbonatos, proporção modal, química mineral e texturas presentes nas amostras da presente tese de doutorado. Os capítulos 4 e 5 são apresentados em forma de artigo. O primeiro artigo, intitulado “Stable (C, O, S) isotopes and whole-rock geochemistry of carbonatites from the Alto Paranaíba Igneous Province – SE Brazil” aborda aspectos da composição química de carbonatitos dos complexos alcalinos da APIP, propõe um índice de evolução geoquímica a partir de três elementos consensuais na literatura sobre a evolução de carbonatitos, e compara esta evolução com os resultados de geoquímica isotópica de C, O e S, este artigo foi submetido à Revista Brasileira de Geociências.

O segundo artigo, “Mineralogy, mineral chemistry and *subsolidus* reactions in carbonatites from the Alto Paranaíba Igneous Province, SE Brazil” apresenta e discute os dados de química mineral e difratometria de raio-x de carbonatos representativos dos complexos alcalino-carbonatíticos da Província, submetido à revista Lithos. Por fim, o último capítulo é destinado à discussão e conclusões da tese.

## **1.2 Justificativa**

Carbonatitos são um grupo de rochas raras, com aproximadamente 600 ocorrências mundiais (Woolley & Kjarsgaard, 2008), que tem sido objeto de inúmeros estudos mineralógicos, geoquímicos e petrogenéticos (Martin *et al.*, 2012, Woolley & Kjarsgaard, 2008, Xu *et al.*, 2007; Chakhmouradian, 2006; Melluso *et al.*, 2004; Ray & Schukla, 2004; Samoilov, 1991; Kjarsgaard, 1998) e no Brasil (Cordeiro, 2010; Grasso, 2010, Barbosa, 2009; Ribeiro, 2008; Comin-Chiaramonti & Gomes, 2005; Brod, 1999; Huang *et al.*, 1995; Toyoda *et al.*, 1994). Entretanto, apesar do interesse que despertam, até o momento ainda não foi possível definir um índice para expressar adequadamente a diferenciação do magma carbonatítico. Isto se deve, dentre outros fatores, à complexidade dos processos petrogenéticos envolvidos, que podem incluir combinações recorrentes de cristalização fracionada, imiscibilidade de líquidos e desgaseificação, à

composição altamente variável e não convencional dos líquidos e respectivas assembleias fracionantes e à ocorrência abundante de transformações mineralógicas *subsolidus*. Neste sentido, o presente trabalho contribui com uma caracterização composicional e textural de fases *liquidus* e *subsolidus* em diversos estágios de formação de carbonatitos na província. Os resultados obtidos permitiram aprofundar o conhecimento sobre a gênese e processos de diferenciação de carbonatitos e propor um ordenamento evolutivo para os carbonatitos da APIP, com base em características mineralógicas, geoquímica e texturais.

### **1.3 Objetivos**

O objetivo geral do presente trabalho é caracterizar do ponto de vista mineralógico, químico e de isótopos estáveis de carbono, oxigênio e enxofre, a composição de carbonatos e sulfetos de complexos carbonatíticos da APIP, contribuindo para o entendimento do arcabouço petrológico já parcialmente estabelecido na literatura para esses complexos.

Como objetivos específicos enumeram-se: a) reconhecer indicadores texturais e mineralógicos de processos como cristalização fracionada, imiscibilidade de líquidos, mistura de magmas, desgaseificação, etc. em carbonatitos; b) caracterizar quimicamente os carbonatos das rochas estudadas; c) determinar a composição isotópica de C, O e S, respectivamente em carbonatos e sulfetos; d) caracterizar processos de carbonatitos por meio de sua composição isotópica.

### **1.4 Localização e vias de acesso**

Os complexos Alcalino-Carbonatíticos Catalão (I e II), Serra Negra, Salitre, Araxá e Tapira estão localizados, respectivamente, próximos às cidades de Catalão (Goiás), Patrocínio, Serra de Salitre, Araxá e Tapira (Minas Gerais). O acesso rodoviário pode ser feito saindo de Brasília pela BR-040 até Cristalina, seguindo pela BR-050 até a cidade de Catalão (cerca de 315 km), região onde estão localizados os dois complexos mais ao norte da província. De Catalão segue-se pela BR-050 até Araguari, alternando para a rodovia MG-223 até

Patrocínio (aproximadamente 520 km de Brasília) e Serra do Salitre (575km de Brasília).



Figura 1.01 – Mapa de localização e acesso às áreas de estudo. Dados vetoriais obtidos na base de dados do Instituto Brasileiro de Geografia e Estatística - IBGE (2013).

Seguindo de Serra do Salitre pela BR-146 por aproximadamente 80km está a cidade de Araxá (630 km de Brasília), que abriga o complexo homônimo. A mesma BR-146 liga a cidade de Araxá à cidade de Tapira distante 45 km (675 km de Brasília), onde está localizado o complexo mais meridional da Província.

O único complexo estudado neste trabalho que não pertence à APIP é o Complexo de Jacupiranga (SP), cujo acesso é feito pela BR-116 a partir da cidade

de São Paulo. O Complexo de Jacupiranga foi incluído como referência para comparação com os da APIP, por tratar-se de um complexo intrudido a maior profundidade, cujos carbonatitos estão relativamente mais preservados de fenômenos de interação *subsolidus* com fluidos tardios (e.g. Santos & Clayton, 1995).

### **1.5 Geologia Regional**

A APIP estabeleceu-se durante o Neocretáceo, ao longo de uma estrutura alongada segundo NW-SE, denominada Arco do Alto Paranaíba. Os magmas alcalinos instalaram-se em encaixantes precambrianas das zonas interna e externa da Faixa de Dobramentos Brasília (Fuck *et al.*, 1994), entre o limite sudoeste do Cráton São Francisco e o limite nordeste da Bacia do Paraná. O soerguimento temporal e espacialmente associado ao magmatismo da APIP foi causado pela pluma mantélica de Trindade, consistente com as idades radiométricas mais amplamente aceitas para a Província, entre 80 e 90 Ma (Gibson *et al.*, 1995; Sonoki & Garda, 1988, Toyoda, 1994).

A diversidade litológica da Província pode ser explicada por diversos processos, tais como fusão parcial de fontes mantélicas metassomatizadas, com graus de enriquecimento variável, diferentes profundidades de fusão no manto e de instalação na crosta, e episódios complexamente interligados e recorrentes de cristalização fracionada e imiscibilidade de líquidos (Brod *et al.*, 2012; Palmieri, 2011; Cordeiro *et al.*, 2010; Grasso, 2010, Barbosa, 2009; Brod, 1999).

Gibson *et al.* (1995) interpretam os magmas kamafugíticos como derivados de uma fonte mantélica rica em clinopiroxênio, possivelmente wehrlítica, sugerindo que a transformação de harzburgito ou lherzolito em wehrlito por interação com fusões carbonáticas pode ser um importante processo na região fonte dos kamafugitos. Ainda segundo Gibson *et al.* (1995), os kimberlitos e lamproítos seriam produtos de um magma parental mais pobre em clinopiroxênio, o que indica fontes distintas em um manto heterogêneo. Nesse modelo, os magmas lamproíticos da província teriam sido gerados em um ambiente menos oxidante do que o dos kamafugitos e dos kimberlitos.

Além dos grandes complexos carbonatíticos, a província é composta por pequenas intrusões sub-vulcânicas de kimberlitos, kamafugitos e kimberlitos, e pelos volumosos derrames e piroclásticas kamafugíticos do Grupo Mata da Corda (Figura 1.01) (Araujo *et al.*, 2001; Brod *et al.*, 2000; Carlson *et al.*, 1996; ; Sgarbi & Valenca, 1993; Almeida & Svisero, 1991; Leonardos *et al.*, 1991; Almeida, 1986; Gibson *et al.*, 1995a; Herz, 1977).

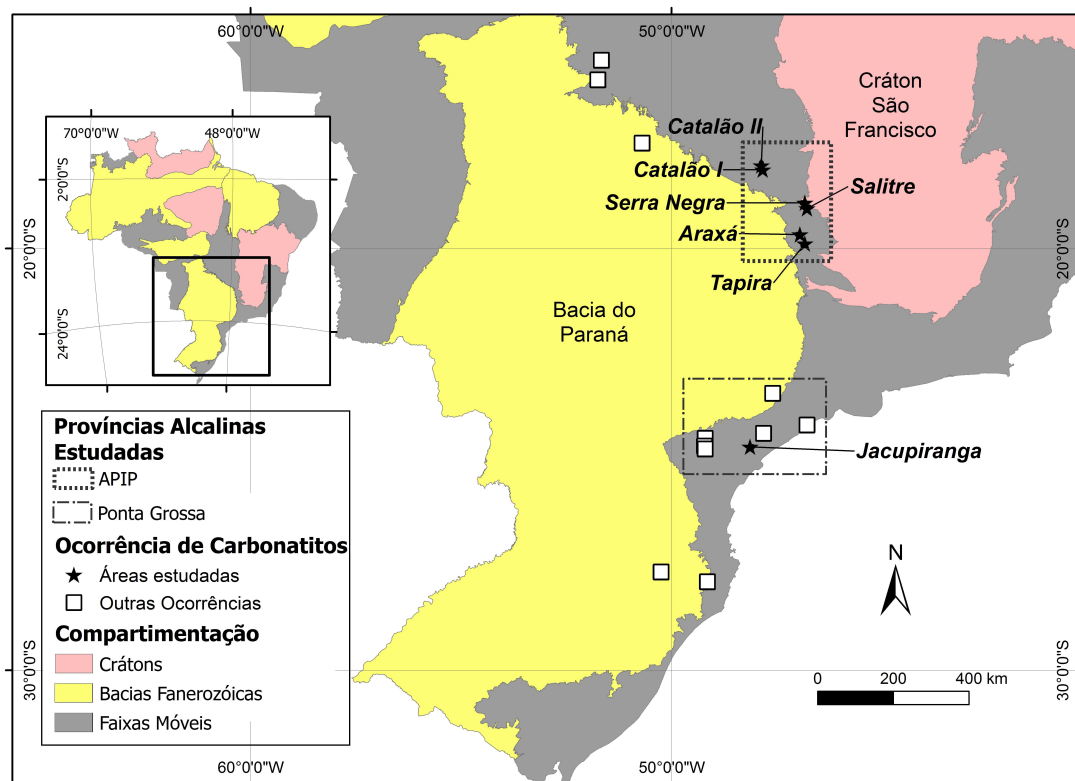


Figura 1.02 – Mapa da área de estudo, modificado a partir de Oliveira *et al.* (2004).

O Grupo Mata da Corda (figura 1.03), está localizado no oeste do estado de Minas Gerais, se sobrepõe à sequência sedimentar da Bacia Sanfranciscana (Grupos Areado e Urucuia) e é caracterizado pela presença de estruturas subvulcânicas (diatremas), derrames e piroclásticas alcalinas e rochas sedimentares epiclásticas (Formações Patos e Capacete, Campos & Dardenne, 1997).

Os complexos carbonatíticos da província são de afinidade ultrapotássica (Brod *et al.*, 2000; Brod, 1999; Gibson *et al.*, 1995; Lloyd & Bailey, 1991), formando uma associação carbonatito-kamafugito. São compostos por rochas de

três séries petrogenéticas distintas (bebedourítica, foscorítica e carbonatítica), relacionadas entre si por processos de cristalização fracionada e/ou imiscibilidade de líquidos (Brod *et al.*, 2004).

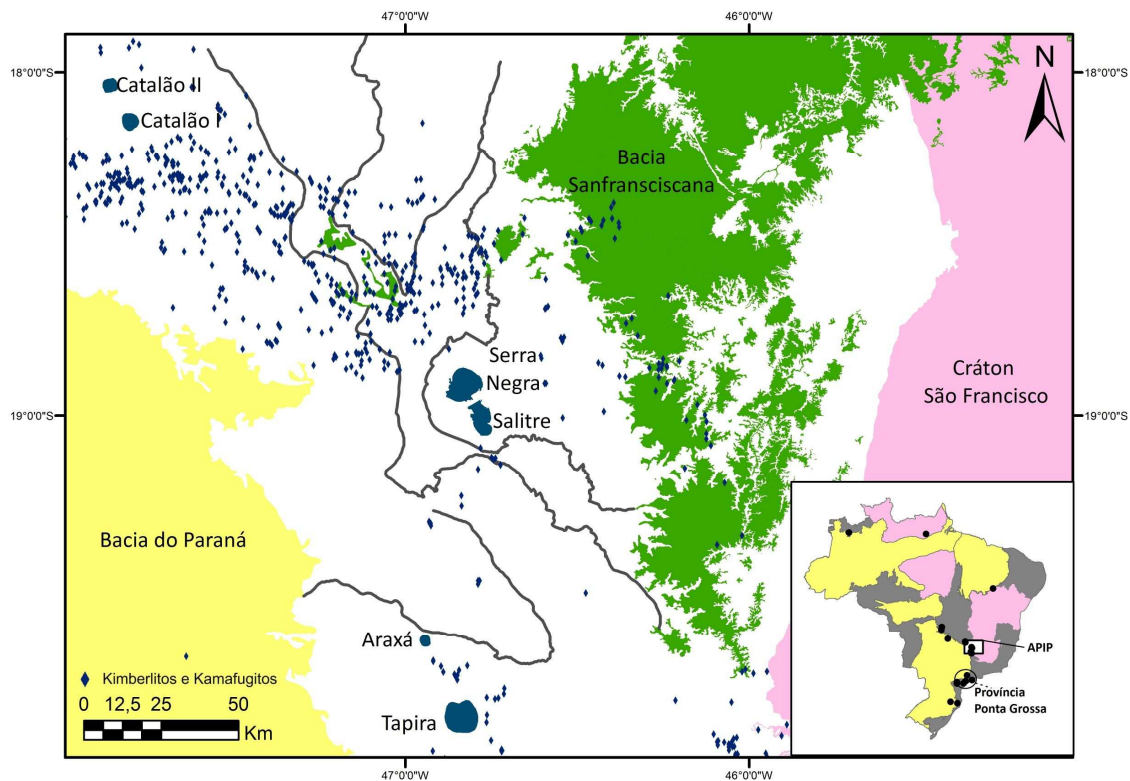


Figura 1.03 – Mapa da Província Ígnea do Alto Paranaíba, modificado a partir de Oliveira *et al.* (2004).

A série bebedourítica (Barbosa *et al.*, 2012) consiste de rochas formadas por cristalização fracionada de um magma silicático ultrapotássico e está bem preservada nos complexos de Tapira e Salitre.

A série foscorítica (Barbosa, 2009; Cordeiro *et al.*, 2010) é composta por rochas derivadas de magmas fosfáticos e está presente em todos os complexos do Alto Paranaíba, mas melhor representada nos de Catalão e Araxá, onde está intimamente ligada a importantes depósitos de fosfato e nióbio.

A série carbonatítica é composta principalmente por calciocarbonatitos, abundantes em Tapira, Salitre e Catalão II, e magnesiocarbonatitos, predominantes em Araxá e Catalão I (Brod, 1999). A intrusão dos magmas carbonatíticos foi muitas vezes acompanhada de desgaseificação, que produziu intensa alteração metassomática nas rochas alcalinas pré-existentes,

especialmente os bebedouritos, transformando-as em flogopititos (Ribeiro *et al.*, 2014; Cordeiro *et al.*, 2011; Brod, 1999).

Catalão I, 20 km a NE da cidade de Catalão, é aproximadamente circular, com 6 km na direção N-S e 5,5 km E-W, encaixado em rochas metassedimentares do Grupo Araxá. Consiste de dunitos, bebedouritos, carbonatitos, foscoritos e nelsonitos, além de flogopititos metassomáticos, e abriga importantes depósitos de P, Nb, terras raras, Ti e vermiculita (Ribeiro *et al.*, 2014, Ribeiro, 2008, Brod *et al.*, 2004; Carvalho & Bressan, 1997).

Catalão II, cerca de 20 km a NNW de Catalão I pela BR-060, intrude rochas do Grupo Araxá, formando um pequeno alto topográfico alongado na direção NE-SW e com margens sinuosas, sugerindo a existência de intrusões múltiplas. Machado Junior (1992) descreve os tipos litológicos como piroxenitos, quartzo sienitos, feldspato alcalino sienitos, calcita carbonatitos, silico-carbonatitos, dolomita carbonatitos e lamprófiros, além de flogopititos metassomáticos. Além destes litotipos, Palmieri *et al.*(2009) e Jácomo *et al.*(2010) reportam a ocorrência de associações de nelsonitos e carbonatitos na porção sul do Complexo.

Serra Negra, a leste da cidade de Patrocínio, é o maior complexo carbonatítico da APIP, com 65 km<sup>2</sup>. Intrude quartzitos do Grupo Canastra, formando uma estrutura dômica muito pronunciada. É composto por calcita carbonatito, dolomita carbonatito, foscorito, bebedourito, dunito e peridotito (Brod *et al.*, 2004; Grasso & Brod, 2009).

Salitre, imediatamente a sul do complexo Serra Negra, forma com este um sistema de intrusões coalescentes (Mariano & Marchetto, 1991), e consiste de três intrusões distintas: i) Salitre I, com 35 km<sup>2</sup>, é composto por bebedourito, tinguaito, traquito, fenito, apatita carbonatito, calcita carbonatito, dolomita carbonatito e foscorito (Barbosa, 2009); ii) Salitre II, com 2,5 km<sup>2</sup>, situado entre Serra Negra e Salitre I, contém principalmente rochas ultramáficas (dunito, perovskitito, bebedourito, localmente cortados por diques e veios carbonatíticos); e iii) Salitre III, que é um pequeno corpo a sul de Salitre I, essencialmente formado por piroxenitos, com foscoritos subordinados.

Araxá (Barreiro) é um complexo relativamente pequeno (15km<sup>2</sup>), circular, localizado cerca de 6 km a sul da cidade de Araxá, composto por carbonatitos, foscoritos, bebedouritos, dunitos, lamprófiros (flogopita-picritos) e um grande



volume de flogopititos derivados do metassomatismo sobre as rochas ultramáficas (Traversa *et al.*, 2001, Issa Filho *et al.*, 1984). A intrusão gerou uma estrutura dômica nos xistos e quartzitos do Grupo Ibiá (Seer, 1999).

Tapira, 30 km a SE da cidade de Araxá, é aproximadamente elíptico, com 35km<sup>2</sup>, composto principalmente por bebedourito e carbonatito, com sienitos subordinados e raros melilitolito e dunito, todos cortados por diques ultramáficos de afinidade kamafugítica (Brod *et al.*, 2000).

O complexo de Jacupiranga, localizado cerca de 10km a oeste da cidade de Jacupiranga e imediatamente a norte da cidade de Cajati, no estado de São Paulo pertence a outra província alcalina (Província Ponta Grossa), tem idade mais antiga (130Ma, Roden *et al.*, 1985), e é caracterizado por afinidade sódica ao invés de potássica. O complexo intruiu o grupo Açungui (Ruberti *et al.*, 2005) e tem um formato oval (aproximadamente 65km<sup>2</sup>) com um pequeno núcleo alongado de carbonatito (Morro da Mina) que intruiu jacupiranguitos. Gaspar & Wyllie (1982; 1983) identificaram cinco intrusões sucessivas de carbonatito que são denominadas de C1 a C5 (da mais antiga a mais recente), onde C1, C3 e C4 são dominados por calcita carbonatito, C2, dominado por calcita carbonatito dolomítico e C5 por ankerita carbonatito (Gaspar & Wyllie, 1983). As rochas silicáticas que compõem o complexo são piroxenitos (jacupiranguitos), peridotitos serpentinizados, ijolitos, nefelina-sienitos, essexitos, monchiquitos e tinguaitos (Gomes *et al.*, 1990).

### **1.6 Isótopos de Carbono, Oxigênio e Enxofre**

Isótopos de Carbono e Oxigênio são utilizados na caracterização de rochas provenientes de diversas fontes, sedimentares, metamórficas e ígneas, com registros de alteração hidrotermal ou não.

No caso das rochas ígneas, por causa de sua alta temperatura de formação pode-se esperar que exibam diferenças relativamente pequenas em composição isotópica (Hoefs, 2010). Segundo Hoefs (2010), a composição de isótopos estáveis será definida pela composição da fonte em que o magma foi gerado, a temperatura de geração e cristalização desse magma, sua história evolutiva e a composição mineralógica da rocha.

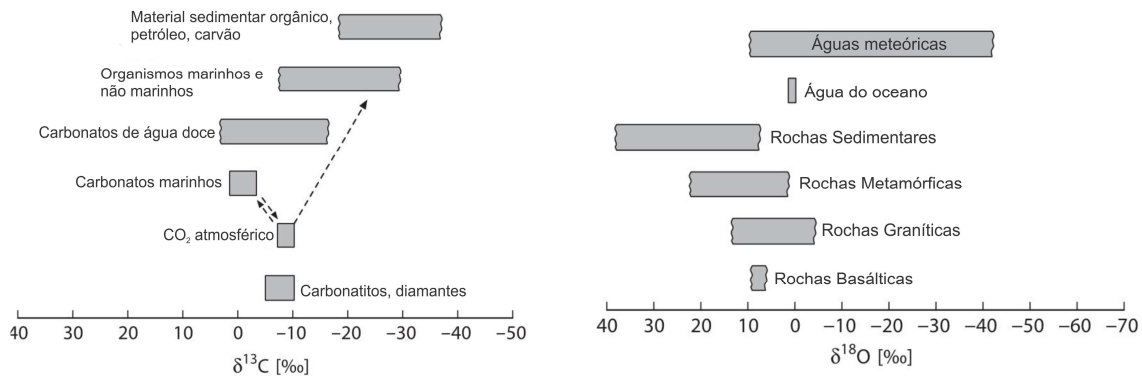


Figura 1.03. Intervalos de variação da composição isotópica de carbono e oxigênio de diferentes reservatórios (Hoefs, 2010).

As principais causas de variação na composição isotópica de carbono e oxigênio incluem diferenças na fonte do magma (Comin-Chiaramonti *et al.*, 2005, Pandit *et al.* 2002, Morikiyo *et al.*, 1990, Taylor *et al.*, 1967), cristalização fracionada (Taylor *et al.*, 1967), diferenças no ambiente de instalação (rochas plutônicas vs. vulcânicas), evolução magmática (Démeny & Harangi, 1996), processos de alteração de baixa temperatura e alteração hidrotermal (Démeny *et al.*, 1998, Santos & Clayton, 1995), desgaseificação de CO<sub>2</sub> em fluidos hidrotermais (Santos & Clayton, 1995, Zheng, 1990), assimilação de rochas crustais (Démeny *et al.*, 1998, Démeny & Harangi, 1996, Santos & Clayton, 1995), rochas de diferentes ambientes tectônicos, interações rocha/água, e desgaseificação de magmas (Mattey, 1991).

Deines (2002) caracterizou isotopicamente os xenólitos do manto, tendo obtido distribuição bimodal de  $\delta^{13}\text{C}$ , com picos proeminentes em -25‰, indicando contaminação das amostras, e em -5‰, que é interpretado como C de alta temperatura.

No caso dos carbonatitos, isótopos de carbono e oxigênio têm sido frequentemente utilizados para caracterizar o fracionamento entre diferentes tipos de carbonatos (Horita, 2014, Hoefs, 2010, Chacko & Deines, 2008, Brod, 1999, Santos & Clayton, 1995), determinar o caráter vulcânico, subvulcânico ou plutônico (Horstmann & Verwoerd, 1997, Santos & Clayton, 1995, Deines & Gold, 1973), comparar complexos carbonatíticos (Nelson *et al.*, 1988), estimar a temperatura de cristalização (Haynes *et al.*, 2003, Censi *et al.*, 1989), detectar

desgaseificação de CO<sub>2</sub> (Horita, 2014, Cordeiro *et al.*, 2011, Brod, 1999, , Reid & Cooper, 1992), alteração hidrotermal ou intempérica (Ripp *et al.*, 2014. Cordeiro *et al.*, 2011, Comin-Chiaramonti *et al.*, 2005, Brod, 1999, Horstmann & Verwoerd, 1997, Schurmann *et al.*, 1997, Morikiyo *et al.*, 1990, Censi *et al.*, 1989), e investigar a evolução de complexos carbonatíticos, caracterizando cada tipo de carbonatito presente no complexo e determinando seu estágio de evolução (Ray *et al.*, 2010, Reid & Cooper, 1992).

Ainda na caracterização de carbonatitos, Deines (1989) defendeu que a variação isotópica de carbono e oxigênio provavelmente estaria relacionada à região da fonte em que o magma foi gerado, porém Santos & Clayton (1995) argumentam que essa hipótese não é plausível, pois implicaria em um fracionamento irreal entre magma e área fonte e não explicaria como a composição isotópica foi preservada durante a ascensão.

Segundo Santos & Clayton (1995), a composição isotópica de carbonatitos não é muito afetada por cristalização fracionada e imiscibilidade de líquidos, porém Ray & Ramesh (2000) argumentam que fracionamento do tipo Rayleigh produz um *trend* bem definido com aumento tanto de  $\delta^{13}\text{C}$  como de  $\delta^{18}\text{O}$ , gerando uma correlação positiva entre esses sistemas. Esse *trend* de fracionamento foi encontrado em diversos trabalhos sobre carbonatitos (Comin-Chiaramonti *et al.*, 2014, Cordeiro *et al.*, 2011, Brod, 1999).

No caso de isótopos de S o fracionamento isotópico pode ser causado por diversos processos e varia de acordo com a temperatura,  $f\text{O}_2$  (Zheng, 1990, Mitchell & Krouse, 1975), balanço de massa, condições de óxido-redução do ambiente (Seal, 2006), diferenciação magmática (Drüppel *et al.*, 2006), desgaseificação de SO<sub>2</sub> e/ou H<sub>2</sub>S (Nikiforov *et al.*, 2006, Zheng, 1990), além de processos sub-atmosféricos e interações com bactérias redutoras (Seal, 2006). Alguns estudos anteriores abordam os controles da variação isotópica de S em função da temperatura, comparando diferentes carbonatitos em um mesmo complexo alcalino, ou distintos complexos entre si, bem como os efeitos da desgaseificação de SO<sub>2</sub> e H<sub>2</sub>S, alterações hidrotermais (Nikiforov *et al.*, 2006) e da fenitização (Drüppel *et al.*, 2006) sobre a composição isotópica original.

Gomide *et al.* (2013) determinaram a composição isotópica de enxofre de sulfetos e sulfatos da APIP e esses dados serão utilizados no presente trabalho

para efeito de comparação com os dados isotópicos de carbono e oxigênio, além da composição química global das amostras analisadas.

Giuliani *et al.* (2014) compilaram dados de isótopos de enxofre disponíveis na literatura, comparados na figura 1.04.

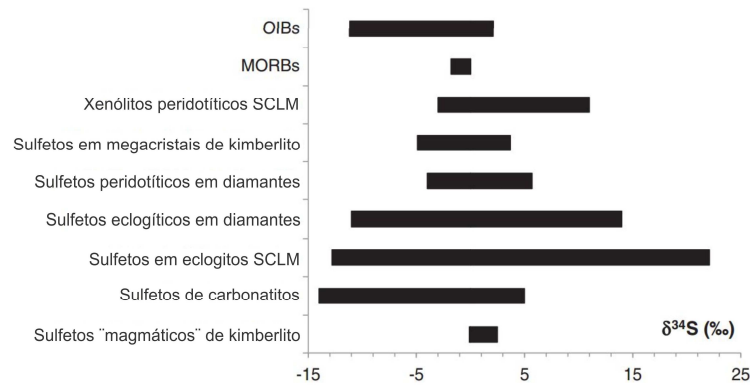


Figura 1.04. Intervalos de variação da composição isotópica de enxofre de diferentes reservatórios (Giuliani *et al.*, 2014 e referências citadas por eles).

Farrel *et al.* (2010) compararam as análises dos três sistemas isotópicos (C, O e S) e definiram campos distintos para diferentes complexos carbonatíticos da Província Superior, no Canadá, argumentando que tais diferenças são relacionadas a heterogeneidade isotópica na área fonte mantélica.

## CAPÍTULO 2

### ***Materiais e Métodos***

As principais ferramentas aplicadas neste trabalho de doutorado incluem petrografia, geoquímica de rocha total, química mineral, imagens eletrônicas e mapeamento composicional em microscópio eletrônico de varredura e em microsonda eletrônica e análise isotópica de carbonatos e sulfetos em rochas da série carbonatítica na APIP.

As amostras foram selecionadas a partir de critérios texturais e mineralógicos definidos em estudos anteriores do Grupo de Pesquisas em Rochas Alcalinas e Mineralizações Associadas (Palmieri, 2011, Cordeiro, 2010, Grasso, 2010, Barbosa, 2009, Ribeiro, 2008, Brod, 1999). Devido ao processo de intemperismo que facilmente atinge os complexos alcalinos, todas as amostras são provenientes de testemunhos de sondagem ou de afloramentos frescos no interior das minas de fosfato, cedidas pelas empresas de mineração Fosfértil (Catalão I, Serra Negra, Salitre), Anglo American (Catalão I e II), e Bunge (Tapira e Araxá).

Foram confeccionadas lâminas delgadas polidas, parte no laboratório de laminação da Universidade de Brasília (UnB) e parte em laboratório comercial externo à universidade. As amostras para as outras técnicas analíticas foram selecionadas a partir da descrição petrográfica dessas lâminas.

As análises de geoquímica de rocha total foram obtidas por ICP-AES (*Inductively Coupled Plasma-Atomic Emission Spectrometry*) para elementos maiores e ICP-MS (*Inductively coupled plasma mass spectrometry*) para elementos traços, no laboratório ACME, Canadá. Os pacotes de análises contratados foram 4A (incluindo análises de C total e S total por 2A Leco) e 4B.

A composição isotópica de carbono e oxigênio foi determinada em separados minerais de carbonatos, em espectrômetro de massa Delta V Plus (Thermo SCIENTIFIC) no laboratório de Geocronologia do Instituto de Geociências da UnB.

A composição química de fases minerais foi determinada por microsonda eletrônica JEOL JXA-8230, em modo WDS, no Laboratório de Microsonda Eletrônica do IG/UnB.

Mapas de composição por EDS e imagens de elétrons retroespalhados e secundários em microscópio eletrônico de varredura (MEV) foram obtidos no Laboratório Multiusuário de Microscopia de Alta Resolução – LabMic/UFG.

Mapas de composição, análises semiquantitativas por EDS e imagens eletrônicas adicionais, obtidos em microscópio eletrônico de varredura por emissão de campo (MEV-FEG), no Laboratório de Microscopia Eletrônica e Análises por Raios X - LAMARX – Universidade Nacional de Córdoba, Argentina, e por microsonda eletrônica no Centro Regional para o Desenvolvimento Tecnológico e Inovação (CRTI/UFG) foram utilizados para auxiliar na interpretação dos dados de química mineral e definição das fases minerais mais finas, principalmente carbonatos.

A composição isotópica de S foi determinada *in situ* por LA-MC-ICP-MS (Laser Ablation-Multi Collector-Inductively Coupled Plasma Mass Spectrometer) em separados minerais de calcopirita, pirita e barita, no Laboratório de Geocronologia do Instituto de Geociências da UnB, durante a Dissertação de Mestrado da Autora (Gomide, 2011).

### **2.1 Análises de Carbono e Oxigênio em carbonatos**

Os carbonatos foram separados manualmente e/ou com o auxílio de uma micro-retífica com broca diamantada, sendo posteriormente moídos em gral de ágata. As análises de Carbono e Oxigênio foram realizadas no Laboratório de Geocronologia do IG/UnB pelo Doutor Luis Henrique Mancini, que forneceu as informações da rotina analítica do laboratório, transcritas abaixo.

#### **Etapas de preparação e extração do gás CO<sub>2</sub> para análise em espectrômetro**

As amostras são pesadas em balança analítica (aproximadamente 300µg) e colocadas em recipientes no GasBench. O GasBench é um dispositivo flexível de fluxo contínuo de preparação de amostras junto com sistema de injeção de gases em ciclo infinito repetitivo, conectado diretamente ao espectrômetro. Com

ele é feita a produção, extração e purificação do gás a ser analisado pelo espectrômetro de massa Delta V Plus (Thermo SCIENTIFIC) de fonte gasosa.

Os recipientes de amostra são dispostos em um bloco térmico à temperatura de 72°C. No braço robótico automático são acopladas três agulhas: a primeira agulha realiza a exaustão e troca do ar atmosférico por Hélio (He); a segunda agulha injeta ácido fosfórico a 100% dando início à seguinte reação:



Após uma hora de reação, a última agulha extrai o gás e o leva a uma coluna de purificação, separando H<sub>2</sub>O ou gases indesejados. Um tubo capilar conduz as amostras ao espectrômetro onde será feita a leitura da composição isotópica.

### **Espectrômetro de massa Delta V Plus (Thermo SCIENTIFIC)**

O espectrômetro de massa de fonte gasosa analisa as moléculas de CO<sub>2</sub> que passam por feixe de elétrons e são ionizadas. Ao passar por uma placa aceleradora as moléculas ionizadas são aceleradas e em seguida são desviadas por um eletro-ímã. A massa da molécula é proporcional ao raio da trajetória do íon. Os íons são separados, em coletores, de acordo com as massas e medidos por pulsos elétricos que são enviados ao computador para a leitura final.

### **Tratamento dos dados**

Os resultados são expressos na notação comum delta per mil (‰), que representa uma comparação com o padrão de referência Pee Dee Belemnite (PDB) para δ<sup>13</sup>C e Standard Mean Ocean Water (SMOW) para δ<sup>18</sup>O que é calculado da seguinte maneira:

$$\delta = \left( \frac{R_{amostra}}{R_{padrão}} \right) \times 10^3$$

Onde R é a razão isotópica (<sup>18</sup>O/<sup>16</sup>O e <sup>13</sup>C/<sup>12</sup>C) medida para a amostra e para o padrão de referência. O erro analítico é estimado em 0,05‰ para δ<sup>13</sup>C e 0,10‰ para δ<sup>18</sup>O.

## 2.2 Análises de Geoquímica de Rocha Total

### Preparo de amostras

Para as análises dos pacotes 4A (análise de elementos maiores por ICP-AES), 4B (análise de elementos traços por ICP-MS), 2A Leco e 1DX do laboratório ACME, as amostras são britadas, moídas, fundidas com metaborato de lítio. O produto da fusão é dissolvido e diluído em ácido nítrico. A perda ao fogo é medida por diferença de percentagem em peso antes e depois de aquecimento a 1000°C.

Os óxidos e elementos determinados em cada pacote, e seus respectivos limites de detecção estão discriminados na tabela 2.01.

Tabela 2.01 – Limites de detecção (L.D.) nos diferentes pacotes analíticos

Óxido/Elemento	Método	Unidade	L. D.	Óxido/Elemento	Método	Unidade	L. D.
SiO <sub>2</sub>	4A	%	0,01	Ba	4B	ppm	1
TiO <sub>2</sub>	4A	%	0,01	Rb	4B	ppm	0,1
Al <sub>2</sub> O <sub>3</sub>	4A	%	0,01	Sr	4B	ppm	0,5
Fe <sub>2</sub> O <sub>3</sub>	4A	%	0,04	Cs	4B	ppm	0,1
MnO	4A	%	0,01	Ga	4B	ppm	0,5
MgO	4A	%	0,01	Ta	4B	ppm	0,1
CaO	4A	%	0,01	Nb	4B	ppm	0,1
Na <sub>2</sub> O	4A	%	0,01	Hf	4B	ppm	0,1
K <sub>2</sub> O	4A	%	0,01	Zr	4B	ppm	0,1
P <sub>2</sub> O <sub>5</sub>	4A	%	0,01	Y	4B	ppm	0,1
LOI	4A	%	-5,1	Th	4B	ppm	0,2
Cr <sub>2</sub> O <sub>3</sub>	4A	%	0,002	U	4B	ppm	0,1
				Ni	4B	ppm	20
				Co	4B	ppm	0,2
TOT/C	2A Leco	%	0,02	Sc	4B	ppm	1
TOT/S	2A Leco	%	0,02	V	4B	ppm	8
				Sn	4B	ppm	1
Ag	1DX	ppm	0,1	W	4B	ppm	0,5
As	1DX	ppm	0,5	Be	4B	ppm	1
Bi	1DX	ppm	0,1	La	4B	ppm	0,1
Cd	1DX	ppm	0,1	Ce	4B	ppm	0,1
Cu	1DX	ppm	0,1	Pr	4B	ppm	0,02
Hg	1DX	ppm	0,01	Nd	4B	ppm	0,3
Mo	1DX	ppm	0,1	Sm	4B	ppm	0,05
				Eu	4B	ppm	0,02



Ni	1DX	ppm	0,1	Gd	4B	ppm	0,05
Pb	1DX	ppm	0,1	Tb	4B	ppm	0,01
Sb	1DX	ppm	0,1	Dy	4B	ppm	0,05
Se	1DX	ppm	0,5	Ho	4B	ppm	0,02
Tl	1DX	ppm	0,1	Er	4B	ppm	0,03
Zn	1DX	ppm	1	Tm	4B	ppm	0,01
				Yb	4B	ppm	0,05
Au	1DX	ppb	0,5	Lu	4B	ppm	0,01

### **2.3 Análises em Microsonda Eletrônica e em Microscópio Eletrônico de Varredura (MEV)**

A Microsonda Eletrônica e o MEV são equipamentos que apresentam estruturas muito parecidas sendo que a Microsonda é otimizada para análise de composição, enquanto que o MEV é otimizado para análise de imagens e análises semi-quantitativas, mas seus princípios de funcionamento são essencialmente os mesmos. Devido a essas similaridades, o funcionamento dos dois equipamentos será descrito em um único tópico. Os parágrafos seguintes são baseados essencialmente nas descrições de Goldstein *et al.* (2003)

#### **Estrutura da Microsonda Eletrônica e do Microscópio Eletrônico de Varredura (MEV)**

São formados por dois componentes principais: o comando de controle e a coluna eletrônica. O comando de controle consiste de um computador e de controladores do tipo *joysticks* responsáveis por controlar todos os elementos da coluna eletrônica. A coluna eletrônica é composta por uma fonte geradora de elétrons, que pode ser um filamento de tungstênio (W) ou um cristal de hexaborato de lantânio (LaB<sub>6</sub>). Estas são fontes termoiônicas, utilizadas em MEV e microsonda convencionais, que geram o feixe eletrônico por meio de uma corrente conduzida pelo filamento ou cristal, que o aquece. Alternativamente, o feixe eletrônico pode ser gerado por emissão de campo (FEG), através de uma diferença de potencial, não envolvendo energia térmica. As análises deste trabalho foram feitas em microsonda com filamento de W, MEV com filamento de W e MEV com fonte geradora de elétrons por emissão de campo.

A fonte geradora emite o feixe de elétrons que passa por dois conjuntos de lentes condensadoras, uma abertura que controla a passagem do feixe, e um conjunto de bobinas magnéticas que controlam a varredura e magnificação da imagem, um conjunto de lentes objetivas, responsáveis pelo foco, e uma abertura final responsável pelo controle do feixe logo antes de incidir na amostra.

Ao incidir, o feixe de elétrons interage com a amostra gerando diversos tipos de resposta que serão identificados em detectores distintos.

O detector de elétrons secundários detecta os elétrons de baixa energia (menor que 50eV), os quais interagem com a superfície da amostra resultando em uma imagem eletrônica com informações da topografia da amostra.

O detector de elétrons retroespalhados é responsável por gerar imagens de contraste por composição. Os elétrons retroespalhados resultam de uma interação mais profunda com a amostra, que depende da voltagem utilizada e do material analisado. Essa interação, que pode chegar a até 5 $\mu$ m, depende do número atômico (Z) do material analisado, o que permite uma individualização de fases em tons de cinza em função do número atômico médio.

A análise química é feita através da medida da energia e distribuição da intensidade de raios-x gerados pela excitação dos elétrons da amostra com a incidência do feixe. Existem dois tipos de detectores para raios-x: EDS (energy dispersive spectrometer) e WDS (wavelength-dispersive spectrometer), ambos podem ser acoplados tanto à microsonda quanto ao MEV, mas a configuração mais utilizada é WDS e EDS na microsonda e EDS no MEV. As microsondas utilizadas neste trabalho possuem cinco espectrômetros de WDS e um de EDS, os dois tipos de MEV utilizados estavam equipados apenas com EDS.

O componente-chave do EDS é um detector semicondutor, que atua como um contador proporcional que, ao detectar os raios-x, os converte em sinal elétrico e gera espectros com picos em energias distintas de acordo com o material presente na amostra. Este sistema é normalmente utilizado, em rotina, para análises qualitativas, e também permite a execução de análises semi-quantitativas rápidas, ou mesmo quantitativas.

No sistema de Dispersão por Comprimento de Onda (WDS), o cristal de difração e o detector do tipo contador proporcional estão contidos em uma mesma circunferência, o princípio de funcionamento do sistema segue a lei de difração de

Bragg:  $n\lambda=2d.\text{sen}\theta$ , onde o cristal de difração se movimenta de acordo com o elemento a ser analisado para permitir a quantificação dos raios-x que chegam no detector obedecendo o ângulo estabelecido. O sistema WDS é mais lento, mas tem resolução em torno de 5eV e consegue diferenciar picos com diferença de energia menor do que 150eV, o que não é possível no sistema EDS.

## **2.4 Análises em Microsonda Eletrônica**

### **Preparo de amostras**

As análises foram realizadas nos laboratórios de microsonda eletrônica da Universidade de Brasília – UnB e do Centro Regional para o desenvolvimento Tecnológico e Inovação (CRTI - UFG). Para essa análise, foram utilizadas lâminas delgadas polidas e metalizadas com carbono. O bom polimento é extremamente importante na análise, para evitar variações dos efeitos de absorção.

### **Procedimentos analíticos**

As amostras foram inicialmente observadas em imagens de elétrons retroespalhados (BSE - back-scattered electrons) e sua composição investigada em modo de dispersão de energia (EDS), com o objetivo de obter uma análise qualitativa. A determinação quantitativa da composição de carbonatos, barita, apatita e sulfetos foi realizada em modo de dispersão por comprimento de onda (WDS).

As análises foram realizadas em um intervalo de tensão de 15kV a 20kV. As correções de absorção e de matriz foram aplicadas pelo algoritmo ZAF (Z - número atômico, A - probabilidade de absorção, F - fluorescência de raios-X secundária).

## **Tratamento dos dados**

Os resultados são expressos em óxidos, que devem ser recalculados para cátions por unidade de fórmula, de acordo com parâmetros específicos para cada mineral. Os carbonatos foram calculados com base em 6, 8, 11, 13 e 15 oxigênios de acordo com o tipo de carbonato, a apatita com base em 25 oxigênios e a barita com base em 4 oxigênios. No caso dos sulfetos o número de cátions por unidade de fórmula foi calculado simplesmente determinando as proporções catiônicas.

### ***2.5 Análises em Microscópio Eletrônico de Varredura (MEV)***

#### **Preparo de amostras**

Algumas análises foram realizadas em lâminas delgadas polidas metalizadas com carbono, muitas vezes na mesma área analisada pela microsonda para definição de distintas fases minerais. Como na microsonda, o bom polimento é extremamente importante na análise, para evitar variações dos efeitos de absorção. Outras análises foram feitas sobre tabletes polidos e metalizados com carbono, no Laboratório Multiusuário de Microscopia de Alta Resolução – LabMic (UFG).

#### **Procedimentos analíticos**

Inicialmente as amostras foram observadas em imagens de elétrons retro-espalhados (BSE) e sua composição investigada em modo de energia dispersiva (EDS) com o objetivo de obter uma análise química qualitativa e identificar as fases presentes. Posteriormente, foram construídos mapas de análise semi-quantitativa de vários pontos em cada área selecionada, sendo possível separar fases de acordo com a composição detectada.

Os mapas foram obtidos em tensão de 15kV e distância de trabalho (WD) de 10mm em todas as análises. As correções de absorção e de matriz foram aplicadas pelo algoritmo ZAF (Z - número atômico, A - probabilidade de absorção, F - fluorescência de raios-X secundária) sobre os resultados semi-quantitativos.

## Tratamento dos dados

Os resultados são expressos em óxidos e os mapas foram tratados no software NSS da thermo finningan gerando a combinação dos elementos mapeados por EDS e criando um mapa de fases facilitando a interpretação da mineralogia presente. Alguns dados foram tratados no software Aztec da Oxford de acordo com o microscópio utilizado.

### 2.6 Análises em Difrátômetro de raios-x

#### Estrutura do Difrátômetro de raio-x

A técnica de difratometria de raios-X consiste em determinar as distâncias interplanares, distâncias mantidas pelos íons ou átomos formadores dos cristais, através do conhecimento do ângulo formado pelo feixe de raios-X gerados pela radiação de  $\text{CuK}\alpha$  incidente e o plano atômico que o difrata e, do comprimento de onda desses raios. O limite de detecção do método, nas condições usuais de trabalho, é de aproximadamente 5%.

Essa determinação se dá pelo fato de que o comprimento de onda dos raios-x é semelhante à distância entre os átomos organizados na estruturas cristalinas que difratam luz, o espalhamento dos raios-x produz um padrão de difração que contém informações da estrutura cristalina do mineral.

O princípio de funcionamento do sistema segue a lei de difração de Bragg:

$$n\lambda = 2d \cdot \sin\theta$$

nos difratômetros  $\lambda$  é fixo ( $\text{CuK}\alpha$ ), conseqüentemente os planos produzem picos de difração em ângulos  $2\theta$  específicos. Cada  $d$  corresponde a uma família específica de planos atômicos  $\{hkl\}$ , tornando possível a interpretação da estrutura cristalina da amostra, facilitando a interpretação mineralógica e/ou a presença de diferentes parâmetros de rede (soluções sólidas, polimorfismo).

A figura 2.01 ilustra esquematicamente o funcionamento de um difratômetro, onde o ângulo de incidência do feixe ( $\omega$ ) é sempre  $\frac{1}{2}$  do ângulo do

detector ( $2\theta$ ). Em alguns equipamentos, a fonte e o detector é que se movimentam para modificar  $2\theta$ , em outros, a modificação do ângulo é feita através da mudança de posição da amostra, o instrumento responsável por essas movimentações é o goniômetro.

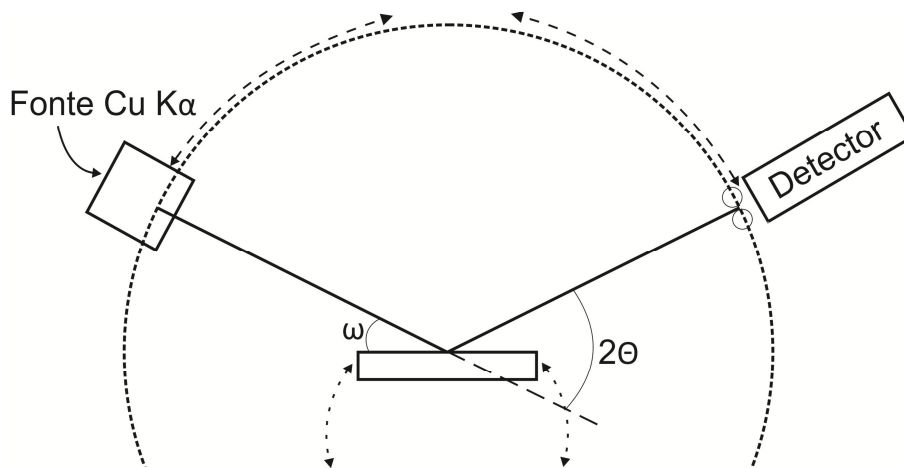


Figura 2.01 - Desenho esquemático básico de um difratômetro de raio-x.

### Preparo de amostras

As amostras foram submetidas à moagem em gral de ágata e o material foi analisado no Difratômetro de Raios-X pelo Método do Pó Não-Orientado (Análise Integral) utilizando porta amostra de silício (análise realizada no CRTI-UFG) ou em lâmina de vidro (IG/UnB).

### Procedimentos analíticos

As análises realizadas no CRTI utilizaram um difratômetro Bruker D8 Discover, com radiação monocromática de um tubo com anodo de cobre acoplado a um monocromador Johansson para  $K\alpha_1$  operando em 40kV e 40mA. As medidas foram efetuadas na configuração Bragg-Brentano  $\theta$ - $2\theta$ , com detector unidimensional Lynxeye®, no intervalo em  $2\theta$  de  $5^\circ$  a  $80^\circ$ , com passo de  $0,005^\circ$ . A amostra foi mantida em rotação de 15 rpm durante a medida para minimizar efeitos de orientação preferencial.

As amostras analisadas no laboratório de difratometria de raio-x da UnB foram realizadas no equipamento de marca RIGAKU modelo ULTIMA IV com detector de alta sensibilidade (DETEX), operando com tubo de cobre e filtro de níquel, sob voltagem de 35kV e corrente de 15mA, velocidade da varredura de 2°/minuto, passo de 0,05°, no intervalo em  $2\theta$  de 3° a 80° e configuração das fendas de Soller (S): 2/3 deg, divergente (fd): 10mm e receptora (fr): 0,3mm.

### **Tratamento dos dados**

A identificação dos minerais foi feita utilizando-se o software JADE 9.0, base WINDOWS, com banco de dados PC-PDF (Powder Diffraction File – PDF para PC) de 2014, produzido pelo *International Center for Diffraction Data* – ICDD. Outros difratogramas foram interpretados em software Diffrac.EVA versão 2.1 comparando parâmetros de rede presentes no banco de dados.

## CAPÍTULO 3

### **Carbonatos**

Carbonatitos são rochas intrusivas ou extrusivas que contêm mais de 50% de carbonatos em volume, e são classificados em calciocarbonatitos quando o carbonato dominante é calcita, magnesiocarbonatitos quando dolomita domina na composição da rocha, ferrocarbonatito quando o carbonato dominante é rico em ferro e natrocarbonatito quando são essencialmente compostos por carbonatos de sódio, potássio e cálcio (Le Maitre, 2002).

Carbonatos são caracterizados pela presença do complexo aniônico  $\text{CO}_3^{2-}$  e podem ser classificados em quatro grupos estruturais diferentes: três anidros (grupos da calcita, da dolomita e da aragonita) e um grupo de carbonatos hidratados, chamados de grupo de carbonatos monoclinicos com hidroxila (Klein, 2002). Existem aproximadamente 60 minerais do grupo dos carbonatos, porém apenas calcita, magnesita, rodocrosita, siderita, dolomita, aragonita, estroncianita e witherita são mais frequentes nas rochas (Deer *et al.*, 2000) e, conseqüentemente, mais estudados.

A estrutura da calcita é romboédrica e o Ca se organiza em coordenação 6 em relação ao oxigênio; a aragonita tem estrutura ortorrômbica com número de coordenação 9, assim, os carbonatos de cátions grandes como o Ba, Sr e Pb ocorrem preferencialmente nessa estrutura. O Ca também ocorre na estrutura do tipo aragonita, pois é relativamente grande para a coordenação da calcita, mas em pressão e temperatura ambiente, esta última é a estrutura estável do carbonato de cálcio. O terceiro grupo de carbonatos anidros é o grupo da dolomita que inclui a dolomita ( $\text{CaMg}(\text{CO}_3)_2$ ) e ankerita ( $\text{CaFe}(\text{CO}_3)_2$ ) com estrutura similar à da calcita, mas com Ca e Mg em alternância (Klein, 2002, Deer *et al.*, 2000, Chang *et al.*, 1998).

Em carbonatitos, os carbonatos de Ca ou Ca e Mg, mais comuns, são caracterizados pela forte presença de elementos traço, como Sr e Ba, em sua composição (Brod, 1999, Barker, 1993, Carlson, 1980), substituições que são facilitadas pela alta temperatura de cristalização. Durante o resfriamento, os carbonatos de carbonatitos desenvolvem uma variedade de feições *subsolidus* resultantes da exsolução dessas impurezas (Barker, 1993).



### **3.1 Química Mineral**

Os estudos de química mineral de carbonatos são caracterizados por diversas dificuldades analíticas, como a volatilização preferencial de elementos durante a análise por microsonda eletrônica ou microscópio eletrônico de varredura, como, por exemplo, o caso do sódio em carbonatos como burbankita, gregoryita e zemkorita.

A caracterização química de carbonatos, especialmente os de carbonatitos, teve seu maior impulso principalmente entre os anos 1960 e 1970 quando surgiram os primeiros trabalhos experimentais e de caracterização desses minerais (Carlson, 1980, Chang & Brice, 1972, Atwood & Fry, 1967, Quon & Heinrich, 1966, Mrose *et al.*, 1961). Após esse período, os carbonatos voltaram a fazer parte da temática das pesquisas a partir de 1990, com foco na caracterização de elementos traço e terras raras em carbonatos e em estudos experimentais (Ionov & Harmer, 2002, Zaitsev *et al.*, 2002, Ni *et al.*, 2000, Buhn *et al.*, 1999, Dawson *et al.*, 1996, Kiseleva *et al.*, 1994, Wall *et al.*, 1993).

Em seguida, surgem os trabalhos de caracterização de carbonatos do vulcão carbonatítico de Oldoinyo Lengai (Mitchell *et al.*, 2012, Zaitsev, 2010, Zaitsev *et al.*, 2008, 2009) e fluorcarbonatos hidrotermais associados à carbonatitos (Ruberti *et al.*, 2008, Andrade *et al.*, 1999). Em todos esses artigos, a composição química dos carbonatos foi determinada por microsonda eletrônica ou microscópio eletrônico de varredura (EDS).

### **3.2 Proporção Modal**

A definição de porcentagem modal de diferentes carbonatos, não é uma tarefa simples. Apesar de existirem diferenças ópticas, como o aumento da birrefringência em carbonatos formados por elementos mais pesados, as características físicas e ópticas dos carbonatos são muito próximas, dificultando ou impossibilitando a distinção entre eles ao microscópio petrográfico convencional. É possível utilizar corantes em solução ácida fraca para a distinção de calcita e dolomita, assim a calcita reage com o ácido diluído a frio e a dolomita não, gerando diferença de relevo, essa reação corrói a superfície da calcita e facilita o tingimento da mesma. A alizarina é utilizada para a distinção de calcita e dolomita, enquanto que o ferrocianeto de potássio é usado para distinguir os carbonatos ferrosos dos não ferrosos.

No entanto, estas técnicas apenas distinguem calcita de dolomita e não se aplicam a outros carbonatos. Diferenças nas características texturais, como presença de exsoluções ou diferenças de granulação (fig. 3.01) podem sugerir variações composicionais, mas a determinação precisa do tipo de carbonato geralmente requer a análise ou mapeamento químico por WDS e/ou EDS, associada com difratometria de raios-x. A figura 3.01 ilustra os resultados de microscopia ótica e mapeamento químico em microsonda eletrônica.

No presente trabalho, utilizou-se o mapeamento de WDS e EDS de toda a lâmina delgada para determinar a composição modal de carbonatos. Como este procedimento pode levar até 16h por amostra, ele foi aplicado a amostras representativas dos diferentes tipos de carbonatitos estudados, e os resultados comparados à composição química da rocha. Os parâmetros obtidos foram utilizados para guiar a estimativa da composição modal a partir da composição química atrelada à composição modal descrita em microscópio petrográfico, nas amostras para as quais não foi possível determinar a moda diretamente.

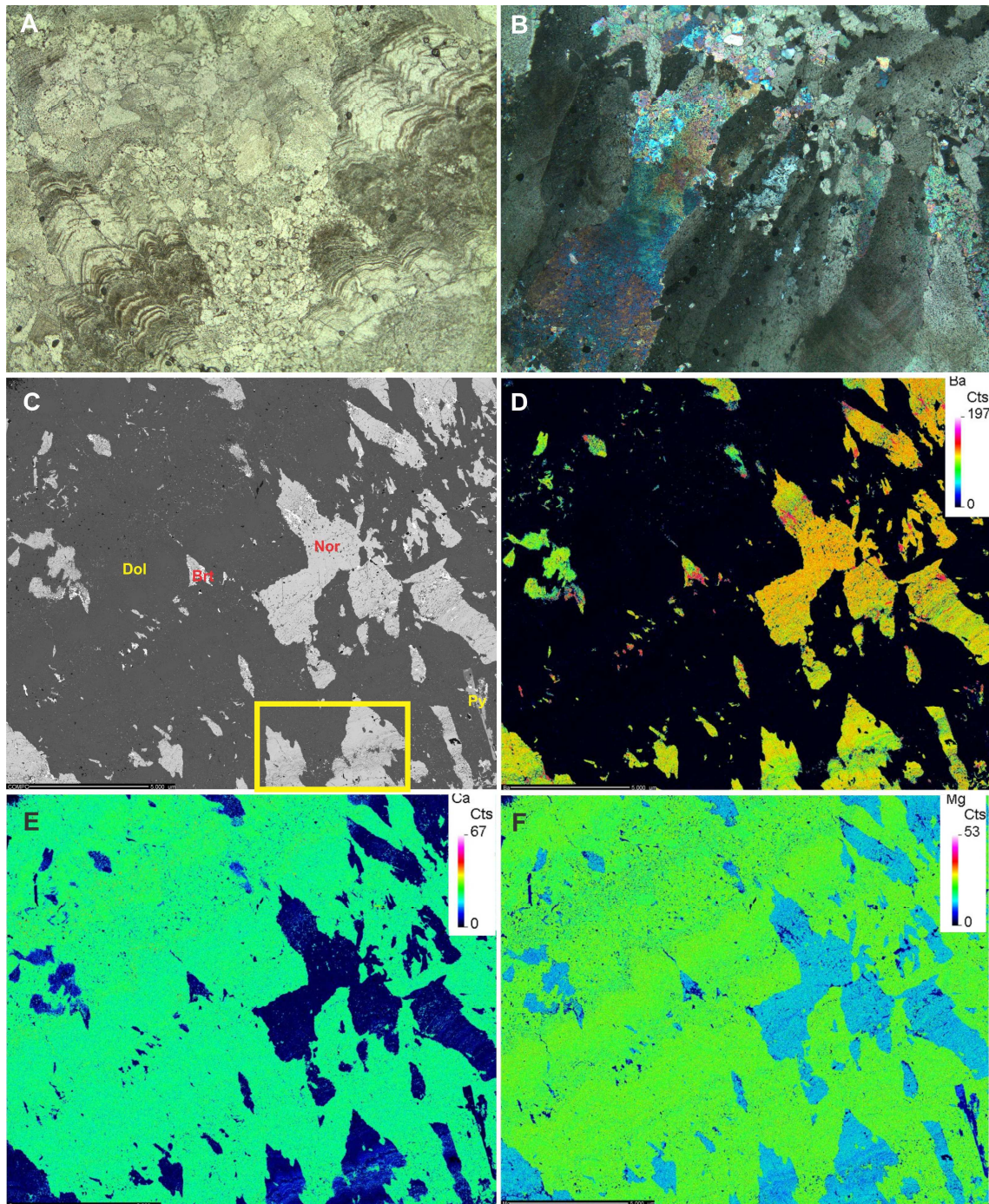


Figura 3.01 –A) Agregado de carbonato marcado por linhas curvas subparalelas na amostra C8-3H. Luz transmitida plano-polarizada. Largura do campo: 5mm. B) Agregado de carbonato de granulação fina a média. Luz transmitida polarização cruzada. Largura do campo: 5mm. C) Composição de imagens de elétrons retroespalhados de toda a lâmina em microsonda eletrônica, retângulo amarelo marca a posição da imagem A. Largura da imagem: 2,5cm. D) Mapa de composição de Ba por WDS em microsonda eletrônica da mesma área da imagem em C. E) Mapa de composição de Ca por EDS em microsonda eletrônica da mesma área da imagem em C. F) Mapa de composição de Mg por EDS em microsonda eletrônica, da mesma área da imagem em C.

### **3.3 Introdução à geoquímica dos carbonatitos estudados**

Com base nos dados já obtidos no presente trabalho e nas interpretações e modelos evolutivos de trabalhos anteriores sobre os complexos da APIP (Barbosa, 2009; Brod, 1999; Cordeiro, 2009; Cordeiro et al., 2010; Cordeiro et al., 2011; Grasso, 2010; Palmieri, 2011; Ribeiro, 2008; Ribeiro et al., 2012) foi possível propor um esquema de classificação dos carbonatitos da província em função de sua composição mineralógica, química, características texturais e estágio evolutivo, apresentada de forma resumida na tabela 3.01. Esta proposta visa integrar os dados deste trabalho em um arcabouço evolutivo do magmatismo carbonatítico de afinidade potássica na província.

Existe um consenso na literatura (e.g. Chakhmouradian *et al.*, 2008; Buhn & Rankin, 1999; Zaitsev *et al.*, 1998, Le Bas, 1979) de que bário e os elementos terras raras tendem a enriquecer-se no magma carbonatítico em direção às fases finais de evolução. Apatita é um mineral mais persistente no intervalo evolutivo dos carbonatitos, e o teor de  $P_2O_5$  pode ser uma variável útil para medir o grau de diferenciação, exceto, talvez, nos estágios finais, onde o fósforo pode estar associado com a cristalização de monazita tardia. A partir desses pressupostos, foi proposto esse critério de evolução (tabela 3.01) e será seguido durante a descrição das rochas.

Tabela 3.01 – Caracterização dos carbonatitos da APIP e do complexo de Jacupiranga de acordo com sua mineralogia, química, texturas e estágio evolutivo.

	Subgrupos	Complexos	Mineralogia	Característica Geoquímica	Obs	Carbonatos	Granulometria
C1	C1a	Jacupiranga	cbt, ap, ol, ± po, ± py, ± mt, ± ilm	Ca-cbt com P2O5 > 9%		Calcita >> dolomita	maior ↓ menor
	C1b	Jacupiranga	cbt, ap, po, ± phl, ± pnt,	Ca-cbt com P2O5 < 9%	Exsol. de dol, str, olk, bkt, anc em calcita	Calcita >> dolomita	
	C1a	Salitre, Tapira	cbt, ap, phl, tfp, po, ±py, ±pcl, ± pv, ±mt, ±ilm, ± cpy, ±ol	Ca-cbt com P2O5 > 3%		Calcita >> dolomita	
	C1b	Catalão II, Salitre, Tapira	cbt, ap, phl, tfp, mt, po, py, ± anf, ±pcl, ± brt, ± cpy, ± ol ± mrc	Ca-cbt com P2O5 < 3%	Exsol. de dol, bkt, nor, anc, olk em calcita	Calcita >> dolomita	
C2		Jacupiranga	cbt, ap, phl, ± py			Dolomita > calcita	
		Catalão I, Serra Negra, Salitre	cbt, phl(?), tfp, mt, py, ± ap, ± brt, ±pcl, ± cpy, ± po, ± ilm, ± ol	Mg-cbt	Exsol. de bkt em dol Py>Cpy>Po	Dolomita > calcita	
C3		Tapira	cbt, tfp, brt, py, ± cpy, ± po, ± ap, ± ol, ± mt, ± ilm	Ca-Cbt	Exsol. de dol, bkt, bacc, anc, olk em cc. Py>Cpy>Po	calcita, baritocalcita, norsethita, estroncianita	
		Araxá					
C4		Araxá, Catalão I, Catalão II, Tapira, Salitre	cbt, cbt coloidal, brt, py, mz, ±phl(?), ±tfp, ±mt, ±pcl, ±ap, ±cpy, ±po,	Ba-mg-cbt com ETR	Exsol de bkt e anc em dol	dolomita, fe-dolomita, estroncianita, ancyllita, parisita, bastnaesita	
		Catalão I, Catalão II, Araxá, Tapira	cbt, brt, tfp, ap, py, ±mt, ±ilm, ±pcl, ±cpy, ±po, ±mz	Ba-Mg-cbt	Exsol. de olk, bens em nor; Exsol. de olk em dol Exsol de bacc em cc	Dolomita e fe-dolomita > calcita; norsethita, burbankita, estroncianita	
C5							

### 3.4 Caracterização textural dos carbonatos estudados

De acordo com a caracterização textural e geoquímica dos carbonatitos da APIP, eles foram divididos em grupos de C1 a C5, do mais primitivo ao mais evoluído (ver capítulo 4). As amostras estudadas apresentam uma grande variedade composicional de carbonatos, que resultam de processos variados, desde cristalização como fase *liquidus* no magma carbonatítico, até produto de transformações *subsolidus*. Abaixo é fornecida a composição ideal dos principais carbonatos identificados.

Ancylita -  $(\text{Sr,Ca})_2\text{REE}_2(\text{CO}_3)_4(\text{OH})_2 \cdot 2\text{H}_2\text{O}$

Baritocalcita -  $\text{BaCa}(\text{CO}_3)_2$

Bastnaesita -  $\text{REE}_2(\text{CO}_3)_2\text{F}_2$

Benstonita -  $(\text{Ba,Sr})_6(\text{Ca,Mn})_6\text{Mg}(\text{CO}_3)_{13}$

Burbankita -  $(\text{Na,Ca})_3(\text{Sr,Ba,Ce})_3(\text{CO}_3)_5$

Calcita –  $(\text{Ca}(\text{CO}_3))_2$

Dolomita –  $\text{CaMg}(\text{CO}_3)_2$

Estroncianita –  $\text{SrCO}_3$

Gregoryita –  $(\text{Na}_2,\text{K}_2,\text{Ca})\text{CO}_3$

Norsethita -  $\text{BaMg}(\text{CO}_3)_2$

Nyerereita –  $\text{Na}_2\text{Ca}(\text{CO}_3)_2$

Olekminskita -  $\text{Sr}(\text{Sr,Ca,Ba})(\text{CO}_3)_2$

Parisita -  $\text{Ca}(\text{Ce,Lu})_2(\text{CO}_3)_3\text{F}_2$

Zemkorita -  $\text{Na}_2\text{Ca}(\text{CO}_3)_2$

O grupo C1 compreende, calcita carbonatitos pouco evoluídos. Os carbonatos nestas rochas são tipicamente calcitas cristalizadas em alta temperatura, com incorporação de elementos em solução sólida, como Ba, Sr, Na e Terras Raras. A exsolução de tais impurezas em baixa temperatura resultou em fases como norsethita, estroncianita, olekminskita, burbankita, ancylita.

Um carbonato alcalino, contendo tanto Na quanto K, possivelmente gregoryita, nyerereita ou zemkorita (figura 3.02c,d) também ocorre como

microinclusões em calcita deste grupo de carbonatitos. Independente de se tratar de material exsolvido ou de uma fase cristalizada diretamente, essas inclusões são importantes, porque indicam que o magma carbonatítico era originalmente rico em álcalis. A presença de álcalis em magmas de calcio- e magnesiocarbonatito é um tema de constante debate na literatura, porque os teores destes elementos são sempre baixos em análises químicas totais destas rochas, (e.g. Woolley & Kempe, 1989), enquanto as únicas lavas carbonatíticas modernas são ricas em álcalis (e.g. Oldoynio Lengai, Tanzania, Bailey, 1993; Dawson, 1989). É possível que calcio- e magnesiocarbonatitos sejam magmas originalmente alcalinos, que perderam Na e K durante eventos de desgaseificação, hipótese que apresenta mais evidências dentre os complexos estudados considerando a alta penetratividade dos processos de fenitização na Província, ou que representem cumulados precoces de calcita e dolomita, com a maior parte do K e Na permanecendo no líquido residual.

Porém, a amostra que contém nyerereita e gregoryita/zemkorita apresenta pirrotita com textura *quench* (figura 3.02a) interpretados por Gomide *et al.* (2013), como resultado de desgaseificação de enxofre a partir de um magma super-resfriado. Como apenas os sulfetos apresentam esta textura é possível que carbonatos alcalinos ainda estivessem estabilizados como fases *liquidus* neste estágio de evolução, produzindo microfenocristais de nyerereita e gregoryita/zemkorita. Alternativamente, é possível que a calcita original tenha incorporado pequenas quantidades de álcalis, posteriormente exsolvidos durante o resfriamento, essa possibilidade é pouco debatida na literatura, porém Pentecost (2005) compilou dados da literatura e descreveu que os álcalis podem substituir o Ca na estrutura da calcita e aragonita em sítios defeituosos representando poucas centenas de ppm na calcita em rochas metamórficas, mas não existem estudos sistemáticos neste sentido, sendo necessário mais estudos nesta área.

Os dados de isótopos estáveis de C, O e S desta amostra são compatíveis com os valores mantélicos ( $\delta^{13}\text{C}=-7,4$ ;  $\delta^{18}\text{O}=7,15$ ;  $\delta^{32}\text{S}=-6,08$ ) e não pertencem a nenhum *trend* de desgaseificação.

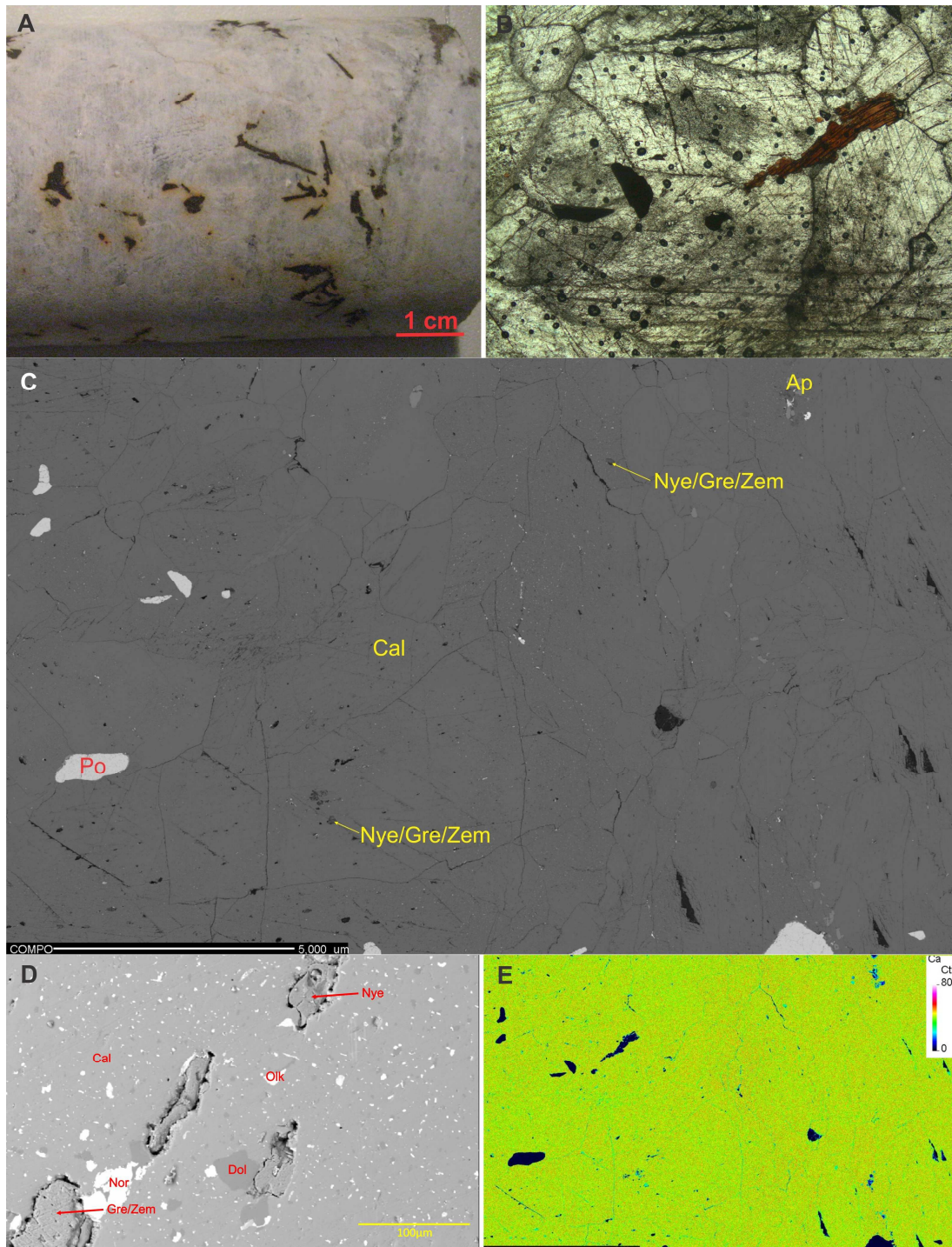


Figura 3.02 – A) Foto macroscópica da amostra SLE360, notar cristais quench de pirrotita. B) Fotomicrografia evidenciando carbonatos sem exsolução (limpo) e com exsolução (aspecto pulverulento), flogopita e pirrotita. Luz transmitida plano-polarizada. Largura do campo: 5mm. C) Composição de imagens de elétrons retroespalhados de toda a lâmina. Largura da imagem: 2,5cm. D) Imagem de elétron retroespalhado, detalhe da imagem C em uma das porções com nyerereite. E) Mapa de composição de Ca por EDS em microsonda eletrônica da mesma composição de imagens em C. Ap=apatita, cal=calcita, dol=dolomita, gre=gregoryita, nye=nyerereite, po=pirrotita, zem=zemkorita.



O grupo C2 é composto por magnesiocarbonatitos pouco evoluídos. Os carbonatos nestas rochas são tipicamente dolomitas cristalizadas em alta temperatura, com incorporação de impurezas que, durante o resfriamento *subsolidus*, resultam em exsoluções (figura 3.03b) de burbankita.

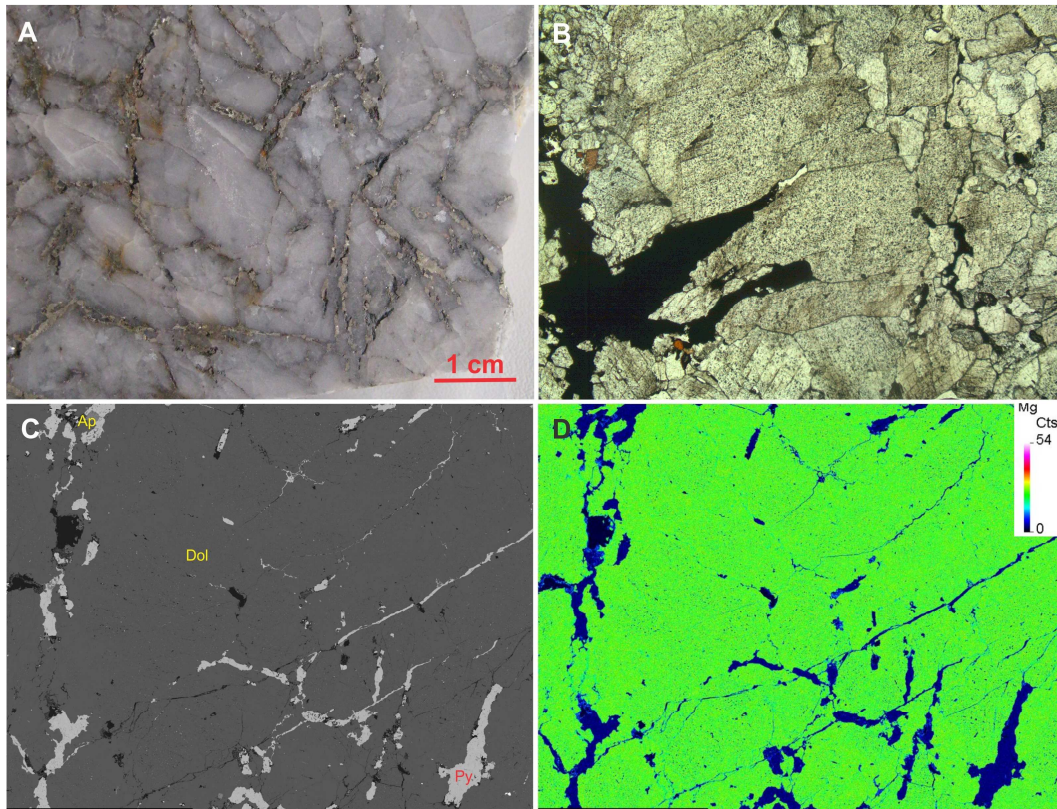


Figura 3.03 – A) Foto macroscópica da amostra CB02 B) Fotomicrografia evidenciando carbonatos com exsoluções (aspecto pulverulento), flogopita e pirita. Luz transmitida plano-polarizada. Largura do campo: 5mm. C) Composição de imagens de elétrons retroespalhados de toda a lâmina. Largura da imagem: 2,5cm. D) Mapa de composição de Mg por EDS em microsonda eletrônica da mesma composição de imagens em C. Ap=apatita, dol=dolomita, py=pirita.

Em C3 é característica a abundância de exsoluções de dolomita, burbankita, baritocalcita, ancylita e olekminkita a partir da calcita hospedeira. Além das exsoluções, em alguns casos (figura 3.04) observam-se bolsões com cristais bem desenvolvidos de estroncianita, baritocalcita e norsethita, sugerindo que estas aparecem pela primeira vez como fases *liquidus* no estágio evolutivo C3.

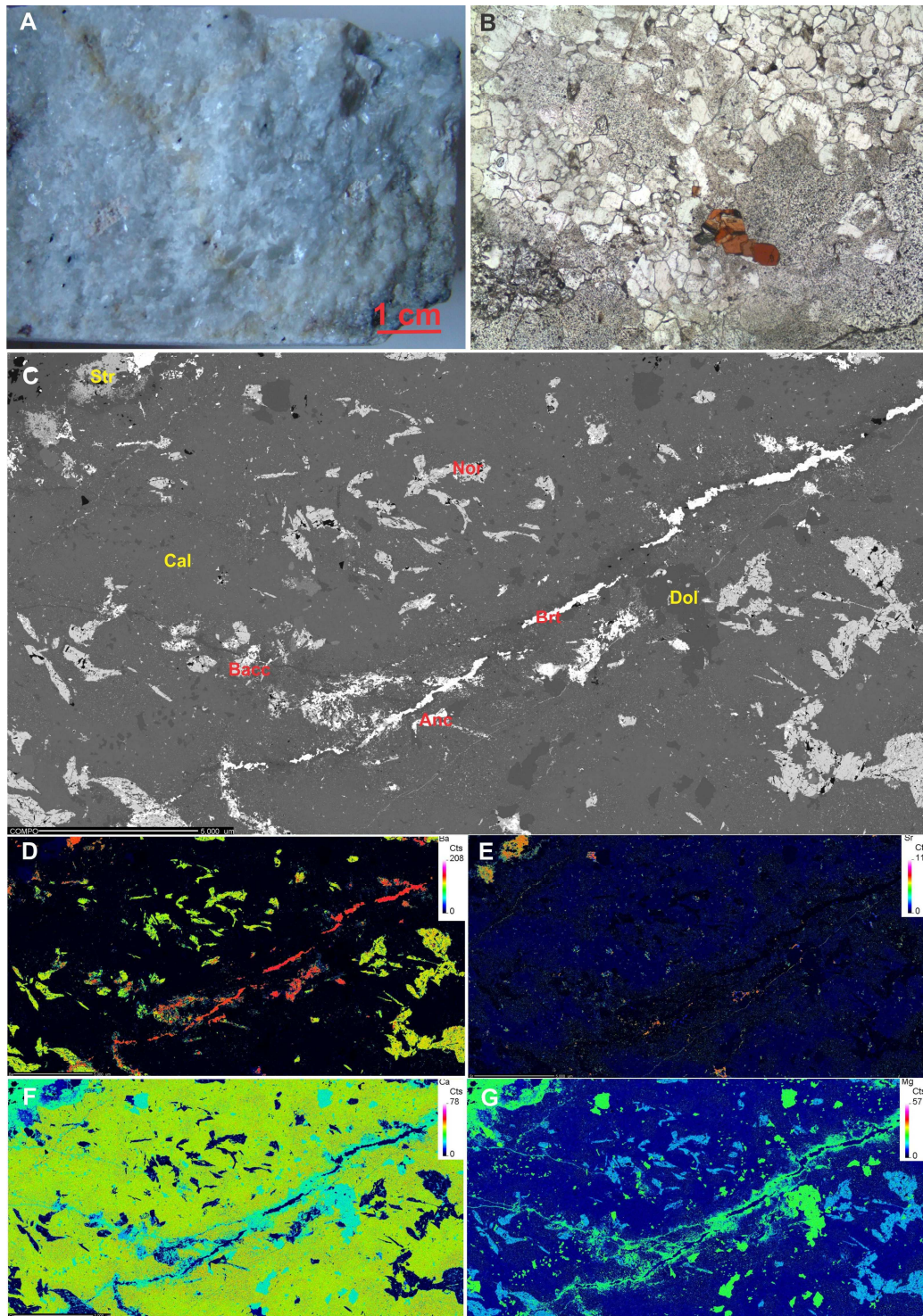


Figura 3.04 – A) Foto macroscópica da amostra AT139 B) Fotomicrografia evidenciando carbonatos com exsoluções (aspecto pulverulento) e sem exsoluções (limpo) e tetraferriphlogopita. Luz transmitida plano-polarizada. Largura do campo: 5mm. C) Composição de imagens de elétrons retroespalhados de toda a lâmina. Largura da imagem: 2,5cm. D) Mapa de composição de Ba por WDS em microsonda eletrônica da mesma composição de imagens em C. E) Mapa de composição de Sr por EDS em microsonda eletrônica da mesma composição de imagens em C. F) Mapa de composição de Ca por EDS em microsonda eletrônica da mesma composição de imagens em C G) Mapa de composição de Mg por EDS em microsonda eletrônica da mesma composição de imagens em C. Anc=ancillita, bacc=baritocalcita, brt=barita, cal=calcita, dol=dolomita, nor=norsethita, str=estroncianita.

Os dolomita carbonatitos do grupo C4 são ricos em Ba mas não contêm quantidades apreciáveis de norsethita. Nestas rochas o principal mineral de bário é a barita. Dolomita apresenta exsoluções de ancylita e burbankita. Aparecem também neste grupo pela primeira vez quantidades apreciáveis de minerais de terras raras cristalizados independentemente (consultar anexos), compreendendo monazita e vários carbonatos (ancylita, parisita e bastnaesita), o aparecimento desses carbonatos em magmas mais evoluídos é consistente com os dados da literatura, que apontam para o enriquecimento em terras raras com a evolução do magma carbonatítico (Chakhmouradian *et al.*, 2008; Buhn & Rankin, 1999; Zaitsev *et al.*, 1998; Le Bas, 1979). É consistente também com dados experimentais de Jones & Wyllie (1983) que confirmam que esses minerais podem se precipitar de magmas a baixas temperaturas. Em um dos experimentos descritos por Jones & Wyllie ocorrem texturas “*quench*” com agregados esferulíticos, alguns contendo cristais dendríticos assim como os encontrados em amostras deste grupo (figura 3.05). Experimentos de Martin *et al.* (2012) registraram texturas semelhantes.

A monazita presente nesse grupo, sistematicamente mostra evidências texturais de substituição de carbonatos, o que pode indicar que carbonatos de terras raras, como bastnaesita e parisita foram precursores da monazita e reafirmando a deposição de carbonatos de terras raras associado à estroncianita com extinção esferulítica como descrito nos carbonatos de Jones & Wyllie (1983).

Barita, dolomita e sulfetos geralmente apresentam relações texturais de equilíbrio, enquanto a monazita de aspecto coloidal e os agregados fibrorradiados de bastnaesita podem ser resultados de alteração dos minerais anteriores por fluidos ricos em terras raras. A estroncianita parece ora estar em equilíbrio com a paragênese primária, ora parece ser um produto tardio, associada a monazita, sugerindo a formação da estroncianita em diferentes estágios de evolução.

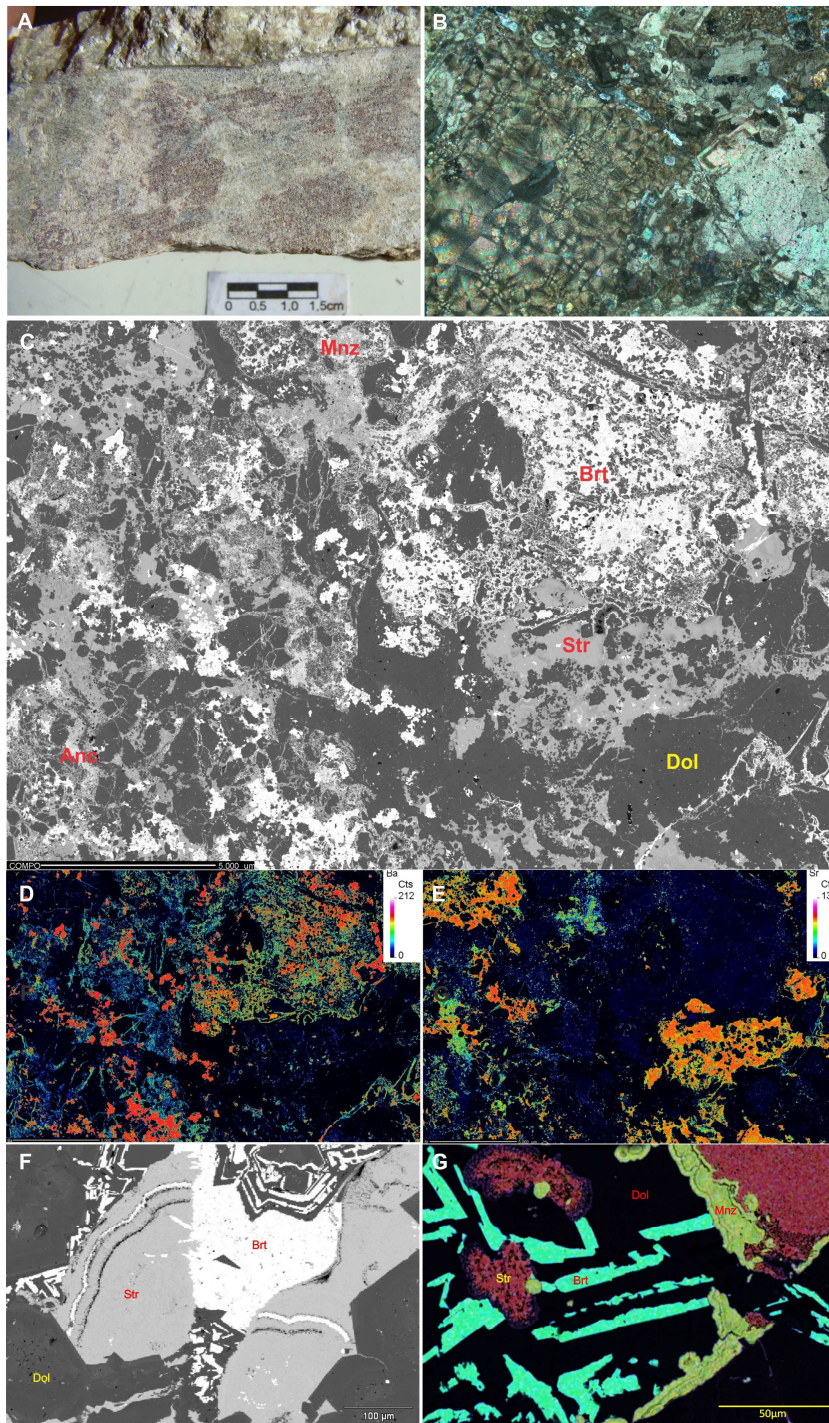


Figura 3.05 – A) Foto macroscópica da amostra C85D B) Fotomicrografia evidenciando carbonatos intercalados com barita e um carbonato com extinção esferulítica. Luz transmitida em polarização cruzada. Largura do campo: 5mm. C) Composição de imagens de elétrons retroespalhados de toda a lâmina. Largura da imagem: 2,5cm. D) Mapa de composição de Ba por WDS em microsonda eletrônica da mesma composição de imagens em C. E) Mapa de composição de Sr por EDS em microsonda eletrônica da mesma composição de imagens em C. F) Imagem de elétrons retroespalhados mostrando dolomita, barita e estroncianita. G) Mapa de composição por EDS em microscópio eletrônico de varredura, notar intercalação de dolomita e barita, e monazita substituindo carbonatos. Anc=ancyllita, brt=barita, dol=dolomita, mnz=monazita, nor=norsethita, str=estroncianita.

Os carbonatitos C5 são dominados por dolomita e Fe-dolomita, com quantidades subordinadas de calcita, norsethita e estroncianita como fases *liquidus* (figuras 3.01 e 3.06). Exsoluções de carbonatos são abundantes e compreendem exsoluções de calcita, dolomita, burbankita, olekminskita e benstonita em norsethita, de olekminskita em dolomita, e de baritocalcita em calcita (ver anexos para maiores detalhes).

A figura 3.01(c e d) mostra uma estrutura de deposição cíclica de norsethita. Na imagem observam-se diversos ciclos com uma textura gradacional onde a norsethita formada em mais alta temperatura, contendo maior quantidade de impurezas, apresenta abundantes exsoluções de calcita, dolomita/Fe-dolomita e burbankita. O tamanho e a quantidade de exsoluções diminui gradativamente em cada ciclo, terminando o ciclo com norsethita de aspecto límpido (livre de exsoluções). Análises químicas por microsonda eletrônica mostram que a norsethita hospedeira das inclusões tem composição mais próxima da ideal do que a norsethita límpida do final de cada ciclo. Estas evidências são consistentes com a interpretação de que a norsethita de alta temperatura, inicialmente mais rica em impurezas como Ca, Na, ETR, Sr, e, possivelmente, com excesso de Mg em relação a Ba, torna-se mais pura por exsolução destes elementos à medida que a rocha resfria. Fenômenos semelhantes foram reportados por Brod (1999) para calcita e dolomita do complexo de Tapira e por Cordeiro *et al.* (2011) para dolomitas do complexo de Catalão I.

A composição isotópica de carbono e oxigênio dos carbonatos nesta amostra ( $\delta^{13}\text{C} = -5,41$  e  $\delta^{18}\text{O} = 10,01$ ) é compatível com carbonatos magmáticos, indicando que o processo de exsolução ocorreu simplesmente por rebaixamento de temperatura, sem envolvimento de alteração hidrotermal.

A figura 3.01c mostra a formação de barita no final de alguns ciclos de cristalização de norsethita. Este efeito está provavelmente relacionado à degaseificação de gases sulfetados (e.g. Gomide *et al.*, 2013), que provoca a oxidação do sistema levando à cristalização de sulfato de bário (barita) em vez de carbonato de bário e magnésio (norsethita). Dados de isótopos estáveis de enxofre (Gomide *et al.*, 2013) são consistentes com esta interpretação.

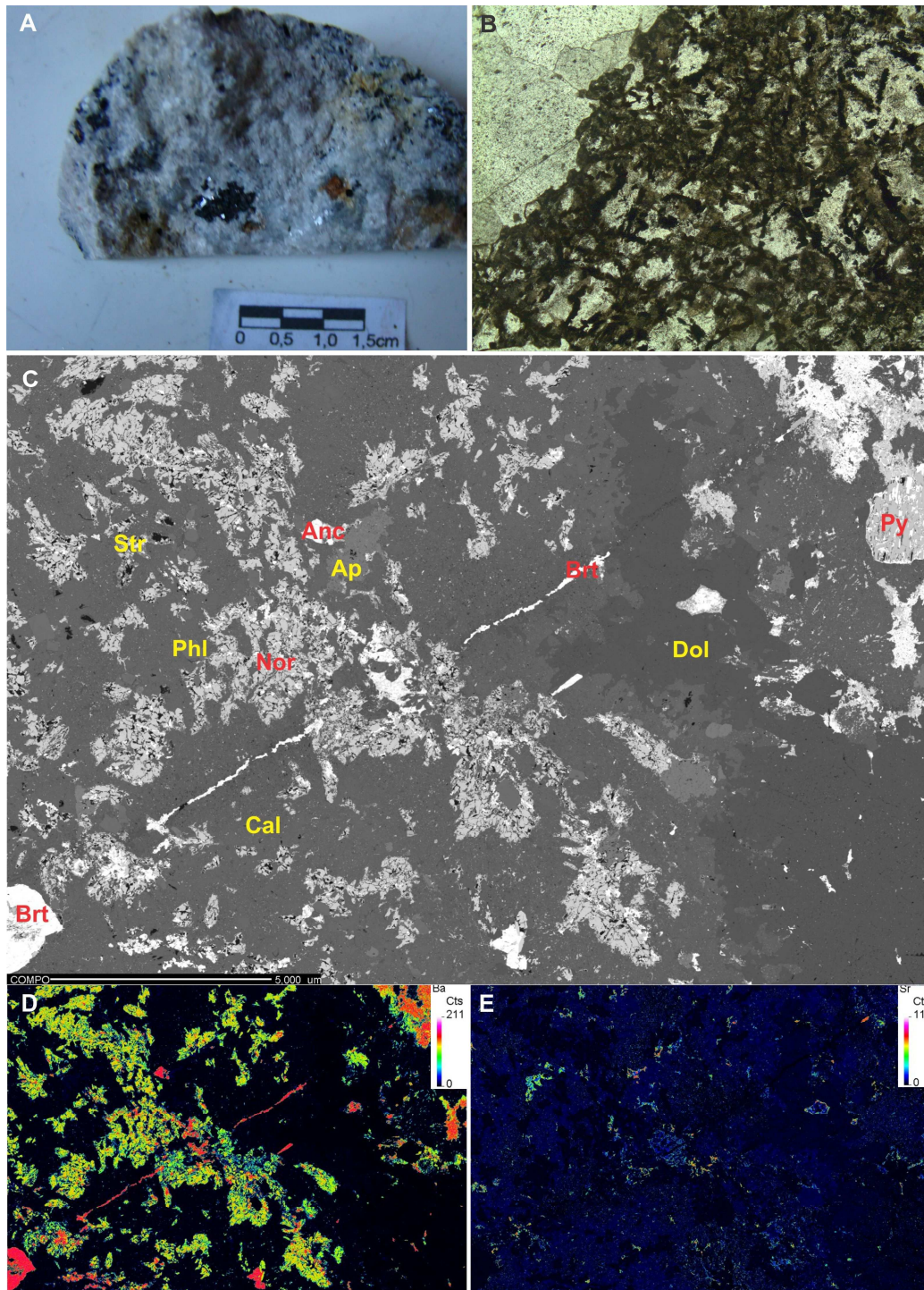


Figura 3.06 – A) Foto macroscópica da amostra AT135 B) Fotomicrografia evidenciando textura quench em carbonatos. Luz transmitida plano-paralela. Largura do campo: 5mm. C) Composição de imagens de elétrons retroespalhados de toda a lâmina. Largura da imagem: 2,5cm. D) Mapa de composição de Ba por WDS em microsonda eletrônica da mesma composição de imagens em C. E) Mapa de composição de Sr por EDS em microsonda eletrônica da mesma composição de imagens em C. Anc=ancyllita, ap=apatita, brt=barita, cal=calcita, dol=dolomita, mnz=monazita, nor=norsethita, py=pirita, str=estroncianita.

## CAPÍTULO 4

### ***Stable (C, O, S) isotopes and whole-rock geochemistry of carbonatites from Alto Paranaíba Igneous Province – SE Brazil***

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#### Abstract

The present work investigates the relationship between whole-rock geochemistry and stable isotope composition from carbonatites belonging to the Tapira, Araxá, Salitre, Serra Negra, Catalão I and Catalão II alkaline-carbonatite complexes of the Alto Paranaíba Igneous Province (APIP), central Brazil and from the Jacupiranga Complex, of the Ponta Grossa Province, southeast Brazil. The APIP complexes are ultrapotassic, comprising bebedourites, phoscorites, nelsonites, and carbonatites, whereas Jacupiranga is a sodic complex composed of ijolite-series rocks, syenites, carbonatites and alkaline gabbros. The geochemistry data, allied to mineralogical constraints allowed us to classify the carbonatites into 5 groups, and to devise a chemical index ( $BaO/(BaO+SrO)$ ) to gauge the magmatic evolution of the studied carbonatites.

The APIP carbonatites evolve from apatite-rich calciocarbonatites toward Ba-, Sr-, and REE-rich magnesiocarbonatites. This evolution is mostly driven by apatite, phlogopite, dolomite, and calcite fractionation and consequent enrichment in monazite, norsethite and strontianite. Baddeleyte is an important phase that affects the trace elements.

Stable isotope data show a wide diversity of petrogenetic processes in play at the APIP, relatively to the Jacupiranga Complex, which is interpreted as a result of

the shallower intrusion levels of the APIP complexes. Such shallower emplacement, at low lithostatic pressure, allowed for a complex interplay of fractional crystallization, liquid immiscibility, degassing and interaction with hydrothermal and carbohydrothermal systems.

*Keywords: Carbonatite, carbonates, geochemistry, stable isotopes, APIP.*

## 4.1 Introduction

Brazilian alkaline provinces have been studied by a range of techniques such as whole-rock geochemistry, mineral chemistry, stable and radiogenic isotope geochemistry, with a range of petrogenetic applications (Gomide *et al.*, 2013, Barbosa, 2009; Cordeiro *et al.*, 2011; Grasso, 2010; Ribeiro, 2008, Comin-Chiaramonti *et al.*, 2001, 2005; Traversa, 2001, Andrade *et al.*, 2002, Huang *et al.*, 1995, Santos & Clayton, 1995). In this work we aim to contribute to the knowledge of carbonatite petrogenetic evolution, investigating the relationships between whole-rock geochemistry and stable isotope geochemistry data. We report geochemical and isotopic data from carbonatites of the Late-Cretaceous Alto Paranaíba Igneous Province in Central Brazil, and discuss their implications for magma evolution, both at single-complex and Province-wide scales. The results are compared with the Early-Cretaceous Jacupiranga carbonatite complex, in the Ponta Grossa Province, SE Brazil.

Alkaline rocks and alkaline-carbonatite associations include highly variable petrographic types and a correspondingly extensive nomenclature. In this work we adopt the nomenclature described by Le Maitre *et al.* (2002) for carbonatites and rocks of the ijolite series, Sahama (1974) for kamafugites, Yegorov (1993) for phoscorites, and Barbosa *et al.* (2012) for bebedourites.

The APIP alkaline carbonatite complexes are multi-stage intrusions formed by rocks derived from the bebedourite, carbonatite and phoscorite petrogenetic series, which are related to each other by a complex interplay of recurrent fractional crystallization, liquid immiscibility and degassing (Barbosa *et al.*, 2012, Brod *et al.*, 2013, Cordeiro *et al.*, 2010, Barbosa, 2009, Ribeiro, 2008, Brod *et al.*, 2004 ). The



ultramafic rocks of all complexes show variable degrees of late-stage metasomatism by fluids derived from extreme carbonatite differentiation.

The bebedourite series (Barbosa *et al.*, 2012) consists of rocks formed by fractional crystallization from an ultrapotassic silicate magma; whereas the phoscoritic series (Cordeiro *et al.*, 2010, Barbosa, 2009) is composed of rocks produced by phosphate magmas; and the carbonatite series is composed essentially by Ca-carbonatites and Mg-Carbonatites with variable degrees of Sr, Ba and rare-earth element (REE) enrichment.

## 4.2 Geological Setting

The APIP, located between Minas Gerais and Goiás state, is the result of an intense mafic ultramafic alkaline and ultrapotassic magmatism (Brod *et al.*, 2004) in Central Brazil during the Late Cretaceous. The province is composed by large volumes of kamafugites (Mata da Corda Group lavas and pyroclastics, and countless subvolcanic bodies), subordinate kimberlites, rare lamproites and several alkaline-carbonatite plutonic complexes (Almeida and Svisero, 1991, Leonardos *et al.*, 1991, Gibson *et al.*, 1995, Brod *et al.*, 2000, 2004, Comin-Chiaramonti and Gomes, 2005, Carlson *et al.*, 2007). Figure 4.01 shows the location of the APIP complexes.

Gibson *et al.* (1995, 1997) and Brod *et al.* (2005) correlated the Late-Cretaceous (ca. 85 Ma) magmatism at the north and northeast borders of the Paraná Basin with the impact of the Trindade mantle plume (Gibson *et al.* 1995) at the sub-continental lithosphere of central Brazil.

The Province was established along an elongated NW-SE structure called the Alto Paranaíba Arc. The alkaline magmas were emplaced into Precambrian rocks from the internal and external zones of the Brasília Fold Belt. Kamafugite is by far the dominant rock-type in the province, forming one of the few known kamafugite-carbonatite associations (Brod *et al.*, 2000).

The ultramafic rocks of all complexes show variable degrees of metasomatism by fluids resulting from extreme carbonatite differentiation. The relatively shallow character of the APIP intrusions is indicated by C and O isotopes (Santos and Clayton, 1995), within-magma chamber pyroclastic deposits (Ribeiro *et al.*, 2005), similarities between bebedourites and xenoliths in volcanic and sub-

volcanic kamafugites in the province (Brod *et al.*, 2000, Seer and Moraes, 1988), and the extent of degassing/metasomatism.

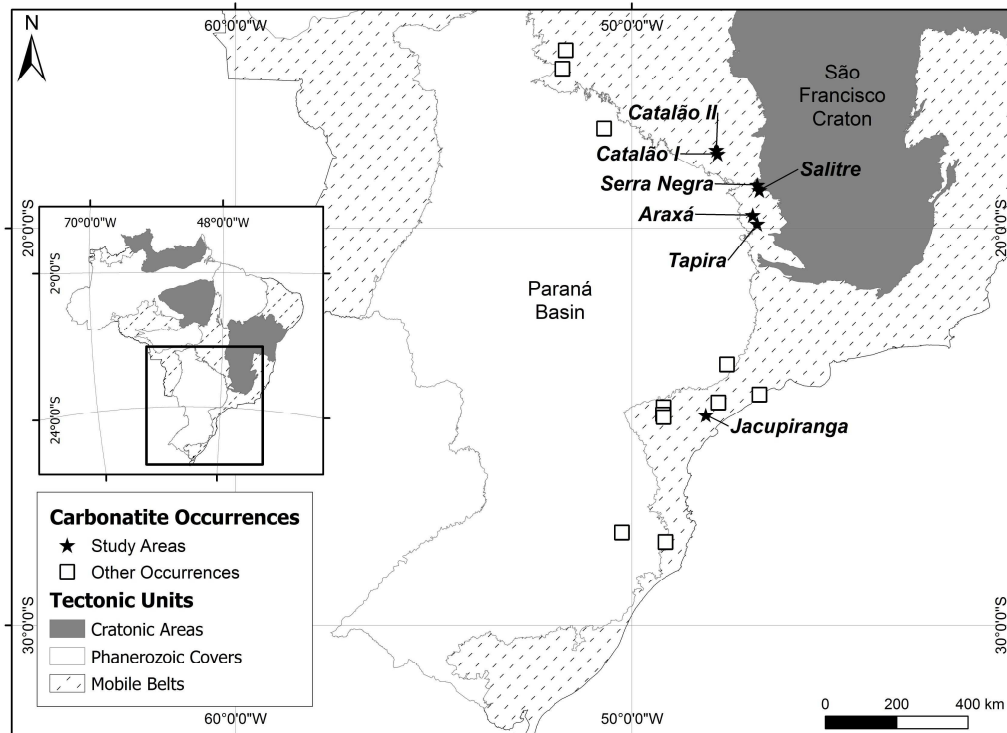


Figure 4.01 – Alkaline-carbonatite complexes northeast and east of the Paraná Basin, modified from Oliveira *et al.* (2004) and Wooley and Kjarsgaard (2008).

The APIP carbonatite complexes comprise, from north to south, Catalão II, Catalão I, Serra Negra, Salitre II, I and III, Araxá and Tapira. The complexes are ultrapotassic, and have a kamafugitic affinity (Brod *et al.*, 2000, Brod, 1999, Gibson *et al.*, 1995, Lloyd & Bailey, 1991), forming a carbonatite-kamafugite association compared to that described in Italy by Stoppa & Cundari (1995) and Stoppa & Wooley (1997).

The Catalão I complex is composed of dunite, clinopyroxenite, bebedourite, carbonatite, phoscorite, nelsonite and phlogopite and evolved from a phlogopite-picrite magma by several stages of fractional crystallization and liquid immiscibility. Magnesiocarbonatite is the dominant carbonatite type in the complex (Cordeiro *et al.*, 2010, Ribeiro, 2008, Brod *et al.*, 2004).

Catalão II is composed of pyroxenite, quartz syenite, alkali-feldspar syenite, calciocarbonatite, silicocarbonatite, lamprophyre and phlogopite (Machado Junior, 1992). Calciocarbonatites dominate over magnesiocarbonatites. Regarding the

phoscorite series, the northern portion of the complex is dominated by phoscorite, whereas the south part is dominated by nelsonite (Palmieri *et al.*, 2009).

Serra Negra is the largest APIP carbonatite complex, with 65 km<sup>2</sup>. It intruded quartzites from the Canastra Group, generating a very pronounced dome structure. The complex is composed by dunites, bebedourites, calciocarbonatites, magnesiocarbonatites and trachytes.

Salitre consists of three bodies located to the south of the Serra Negra complex, composing a system of coalescing intrusions with the latter. The rocks present in the complex are bebedourites, dunites, perovskitites, tinguaites, trachytes, fenites, phoscorites, apatite-carbonatites, calciocarbonatite and magnesiocarbonatites (Barbosa, 2009, Brod *et al.*, 2004, Mariano & Marchetto, 1991).

The Araxá complex is composed of carbonatites, phoscorites, and metasomatic phlogopitites derived from ultramafic rocks (bebedourite and dunite). Magnesiocarbonatite is the dominant carbonatite type in this complex. The intrusion generated a dome structure in schists and quartzites from the Ibiá group (Seer, 1999).

Tapira is an approximately elliptic complex, composed of bebedourite with subordinate carbonatite and syenite, and rare melilitolite and dunite, all cut by ultramafic dikes of kamafugite affinity. Calciocarbonatite dominates over magnesiocarbonatite (Brod *et al.*, 2003).

Jacupiranga, the only complex from the Ponta Grossa Province studied in this work, is located about 10 kilometers west of the City of Jacupiranga and immediately to the north of the City of Cajati, São Paulo State. The complex is composed by pyroxenite (jacupirangite), serpentinized peridotite, ijolite, nepheline-syenite, carbonatite, essexite, monchiquite and tinguaité (Gomes *et al.*, 1990). It intruded Precambrian metasedimentary rocks of the Açungui group (Ruberti *et al.*, 2005) and has an oval (approximate 65km<sup>2</sup>) shape, with a small elongated core composed of carbonatite intruding jacupirangites. Gaspar & Wyllie (1982; 1983) identified five successive carbonatite intrusions called C1 to C5, from the oldest to most recent. C1, C3 and C4 are dominated by calciocarbonatite, C2, dominated by dolomite calcite carbonatite and C5 by ankerite carbonatite (Gaspar & Wyllie, 1983).

### 4.3 Materials and Methods

Analysed samples were first examined under a petrographic microscope to determine mineralogical and textural characteristics. Selected samples were ground in an agate mill and sent to the ACME Labs in Canada for whole-rock chemical analysis (ACME 4A and 4B packages). Powders produced from whole-rock and/or mineral separates were analysed for carbon and oxygen isotopes using a Delta V plus gas-source mass spectrometer at the University of Brasília. The Sulphur isotopes data are from Gomide *et al.* (2013).

### 4.4 Results and Discussion

The studied APIP carbonatites were classified into five groups on the basis of their modal composition, petrographic characteristics, and interpretations and evolution models of previous works (Ribeiro *et al.*, 2014, Cordeiro *et al.*, 2011; Palmieri, 2011, Cordeiro *et al.*, 2010; Grasso, 2010; Barbosa, 2009; Cordeiro, 2009; Ribeiro, 2008; Brod, 1999). The modal composition of key minerals are given in figure 4.02 and the geochemical and textural characteristics, and the evolution stage of each group are summarized in table 3.01.

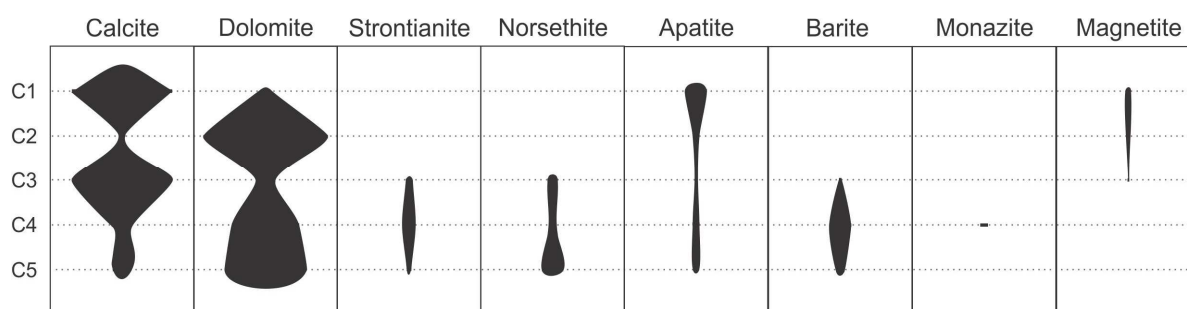


Figure 4.02 – Comparative modal composition of key mineral phases with different carbonatite evolution stages.

Early-stage carbonatites (C1) are rich in apatite, phlogopite and magnetite, but all three phases tend to diminish or disappear at the intermediate stages (C2 or C3) resuming crystallization in later stages (C4 and C5). Barite is typically lacking in the initial stages, appearing for the first time at calciocarbonatites C3 and becoming more abundant toward late stages.

*Table 4.01 – Characterization of the studied carbonatite carbonatite groups based on mineralogy, textures, chemistry and evolution stage. Jacupiranga samples are taken as representative of the least evolved stages.*

	Subgroups	Complex	Mineralogy	Geochemistry Characteristics	Carbonates	Grain Size
C1	C1a	Jacupiranga	cb, ap, ol, ± po, ± py, ± mag, ± ilm	Ca-cbt com P <sub>2</sub> O <sub>5</sub> > 9%	Cal >> Dol	coarser ↓ finer
	C1b	Jacupiranga	cb, ap, po, ± phl, ± pn,	Ca-cbt com P <sub>2</sub> O <sub>5</sub> < 9%	Cal >> Dol	
	C1a	Salitre, Tapira	cb, ap, phl, tfp, po, ±py, ±pcl, ± prv, ±mag, ±ilm, ± ccp, ±ol	Ca-cbt with P <sub>2</sub> O <sub>5</sub> > 3%	Cal >> Dol	
	C1b	Catalão II, Salitre, Tapira	cb, ap, phl, tfp, mag, po, py, ± amp, ±pcl, ± brt, ± ccp, ± ol ± mrc	Ca-cbt with P <sub>2</sub> O <sub>5</sub> < 3%	Cal >> Dol	
C2		Jacupiranga	Cb, ap, phl, ±py			
		Catalão I, Serra Negra, Salitre	cb, phl, tfp, mag, py, ± ap, ± brt, ±pcl, ± ccp, ± po, ± ilm, ± ol	Mg-cbt	Dol > Cal	
C3		Tapira Araxá	cb, tfp, brt, py, ± ccp, ± po, ± ap, ± ol, ± mag, ± ilm	Ca-Cbt	cal, bacc, nor, str	
C4		Araxá, Catalão I, Catalão II, Tapira, Salitre	cb, cb coloidal, brt, py, mnz, ±phl, ±tfp, ±mag, ±pcl, ±ap, ±ccp ±po	Ba-mg-cbt com ETR	dol, fe-dol, str, anc, par, bast	
C5	C5a	Catalão I, Catalão II, Araxá, Tapira	cbt, brt, phl, tfp, ap, py, ±mag, ±ilm, ±pcl, ±ccp, ±po, ±mnz	Ba-Mg-cbt	Dol and fe-dol > cal; nor, bkt, str	
	C5b	Catalão I, Salitre	cbt, ap, brt, py, ±mag, ±ilm, ±mnz	Ba-Mg-cbt	Dol > cal	

Amp: amphibole, Ap: apatite, Brt: barite, Cal: calcite, Cb: carbonate, Ccp: chalcopyrite, Dol: dolomite, Ilm: ilmenite, Mag: magnetita, Mnz: monazite, Mrc: marcasite, Ol: olivine, Pcl: pyrochlore, Phl: phlogopite, Pn: pentlandite, Po: pyrrhotite, Prv: perovskite, Py: pyrite, Str: strontianite (Whitney & Evans, 2010). Anc: ancylite, Bacc: barytocalcite, Bast: bastnaesite, Bkt: burbankite, Nor: norsethite, Par: parisite, Tfp: tetraferriphlogopite.

Monazite is restricted to the most evolved carbonatites. Pyrite is present in all stages. Calcite is the dominant carbonate phase at C1 and C3, while dolomite dominates in C2, C4 and C5 groups. Strontianite and norsethite appear at the first time as *liquidus* phases in calciocarbonatite C3 and increase in abundance toward more evolved carbonatites. Barytocalcite is present in C3 but only locally, and restricted to this group.

#### 4.4.1 Whole Rock Geochemistry

Whole-rock chemistry data were plotted in the carbonatite classification diagram of Woolley & Kempe (1989). Carbonatites from groups C1 and C3 plot in the field of calciocarbonatite, whereas carbonatites from groups C2, C4 and C5 plot in the field of magnesiocarbonatites (figure 4.03).

C1-type calciocarbonatites (figure 4.03) are present in the Catalão II, Salitre, Tapira and Jacupiranga complexes. Mineralogically they are unevolved, containing large amounts of silicates such as olivine, amphibole and Al-rich phlogopite, carbonate minerals restricted to calcite and possibly dolomite, and significant amounts of apatite and magnetite. Samples showing evidence of compositional layering (cumulates) were individualized as subgroup 1a, the remaining being assigned to group 1b.

The C3 calciocarbonatites (figure 4.03) were identified only in samples from Tapira and differ from the C1 calciocarbonatites because they contain primary norsethite and barytocalcite, and tetraferriphlogopite instead of aluminous phlogopite, indicating that C3 are a more evolved version of calciocarbonatite. The presence of Sr-, Ba- and REE-rich exsolutions in calcite suggest crystallization of the latter at relative high temperature (700°C-650°C for carbonatites). Similar features were observed by (Brod, 1999) for Tapira carbonatites and by Cordeiro *et al.* (2011) for Catalão I.

C2-type magnesiocarbonatites (figure 4.03) are present in Catalão I, Serra Negra, Salitre and Jacupiranga. These rocks have a relatively simple primary carbonate composition, restricted to dolomite and calcite. The presence of abundant exsolutions of burbankite indicates that these carbonates crystallized at relatively high temperature. This group of magnesiocarbonatites is little differentiated but may

not represent the most primitive magnesiocarbonatite in the province, since magnesiocarbonatites with olivine are described by Barbosa (2009) from Salitre and by Grasso (2010) from Serra Negra.

The C4 group consists of Ba- and REE-rich magnesiocarbonatites (figure 4.03), whose carbonate assembly consists mainly of dolomite, Fe-dolomite and strontianite (often colomorph). Carbonatites from this group comprise samples from Araxá, Tapira and Salitre.

C5-type magnesiocarbonatites studied in this work are from Catalão I, Catalão II, Araxá and Tapira complexes. They are enriched in Ba and characterized by a wide variety of carbonates, including dolomite, fe-dolomite, norsethite, burbankite, calcite, benstonite, olekminskite, strontianite, baritocalcite. Two samples from this group belong to a degassing trend defined by carbon and oxygen stable isotopes similar to those described by Cordeiro *et al.* (2011), and were separated as a 5b type, while the other samples were named as 5a.

The determination of the evolution stage in carbonatites is a difficult task, because the concentration of elements typically used to monitor differentiation in common magmas may be strongly modified by the crystallization of specific fases in carbonatite magmas. For example, MgO is an essential constituent of olivine, which is an early-stage phase in the carbonatite magma, but also in dolomite, which may be a late-stage mineral. The same reasoning applies to FeO (early-stage magnetite and late-stage Fe-dolomite or ankerite). SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> essentially participate in silicates and should decrease with the evolution of carbonatite magma, as silicates are mostly crystallized at the early stages. However, the concentration of these elements is generally very low in carbonatites to start with, and their use as a differentiation index is limited for the most part of the evolution range.

There is a literature consensus (e.g. Xie *et al.*, 2009, Chakhmouradian *et al.*, 2008; Sokolov, 2002, Buhn & Rankin, 1999; Zaitsev *et al.*, 1998, Jones *et al.*, 1996, Le Bas, 1979) that barium and the rare earth elements tend to be enriched toward the final stages of evolution in the carbonatite magma. Also, apatite is the most persistent mineral in the carbonatite evolution range, and P<sub>2</sub>O<sub>5</sub> contents can be a useful tool to measure the differentiation degree, except perhaps in the final stages, where phosphorus may be associated with the late-stage crystallization of monazite.

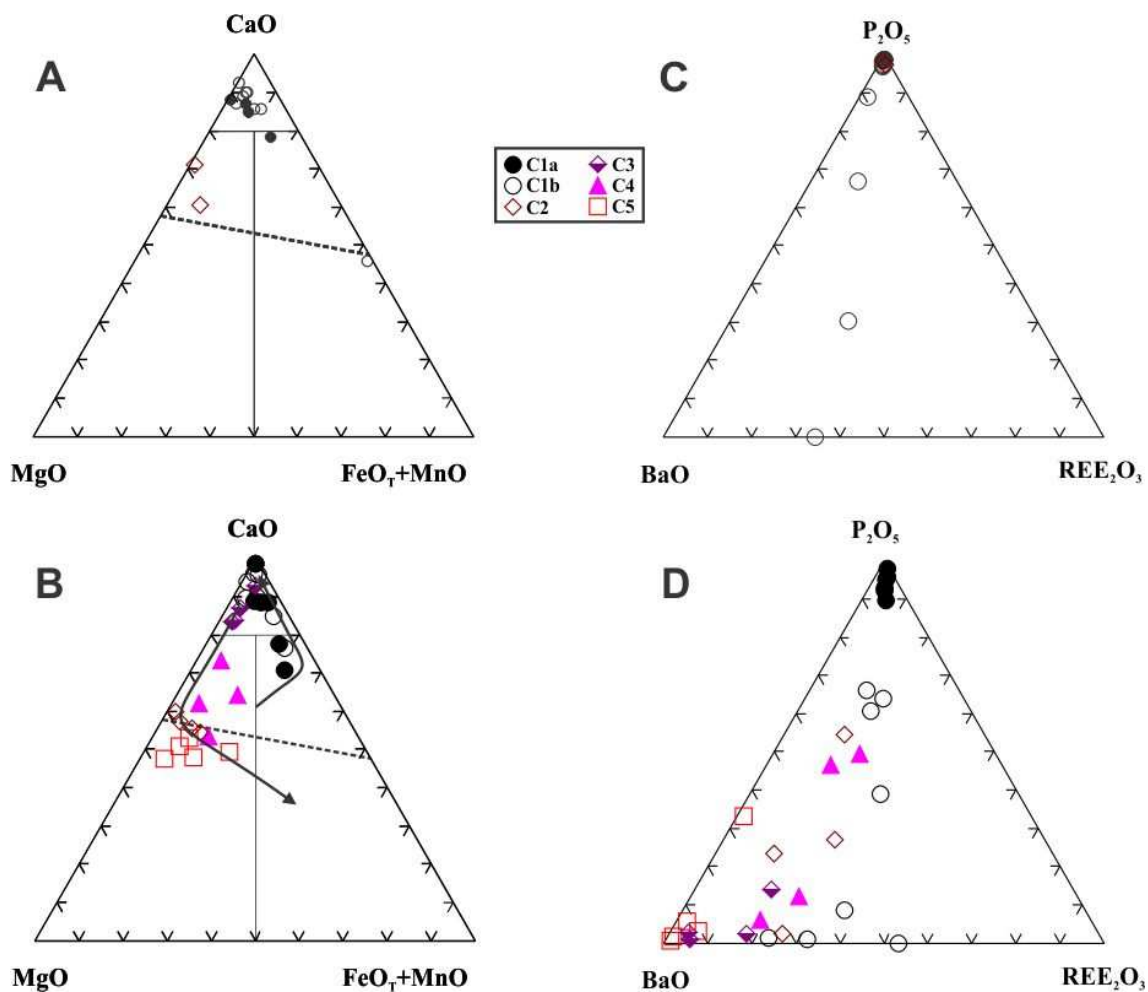


Figure 4.03 –Carbonate classification diagram after Wooley & Kempe (1989) for the studied samples. The arrows indicate possible evolution trends for APiP carbonatites (Ribeiro et al., 2014). Dashed line connects the compositions of pure dolomite and pure ankerite. A) Jacupiranga, B) APiP.  $P_2O_5 \times BaO \times REE_2O_3$  diagram, where C1, C2, C3 and C5 evolve from  $P_2O_5$  toward BaO enrichment, but C4 evolves in the opposite direction (from BaO to  $P_2O_5$ ). C) Jacupiranga, D) APiP.

Figure 4.03 shows phosphorus, barium and rare earth element variation for different carbonatite compositional groups (see table 4.01), indicating the progress of each group based on mineral paragenesis and overall chemical composition. It is possible to observe that groups C1, C2, C3 and C5 evolved mostly by enrichment in BaO and depletion in  $P_2O_5$ , while the C4 group, which contains carbonatites with higher concentrations of rare earth elements.

Figure 3.04 shows a general evolution by increase in Ba, Sr and REE, where C5 is located in an intermediate position, in the case of REE.



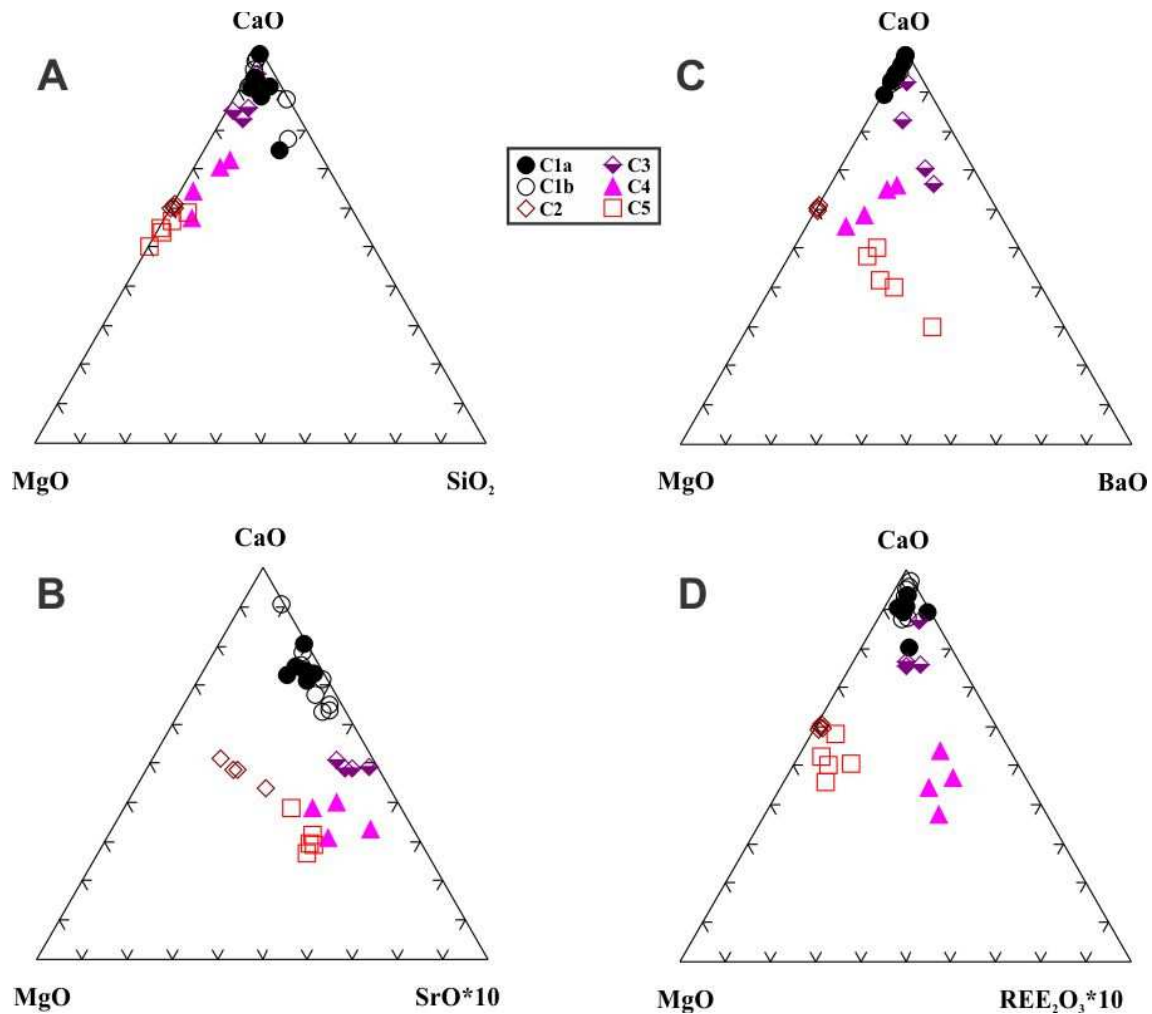


Figure 4.04 – CaO x MgO x (A)SiO<sub>2</sub>, (B)SrO, (C)BaO and (D)REE<sub>2</sub>O<sub>3</sub> graph, where C1, C2, C3, C4 and C5 evolves from CaO toward MgO and BaO, C1 and C3 evolves from CaO toward SrO while C2, C4 and C5 evolves from MgO toward SrO. C4 and C5 are the groups that present the highest REE<sub>2</sub>O<sub>3</sub> content.

#### 4.4.2 Major Elements

The evolution sequences inferred from the mineral paragenesis and chemical changes observed in figures 4.03 and 4.04 were used to establish a sequential arrangement of samples in each group. This and the mineralogy present in these samples was then used to search for an index that could proxy for magmatic evolution of the studied carbonatites. Figures 4.05 to 3.11 show the behaviour of several major element oxides with BaO/(BaO+SrO) as an evolution index. The two C5b outgassed magnesiocarbonatite samples were not plotted since it would not be possible to establish trends of variation on the basis of two samples alone.

The C1 and C2 carbonatites from Jacupiranga (figure 4.05) show an evolution similar to that of the corresponding, most primitive carbonatite group of the APIP (figure 4.06). C1a and C1b from Jacupiranga largely overlap in the region of low values of BaO/(BaO+SrO), not exceeding 0,24, as expected for primitive compositions. The C1a cumulates show some positive correlation of BaO/(BaO+SrO) with REE and Na<sub>2</sub>O resulting from apatite accumulation, whereas the mostly residual C1b carbonatites show the opposite behavior as a result of apatite removal. CaO and MgO present an erratic behavior.

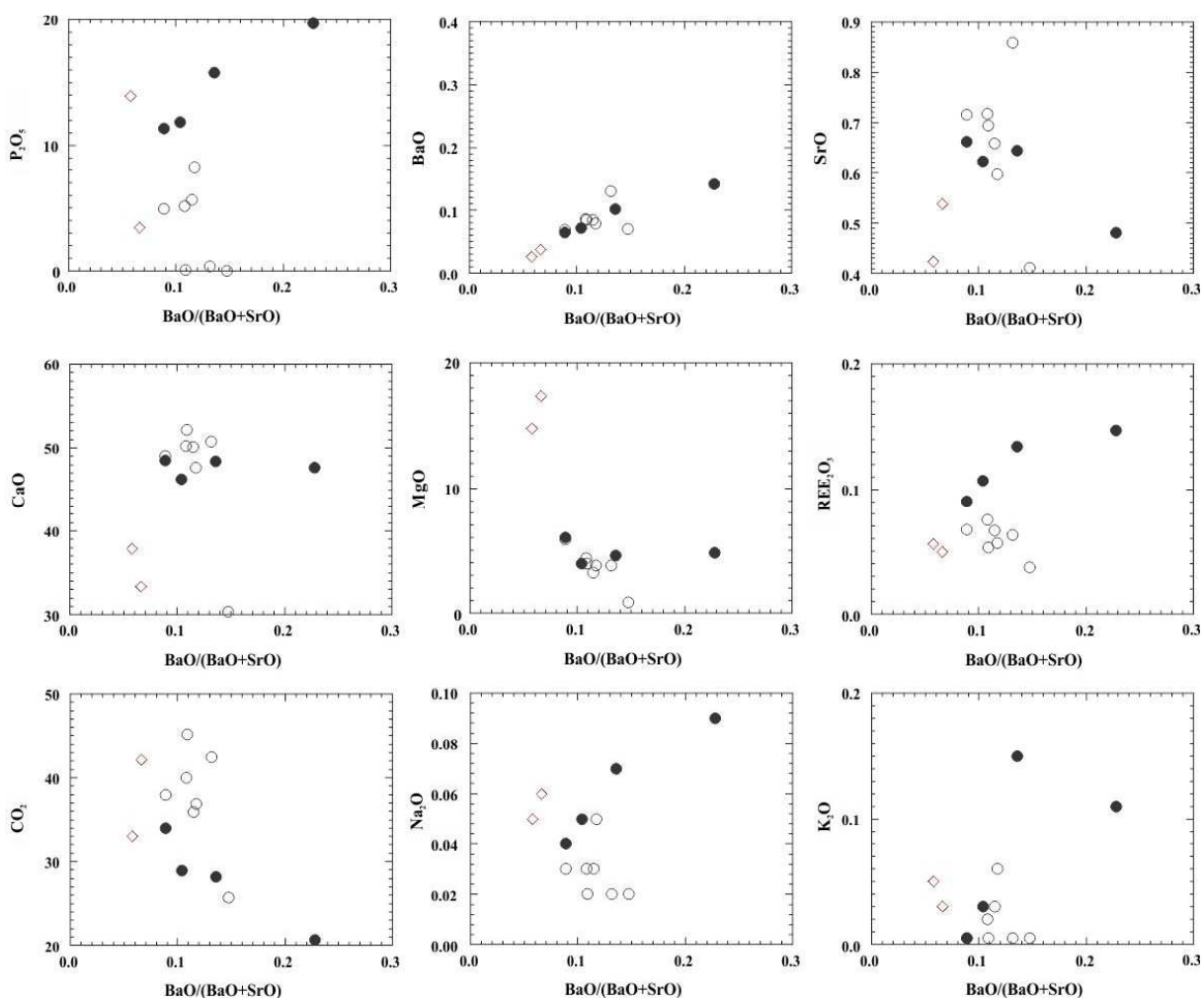


Figure 4.05 – Behavior of selected major element oxides with magma evolution for the Jacupiranga C1 calciocarbonatites and C2 magnesiocarbonatites. Symbols as figure 4.03.

The APIP C1 calciocarbonatites (figure 4.06) evolve by increase in BaO and CO<sub>2</sub>, indicating the increased amount of carbonate in the rock. The BaO content are very low relative to other APIP carbonatites, reaching a maximum at around 0.5%.

$K_2O$ , REE and  $P_2O_5$  decrease with C1 evolution. Both REE and  $P_2O_5$  are controlled only by apatite fractionation at these early stages, while  $K_2O$  is controlled by phlogopite fractionation.  $CaO$  and  $MgO$  have mutually opposite behaviors, although with considerable scattering, and their distribution is probably controlled by independent factors, such as the removal of these elements from magma during fractionation of apatite and silicates, and its accompanying increase in carbonate enrichment. Furthermore, the opposite  $CaO$  and  $MgO$  trends may be associated with the presence of small but varying amounts of dolomite in the rock. The sodium content is usually very low and independent of the stage of evolution of these rocks. One extreme  $Na_2O$  content of about 0.8% can be explained by the presence of amphibole.

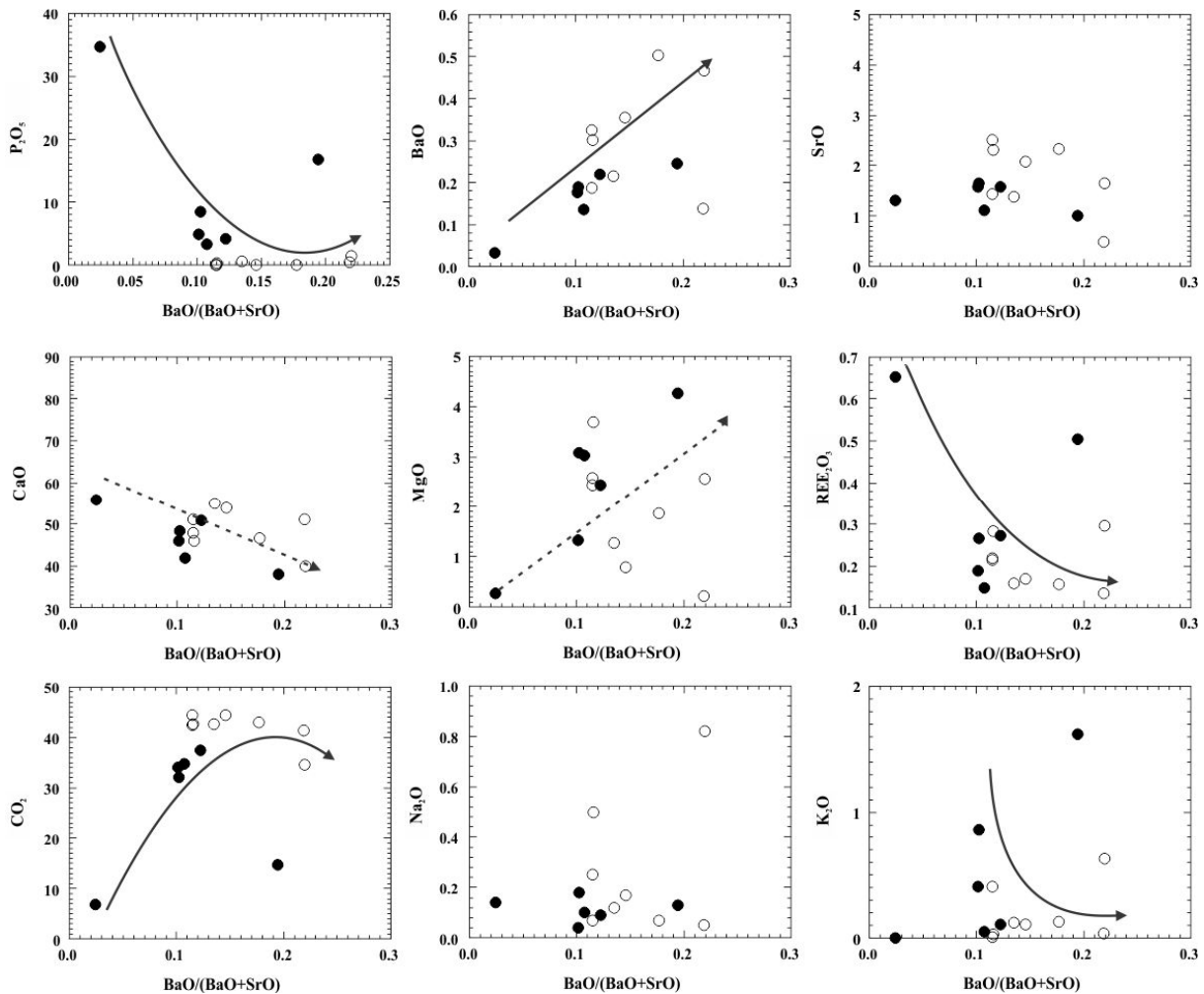


Figure 4.06 – Behavior of selected major element oxides with magma evolution for the APIP C1 calciocarbonatites. Symbols as in figure 4.03.

APIP C2 magnesiocarbonatites (Figure 4.07) are characterized by the increase in BaO with magmatic evolution, although the levels of barium are still relatively low when compared with other magnesiocarbonatites. The CaO content is insensitive to evolution, reflecting the scarcity or absence of calcite in these rocks. The  $P_2O_5$  content is low (maximum 0.2%), but systematically decreases, signaling apatite fractionation. The similar behavior of SrO and  $Na_2O$  are probably also related to the removal of apatite. It is important to note that, unlike C1, the calcite is absent or very rare in C2 carbonatites, which implies a control of the SrO content by fractionating apatite, since strontium does not enter the structure of dolomite easily.

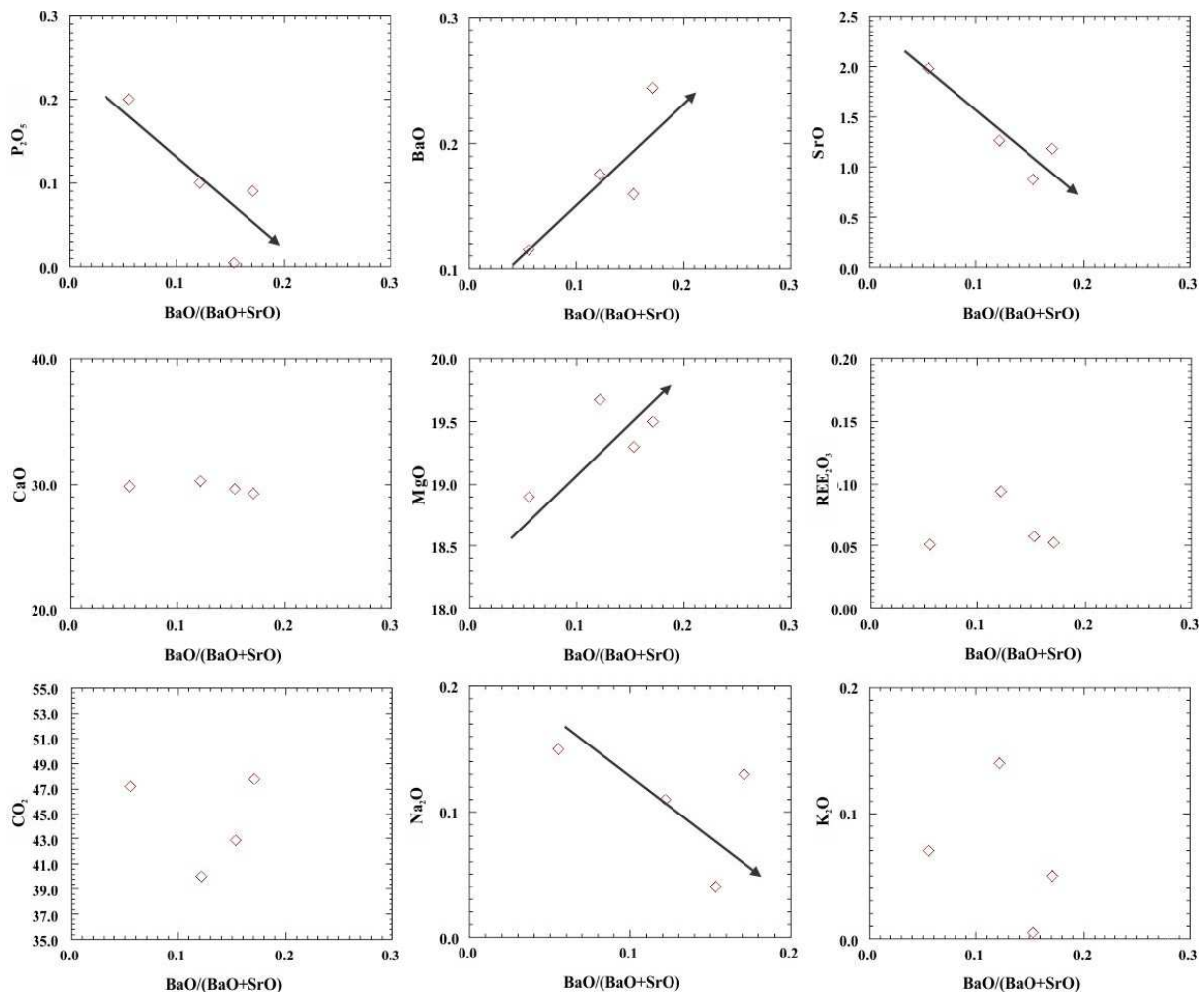


Figure 4.07 – Behavior of selected major element oxides with magma evolution of the APIP C2 magnesiocarbonatites. Symbols as in figure 4.03.

In our studied sample set, the C3-type carbonatites are restricted to samples from the Tapira complex. In this group there is no obvious control of fractionating apatite on the content of  $P_2O_5$ , which shows erratic variation. BaO, MgO,  $Na_2O$ , and

less obviously, REE increase with magmatic evolution whereas CaO and SrO decrease (figure 4.08), suggesting that calcite crystallization gives way to other carbonates such as norsethite ( $\text{BaMg}(\text{CO}_3)_2$ ) and, more rarely, burbankite ( $(\text{Na,Ca})_3(\text{Sr,Ba,Ce})_3(\text{CO}_3)_5$ ) and baritocalcite ( $\text{BaCa}(\text{CO}_3)_2$ ) with magma evolution. The atypical behavior of  $\text{CO}_2$ , which increases slightly at first and then constantly decreases, is possibly related to the same mineralogical effect, because carbonates containing heavy elements such as Ba, Sr and REE will naturally have a lower  $\text{CO}_2$  proportion by weight. It is important to note that the levels of BaO (up to 13%) and SrO (up to 5%) are substantially greater than in C1 and C2 carbonatites. The contents of  $\text{K}_2\text{O}$  are low and decrease very quickly in the early evolution of C3, indicating total consumption of phlogopite as the silicate formed at this stage.

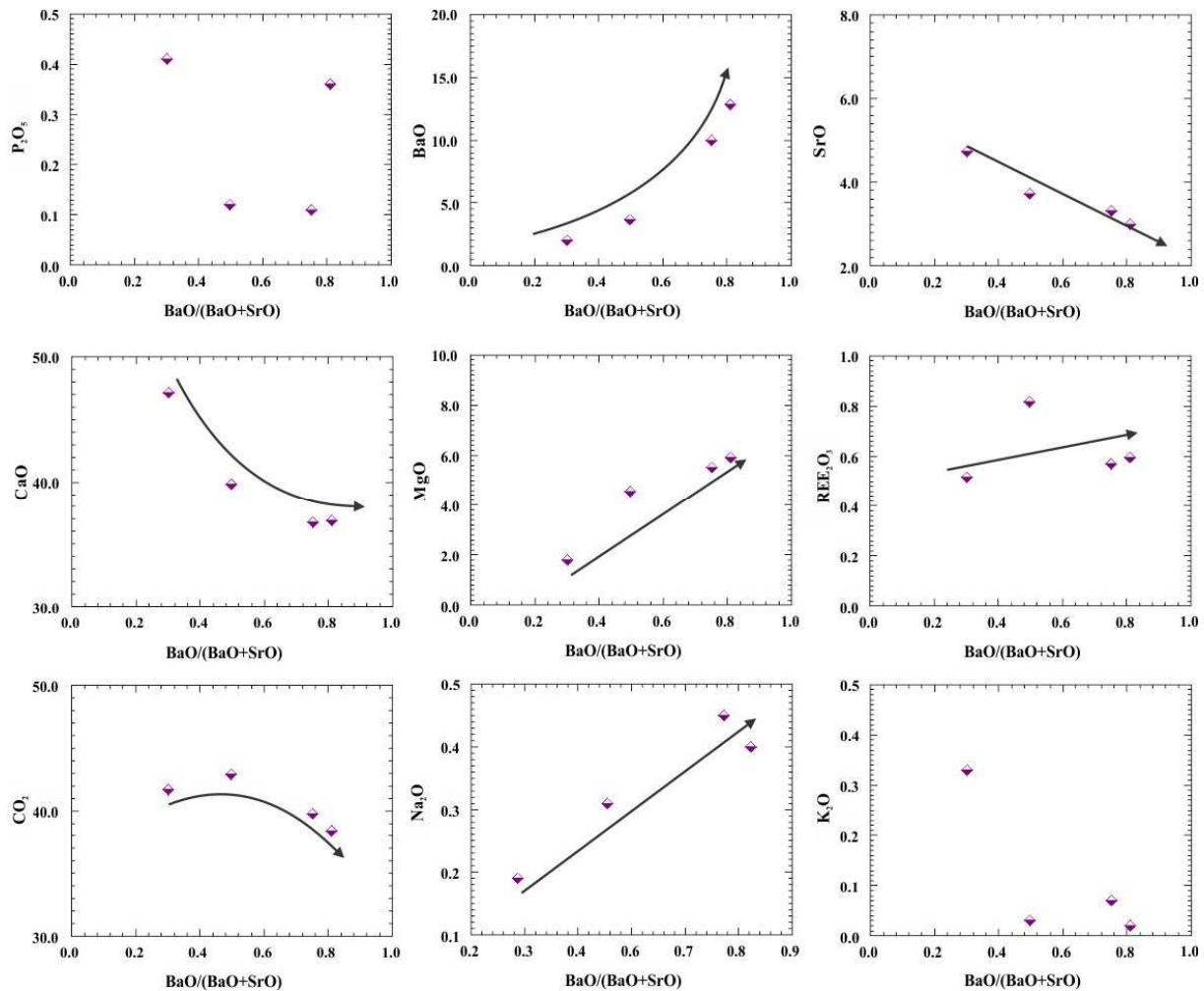


Figure 4.08 – Behavior of selected major element oxides with magma evolution for the APIP C3 calcicarbonatites. Symbols as in figure 4.03.

C4 magnesiocarbonatites occur in the Salitre, Araxá and Tapira complexes, and are characterized by the presence of monazite, instead of carbonates, as the main rare earth mineral. This fact is illustrated by the high REE content (up to 2.5%) in carbonatites of this group and confirmed by SEM and electron microprobe analyses. In addition to REE, there is an increase in  $K_2O$ ,  $Na_2O$  and  $MgO$ , and an increase followed by an important decrease in the concentration of  $BaO$ ,  $CaO$  and  $CO_2$  with magma evolution (figure 4.09). A notable feature is the negative correlation between  $BaO$  and REE, which is not observed in the other groups.

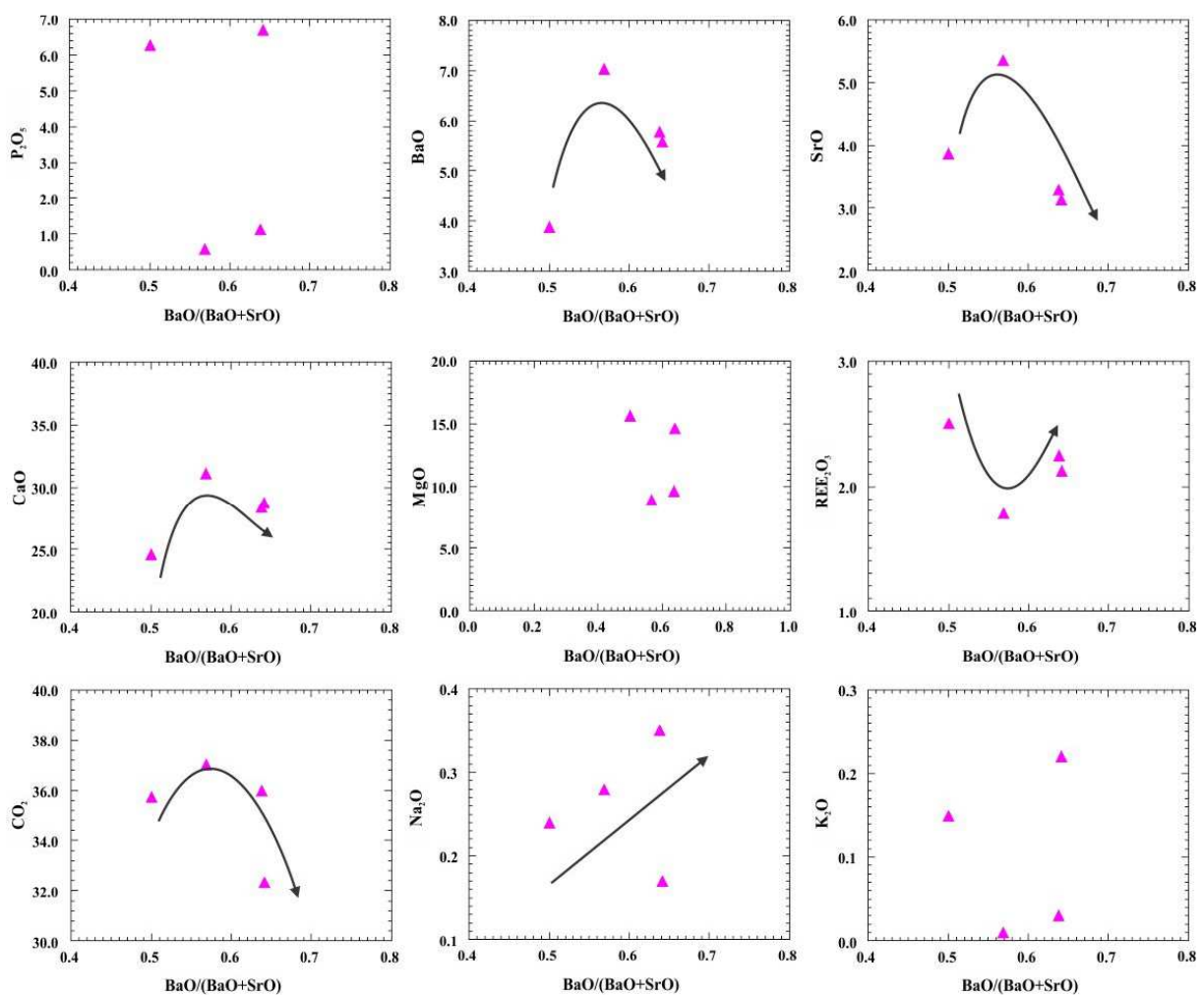


Figure 4.09 – Behavior of selected major element oxides with magma evolution from the APiP C4 magnesiocarbonatites. Symbols as in figure 4.03.

The C5 magnesiocarbonatites are from the Catalão I, Catalão II, Araxá and Tapira complexes and show increasing  $BaO$ ,  $SrO$ ,  $Na_2O$  and  $CO_2$ , and decreasing  $CaO$  and  $K_2O$  with evolution (Figure 4.10). Some of the less evolved samples of this

group have very high  $P_2O_5$  (up to 8-9%) and phosphorus contents are strongly controlled by the apatite fractionation at the early stages. This fact contrasts with the low phosphorus observed in C2, and suggests that carbonatites from C5 represent a distinct magmatic pulse. The strong increase in BaO, SrO and  $Na_2O$  indicates the crystallization of rare or complex carbonates such as norsethite, burbankite, benstonite, olekminskite, strontianite and baritocalcite, whose occurrence is confirmed in electron microscopy and electron microprobe analyses. The replacement of dolomite by these other carbonate minerals as the main crystallizing phases in the magma explains most of the observed chemical changes, including a consistent decrease in CaO, but does not explain the progressive increase in  $CO_2$ . At the current stage the reasons for this behavior are not clear.

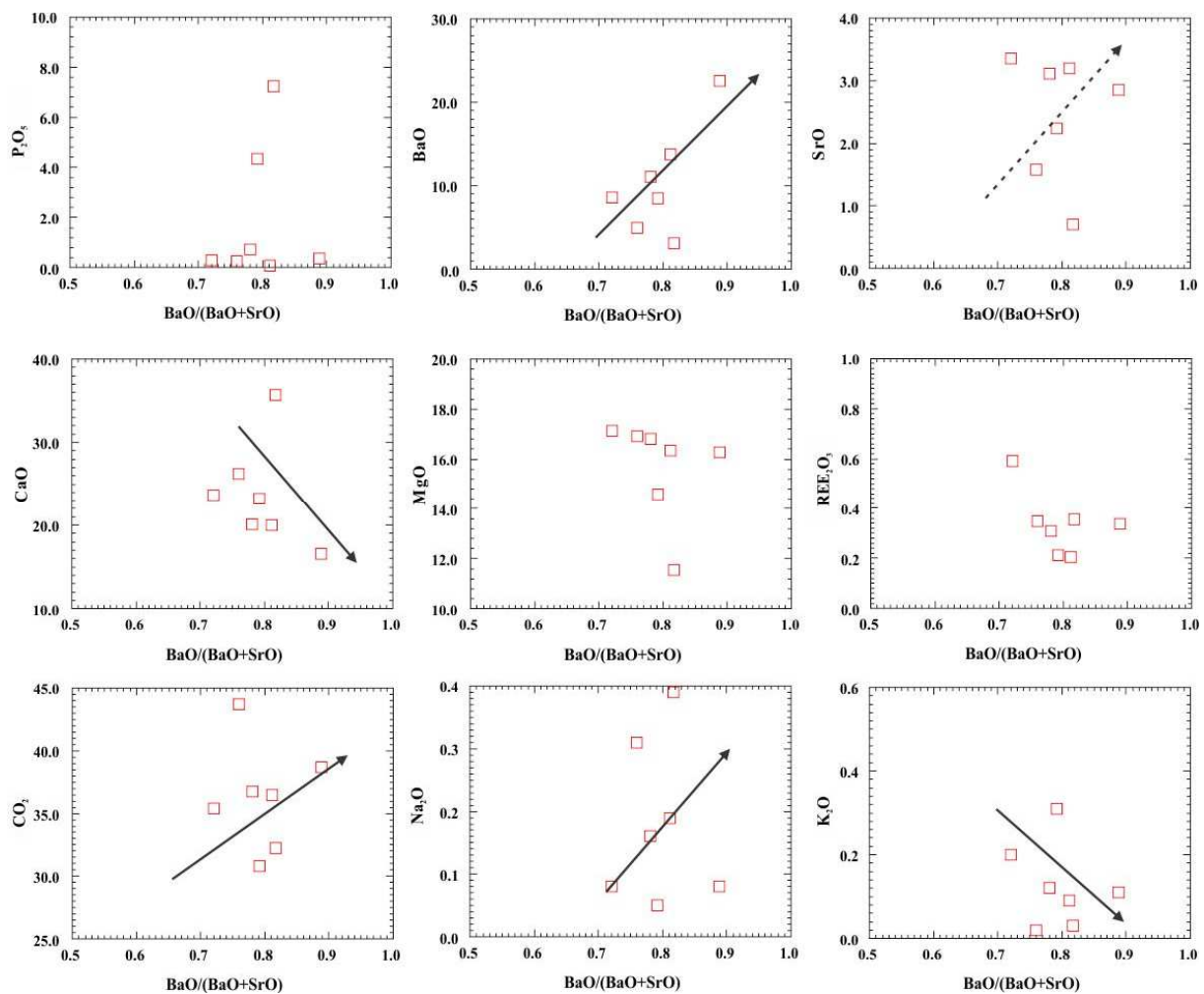


Figure 4.10 – Behavior of selected major element oxides with magma evolution in APiP C5 magnesiocarbonatites. Symbols as in figure 4.03.

Applying the same classification concepts to APIP carbonatite analyses from the literature (Grasso, 2010, Palmieri, 2010, Barbosa, 2009, Cordeiro, 2009, Comin-Chiaramonti *et al.*, 2005, Traversa *et al.*, 2001, Brod, 1999, Morbidelli *et al.*, 1997, Araujo, 1996, Machado Junior, 1992) it was possible to build compositional fields for the province. The general trends for the province (figure 4.11 and 4.12) are similar to those described before for our samples, such as increase in BaO and CO<sub>2</sub>, and decrease in K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> with evolution. Possible exceptions are some C1a apatite-rich cumulate rocks with anomalously high P<sub>2</sub>O<sub>5</sub>, associated with the fractionation of apatite, but not clear for the province as a whole.

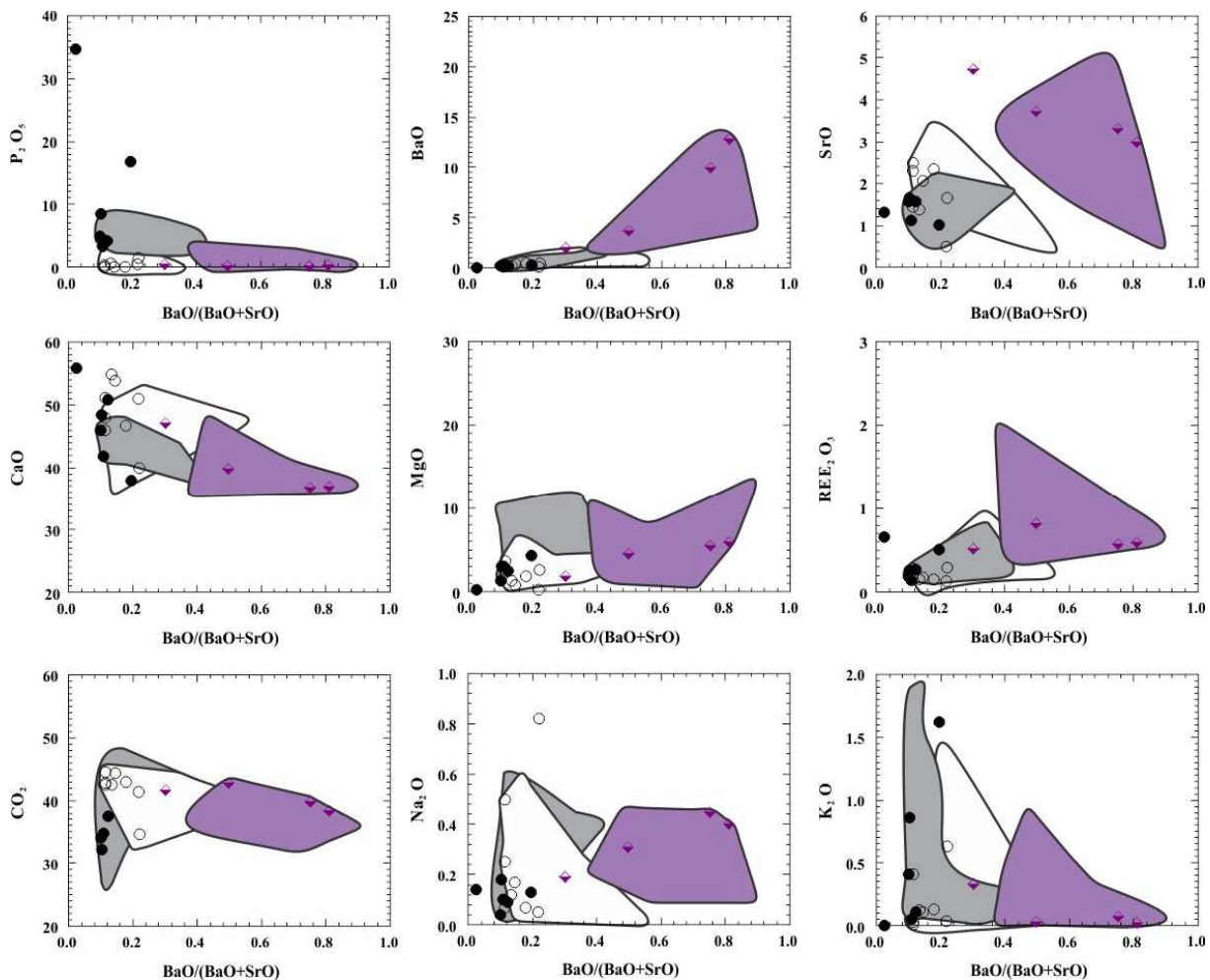


Figure 4.11 – Behavior of selected major element oxides with magma evolution for the APIP C1 and C3 calciocarbonatites, samples from this work compared with all province data (Grasso, 2010, Palmieri, 2010, Barbosa, 2009, Cordeiro, 2009, Comin-Chiaramonti *et al.*, 2005, Traversa *et al.*, 2001, Brod, 1999, Morbidelli *et al.*, 1997, Araujo, 1996, Machado Junior, 1991). Symbols as in figure 4.03; gray field: C1a, White field: C1b, violet field: C3.



C2 samples from this work plot inside the APIP carbonatite fields (figure 4.12), except for the  $\text{CO}_2$  and SrO contents of some samples, which cover slightly larger areas. In general, the classification fits well, maintaining the trends described for this group, such as increase in BaO and REE contents, whereas CaO is insensitive to evolution, and  $\text{P}_2\text{O}_5$  content is low.

Samples from the C3 group (figure 4.11) fit very well to the province fields. BaO, MgO and  $\text{Na}_2\text{O}$  increase whereas CaO, SrO,  $\text{K}_2\text{O}$  and  $\text{CO}_2$  decrease in the entire province, following the behavior described for this group from our samples.  $\text{P}_2\text{O}_5$  is low and insensitive to magma evolution.

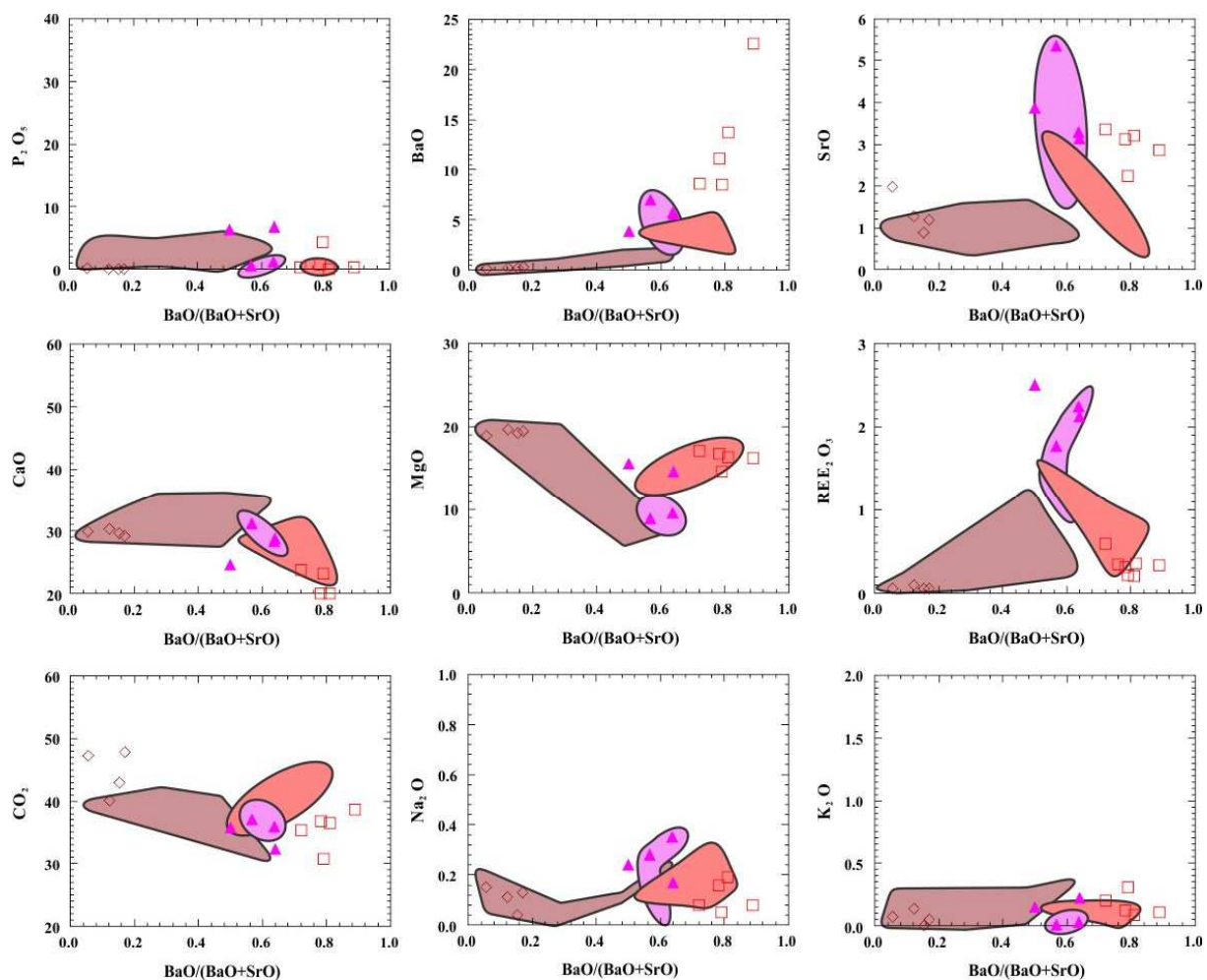


Figure 4.12 – Behavior of selected major element oxides with magma evolution for the APIP C2, C4 and C5 calcicarbonatites, samples from this work compared with data from the whole province (Grasso, 2010, Brod, 1999, Traversa et al., 2001, Palmieri, 2010, Barbosa, 2009, Cordeiro, 2009, Gomes e Comin Chiaramonti, 2005, Araujo, 1996, Morbidelli et al., 1997, Machado Junior, 1991). Symbols as in figure 4.03; brown field: C2, pink field: C4, red field: C5.

C4 group samples (figure 4.12) plot mostly inside the province fields or following the same trend. Available data for carbonatites with C4 characteristics in the whole province is scarce generating a restricted field, but even in this case the samples from our dataset and from the whole province have very similar chemical behavior which strengthens the efficiency of the devised classification scheme. The whole-province C4 trends are marked by high REE content, an increase in  $K_2O$ ,  $Na_2O$ , and a decrease in the concentration of  $BaO$ ,  $CaO$  and  $CO_2$ .

The C5 group shows only partial coincidence between the compositional range of our dataset and the whole province, suggesting that our samples have a more extreme composition, particularly for  $BaO$ . However, even when the fields do not coincide, the two trends are similar except for  $BaO$ . This group shows increasing  $BaO$ ,  $Na_2O$  and  $CO_2$  contents, and decreasing  $SrO$ ,  $CaO$ , REE,  $CO_2$  and  $K_2O$  with evolution.

#### 4.4.3 Trace Elements

Trace elements in the carbonatite magma may be greatly affected by specific late-stage fractionating phases such as sphene, apatite, perovskite, monazite, or zircon (e.g. Nelson *et al.*, 1988). Pyrochlore and baddeleyite, which are additional common phases in our sample set, may also have a great effect on some trace elements such as the HFSE and REE. Liquid immiscibility is another important process affecting trace element distribution in carbonatites and associated rocks, including major changes in geochemically similar element pairs, such as Nb-Ta, Zr-Hf and the REE (e.g. Brod *et al.*, 2013, Veksler *et al.*, 1998, 2012, Hamilton *et al.*, 1989).

Figure 4.13 shows the behavior of some key chondrite-normalized (Thompson *et al.*, 1982) elemental ratios with carbonatite evolution.  $La_{(n)}/Yb_{(n)}$  tends to increase with magma evolution within the same carbonatite group and, in most cases, between different groups. Group C5 is an exception, since most samples have lower  $La_{(n)}/Yb_{(n)}$  for high  $BaO/(BaO+SrO)$

$U_{(n)}/Th_{(n)}$  decreases with evolution in C1 group with significant fractionation, which may reflect the crystallization of pyrochlore.

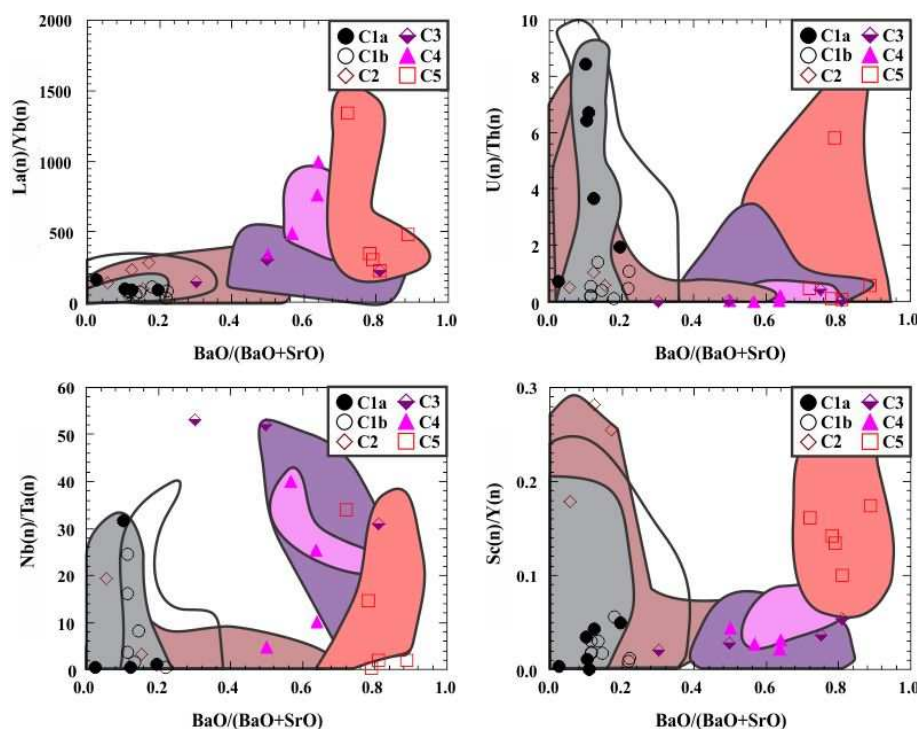


Figure 4.13 – Trace elements signature for this work APiP samples compared with all province data. Gray field: C1a, White field: C1b, violet field: C3, brown field: C2, pink field: C4, red field: C5.

The  $Nb_{(n)}/Ta_{(n)}$  ratio is complex, and its variation in figure 4.13 does not seem to be affected by fractional crystallization, since the variability of the  $Nb/Ta$  ratio is far greater than that of the  $BaO/(BaO+SrO)$ . Brod *et al.* (2013) have shown that liquid immiscibility in the Tapira Complex of APiP resulted in the increase of the  $Nb_{(n)}/Ta_{(n)}$  of the carbonate conjugate, sometimes by several orders of magnitude, if compared with the same ratio in the parental liquid. In our dataset most samples from C1a and some samples from C5 show values near 1.3, which is the  $Nb_{(n)}/Ta_{(n)}$  ratio of the parental magma of the APiP complexes (Brod *et al.*, 2013). For the other samples, the high values of  $Nb_{(n)}/Ta_{(n)}$  suggest that they have been involved in liquid immiscibility at some point in their evolution. The fact that there are variable  $Nb_{(n)}/Ta_{(n)}$  within a single group suggests that both crystal fractionation and liquid immiscibility played a role in magma evolution in most cases.

$Sc_{(n)}/Y_{(n)}$  displays an interesting behavior, allowing an efficient separation of groups C2 and C5, which show high values of this ratio.

#### 4.4.4 Multielementar diagrams and Rare Earth Elements

Figure 4.14 shows chondrite-normalized multielement diagrams (Thompson, 1982). The C1 carbonatites, both from Jacupiranga and APIP may be divided into: (a) carbonatites containing cumulus apatite, characterized by a positive anomaly in phosphorus, and (b) residual carbonatite from fractional crystallization processes, which have a negative P anomaly. According to this criterion alone, most C1b carbonatites from Jacupiranga should be considered apatite-rich cumulates. However, the behavior of other major and trace elements, as well as the distinct REE patterns between Jacupiranga C1a and C1b support the proposed division.

In Jacupiranga, the chondrite-normalized Nb/Ta are typically lower than 1 in C1 and higher than 1 in C2, although the differences are relatively small. In the APIP dataset C1b shows values of chondrite-normalized Nb/Ta significantly higher than most C1a samples, suggesting that liquid immiscibility may have played a role at a differentiation stage as early as C1b very early differentiation stages.

The two C1 subgroups may be recognized in chondrite-normalized rare earth elements diagrams (figure 4.14). The apatite-rich cumulates show higher REE concentrations, especially from medium- and light-REE, indicating that apatite is a major REE carrier at this stage in both Jacupiranga and the APIP. The  $La_{(n)}/Lu_{(n)}$  ratio of C1a from Jacupiranga varies from 52 to 92, whereas in C1b this ratio varies from 22 to 46. In the APIP early stage carbonatites,  $La_{(n)}/Lu_{(n)}$  varies from 100 to 250 for C1a and from 35 to 140 in C1b.

In the C2 magnesiocarbonatites, the Jacupiranga samples show a a P positive anomaly, indicating apatite accumulation, whereas the APIP samples always show a negative P anomaly, indicating that they are residual carbonatites. Regarding the chondrite-normalized Nb/Ta ratio the Jacupiranga C2 show values close to or lower than 1, suggesting that liquid immiscibility was not involved in their generation. Only two APIP samples have available Ta data. Both presents relatively high Nb/Ta, reaching up to 19, indicating that they are the product of immiscible liquids..

$La_{(n)}/Lu_{(n)}$  ratio of the C2 magnesiocarbonatites varies from 136 to 362 in the APIP and from 41 to 50 in Jacupiranga. Both C1 and C2 group in the carbonatites

of the APIP have total contents of REE higher than their equivalents in Jacupiranga, suggesting that the REE enrichment is a Province-related feature.

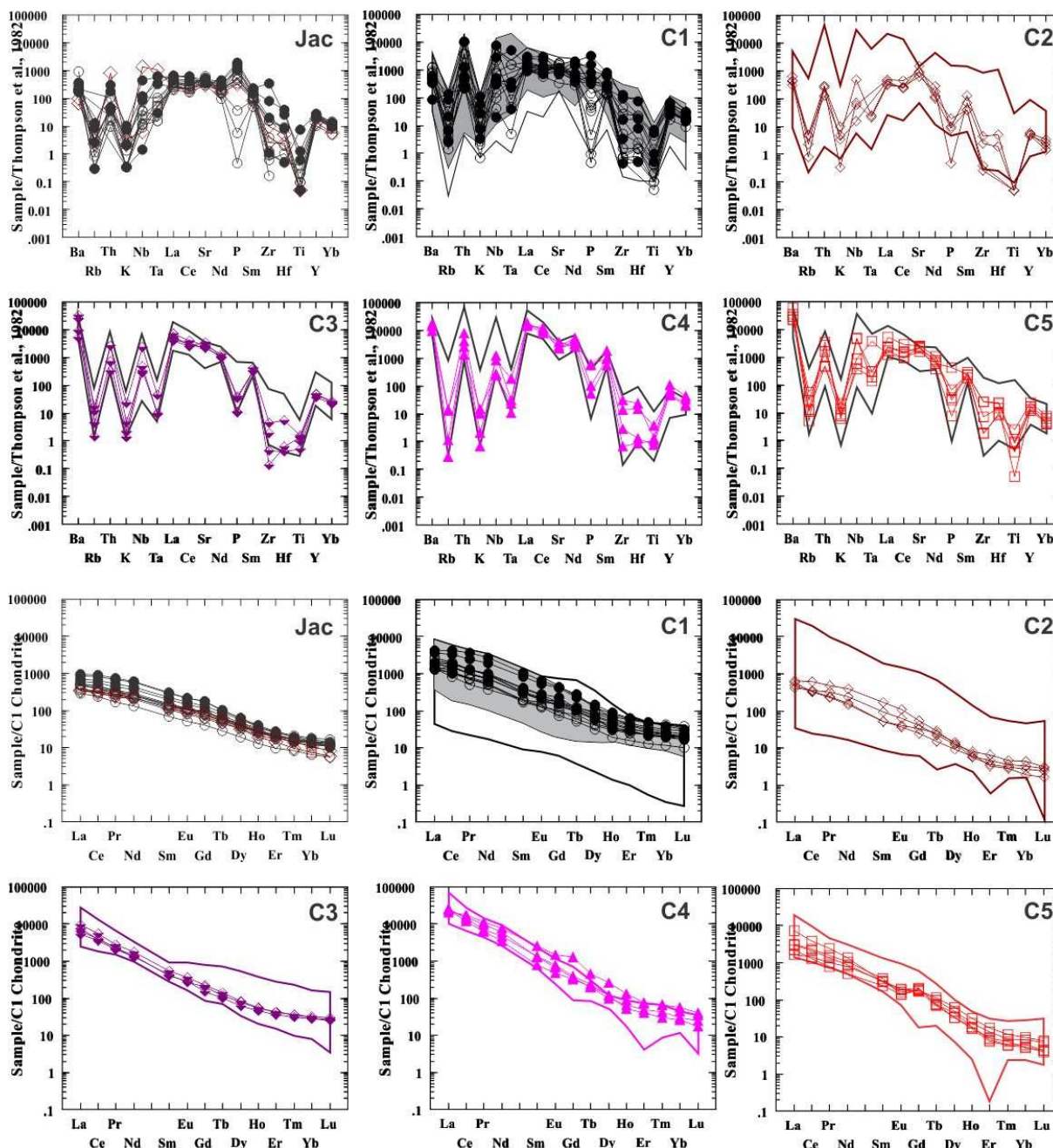


Figure 4.14 – Multi-element diagram for C1a, C1b, C2, C3, C4 and C5 carbonatites. The fields represents the province fields for each group and Rare Earth elements diagrams. The fields represents the APIP range for each group (gray = C1a, black outline = C1b). Symbols as in figure 4.03.

The C3 calciocarbonatites show a negative P anomaly and high chondrite-normalized Nb/Ta ratio (31 to 53), which indicates a relatively evolved carbonatite generated by liquid immiscibility and that underwent apatite fractionation. Their

$\text{La}_{(n)}/\text{Lu}_{(n)}$  ratio varies between 178 and 354, similar to C2 and slightly higher than C1.

The C4 magnesiocarbonatites exhibit a  $\text{Nb}_{(n)}/\text{Ta}_{(n)}$  ratio ranging from 5 to 40 and a negative P anomaly indicating the involvement of liquid immiscibility and the fractionation of apatite at an earlier stage of magmatic evolution. The samples of this group also have a slight negative Sr anomaly, which may be explained by fractionation of Sr-rich carbonates, such as strontianite or even Sr-rich calcite at an earlier stage. Alternatively, this feature may be an artifact of the monazite enrichment observed in C4. The REE diagram (Fig. 4.14) shows a strong LREE/HREE fractionation ( $\text{La}_{(n)}/\text{Lu}_{(n)}$  between 520 and 1515).

The magmatic evolution of the C5 group also involved immiscibility, in most cases, with  $\text{Nb}_{(n)}/\text{Ta}_{(n)}$  reaching a maximum of 37. Part of the C5 sample set shows negative P anomaly, indicating prior apatite fractionation. The REE diagram (Fig. 4.14) shows very strong LREE/HREE enrichment, the  $\text{La}_{(n)}/\text{Lu}_{(n)}$  ratio ranging from 180 to 1635.

#### 4.4.5 Stable Isotopes (C, O, S)

Figure 4.15 depicts the carbon, oxygen and sulfur stable isotope composition. The carbon and oxygen data were obtained from carbonates, using a Delta V Plus gas source mass spectrometer at the Geochronology Lab, University of Brasília, after reaction with phosphoric acid. The sulfur isotopic data were obtained by Gomide *et al.* (2013) in sulfides. The values are expressed in  $\delta$  notation per thousand (see calculation in chapter 1) compared to the PDB (Pee Dee Belemnite) reference standards for carbon, SMOW (Standard Mean Ocean Water) for oxygen and V-CDT (Vienna Canyon Diablo Troilite) for sulfur.

The Jacupiranga samples show a carbon and oxygen isotopic composition that evolves according to Rayleigh fractionation. All Jacupiranga samples plot inside the range defined as mantle values (Taylor *et al.*, 1967).

Similarly to Jacupiranga, the C1 calciocarbonatites from APIP show a C and O isotopic evolution by magmatic fractionation and all the samples have values consistent with the mantle range. The C2 magnesiocarbonatites also show isotopic evolution consistent with magma fractionation, but reach higher  $\delta^{18}\text{O}$  values,

slightly exceeding the mantle range. Some C2 samples suggest hydrothermal alteration trends, with a shift to high  $\delta^{18}\text{O}$  values at relatively constant  $\delta^{13}\text{C}$ .

C3 calciocarbonatites follow a magmatic fractionation trend, but one sample has a shift to higher  $\delta^{18}\text{O}$  values suggesting that it has been affected by hydrothermal alteration.

The C4 magnesiocarbonatites exhibit two trends, both starting within the mantle composition range. One trend evolves into heavier carbon and oxygen isotopic compositions, typical of magmatic fractionation or of interaction with fluids rich in both  $\text{H}_2\text{O}$  and  $\text{CO}_2$ , whereas the other evolves by increasing  $\delta^{18}\text{O}$  at relatively constant  $\delta^{13}\text{C}$ , indicative of hydrothermal alteration.

The C5 carbonatites also show two evolution trends, analogous to those observed in C4 and interpreted in the same way as (i) indicative of magmatic fractionation or interaction with carbohydrothermal fluids interaction, and (ii) hydrothermal alteration.

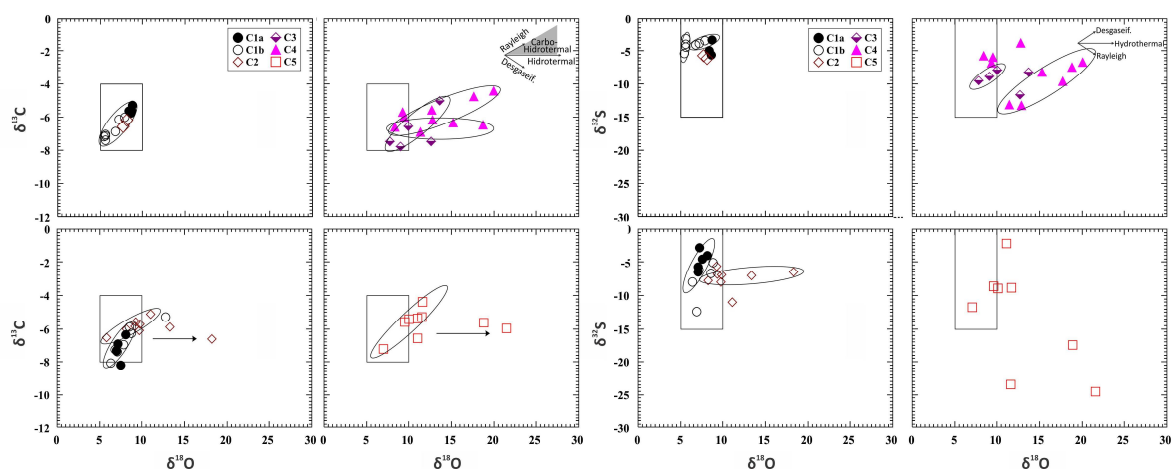


Figure 4.15 – Left side: Stable isotope composition of carbon and oxygen in carbonates for Jacupiranga and for APIP groups C1 to C5. Right side: Stable isotope compositions of sulfur in sulfides and oxygen in carbonates for Jacupiranga and for APIP groups C1 to C5. The rectangular field corresponds to the isotopic composition of the mantle defined for carbon and oxygen by Taylor et al. (1967) and for sulfur by Deines (1989), Mitchell & Krouse (1975), Druppel et al. (2006), Nikiforov et al. (2006). Arrows indicate changes expected in Rayleigh fractionation, low temperature hydrothermal alteration without the participation of  $\text{CO}_2$  and degassing (Ray & Ramesh, 2000, Taylor et al., 1967). The gray triangle in the inset illustrates the expected variations (e.g. Santos & Clayton, 1995) in low-temperature carbohydrothermal alteration with high  $\text{H}_2\text{O}:\text{CO}_2$  (1000:1) and variable fluid/rock ratios. Sulfur isotope data are from Gomide et al. (2013), carbon and oxygen data from this work.

Santos & Clayton (1995) interpreted carbon and oxygen isotopic differences between carbonatites from Jacupiranga and from the APIP as a result of different levels of intrusion. In that model, Jacupiranga carbonatites crystallized in a deeper-seated magma chamber, are less evolved and have more restricted isotopic compositions. The APIP carbonatites would have been emplaced in much shallower chambers, the lower lithostatic pressure allowing for a greater variety of differentiation processes. Our data are consistent with the interpretations of Santos & Clayton (1995). We interpret the APIP C1, C2 and C3 carbonatites as representing less evolved magmas, while C4 and C5 formed at later stages and therefore were more susceptible to processes such as degassing and subsequent hydrothermal and carbohydrothermal alteration. However, some interaction with external fluids cannot be ruled out, especially in the cases of  $\delta^{18}\text{O}$ -only variation.

Regarding the coupled variation in S and O isotopes, the Jacupiranga samples plot in a very restrict interval, compatible with mantle composition. The small composition ranges do not allow the definition of conclusive trends.

In the APIP samples, all groups show S isotopic composition compatible with the mantle range, except for a few C5 samples showing textural evidence of sulfur degassing and/or hydrothermal alteration (Gomide *et al.*, 2013).

APIP C1 calciocarbonatites show higher  $\delta^{34}\text{S}$  values, on average, than the C2 magnesiocarbonatites, and the latter define a clearly decreasing trend of  $\delta^{34}\text{S}$ , which is consistent with the observation that the  $\delta^{34}\text{S}$  values in sulfides decrease with magmatic evolution of each complex (Gomide *et al.*, 2013). Although the carbon-oxygen diagram suggests that some samples from this group were possibly affected by hydrothermal alteration the sulfur isotopes appear to be unaffected by this process.

The C4 samples with petrographic evidence of sulfur degassing (Gomide *et al.*, 2013) are aligned along two positive correlation lines in the  $\delta^{34}\text{S}$ - $\delta^{18}\text{O}$  diagram. Similar correlations are observed in the other groups (C1a, C3 and C4), and it is possible that this feature is a sulfur degassing characteristic. However, the joint behavior of sulfur and oxygen isotopes still needs to be studied in more detail, because the relationship between these two systems probably is not trivial. For example, the two elements participate in multiple minerals (carbonates, oxides, silicates, sulfates and sulfides), may be degassed as distinct species ( $\text{CO}_2$ ,  $\text{H}_2\text{S}$ ,



SO<sub>2</sub>) at different times during magmatic evolution and are sensitive to variations in the oxidation state of the system.

#### 4.5 Conclusions

A major difficulty in the study of carbonatite magmatism is to establish a numerical parameter for gauging magmatic evolution, analogous to differentiation indexes used in the study of silicate magmas, against which to measure other geochemical, isotopic, mineralogical and textural properties. This work proposes an integrated method of assessment of the magmatic differentiation stage in carbonatites of the Alto Paranaíba Igneous Province. The studied carbonatites were classified into the successively more evolved groups C1 to C5. The evolution of groups C1, C2, C3 and C5 may be monitored by BaO enrichment and P<sub>2</sub>O<sub>5</sub> depletion, whereas C4, a group of REE-rich carbonatites evolves through enrichment of both rare earths and phosphorus.

In this work we devise a differentiation index involving BaO and SrO apply it to our sample set and to data for APIP carbonatites from the literature.

The evolution of C1 calciocarbonatites results in increased calcite component in the magma, by removal of apatite (plus olivine, phlogopite and magnetite). In our samples, this mostly produces apatite cumulates (C1a) and a residual carbonatite (C1b).

The C2 Group consists of unevolved magnesiocarbonatites crystallizing apatite and dolomite, and may also represent cumulates (e.g. C2 samples from Jacupiranga) or residual carbonatite (e.g. C2 samples from APIP)

The C3 calciocarbonatites in our sample set are all from the Tapira Complex. This group is characterized by fractionation of apatite, calcite and phlogopite, leading to a residual concentration of Ba, Mg, and Na, and leading to the crystallization of carbonates as norsethite, baritocalcite and burbankite directly from the magma. This group marks the exhaustion of the silicatic component in calciocarbonatites, with the end of phogopite crystallization. The C3 geochemical characteristics, in particular its high chondrite-normalized Nb/Ta and the strong negative Zr and Hf anomalies, indicate that these melts were produced by liquid immiscibility (eg Brod *et al.*, 2013).

The C4 group consists of Ba-, Sr- and REE-rich magnesiocarbonatites. The main *liquidus* phases are dolomite, Fe-dolomite, norsethite and strontianite. Its distinctive feature is the strong enrichment in monazite, marked by a concomitant increase in  $P_2O_5$  and  $REE_2O_3$  with magmatic evolution. The geochemical characteristics indicate the involvement of liquid immiscibility in the evolution of these magmas.

The geochemical characteristics of the C5 group of magnesiocarbonatites indicate strong apatite and phlogopite fractionation, with decrease in CaO,  $P_2O_5$  and  $K_2O$ , and enrichment in Ba, Sr, Na and  $CO_2$ , resulting in direct crystallization of burbankite, strontianite and norsethite as liquid phases. Exsolutions of olekminskite and benstonite in norsethite, of olekminskite in dolomite, and of baritocalcite in calcite indicates that the C5 carbonatites were crystallized in still relatively high temperature conditions. The high chondrite-normalized Nb/Ta indicate the involvement of liquid immiscibility processes in the evolution of these magmas. Previous work (Junqueira-Brod *et al.*, In prep., Gomide *et al.* 2013) identified degassing of  $CO_2$  as well as sulfur an important petrogenetic process in samples of this group.

The carbon, oxygen and sulfur isotopic data are consistent with the interpretation of Santos & Clayton (1995) that the APIP complexes were emplaced at shallower crustal levels than the Jacupiranga complex. The lower lithostatic pressure at these shallower levels allowed a much greater diversity of petrogenetic processes to act in the evolution of the APIP carbonatite magmas, including fractional crystallization, liquid immiscibility, degassing and interaction with hydrothermal and carbohydrothermal systems, often in recurring events (Barbosa *et al.*, 2012; Cordeiro *et al.*, 2010; Brod *et al.*, 2013; Gomide *et al.*, 2013).

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## CAPÍTULO 5

### ***Mineralogy, Mineral Chemistry and subsolidus reactions in carbonatites from the Alto Paranaíba Igneous Province, SE Brazil***

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#### Abstract

We discuss the mineral chemistry of carbonates from carbonatites belonging to the Tapira, Araxá, Salitre, Serra Negra, Catalão I and Catalão II alkaline-carbonatite complexes of the Alto Paranaíba Igneous Province (APIP), central Brazil. The APIP complexes are composed of alkaline silicate rocks (bebedourite, alkali clinopyroxenite, minor syenite), phoscorites, nelsonites, and carbonatites. A diversity of carbonates were found in the province, in addition to calcite and dolomite (the two most common carbonate species), including strontianite, olekminskite, burbankite, ancylite, norsethite, barytocalcite, bastnaesite, parisite and benstonite. Early-stage calciocarbonatites and magnesiocarbonatites are typically composed of high temperature calcites and dolomites which, upon *subsolidus* recrystallization, exsolve burbankite, olekminskite and ancylite. Microinclusions of nyerereite and gregoryite/zemkorite constitute the first known occurrence of álcali carbonates in Brazilian carbonatites. Intermediate- and late-stage carbonatite crystallize strontianite, norsethite and barytocalcite as *liquidus* phases and very evolved carbonatites may may crystallize REE carbonates. The textural, mineralogical and compositional evidence presented here help understand the magmatic evolution of carbonatites by fractional crystalization, degassing and late-stage fluids.

**Keywords:** Carbonatite, carbonates, mineral chemistry.



## 5.1 Introduction

Carbonatite complexes and alkaline rocks from the Alto Paranaíba Igneous Province (APIP) and other alkaline provinces peripheral to the Paraná Basin have been the subject of studies comprising geochemistry, mineralogy, and stable (mostly C, O) and radiogenic (Sr, Nd, Pb, Os, Hf) isotopes (e.g. Barbosa *et al.*, 2012, Cordeiro *et al.*, 2011, Ruberti *et al.*, 2008, Carlson *et al.*, 2007, Comin-Chiaramonti and Gomes, 2005, Comin-Chiaramonti *et al.*, 2001, Gibson *et al.*, 1995, Santos and Clayton, 1995). In this work we report the carbonate mineralogy from APIP carbonatites and discuss the petrogenetic implications for the magma evolution at the single-complex and Province scales.

Alkaline rocks and alkaline-carbonatite associations include highly variable petrographic types and a correspondingly extensive nomenclature. We adopt the nomenclature defined by Le Maitre *et al.* (2002), Sahama (1974), Le Bas (1979), Yegorov (1993), Wall and Zaitsev (2004) and Barbosa *et al.* (2012) to which the reader is referred for detailed nomenclature discussions.

Based on interpretations and evolution models of previous works (Ribeiro *et al.*, 2014, Cordeiro *et al.*, 2011; Palmieri, 2011; Cordeiro *et al.*, 2010; Grasso, 2010; Barbosa, 2009; Cordeiro, 2009; Ribeiro, 2008; Brod, 1999) and new geochemical and isotopic data, Gomide *et al.* (in preparation) propose a classification of APIP carbonatites according to mineralogical composition, geochemistry, textural characteristics and magmatic stage of evolution, which will also be used in this work.

A range of carbonate species are described from carbonatites complexes, including essential phases such as calcite, dolomite and ankerite, and carbonates of a more restricted occurrence such as spurrite, siderite, burbankite, huanghoite, ancylite, carbocernaite, barytocalcite, norsethite, calcio-ancylite, magnesite, witherite, bastnaesite and parisite (Manfredi, 2013, Chakmouradian & Zaitsev, 2002, Zaitsev *et al.*, 2002, Traversa *et al.*, 2001; Andrade *et al.*, 1999; Harmer & Gittins, 1997; Jones *et al.*, 1996, Bailey, 1993; Gomes *et al.*, 1990). In this work, we describe some of these carbonates and discuss their implications in magma evolution and in *subsolidus* reactions.

Evolved carbonatites are described all over the world and there is a consensus in the literature that many REE-rich carbonates are more common in late-stage carbonatites (Zaitsev *et al.*, 2002; Andrade *et al.*, 1999, Wall & Mariano, 1996) and may be interpreted as secondary replacement products (e.g. Ruberti *et al.*, 2008; Andrade *et al.*, 1999; Hogarth *et al.*, 1985). However, some papers show that these minerals may occur as phases directly crystallized from late stage carbonatite magmas or carbohydrothermal solutions (Zaitsev *et al.*, 2014, Ribeiro, 2008, Böhn *et al.*, 1999).

This work discusses the crystallization of some of these phases from late-stage carbonatite magmas or carbohydrothermal solutions, and/or as a product of *subsolidus* exsolutions from other carbonates (calcite, dolomite and norsethite).

## 5.2 Geological Setting

Voluminous Cretaceous alkaline magmatism occurred in central and southern Brazil, and in eastern Paraguay (Comin-Chiaramonti *et al.*, 1996, 2005). Gibson *et al.* (1995) interpreted the Early-Cretaceous alkaline magmatism (ca. 130 Ma) and the contemporaneous Paraná magmatism as related with the Tristan da Cunha mantle plume, whereas Gibson *et al.* (1995, 1997) and Brod *et al.* (2005) correlated the Late-Cretaceous magmatism (ca. 85 Ma) at the north and northeast borders of Paraná Basin with the impact of Trindade mantle plume (Gibson *et al.* 1995) at the sub-continental lithosphere of central Brazil.

The APIP results from an intense Late-Cretaceous alkaline magmatism that generated intrusive (dykes, plugs, diatremes, and carbonatitic complexes) and extrusive (lavas and pyroclastic rocks) bodies (Carlson *et al.*, 2007, Comin-Chiaramonti and Gomes, 2005, Brod *et al.*, 2000, Gibson *et al.*, 1995, Leonardos *et al.*, 1991). Figure 5.01 shows the location of each carbonatite complex in the province.

The APIP is one of the largest ultramafic-ultrapotassic provinces of the world (Gibson *et al.* 1995). Kamafugite is by far the dominant rock-type in the province, forming one of the few known kamafugite-carbonatite associations (Brod *et al.*, 2000).

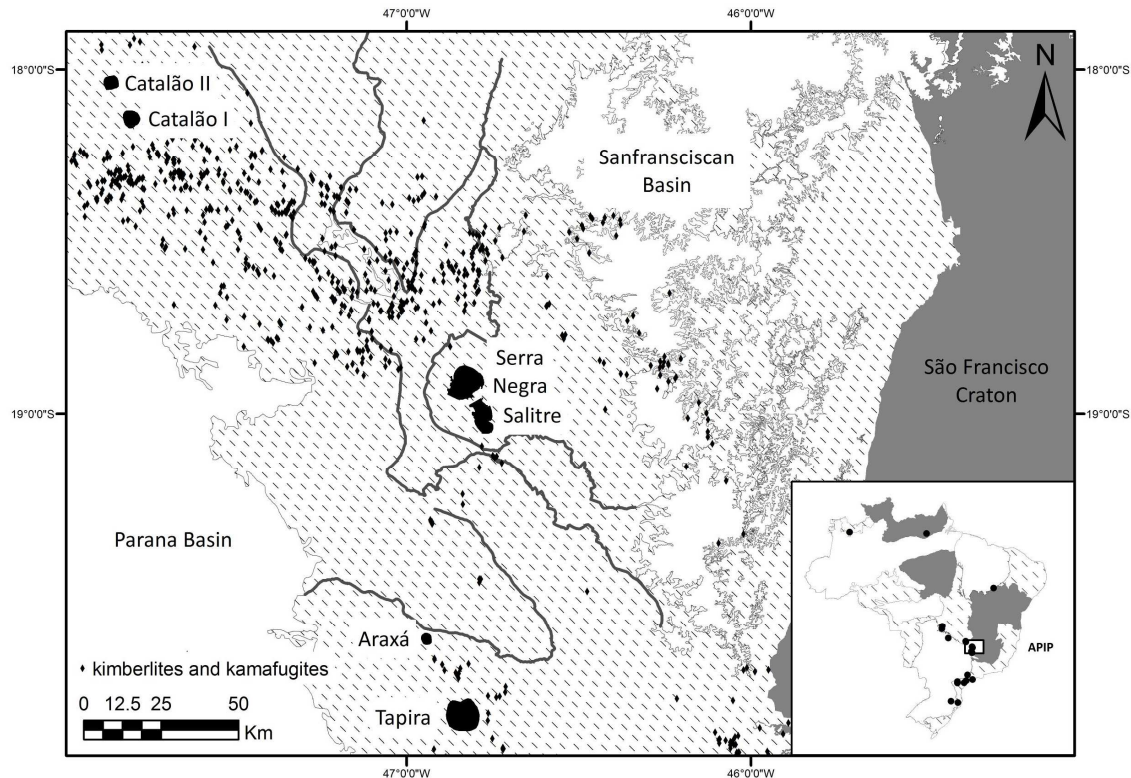


Figure 5.01 – Alkaline-carbonatite complexes from Alto Paranaíba Igneous Province (APIP). Modified from Oliveira *et al.* (2004) and Wooley and Kjarsgaard (2008).

The APIP alkaline carbonatite complexes are multi-stage intrusions formed by rocks derived from the bebedourite, carbonatite and phoscorite petrogenetic series, which are related to each other by fractional crystallization, liquid immiscibility and degassing (Brod *et al.*, 2004, Ribeiro, 2008, Barbosa, 2009, Cordeiro *et al.*, 2010, Barbosa *et al.*, 2012, Brod *et al.*, 2013). The ultramafic rocks of all complexes show variable degrees of metasomatism by fluids resulting from extreme carbonatite differentiation. The relatively shallow character of the APIP intrusions is indicated by C and O isotopes (Santos and Clayton, 1995), within-magma chamber pyroclastic deposits (Ribeiro *et al.*, 2005), and similarities with xenoliths in volcanic and sub-volcanic kamafugites in the province (Brod *et al.*, 2000, Seer and Moraes, 1988).

Table 5.01 summarizes the mineralogical and petrographic characteristics of each complex.

*Table 5.01 – Characteristics of alkaline carbonatite complexes from the Alto Paranaíba Igneous Province*

	rock types	General observations	References
Catalão I	dun, cpxt, beb, carb, phosc, nels, phlt	Evolved from a phlogopite-picrite magma by several stages of fractional crystallization and liquid immiscibility. Magnesiocarbonatite is by far the dominant carbonatite type in the complex.	Brod <i>et al.</i> , 2004; Ribeiro, 2008, Cordeiro <i>et al.</i> , 2010
Catalão II	pxt, quartz syenites, alkali-feldspar syenites, Ca-carb, Si-carb, Mg-carb, lamp, phlt	Two main magmatic systems, one dominated by calciocarbonatites, phoscorites and bebedourites, in the north, and the other dominated by magnesiocarbonatites and nelsonite, in the south.	Machado Junior (1992), Palmieri <i>et al.</i> (2010)
Serra Negra	dun, beb, Ca-carb, Mg-carb, trach	The largest APIP carbonatite complex, with 65 km <sup>2</sup> , intruded Precambrian metasedimentary rocks generating a very pronounced dome structure.	Grasso <i>et al.</i> 2010, Brod <i>et al.</i> 2004
Salitre	beb, dun, pvkt, ting, trach, fen, phosc, ap-carb, Ca-carb, Mg-carb	Consists of three bodies located to the south of the Serra Negra Complex, and compose with the latter a system of coalescing intrusions	Mariano & Marchetto, 1991, Brod <i>et al.</i> , 2004, Barbosa <i>et al.</i> , 2010
Araxá	carb, phosc, phlt derived from the metasomatism of ultramafic rocks (beb and dun). Mg-carb is the dominant.	Intruded into Neoproterozoic schists and quartzites, generating a dome structure	Seer 1999
Tapira	beb, with subordinate carb and syenite with rare melilit and dun, all cut by ultramafic dikes of kamafugite affinity.	Approximately elliptic, with 35km <sup>2</sup> . Calciocarbonatite dominates over magnesiocarbonatite.	Brod <i>et al.</i> , 2003
<p>* dun=dunite, cpxt=clinopyroxenite, beb=bebedourite, carb=carbonatite, phosc=phoscorite, nels=nelsonite, phlt=phlogopites, pxt=pyroxenites, quartz syenites, alkali-feldspar syenites, Ca-cbt=calcite carbonatites, Si-cbt= silico-carbonatites, Mg-cbt=dolomite carbonatites, lamp= lamprophyres, trach=trachytes, pvkt=perovskite, ting=tinguaite, ap-carb=apatite-carbonatite, fen=fenite, melilit=melilitolite.</p>			

### 5.3 Materials and Methods

The rocks were fixed on a glass slide and polished at the thin-sectioning laboratory at the University of Brasilia. The rock mineralogy was defined by optical microscopy and then the slides were carbon-coated and characterized with JXA-8230 electron probe microanalysers at the Universities of Brasilia and Goiás (Brazil), by scanning electron microscopy at the High Resolution Microscopy Laboratory (LabMic), University of Goiás and at the Electron Microscopy and X-Ray Analysis Laboratory (LAMARX), Cordoba Nacional University (Argentina). X-Ray Diffraction analyses by the powder method were obtained at the Universities of Brasilia and Goiás, using a Rigaku Ultima IV and a Bruker D8 Discover respectively.

## 5.4 Results and Discussion

Gomide *et al.* (in preparation) classify the APIP carbonatites in at least five groups (C1, C2, C3, C4 and C5). C1 are unevolved calciocarbonatites, subdivided into C1a and C1b for P<sub>2</sub>O<sub>5</sub> contents respectively higher and lower than 3 wt. %, the former representing apatite-rich cumulates.

C2 are unevolved magnesiocarbonatites where the high temperature dolomite typically shows burbankite exsolutions due to reequilibration at *subsolidus* temperatures. C3 comprises calciocarbonatites with high BaO contents, and containing calcite, barytocalcite, norsethite and strontianite as carbonate phases. C4 is a Ba-Mg-Carbonatite dominated by dolomite, Fe-rich dolomite, strontianite, ancylite, parasite and bastnaesite with the dolomite containing burbankite and ancylite exsolutions.

C5 magnesiocarbonatites are dominated by dolomite and Fe-rich dolomite, with subordinate calcite, norsethite, burbankite and strontianite. Norsethite contains exsolutions of olekminskite and benstonite, dolomite contains exsolutions of olekminskite, and calcite exsolves barytocalcite.

Table 5.02 lists the carbonates that will be discussed in this work and their respective chemical formulae.

*Table 5.02 Carbonates discussed in this work with the respective chemical formulae.*

Mineral	Chemical Formula
Ancylite	(Sr,Ca) <sub>2</sub> REE <sub>2</sub> (CO <sub>3</sub> ) <sub>4</sub> (OH)·2H <sub>2</sub> O
Barytocalcite	BaCa(CO <sub>3</sub> ) <sub>2</sub>
Bastnaesite	REE <sub>2</sub> (CO <sub>3</sub> ) <sub>2</sub> F <sub>2</sub>
Benstonite	(Ba,Sr) <sub>6</sub> (Ca,Mn) <sub>6</sub> Mg(CO <sub>3</sub> ) <sub>13</sub>
Burbankite	(Na,Ca) <sub>3</sub> (Sr,Ba,ETR) <sub>3</sub> (CO <sub>3</sub> ) <sub>5</sub>
Calcite	CaCO <sub>3</sub>
Dolomite	CaMg(CO <sub>3</sub> ) <sub>2</sub>
Fe-dolomite	Ca(Mg,Fe)(CO <sub>3</sub> ) <sub>2</sub>
Gregoryite	(Na,K,Ca) <sub>2</sub> (CO <sub>3</sub> ) <sub>2</sub>
Norsethite	BaMg(CO <sub>3</sub> ) <sub>2</sub>
Nyerereite	Na <sub>2</sub> Ca(CO <sub>3</sub> ) <sub>2</sub>
Olekminskite	Sr(Sr,Ca,Ba)(CO <sub>3</sub> ) <sub>2</sub>
Parasite	Ca(Ce,La) <sub>2</sub> (CO <sub>3</sub> ) <sub>3</sub> F <sub>2</sub>
Strontianite	Sr <sub>2</sub> (CO <sub>3</sub> ) <sub>2</sub>
Zemkorite	(Na,K) <sub>2</sub> Ca(CO <sub>3</sub> ) <sub>2</sub>

Figure 5.02 illustrates the mineralogical composition of the C1 to C5 groups. Calcite is the essential constituent of C1 and C3 and may be locally present in C2 and C4. Dolomite is the dominant carbonate in C2, C4 and C5. Strontianite and norsethite are typically present in C3, C4 and C5. REE carbonates are present as *liquidus* phases only in the late-stage C4 and C5 carbonatites, but may occur as *subsolidus* exsolutions in other groups. Olivine occurs only in C1 carbonatites, apatite is typical of C1 but may be present as a subordinate constituent in C2, C3, C4 and C5, in progressively smaller amounts. Baryte is present in the more evolved groups, C3, C4 and C5, but also in a few C2 samples. Magnetite is present consistently in the early stages. Phlogopite may be present in all groups but becomes progressively rarer and evolves toward tetraferriphlogopite from C3 on.

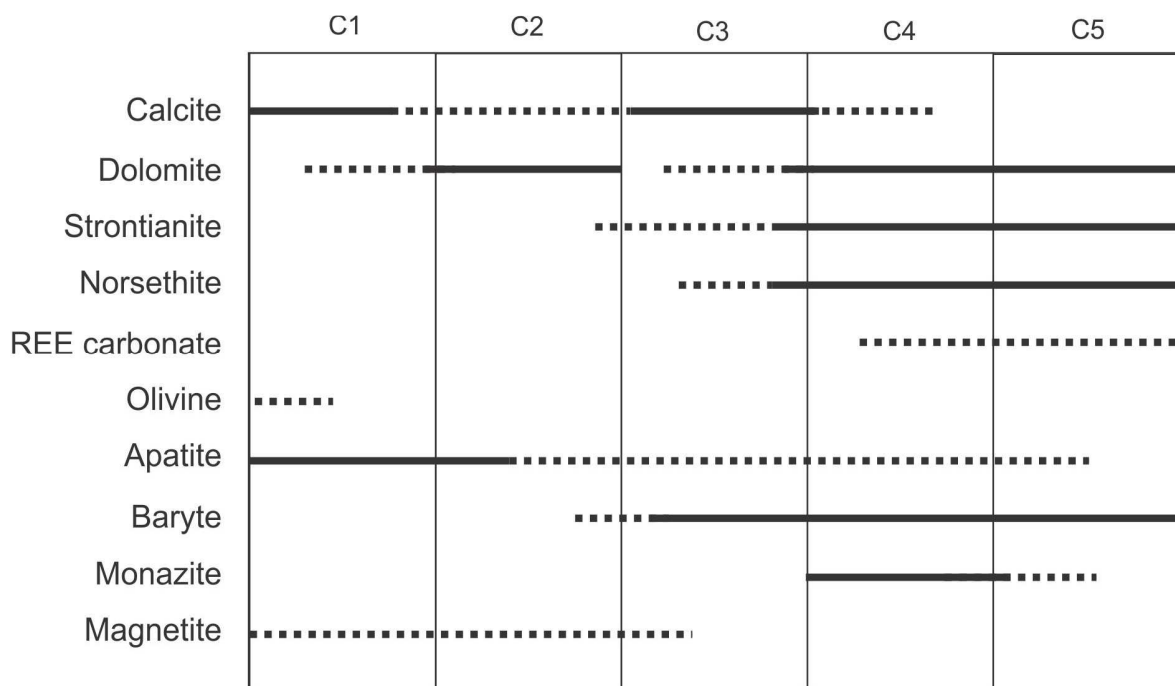


Figure 5.02– Mineral compositions from C1 to C5. REE carbonate includes ancylite and/or bastnaesite and/or parisite.

### 5.4.1 Electron imaging and compositional mapping

The C1 group of unevolved calciocarbonatites is characterized by the dominance of calcite over dolomite. The abundant exsolutions present in the calcite indicate that it crystallized at high temperature, incorporating many impurities, later exsolved as dolomite, strontianite, olekminskite, burbankite, norsethite and fewer ancylite exsolutions during *subsolidus* reequilibration.

An alkaline carbonate with Na and K, that probably is nyerereite and gregoryite and/or zemkorite (figure 5.03) is also present as microinclusions in C1 calcite, and is the first occurrence of alkaline carbonate reported from Brazilian carbonatites. The presence of alkaline carbonate inclusions is important because it indicates that the carbonatitic magma was originally enriched in alkalis. The presence of alkalis in calcio and magnesiocarbonatite is a subject of constant debate, since the levels of these elements are very low in most carbonatite whole-rock geochemical analysis (e.g. Wooley & Kempe, 1989), but the only modern carbonatite lavas are alkali-rich (e.g. Oldoinyo Lengai, Tanzania, Zaitsev *et al.*, 2008, 2009, Bailey, 1993; Dawson, 1989). Chen *et al.* (2013) described Na- and K-bearing magmatic carbonates in their chemical investigation of melt inclusions in the Oka complex, Canada. Mitchell and Kjarsgaard (2010) experimentally determined that crystallization under hypabyssal conditions could result in gregoryite cumulates, and dolomite- and eitelite-bearing assemblages. Zaitsev *et al.* (2010) described nyerereite inclusions in calcite carbonatites from Tanzania, similar to the feature described here. It is possible that calciocarbonatites and magnesiocarbonatites are originally alkali-rich magmas, that lost Na and K during degassing events, or that they represent early calcite and dolomite cumulates, where most of the original K and Na remained in the residual liquid (Lee & Wyllie, 1998, Bailey, 1993, Bailey & Hampton, 1990, Macdonald and Bailey, 1973, Dawson, 1964).

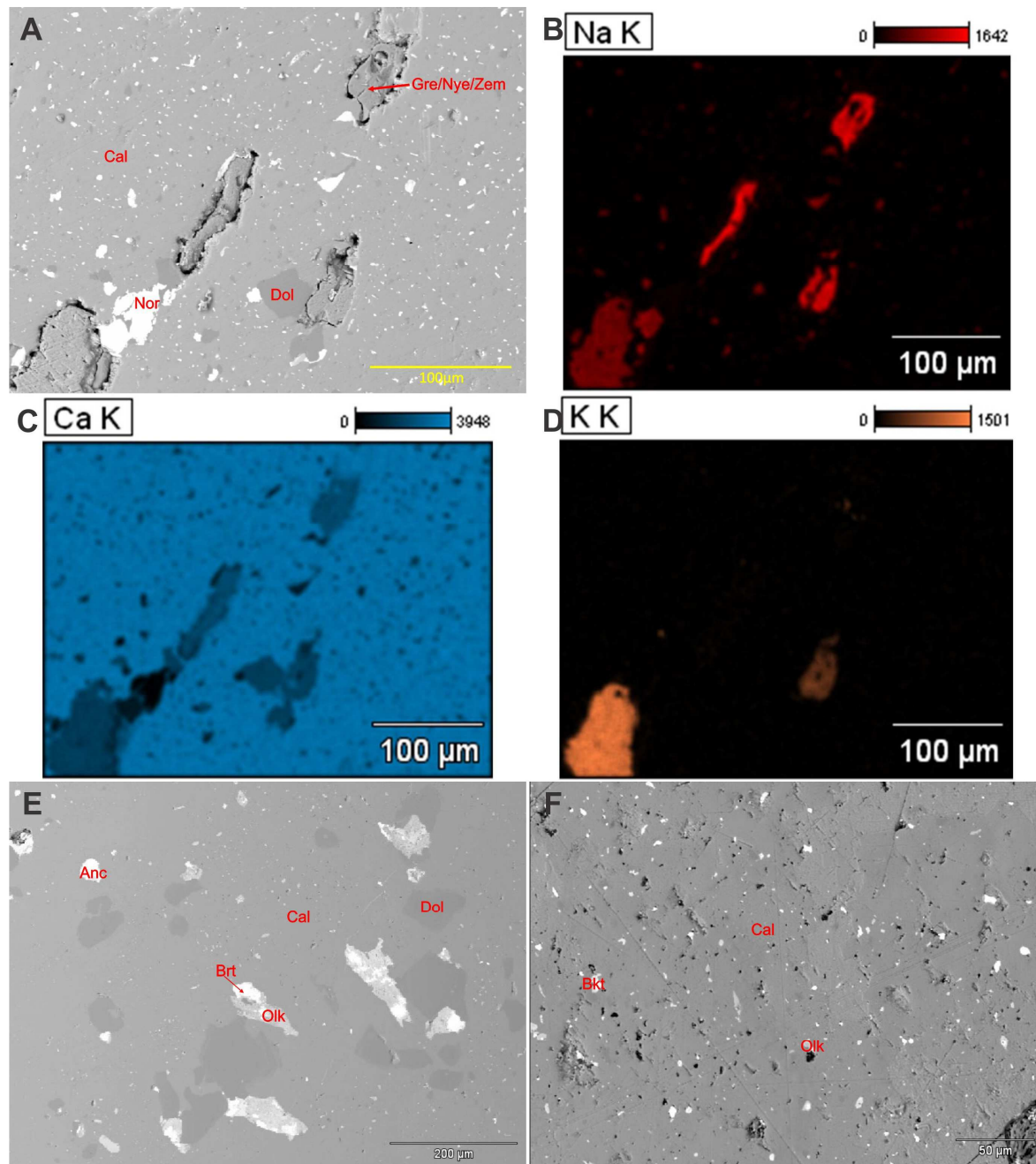


Figure 5.03 – Group C1. Backscattering electron images and EDS mapping of carbonates. A) calcite with dolomite, norsethite and olekminskite exsolutions, and nyerereite, gregoryite or zemkorite inclusions; B) Na EDS map showing the Na-rich carbonates. C) Ca EDS map showing the Ca-rich carbonates. D) K EDS map, showing the K-rich carbonates. E) calcite with dolomite, olekminskite and ancylite exsolutions. F) Calcite with burbankite and olekminskite exsolutions. Cal: calcite, bkt: burbankite, dol: dolomite, gre: gregoryite, nor: norsethite, nye: nyerereite, olk: olekminskite, zem: zemkorite.

The C2 group comprises unevolved magnesiocarbonatites. The carbonate in this rock is typically dolomite, whose exsolutions of calcite, olekminskite, burbankite and ancylite (figure 5.03) suggest high temperature crystallization.



Some of the calcite inclusions in dolomite contain their own burbankite and barytocalcite exsolutions, suggesting a very complex *subsolidus* cooling history for these rocks.

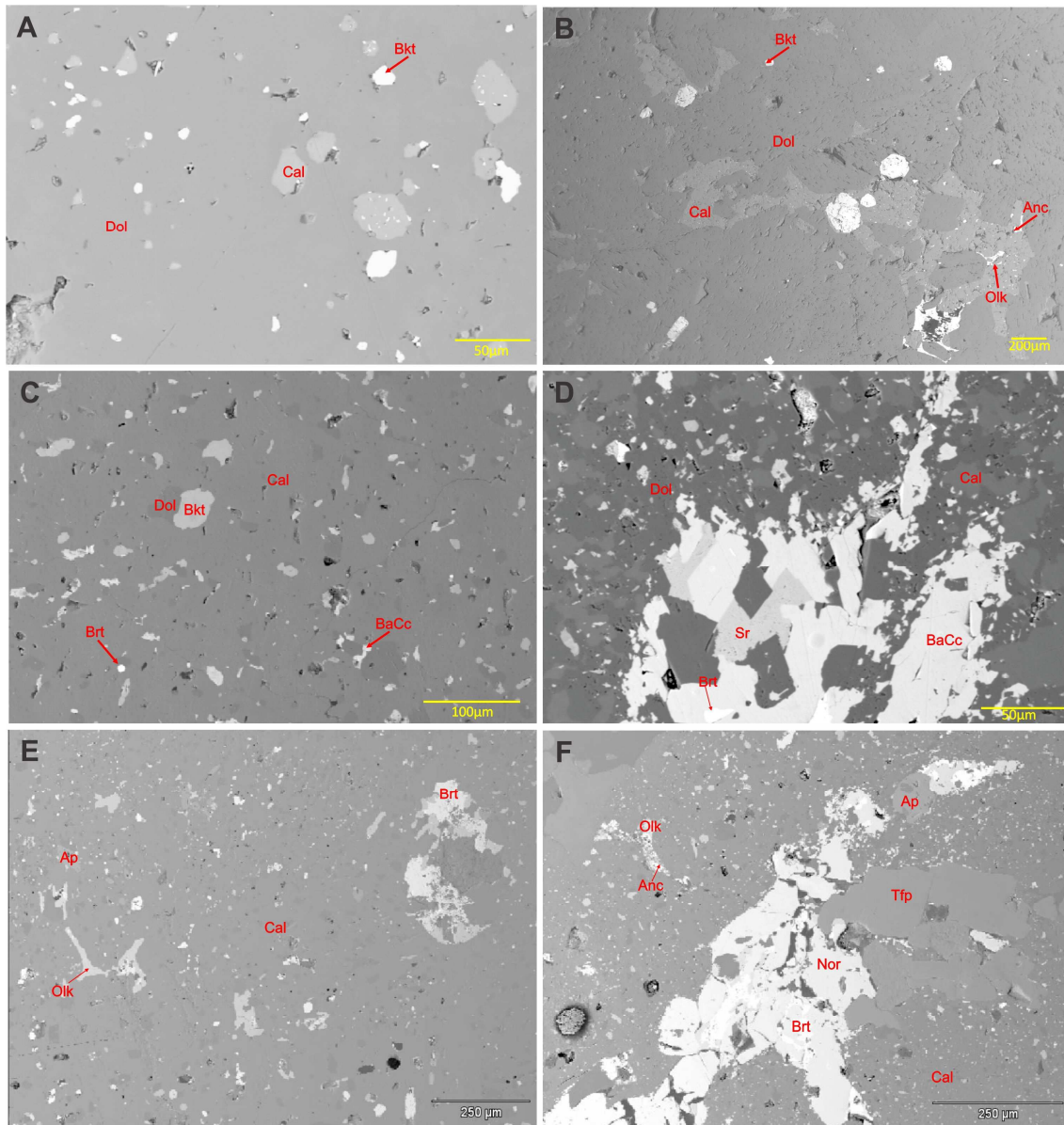


Figure 5.04 – Backscattering electron images of carbonates. C2 magnesiocarbonatites: A – dolomite with calcite and burbankite exsolutions. B – dolomite with calcite, burbankite, olekminskite and ancylite exsolutions. C3 calciocarbonatites: C - calcite with exsolved burbankite, dolomite and barytocalcite; D – Calcite and dolomite with pockets representing direct crystallization of strontianite, baritocalcite and barite; E – calcite with olekminskite exsolutions, apatite microinclusions and barite pockets; image F – Liquidus tetraferriphlogopite, apatite, norsethite, barite, and calcite, the latter with abundant olekminskite and ancylite exsolutions. Anc: ancylite, bck: baritocalcite, bkt: burbankite, brt: baryte, cal: calcite, dol: dolomite, olk: olekminskite, str: estrontianite, tfp: tetraferriphlogopite.

C3 calciocarbonatites are characterized by abundant exsolutions (figure 5.04c-f) of dolomite, burbankite, baritocalcite, ancylite and olekminkite in calcite, indicating the high temperature origin of the latter. Well developed crystals of strontianite, baritocalcite and norsethite in some areas suggest that these minerals appear as *liquidus* phases for the first time at the C3 evolution stage. Figure 5.05 illustrate the chemical composition of a calcite with and without exsolutions.

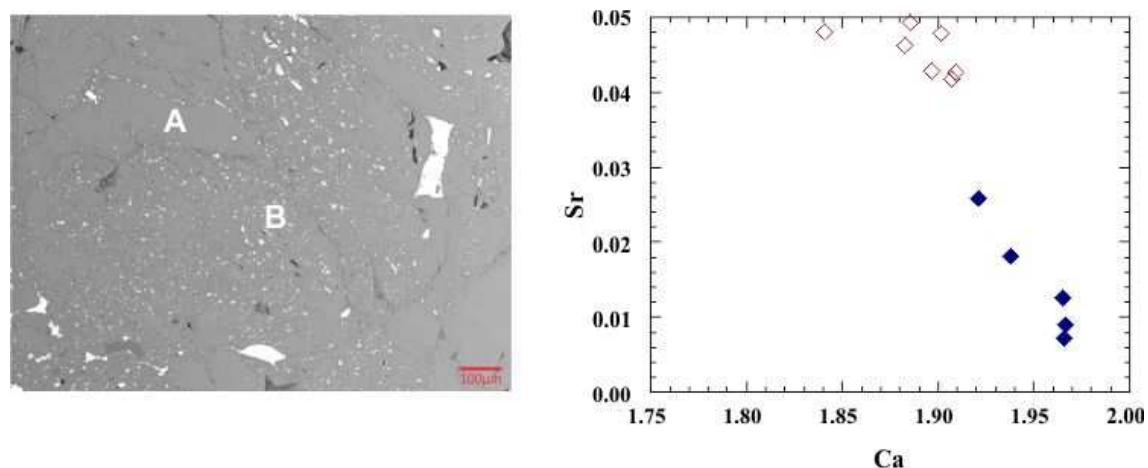


Figure 5.05 – Backscattering electron image of C3 calciocarbonatite showing a high-Sr inclusion-free calcite (indicated by A and by open diamond symbols). Calcite containing large amounts of exsolutions (B, solid diamonds) show a lower Sr content.

The C4 magnesiocarbonatites are dominated by dolomite and Fe-rich dolomite, with calcite, norsethite and strontianite as subordinate *liquidus* phases. Calcite, ancylite and burbankite are exsolved from dolomite, and barytocalcite is exsolved from calcite. Although they are enriched in Ba, the C4 carbonatites do not contain much norsethite. In these rocks, the major Ba carrier is barite. This group is also the first in the evolution sequence that contains independently crystalized REE minerals, comprising monazite and carbonates (ancylite, parisite and bastnaesite).

Figure 5.06 illustrates some textural relationships in C4 carbonatites. Barite, dolomite and sulphides generally show equilibrium textures, while the colomorph monazite, and the radial fibrous bastnaesite aggregates may result from alteration other minerals by REE-rich fluids. In some cases strontianite seems to be in equilibrium with a primary paragenesis (figure 5.06e) and in others it seems to be a late-stage product, associated with monazite (figure 5.06d).

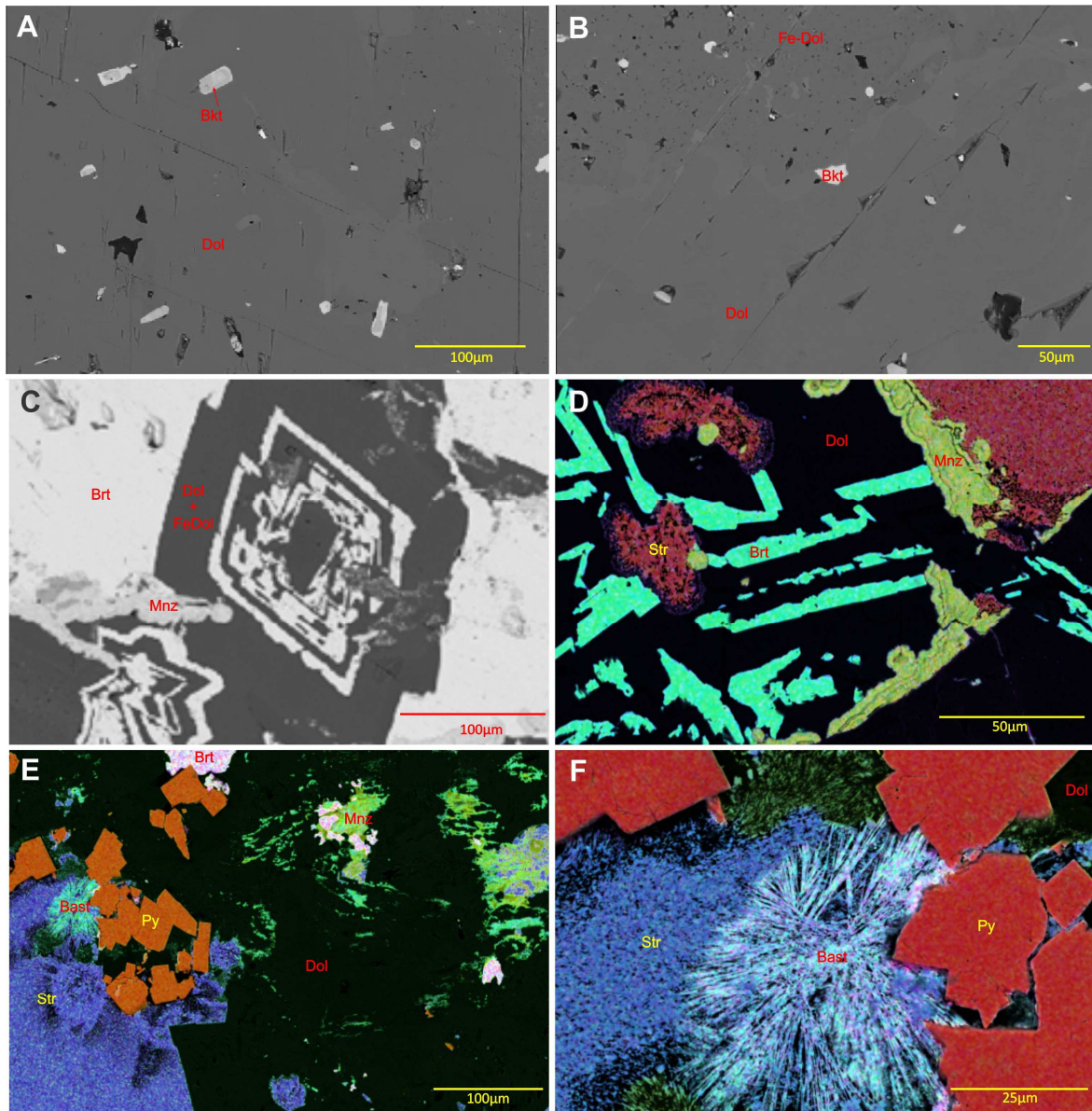


Figure 5.06 – Backscattering electron images of C4 magnesiocarbonatites. A – zoned burbankite inclusions in dolomite. B – dolomite and Fe-rich dolomite with burbankite inclusions. C – rhythmic intergrowth of dolomite and barite. Note the presence of monazite with a collomorph aspect. D – false-color EDS mapping, showing the relationship between dolomite, barite, strontianite and monazite. E – false-color EDS mapping, showing textural relationships between dolomite, barite, strontianite, monazite and pyrite. Dolomite, barite, pyrite and, probably, part of the strontianite are primary phases, whereas the bastnaesite and the monazite may have been formed as late-stage substitution products of other carbonates. F – Detail from the left portion of “E”, showing fibrous bastnaesite. Brt: baryte, dol: dolomite, fedol: fe-dolomite, mnz: monazite, str: strontianite, bast: bastnaesite, py: pyrite.

Burbankite inclusions in dolomite are sometimes euhedral and concentrically zoned (figure 5.06a) suggesting that burbankite was already crystallized when the dolomite was formed.

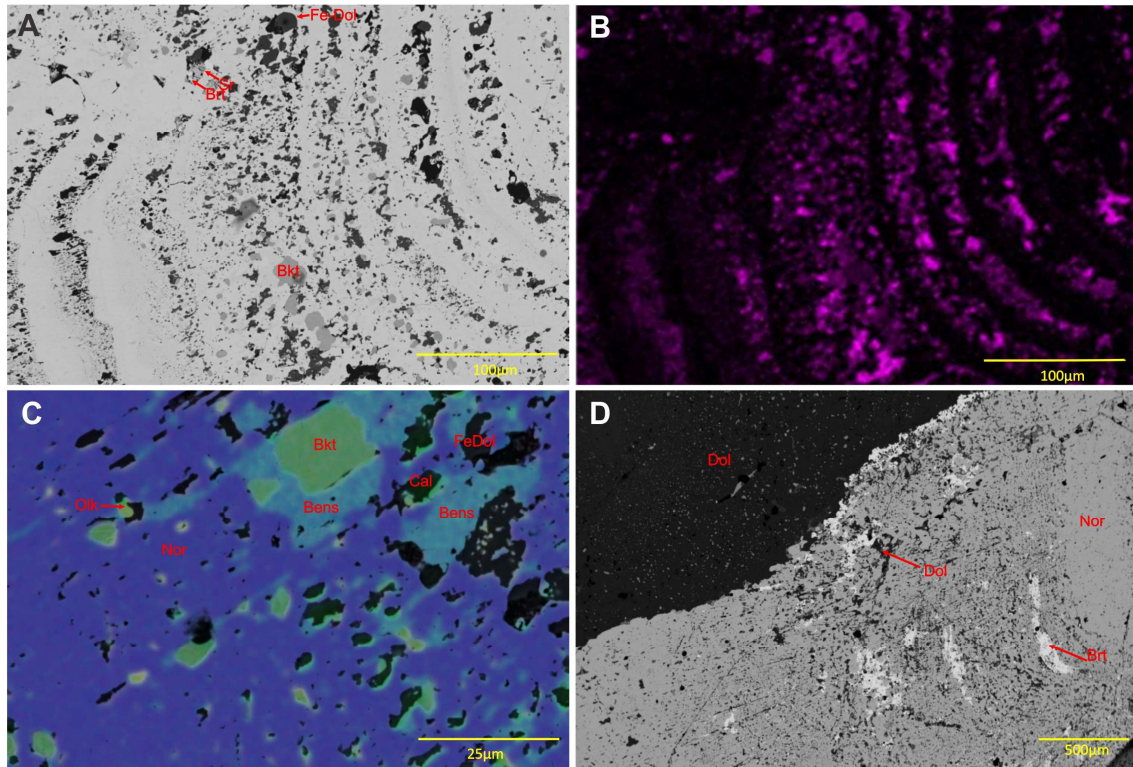


Figure 5.07 – Backscattering electron images of carbonates from the C5 magnesiocarbonatites. A – Gradational cycles of norsethite crystallization with abundant micro inclusions (exsolutions) of other carbonates. B – Ca EDS map showing the concentration of Ca-rich carbonates at the beginning of each cycle. C – False-color EDS map detailing one of the layers from image A, showing the presence of norsethite, olekminskite, benstonite, burbankite, calcite and Fe-dolomite; D – formation of barite in some of the norsethite crystallization cycles. Brt: barite, cal: calcite, dol: dolomite, fedol: fe-dolomite, str: strontianite, bkt: burbankite, olk: olekminskite, nor: norsethite, bens: benstonite.

One sample from this group shows an interesting texture of alternating barite and dolomite/Fe-dolomite bands pseudomorphosing a rhombohedral carbonate (figure 5.06c,d). This is interpreted as an oscillatory zoning of alternating dolomite and norsethite, where the norsethite zones were subsequently replaced by barite. The detection of remnant norsethite by X-ray diffraction (figure 5.09) and by WDS/EDS mapping of this sample support this interpretation. Fitch (1931) studied superficial interactions of witherite and sulphuric acid generated by oxidation and hydration of associated sulphides, resulting in the replacement of

witherite with barite. An analogous process may have occurred in the sample represented in figure 5.06c,d. Baryte is present in C4 carbonatites as two varieties: the one crystallized directly from the carbonatite magma is slightly richer in Sr (1.2 wt. % SrO) than the barite replacing norsethite, at probably low temperatures (0,6 wt. % SrO).

Group C5 is characterized by dominant dolomite and Fe-dolomite, with subordinate calcite, norsethite, burbankite and strontianite as *liquidus* phases. Dolomite from this group contains exsolutions of olekminskite and calcite, norsethite contains exsolved calcite, burbankite, olekminskite, ancyllite and benstonite, and calcite contains exsolved barytocalcite.

Figure 5.07 shows a cyclic deposition of norsethite. In figure 5.07a there are various gradational cycles from right to left, where norsethite formed at higher temperature contains more impurities, which, in turn, result in abundant calcite, dolomite/Fe-dolomite and burbankite exsolution. The size and number of micro inclusions decrease gradually on each cycle, from right to left, ending the cycle with a clear, exsolution-free norsethite. EPMA analyses show that the norsethite hosting inclusions is compositionally closer to ideal norsethite than the exsolution-free norsethite at the end of each cycle. This suggests that the high-temperature norsethite is enriched in impurities such as Ca, Na, ETR, Sr, and probably has exceeding Mg relative to Ba, but exsolves these elements upon reequilibration at lower temperatures. This is similar to the features described earlier for calcite and dolomite, and also reported by Brod (1999) for calcite and dolomite from the Tapira complex and by Cordeiro *et al.* (2011) for dolomite from the Catalão I complex.

The carbon and oxygen isotope composition for carbonates from this sample ( $\delta^{13}\text{C} = -5,41$  and  $\delta^{18}\text{O} = 10,01$ ) is consistent with magmatic carbonate, suggesting that exsolution process occurred only by cooling, without hydrothermal contribution.

Figure 5.07b is a Ca EDS map highlighting carbonate inclusions such as calcite and dolomite (represented in dark grey on figure 5.07a). Calcite dominates at the beginning of each cycle, while dolomite is more abundant to the end, consistent with the expected evolution, considering that Ca does not substitute easily in the norsethite structure, and should be present only at high temperature.

Figure 5.07c shows an EDS detail map of a micro inclusion enriched zone. The burbankite exsolutions in norsethite are circled by benstonite halos, suggesting that the Sr, Na and REE diffusion is more efficient than the Ca diffusion in this system.

The figure 5.07d shows the formation of barite at the end of some cycles of norsethite crystallization. This effect is probably related to sulphur degassing (e.g. Gomide *et al.*, 2013), or CO<sub>2</sub> degassing (Cordeiro, 2011; Brod, 1999; Bailey, 1993; Bailey & Hampton, 1990; Zheng, 1990), that causes oxidation of the system driving it to crystallize barite instead of a Ba-Mg carbonate (norsethite).

### 5.4.2 Mineralogical characterization by X-Ray diffraction

The X-ray diffraction of samples from C1 group (figure 5.08) confirmed the presence of calcite, dolomite, apatite, pyrrhotite, pyrite, magnetite, ilmenite and strontianite.

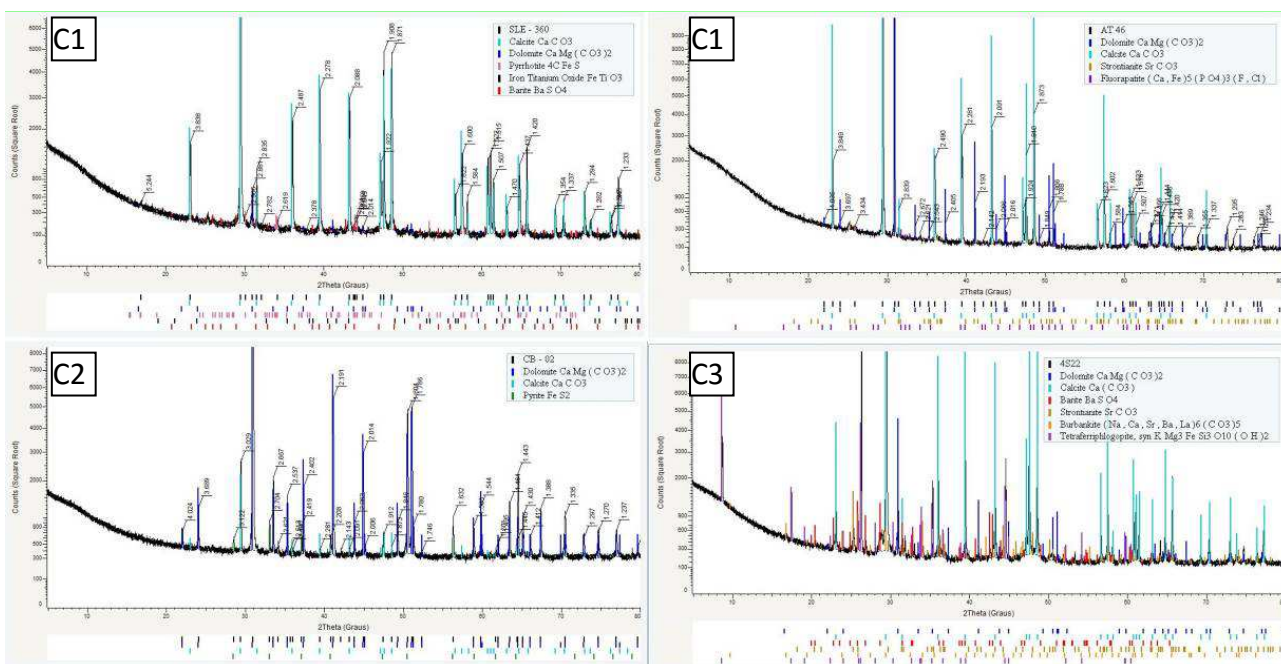


Figure 5.08 – Representative X-ray diffraction patterns from C1 group, C2 and C3.

Samples from C2 (figure 5.08) contain calcite, dolomite and pyrite. In the C3 group the mineral phases identified by XRD are dolomite, calcite, barite, strontianite, burbankite and tetraferriphlogopite

C4 samples (figure 5.09) registered dolomite, apatite, barite, strontianite, norsethite, pyrite, burbankite, monazite, calcite, phlogopite and ankerite.

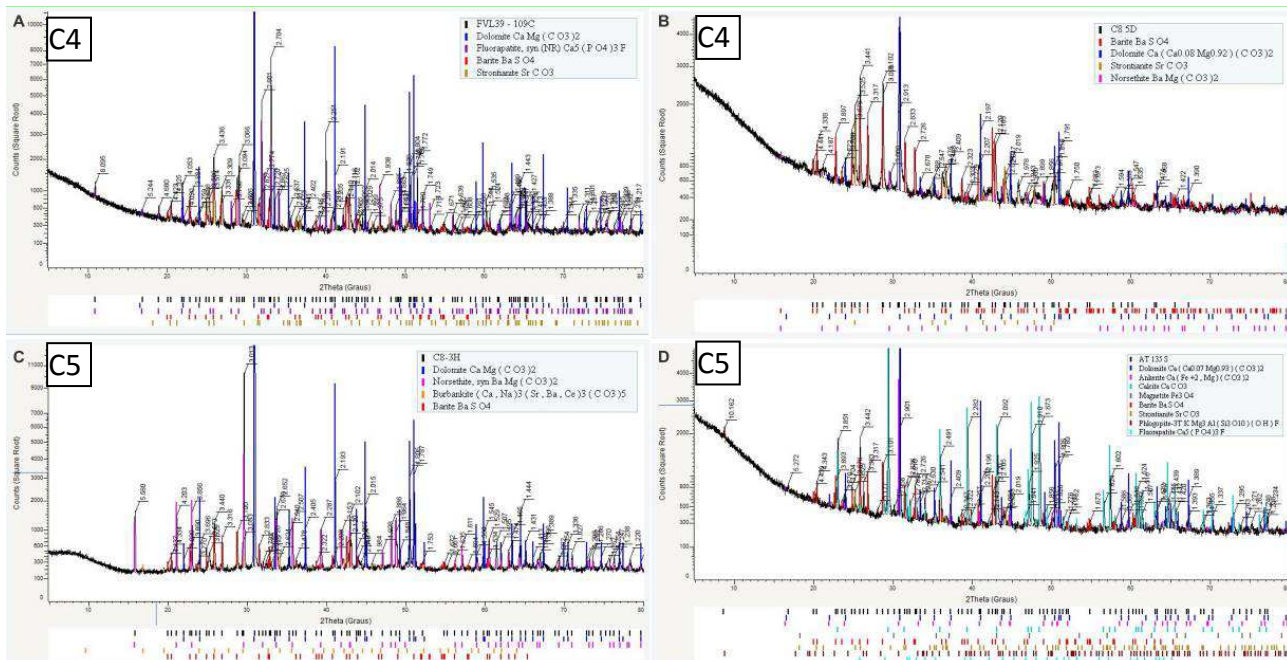


Figure 5.09 – Representative X-ray diffraction patterns from carbonatite C4 (first line) and C5 (second line).

Group C5 XRD results show dolomite, norsethite, burbankite, barite, pyrite, calcite, strontianite and phlogopite confirming the earlier descriptions.

### 5.4.3 Carbonate Mineral Chemistry

Calcite, dolomite and ankerite are the most common carbonates described in alkaline carbonatite complexes with dolomite and ankerite more concentrated in late stage carbonatites (Cordeiro, 2010, Barbosa, 2009; Buhn & Rankin, 1999; Brod, 1999; Zaitsev *et al.*, 1998, Le Bas, 1989; Le Bas, 1981). Some carbonatites contain various REE-rich carbonates, particularly in late-stage products, occurring as secondary replacement textures, as phases directly crystallized from late stage carbonatite magmas, from carbohydrothermal solution or even as exsolutions inside other carbonate phases (Zaitsev *et al.*, 2014, Ruberti *et al.*, 2008; Zaitsev *et al.*, 2002; Andrade *et al.*, 1999; Bühn *et al.*, 1999; Wall & Mariano, 1996; Wall *et al.*, 1993; Hogarth *et al.*, 1985).

Carbonates from carbonatites usually have high Sr and Ba contents (Chang *et al.* 1998; Hogarth *et al.*, 1985). In the calcites studied in this work, SrO contents vary from 0.03 to 8.69 wt.%, MgO from 0 to 1.5 wt. %, BaO from 0 to 1 wt.% and MnO up to 1.55 wt.%. Such high MgO and MnO contents are also a common feature in carbonatite calcites.

Wall *et al.* (1993) described calcites with a SrO content of about 13 wt.% and interpreted them as crystallized at high temperatures. According to Carlson (1980), this high-Sr calcites can also host more REE elements causing exsolution of REE-rich carbonates (Wall *et al.*, 1993).

Jacobson & Usdowski (1976) conducted experimental studies between calcite, dolomite and liquids and pointed out that if the Ca-carbonate crystallizes with an aragonite structure, the Sr content can be much higher than in calcite because there is a solid solution between strontianite and aragonite, and aragonite may not be transformed only by dissolution-reprecipitation reaction, but may be recrystallized to calcite (partially) in the solid state, resulting in a calcite that will be anomalously rich in Sr. If this process occur, the resultant calcite will be anomalously enriched in Sr. Hurai *et al.* (2013) described aragonite phenocrysts in carbonatite and carbonated syenite xenoliths corroborating this possibility.

Experimental studies by Carlson (1980) about Sr substitution in calcium carbonates concluded that calcite accepts higher Sr concentration at higher temperature, but our data show some high Sr content in calcite from the C5 evolved carbonatites. (figure 5.10). It is possible that calcite from the earlier carbonatites have undergone more intense *subsolvus* exsolution of Sr and other impurities, resulting in a composition closer to the ideal calcite at low temperature. Alternatively, if Sr is concentrated in the final stages of carbonatite activity, its higher activity may drive a higher occupancy of the Ca-sites in calcite by Sr (e.g. Jacobson & Usdowski, 1976). Considering the temperatures observations from Carlson (1980) and Jacobson & Usdowski (1976) these data indicates that the more evolved APIP carbonatites still crystallize in temperature sufficient to accept Sr in the structure.

Dolomite shows up to 5.5 wt.% SrO, 1.2 wt.% BaO and 2.2 wt.% MnO. This SrO content is unexpectedly high, considering the fact that calcite has twice as many Ca-sites for substitution as dolomite, showing a 2:1 relationship in



partitioning behavior (Jacobson & Usdowski, 1976). Sr is expected to be in a higher concentration in calcite than dolomite, whereas MnO is expected to show the opposite behavior (Dawson, 1996, Atwood & Fry, 1967), which is in good agreement with the data presented here.

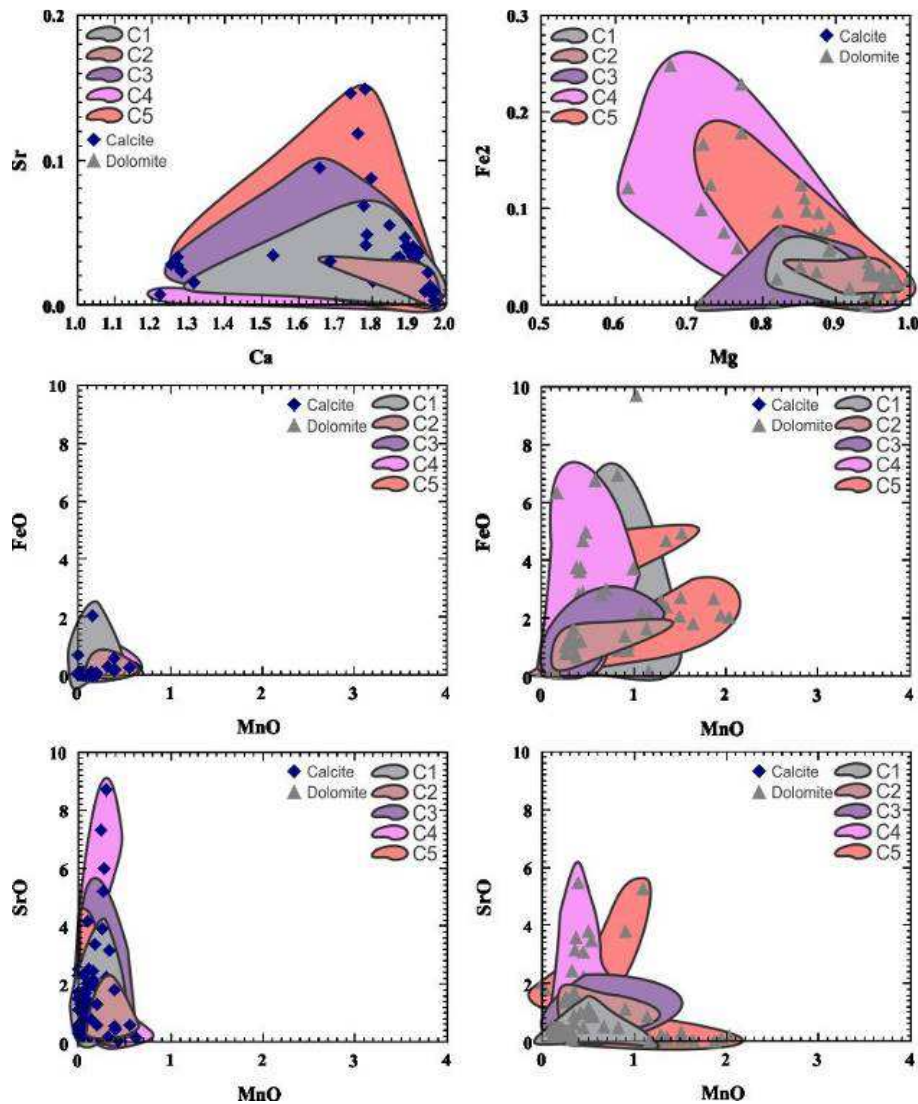


Figure 5.10 – Strontium, calcium, iron, magnesium and manganese distribution in the analysed calcites and dolomites.

Figure 5.10 shows the evolution of Sr, Ca, Fe and Mn contents in dolomite and calcite. Calcite shows a higher degree of Ca-Sr substitution in the more evolved carbonatites, although it is not clear whether this results from Sr enrichment in the magma or from more extensive exsolution of Sr-rich phases in the early-stage carbonates. Dolomite evolves mostly toward Fe enrichment, but the behavior of MnO and SrO appear variable from one group to the next. For

instance, C4 dolomites evolve mostly by SrO enrichment, while C5 shows two groups, one representing exsolutions and other one representing the crystallized directly from magma.

Iron contents in dolomite is systematically higher with magma evolution, C2 and C3 groups evolves with a positive correlation, C4 evolves only in the iron direction and C5 seems to represent two groups of dolomite. The group that has higher iron content represent exsolutions in norsethite and the other one is crystallized directly from magma. In calcite, iron and manganese content are too low to define an evolution trend.

The distribution of the elements in figure 5.10 is consistent with the findings of Dawson *et al.* (1996) in terms of partition coefficients, whereby Sr tends to enter the calcite structure whereas Fe and Mn partition preferably to dolomite.

The other carbonates found in this research are summarized as representative analysis in table 5.03

*Table 5.03 Composition ranges for carbonates described in this work.*

Mineral	FeO	MnO	MgO	CaO	K <sub>2</sub> O	Na <sub>2</sub> O	SrO	BaO	REE <sub>2</sub> O <sub>3</sub>	F	CO <sub>2</sub>
Ancylite (H <sub>2</sub> O: 4.84-5.45)	0-0.7	-	0-0.1	0.8-3.4	-	0.2-0.5	10.5-14.9	-	39.1-50.8	0.6-1.7	17.7-27.9
Barytocalcite	0.1-0.8	0-0.2	0.1-2.7	21.1-23.2	-	0.1-0.8	0.1-1.0	45.7-56.9	0.01-0.8	0.00	30.3-35.2
Bastnaesite	-	-	-	3.5-6.6	-	-	0.8-1.6	-	46.1-66.9	0-6.8	17.0-21.14
Benstonite	0.1-0.2	0-0.2	1.88-4-45	14.5-20.1	-	0.1-1.0	5.5-8.7	37.48-49.1	0-2.4	-	28.7-36.2
Burbankite	0-0.4	0-0.2	0-4.9	6.0-29.4	0-0.3	4.4-11.5	15.2-38.6	1.5-20.0	0.4-18.9	0-0.2	26.6-40.4
Calcite	0-1.3	0-1.6	0-8.1	41.3-57.1	0-0.35	0-3.1	0-8.7	0-3.5	0-7.9	0-6.0	37.2-52.6
Dolomite	0.1-16.8	0-4.0	8.6-22.5	23.9-39.9	0-0.1	0-1.2	0-5.5	0-2.9	0-2.7	-	37.6-52.9
Gregoryite/ Zemkorite*	-	-	-	33.2	16.5	10.7	1.4	-	-	-	38.3
Norsethite	0-1.34	0-0.3	10.7-16.9	0-2.8	-	0-0.6	0-3.5	46.1-56.9	0-1.3	-	28.7-35.0
Nyerereite*	-	-	-	36.7	1.7	18.9	-	-	-	-	42.7
Olekminskite	0-0.8	0-0.1	0-2.8	2.0-25.0	0-0.1	0.1-0.4	37.0-64.4	1.0-11.1	0-2.5	-	18.0-37.4
Parisite	0-1.1	-	0-0.1	5.5-12.0	-	-	1.0-1.8	-	41.6-63.0	1.3-9.4	21.8-26.3
Strontianite	0-1.1	-	-	1.7-8.9	-	0-0.6	45.8-66.5	0-6.1	0-2.4	-	23.0-33.2

*Compositional classification was based on catalographic cards of Mineralogical Society of America Handbook of Mineralogy (Anthony et al., 2001). All oxides are wt.%. The amount of CO<sub>2</sub> and H<sub>2</sub>O is inferred by stoichiometry. \*Semi-quantitative analysis by EDS, the amount of CO<sub>2</sub> from this sample were inferred by the available data in the literature.*

Figure 5.11 summarizes the chemical variability of the studied carbonates.

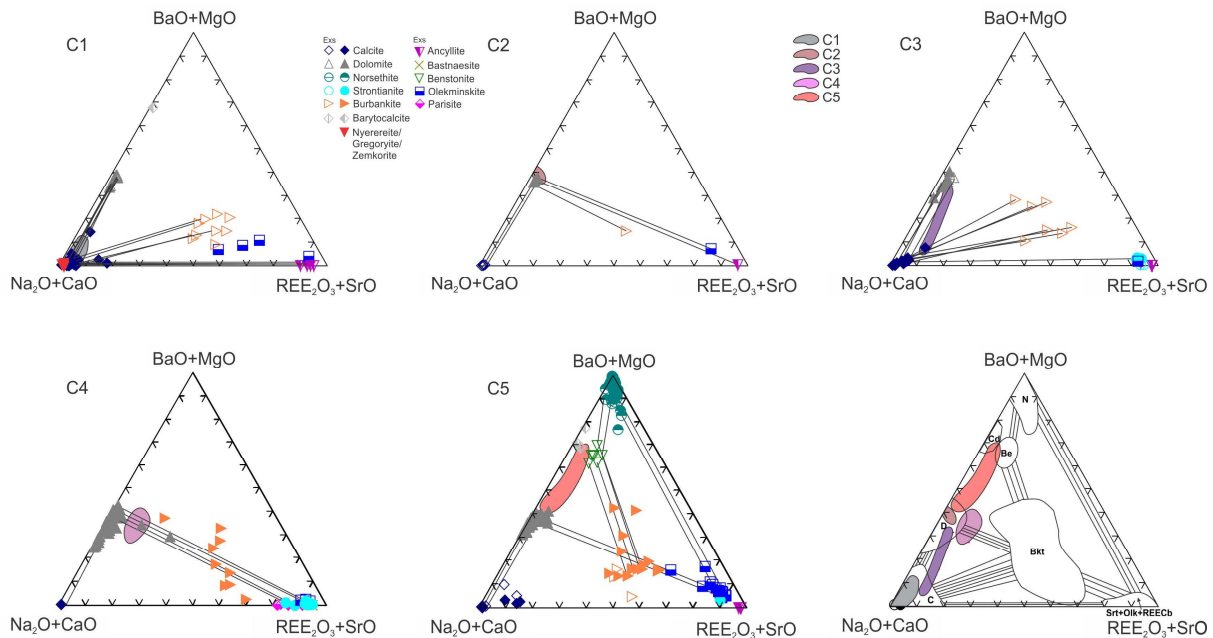


Figure 5.11 – Compositional variation of the studied carbonates by carbonatite group. Carbonates considered as liquidus phases and carbonates that are the product of subsolidus reequilibration are plotted separately (see inset). Coloured fields represents the whole-rock chemical analyses for each group. White fields were built considering the carbonates compositions. N=norsethite, Be=benstonite, Cd=calcite disordered (barytocalcite or polymorphs), D=dolomite, C=calcite, Bkt=burbankite, Str=strontianite, Olk=olekminskite, REECb=REE-carbonates.

Considering that some of the studied carbonates occur both as *liquidus* phases and as *subsolidus* exolutions, they were distinguished in figure 5.11. Despite the fact that there is no experimental data characterizing all these carbonates in a single system, some useful observations can be drawn from the diagrams.

C1 is dominantly composed of calcite, which contains dolomite, burbankite, olekminskite and ancyllite exolutions, C2 is composed by dominant dolomite with calcite, burbankite, olekminskite and ancyllite exolutions.

C3 is dominated by calcite over dolomite and strontianite, with burbankite, strontianite and ancyllite exolutions in calcite. The burbankite from C4 occurs as microinclusions in dolomite but these are texturally consistent with a incipient *liquidus* phase rather than exolutions. The other *liquidus* phases are dolomite,

which is the dominant carbonate type, and strontianite. Calcite, burbankite, olekminskite, ancylite and bastnaesite are exsolutions in dolomite.

Group C5 has dolomite and norsethite as dominant *liquidus* phases, with subordinate calcite, strontianite and burbankite. Barytocalcite, burbankite, bestonite, olekminskite and ancylite are exsolutions in dolomite and norsethite.

Benstonite results from a norsethite-burbankite reaction, as described in C5. The burbankite field in figure 5.11 seems very large, but this may be due to analytical uncertainties, probably regarding Na.

Analyses of four Ca-Sr carbonate pairs from three samples, two from C1 (Tapira) and one from C5 (Araxá), could be plotted in the diagram proposed by Carlson (1980), shown in figure 5.12. In this system, they match only the isothermal section at 350°C. Since the Sr-bearing carbonates present in these samples are exsolutions within calcite grains, this temperature is taken as a reference for the *subsolidus* reequilibration of the samples. This seems a reasonable estimate, since temperatures of carbonatite magmas are estimated about 600° and 550°C, persisting to lower temperatures in the case of late-stage differentiates, and the measured temperature of lavas at Oldoinio Lengai was as low as 490°C (Kraft and Keller, 1989; Jones and Wyllie, 1983; Wyllie, 1966). It is also consistent with temperature estimates for late-stage carbonatites, which may reach 475°C and 420°C in the APIP, and in the Swartbooisdrif carbonatite, Namibia (Gomide *et al.*, 2013; Thompson *et al.*, 2002). Samples AT-49 and AT-46 are C1 calciocarbonatites from the Tapira complex, while C8-3H is a C5 magnesiocarbonatite from the Araxá complex. AT-46 indicates that exsolution occurred at 1kbar, i.e. less than 5km deep. Sample AT-49 registered two exsolutions moments: one at 3kbar and another one at 2kbar. These estimates are consistent with a relatively shallow emplacement expected for the APIP carbonatite complexes (e.g. Santos & Clayton, 1995).

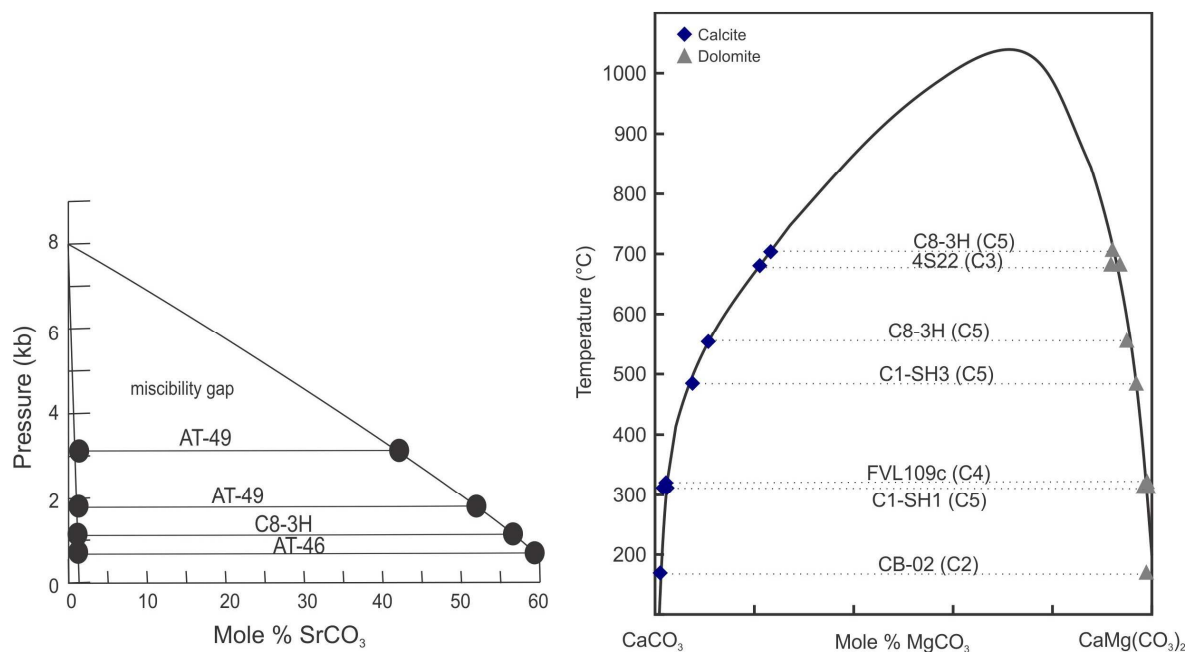


Figure 5.12 – Isothermal section at 350°C (left) in the system calcite-Sr-aragonite after Carlson (1980) and calcite-dolomite solvus (right) after Chang et al. (1998) for the APiP samples.

According to calcite-dolomite solvus (figure 5.12), sample C8-3H, from the C5 group underwent two *subsolidus* reequilibrium steps registered by calcite–dolomite pairs, the first one at 700°C, the second at 550°C representing two exsolution stages at relatively high temperature for a carbonatite magma.

The 4S22 sample, a C3 calciocarbonatite, fits a ca. 690 °C, which may indicate that the dolomite and the calcite crystallized together, rather than being related by *subsolidus* processes because this temperature is relatively high for a carbonatitic magma, probably the first temperature (700°C) given by the sample C83H indicates the same. Therefore, it's possible to conclude that these inclusions are blebs of dolomite inside calcite crystallized at the same time.

Sample C1-SH3 (a C5 magnesiocarbonatite) yields an exsolution temperature of approximately 500 °C, FVL109 (C4) and C1 SH1 (C5) yields reequilibration temperatures little over 300 °C and CB-02, a C2 magnesiocarbonatite records a temperature of approximately 180 °C for the calcite-dolomite pair.

Among these variable estimates, temperatures above 500°C should represent coexisting *liquidus* carbonates, rather than the product of *subsolidus*

transformations, whereas temperatures below 450°C should represent *subsolidus* processes.

Figures 5.13 and 5.14 depict *subsolidus* phase relations from the literature, with our determined mineral chemistry ranges and whole-rock geochemistry for the APIP carbonatites, in order to gain insight on the real phases actually present in the samples.

Figure 5.13a shows the  $\text{CaCO}_3\text{-MgCO}_3\text{-FeCO}_3$  system with the whole set of calcite and dolomite analyses. Figure 5.13b shows the whole-rock chemical composition of groups C1 to C5. Some whole-rock analyses from the C1 group plot inside the calcite + dolomite + siderite field, but the iron present in these samples is contained in magnetite and, therefore, is not available for carbonate crystallization. Carbonatites from the C2, C3 and C4 groups are expected to contain both calcite and dolomite, with C3 dominated by calcite and the other two dominated by dolomite. C5 rocks are mostly contained in the dolomite solid solution field, suggesting that they should be composed entirely of dolomite. These estimates are in good agreement with the actual observations in these rocks. .

Figures 5.13c and 5.13d depict the system  $\text{MgCO}_3\text{-CaCO}_3\text{-BaCO}_3$ . Goldsmith and Graf (1960) and Goldsmith and Newton (1969) indicate that moderate temperatures are required for mixtures involving  $\text{MgCO}_3$  to react in a reasonable length of time. The phase relations were experimentally determined by Brice and Chang (1973) at 650°C and variable pressures. We chose the 5kbar diagram to represent our samples, the stable  $\text{CaCO}_3$  phase at this pressure is calcite.

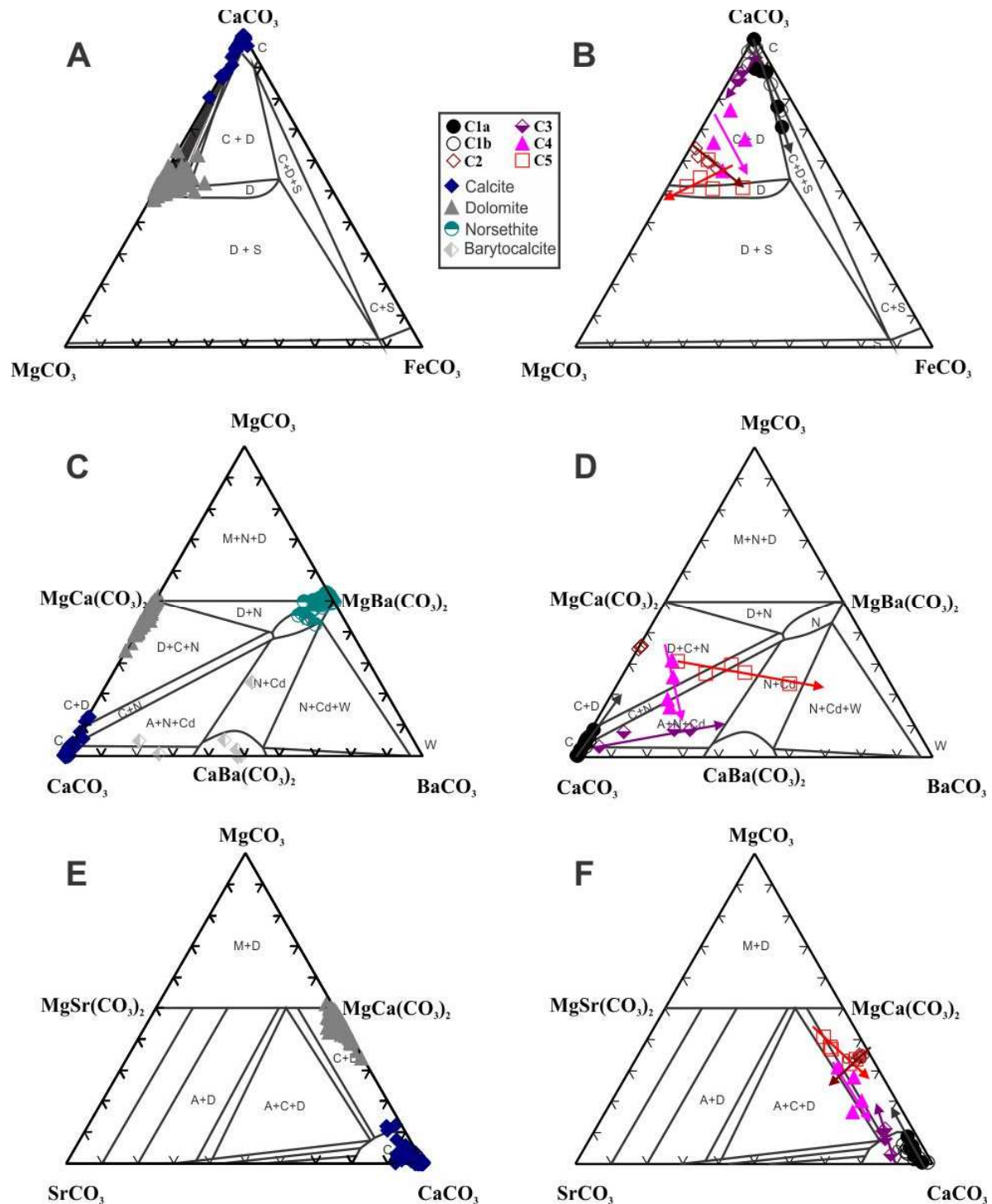


Figure 5.13 – A) Subsolidus relations in the system  $\text{CaCO}_3\text{-MgCO}_3\text{-FeCO}_3$  at  $450^\circ\text{C}$ . D=dolomite solid solution, C=calcite solid solution, S=siderite-magnesite solid solution. After Rosenberg (1967), Goldsmith (1983) and Chang et al. (1998). B) Subsolidus phase relations in the system  $\text{MgCO}_3\text{-CaCO}_3\text{-BaCO}_3$  at  $650^\circ\text{C}$  and 5 kbar. A=aragonite, C=calcite, Cd=disordered calcite, D=dolomite, M=magnesite, N=norsethite, W=witherite. After Brice and Chang (1973). C) Subsolidus phase relations in the system  $\text{MgCO}_3\text{-CaCO}_3\text{-SrCO}_3$  at  $650^\circ\text{C}$  and 5kbar. A=aragonite type solid solution, C=calcite solid solution, D= dolomite type solid solution, M=magnesite Brice and Chang (1973).

Figures 5.13c and d show that C1 and C2 chemistry would theoretically form only calcite and calcite + dolomite respectively, which is consistent with the actual observed mineral compositions. In this system, C1 carbonatites show a very restricted composition range, dominated by calcite with some dolomite possibly as a limited solid solution, as observed in the studied samples. C2 comprises dolomite-dominated mixtures of dolomite and calcite.

C3, C4 and C5 belong to fields that would generate more than two phases. C3 evolves in the stability field of aragonite + norsethite + disordered calcite with a composition similar to barytocalcite, alstonite or paralstonite, which explains the fact that carbonates other than calcite and dolomite appear as *liquidus* phases. C4 magnesiocarbonatites are expected to change mineralogical composition from dolomite + calcite + norsethite to calcite + norsethite to aragonite + norsethite + disordered calcite (baritocalcite) with evolution. This is consistent with the Ba increase observed in this group and with the actual mineral associations. where dolomite, calcite and norsethite are all *liquidus* phases. Finally, C5 carbonatites show the widest mineralogical range, starting with dolomite + calcite + norsethite, evolving to norsethite + calcite, then norsethite + aragonite + baritocalcite, and norsethite + baritocalcite in the extremely evolved samples. The most Ba-rich C5 samples are probably displaced toward Badue to the presence of barite in these samples. In this case, the actual *liquidus* phases present in the rocks are calcite, dolomite, norsethite and barytocalcite.

Figure 5.13e and f show the system  $\text{SrCO}_3\text{-MgCO}_3\text{-CaCO}_3$  which all data plots between dolomite and calcite with limited solid solution to Sr, near the limit with the stability field of calcite + aragonite + dolomite. It is possible that the argument of Jacobson & Usdowski (1976), that applies to our samples, indicating that calcites with the highest Sr content were first crystallized as aragonite and then inverted to the calcite structure, maintaining only part of the Sr in solid solution.



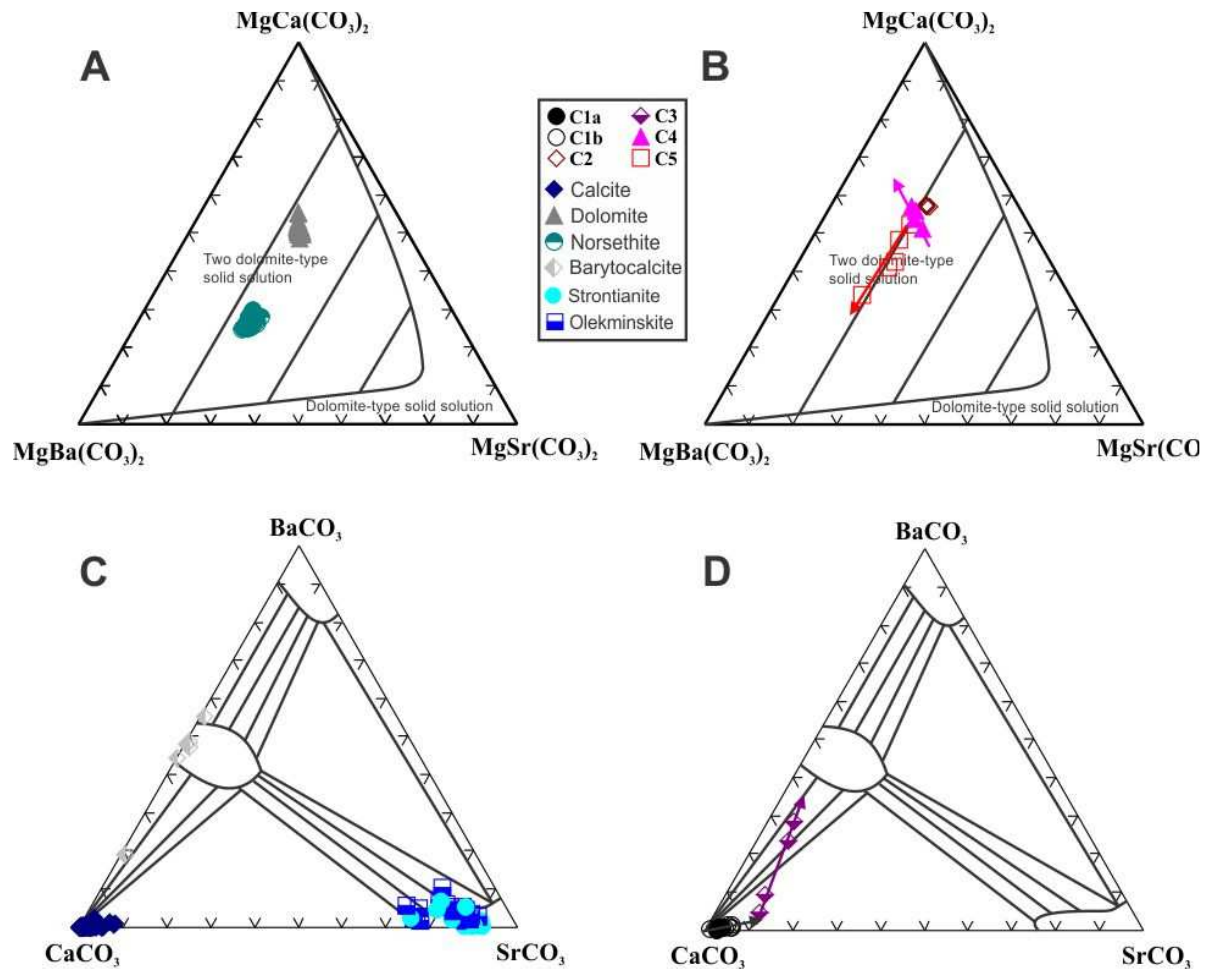


Figure 5.14 – A and B) Subsidiary phase relations in the dolomite plane  $MgCa(CO_3)_2$ - $MgSr(CO_3)_2$ - $MgBa(CO_3)_2$  at 650°C and 5 kbar. Brice and Chang (1973). C and D) Subsidiary relations in the system  $BaCO_3$ - $CaCO_3$ - $SrCO_3$  at 100°C. After Speer (1983).

The whole-rock chemistry data plotted in figure 5.14a is consistent with the system crystallizing two types of solid solutions, but the mineral chemistry data seems to be unconflicting with the diagram, suggesting that the temperature and pressure conditions adopted by Brice and Chang (1973) are not ideal to explain the behavior of our samples. An increase in temperature would presumably enlarge the field of a single type solid solution, conforming to our samples, but there are no experimental studies available to that effect so far.

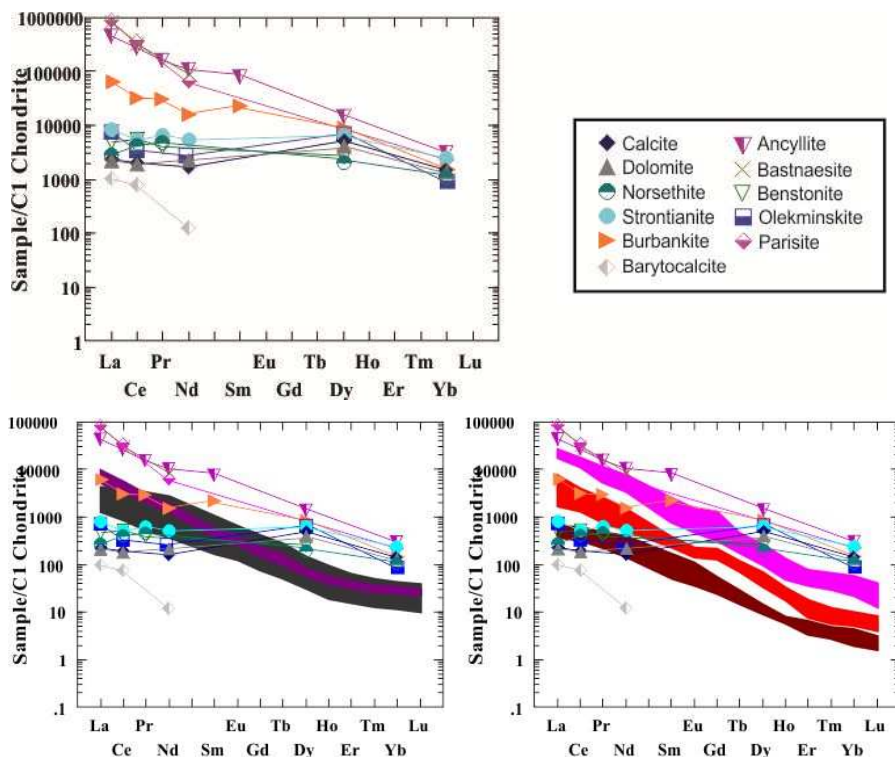


Figure 5.15 – REE element diagrams of average values (EPMA data) from APiP carbonates. The bottom diagrams show carbonate values (divided by 10) compared with the APiP whole-rock carbonatite fields. Black field: C1, brown field: C2, violet field: C3, pink field: C4, red field: C5.

The REE data for carbonates determined by electron microprobe and the results are consistent with other results obtained in carbonatites by synchrotron-XRF for burbankite (Buhn *et al.*, 1999), by La-ICP-MS for carbonatite calcites (Xu *et al.*, 2007, Horning-Kjarsgaard, 1998) and by electron-microprobe for burbankite, bastnaesite, parisite, ancylite and fluorcarbonates in general (Ruberti *et al.*, 2008, Zaitsev *et al.*, 1998). Figure 5.15 shows to the average analyses for each carbonate type.

Ancylite and bastnaesite have the highest REE carbonates contents and bastnaesite presents higher LREE/HREE fractionation from the carbonates that has REE as an structural composition. Burbankite and parisite show the same REE pattern but at lower concentrations. Other carbonates, olekminskite, strontianite and benstonite have REE content higher than the coexisting calcite and dolomite. Ionov & Harmer (2002) described interstitial carbonates with higher REE values than carbonate phenocrysts, indicating that the trace element composition of carbonates is controlled by order of crystallization, which is in agreement with the carbonate composition described here.

Ionov & Harmer (2002) also defined that late-magmatic interstitial carbonates, apatite and accessory minerals are major hosts for REE and incompatible elements, which is consistent with the mineral chemistry and carbonatite evolution shown here, and supports the hypothesis that the calcites from more evolved carbonatites have higher Sr, although in the same sample the Sr content is controlled by the presence or not of exsolutions (figure 5.10).

The whole-rock field in figure 5.15, compared with the REE carbonate patterns shows that the main carbonates present in the APIP carbonatites are not the only REE-fractionating phase, since calcite, dolomite and norsethite have a parallel to subparallel pattern while the whole-rock shows a high LREE/HREE fractionation as suggested by Hornig-Kjarsgaard (1998).

## 5.5 Conclusions

The diversity of carbonate phases and composition in carbonatite rocks and the relationship between those phases is extremely importante to understand the evolution of these rock types.

The C1 calciocarbonatites, the less evolved type in the APIP, are dominated by calcite, which crystalized at high temperatures, incorporating ions that were later exsolved as dolomite, strontianite, olekminskite, burbankite, norsethite and, in more rare cases, ancyllite. An alkaline carbonate with Na and K, probably nyerereite and gregoryite and/or zemkorite, reported from the first time from the APIP may represent a *liquidus* phase or another type of exsolution, but in any case, it signals that the original carbonatite magma was alkali-rich.

The C2 magnesiocarbonatites are less evolved than the other magnesiocarbonatites described here. Dolomite crystalized at high temperature coexisting with subordinate calcite. Calcite, olekminskite, burbankite and ancyllite are exsolved from dolomite during *subsolidus* cooling. The calcite exsolutions, in turn, exsolve other carbonates, indicating a complex cooling history.

The C3 calciocarbonatites are dominated by calcite, which has abundant exsolutions of dolomite, burbankite, baritocalcite, ancyllite and olekminskite. Calcite, strontianite, baritocalcite and norsethite are *liquidus* phases.

C4 magnesiocarbonatites are dominated by dolomite and Fe-dolomite, with calcite, norsethite and strontianite as subordinate *liquidus* phases. Burbankite may be an additional, incipient *liquidus* mineral. *Subsolidus* reequilibration resulted in exsolutions of calcite and ancylite in dolomite, and of baritocalcite and ancylite in calcite. This group is the first in evolution trend of the APIP carbonatites to crystallize REE minerals independently, namely monazite and carbonates (ancylite, parasite and bastnaesite). Norsethite is often replaced by barite, which may also occur as a phase crystallized directly from magma. Monazite may also replace carbonates in this group.

The carbonates that comprises group C5 are dominantly dolomite and Fe-dolomite, with subordinate calcite, norsethite, burbankite and strontianite. The exsolved phases comprise calcite, burbankite, olekminskite, ancylite and benstonite in norsethite, olekminskite and calcite in dolomite, and barytocalcite in calcite. The cyclic deposition and the chemical characteristics of norsethite indicates that it formed at high temperature. The layered texture represents many pulses of norsethite precipitation causing later difference in exsolutions. These may be interpreted as degassing pulses considering that barite is present at the end of each cycle barite, which indicates a change in the oxidation of magma. Burbankite exsolutions in norsethite are circunded by benstonite halos, indicating that the Sr, Na and REE diffusion is more efficient then the diffusion of Ca in this system.

The high Sr content is associated with REE enriched carbonates and indicates that the calcites with these characteristics were crystallized at high temperatures, but some of these high-Sr calcite may have crystalized first as aragonite and later inverted to calcite. C5 carbonatites show higher Sr contents than the other groups. It is possible that the earliest carbonates formed had reequilibrated more efficiently during cooling, exsolving most of the excess Sr or that the Sr enrichment in carbonate is a differentiation feature, driven by increased Sr activity in the liquid, in which case, the more evolved carbonatites would crystalize in temperature still high enough for the calcite structure to accept Sr substitution.

Dolomite shows similar features. In C4 carbonatites, dolomite evolves toward increasing SrO, while C5 shows two groups, one representing exsolutions (lower Sr contents) and other one representing dolomite crystalized directly from

magma. Iron content in dolomite of this group highlights two varieties also, high iron dolomite exsolved from norsethite and dolomite with lower iron content crystallized directly from the magma.

Coexisting carbonate pairs indicated temperatures of 350°C and lower for the exsolution in the system Calcite-Strontianite at different depths. The calcite-dolomite solvus records at least two main sets of temperature, above 500°C, interpreted as magmatic and below 450°C and as low as 180°C, interpreted as *subsolidus* reequilibration.

The whole-rock composition of carbonatites agrees well with the actual mineral associations observed and with the changes in fractionating assembly.

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## CAPÍTULO 6

### Conclusões

Uma das maiores dificuldades no estudo do magmatismo carbonatítico é estabelecer um parâmetro numérico de evolução magmática (análogo aos índices de diferenciação utilizados no estudo de magmas silicáticos) com o qual se possa aferir as demais propriedades geoquímicas, isotópicas, mineralógicas e texturais. Neste trabalho foi proposto um método integrado de avaliação do estágio de diferenciação magmática e os carbonatitos estudados foram classificados em grupos de rochas sucessivamente mais evoluídas de C1 a C5. Os grupos C1, C2, C3 e C5 evoluem principalmente por enriquecimento em BaO e empobrecimento em  $P_2O_5$ , enquanto o grupo C4 que contém os carbonatitos com maiores concentrações de elementos terras raras evolui por enriquecimento em terras raras e fósforo.

A partir desse método integrado, foi possível estabelecer um índice de diferenciação envolvendo BaO e SrO como guia de evolução de carbonatitos, em comparação com outras análises da província, de diversos autores e com amostras de Jacupiranga. Esse esquema de classificação funcionou muito bem e pode ser aplicado como uma classificação geral de carbonatitos, trazendo uma contribuição importante para o estudos dessas rochas.

As características geoquímicas indicam que a evolução dos calciocarbonatitos C1 resulta em aumento do componente calcítico no magma, por fracionamento de apatita, flogopita e enriquecimento em carbonato, permitindo a subdivisão das amostras em um sub-grupo de cumulados ricos em apatita (C1a) e outro de carbonatitos residuais (C1b).

O Grupo C2 é composto de magnesiocarbonatitos pouco evoluídos, caracterizados pelo fracionamento de apatita e dolomita.

O grupo de calciocarbonatitos C3, presente principalmente em Tapira, é caracterizado pelo fracionamento de apatita, calcita e flogopita, levando a um enriquecimento residual em Ba, Mg e Na, que permitiu a cristalização de carbonatos como norsethita, baritocalcita e burbankita diretamente a partir do magma. Este grupo marca a exaustão do componente silicático nos

calciocarbonatitos, com o consumo final de flogopita. As características geoquímicas de C3, em particular a alta razão Nb/Ta e as fortes anomalias negativas de Zr e Hf (e.g. Brod *et al.*, 2012), indicam que estes magmas foram gerados por imiscibilidade de líquidos.

O grupo C4 consiste de magnesiocarbonatitos ricos em Ba e ETR, cuja assembleia de carbonatos é composta principalmente por dolomita, Fe-dolomita e estroncianita. Sua característica distintiva é o forte enriquecimento em monazita, marcado por um aumento concomitante de  $P_2O_5$  e  $ETR_2O_3$  com a evolução magmática. As características geoquímicas indicam o envolvimento de imiscibilidade de líquidos na evolução destes magmas.

O Grupo C5 caracteriza-se pelo predomínio de dolomita e/ou Fe-dolomita sobre calcita. Suas características geoquímicas indicam forte fracionamento de apatita e flogopita, com diminuição dos teores de CaO,  $P_2O_5$  e  $K_2O$ , e enriquecimento em Ba, Sr, Na e  $CO_2$ , resultando na cristalização direta de burbankita, estroncianita e norsethita. Exsoluções de olekminskita e benstonita em norsethita, de olekminskita em dolomita e de baritocalcita em calcita indicam que os minerais hospedeiros cristalizaram-se em condições de temperatura ainda relativamente alta. As características geoquímicas indicam o envolvimento de processos de imiscibilidade de líquidos na evolução destes magmas. Trabalhos anteriores (Junqueira-Brod *et al.* Em prep., Gomide *et al.* 2013) identificaram desgaseificação tanto de  $CO_2$  quanto de enxofre em amostras desse grupo.

Os dados isotópicos de carbono, oxigênio e enxofre obtidos até o momento são compatíveis com a interpretação de Santos & Clayton (1995) de que os complexos da APIP instalaram-se em níveis crustais mais rasos.

A menor profundidade e, conseqüentemente, menor pressão, permitiu que uma diversidade muito maior de processos petrogenéticos atuasse na evolução dos magmas da APIP, incluindo cristalização fracionada, imiscibilidade de líquidos, desgaseificação e interação com sistemas hidrotermais e carbohidrotermais, muitas vezes em eventos recorrentes (Barbosa *et al.*, 2012; Brod *et al.*, 2012; Cordeiro *et al.*, 2010; Gomide *et al.*, 2013).

Diferenças no grau de evolução petrogenética são também observados entre os carbonatitos da APIP. A figura 6.01 apresenta um resumo da porcentagem de amostras utilizadas no presente estudo pertencentes a cada

grupo de carbonatitos, nos diferentes complexos. Observa-se dois grupos dentre os complexos da APIP: nos complexos de Serra Negra, Salitre e Tapira predominam carbonatitos calcíticos e dolomíticos mais primitivos (C1a, C1b, C2 e C3), enquanto os complexos de Araxá, Catalão I e Catalão II são dominados por magnesiocarbonatitos evoluídos.

	Jacupiranga	Serra Negra	Salitre	Tapira	Araxá	Catalão I	Catalão II
C1a	— —		— —	— —			
C1b	— — —		— —	—			— —
C2	—	— — —	— —	—	— —	—	
C3				— —			
C4			—	—	— —	— —	—
C5		— —	—	—	— —	— — —	—

% de amostras por complexo

Figura 6.01 – Quadro ilustrativo da porcentagem de amostras pertencentes aos complexos para cada grupo de carbonatitos, os complexos estão organizados por grau crescente de evolução, da esquerda para a direita.

A diversidade de fases carbonáticas e composição em rochas carbonatíticas e a relação entre elas é extremamente importante para compreender a evolução destes tipos de rochas.

Os calciocarbonatitos C1 são menos evoluídos, dominados por calcita sobre dolomita, e a calcita foi cristalizada em temperaturas elevadas, com incorporação de impurezas que foram exsolvidas como dolomita, estroncianita, olekminskita, burbankita, norsethita e ancylita (pouca) e um carbonato alcalino, com Na e K, provavelmente nyerereite e gregoryite e/ou zemkorite. A relação deste último ainda não está clara e, alternativamente, pode representar exsolução ou fase *liquidus*. A presença de carbonato rico em Na e K é muito importante porque é a primeira vez que é descrito na APIP e indica que o magma foi enriquecido em álcalis. Estes carbonatos são descritos no único vulcão carbonatítico do mundo, o Oldoinio Lengai.

Os magnesiocarbonatitos C2 são menos evoluídos do que os outros magnesiocarbonatitos descritos e são caracterizados por dolomita cristalizada em alta temperatura dominando sobre calcita e exsolveu calcita, olekminskita, burbankita e ancylita. Exsoluções de calcita apresentam outras exsoluções

representando dois momentos de reação, uma caracterizada pela exsolução de calcita de dolomita e, em seguida, outros carbonatos exsolvem da calcita.

A característica dos calciocarbonatitos C3 é a abundância de exsoluções de dolomita, burbankita, baritocalcita, ancylita e olekminskita exsolvidas de calcita e estrontianita, baritocalcita e norsethite como fases *liquidus*.

Magnesiocarbonatitos C4 são dominados por dolomita e Fe-dolomita, com calcita, norsethita e estroncianita subordinadas como fases *liquidus*. Marcado por exsoluções de calcita e ancylita em dolomita, de baritocalcita e ancylita em calcita. Este grupo é o primeiro da sequência de evolução que contém algumas quantidades de minerais de terras raras cristalizados de forma independente, compreendendo monazita e carbonatos (ancylita, parisita e bastnaesita). Este grupo é o único que apresenta cristais euédricos de burbankita zonados. A norsethite neste grupo é substituída por barita, mas o referido mineral está presente de duas maneiras: uma cristalizada diretamente do magma e outra substituindo norsethita por fluidos em estágio final ou mesmo hidrotermal. Monazita também substitui carbonatos indicando que haviam mais carbonatos de terras raras presentes.

Os carbonatos que compreendem o grupo C5 são dolomita e Fe-dolomita dominante, com calcita subordinada, norsethita, burbankita e estroncianita. As exsoluções deste grupo são compostas por calcita, burbankita, olekminskita, ancylita e benstonita em norsethita, de olekminskita e calcita em dolomita, e de baritocalcite em calcita. A deposição cíclica de norsethita indica que a norsethita é formada a uma temperatura elevada, contém mais impurezas e apresenta exsoluções de calcita, dolomita/Fe-dolomita e burbankita. A textura em camadas representa diversos pulsos de precipitação de norsethita causando diferença também nas exsoluções. Estes pulsos podem ser interpretados como desgaseificação considerando que, ao final de cada ciclo, a barita está presente, indicando a oxidação do magma. Exsoluções de burbankita em norsethita são circundadas por halos de benstonita, indicando que o Sr, Na e ETR têm difusão mais eficiente que a difusão de Ca neste sistema.

O alto teor de Sr está associado com o enriquecimento de ETR nos carbonatos e indica que as calcitas com esta características foram cristalizadas a temperaturas elevadas, algumas destas calcitas com elevado teor de Sr podem

ter sido cristalizadas pela primeira vez com a estrutura da aragonita. Carbonatitos C5 apresentam conteúdos de Sr mais altos do que os demais grupos, talvez os grupos iniciais tenham exsolvido o Sr e é por isso que a análise mostra calcita mais pura e a outra possibilidade é que a fase final concentra mais Sr no líquido e há mais atividade de Sr para substituir na estrutura de calcita, provando que os carbonatitos mais evoluídos ainda cristalizaram em temperatura suficiente para aceitar Sr na estrutura.

Dolomita também é afetada por este processo. A dolomita de C4 evolui principalmente em direção ao aumento de Sr, enquanto C5 mostra dois grupos, um que representa as exsoluções (menos Sr) e outro representando o cristalizado diretamente do magma. O teor de ferro do grupo também mostra dois grupos, um de exsolução em norsethita com maior teor de ferro e o outro é cristalizado diretamente a partir do magma.

As temperaturas definidas por pares de carbonato indicam temperaturas de 350°C a temperaturas inferiores para as exsoluções no sistema calcita-estroncianita em diferentes profundidades e a temperatura de formação de carbonatos de fase *liquidus* e exsoluções estão representados no diagrama *solvus* calcita-dolomita. O grupo C5 apresenta dois momentos de re-equilíbrio que registraram temperatura entre dois pares de calcita-dolomite, o primeiro a 700 ° C, e o segundo a 550°C, em que representa duas fases de exsolução, uma temperatura relativamente elevada para um magma carbonatítico. Carbonatitos C3 apresentam temperaturas de 700°C, representando a cristalização ao mesmo tempo de calcita e dolomita. O grupo C4 exsolveu a 500°C, enquanto que a amostra representativa de C2 exsolveu a aproximadamente 180°C. Temperaturas acima de 500°C são interpretadas como magmáticas, enquanto que abaixo de 450°C é interpretado como reequilíbrio *subsolidus*.

Diagramas de relações *subsolidus* mostram que a composição química de C1 e C2 formaria somente calcita e dolomita, respectivamente, o que é consistente com a análise de química mineral. Carbonatitos C3, C4 e C5 pertencem aos campos que geram mais de duas fases somando as evidências de que carbonatos diferentes de calcita e dolomita começam a se formar diretamente do magma nesses grupos, representando fases *liquidus*.



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## ANEXOS

Anexo A – Geoquímica de Rocha Total - Elementos Maiores

Anexo B – Geoquímica de Rocha Total - Elementos Traços e Terras Raras

Anexo C – Geoquímica Isotópica – Dados de C, O e S

Anexo D – Dados de Química Mineral de Carbonatos

Baritocalcita

Bastnaesita

Benstonita

Burbankita

Calcita

Dolomita

Fe-Dolomita

Norsethita

Olekminskita

Parisita

Estroncianita

Anexo E – Imagens de elétrons retroespalhados e Mapas de Composição por EDS

Anexo F – Composição de imagens de elétrons retroespalhados e Mapas de Composição por WDS e EDS de lâmina inteira.

### Dados de Geoquímica de Rocha Total – Elementos Maiores

Amostra	C2AA165907	C2AA273561	SL10A2577B	SL9380	SLASL15	SLE360	SLFVL184	TPAT128	TPAT46
Rocha	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito
Unidade	C1	C1	C1	C1	C1	C1	C1	C1	C1
Complexo	Catalaoll	Catalaoll	Salitre	Salitre	Salitre	Salitre	Salitre	Tapira	Tapira
Província	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP
Fonte	Este trabalho	Palmieri (2010)	Barbosa (2009)	Barbosa (2009)	Barbosa (2009)	Este trabalho	Barbosa (2009)	Brod (1999)	Brod (1999)
SiO <sub>2</sub>	8.93	0.42	0.14	1.61	1.19	0.06	3.12	8.56	0.86
TiO <sub>2</sub>	0.44	0.04	0	0.15	0.05	0.005	0.05	0.71	0.02
Al <sub>2</sub> O <sub>3</sub>	0.2	0.01	0	0.12	0.2	0	0	1.88	0.28
Fe <sub>2</sub> O <sub>3</sub> (T)	10.5	7.05	0.43	3.21	9.92	1.62	3.1	12.36	1.61
MnO	0.25	0.13	0.03	0.11	0.12	0.12	0.15	0.22	0.26
MgO	2.56	1.86	0.27	2.59	3.03	0.79	3.08	4.27	3.69
CaO	39.9	46.65	55.8	51.15	41.85	53.84	48.32	37.99	45.96
Na <sub>2</sub> O	0.82	0.07	0.14	0.07	0.1	0.17	0.18	0.13	0.5
K <sub>2</sub> O	0.63	0.13	0	0.41	0.05	0.11	0.86	1.62	0.03
P <sub>2</sub> O <sub>5</sub>	1.49	0.01	34.63	0	3.38	0.005	8.45	16.73	0.37
BaO	0.466	0.5037	0.0326	0.187	0.135	0.3548	0.1889	0.2444	0.3007
SrO	1.6534	2.3393	1.3159	1.4391	1.1218	2.0766	1.656	1.0137	2.3054
LOI	31.7	35.5	7	38.4	35.62	40.7	30.1	13.5	41.52
Nb <sub>2</sub> O <sub>5</sub>	0.0444	0.0079	0.001	0.2806	0.0145	0.002	0.3727	0.0203	0.1085
REE <sub>2</sub> O <sub>3</sub>	0.2956	0.1556	0.6531	0.2139	0.1467	0.1697	0.2652	0.5042	0.2828
Total	99.92	94.88	100.44	99.97	96.94	100.01	99.9	99.87	98.1
CO <sub>2</sub>	34.59	42.98	6.82	42.51	34.71	44.38	32.14	14.8	42.73
TotS	0.75	2	0.12	0.88	0.91	0.62	0.68	0.47	0.33

### Dados de Geoquímica de Rocha Total – Elementos Maiores

Amostra	TPAT49	TPAT53	TPTAPS	J15052C	J15053E	JC1	JC3B	J15053D	J1605
Rocha	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito
Unidade	C1	C1	C1	C1a	C1a	C1a	C1a	C1b	C1b
Complexo	Tapira	Tapira	Tapira	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga
Província	APIP	APIP	APIP	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa
Fonte	Brod (1999)	Brod (1999)	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho
SiO <sub>2</sub>	1.05	3.24	1.16	0.29	0.8	2.49	1.7	0.06	0.81
TiO <sub>2</sub>	0.01	0.54	0.1	0	0.06	0.13	0.74	0	0.01
Al <sub>2</sub> O <sub>3</sub>	0.14	0.44	0.06	0	0.27	0.16	0.18	0	0.02
Fe <sub>2</sub> O <sub>3</sub> (T)	0.54	4.91	4.48	0.43	9.51	3.97	2.82	1.96	1.52
MnO	0.25	0.15	0.11	0.12	0.15	0.12	0.13	0.12	0.13
MgO	2.43	1.33	2.44	6.05	3.96	4.78	4.61	3.92	5.87
CaO	47.95	45.9	50.78	48.53	46.27	47.59	48.38	52.12	49.07
Na <sub>2</sub> O	0.25	0.04	0.09	0.04	0.05	0.09	0.07	0.02	0.03
K <sub>2</sub> O	0.01	0.41	0.11	0	0.03	0.11	0.15	0	0
P <sub>2</sub> O <sub>5</sub>	0.05	4.87	4.25	11.3	11.85	19.74	15.8	0.06	4.94
BaO	0.32	0.18	0.22	0.064	0.072	0.14	0.10	0.085	0.069
SrO	2.51	1.57	1.58	0.66	0.62	0.48	0.64	0.69	0.71
LOI	43.10	34.50	34.00	32.30	26.10	19.60	24.40	40.80	36.60
Nb <sub>2</sub> O <sub>5</sub>	0.04	0.03	0.14	0.00	0.00	0.01	0.02	0.00	0.00
REE <sub>2</sub> O <sub>3</sub>	0.22	0.19	0.27	0.09	0.11	0.15	0.13	0.053	0.07
Total	98.87	98.38	99.81	99.89	99.93	99.87	99.88	99.89	99.87
CO <sub>2</sub>	44.49	34.06	37.52	34.01	28.99	20.63	28.18	45.15	37.99
TotS	0	0.31	0.63	0.13	0.28	0.05	0.62	0.56	0.38

### Dados de Geoquímica de Rocha Total – Elementos Maiores

Amostra	J17052B	JC3	JC4	JCCG01	JCCG02	JCL250	C1CB02	J080DIQUE	J140N3B
Rocha	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito
Unidade	C1b	C1b	C1b	C1b	C1b	C1b	C2	C2	C2
Complexo	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Catalaol	Jacupiranga	Jacupiranga
Província	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	APIP	PontaGrossa	PontaGrossa
Fonte	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho
SiO <sub>2</sub>	0.21	0.17	0.57	0.17	0.13	0.34	0.23	0.41	0.24
TiO <sub>2</sub>	0.02	0.04	0.01	0	0	0	0.005	0	0
Al <sub>2</sub> O <sub>3</sub>	0.04	0.03	0.1	0	0.01	0.04	0	0.05	0.09
Fe <sub>2</sub> O <sub>3</sub> (T)	1.88	2.04	4.44	38.78	0.23	5.66	6	4.46	0.62
MnO	0.13	0.13	0.12	0.07	0.14	0.12	0.36	0.22	0.13
MgO	4.36	3.67	3.82	0.88	3.82	3.24	19.67	17.36	14.74
CaO	50.17	50.74	47.59	30.38	50.73	50.15	30.29	33.39	37.91
Na <sub>2</sub> O	0.03	0.04	0.05	0.02	0.02	0.03	0.11	0.06	0.05
K <sub>2</sub> O	0.02	0.03	0.06	0	0	0.03	0.14	0.03	0.05
P <sub>2</sub> O <sub>5</sub>	5.16	3.51	8.24	0	0.39	5.68	0.1	3.46	13.88
BaO	0.09	0.36	0.08	0.07	0.13	0.09	0.18	0.04	0.026
SrO	0.72	0.78	0.60	0.41	0.86	0.66	1.27	0.54	0.42
LOI	37.00	38.30	34.20	3.40	43.40	33.80	41.20	39.50	31.50
Nb <sub>2</sub> O <sub>5</sub>	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.00
REE <sub>2</sub> O <sub>3</sub>	0.08	0.07	0.06	0.04	0.06	0.07	0.09	0.05	0.06
Total	99.90	99.92	99.95	74.22	99.92	99.91	99.64	99.64	99.73
CO <sub>2</sub>	39.98	41.44	36.86	25.72	42.51	35.95	40.05	42.18	33.05
TotS	0.14	0.49	0.31	16.73		0.60	2.42	1.92	

### Dados de Geoquímica de Rocha Total – Elementos Maiores

Amostra	SLFSALT0287	SNLG08	SNLG38	TP4S22	TPAT138	TPAT139	TPAT140	AXC85D	SL109C
Rocha	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito
Unidade	C2	C2	C2	C3	C3	C3	C3	C4	C4
Complexo	Salitre	SerraNegra	SerraNegra	Tapira	Tapira	Tapira	Tapira	Araxa	Salitre
Província	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP
Fonte	Barbosa (2009)	Grasso (2010)	Grasso (2010)	Brod (1999)	Brod (1999)	Brod (1999)	Brod (1999)	Este trabalho	Este trabalho
SiO <sub>2</sub>	0.62	0.2	0.14	1.04	0.6	2.15	2.19	2.64	1.34
TiO <sub>2</sub>	0.005	0.005	0.005	0.16	0.14	0.1	0.05	0.14	0.38
Al <sub>2</sub> O <sub>3</sub>	0	0.02	0.01	0.02	0.41	0.27	0.29	0.12	0.09
Fe <sub>2</sub> O <sub>3</sub> (T)	3.87	0.93	1.88	1.97	1.08	1.44	1.26	5.75	2.61
MnO	0.8	0.25	0.4	0.13	0.34	0.31	0.3	0.69	0.56
MgO	19.3	18.9	19.5	1.81	5.93	5.51	4.55	15.62	14.65
CaO	29.64	29.86	29.23	47.11	36.89	36.72	39.83	24.57	28.73
Na <sub>2</sub> O	0.04	0.15	0.13	0.19	0.4	0.45	0.31	0.24	0.17
K <sub>2</sub> O	0.005	0.07	0.05	0.33	0.02	0.07	0.03	0.15	0.22
P <sub>2</sub> O <sub>5</sub>	0.005	0.2	0.09	0.41	0.36	0.11	0.12	6.26	6.69
BaO	0.16	0.12	0.24	2.03	12.83	9.97	3.70	3.88	5.59
SrO	0.88	1.98	1.18	4.73	2.99	3.30	3.73	3.87	3.13
LOI	44.50	47.21	47.82	39.40	37.20	37.99	39.68	33.00	32.20
Nb <sub>2</sub> O <sub>5</sub>	0.00	0.02	0.00	0.12	0.02	0.01	0.02	0.04	0.01
REE <sub>2</sub> O <sub>3</sub>	0.06	0.05	0.05	0.52	0.60	0.57	0.82	2.50	2.13
Total	99.88	99.96	100.73	99.97	99.79	98.98	96.87	99.50	101.44
CO <sub>2</sub>	42.91	47.20	47.75	41.70	38.37	39.76	42.87	35.73	32.32
TotS	0.40		0.07	0.47	0	0	0.16	1.15	1.38



### Dados de Geoquímica de Rocha Total – Elementos Maiores

Amostra	TPAT103	TPAT137	AXC83E	AXC83H	C1L15250	TPAT135
Rocha	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito	Carbonatito
Unidade	C4	C4	C5	C5	C5	C5
Complexo	Tapira	Tapira	Araxa	Araxa	Catalaol	Tapira
Província	APIP	APIP	APIP	APIP	APIP	APIP
Fonte	Brod (1999)	Brod (1999)	Este trabalho	Este trabalho	Este trabalho	Brod (1999)
SiO <sub>2</sub>	2.38	3.08	0.49	0.22	1.75	2.2
TiO <sub>2</sub>	0.08	0.11	0.04	0.25	0.08	0.06
Al <sub>2</sub> O <sub>3</sub>	0.55	0.51	0.01	0	0.08	0.6
Fe <sub>2</sub> O <sub>3</sub> (T)	6.19	2.31	5.26	2.93	9.88	3.18
MnO	0.52	0.35	0.37	0.29	0.28	0.58
MgO	9.6	8.91	16.8	16.33	14.6	16.92
CaO	28.4	31.13	20.09	20.05	23.23	26.26
Na <sub>2</sub> O	0.35	0.28	0.16	0.19	0.05	0.31
K <sub>2</sub> O	0.03	0.01	0.12	0.09	0.31	0.02
P <sub>2</sub> O <sub>5</sub>	1.13	0.57	0.71	0.08	4.34	0.27
BaO	5.78	7.04	11.12	13.72	8.51	4.98
SrO	3.29	5.35	3.12	3.20	2.24	1.58
LOI	31.76	35.99	36.10	39.10	31.20	41.65
Nb <sub>2</sub> O <sub>5</sub>	0.01	0.06	0.22	0.03	0.04	0.07
REE <sub>2</sub> O <sub>3</sub>	2.25	1.78	0.31	0.20	0.21	0.35
Total	92.32	97.48	98.79	99.00	100.48	99.03
CO <sub>2</sub>	35.97	37.01	36.75	36.50	30.78	43.72
TotS	1.14	0.20	1.55	0.93	2.13	0.35

## Dados de Geoquímica de Rocha Total – Elementos Traços e Terras Raras

Amostra	C2AA165907	C2AA273561	SL10A2577B	SL9380	SLASL15	SLE360	SLFVL184	TPAT128	TPAT46	TPAT49	TPAT53
Unidade	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1	C1
Complexo	Catalaoll	Catalaoll	Salitre	Salitre	Salitre	Salitre	Salitre	Tapira	Tapira	Tapira	Tapira
Província	APIP	APIP	APIP Barbosa	APIP Barbosa	APIP Barbosa	APIP	APIP Barbosa	APIP	APIP	APIP	APIP
Fonte	Este trabalho	Palmieri (2010)	(2009)	(2009)	(2009)	Este trabalho	(2009)	Brod (1999)	Brod (1999)	Brod (1999)	Brod (1999)
Ba	4174	4511	292	1675	1209	3178	1692	2189	2694	2905	1587
Rb	24.6	5.9	0	11.2	0.9	1.6	29.1	47.3	0.5	1	7.7
Sr	13981	19781	11127	12169	9485	17560	14003	8572	19494	21197	13288
Cs	0.3		0	0.2	0		0.5	0.8	0.02	0.03	
Ga	4.5		6.3	3.5	0		13.4	7.1	3.86	2.65	
Ta	31.6		0.8	31.1		0.1	4.7	7.3	1.76	0.92	
Nb	310.3	55	6.8	1961.8	101.7	14.2	2605.2	141.8	758.7	259.5	177.7
Hf	4	0.5	0.1	4.7			1.6	15.2	0.28	0.16	
Zr	312.6	33.5	2.9	182.5	114.2	3.5	23.4	846.5	5.1	4.8	647
Y	93.5	32.8	119.4	60.4	50.4	53.9	63.2	134.8	80.47	69.37	86.5
Th	158.2	20.9	9.3	408.5	10.8	10.5	23.8	52.4	48.98	11.91	19
U	32.4	0.5	1.3	43.4	13.8	0.8	29.1	19.2	1.99	0.46	30.5
Ni		1.1		1.3	16.5	3.2		2.5	9.2	6.6	12.3
V	106	22	61	18	36.9		0.49	252	4.5	4	135.6
Cu	22	875.6	3.8	34.2	97.5	26.8	1.9	65	5.6	1.3	
Pb	27.6	8.2	2.4	7	9.9	6.4	5.2	4.5	13.1	11.3	8.1
Zn	58	7	2	17	32.2	3	17	103	6.8	3.8	
Sc	5	8	2	8	0	4	3	29	6.1	5.5	13
Co	13.9	176.3	3.5	34.1	90.3	10.4	9.3	34.9	20	1.6	10.9
La	643.4	332.4	998.4	298.3	326.8	373.2	448.2	839.5	536.5	408.7	445.8
Ce	1200.4	615.1	2627.6	968.4	658.2	700.6	1125	2030	1156.5	937.1	844.4
Pr	121.28	67.7	347.95	95.07		68.81	123.12	228.68	123.9	91.9	
Nd	422.5	248.5	1266.5	352.5	267.8	230.9	447.4	904.6	451.9	324	328.6
Sm	46.71	28.22	162.48	45.2		26.2	49.6	122.86	59.9	43.7	
Eu	12.1	7.42	36.69	12.76		7.28	13.2	30.56	15.55	11.54	
Gd	35.88	14.87	87.08	26.64		21.16	31.18	86.38	35.27	27.49	
Tb	4.66	1.93	10.19	3.79		2.27	3.93	8.47	4.34	3.43	
Dy	21.87	7.97	32.22	15.34		10.04	15.48	36.69	18.75	14.77	
Ho	3.35	1.07	3.48	1.94		1.66	1.79	5.05	2.96	2.34	
Er	7.49	2.58	6.76	4.9		4.02	4.64	10.55	6.49	5.13	
Tm	0.93	0.33	0.73	0.55		0.6	0.53	1.24	0.824	0.706	
Yb	5.29	2.03	4.14	3.36		3.48	3.2	6.59	4.51	3.87	
Lu	0.72	0.25	0.43	0.43		0.53	0.41	0.79	0.603	0.546	

### Dados de Geoquímica de Rocha Total – Elementos Traços e Terras Raras

Amostra	TPTAPS	J15052C	J15053E	JC1	JC3B	J15053D	J1605	J17052B	JC3	JC4	JCCG01
Unidade	C1	C1a	C1a	C1a	C1a	C1b	C1b	C1b	C1b	C1b	C1b
Complexo	Tapira	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga
Província	APIP	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa
Fonte	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho
Ba	1971	575	646	1270	907	760	621	777	3206	708	637
Rb	2.3	0.1	0.9	2.9	4.3	0.1		0.4	0.9	1.2	
Sr	13364	5592.3	5259.5	4067	5450.6	5872.2	6044.4	6062.2	6613	5043.1	3473.1
Cs				0.1							
Ga	0.9		1.7	1.4	0.5					0.7	0.7
Ta	104.9	0.6	12.5	6.7	11.5	0.3	1.1	1.6	0.3	6.2	
Nb	996.8	0.5	29.3	42	152.2	6.6	3.1	4.1	3.9	12.3	8.7
Hf	3.6	1.7	7.8	5.2	0.1		1.6	0.2	0.1	1.8	
Zr	112.2	132.9	554.8	2321.4	7.3	8.6	109.7	4.1	6.8	107.5	6
Y	74.2	46.3	53	50.7	55.5	36.7	39.5	42.7	44.1	50.1	21.4
Th	437.2	1.5	2	12.7	7.2	0.4	0.9	1.8	0.7	1.8	
U	305.1		0.3	2.3	0.8					0.2	
Ni		0.2		0.2	46.5		1.5		4.8		102
V	57		93	88	34			12	19	39	
Cu	7.6	6.8	4.8	8.3	133.3	2.1	20.2	9.8	27.7	0.8	361.9
Pb	4.3	6.1	6.1	3.5	5.2	4.6	5.7	5.4	8.1	12.7	10.8
Zn	19	1	32	19	7	2	6	6	6	13	20
Sc	14	8	20	34	12	10	11	12	13	14	13
Co	33.7	9.4	32.6	9.2	40.2	44.3	23.8	14.2	31.1	38.3	394.2
La	471.8	141.8	165.9	223.1	200.6	95.7	111.9	126.6	125.2	87.7	67.7
Ce	1103.8	331.3	394.4	550.8	495.3	189.9	248.3	280	280.7	201.8	144.4
Pr	122.34	40.88	48.93	68.9	62.59	22.98	29.72	33.31	32.03	24.5	16.35
Nd	477.1	174.7	204.5	289.7	265.9	94.7	125.3	133.6	125.2	103	61.5
Sm	62.48	29.57	35.27	46.23	44.06	15.62	21.26	23.51	21.99	19.48	10.55
Eu	15.87	8.5	9.83	12.76	12.32	4.67	6.16	6.7	6.48	6.01	3.03
Gd	45.54	23.57	27.56	36.54	36.4	12.37	16.77	18.86	18.92	18.67	8.1
Tb	4.28	2.76	3.25	3.68	3.75	1.69	2.12	2.31	2.25	2.34	1.06
Dy	18.01	12.1	14.1	15.62	16.28	8.34	9.79	10.26	10.53	11.03	4.75
Ho	2.62	1.72	2.03	2.01	2.25	1.2	1.49	1.55	1.61	1.92	0.73
Er	5.41	3.5	4.31	3.93	4.43	2.86	3.36	3.38	3.72	4.41	1.62
Tm	0.67	0.42	0.48	0.39	0.49	0.39	0.41	0.41	0.44	0.54	0.21
Yb	3.73	2.27	2.56	2.3	2.89	2.25	2.14	2.46	2.54	3.13	1.08
Lu	0.49	0.29	0.31	0.26	0.35	0.28	0.28	0.31	0.34	0.42	0.14

### Dados de Geoquímica de Rocha Total – Elementos Traços e Terras Raras

Amostra	JCCG02	JCL250	C1CB02	J080DIQUE	J140N3B	SLFSALT0287	SNLG08	SNLG38	TP4S22	TPAT138	TPAT139
Unidade	C1b	C1b	C2	C2	C2	C2	C2	C2	C3	C3	C3
Complexo	Jacupiranga	Jacupiranga	Catalaol	Jacupiranga	Jacupiranga	Salitre	SerraNegra	SerraNegra	Tapira	Tapira	Tapira
Província	PontaGrossa	PontaGrossa	APIP	PontaGrossa	PontaGrossa	APIP	APIP	APIP	APIP	APIP	APIP
Fonte	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Este trabalho	Barbosa (2009)	Grasso (2010)	Grasso (2010)	Brod (1999)	Brod (1999)	Brod (1999)
Ba	1169	764	1573	340	231	1427	1034	2187	18194	114871	89303
Rb	0.3		1.7	0.8	1.1	0.27	1.6	0.8	6.3	0.5	4.2
Sr	7267.1	5562.2	10723	4553.3	3587.7	7447	16754	10003	39983	25250	27940
Cs									0.2	0.04	
Ga		1	0.8	0.8	0.6					7.05	
Ta	0.5	2.1		20.6	1	0.42	0.5		0.9	0.2	
Nb	11.9	39.3	20.3	489.5	2.2	24.43	168.7	5.3	835.6	108.5	97.4
Hf		0.4	1	0.5	1	0.37			1.1	0.12	
Zr	1.1	27.1	30.4	18.2	66	16.54	2.7	1.8	31.1	0.9	12.4
Y	42.5	38.5	10.7	27.2	38.8	11.45	9.1	9.1	91.7	71.55	97.3
Th	0.7	4.3	12.1	33	1.9	10.08	5.3	11.6	114.4	13.18	110
U			2.4	0.6	0.1	1.1	0.5		0.3	0.11	8.9
Ni	0.2		14.4					1.6		18.4	5.7
V		32		9		14.96			14	1	29.5
Cu	43.1	34.6	335.4	4.7	0.5		0.9		92.5	5	
Pb	8.1	6.5	3.2	21.1	2.5		5.9	5.4	16.5	24.7	1
Zn	1	14	10	11	3		6	10	7	17.9	
Sc	13	15	13	14	7		7	10	8	16.8	15.6
Co	1.9	57.2	102	22.2	1.8		2.8	3.6	24.8	2.9	0.3
La	112.3	120.7	153.7	83.1	81.2	98.89	112.5	135.4	1248.7	1575.9	1766.4
Ce	234.2	244.5	375.2	174.9	196.8	220.94	205.8	201	2164.1	2491.6	2503.4
Pr	26.81	29.48	46.02	22.52	26.02	30.41	22.98	21.14	194.96	218.9	
Nd	105.8	118.7	181.6	96.3	110.4	109.33	75.4	66.9	636.9	658.9	600.8
Sm	17.64	19.72	25.75	17.08	21	14.36	8.03	7.8	66.14	63.3	
Eu	5.4	5.95	6.31	5.17	6.23	3.59	2.14	2.36	16.25	17.2	
Gd	15.48	15.44	11.36	13.61	18.09	8.05	5.12	6.93	42.91	30.67	
Tb	1.94	2.07	1.08	1.8	2.3	0.82	0.56	0.93	4.49	3.88	
Dy	9.28	9.11	3.34	7.86	10.21	3.04	2.3	3.56	20.07	16.07	
Ho	1.58	1.37	0.31	1.08	1.54	0.45	0.33	0.38	3.01	2.59	
Er	3.39	3.12	0.58	2.3	3.21	1.04	0.74	0.53	7.16	6.07	
Tm	0.43	0.37	0.08	0.25	0.36	0.1156	0.09	0.07	0.94	0.814	
Yb	2.46	1.97	0.45	1.26	1.83	0.72	0.56	0.32	5.71	4.74	
Lu	0.36	0.28	0.06	0.15	0.21	0.0777	0.07	0.04	0.75	0.651	

### Dados de Geoquímica de Rocha Total – Elementos Traços e Terras Raras

Amostra	TPAT140	AXC85D	SL109C	TPAT103	TPAT137	AXC83E	AXC83H	C1L15250	TPAT135
Unidade	C3	C4	C4	C4	C4	C5	C5	C5	C5
Complexo	Tapira	Araxa	Salitre	Tapira	Tapira	Araxa	Araxa	Catalaol	Tapira
Província	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP
Fonte	Brod (1999)	Este trabalho	Este trabalho	Brod (1999)	Brod (1999)	Este trabalho	Este trabalho	Este trabalho	Brod (1999)
Ba	33105	34714	50067	51755	63048	99597	122884	76220	44582
Rb	1.5	4.7	5.1	0.4	0.1	4.4	1.8	19.5	2.5
Sr	31513	32731	26480	27792	45225	26342	27028	18975	13336
Cs	0.06			0.03	0.01			0.3	0.07
Ga	8.43			31.95	21.57			1.4	4.31
Ta	0.18	3.7	0.5	0.22	0.62	6.1	5.8	73.5	0.21
Nb	164	307.9	88.9	97.7	434.8	1563.4	200.9	305.7	515.4
Hf	0.08	5	3	0.27	0.18	1.8	1.6	4.5	0.22
Zr	3	217.2	97.3	19.9	4.9	11.8	13.1	170.8	5.4
Y	93.08	224.4	95	105.26	144.26	32.5	46.4	24.1	58.23
Th	29.23	330.5	57.8	110.57	181.32	108.6	148.7	18.3	91.14
U	0.18	3.8	2.5	1.1	0.64	2	2	20.2	0.42
Ni	11.7	55.2	4.1	21.5	16	5		4	6.4
V	3	50	18	16.3	8.6	15	19	57	5.7
Cu	7.8	1.5	88.1	46.7	22.2	16.6	1.7	190.4	0
Pb	32.5	1029.5	193.4	11.6	14.8	32	15.7	3.6	8.8
Zn	6.8	392	261	17.2	16.7	105	22	22	17.6
Sc	11.3	43	13	10.1	16.7	20	20	14	20.3
Co	5.6	21.7	9.2	59	6.3	45.2	21.2	145.9	1.2
La	2274	4930.8	6354.1	5623.4	5599.1	719.1	535.4	397.9	947.9
Ce	3399.5	11000.7	8541.2	9482.7	7099.3	1277.4	793.7	860.4	1443.6
Pr	272.9	1053.1	700.1	927.8	597.6	124.93	73.31	95.72	125.7
Nd	831.6	3552.2	2203.9	2785.5	1613.5	412.2	236.5	362.7	376.8
Sm	84.6	388.4	200.85	198	118.4	46.37	35.94	47.95	38.3
Eu	21.94	86.13	44.82	38.14	27.84	9.13	8.14	11.48	10.13
Gd	46.67	264.68	81.99	73.75	66.31	37.38	36.15	34.05	19.24
Tb	5.53	16.86	8.74	7.37	7.51	3.6	4.19	2.6	2.79
Dy	21.39	66.04	30.37	24.45	29.91	12.5	15.65	8.26	12.62
Ho	3.15	7.32	2.98	3.78	5.01	1.35	1.78	0.92	2.14
Er	6.82	12.64	6.66	8.13	12.18	2.22	2.83	1.26	5.27
Tm	0.916	1.66	0.76	1.058	1.677	0.22	0.29	0.15	0.669
Yb	5.03	9.86	4.27	4.98	7.71	1.39	1.63	0.89	3.01
Lu	0.688	1.02	0.45	0.63	0.894	0.18	0.2	0.1	0.314

## Dados de Geoquímica Isotópica

Amostra	C2AA165907	C2AA273561	SL10A2577B	SL9380	SLASL15	SLE360	SLFVL184	TPAT128	TPAT46
Mineral	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto
Unidade	C1	C1	C1	C1	C1	C1	C1	C1	C1
Complexo	Catalaoll	Catalaoll	Salitre	Salitre	Salitre	Salitre	Salitre	Tapira	Tapira
Província	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP
$\delta^{13}\text{C}$	-6.26	-5.9	-7.35	-7.25	-6.92	-7.41	-7.29	-8.21	-8.07
$\delta^{18}\text{O}$	8.83	8.52	7	6.87	7.22	7.15	7.06	7.53	6.37
$\delta^{32}\text{S}$	-5.09	-6.68	-6.44	-12.36	-2.84	-6.08	-5.65	-4.47	-7.93

Amostra	TPAT49	TPAT53	TPTAPS	J15052C	J15053E	JC1	JC3B	J15053D	J1605
Mineral	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto
Unidade	C1	C1	C1	C1a	C1a	C1a	C1a	C1b	C1b
Complexo	Tapira	Tapira	Tapira	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga	Jacupiranga
Província	APIP	APIP	APIP	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa	PontaGrossa
$\delta^{13}\text{C}$			-6.35	-5.27	-5.65	-5.65	-5.78	-6.13	-7.15
$\delta^{18}\text{O}$			8.08	8.8	8.4	8.74	8.63	7.21	5.64
$\delta^{32}\text{S}$	-9.01	-6.79	-3.95		-4.99	-3.34	-5.56	-3.88	-4.40

## Dados de Geoquímica Isotópica

Amostra	SLFSALT0287	SNLG08	SNLG38	TP4S22	TPAT138	TPAT139	TPAT140	AXC85D	SL109C
Mineral	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto
Unidade	C2	C2	C2	C3	C3	C3	C3	C4	C4
Complexo	Salitre	SerraNegra	SerraNegra	Tapira	Tapira	Tapira	Tapira	Araxa	Salitre
Província	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP	APIP
$\delta^{13}\text{C}$	-6			-6.56	-7.77	-5.04	-7.48	-4.79	-6.62
$\delta^{18}\text{O}$	8.23			9.98	9.05	13.69	12.61	17.69	8.36
$\delta^{32}\text{S}$	-7.72	-8.13	-8.78	-7.9	-8.79	-8.21	-11.59	-9.61	-5.7

Amostra	TPAT103	TPAT137	AXC83E	AXC83H	C1L15250	TPAT135
Mineral	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto	Cbt/Sulfeto
Unidade	C4	C4	C5	C5	C5	C5
Complexo	Tapira	Tapira	Araxa	Araxa	Catalaol	Tapira
Província	APIP	APIP	APIP	APIP	APIP	APIP
$\delta^{13}\text{C}$	-6.92	-6.36	-7.23	-5.41	-6.56	
$\delta^{18}\text{O}$	11.41	15.26	7	10.01	11.06	
$\delta^{32}\text{S}$	-13.15	-8.15	-11.69	-8.91	-2.2	-13.58

## Dados de Química Mineral de Carbonatos – Ancylita

Amostra	Fsalt0287	AT139	AT139	AT139	AT139	AT139	AT135	AT49	AT135	AT135	AT49	AT46	AT46
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C3	C3	C3	C3	C3	C4a	C1b	C4a	C4a	C1b	C1b	C1b
textura	exsolution	exsolution	exsolution	exsolution	exsolution	exsinstront	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution
Complexo	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita	Ancylita
K <sub>2</sub> O	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y <sub>2</sub> O <sub>3</sub>	0.00	0.14	0.23	0.09	0.38	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.02	0.15	0.00	0.15	0.00	0.00	0.16	0.07	0.76	0.54	0.14	0.01	0.04
MnO	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
MgO	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.03
CaO	1.51	0.91	0.81	0.95	0.87	4.22	1.15	2.76	0.96	1.44	3.44	4.48	6.00
Na <sub>2</sub> O	0.38	0.32	0.31	0.37	0.32	0.42	0.20	0.25	0.21	0.36	0.24	0.42	0.49
SrO	13.33	13.33	13.78	13.86	14.30	30.37	10.53	11.24	12.53	12.60	12.97	14.06	14.94
BaO	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La <sub>2</sub> O <sub>3</sub>	11.18	14.33	14.76	14.93	12.48	9.38	17.71	12.76	16.95	17.08	11.85	11.70	10.08
Ce <sub>2</sub> O <sub>3</sub>	20.01	23.62	23.04	23.00	20.03	20.23	23.30	24.33	24.36	25.14	20.44	23.00	19.62
Pr <sub>2</sub> O <sub>3</sub>	1.92	1.87	2.08	1.95	1.95	2.33	1.56	2.68	2.06	1.87	1.98	2.36	1.96
Nd <sub>2</sub> O <sub>3</sub>	4.66	6.60	5.65	6.14	6.40	8.49	4.58	8.91	5.60	5.69	7.60	7.96	9.87
Dy <sub>2</sub> O <sub>3</sub>	0.49	0.52	0.53	0.32	0.59	0.41	0.38	0.19	0.62	0.24	0.43	0.73	0.44
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.13	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.02	0.02	0.12	0.00
Cl	0.02	0.01	0.00	0.00	0.02	0.01	0.02	0.02	0.00	0.01	0.03	0.00	0.03
F	1.43	0.90	1.23	0.58	1.08	0.19	1.07	0.98	1.39	1.69	1.30	1.13	0.43
Total1	48.19	53.80	54.14	54.02	49.28	65.51	54.59	52.43	57.68	59.23	50.41	54.82	51.65
TotalETR	39.14	47.70	47.25	47.48	42.47	42.21	48.40	50.34	50.76	50.77	44.15	48.04	45.12
CO <sub>2</sub>	17.71	19.49	19.38	19.72	18.37	27.94	18.66	20.62	20.38	20.73	20.25	22.61	23.48
H <sub>2</sub> O							4.84	5.18	5.25	5.31	4.95	5.45	5.43
Total <sub>2</sub>	73.26	82.66	82.46	83.04	77.15	105.97	85.04	91.06	92.18	93.11	86.91	95.74	95.79



## Dados de Química Mineral de Carbonatos – Ancyilita (cont.)

Amostra	Fsalt0287	AT139	AT139	AT139	AT139	AT139	AT135	AT49	AT135	AT135	AT49	AT46	AT46
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C3	C3	C3	C3	C3	C4a	C1b	C4a	C4a	C1b	C1b	C1b
textura	exsolution	exsolution	exsolution	exsolution	Exsolution	exsinstront	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution
Complexo	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita	Ancyilita
Proporção atômica para 13 (O, OH) / 4 Metais e 4 Carbonos													
Fe <sup>2+</sup>	0.0027	0.0181	0.0000	0.0178	0.0000	0.0000	0.0200	0.0083	0.0870	0.0600	0.0161	0.0014	0.0043
Mn	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0000	0.0000	0.0000
Mg	0.0121	0.0000	0.0000	0.0011	0.0005	0.0000	0.0000	0.0035	0.0000	0.0008	0.0000	0.0000	0.0062
Ca	0.2564	0.1406	0.1257	0.1439	0.1426	0.4791	0.1846	0.4035	0.1413	0.2061	0.5152	0.6057	0.7824
Na	0.1181	0.0902	0.0866	0.1022	0.0953	0.0859	0.0585	0.0670	0.0565	0.0935	0.0659	0.1024	0.1157
Sr	1.2255	1.1170	1.1544	1.1386	1.2702	1.8667	0.9118	0.8905	0.9937	0.9756	1.0512	1.0283	1.0550
Ba	0.0000	0.0000	0.0000	0.0000	0.0000	0.0227	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
La	0.6538	0.7634	0.7863	0.7804	0.7049	0.3667	0.9751	0.6431	0.8554	0.8413	0.6110	0.5442	0.4529
Ce	1.1616	1.2495	1.2188	1.1932	1.1229	0.7851	1.2732	1.2169	1.2200	1.2293	1.0461	1.0619	0.8749
Pr	0.1111	0.0986	0.1092	0.1005	0.1088	0.0901	0.0849	0.1333	0.1029	0.0908	0.1008	0.1086	0.0870
Nd	0.2637	0.3405	0.2916	0.3105	0.3501	0.3214	0.2441	0.4347	0.2738	0.2712	0.3795	0.3583	0.4293
Dy	0.0252	0.0240	0.0246	0.0145	0.0291	0.0139	0.0182	0.0085	0.0272	0.0102	0.0195	0.0295	0.0171
Yb	0.0000	0.0055	0.0000	0.0036	0.0011	0.0000	0.0000	0.0000	0.0000	0.0007	0.0008	0.0048	0.0000
C	3.8345	3.8446	3.8235	3.8147	3.8406	4.0438	3.8044	3.8459	3.8076	3.7800	3.8644	3.8934	3.9043
Cl	0.0056	0.0027	0.0000	0.0000	0.0039	0.0025	0.0056	0.0035	0.0000	0.0029	0.0071	0.0000	0.0052
F	0.7183	0.4117	0.5616	0.2586	0.5236	0.0627	0.5057	0.4221	0.6015	0.7152	0.5751	0.4522	0.1641
ΣCation	7.7228	7.7299	7.6865	7.7960	7.7386	8.1366	7.6340	7.7228	7.6377	7.6254	7.7559	7.8315	7.9808

## Dados de Química Mineral de Carbonatos – Baritocalcita/Bastnaesita

Amostra	C83H	C83H	C83H	CB02	CB02	AT135	AT135	SLE360	C87G	C87G	C87G	C87G	C87G
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG
Unidade	C4a	C4a	C4	C2	C2	C4a	C4a	C1b	C5	C5	C5	C5	C5
textura	exsindol	exsinnor	exsinnor	exsindol	Exsindol	ok	ok	exsinCalci-	fi-	fi-	fi-	fi-	fi-
Comple-								ta	bro_radial	bro_radial	bro_radial	bro_radial	bro_radial
xo	Araxá	Araxá	Araxá	Catalão	Catalão	Tapira	Tapira	Salitre	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Baritocalci-	Baritocalci-	Baritocalci-	ta	ta	Baritocalci-	Baritocalci-	ta	Bastnaesi-	Bastnaesi-	Bastnaesi-	Bastnaesi-	Bastnaesi-
Mineral	ta	ta	ta			ta	ta		ta	ta	ta	ta	ta
K <sub>2</sub> O				0.00	0.05	0.00	0.00	0.00					
FeO	0.20	0.08	0.12	0.44	0.81	0.08	0.07	0.11	0.20				
MnO	0.02	0.08	0.18	0.08	0.11	0.00	0.00	0.07	0.00				
MgO	0.54	2.74	1.81	0.16	7.12	0.03	0.02	1.53	0.05				
CaO	19.08	15.02	39.62	34.14	14.98	21.05	22.44	23.18	3.56	4.78	4.69	4.37	6.63
Na <sub>2</sub> O	0.08	0.16	0.42	0.51	0.77	0.65	0.64	0.56	0.00				
SrO	0.98	0.56	0.84	0.39	0.36	0.63	0.39	0.10	0.76	1.49	4.35	7.58	1.56
BaO	47.96	52.10	26.01	32.46	45.73	55.54	56.92	50.71	0.00				
La <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.05	0.00	0.02	0.00	0.01	0.06	27.33	25.92	23.85	17.27	22.46
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.21	1.28	0.00	0.08	1.54	1.44	0.30	27.93	27.08	22.25	15.54	25.53
Pr <sub>2</sub> O <sub>3</sub>			0.04	0.00	0.00	0.00	0.10	0.00	4.50				
Nd <sub>2</sub> O <sub>3</sub>			0.00	0.01	0.00	0.00	0.00	0.00	4.85				
Dy <sub>2</sub> O <sub>3</sub>			0.00	0.19	0.15	0.28	0.25	0.22	0.00				
Yb <sub>2</sub> O <sub>3</sub>			0.02	0.00	0.01	0.00	0.00	0.03	0.00				
Cl	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.01	0.10				
F	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	6.83	1.49		1.24	1.45
Total1	68.87	71.00	70.33	68.24	69.98	79.64	81.98	76.63	66.96	60.76	55.14	46.00	57.63
Tota-													
IETR	0.01	0.21	1.72	0.28	0.47	2.02	2.46	0.77	64.61	53.00	46.10	32.81	47.99
CO <sub>2</sub>	29.94	30.25	41.83	37.22	34.03	33.82	35.29	35.17	20.65	21.14	20.11	17.03	21.04
H <sub>2</sub> O													
Total2	98.81	101.28	112.55	105.74	104.38	113.91	118.28	112.20	94.06	90.82	83.55	68.41	86.70

## Dados de Química Mineral de Carbonatos – Baritocalcita/Bastnaesita (cont.)

Amostra	C83H	C83H	C83H	CB02	CB02	AT135	AT135	SLE360	C87G	C87G	C87G	C87G	C87G
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG
Unidade	C4a	C4a	C4	C2	C2	C4a	C4a	C1b	C5	C5	C5	C5	C5
textura	exsindol	exsinnor	exsinnor	exsindol	Exsindol	ok	ok	exsinCalci- ta	fi- bro_radial	fi- bro_radial	fi- bro_radial	fi- bro_radial	fi- bro_radial
Comple- xo	Araxá	Araxá	Araxá	CatalãoI	CatalãoI	Tapira	Tapira	Salitre	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Baritocalci- ta	Baritocalci- ta	Baritocalci- ta	Baritocalci- ta	Baritocalci- ta	Baritocalci- ta	Baritocalci- ta	Baritocalci- ta	Bastnaesi- ta	Bastnaesi- ta	Bastnaesi- ta	Bastnaesi- ta	Bastnaesi- ta
Proporção atômica para 6 O / 2 Metais 2 Car- bonos									Proporção atômica para 8 (O, F) / 2 Metais, 2 Carbonos				
Fe <sup>2+</sup>	0.0081	0.0032	0.0034	0.0136	0.0291	0.0028	0.0025	0.0039	0.0121	0.0000	0.0000	0.0000	0.0000
Mn	0.0006	0.0032	0.0054	0.0025	0.0039	0.0000	0.0000	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000
Mg	0.0396	0.1977	0.0941	0.0087	0.4547	0.0017	0.0013	0.0948	0.0053	0.0000	0.0000	0.0000	0.0000
Ca	0.9995	0.7779	1.4790	1.3478	0.6881	0.9719	0.9935	1.0333	0.2768	0.4300	0.4575	0.4953	0.5644
Na	0.0077	0.0150	0.0280	0.0367	0.0636	0.0544	0.0510	0.0448	0.0000	0.0000	0.0000	0.0000	0.0000
Sr	0.0277	0.0158	0.0169	0.0084	0.0088	0.0158	0.0093	0.0025	0.0320	0.0725	0.2297	0.4650	0.0719
Ba	0.9187	0.9867	0.3551	0.4687	0.7681	0.9380	0.9216	0.8269	0.0000	0.0000	0.0000	0.0000	0.0000
La	0.0001	0.0000	0.0006	0.0000	0.0004	0.0000	0.0002	0.0009	0.7318	0.8026	0.8009	0.6739	0.6582
Ce	0.0000	0.0036	0.0164	0.0000	0.0012	0.0243	0.0217	0.0046	0.7421	0.8324	0.7416	0.6019	0.7426
Pr	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0015	0.0000	0.1191	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.1257	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0022	0.0021	0.0039	0.0033	0.0029	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0002	0.0000	0.0001	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9983	1.9966	1.9899	1.8723	1.9917	1.9898	1.9912	1.9979	2.0463	2.4236	2.4995	2.4593	2.2821
Cl	0.0000	0.0016	0.0000	0.0001	0.0015	0.0002	0.0000	0.0004	0.0117	0.0000	0.0000	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0094	0.0000	0.0000	1.5671	0.3956	0.0000	0.4149	0.3643
ΣCation	4.0022	4.0044	4.0064	4.0098	4.0248	4.0106	4.0111	4.0181	4.2136	4.5611	4.7292	4.6954	4.5664

## Dados de Química Mineral de Carbonatos – Benstonita/Burbankita

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	CB02	CB02	AT139	AT139	AT139	CB02
Método	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4	C4	C4	C4	C4a	C4a	C4a	C2	C2	C3	C3	C3	C2
textura	exsinnor	exsinnor	exsinnor	exsinnor	Exsinnor	rea-	rea-	exsindol	exsindol	exsolution	ok	exsolution	exsindol
Comple-	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Catalão	Catalão	Tapira	Tapira	Tapira	Catalão
xo	Benstoni-	Benstoni-	Benstoni-	Benstoni-	Benstoni-	Benstoni-	Benstoni-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-
Mineral	ta	ta	ta	ta	ta	Benstonita	Benstonita	ta	ta	ta	ta	ta	ta
K <sub>2</sub> O								0.08	0.00	0.00	0.00	0.06	0.08
FeO	0.16	0.08	0.16	0.16	0.21			0.00	0.03	0.00	0.00	0.08	0.03
MnO	0.18	0.12	0.08	0.13	0.06			0.01	0.00	0.03	0.00	0.03	0.07
MgO	2.29	2.34	4.45	4.85	4.20	1.98	1.88	0.03	0.03	0.00	0.00	0.00	0.00
CaO	18.57	18.27	15.65	20.08	14.47	15.85	15.70	17.63	29.38	16.12	17.43	17.80	18.01
Na <sub>2</sub> O	0.57	0.65	0.47	0.53	0.99	0.11	0.09	7.01	4.67	5.26	6.53	6.67	7.05
SrO	5.06	5.36	5.07	5.50	8.71	6.85	8.25	33.39	30.64	25.02	28.51	27.47	38.55
BaO	47.08	48.16	49.09	40.78	42.92	40.18	37.48	11.80	2.94	9.78	10.83	18.18	10.11
La <sub>2</sub> O <sub>3</sub>	0.08	0.02	0.01	0.12	0.41			0.03	0.00	1.78	1.59	0.45	0.00
Ce <sub>2</sub> O <sub>3</sub>	1.37	1.64	1.34	1.25	0.50	0.00	0.00	0.15	0.00	4.11	3.74	0.30	0.08
Pr <sub>2</sub> O <sub>3</sub>	0.01	0.10	0.07	0.05				0.02	0.00	0.20	0.62	0.22	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00				0.00	0.00	0.89	1.23	0.31	0.18
Dy <sub>2</sub> O <sub>3</sub>	0.08	0.00	0.00	0.00				0.30	0.23	0.61	0.44	0.31	0.11
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.02	0.00	0.00				0.00	0.04	0.00	0.00	0.00	0.01
Cl	0.00	0.00	0.01	0.00	0.00			0.00	0.00	0.00	0.00	0.01	0.00
F	0.00	0.00	0.00	0.00	0.00			0.16	0.00	0.03	0.15	0.18	0.00
Total1	75.36	76.64	76.34	73.39	72.47	64.97	63.40	70.41	67.88	62.12	68.86	71.18	73.89
TotalETR	2.10	2.41	1.93	1.98	0.91	0.00	0.00	1.06	0.34	7.90	8.13	1.67	0.48
CO <sub>2</sub>	33.91	34.22	34.38	36.18	33.11	29.12	28.70	36.74	40.40	31.94	35.71	36.11	38.60
H <sub>2</sub> O													
Total2	109.92	111.61	111.29	110.18	105.70	94.09	92.10	107.96	108.62	96.07	107.31	108.13	112.90

## Dados de Química Mineral de Carbonatos – Benstonita/Burbankita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	CB02	CB02	AT139	AT139	AT139	CB02
Método	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4	C4	C4	C4	C4a	C4a	C4a	C2	C2	C3	C3	C3	C2
textura	exsinnor	exsinnor	exsinnor	exsinnor	Exsinnor	rea- cao_nor_bkt	rea- cao_nor_bkt	exsindol	exsindol	exsolution	ok	exsolution	exsindol
Comple- xo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Catalãol	Catalãol	Tapira	Tapira	Tapira	Catalãol
Mineral	Benstoni- ta	Benstoni- ta	Benstoni- ta	Benstoni- ta	Benstoni- ta	Benstoni- ta	Benstoni- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta
Proporção atômica para 8(O,F)/2Metais,2Carbonos													
Fe <sup>2+</sup>	0.0057	0.0027	0.0058	0.0053	0.0076	0.0000	0.0000	0.0000	0.0021	0.0000	0.0000	0.0071	0.0021
Mn	0.0066	0.0044	0.0028	0.0044	0.0024	0.0000	0.0000	0.0008	0.0000	0.0026	0.0000	0.0027	0.0055
Mg	0.1473	0.1491	0.2817	0.2920	0.2767	0.1485	0.1431	0.0049	0.0045	0.0000	0.0000	0.0000	0.0000
Ca	0.8574	0.8353	0.7129	0.8691	0.6853	0.8543	0.8586	1.8779	2.8508	1.9580	1.8933	1.9257	1.8296
Na	0.0474	0.0538	0.0390	0.0414	0.0850	0.0107	0.0089	1.3502	0.8198	1.1562	1.2838	1.3066	1.2968
Sr	0.1263	0.1327	0.1249	0.1288	0.2232	0.1998	0.2442	1.9248	1.6095	1.6453	1.6760	1.6081	2.1198
Ba	0.7948	0.8055	0.8177	0.6454	0.7433	0.7920	0.7496	0.4596	0.1043	0.4347	0.4302	0.7194	0.3758
La	0.0013	0.0003	0.0001	0.0018	0.0067	0.0000	0.0000	0.0011	0.0000	0.0743	0.0596	0.0166	0.0000
Ce	0.0215	0.0256	0.0209	0.0184	0.0081	0.0000	0.0000	0.0056	0.0000	0.1705	0.1387	0.0113	0.0026
Pr	0.0002	0.0015	0.0011	0.0007	0.0000	0.0000	0.0000	0.0008	0.0000	0.0082	0.0227	0.0081	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0361	0.0447	0.0113	0.0060
Dy	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0094	0.0067	0.0222	0.0144	0.0100	0.0035
Yb	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0004
C	1.9948	1.9942	1.9953	1.9950	1.9978	2.0000	2.0000	4.9857	4.9963	4.9453	4.9428	4.9775	4.9976
Cl	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0007	0.0017	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0490	0.0000	0.0104	0.0471	0.0578	0.0009
ΣCation	4.0127	4.0144	4.0093	4.0107	4.0367	4.0053	4.0044	10.6431	10.4025	10.4657	10.5250	10.6106	10.6426

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	Fsalt0287	CB02	SLE360	4s22	SLE360	C83H	SL109C	4s22	AT135	SLE360	SL109C	SL109C	SLE360
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C1b exsinCalci- ta	C3	C1b exsinCalci- ta	C4	C5	C3	C4a	C1b exsinCalci- ta	C5	C5	C1b exsinCalci- ta
textura	exsolution	exsindol		exsolution		exsolution	exsolution	exsolution	exsolution		exsolution	exsolution	
Comple- xo	Salitre Burbanki- ta	Catalão Burbanki- ta	Salitre Burbankita	Tapira Burbanki- ta	Salitre Burbankita	Araxá Burbanki- ta	Salitre Burbanki- ta	Tapira Burbanki- ta	Tapira Burbanki- ta	Salitre Burbankita	Salitre Burbanki- ta	Salitre Burbanki- ta	Salitre Burbankita
Mineral													
K <sub>2</sub> O	0.03	0.26	0.11	0.03	0.18		0.19	0.02	0.00	0.10	0.13	0.08	0.13
FeO	0.03	0.19	0.01	0.00	0.00	0.22	0.22	0.00	0.26	0.15	0.18	0.22	0.00
MnO	0.00	0.10	0.04	0.01	0.00	0.16	0.16	0.00	0.00	0.00	0.14	0.00	0.00
MgO	0.00	4.18	0.00	0.38	0.00	4.98	0.84	0.01	0.18	0.02	0.55	0.01	0.05
CaO	21.12	17.00	18.07	18.28	17.47	18.03	9.63	19.46	20.00	18.56	12.78	18.87	22.87
Na <sub>2</sub> O	5.96	5.55	4.52	5.02	5.19	5.48	6.04	6.19	6.20	6.26	6.98	8.03	6.28
SrO	29.91	26.46	24.90	17.09	27.31	15.20	12.99	20.59	34.39	27.03	19.35	25.44	30.48
BaO	10.52	9.23	9.79	16.54	12.67	5.51	21.71	6.14	2.80	5.95	15.24	14.32	13.43
La <sub>2</sub> O <sub>3</sub>	0.85	0.01	2.75	1.01	0.67	0.02	2.98	1.40	0.35	1.93	1.72	2.52	0.35
Ce <sub>2</sub> O <sub>3</sub>	1.61	0.02	4.57	0.82	0.43	0.04	9.59	2.76	0.46	4.28	5.29	8.90	0.94
Pr <sub>2</sub> O <sub>3</sub>	0.29	0.01	0.54	0.13	0.25	0.02	1.18	0.24	0.06	0.83	0.90	0.99	0.02
Nd <sub>2</sub> O <sub>3</sub>	0.85	0.00	1.20	0.00	0.26	0.00	2.52	0.89	0.10	1.60	2.20	3.32	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.08	0.05	0.35	0.29	0.11	0.03	0.53	0.24	0.18	0.27	0.20	0.22	0.51
Yb <sub>2</sub> O <sub>3</sub>	0.03	0.03	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Cl	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.03	0.01	0.01
F	0.06	0.01	0.04	0.00	0.12	0.00	0.33	0.10	0.00	0.17	0.32	0.00	0.10
Total1	70.06	62.74	64.69	59.16	63.85	49.65	64.52	56.66	64.64	64.35	62.64	78.35	74.51
TotalETR	4.24	0.61	9.60	2.64	1.80	0.40	17.46	5.88	1.31	9.49	10.89	16.52	2.23
CO <sub>2</sub>	37.67	36.07	33.37	31.04	33.10	31.86	29.40	31.75	36.21	34.84	31.28	39.98	39.86
H <sub>2</sub> O													
Total2	109.49	99.38	100.33	91.01	97.60	81.84	98.66	90.07	101.36	102.40	97.67	123.42	115.27

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	Fsalt0287	CB02	SLE360	4s22	SLE360	C83H	SL109C	4s22	AT135	SLE360	SL109C	SL109C	SLE360
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C1b	C3	C1b	C4	C5	C3	C4a	C1b	C5	C5	C1b
textura	exsolution	exsindol	exsinCalci- ta	exsolution	exsinCalci- ta	exsolution	exsolution	exsolution	exsolution	exsinCalci- ta	exsolution	exsolution	exsinCalci- ta
Comple- xo	Salitre	Catalão	Salitre	Tapira	Salitre	Araxá	Salitre	Tapira	Tapira	Salitre	Salitre	Salitre	Salitre
Mineral	Burbanki- ta	Burbanki- ta	Burbankita	Burbanki- ta	Burbankita	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbankita	Burbanki- ta	Burbanki- ta	Burbankita

Proporção atômica para  
15O/6Metais,5Carbonos

Fe <sup>2+</sup>	0.0023	0.0160	0.0007	0.0000	0.0000	0.0213	0.0226	0.0000	0.0223	0.0128	0.0171	0.0163	0.0000
Mn	0.0000	0.0084	0.0040	0.0011	0.0000	0.0151	0.0168	0.0000	0.0000	0.0000	0.0139	0.0000	0.0000
Mg	0.0000	0.6324	0.0000	0.0660	0.0000	0.8537	0.1508	0.0020	0.0269	0.0034	0.0941	0.0017	0.0072
Ca	2.1876	1.8483	2.0966	2.3000	2.0624	2.2200	1.2471	2.3826	2.1628	2.0621	1.5716	1.8177	2.2442
Na	1.1176	1.0912	0.9499	1.1425	1.1082	1.2202	1.4142	1.3707	1.2134	1.2575	1.5539	1.4001	1.1155
Sr	1.6770	1.5571	1.5637	1.1637	1.7453	1.0124	0.9103	1.3644	2.0122	1.6252	1.2885	1.3259	1.6188
Ba	0.3985	0.3670	0.4155	0.7610	0.5470	0.2483	1.0281	0.2750	0.1106	0.2418	0.6858	0.5045	0.4819
La	0.0302	0.0004	0.1097	0.0435	0.0270	0.0009	0.1329	0.0592	0.0128	0.0737	0.0728	0.0837	0.0117
Ce	0.0569	0.0008	0.1812	0.0354	0.0174	0.0018	0.4245	0.1156	0.0171	0.1625	0.2223	0.2928	0.0315
Pr	0.0103	0.0005	0.0212	0.0057	0.0098	0.0008	0.0520	0.0102	0.0023	0.0313	0.0378	0.0325	0.0006
Nd	0.0293	0.0000	0.0462	0.0000	0.0100	0.0000	0.1087	0.0361	0.0035	0.0592	0.0901	0.1065	0.0000
Dy	0.0026	0.0015	0.0122	0.0109	0.0038	0.0011	0.0206	0.0089	0.0059	0.0090	0.0073	0.0063	0.0149
Yb	0.0009	0.0009	0.0000	0.0000	0.0000	0.0013	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
C	4.9730	4.9969	4.9351	4.9763	4.9809	4.9976	4.8513	4.9542	4.9899	4.9320	4.9043	4.9070	4.9842
Cl	0.0008	0.0000	0.0007	0.0010	0.0017	0.0019	0.0041	0.0000	0.0000	0.0000	0.0064	0.0017	0.0011
F	0.0168	0.0032	0.0144	0.0000	0.0429	0.0000	0.1261	0.0376	0.0000	0.0571	0.1173	0.0000	0.0290
ΣCation	10.5031	10.5371	10.3434	10.5281	10.5152	10.6039	10.4068	10.5912	10.5883	10.4904	10.5831	10.5164	10.5230

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	SLE360	SLE360	C83H	C83H	SLE360	C83H	4s22	SLE360	C83H	SL109C	4s22	AT135	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C1b	C4	C4	C1b	C4	C3	C1b	C4	C5	C3	C4a	C4
textura	exsinCalci-	exsinCalci-	exsinnor	exsinnor	exsinCalci-	exsinnor	exsolution	exsinCalci-	exsinnor	exsolution	exsolution	exsolution	exsinnor
Comple-	Salitre	Salitre	Araxá	Araxá	Salitre	Araxá	Tapira	Salitre	Araxá	Salitre	Tapira	Tapira	Araxá
xo	Burbankita	Burbankita	Burbanki-	Burbanki-	Burbankita	Burbanki-	Burbanki-	Burbankita	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-
Mineral	Burbankita	Burbankita	ta	ta	Burbankita	ta	ta	Burbankita	ta	ta	ta	ta	ta
K <sub>2</sub> O	0.09	0.09			0.16		0.05	0.08		0.02	0.01	0.09	
FeO	0.02	0.00	0.00	0.08	0.00	0.00	0.02	0.00	0.03	0.16	0.00	0.00	0.06
MnO	0.05	0.00	0.02	0.03	0.00	0.02	0.02	0.00	0.00	0.09	0.00	0.02	0.05
MgO	0.06	0.00	0.10	1.35	0.13	0.03	0.00	0.20	0.02	0.05	0.02	0.00	1.91
CaO	24.55	13.65	12.30	15.97	12.65	12.57	10.15	15.51	11.35	14.54	13.30	19.93	10.20
Na <sub>2</sub> O	6.04	4.40	5.41	5.49	5.61	5.70	5.82	5.87	5.92	5.94	6.03	6.10	6.18
SrO	31.17	21.01	31.41	19.65	27.24	37.14	26.05	31.24	34.63	31.57	31.63	24.55	15.21
BaO	9.27	14.26	12.79	31.52	13.30	11.15	10.83	10.22	11.04	5.06	9.33	10.63	14.40
La <sub>2</sub> O <sub>3</sub>	0.21	5.47	1.61	1.79	0.88	2.29	6.21	2.35	3.12	0.62	2.52	1.02	2.44
Ce <sub>2</sub> O <sub>3</sub>	0.05	7.95	1.90	0.54	0.46	2.20	6.06	3.75	3.37	1.89	3.34	1.54	2.23
Pr <sub>2</sub> O <sub>3</sub>	0.14	0.62	0.22	0.19	0.19	0.22	0.43	0.48	0.35	0.20	0.44	0.13	0.17
Nd <sub>2</sub> O <sub>3</sub>	0.00	1.73	0.00	0.00	0.55	0.29	0.67	0.92	0.12	0.48	0.51	0.52	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.38	0.33	0.08	0.00	0.21	0.00	0.31	0.34	0.00	0.30	0.26	0.22	0.00
Yb <sub>2</sub> O <sub>3</sub>	0.01	0.05	0.00	0.02	0.07	0.01	0.00	0.01	0.02	0.03	0.02	0.03	0.00
Cl	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.00
F	0.01	0.12	0.00	0.00	0.00	0.14	0.17	0.05	0.00	0.00	0.00	0.01	0.00
Total1	71.44	66.86	65.52	76.44	60.27	71.25	65.35	69.19	69.49	59.95	66.22	63.80	52.68
TotalETR	1.27	16.75	4.39	3.11	2.45	5.57	14.07	8.31	7.59	3.93	7.48	3.90	5.59
CO <sub>2</sub>	39.89	31.34	31.79	36.20	30.09	34.42	30.07	34.97	33.06	31.75	32.86	34.50	26.64
H <sub>2</sub> O													
Total2	112.33	101.48	98.19	113.42	91.46	106.69	97.15	106.35	103.64	93.12	100.70	99.63	80.24



## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	SLE360	SLE360	C83H	C83H	SLE360	C83H	4s22	SLE360	C83H	SL109C	4s22	AT135	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C1b	C4	C4	C1b	C4	C3	C1b	C4	C5	C3	C4a	C4
textura	exsinCalci- ta	exsinCalci- ta	exsinnor	exsinnor	exsinCalci- ta	exsinnor	exsolution	exsinCalci- ta	exsinnor	exsolution	exsolution	exsolution	exsinnor
Comple- xo	Salitre	Salitre	Araxá	Araxá	Salitre	Araxá	Tapira	Salitre	Araxá	Salitre	Tapira	Tapira	Araxá
Mineral	Burbankita	Burbankita	Burbanki- ta	Burbanki- ta	Burbankita	Burbanki- ta	Burbanki- ta	Burbankita	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta	Burbanki- ta
Proporção atômica para 15O/6Metais,5Carbonos													
Fe <sup>2+</sup>	0.0018	0.0000	0.0000	0.0068	0.0002	0.0000	0.0017	0.0000	0.0028	0.0151	0.0000	0.0000	0.0069
Mn	0.0041	0.0000	0.0018	0.0025	0.0000	0.0021	0.0019	0.0000	0.0000	0.0084	0.0000	0.0018	0.0060
Mg	0.0075	0.0000	0.0162	0.2033	0.0233	0.0044	0.0000	0.0304	0.0025	0.0092	0.0028	0.0000	0.3871
Ca	2.4113	1.6679	1.5090	1.7243	1.6435	1.4208	1.2946	1.7219	1.3334	1.7859	1.5727	2.2552	1.4893
Na	1.0732	0.9722	1.2006	1.0722	1.3194	1.1652	1.3445	1.1780	1.2595	1.3199	1.2899	1.2485	1.6329
Sr	1.6572	1.3891	2.0856	1.1485	1.9163	2.2716	1.7988	1.8764	2.2023	2.0988	2.0237	1.5032	1.2015
Ba	0.3331	0.6371	0.5738	1.2448	0.6321	0.4607	0.5050	0.4148	0.4744	0.2273	0.4032	0.4398	0.7689
La	0.0070	0.2299	0.0681	0.0665	0.0394	0.0891	0.2729	0.0897	0.1263	0.0261	0.1024	0.0395	0.1227
Ce	0.0018	0.3320	0.0795	0.0198	0.0205	0.0849	0.2640	0.1422	0.1352	0.0794	0.1350	0.0596	0.1110
Pr	0.0046	0.0256	0.0092	0.0071	0.0086	0.0083	0.0188	0.0180	0.0138	0.0082	0.0176	0.0052	0.0085
Nd	0.0000	0.0704	0.0000	0.0000	0.0236	0.0108	0.0284	0.0339	0.0047	0.0196	0.0203	0.0198	0.0000
Dy	0.0112	0.0121	0.0030	0.0000	0.0082	0.0000	0.0118	0.0112	0.0000	0.0111	0.0092	0.0075	0.0000
Yb	0.0003	0.0018	0.0000	0.0005	0.0027	0.0004	0.0000	0.0002	0.0005	0.0009	0.0007	0.0011	0.0000
C	4.9935	4.8780	4.9704	4.9811	4.9830	4.9569	4.8884	4.9463	4.9498	4.9694	4.9503	4.9741	4.9547
Cl	0.0020	0.0000	0.0000	0.0041	0.0000	0.0014	0.0000	0.0019	0.0019	0.0000	0.0011	0.0011	0.0000
F	0.0035	0.0433	0.0000	0.0000	0.0000	0.0477	0.0636	0.0151	0.0000	0.0000	0.0000	0.0020	0.0000
ΣCation	10.5208	10.2391	10.5390	10.4965	10.6238	10.4947	10.4461	10.4787	10.5276	10.6012	10.5431	10.5719	10.7236

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	SL109C	4s22	SL109C	C83H	SLE360	AT135	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C3	C5	C4	C1b	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Exsolution	exsolution	exsolution	exsinnor	exsinCalcita	exsolution	exsindol	exsindol	exsinnor	exsindol	exsinnor	exsinnor	exsinnor
Complexo	Salitre	Tapira	Salitre	Araxá	Salitre	Tapira	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita
K <sub>2</sub> O	0.06	0.03	0.15		0.04	0.00							
FeO	0.09	0.00	0.35	0.17	0.00	0.16	0.11	0.18	0.00	0.19	0.00	0.06	0.01
MnO	0.08	0.00	0.05	0.06	0.00	0.03	0.02	0.02	0.00	0.04	0.05	0.04	0.02
MgO	0.08	0.00	2.06	3.76	0.04	0.18	0.03	2.78	0.03	0.92	0.00	0.94	0.02
CaO	13.99	14.45	11.96	6.05	18.37	15.32	17.87	18.13	15.54	18.48	15.88	15.61	12.73
Na <sub>2</sub> O	6.19	6.31	6.55	8.06	8.41	11.50	1.14	1.05	0.97	0.98	1.07	1.13	0.90
SrO	30.85	22.87	14.41	23.60	26.20	24.28	36.87	32.86	34.89	26.82	35.97	28.63	36.05
BaO	9.60	20.06	17.60	25.08	6.88	7.86	10.86	7.13	12.93	8.66	12.83	17.98	12.91
La <sub>2</sub> O <sub>3</sub>	3.16	4.27	2.99	1.62	0.20	1.17	1.27	0.65	2.85	0.93	2.02	3.06	3.20
Ce <sub>2</sub> O <sub>3</sub>	4.41	4.75	9.72	0.81	0.39	1.40	1.76	0.24	2.18	0.21	1.35	1.65	3.02
Pr <sub>2</sub> O <sub>3</sub>	0.45	0.48	1.48	0.16	0.00	0.25							
Nd <sub>2</sub> O <sub>3</sub>	0.85	0.42	3.61	0.00	0.15	0.30							
Dy <sub>2</sub> O <sub>3</sub>	0.32	0.28	0.39	0.00	0.05	0.21							
Yb <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.08	0.00	0.00	0.00							
F	0.02	0.00	0.25	0.00	0.00	0.02	0.06	0.02	0.03	0.01	0.09	0.06	0.09
Total1	68.47	72.82	66.00	69.24	60.50	61.94	70.05	63.14	69.41	57.23	69.25	69.17	69.09
TotalETR	9.48	10.62	18.96	3.05	0.87	3.62	3.03	0.89	5.03	1.14	3.37	4.71	6.21
CO <sub>2</sub>	33.96	34.15	32.77	32.76	33.76	34.05	34.67	34.41	32.98	30.57	33.24	32.90	31.61
H <sub>2</sub> O													
Total2	104.32	108.55	104.92	102.61	94.54	97.02	105.11	97.65	103.09	87.96	102.93	102.70	101.53

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	SL109C	4s22	SL109C	C83H	SLE360	AT135	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C3	C5	C4	C1b	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Exsolution	exsolution	exsolution	exsinnor	exsinCalcita	exsolution	exsindol	exsindol	exsinnor	exsindol	exsinnor	exsinnor	exsinnor
Complexo	Salitre	Tapira	Salitre	Araxá	Salitre	Tapira	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita	Burbankita

Proporção atômica para  
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Fe <sup>2+</sup>	0.0080	0.0000	0.0321	0.0159	0.0000	0.0143	0.0100	0.0158	0.0000	0.0188	0.0000	0.0051	0.0007
Mn	0.0075	0.0000	0.0047	0.0056	0.0002	0.0027	0.0021	0.0018	0.0000	0.0044	0.0043	0.0040	0.0021
Mg	0.0125	0.0000	0.3339	0.6247	0.0061	0.0294	0.0050	0.4369	0.0044	0.1637	0.0005	0.1543	0.0029
Ca	1.5970	1.6377	1.3929	0.7215	2.1323	1.7576	2.0157	2.0507	1.8391	2.3687	1.8658	1.8514	1.5678
Na	1.2773	1.2937	1.3792	1.7399	1.7668	2.3875	0.2335	0.2145	0.2075	0.2266	0.2282	0.2427	0.1999
Sr	1.9054	1.4023	0.9084	1.5232	1.6457	1.5072	2.2504	2.0115	2.2344	1.8601	2.2881	1.8374	2.4026
Ba	0.4006	0.8311	0.7493	1.0939	0.2920	0.3295	0.4478	0.2951	0.5597	0.4057	0.5513	0.7800	0.5812
La	0.1241	0.1667	0.1198	0.0664	0.0079	0.0461	0.0492	0.0255	0.1159	0.0409	0.0818	0.1249	0.1354
Ce	0.1719	0.1841	0.3866	0.0331	0.0155	0.0550	0.0677	0.0093	0.0882	0.0091	0.0541	0.0667	0.1270
Pr	0.0174	0.0184	0.0584	0.0066	0.0000	0.0098	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0324	0.0157	0.1400	0.0000	0.0057	0.0113	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0111	0.0097	0.0136	0.0000	0.0019	0.0071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0003	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	4.9384	4.9312	4.8619	4.9791	4.9942	4.9760	4.9819	4.9597	4.9734	4.9916	4.9785	4.9715	4.9598
Cl	0.0000	0.0041	0.0013	0.0062	0.0028	0.0000	0.0005	0.0059	0.0000	0.0000	0.0000	0.0032	0.0000
F	0.0074	0.0000	0.0842	0.0000	0.0000	0.0081	0.0213	0.0080	0.0091	0.0038	0.0302	0.0224	0.0338
ΣCation	10.5133	10.5071	10.4102	10.8265	10.8710	11.1439	10.0644	10.0728	10.0230	10.0921	10.0526	10.0391	9.9850

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	C83H	C83H	C83H	C83H core	C83H rim	C83H rim	C83H	C83H	SL109C	SL109C	SL109C	C83H	C83H
Método	EPMA	FEG	FEG	FEG	FEG	FEG	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C5	C5	C5	C4a	C4a
textura	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsolution	exsolution	exsolution	exsindol	exsindol
Comple-	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Salitre	Salitre	Salitre	Araxá	Araxá
xo	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-
Mineral	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta_x	ta_x
K <sub>2</sub> O									0.02	0.00	0.15		
FeO	0.07								0.13	0.15	0.82	0.09	0.15
MnO	0.00								0.04	0.11	0.58	0.02	0.02
MgO	0.05	0.18							0.04	1.25	6.75	0.03	2.37
CaO	14.18	11.76	9.66	9.44	9.16	8.28	8.23	7.84	14.24	14.85	16.00	14.31	15.47
Na <sub>2</sub> O	1.15	4.88	8.37	6.19	1.84	3.67	1.60	1.69	5.12	6.64	6.28	9.92	10.31
SrO	36.81	29.92	27.78	25.91	28.14	22.80	16.28	16.74	45.27	38.66	6.73	29.52	28.04
BaO	13.11	10.02	9.35	7.79	8.87	8.23	9.18	8.81	1.50	4.74	13.26	8.69	6.09
La <sub>2</sub> O <sub>3</sub>	2.74		2.10	2.79	5.31	4.23	2.69	2.36	0.28	0.66	0.89	1.02	0.56
Ce <sub>2</sub> O <sub>3</sub>	1.95	0.00	1.87	2.40	4.85	3.80	2.43	2.17	0.25	1.23	2.22	1.37	0.18
Pr <sub>2</sub> O <sub>3</sub>									0.01	0.16	0.44		
Nd <sub>2</sub> O <sub>3</sub>									0.17	0.02	0.64		
Dy <sub>2</sub> O <sub>3</sub>									0.22	0.41	0.02		
Yb <sub>2</sub> O <sub>3</sub>									0.04	0.03	0.03		
Cl	0.01								0.01	0.01	0.04	0.00	0.03
F	0.09								0.00	0.00	0.08	0.06	0.02
Total1	70.16	56.76	59.13	54.52	58.17	51.01	40.41	39.61	67.06	68.40	53.72	65.06	63.28
TotalETR	4.69	0.00	3.97	5.19	10.16	8.03	5.12	4.53	1.12	2.63	4.68	2.38	0.73
CO <sub>2</sub>	32.87	28.47	29.22	26.63	26.10	23.60	18.71	18.38	34.95	36.40	33.17	34.14	36.05
H <sub>2</sub> O													
Total2	103.65	85.23	88.90	81.88	85.69	75.73	59.84	58.62	102.59	105.55	88.42	99.50	99.41

## Dados de Química Mineral de Carbonatos – Burbankita (cont.)

Amostra	C83H	C83H	C83H	C83H core	C83H rim	C83H rim	C83H	C83H	SL109C	SL109C	SL109C	C83H	C83H
Método	EPMA	FEG	FEG	FEG	FEG	FEG	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C5	C5	C5	C4a	C4a
textura	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsolution	exsolution	exsolution	exsindol	exsindol
Comple-	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Salitre	Salitre	Salitre	Araxá	Araxá
xo	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-
Mineral	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta_x	ta_x

Proporção atômica para  
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Fe <sup>2+</sup>	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0114	0.0128	0.0741	0.0082	0.0129
Mn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039	0.0092	0.0525	0.0017	0.0015
Mg	0.0076	0.0345	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0059	0.1875	1.0838	0.0041	0.3561
Ca	1.6823	1.6206	1.2915	1.3820	1.3599	1.3613	1.7107	1.6606	1.5943	1.5955	1.8479	1.6399	1.6715
Na	0.2466	1.2169	2.0249	1.6399	0.4943	1.0919	0.6018	0.6478	1.0374	1.2919	1.3117	2.0571	2.0166
Sr	2.3631	2.2314	2.0100	2.0529	2.2609	2.0287	1.8315	1.9190	2.7436	2.2484	0.4204	1.8307	1.6396
Ba	0.5687	0.5050	0.4572	0.4171	0.4816	0.4948	0.6979	0.6825	0.0615	0.1861	0.5601	0.3643	0.2405
La	0.1118	0.0000	0.0966	0.1406	0.2714	0.2394	0.1925	0.1721	0.0109	0.0242	0.0355	0.0400	0.0208
Ce	0.0792	0.0000	0.0854	0.1202	0.2459	0.2133	0.1725	0.1572	0.0096	0.0453	0.0874	0.0535	0.0065
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0058	0.0172	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0007	0.0246	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0075	0.0134	0.0008	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0009	0.0009	0.0000	0.0000
C	4.9681	5.0000	4.9780	4.9684	4.9373	4.9451	4.9558	4.9601	4.9861	4.9841	4.8807	4.9847	4.9623
Cl	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0015	0.0066	0.0005	0.0056
F	0.0326	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0256	0.0216	0.0077
ΣCation	10.0364	10.6084	10.9435	10.7211	10.0512	10.3745	10.1627	10.1992	10.4963	10.6118	10.5740	10.9851	10.9778

## Dados de Química Mineral de Carbonatos – Burbankita/Calcita

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4	C4a	C4a	C4a	C4a	C4a	
textura	exsinnor	interst_dol	exsindol	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsindol	exsindol	exsindol	exsinnor	exsindol	
Comple-	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	
xo	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	
Mineral	ta_x	ta_x	ta_x	ta_x	ta_x	ta_x	ta_x	ta_x	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	
K <sub>2</sub> O															
FeO	0.00	0.06	0.18	0.00	0.05	0.01	0.05	0.22	0.11	0.17	0.16			0.24	
MnO	0.00	0.02	0.04	0.04	0.04	0.02	0.00	0.28	0.24	0.21	0.05				
MgO	0.02	0.02	0.87	0.00	0.77	0.01	0.04	1.13	0.32	0.23	2.33	1.38		4.22	
CaO	12.71	11.47	17.54	13.00	12.79	10.60	11.57	48.26	57.05	54.97	52.70	47.22		41.33	
Na <sub>2</sub> O	9.80	9.53	10.20	9.75	9.83	9.74	9.75	0.39	0.01	0.00	0.02				
SrO	28.53	36.14	25.45	29.46	23.45	30.00	30.04	5.99	1.15	0.48	2.38	2.44		4.16	
BaO	10.58	8.95	8.21	10.50	14.73	10.74	10.70	1.85	0.10	0.02	3.53				
La <sub>2</sub> O <sub>3</sub>	2.33	0.00	0.88	1.66	2.51	2.66	2.23	0.14	0.00	0.03	0.07				
Ce <sub>2</sub> O <sub>3</sub>	1.75	0.00	0.19	1.07	1.31	2.48	1.56	0.27	0.10	0.00	0.32	0.00		0.00	
Pr <sub>2</sub> O <sub>3</sub>								0.00							
Nd <sub>2</sub> O <sub>3</sub>								0.00							
Dy <sub>2</sub> O <sub>3</sub>								0.10							
Yb <sub>2</sub> O <sub>3</sub>								0.02							
Cl	0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01				
F	0.03	0.00	0.01	0.09	0.06	0.09	0.09	0.00	0.00	0.00	0.03				
Total1	65.74	66.24	63.57	65.57	65.53	66.47	66.04	58.51	59.08	56.10	61.63	51.04		49.95	
TotalETR	4.07	0.00	1.07	2.72	3.82	5.14	3.79	0.82	0.10	0.03	0.39	0.00		0.00	
CO <sub>2</sub>	33.36	33.76	35.59	33.51	33.25	32.68	33.07	42.98	45.89	43.84	46.19	39.60		38.96	
H <sub>2</sub> O															
Total2	99.65	100.00	99.30	99.42	99.29	99.83	99.60	101.90	104.98	99.95	107.86	90.64		88.91	

## Dados de Química Mineral de Carbonatos – Burbankita/Calcita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4	C4a	C4a	C4a	C4a
textura	exsinnor	interst_dol	exsindol	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsinnor	exsindol	exsindol	exsindol	exsindol
Comple-	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
xo	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Burbanki-	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	ta_x	ta_x	ta_x	ta_x	ta_x	ta_x	ta_x	ta_x	Calcita	Calcita	Calcita	Calcita	Calcita
Proporção atômica para 15O/6Metais,5Carbonos													
Fe <sup>2+</sup>	0.0000	0.0055	0.0153	0.0000	0.0041	0.0005	0.0050	0.0063	0.0030	0.0047	0.0041	0.0000	0.0074
Mn	0.0000	0.0017	0.0036	0.0035	0.0033	0.0017	0.0000	0.0080	0.0065	0.0058	0.0013	0.0000	0.0000
Mg	0.0036	0.0029	0.1335	0.0004	0.1251	0.0023	0.0062	0.0573	0.0150	0.0112	0.1100	0.0761	0.2317
Ca	1.4885	1.3329	1.9312	1.5169	1.5015	1.2637	1.3658	1.7611	1.9497	1.9676	1.7891	1.8715	1.6307
Na	2.0772	2.0033	2.0324	2.0574	2.0886	2.1016	2.0823	0.0255	0.0004	0.0000	0.0013	0.0000	0.0000
Sr	1.8085	2.2730	1.5165	1.8602	1.4901	1.9366	1.9184	0.1183	0.0212	0.0093	0.0437	0.0523	0.0888
Ba	0.4530	0.3802	0.3308	0.4482	0.6326	0.4685	0.4617	0.0247	0.0013	0.0003	0.0438	0.0000	0.0000
La	0.0938	0.0000	0.0334	0.0665	0.1013	0.1092	0.0907	0.0017	0.0000	0.0003	0.0008	0.0000	0.0000
Ce	0.0699	0.0000	0.0070	0.0425	0.0526	0.1010	0.0628	0.0033	0.0012	0.0000	0.0037	0.0000	0.0000
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
C	4.9783	4.9993	4.9931	4.9818	4.9761	4.9666	4.9726	1.9986	1.9982	1.9994	1.9981	2.0000	1.9587
Cl	0.0000	0.0024	0.0000	0.0000	0.0032	0.0000	0.0021	0.0000	0.0001	0.0000	0.0008	0.0000	0.0000
F	0.0090	0.0000	0.0033	0.0300	0.0222	0.0327	0.0324	0.0000	0.0000	0.0000	0.0025	0.0000	0.0000
ΣCation	10.9731	11.0000	10.9990	10.9774	10.9765	10.9566	10.9685	4.0094	3.9982	3.9993	3.9971	4.0000	3.9587

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	CB02	CB02	CB02	CB02	C1SH1	C1SH1	C1SH1	CB04A	CB04A	CB04A	CB04A	CB04A	Fsalt0287
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C2	C2	C4	C4	C4	N2	N2	N2	N2	N2	C2
textura	exsindol	exsindol	exsindol	exsindol	ok	ok	ok	ok	ok	ok	ok	ok	intersticial_exs
Complexo Mineral	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Salitre Calcita
K <sub>2</sub> O	0.00	0.00	0.00	0.35									0.00
FeO	0.04	0.08	0.13	0.58	0.22	1.00	0.64	0.90	1.25	0.69	0.46	1.04	0.14
MnO	0.20	0.20	0.14	0.39	0.01	0.05	0.08	1.08	1.55	0.72	0.91	1.08	0.39
MgO	0.04	0.12	0.21	5.60	0.22	2.69	0.40	0.75	1.15	0.57	0.43	1.36	0.00
CaO	63.21	62.16	62.85	54.26	42.87	44.74	48.66	55.31	55.64	54.03	54.05	53.39	63.15
Na <sub>2</sub> O	0.29	0.29	0.30	0.36	2.35	2.42	3.14	0.02	0.00	0.03	0.02	0.01	0.26
SrO	0.59	1.30	0.77	1.79	2.50	3.47	3.20	0.31	0.79	0.29	0.48	0.36	0.54
BaO	0.00	0.00	0.00	0.46	0.26	0.56	0.34	0.31	0.16	0.07	0.04	0.06	0.00
La <sub>2</sub> O <sub>3</sub>	0.00	0.05	0.00	0.00	0.17	0.09	0.04	0.00	0.00	0.00	0.00	0.02	0.02
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.13	0.01	0.33	0.07	0.11	0.04	0.04	0.09	0.00	0.07	0.00
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.01	0.00	0.08	0.03	0.03						0.01
Nd <sub>2</sub> O <sub>3</sub>	0.10	0.05	0.00	0.00	0.31	0.24	0.16						0.00
Dy <sub>2</sub> O <sub>3</sub>	0.09	0.23	0.18	0.18	0.00	0.15	0.16						0.17
Yb <sub>2</sub> O <sub>3</sub>	0.02	0.00	0.00	0.00	0.00	0.02	0.03						0.01
Cl	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00
F	0.00	0.00	0.00	0.00	6.01	5.01	4.92	0.00	0.00	0.00	0.00	0.00	0.00
Total1	64.47	64.21	64.59	63.51	54.95	60.11	61.52	58.73	60.61	56.53	56.40	57.41	64.50
TotalETR	0.45	0.64	0.56	0.28	1.18	0.91	2.06	0.04	0.04	0.09	0.00	0.09	0.27
CO <sub>2</sub>	50.40	50.00	50.42	50.53	37.15	42.28	43.29	45.69	47.06	44.09	43.96	44.90	50.37
H <sub>2</sub> O													
Total2	115.31	114.79	115.44	114.30	90.25	101.02	104.65	104.43	107.67	100.64	100.36	102.32	115.13



## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	CB02	CB02	CB02	CB02	C1SH1	C1SH1	C1SH1	CB04A	CB04A	CB04A	CB04A	CB04A	Fsalt0287
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C2	C2	C4	C4	C4	N2	N2	N2	N2	N2	C2
textura	exsindol	exsindol	exsindol	exsindol	ok	ok	ok	ok	ok	ok	ok	ok	intersticial_exs
Complexo Mineral	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Salitre Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0011	0.0020	0.0032	0.0140	0.0068	0.0275	0.0173	0.0240	0.0325	0.0191	0.0128	0.0282	0.0034
Mn	0.0050	0.0049	0.0034	0.0097	0.0003	0.0013	0.0022	0.0292	0.0409	0.0200	0.0256	0.0295	0.0095
Mg	0.0019	0.0050	0.0092	0.2419	0.0123	0.1324	0.0191	0.0359	0.0535	0.0280	0.0211	0.0654	0.0002
Ca	1.9649	1.9495	1.9556	1.6849	1.7016	1.5835	1.6867	1.8960	1.8526	1.9125	1.9285	1.8464	1.9668
Na	0.0160	0.0162	0.0167	0.0203	0.1686	0.1551	0.1971	0.0012	0.0002	0.0022	0.0015	0.0007	0.0148
Sr	0.0099	0.0221	0.0129	0.0301	0.0537	0.0665	0.0601	0.0057	0.0142	0.0055	0.0092	0.0067	0.0091
Ba	0.0000	0.0000	0.0000	0.0052	0.0037	0.0072	0.0043	0.0039	0.0020	0.0009	0.0005	0.0008	0.0000
La	0.0000	0.0006	0.0000	0.0000	0.0023	0.0011	0.0004	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002
Ce	0.0000	0.0000	0.0014	0.0001	0.0044	0.0009	0.0013	0.0005	0.0005	0.0011	0.0000	0.0009	0.0000
Pr	0.0000	0.0000	0.0001	0.0000	0.0011	0.0003	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
Nd	0.0010	0.0005	0.0000	0.0000	0.0041	0.0028	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0008	0.0022	0.0017	0.0017	0.0000	0.0016	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016
Yb	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
C	1.9962	1.9984	1.9991	1.9993	1.8787	1.9069	1.9121	1.9961	1.9965	1.9887	1.9987	1.9787	1.9993
Cl	0.0000	0.0000	0.0000	0.0000	0.0009	0.0005	0.0000	0.0006	0.0000	0.0000	0.0008	0.0005	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.7041	0.5238	0.5033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0038	4.0053	4.0061	4.0088	3.8433	3.8971	3.9225	3.9981	3.9964	3.9938	3.9997	3.9880	4.0062

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	FVL184	FVL184	Fsalt0287	Fsalt0287	FVL184	FVL184	FVL184	FVL184	Fsalt0287	FVL184	FVL184	FVL184	FVL184
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1a	C1a	C2	C2	C1a	C1a	C1a	C1a	C2	C1a	C1a	C1a	C1a
textura	ok	ok	intersticial_exs	intersticial_exs	ok	ok	ok	ok	intersticial_exs	ok	ok	ok	ok
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.10
FeO	0.04	0.07	0.28	0.18	0.10	0.06	0.04	0.07	0.25	0.09	0.17	0.26	0.19
MnO	0.05	0.02	0.32	0.40	0.21	0.30	0.17	0.18	0.56	0.18	0.24	0.33	0.27
MgO	0.02	0.04	0.04	0.05	0.09	0.16	0.22	0.23	0.24	0.39	1.14	1.35	2.88
CaO	59.77	59.63	65.27	62.42	62.52	64.58	63.90	60.52	61.84	61.82	60.68	58.02	56.38
Na <sub>2</sub> O	0.35	0.68	0.37	0.43	0.36	0.46	0.31	0.65	0.37	0.33	0.28	0.45	0.81
SrO	1.26	1.28	0.18	0.42	0.18	2.22	0.33	1.18	0.57	1.37	1.16	3.15	0.90
BaO	0.00	0.09	0.00	0.05	0.14	0.22	0.10	0.15	0.00	0.20	0.07	0.27	0.15
La <sub>2</sub> O <sub>3</sub>	0.07	0.19	0.04	0.01	0.05	0.11	0.00	0.19	0.00	0.00	0.00	0.00	0.06
Ce <sub>2</sub> O <sub>3</sub>	0.28	0.17	0.03	0.00	0.05	0.18	0.13	0.33	0.02	0.02	0.03	0.11	0.10
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.03	0.08	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.05	0.03
Nd <sub>2</sub> O <sub>3</sub>	0.13	0.15	0.00	0.00	0.00	0.05	0.00	0.16	0.00	0.02	0.06	0.01	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.17	0.02	0.08	0.21	0.10	0.28	0.10	0.09	0.19	0.07	0.13	0.25	0.05
Yb <sub>2</sub> O <sub>3</sub>	0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.05	0.00	0.08	0.02	0.00
Cl	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.02
F	2.82	2.88	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	64.65	65.07	66.70	63.96	63.69	68.39	65.21	63.51	63.85	64.49	63.78	64.02	61.73
TotalETR	0.95	0.81	0.26	0.32	0.37	0.76	0.57	0.96	0.44	0.19	0.40	0.57	0.40
CO <sub>2</sub>	48.02	48.18	52.07	49.97	49.82	52.63	51.06	49.16	49.92	50.05	49.94	49.26	48.77
H <sub>2</sub> O													
Total2	112.08	112.49	118.96	114.24	113.78	121.48	116.70	113.11	114.19	114.72	114.08	113.74	110.75

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	FVL184	FVL184	Fsalt0287	Fsalt0287	FVL184	FVL184	FVL184	FVL184	Fsalt0287	FVL184	FVL184	FVL184	FVL184
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1a	C1a	C2	C2	C1a	C1a	C1a	C1a	C2	C1a	C1a	C1a	C1a
textura	ok	ok	intersticial_exs	intersticial_exs	ok	ok	ok	ok	intersticial_exs	ok	ok	ok	ok
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0006	0.0013	0.0067	0.0043	0.0025	0.0014	0.0009	0.0016	0.0062	0.0022	0.0041	0.0065	0.0048
Mn	0.0009	0.0004	0.0075	0.0098	0.0053	0.0070	0.0040	0.0045	0.0139	0.0045	0.0060	0.0083	0.0067
Mg	0.0007	0.0013	0.0018	0.0021	0.0039	0.0065	0.0093	0.0102	0.0107	0.0171	0.0497	0.0597	0.1282
Ca	1.3166	1.3161	1.9663	1.9598	1.9689	1.9242	1.9629	1.9250	1.9422	1.9376	1.9058	1.8475	1.8024
Na	0.0138	0.0272	0.0201	0.0243	0.0203	0.0250	0.0172	0.0374	0.0210	0.0189	0.0161	0.0259	0.0466
Sr	0.0150	0.0153	0.0030	0.0072	0.0030	0.0359	0.0055	0.0202	0.0097	0.0232	0.0197	0.0543	0.0156
Ba	0.0000	0.0008	0.0000	0.0006	0.0016	0.0024	0.0012	0.0018	0.0000	0.0022	0.0008	0.0031	0.0017
La	0.0006	0.0014	0.0004	0.0001	0.0005	0.0012	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0006
Ce	0.0021	0.0013	0.0003	0.0000	0.0005	0.0018	0.0014	0.0035	0.0002	0.0002	0.0003	0.0012	0.0010
Pr	0.0000	0.0002	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0005	0.0004
Nd	0.0010	0.0011	0.0000	0.0000	0.0000	0.0005	0.0000	0.0017	0.0000	0.0002	0.0007	0.0001	0.0000
Dy	0.0011	0.0002	0.0007	0.0019	0.0009	0.0025	0.0010	0.0009	0.0018	0.0006	0.0012	0.0024	0.0005
Yb	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002	0.0000	0.0005	0.0000	0.0007	0.0002	0.0000
C	1.3477	1.3549	1.9990	1.9995	1.9993	1.9981	1.9984	1.9926	1.9978	1.9990	1.9984	1.9990	1.9871
Cl	0.0001	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0002	0.0004	0.0008
F	0.1832	0.1876	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.4468	3.4586	4.0081	4.0109	4.0088	4.0094	4.0059	4.0146	4.0080	4.0080	4.0058	4.0104	4.0209

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	SLE360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C5
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita
K <sub>2</sub> O	0.00												0.00
FeO	0.04	0.10	0.10	0.06	0.10	0.23	0.04	0.08	0.05	0.07	0.14	0.09	0.46
MnO	0.00	0.08	0.15	0.20	0.21	0.38	0.20	0.10	0.12	0.10	0.15	0.15	0.10
MgO	0.01	0.60	0.68	0.71	0.71	0.46	0.10	0.90	0.74	0.73	0.78	0.90	0.31
CaO	55.07	52.04	51.95	55.08	54.98	53.89	54.68	52.14	52.23	52.65	54.56	54.63	39.52
Na <sub>2</sub> O	0.85	0.05	0.03	0.03	0.01	0.02	0.05	0.16	0.18	0.16	0.27	0.30	1.01
SrO	1.73	1.70	2.00	1.83	1.87	1.37	0.35	2.05	1.96	1.45	1.96	2.14	4.16
BaO	0.03	0.23	0.27	0.29	0.28	0.27	0.11	0.31	0.31	0.26	0.31	0.43	0.11
La <sub>2</sub> O <sub>3</sub>	0.42	0.04	0.06	0.00	0.00	0.03	0.00	0.04	0.03	0.00	0.06	0.05	0.17
Ce <sub>2</sub> O <sub>3</sub>	0.78	0.06	0.04	0.09	0.07	0.03	0.02	0.12	0.09	0.05	0.09	0.11	0.39
Pr <sub>2</sub> O <sub>3</sub>	0.14	0.00	0.03	0.00	0.08	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.10
Nd <sub>2</sub> O <sub>3</sub>	0.16	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.04	0.04	0.01	0.01	0.30
Dy <sub>2</sub> O <sub>3</sub>	0.22	0.02	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.19
Yb <sub>2</sub> O <sub>3</sub>	0.02	0.00	0.02	0.00	0.00	0.07	0.01	0.04	0.04	0.02	0.00	0.00	0.07
Cl	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.02	0.11
F	2.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.81
Total1	61.76	54.90	55.29	58.29	58.26	56.79	55.64	55.93	55.71	55.47	58.50	58.81	49.16
TotalETR	2.07	0.15	0.15	0.13	0.23	0.23	0.11	0.21	0.23	0.13	0.16	0.24	1.44
CO <sub>2</sub>	45.15	42.48	42.65	45.07	45.06	43.92	43.43	43.15	43.02	43.05	45.03	45.32	34.59
H <sub>2</sub> O													
Total2	106.58	97.44	98.00	103.40	103.48	100.88	99.16	99.14	98.85	98.60	103.53	104.21	83.42

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	SLE360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL360	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C1b	C5
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo Mineral	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita	Salitre Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0011	0.0028	0.0028	0.0015	0.0026	0.0063	0.0011	0.0023	0.0014	0.0020	0.0038	0.0025	0.0112
Mn	0.0000	0.0022	0.0043	0.0056	0.0059	0.0107	0.0057	0.0030	0.0035	0.0029	0.0040	0.0042	0.0023
Mg	0.0006	0.0309	0.0346	0.0343	0.0346	0.0226	0.0052	0.0457	0.0376	0.0368	0.0380	0.0435	0.0132
Ca	1.8647	1.9215	1.9105	1.9176	1.9142	1.9214	1.9750	1.8951	1.9039	1.9171	1.8986	1.8915	1.2217
Na	0.0518	0.0036	0.0022	0.0018	0.0004	0.0015	0.0033	0.0105	0.0120	0.0104	0.0168	0.0185	0.0564
Sr	0.0317	0.0340	0.0398	0.0344	0.0353	0.0264	0.0067	0.0403	0.0387	0.0285	0.0370	0.0401	0.0695
Ba	0.0004	0.0031	0.0036	0.0037	0.0035	0.0035	0.0015	0.0041	0.0041	0.0034	0.0040	0.0054	0.0013
La	0.0049	0.0005	0.0007	0.0000	0.0000	0.0004	0.0000	0.0005	0.0003	0.0000	0.0007	0.0006	0.0018
Ce	0.0090	0.0007	0.0005	0.0010	0.0009	0.0004	0.0002	0.0015	0.0011	0.0007	0.0011	0.0012	0.0042
Pr	0.0016	0.0000	0.0004	0.0000	0.0009	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0011
Nd	0.0018	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0001	0.0005	0.0004	0.0001	0.0001	0.0031
Dy	0.0022	0.0002	0.0000	0.0000	0.0000	0.0001	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018
Yb	0.0002	0.0000	0.0002	0.0000	0.0000	0.0007	0.0001	0.0004	0.0004	0.0002	0.0000	0.0000	0.0006
C	1.9481	1.9984	1.9990	1.9996	1.9993	1.9954	1.9990	1.9985	1.9982	1.9977	1.9967	1.9994	1.3626
Cl	0.0006	0.0000	0.0001	0.0007	0.0002	0.0002	0.0000	0.0003	0.0000	0.0000	0.0029	0.0009	0.0054
F	0.2817	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2560
ΣCation	3.9233	3.9999	3.9997	4.0001	3.9990	3.9957	4.0001	4.0035	4.0036	4.0028	4.0042	4.0080	3.4695

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	SLE360	SL109C	SL109C	AT139	AT139	AT139	AT139	AT139	AT139	TAPS	TAPS	TAPS	AT46
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C5	C5	C3	C3	C3	C3	C3	C3	C1a	C1a	C1a	C1b
textura	Ok	exsolution	exsolution	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo	Salitre	Salitre	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	2.04	0.07	0.16	0.29	0.14	0.06	0.42	0.12	0.40	0.10	0.04	0.35	0.38
MnO	0.15	0.07	0.43	0.40	0.33	0.03	0.27	0.40	0.39	0.05	0.11	0.21	0.25
MgO	0.17	0.08	0.02	0.03	0.03	0.05	0.14	0.18	0.62	1.18	0.47	8.08	0.45
CaO	57.55	62.18	63.70	63.69	64.63	54.82	58.23	55.39	58.86	54.54	51.00	46.15	55.74
Na <sub>2</sub> O	0.30	0.34	0.34	0.34	0.47	0.77	0.35	0.41	0.38	0.48	2.14	1.02	0.34
SrO	0.61	0.12	0.03	0.37	0.09	2.64	1.21	1.95	2.33	2.32	2.53	1.90	1.78
BaO	0.01	0.01	0.06	0.00	0.00	0.01	0.25	0.25	0.42	0.51	0.84	0.21	0.31
La <sub>2</sub> O <sub>3</sub>	0.00	0.02	0.06	0.02	0.00	0.18	0.00	0.05	0.00	1.54	0.00	0.07	0.05
Ce <sub>2</sub> O <sub>3</sub>	0.04	0.05	0.00	0.06	0.00	0.28	0.08	0.10	0.00	3.19	0.22	0.10	0.07
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.03	0.00	0.08	0.02	0.10	0.05	0.00	0.00	0.41	0.03	0.03	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.15	0.06	0.14	0.41	0.00	0.10	0.03	0.62	0.00	0.07	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.25	0.07	0.38	0.11	0.39	0.00	0.17	0.04	0.33	0.30	0.20	0.18
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.04	0.02
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00
F	0.00	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Total1	60.87	63.01	64.78	65.19	65.76	61.91	60.99	58.85	63.54	63.97	57.43	58.08	59.36
TotalETR	0.24	0.50	0.51	0.76	0.43	2.01	0.22	0.79	0.10	6.45	0.80	0.61	0.55
CO <sub>2</sub>	47.23	49.41	50.77	51.03	51.54	45.35	47.17	45.38	48.79	47.39	43.69	47.13	45.85
H <sub>2</sub> O													
Total2	108.30	112.84	116.00	116.90	117.72	107.55	108.31	104.88	112.42	113.08	101.70	105.65	105.65

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	SLE360	SL109C	SL109C	AT139	AT139	AT139	AT139	AT139	AT139	TAPS	TAPS	TAPS	AT46
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C5	C5	C3	C3	C3	C3	C3	C3	C1a	C1a	C1a	C1b
textura	Ok	exsolution	exsolution	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo Mineral	Salitre Calcita	Salitre Calcita	Salitre Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0530	0.0018	0.0038	0.0069	0.0032	0.0010	0.0108	0.0033	0.0101	0.0026	0.0011	0.0090	0.0101
Mn	0.0039	0.0017	0.0104	0.0097	0.0078	0.0006	0.0070	0.0108	0.0099	0.0013	0.0030	0.0054	0.0068
Mg	0.0077	0.0037	0.0007	0.0011	0.0013	0.0017	0.0064	0.0085	0.0279	0.0537	0.0229	0.3730	0.0213
Ca	1.9122	1.9735	1.9664	1.9571	1.9656	1.2701	1.9360	1.9144	1.8910	1.7814	1.7864	1.5306	1.9072
Na	0.0182	0.0197	0.0192	0.0189	0.0261	0.0323	0.0212	0.0253	0.0220	0.0285	0.1356	0.0613	0.0212
Sr	0.0109	0.0020	0.0004	0.0062	0.0014	0.0331	0.0217	0.0365	0.0405	0.0410	0.0480	0.0341	0.0330
Ba	0.0001	0.0001	0.0007	0.0000	0.0000	0.0001	0.0030	0.0031	0.0050	0.0061	0.0108	0.0025	0.0038
La	0.0000	0.0003	0.0006	0.0002	0.0000	0.0014	0.0000	0.0005	0.0000	0.0173	0.0000	0.0008	0.0006
Ce	0.0004	0.0005	0.0000	0.0006	0.0000	0.0022	0.0009	0.0011	0.0000	0.0355	0.0026	0.0012	0.0008
Pr	0.0000	0.0003	0.0000	0.0009	0.0002	0.0008	0.0005	0.0000	0.0000	0.0045	0.0004	0.0003	0.0000
Nd	0.0000	0.0000	0.0015	0.0006	0.0014	0.0032	0.0000	0.0011	0.0003	0.0067	0.0000	0.0007	0.0000
Dy	0.0000	0.0024	0.0007	0.0035	0.0010	0.0027	0.0000	0.0018	0.0004	0.0032	0.0031	0.0020	0.0019
Yb	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0004	0.0001
C	1.9997	1.9984	1.9972	1.9983	1.9974	1.3388	1.9986	1.9986	1.9972	1.9724	1.9501	1.9920	1.9992
Cl	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0007	0.0005	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.2065	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0082	4.0072	4.0064	4.0065	4.0097	3.4424	4.0087	4.0094	4.0086	3.9894	4.0607	4.0275	4.0085

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	AT46	AT46	AT49	AT49	AT46	AT46	4s22	4s22	4s22	4s22	4s22	4s22	4s22
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C1b	C1b	C1b	C1b	C1b	C3	C3	C3	C3	C3	C3	C3
textura	Ok	ok	ok	ok	ok	ok	exsolution	exsolution	exsolution	exsolution	ok	ok	ok
Complexo	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.04	0.00
FeO	0.05	0.28	0.03	0.68	0.07	0.00	0.59	0.11	0.01	0.06	0.20	0.14	0.23
MnO	0.00	0.25	0.06	0.00	0.03	0.00	0.27	0.17	0.03	0.10	0.13	0.06	0.18
MgO	0.02	0.71	0.02	0.00	0.00	0.04	4.47	0.74	0.08	0.05	0.80	0.60	1.77
CaO	56.00	54.87	56.27	56.42	56.61	56.99	49.10	52.29	54.17	54.78	55.36	55.39	56.37
Na <sub>2</sub> O	0.48	0.29	0.74	0.68	0.51	0.51	0.31	0.31	1.03	0.69	0.33	0.32	0.39
SrO	1.13	3.91	1.81	1.52	1.49	1.46	5.19	3.05	2.27	1.84	2.52	3.01	2.72
BaO	0.00	0.03	0.12	0.00	0.02	0.05	0.04	0.53	0.00	0.03	0.51	0.36	0.16
La <sub>2</sub> O <sub>3</sub>	0.01	1.81	0.17	0.04	0.00	0.00	0.05	0.09	0.45	0.26	0.03	0.08	0.05
Ce <sub>2</sub> O <sub>3</sub>	0.14	3.48	0.45	0.00	0.19	0.00	0.10	0.02	1.05	0.21	0.11	0.05	0.02
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.81	0.05	0.00	0.00	0.03	0.01	0.02	0.05	0.08	0.03	0.00	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.00	1.31	0.33	0.00	0.03	0.12	0.00	0.00	0.50	0.19	0.00	0.00	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.17	0.25	0.22	0.14	0.32	0.05	0.09	0.09	0.31	0.23	0.12	0.15	0.16
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.03	0.00	0.00	0.05	0.00	0.00	0.08	0.00	0.01	0.00	0.01
Cl	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.01	0.03
F	4.97	0.00	2.92	3.72	4.19	4.56	0.00	0.00	2.06	2.18	0.00	0.00	0.00
Total1	62.79	65.63	62.58	63.05	63.10	63.61	60.14	57.33	61.20	60.25	60.01	60.01	62.00
TotalETR	0.46	7.94	1.51	0.55	0.69	0.42	0.49	0.32	2.81	1.24	0.57	0.37	0.40
CO <sub>2</sub>	44.94	48.14	45.96	45.96	45.67	45.87	46.51	43.77	45.07	44.77	46.13	45.95	48.03
H <sub>2</sub> O													
Total2	105.94	116.43	108.21	107.95	107.50	107.99	106.98	101.31	106.71	104.88	106.56	106.20	110.35



## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	AT46	AT46	AT49	AT49	AT46	AT46	4s22	4s22	4s22	4s22	4s22	4s22	4s22
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C1b	C1b	C1b	C1b	C1b	C3	C3	C3	C3	C3	C3	C3
textura	Ok	ok	ok	ok	ok	ok	exsolution	exsolution	exsolution	exsolution	ok	ok	ok
Complexo Mineral	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0013	0.0071	0.0008	0.0176	0.0017	0.0001	0.0156	0.0031	0.0001	0.0012	0.0052	0.0037	0.0058
Mn	0.0000	0.0065	0.0015	0.0000	0.0007	0.0000	0.0072	0.0048	0.0006	0.0018	0.0034	0.0015	0.0047
Mg	0.0008	0.0317	0.0007	0.0000	0.0000	0.0016	0.2098	0.0371	0.0026	0.0016	0.0380	0.0286	0.0805
Ca	1.8751	1.7757	1.8732	1.8659	1.8780	1.8761	1.6556	1.8743	1.2548	1.2819	1.8826	1.8908	1.8404
Na	0.0289	0.0167	0.0445	0.0405	0.0306	0.0304	0.0192	0.0200	0.0430	0.0293	0.0204	0.0198	0.0233
Sr	0.0205	0.0685	0.0326	0.0272	0.0268	0.0260	0.0946	0.0591	0.0284	0.0232	0.0463	0.0557	0.0480
Ba	0.0000	0.0003	0.0015	0.0000	0.0002	0.0006	0.0005	0.0070	0.0000	0.0003	0.0064	0.0045	0.0020
La	0.0001	0.0201	0.0019	0.0004	0.0000	0.0000	0.0006	0.0011	0.0036	0.0021	0.0003	0.0009	0.0005
Ce	0.0016	0.0385	0.0051	0.0000	0.0022	0.0000	0.0011	0.0003	0.0083	0.0017	0.0013	0.0006	0.0002
Pr	0.0000	0.0089	0.0005	0.0000	0.0000	0.0004	0.0001	0.0002	0.0004	0.0006	0.0004	0.0000	0.0000
Nd	0.0000	0.0142	0.0037	0.0000	0.0003	0.0013	0.0000	0.0000	0.0039	0.0015	0.0000	0.0000	0.0000
Dy	0.0017	0.0024	0.0022	0.0014	0.0032	0.0005	0.0010	0.0010	0.0022	0.0016	0.0012	0.0015	0.0016
Yb	0.0000	0.0000	0.0003	0.0000	0.0000	0.0004	0.0000	0.0000	0.0005	0.0000	0.0001	0.0000	0.0001
C	1.9175	1.9855	1.9496	1.9371	1.9304	1.9243	1.9985	1.9994	1.3303	1.3348	1.9989	1.9989	1.9980
Cl	0.0000	0.0008	0.0000	0.0000	0.0000	0.0001	0.0012	0.0007	0.0003	0.0000	0.0000	0.0005	0.0013
F	0.4911	0.0000	0.2865	0.3628	0.4098	0.4435	0.0000	0.0000	0.1409	0.1505	0.0000	0.0000	0.0000
ΣCation	3.8490	3.9790	3.9210	3.8967	3.8760	3.8652	4.0070	4.0084	3.4531	3.4502	4.0078	4.0079	4.0086

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	4s22	AT135	AT135	AT135	AT135	AT135	AT135	4s22	4s22	4s22	TAPS	4s22	4s22
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C3	C4a	C4a	C4a	C4a	C4a	C4a	C3	C3	C3	C1a	C3	C3
textura	Exsolution	ok	ok	ok	exsolution	ok	exsolution	ok	ok	ok	ok	exsolution	ok
Complexo Mineral	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
FeO	0.04	0.02	0.10	0.04	0.14	0.00	0.15	0.24	0.15	0.19	0.04	0.16	0.24
MnO	0.02	0.00	0.02	0.00	0.24	0.02	0.30	0.08	0.16	0.18	0.04	0.17	0.09
MgO	0.02	0.00	0.09	0.02	0.15	0.01	0.02	0.76	0.37	0.67	1.23	0.82	0.40
CaO	56.77	53.77	54.33	55.45	47.07	56.08	56.25	57.57	57.67	57.87	57.97	58.17	58.20
Na <sub>2</sub> O	0.71	0.70	0.67	0.78	1.76	0.53	1.38	0.30	0.40	0.27	0.29	0.29	0.37
SrO	2.23	2.31	2.13	2.51	7.30	2.27	8.69	3.32	2.34	2.79	1.23	2.96	2.40
BaO	0.02	0.00	0.00	0.00	1.20	0.00	1.09	0.67	0.58	0.80	0.16	0.65	0.35
La <sub>2</sub> O <sub>3</sub>	0.31	0.43	0.17	0.28	0.13	0.21	0.00	0.03	0.02	0.07	0.00	0.00	0.05
Ce <sub>2</sub> O <sub>3</sub>	0.53	0.89	0.32	0.70	0.38	0.68	0.06	0.00	0.03	0.18	0.20	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>	0.09	0.08	0.11	0.09	0.01	0.17	0.02	0.03	0.02	0.00	0.00	0.00	0.10
Nd <sub>2</sub> O <sub>3</sub>	0.59	0.58	0.42	0.64	0.00	0.32	0.00	0.00	0.00	0.02	0.03	0.03	0.03
Dy <sub>2</sub> O <sub>3</sub>	0.35	0.07	0.10	0.22	0.24	0.10	0.18	0.19	0.34	0.04	0.27	0.30	0.16
Yb <sub>2</sub> O <sub>3</sub>	0.03	0.04	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.06	0.00	0.04	0.00
Cl	0.02	0.00	0.00	0.01	0.03	0.01	0.00	0.01	0.01	0.00	0.00	0.04	0.07
F	2.53	3.10	4.33	2.77	0.08	4.20	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Total1	63.34	61.22	62.20	62.56	58.52	64.03	68.10	63.16	61.72	63.05	61.20	63.25	62.22
TotalETR	2.20	2.22	1.43	2.30	0.98	1.84	0.44	0.32	0.58	0.53	0.63	0.50	0.44
CO <sub>2</sub>	46.68	44.28	44.58	45.79	42.29	45.87	49.58	48.12	47.44	48.12	47.83	48.52	47.82
H <sub>2</sub> O													
Total2	110.31	105.09	105.90	108.50	101.25	109.08	118.06	111.55	109.68	111.45	109.46	112.26	110.40

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	4s22	AT135	AT135	AT135	AT135	AT135	AT135	4s22	4s22	4s22	TAPS	4s22	4s22
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C3	C4a	C4a	C4a	C4a	C4a	C4a	C3	C3	C3	C1a	C3	C3
textura	Exsolution	ok	ok	ok	exsolution	ok	exsolution	ok	ok	ok	ok	exsolution	ok
Complexo Mineral	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0008	0.0004	0.0019	0.0006	0.0041	0.0000	0.0037	0.0060	0.0038	0.0048	0.0011	0.0040	0.0061
Mn	0.0003	0.0000	0.0004	0.0000	0.0070	0.0004	0.0076	0.0021	0.0041	0.0047	0.0010	0.0042	0.0024
Mg	0.0006	0.0000	0.0030	0.0005	0.0075	0.0004	0.0010	0.0344	0.0170	0.0301	0.0562	0.0369	0.0183
Ca	1.2704	1.2669	1.2837	1.2648	1.7414	1.2842	1.7801	1.8759	1.9069	1.8855	1.9004	1.8803	1.9089
Na	0.0288	0.0299	0.0285	0.0324	0.1176	0.0220	0.0790	0.0176	0.0239	0.0157	0.0170	0.0168	0.0217
Sr	0.0270	0.0294	0.0272	0.0310	0.1462	0.0281	0.1488	0.0585	0.0418	0.0492	0.0219	0.0518	0.0426
Ba	0.0002	0.0000	0.0000	0.0000	0.0163	0.0000	0.0127	0.0080	0.0070	0.0095	0.0019	0.0076	0.0042
La	0.0024	0.0035	0.0014	0.0022	0.0016	0.0016	0.0000	0.0004	0.0002	0.0007	0.0000	0.0000	0.0006
Ce	0.0041	0.0072	0.0026	0.0055	0.0048	0.0053	0.0007	0.0000	0.0004	0.0019	0.0023	0.0000	0.0000
Pr	0.0007	0.0006	0.0009	0.0007	0.0001	0.0013	0.0002	0.0004	0.0002	0.0000	0.0000	0.0000	0.0011
Nd	0.0044	0.0046	0.0033	0.0049	0.0000	0.0024	0.0000	0.0000	0.0000	0.0002	0.0003	0.0003	0.0004
Dy	0.0024	0.0005	0.0007	0.0015	0.0026	0.0007	0.0017	0.0018	0.0034	0.0004	0.0027	0.0029	0.0015
Yb	0.0002	0.0002	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0004	0.0000
C	1.3310	1.3295	1.3421	1.3310	1.9939	1.3385	1.9991	1.9983	1.9989	1.9978	1.9982	1.9987	1.9986
Cl	0.0005	0.0000	0.0000	0.0002	0.0019	0.0005	0.0000	0.0003	0.0004	0.0000	0.0000	0.0018	0.0038
F	0.1668	0.2156	0.3019	0.1862	0.0082	0.2836	0.0000	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.4421	3.4318	3.4252	3.4399	4.0498	3.4219	4.0372	4.0050	4.0094	4.0046	4.0054	4.0057	4.0077

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	4s22	4s22	AT135	4s22	AT46	TAPS	TAPS	4s22	TAPS	TAPS	4s22	4s22	TAPS
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C3	C3	C4a	C3	C1b	C1a	C1a	C3	C1a	C1a	C3	C3	C1a
textura	Ok	exsolution	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo Mineral	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita	Tapira Calcita
K <sub>2</sub> O	0.06	0.12	0.00	0.00	0.00	0.01	0.00	0.26	0.00	0.00	0.00	0.00	0.00
FeO	0.18	0.13	0.30	0.13	0.30	0.01	0.09	0.08	0.05	0.05	0.09	0.07	0.08
MnO	0.18	0.14	0.42	0.10	0.32	0.09	0.04	0.08	0.07	0.11	0.16	0.17	0.10
MgO	0.50	0.54	0.35	0.56	0.49	0.97	1.01	0.53	1.18	1.01	0.20	0.34	0.63
CaO	58.34	58.37	58.56	58.96	59.45	59.55	59.56	59.76	59.87	60.06	60.68	61.07	61.34
Na <sub>2</sub> O	0.34	0.55	0.29	0.34	0.24	0.37	0.32	0.33	0.29	0.32	0.24	0.32	0.26
SrO	2.44	2.38	0.32	2.74	0.81	1.44	1.24	1.48	1.16	1.19	0.41	1.06	0.84
BaO	0.85	0.40	0.03	0.28	0.38	0.15	0.20	0.52	0.29	0.38	0.02	0.25	0.23
La <sub>2</sub> O <sub>3</sub>	0.03	0.02	0.00	0.00	0.05	0.01	0.00	0.02	0.02	0.05	0.01	0.00	0.02
Ce <sub>2</sub> O <sub>3</sub>	0.03	0.15	0.00	0.09	0.16	0.13	0.09	0.04	0.00	0.21	0.05	0.00	0.08
Pr <sub>2</sub> O <sub>3</sub>	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.04	0.00	0.04	0.01	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.16	0.13	0.00	0.00	0.00	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.27	0.19	0.13	0.14	0.20	0.23	0.26	0.20	0.06	0.17	0.09	0.18	0.21
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.03	0.07	0.02	0.00	0.00	0.03
Cl	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	62.99	62.69	60.35	63.19	62.20	62.75	62.55	62.84	62.94	63.37	61.86	63.44	63.65
TotalETR	0.61	0.43	0.21	0.46	0.53	0.43	0.57	0.79	0.50	0.54	0.29	0.31	0.38
CO <sub>2</sub>	48.25	48.19	47.21	48.62	48.34	48.89	48.88	48.79	49.26	49.32	48.43	49.31	49.65
H <sub>2</sub> O													
Total2	111.79	111.12	107.77	112.18	110.86	111.93	111.90	112.36	112.68	112.97	110.52	113.06	113.58

## Dados de Química Mineral de Carbonatos – Calcita (cont.)

Amostra	4s22	4s22	AT135	4s22	AT46	TAPS	TAPS	4s22	TAPS	TAPS	4s22	4s22	TAPS
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C3	C3	C4a	C3	C1b	C1a	C1a	C3	C1a	C1a	C3	C3	C1a
textura	Ok	exsolution	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita	Calcita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0045	0.0033	0.0079	0.0031	0.0076	0.0002	0.0022	0.0021	0.0013	0.0012	0.0023	0.0018	0.0020
Mn	0.0045	0.0037	0.0110	0.0027	0.0082	0.0022	0.0010	0.0020	0.0018	0.0027	0.0041	0.0043	0.0025
Mg	0.0226	0.0243	0.0161	0.0250	0.0220	0.0433	0.0449	0.0235	0.0524	0.0448	0.0091	0.0152	0.0276
Ca	1.8968	1.8990	1.9446	1.9016	1.9279	1.9109	1.9107	1.9211	1.9062	1.9102	1.9657	1.9378	1.9379
Na	0.0202	0.0324	0.0173	0.0199	0.0143	0.0217	0.0185	0.0193	0.0165	0.0184	0.0143	0.0184	0.0146
Sr	0.0429	0.0419	0.0058	0.0478	0.0142	0.0250	0.0216	0.0258	0.0200	0.0204	0.0072	0.0182	0.0143
Ba	0.0101	0.0048	0.0004	0.0033	0.0045	0.0018	0.0023	0.0061	0.0034	0.0044	0.0002	0.0029	0.0026
La	0.0003	0.0003	0.0000	0.0000	0.0005	0.0001	0.0000	0.0002	0.0003	0.0006	0.0001	0.0000	0.0002
Ce	0.0004	0.0017	0.0000	0.0010	0.0018	0.0015	0.0010	0.0004	0.0000	0.0022	0.0006	0.0000	0.0009
Pr	0.0002	0.0001	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0004	0.0000	0.0004	0.0001	0.0000
Nd	0.0000	0.0000	0.0000	0.0001	0.0004	0.0000	0.0000	0.0018	0.0013	0.0000	0.0000	0.0000	0.0000
Dy	0.0026	0.0018	0.0013	0.0013	0.0020	0.0022	0.0025	0.0020	0.0006	0.0016	0.0008	0.0017	0.0020
Yb	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0001	0.0002	0.0006	0.0001	0.0000	0.0000	0.0002
C	1.9990	1.9979	1.9973	1.9985	1.9974	1.9991	1.9981	1.9988	1.9988	1.9989	1.9989	1.9938	1.9990
Cl	0.0000	0.0004	0.0001	0.0000	0.0000	0.0000	0.0005	0.0000	0.0002	0.0000	0.0000	0.0005	0.0004
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0074	4.0133	4.0059	4.0076	4.0043	4.0090	4.0070	4.0068	4.0060	4.0071	4.0056	4.0065	4.0052

## Dados de Química Mineral de Carbonatos – Calcita / Dolomita

Amostra	TAPS	AT135	4s22	AT135	4s22	AT135	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método Unidade	EPMA C1a	EPMA C4a	EPMA C3	EPMA C4a	EPMA C3	EPMA C4a	EPMA C4 exsoluti- on	EPMA C4 exsoluti- on	EPMA C4 exsoluti- on	EPMA C4a camadaem- nors	EPMA C4a camadaem- nors	EPMA C4a camadaem- nors	EPMA C4a camadaem- nors
textura Comple- xo Mineral	ok	Ok	ok	ok	ok	ok	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00							
FeO	0.04	0.16	0.11	0.17	0.09	0.25	0.97	1.00	1.06	3.62	1.19	0.73	2.84
MnO	0.05	0.34	0.15	0.37	0.19	0.62	0.37	0.42	0.40	0.41	0.45	0.24	0.40
MgO	1.00	0.04	0.14	0.07	0.09	0.02	21.69	22.03	22.02	17.88	19.35	18.21	18.46
CaO	62.51	62.68	63.04	64.40	64.56	65.27	28.71	28.47	28.25	29.55	30.36	32.54	29.65
Na <sub>2</sub> O	0.35	0.32	0.23	0.34	0.32	0.28	0.32	0.28	0.30	0.02	0.04	0.03	0.00
SrO	1.45	0.03	0.75	0.12	0.54	0.14	2.79	2.75	1.89	0.15	0.15	0.28	0.33
BaO	0.14	0.06	0.00	0.09	0.00	0.00	0.00	0.00	0.03	0.44	0.25	0.22	0.44
La <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.08	0.00	0.06
Ce <sub>2</sub> O <sub>3</sub>	0.02	0.09	0.02	0.03	0.00	0.02	0.14	0.00	0.02	0.04	0.00	0.02	0.08
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.01	0.06	0.07	0.00	0.01	0.03	0.00				
Nd <sub>2</sub> O <sub>3</sub>	0.14	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.01				
Dy <sub>2</sub> O <sub>3</sub>	0.16	0.37	0.08	0.12	0.15	0.20	0.03	0.00	0.07				
Yb <sub>2</sub> O <sub>3</sub>	0.03	0.07	0.00	0.04	0.00	0.04	0.04	0.01	0.01				
Cl	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	65.57	63.71	64.48	65.60	65.78	66.59	54.99	54.95	53.99	52.19	51.90	52.30	52.35
TotalETR	0.52	0.81	0.19	0.45	0.37	0.63	0.40	0.18	0.32	0.04	0.08	0.02	0.15
CO <sub>2</sub>	51.24	50.01	50.32	51.38	51.48	52.20	48.55	48.68	48.22	45.41	46.15	46.23	45.73
H <sub>2</sub> O													
Total2	117.30	114.44	114.95	117.40	117.63	119.40	103.80	103.81	102.49	97.60	98.05	98.53	98.10

## Dados de Química Mineral de Carbonatos – Calcita / Dolomita (cont.)

Amostra	TAPS	AT135	4s22	AT135	4s22	AT135	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método Unidade	EPMA C1a	EPMA C4a	EPMA C3	EPMA C4a	EPMA C3	EPMA C4a	EPMA C4 exsoluti- on	EPMA C4 exsoluti- on	EPMA C4 exsoluti- on	EPMA C4a camadaem- nors	EPMA C4a camadaem- nors	EPMA C4a camadaem- nors	EPMA C4a camadaem- nors
textura Comple- xo Mineral	ok Tapira Calcita	Ok Tapira Calcita	ok Tapira Calcita	ok Tapira Calcita	ok Tapira Calcita	ok Tapira Calcita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita
Proporção atômica para 6 O													
Fe <sup>2+</sup>	0.0010	0.0038	0.0027	0.0040	0.0021	0.0058	0.0245	0.0251	0.0269	0.0975	0.0316	0.0193	0.0759
Mn	0.0012	0.0084	0.0037	0.0089	0.0045	0.0148	0.0094	0.0108	0.0102	0.0112	0.0120	0.0064	0.0108
Mg	0.0425	0.0016	0.0062	0.0030	0.0037	0.0008	0.9751	0.9881	0.9969	0.8586	0.9152	0.8596	0.8804
Ca	1.9132	1.9660	1.9649	1.9659	1.9666	1.9608	0.9277	0.9176	0.9194	1.0197	1.0320	1.1038	1.0165
Na	0.0195	0.0183	0.0131	0.0190	0.0177	0.0151	0.0188	0.0164	0.0178	0.0012	0.0024	0.0020	0.0000
Sr	0.0240	0.0005	0.0126	0.0019	0.0089	0.0022	0.0488	0.0480	0.0333	0.0029	0.0028	0.0051	0.0062
Ba	0.0015	0.0007	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0003	0.0056	0.0032	0.0028	0.0055
La	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0010	0.0000	0.0007
Ce	0.0002	0.0009	0.0002	0.0003	0.0000	0.0002	0.0016	0.0000	0.0002	0.0005	0.0000	0.0003	0.0010
Pr	0.0000	0.0000	0.0001	0.0006	0.0007	0.0000	0.0001	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0014	0.0007	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
Dy	0.0015	0.0035	0.0007	0.0011	0.0013	0.0018	0.0003	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
Yb	0.0003	0.0006	0.0000	0.0004	0.0000	0.0004	0.0004	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
C	1.9985	1.9988	1.9988	1.9989	1.9985	1.9984	1.9994	1.9998	1.9994	1.9972	1.9991	1.9983	1.9980
Cl	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0006	0.0004	0.0011	0.0010	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0075	4.0062	4.0053	4.0075	4.0067	4.0047	4.0079	4.0075	4.0075	3.9999	4.0004	3.9991	3.9977

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	camadaem-	camadaem-	camadaem-	camadaem-	ok	camadaem-	camadaem-	camadaem-	camadaem-	oklim-	oklim-	oklim-	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O													
FeO	2.81	2.91	1.13	4.70	1.47	1.21	1.18	1.34	1.31	1.27	1.12	1.22	1.04
MnO	0.61	0.44	0.45	0.45	0.43	0.46	0.40	0.37	0.40	0.42	0.45	0.48	0.45
MgO	18.61	18.28	20.05	17.98	19.48	19.66	20.07	19.40	19.62	19.59	19.63	19.75	19.71
CaO	30.56	28.56	30.65	28.85	30.14	29.79	29.94	30.17	29.92	30.02	29.65	30.08	29.47
Na <sub>2</sub> O	0.08	0.10	0.01	0.06	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
SrO	0.39	0.41	0.62	0.72	1.02	1.15	1.28	1.42	1.49	1.54	1.71	1.87	2.24
BaO	0.14	0.08	0.00	0.89	0.11	0.08	0.10	0.03	0.05	0.00	0.00	0.04	0.12
La <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.06
Ce <sub>2</sub> O <sub>3</sub>	0.07	0.00	0.04	0.00	0.00	0.10	0.00	0.00	0.00	0.03	0.00	0.06	0.05
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.02	0.02	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	53.30	50.87	52.99	53.68	52.65	52.47	53.08	52.83	52.88	52.91	52.58	53.58	53.16
Total- IETR	0.07	0.00	0.04	0.00	0.00	0.10	0.05	0.10	0.00	0.03	0.00	0.06	0.11
CO <sub>2</sub>	46.68	44.71	47.21	46.04	46.55	46.43	46.99	46.55	46.62	46.67	46.40	47.06	46.58
H <sub>2</sub> O													
Total2	99.98	95.58	100.20	99.72	99.20	98.91	100.07	99.39	99.50	99.58	98.98	100.65	99.76



## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	camadaem- nors	camadaem- nors	camadaem- nors	camadaem- nors	ok	camadaem- nors	camadaem- nors	camadaem- nors	camadaem- nors	oklim- pa	oklim- pa	oklim- pa	oksuja
Com- plexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolo- mita	Dolomita	Dolomita	Dolomita	Dolomita	Dolo- mita	Dolo- mita	Dolo- mita	Dolo- mita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0737	0.0797	0.0293	0.1250	0.0387	0.0320	0.0308	0.0353	0.0344	0.0334	0.0297	0.0318	0.0273
Mn	0.0161	0.0122	0.0117	0.0121	0.0114	0.0123	0.0106	0.0099	0.0106	0.0110	0.0120	0.0126	0.0119
Mg	0.8699	0.8913	0.9271	0.8523	0.9135	0.9246	0.9324	0.9097	0.9184	0.9165	0.9238	0.9159	0.9235
Ca	1.0266	1.0008	1.0186	0.9829	1.0161	1.0068	0.9995	1.0168	1.0067	1.0097	1.0029	1.0027	0.9926
Na	0.0049	0.0062	0.0006	0.0038	0.0000	0.0006	0.0000	0.0000	0.0000	0.0011	0.0000	0.0009	0.0002
Sr	0.0070	0.0078	0.0112	0.0133	0.0186	0.0210	0.0230	0.0259	0.0271	0.0280	0.0314	0.0338	0.0407
Ba	0.0017	0.0011	0.0000	0.0110	0.0013	0.0010	0.0012	0.0004	0.0007	0.0000	0.0000	0.0005	0.0015
La	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0012	0.0000	0.0000	0.0000	0.0000	0.0007
Ce	0.0008	0.0000	0.0004	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0004	0.0000	0.0007	0.0005
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9987	1.9966	1.9989	1.9989	1.9996	1.9994	1.9986	1.9993	1.9985	1.9998	1.9998	1.9990	1.9992
Cl	0.0008	0.0011	0.0009	0.0000	0.0004	0.0004	0.0000	0.0004	0.0000	0.0000	0.0006	0.0004	0.0004
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0009	3.9996	3.9991	4.0007	3.9998	3.9995	3.9984	3.9990	3.9985	4.0002	3.9996	3.9992	3.9990

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C83H	C85D	C85D	C85D	C87G	C87G	C87G	C87G	C87G	C87G	C87G	C87G	C87G
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5
textura	oklimpa	Intercrescbarita	Intercrescbarita	Intercrescbarita	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O													
FeO	0.97	3.26	0.18	0.18	1.66	4.54	4.68	2.96	3.98	4.31	3.44	3.08	3.50
MnO	0.32	0.24	0.03	0.00	0.14	0.31	0.56	0.18	0.76	0.66	0.22	0.20	0.35
MgO	19.56	16.55	19.08	18.98	19.38	16.44	15.98	17.55	17.23	13.96	16.87	17.14	15.84
CaO	30.08	29.80	30.43	29.83	33.80	31.01	31.54	32.00	32.30	28.46	30.89	30.94	30.42
Na <sub>2</sub> O	0.00	0.06	0.02	0.03	0.00	0.02	0.00	0.00	0.02	0.03	0.00	0.00	0.02
SrO	2.45	0.47	1.78	2.03	0.29	0.39	0.40	0.43	0.51	0.57	0.60	0.61	0.62
BaO	0.00	0.17	1.21	1.13	0.06	0.26	0.00	0.00	0.00	0.02	0.00	0.06	0.00
La <sub>2</sub> O <sub>3</sub>	0.05	0.09	0.17	0.00	0.02	0.00	0.06	0.10	0.27	0.19	0.06	0.08	0.07
Ce <sub>2</sub> O <sub>3</sub>	0.03	0.20	0.22	0.00	0.08	0.05	0.14	0.11	0.26	0.16	0.11	0.15	0.17
Pr <sub>2</sub> O <sub>3</sub>			0.08		0.02					0.04			
Nd <sub>2</sub> O <sub>3</sub>			0.08		0.00					0.34			
Dy <sub>2</sub> O <sub>3</sub>			0.00		0.00					0.00			
Yb <sub>2</sub> O <sub>3</sub>			0.00		0.00					0.00			
Cl	0.01	0.01	0.00	0.02	0.01	0.00	0.01	0.00	0.01	0.05	0.00	0.01	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	53.46	50.86	53.12	52.21	55.54	53.01	53.51	53.33	55.34	48.39	52.18	52.29	51.13
TotalETR	0.07	0.29	0.55	0.00	0.15	0.05	0.19	0.21	0.53	0.83	0.17	0.23	0.24
CO <sub>2</sub>	46.82	43.99	46.11	45.45	48.99	45.53	45.67	46.45	47.47	41.11	45.21	45.36	43.91
H <sub>2</sub> O													
Total2	100.28	94.89	99.39	97.66	104.58	98.55	99.20	99.81	102.87	89.96	97.41	97.68	95.06

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C83H	C85D	C85D	C85D	C87G core	C87G	C87G	C87G	C87G	C87G rim	C87G	C87G	C87G
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5
textura	oklimpa	Intercrescbari- ta	Intercrescbari- ta	Intercrescbari- ta	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1
Comple- xo	Araxá Dolomi- ta	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0253	0.0907	0.0047	0.0047	0.0415	0.1220	0.1251	0.0781	0.1027	0.1283	0.0931	0.0831	0.0976
Mn	0.0084	0.0067	0.0008	0.0000	0.0036	0.0084	0.0153	0.0049	0.0199	0.0199	0.0059	0.0055	0.0098
Mg	0.9118	0.8199	0.9028	0.9099	0.8629	0.7878	0.7625	0.8241	0.7918	0.7397	0.8140	0.8245	0.7867
Ca	1.0076	1.0609	1.0348	1.0281	1.0819	1.0682	1.0818	1.0804	1.0664	1.0840	1.0710	1.0696	1.0855
Na	0.0000	0.0040	0.0014	0.0021	0.0002	0.0010	0.0000	0.0000	0.0011	0.0019	0.0000	0.0001	0.0015
Sr	0.0444	0.0091	0.0328	0.0378	0.0051	0.0072	0.0074	0.0079	0.0090	0.0116	0.0112	0.0114	0.0120
Ba	0.0000	0.0023	0.0150	0.0142	0.0007	0.0032	0.0000	0.0000	0.0000	0.0002	0.0000	0.0008	0.0000
La	0.0006	0.0011	0.0020	0.0000	0.0002	0.0000	0.0007	0.0012	0.0030	0.0025	0.0007	0.0010	0.0009
Ce	0.0003	0.0025	0.0025	0.0000	0.0009	0.0006	0.0016	0.0012	0.0029	0.0020	0.0013	0.0017	0.0021
Pr	0.0000	0.0000	0.0009	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0043	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9983	1.9956	1.9979	1.9959	1.9983	1.9981	1.9958	1.9981	1.9973	1.9955	1.9975	1.9982	1.9966
Cl	0.0003	0.0003	0.0002	0.0013	0.0003	0.0000	0.0007	0.0000	0.0003	0.0028	0.0000	0.0007	0.0007
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9985	3.9982	3.9977	3.9971	3.9984	3.9988	3.9953	3.9980	3.9965	3.9944	3.9976	3.9977	3.9965

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C87G	C87G rim	C87G	C87G	C87G rim	C87G	C87G	C87G core	C87G	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG
Unidade	C5	C5	C5	C5	C5	C5	C5	C5	C5	C4a	C4a	C4a	C4a
textura	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	camadaemnors	camadaemnors	oksuja	oklimpa
Complexo Mineral	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita
K <sub>2</sub> O													
FeO	3.83	4.29	4.37	3.78	3.91	3.72	4.28	1.40	3.93	6.33	3.78	1.08	1.16
MnO	0.75	0.62	0.54	0.63	0.71	0.66	0.72	0.13	0.48	0.17	0.42	0.39	0.37
MgO	17.94	16.52	16.03	16.43	17.64	17.05	15.61	16.29	15.90	15.38	16.43	18.49	17.51
CaO	32.30	32.26	31.14	30.47	32.12	32.09	30.44	27.07	30.01	28.47	27.02	26.99	25.77
Na <sub>2</sub> O	0.00	0.04	0.00	0.01	0.03	0.00	0.01	0.09	0.00				
SrO	0.64	0.69	0.70	0.73	0.79	0.81	0.94	1.43	2.17	0.52	0.38	1.23	3.58
BaO	0.01	0.00	0.09	0.13	0.00	0.10	0.00	1.17	0.00	0.74			
La <sub>2</sub> O <sub>3</sub>	0.19	0.06	0.11	0.08	0.22	0.16	0.17	0.20	0.14				
Ce <sub>2</sub> O <sub>3</sub>	0.20	0.07	0.15	0.14	0.30	0.19	0.15	0.10	0.19	0.00	0.00	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>								0.14					
Nd <sub>2</sub> O <sub>3</sub>								0.34					
Dy <sub>2</sub> O <sub>3</sub>								0.00					
Yb <sub>2</sub> O <sub>3</sub>								0.00					
Cl	0.00	0.00	0.02	0.01	0.00	0.01	0.02	0.04	0.00				
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Total1	55.91	54.54	53.16	52.51	55.76	54.78	52.34	47.93	52.83	51.61	48.03	48.18	48.39
TotalETR	0.39	0.13	0.26	0.21	0.52	0.35	0.31	0.80	0.33	0.00	0.00	0.00	0.00
CO <sub>2</sub>	48.16	46.72	45.36	45.00	47.83	46.96	44.51	41.19	44.64	43.55	41.88	42.80	41.80
H <sub>2</sub> O													
Total2	104.12	101.28	98.55	97.54	103.66	101.79	96.89	89.61	97.52	95.16	89.91	90.98	90.19

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C87G	C87G rim	C87G	C87G	C87G rim	C87G	C87G	C87G core	C87G	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG
Unidade	C5	C5	C5	C5	C5	C5	C5	C5	C5	C4a	C4a	C4a	C4a
textura	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	dolomita1	camadaemnors	camadaemnors	oksuja	oklimpa
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0973	0.1125	0.1179	0.1024	0.1002	0.0969	0.1177	0.0416	0.1066	0.1781	0.1106	0.0309	0.0340
Mn	0.0193	0.0163	0.0148	0.0172	0.0184	0.0173	0.0201	0.0038	0.0133	0.0048	0.0124	0.0113	0.0110
Mg	0.8125	0.7715	0.7716	0.7943	0.8049	0.7915	0.7647	0.8615	0.7682	0.7712	0.8567	0.9435	0.9147
Ca	1.0513	1.0827	1.0769	1.0588	1.0533	1.0707	1.0715	1.0293	1.0419	1.0260	1.0126	0.9898	0.9675
Na	0.0000	0.0022	0.0000	0.0009	0.0020	0.0000	0.0004	0.0065	0.0000	0.0000	0.0000	0.0000	0.0000
Sr	0.0112	0.0125	0.0130	0.0137	0.0140	0.0146	0.0179	0.0295	0.0408	0.0101	0.0077	0.0244	0.0727
Ba	0.0001	0.0000	0.0011	0.0016	0.0000	0.0012	0.0000	0.0163	0.0000	0.0098	0.0000	0.0000	0.0000
La	0.0021	0.0007	0.0013	0.0009	0.0025	0.0018	0.0020	0.0027	0.0017	0.0000	0.0000	0.0000	0.0000
Ce	0.0022	0.0008	0.0017	0.0016	0.0034	0.0022	0.0017	0.0012	0.0023	0.0000	0.0000	0.0000	0.0000
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0043	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9970	1.9983	1.9990	1.9923	1.9987	1.9969	1.9966	1.9955	1.9753	2.0000	2.0000	2.0000	2.0000
Cl	0.0000	0.0000	0.0009	0.0006	0.0000	0.0006	0.0012	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9960	3.9993	3.9981	3.9964	3.9982	3.9963	3.9958	3.9969	3.9770	4.0000	4.0000	4.0000	4.0000

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C83H	C85D core	C85D rim	C85D	C87G	C87G rim	C87G	C87G core	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1
Método	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C5	C5	C5	C5	C5	C5	C5	C4	C4	C4	C4	C4
textura	camadaem nors	ok	ok	ok	oklimpa	ok	ok	ok	ok	exsolution	exsolution	ok	ok
Complexo Mineral	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita
K <sub>2</sub> O													
FeO	1.51	7.69		2.52	1.13	3.47	3.60	2.20	0.29	0.22	3.78	0.15	0.29
MnO									0.21	0.32	0.38	0.19	0.31
MgO	14.64	14.53	17.12	14.04	15.90	13.74	14.06	14.93	21.98	21.33	19.33	20.61	21.03
CaO	24.88	26.25	26.17	30.28	30.63	29.14	28.31	27.09	30.81	31.90	30.68	32.27	33.61
Na <sub>2</sub> O									0.38	0.33	0.30	0.31	0.27
SrO	2.63		1.25	0.92	0.35	0.26	0.72	1.80	0.44	0.27	0.32	0.46	0.38
BaO									0.00	0.13	0.14	0.26	0.31
La <sub>2</sub> O <sub>3</sub>									0.00	0.05	0.00	0.02	0.05
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.05
Pr <sub>2</sub> O <sub>3</sub>									0.02	0.04	0.05	0.00	0.03
Nd <sub>2</sub> O <sub>3</sub>									0.00	0.03	0.01	0.00	0.00
Dy <sub>2</sub> O <sub>3</sub>									0.00	0.00	0.00	0.03	0.02
Yb <sub>2</sub> O <sub>3</sub>									0.01	0.02	0.00	0.04	0.02
Cl	0.05								0.00	0.00	0.00	0.00	0.00
F									0.00	0.00	0.00	0.00	0.00
Total1	43.71	48.47	44.54	47.76	48.01	46.61	46.69	46.02	54.13	54.55	54.93	54.34	56.30
TotalETR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.16	0.38	0.43
CO <sub>2</sub>	37.55	41.18	39.76	41.03	42.24	40.11	40.08	39.67	49.04	49.14	48.16	48.63	50.27
H <sub>2</sub> O													
Total2	81.25	89.65	84.30	88.79	90.25	86.72	86.77	85.69	103.51	103.99	103.25	103.26	106.90

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C83H	C85D core	C85D rim	C85D	C87G	C87G rim	C87G	C87G core	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1
Método	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C5	C5	C5	C5	C5	C5	C5	C4	C4	C4	C4	C4
textura	camadaemnors	ok	ok	ok	oklimpa	ok	ok	ok	ok	exsolution	exsolution	ok	ok
Complexo Mineral	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Araxá Dolomita	Catalão Dolomita	Catalão Dolomita	Catalão Dolomita	Catalão Dolomita	Catalão Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0492	0.2288	0.0000	0.0752	0.0328	0.1060	0.1100	0.0679	0.0073	0.0054	0.0961	0.0037	0.0070
Mn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0054	0.0081	0.0099	0.0049	0.0076
Mg	0.8511	0.7706	0.9403	0.7473	0.8220	0.7481	0.7661	0.8218	0.9782	0.9476	0.8758	0.9254	0.9130
Ca	1.0396	1.0006	1.0330	1.1584	1.1381	1.1403	1.1086	1.0717	0.9854	1.0184	0.9991	1.0411	1.0487
Na	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0221	0.0192	0.0179	0.0183	0.0154
Sr	0.0595	0.0000	0.0267	0.0190	0.0070	0.0055	0.0153	0.0385	0.0076	0.0047	0.0057	0.0080	0.0064
Ba	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0017	0.0031	0.0036
La	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0002	0.0005
Ce	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0006
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0005	0.0006	0.0000	0.0004
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0000	0.0003	0.0002
C	1.9995	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	1.9987	1.9991	1.9989	1.9995	1.9985
Cl	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9989	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	4.0094	4.0081	4.0080	4.0077	4.0059

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C1SH1	C1SH1	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	C1SH1
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4	C4	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C4a
textura	Ok	exsolution	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo Mineral	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão
	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O														
FeO	0.22	0.54	0.79	0.60	0.76	0.77	0.60	0.79	0.63	0.63	0.57	0.62	0.30	
MnO	0.26	0.39	0.59	0.33	0.46	0.24	0.24	0.30	0.43	0.28	0.29	0.42	0.38	
MgO	21.00	17.92	20.12	20.16	20.23	20.03	19.77	19.87	20.06	20.14	20.02	19.99	18.89	
CaO	31.75	29.35	29.44	29.88	29.43	29.55	29.57	29.31	28.80	29.60	28.80	29.01	32.00	
Na <sub>2</sub> O	0.28	0.32	0.03	0.00	0.00	0.03	0.03	0.02	0.03	0.01	0.04	0.03	0.01	
SrO	0.45	5.50	1.46	1.71	1.73	1.74	1.77	1.81	1.92	1.98	2.65	1.98	0.24	
BaO	0.55	1.01	0.00	0.02	0.00	0.00	0.00	0.06	0.16	0.07	0.08	0.00	0.17	
La <sub>2</sub> O <sub>3</sub>	0.01	0.04	0.00	0.02	0.00	0.05	0.02	0.02	0.04	0.00	0.00	0.00	0.00	
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.02	0.04	0.03	0.03	0.00	0.00	0.05	0.00	0.05	0.13	0.10	0.06	
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.00												
Nd <sub>2</sub> O <sub>3</sub>	0.02	0.02												
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.00												
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00												
Cl	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total1	54.53	55.09	52.57	52.75	52.65	52.46	51.99	52.26	52.09	52.76	52.58	52.22	52.10	
TotalETR	0.32	0.30	0.04	0.05	0.03	0.05	0.02	0.07	0.05	0.05	0.13	0.10	0.06	
CO <sub>2</sub>	48.77	46.11	46.59	46.78	46.69	46.47	46.08	46.20	46.05	46.67	46.20	46.14	46.34	
H <sub>2</sub> O														
Total2	103.61	101.43	99.17	99.54	99.34	98.93	98.07	98.47	98.15	99.43	98.80	98.37	98.45	



## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C1SH1	C1SH1	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	AO41870	C1SH1
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4	C4	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C4a
textura	Ok	exsolution	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0054	0.0143	0.0208	0.0156	0.0199	0.0204	0.0159	0.0210	0.0166	0.0166	0.0152	0.0165	0.0080
Mn	0.0065	0.0106	0.0157	0.0086	0.0123	0.0065	0.0064	0.0081	0.0117	0.0075	0.0078	0.0112	0.0102
Mg	0.9400	0.8487	0.9420	0.9410	0.9457	0.9399	0.9367	0.9388	0.9503	0.9420	0.9455	0.9457	0.8894
Ca	1.0215	0.9988	0.9907	1.0022	0.9889	0.9964	1.0069	0.9953	0.9808	0.9950	0.9778	0.9866	1.0826
Na	0.0164	0.0196	0.0017	0.0001	0.0002	0.0015	0.0020	0.0011	0.0017	0.0003	0.0022	0.0018	0.0003
Sr	0.0079	0.1013	0.0266	0.0310	0.0315	0.0317	0.0327	0.0333	0.0354	0.0361	0.0487	0.0364	0.0043
Ba	0.0065	0.0126	0.0000	0.0002	0.0000	0.0000	0.0000	0.0008	0.0020	0.0008	0.0009	0.0000	0.0021
La	0.0001	0.0005	0.0000	0.0002	0.0000	0.0006	0.0002	0.0002	0.0005	0.0000	0.0000	0.0000	0.0000
Ce	0.0000	0.0002	0.0004	0.0003	0.0004	0.0000	0.0000	0.0005	0.0000	0.0005	0.0015	0.0011	0.0007
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9994	1.9995	1.9978	1.9995	1.9988	1.9968	1.9999	1.9991	1.9983	1.9989	1.9987	1.9991	1.9981
Cl	0.0006	0.0002	0.0006	0.0003	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0002	0.0003	0.0001
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0068	4.0086	3.9985	3.9993	3.9990	3.9976	4.0008	3.9994	3.9992	3.9992	3.9996	3.9995	3.9981

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH3	C1SH3	C1SH3
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo Mineral	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão
	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O													
FeO	0.32	0.28	0.35	2.40	0.32	1.43	0.38	0.39	0.15	0.24	0.19	0.43	0.32
MnO	0.35	0.25	0.33	0.39	0.34	0.48	0.39	0.39	0.25	0.33	0.13	0.18	0.13
MgO	19.04	19.06	19.06	17.85	19.02	18.72	19.44	19.05	20.33	18.85	20.46	20.80	20.70
CaO	31.63	31.63	31.48	31.15	32.12	31.22	32.56	32.36	30.16	31.89	31.64	30.42	31.15
Na <sub>2</sub> O	0.04	0.02	0.06	0.02	0.07	0.00	0.02	0.02	0.02	0.04	0.01	0.05	0.01
SrO	0.25	0.32	0.36	0.38	0.40	0.41	0.43	0.51	0.63	0.70	0.60	0.72	0.80
BaO	0.10	0.22	0.43	0.21	0.12	0.30	0.42	0.15	0.01	0.50	0.11	0.05	0.03
La <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.06	0.04	0.00	0.04	0.04	0.03	0.08	0.08	0.00	0.12	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.03	0.12	0.09	0.19	0.08	0.09	0.18	0.07	0.00	0.09	0.01	0.07	0.07
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.00	0.01	0.01	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	51.81	51.91	52.21	52.74	52.55	52.79	53.88	52.99	51.74	52.72	53.17	52.85	53.22
TotalETR	0.03	0.12	0.15	0.23	0.08	0.13	0.22	0.11	0.08	0.17	0.01	0.19	0.07
CO <sub>2</sub>	46.21	46.21	46.30	45.98	46.67	46.43	47.64	46.98	46.44	46.48	47.66	47.37	47.71
H <sub>2</sub> O													
Total2	98.02	98.13	98.53	98.75	99.23	99.24	101.54	99.98	98.19	99.23	100.83	100.24	100.94

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH3	C1SH3	C1SH3
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo Mineral	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita	CatalãoI Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0084	0.0073	0.0091	0.0638	0.0083	0.0377	0.0098	0.0101	0.0038	0.0064	0.0048	0.0110	0.0083
Mn	0.0093	0.0068	0.0087	0.0104	0.0090	0.0129	0.0101	0.0102	0.0068	0.0087	0.0033	0.0048	0.0035
Mg	0.8997	0.8996	0.8983	0.8457	0.8890	0.8801	0.8906	0.8845	0.9559	0.8848	0.9373	0.9583	0.9475
Ca	1.0739	1.0732	1.0662	1.0607	1.0789	1.0549	1.0722	1.0794	1.0191	1.0757	1.0415	1.0069	1.0246
Na	0.0022	0.0012	0.0034	0.0013	0.0040	0.0000	0.0012	0.0014	0.0009	0.0025	0.0003	0.0027	0.0003
Sr	0.0045	0.0059	0.0066	0.0071	0.0073	0.0074	0.0076	0.0092	0.0114	0.0127	0.0107	0.0129	0.0143
Ba	0.0012	0.0027	0.0053	0.0027	0.0015	0.0037	0.0051	0.0018	0.0001	0.0061	0.0013	0.0007	0.0004
La	0.0000	0.0000	0.0007	0.0005	0.0000	0.0005	0.0004	0.0004	0.0009	0.0009	0.0000	0.0014	0.0000
Ce	0.0004	0.0014	0.0011	0.0022	0.0009	0.0010	0.0020	0.0008	0.0000	0.0010	0.0001	0.0008	0.0008
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9991	1.9977	1.9981	1.9949	1.9978	1.9993	1.9989	1.9974	1.9996	1.9980	1.9992	1.9984	1.9997
Cl	0.0000	0.0004	0.0001	0.0000	0.0000	0.0004	0.0009	0.0002	0.0004	0.0002	0.0007	0.0006	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0000	3.9983	3.9994	3.9962	4.0000	3.9985	3.9988	3.9986	3.9994	3.9991	3.9992	3.9993	3.9997

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C1SH3	C1SH3	C1SH3	C1SH3	C1SH3	C1SH3	C1SH3	CB02	CB02	CB02	CB02	CB02	CB02
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C2	C2	C2	C2	C2	C2
textura	Ok	ok	ok	ok	ok	ok	ok	oksuja	oksuja	oklimpa	oklimpa	oklimpa	oklimpa
Complexo Mineral	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O													
FeO	0.35	0.39	0.33	0.46	0.65	0.73	0.69	1.21	1.30	0.78	0.79	0.86	0.81
MnO	0.27	0.21	0.23	0.18	0.25	0.31	0.25	0.42	0.32	0.25	0.36	0.36	0.35
MgO	20.38	20.67	20.34	20.57	20.35	19.34	19.89	20.40	20.95	20.44	20.50	20.57	21.03
CaO	31.71	32.13	32.08	31.56	30.61	32.01	30.49	28.83	28.47	28.98	28.63	28.62	28.41
Na <sub>2</sub> O	0.00	0.00	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.03	0.05
SrO	0.90	0.90	0.96	0.98	1.00	1.37	1.47	0.77	1.45	1.52	1.67	1.54	1.45
BaO	0.10	0.11	0.00	0.08	0.09	0.19	0.07	0.00	0.00	0.00	0.17	0.08	0.00
La <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.11	0.00	0.00	0.10	0.02	0.00	0.00	0.00	0.03	0.00	0.02
Ce <sub>2</sub> O <sub>3</sub>	0.07	0.05	0.05	0.00	0.03	0.00	0.06	0.01	0.01	0.03	0.02	0.03	0.03
Pr <sub>2</sub> O <sub>3</sub>								0.06	0.05	0.03	0.00	0.03	0.09
Nd <sub>2</sub> O <sub>3</sub>								0.00	0.01	0.00	0.02	0.01	0.01
Dy <sub>2</sub> O <sub>3</sub>								0.00	0.00	0.00	0.00	0.00	0.00
Yb <sub>2</sub> O <sub>3</sub>								0.00	0.00	0.00	0.00	0.00	0.04
Cl	0.00	0.02	0.00	0.00	0.00	0.02	0.04	0.00	0.02	0.01	0.01	0.00	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	53.78	54.52	54.15	53.88	53.00	54.08	52.96	51.72	52.52	52.05	52.19	52.09	52.16
TotalETR	0.07	0.06	0.16	0.00	0.03	0.10	0.07	0.09	0.09	0.09	0.11	0.09	0.19
CO <sub>2</sub>	47.96	48.59	48.20	48.09	47.27	47.55	46.89	46.27	46.85	46.39	46.37	46.40	46.67
H <sub>2</sub> O													
Total2	101.75	103.12	102.37	101.97	100.27	101.64	99.85	98.07	99.44	98.51	98.63	98.55	98.97

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	C1SH3	C1SH3	C1SH3	C1SH3	C1SH3	C1SH3	C1SH3	CB02	CB02	CB02	CB02	CB02	CB02
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C2	C2	C2	C2	C2	C2
textura	Ok	ok	ok	ok	ok	ok	ok	oksuja	oksuja	oklimpa	oklimpa	oklimpa	oklimpa
Complexo Mineral	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI
	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0090	0.0098	0.0083	0.0116	0.0169	0.0187	0.0181	0.0321	0.0340	0.0206	0.0208	0.0227	0.0213
Mn	0.0070	0.0052	0.0060	0.0046	0.0067	0.0082	0.0065	0.0114	0.0084	0.0068	0.0097	0.0096	0.0094
Mg	0.9279	0.9287	0.9210	0.9336	0.9399	0.8874	0.9260	0.9621	0.9754	0.9618	0.9650	0.9676	0.9827
Ca	1.0375	1.0373	1.0442	1.0298	1.0158	1.0555	1.0203	0.9773	0.9529	0.9801	0.9685	0.9675	0.9542
Na	0.0000	0.0000	0.0007	0.0025	0.0005	0.0000	0.0000	0.0000	0.0000	0.0013	0.0010	0.0020	0.0028
Sr	0.0159	0.0158	0.0169	0.0172	0.0179	0.0245	0.0266	0.0141	0.0262	0.0278	0.0306	0.0281	0.0263
Ba	0.0012	0.0013	0.0000	0.0009	0.0011	0.0023	0.0008	0.0000	0.0000	0.0000	0.0021	0.0009	0.0000
La	0.0000	0.0001	0.0012	0.0000	0.0000	0.0011	0.0002	0.0000	0.0000	0.0000	0.0003	0.0000	0.0002
Ce	0.0008	0.0005	0.0005	0.0000	0.0004	0.0000	0.0006	0.0001	0.0001	0.0003	0.0002	0.0004	0.0004
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0005	0.0004	0.0000	0.0003	0.0010
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0002	0.0001	0.0001
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
C	1.9994	1.9991	1.9992	1.9993	1.9990	1.9979	1.9994	1.9987	1.9980	1.9990	1.9986	1.9985	1.9975
Cl	0.0000	0.0009	0.0000	0.0000	0.0000	0.0010	0.0019	0.0001	0.0009	0.0003	0.0003	0.0000	0.0004
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9993	3.9990	3.9991	4.0005	3.9994	3.9976	3.9988	3.9983	3.9982	3.9993	3.9990	3.9994	3.9988

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	CB02	CB02	CB02	CB02	CB02	CB02	CB14	CB14	CB14	CB14	CB14	FVL184	Fsalt0287
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C2	C2	C2	C2	P1	P1	P1	P1	P1	C1a	C2
textura	Oklimpa	oksuja	oksuja	oklimpa	oklimpa	oklimpa	ok	ok	ok	ok	ok	exsolution	ok
Complexo	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	CatalãoI	Salitre	Salitre
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O												0.11	0.01
FeO	1.06	1.50	1.18	1.66	1.18	1.15	0.68	0.31	0.87	0.35	2.63	1.03	1.65
MnO	0.26	0.32	0.36	0.34	0.29	0.32	0.55	0.23	0.61	0.21	2.05	0.41	1.14
MgO	20.95	20.41	19.71	19.85	20.02	20.02	20.53	20.86	20.16	20.55	19.30	17.73	19.53
CaO	28.50	29.26	28.69	28.39	28.72	28.36	31.68	31.69	31.40	30.05	28.42	33.45	33.53
Na <sub>2</sub> O	0.01	0.11	0.02	0.01	0.08	0.01	0.01	0.00	0.04	0.00	0.03	0.30	0.35
SrO	1.38	1.43	1.39	1.68	1.45	1.48	0.52	0.56	0.83	0.95	1.51	0.97	0.88
BaO	0.20	0.05	0.00	0.04	0.07	0.00	0.03	0.07	0.04	0.05	0.07	0.00	0.02
La <sub>2</sub> O <sub>3</sub>	0.02	0.02	0.04	0.02	0.02	0.02	0.04	0.04	0.00	0.04	0.01	0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.02	0.00	0.06	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.07	0.00	0.00						0.00	0.01
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.03	0.00	0.00	0.03						0.00	0.04
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00						0.09	0.17
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.00	0.03	0.01	0.00						0.00	0.00
Cl	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.01	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	52.47	53.10	51.48	52.11	51.88	51.37	54.06	53.86	53.97	52.20	54.06	53.94	57.09
TotalETR	0.04	0.15	0.14	0.16	0.04	0.04	0.04	0.04	0.03	0.04	0.01	0.14	0.39
CO <sub>2</sub>	46.72	47.11	45.63	45.98	46.02	45.66	48.29	48.26	47.96	46.80	46.94	47.16	50.08
H <sub>2</sub> O													
Total2	99.20	100.34	97.15	98.19	97.93	97.05	102.35	102.13	101.93	99.01	101.00	101.24	107.56

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	CB02	CB02	CB02	CB02	CB02	CB02	CB14	CB14	CB14	CB14	CB14	FVL184	Fsalt0287
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C2	C2	C2	C2	P1	P1	P1	P1	P1	C1a	C2
textura	Oklimpa	oksuja	oksuja	oklimpa	oklimpa	oklimpa	ok	ok	ok	ok	ok	exsolution	ok
Complexo	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Salitre	Salitre
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0277	0.0391	0.0317	0.0441	0.0315	0.0308	0.0173	0.0079	0.0223	0.0092	0.0686	0.0268	0.0402
Mn	0.0068	0.0083	0.0098	0.0093	0.0079	0.0086	0.0141	0.0058	0.0157	0.0057	0.0540	0.0107	0.0281
Mg	0.9784	0.9461	0.9430	0.9424	0.9500	0.9573	0.9283	0.9435	0.9176	0.9584	0.8974	0.8205	0.8506
Ca	0.9566	0.9748	0.9865	0.9687	0.9791	0.9747	1.0296	1.0301	1.0270	1.0076	0.9499	1.1127	1.0497
Na	0.0004	0.0066	0.0009	0.0008	0.0049	0.0007	0.0006	0.0000	0.0021	0.0000	0.0016	0.0181	0.0196
Sr	0.0251	0.0257	0.0259	0.0311	0.0268	0.0275	0.0091	0.0099	0.0146	0.0172	0.0274	0.0174	0.0149
Ba	0.0024	0.0006	0.0000	0.0005	0.0008	0.0000	0.0004	0.0008	0.0005	0.0007	0.0008	0.0000	0.0002
La	0.0002	0.0002	0.0004	0.0002	0.0002	0.0002	0.0004	0.0004	0.0000	0.0004	0.0001	0.0000	0.0000
Ce	0.0002	0.0000	0.0007	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000
Pr	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
Nd	0.0000	0.0000	0.0004	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0016
Yb	0.0000	0.0001	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9983	1.9996	1.9993	1.9990	1.9995	1.9998	1.9998	1.9993	1.9992	1.9992	1.9995	1.9992	1.9977
Cl	0.0002	0.0000	0.0004	0.0005	0.0004	0.0007	0.0003	0.0000	0.0000	0.0000	0.0010	0.0004	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9984	4.0026	3.9994	3.9989	4.0017	3.9999	3.9999	3.9991	4.0002	3.9992	4.0001	4.0080	4.0070

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	Fsalt0287	Fsalt0287	FVL184	SL109C	SLE360	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SLE360	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C1a	C5	C1b	C5	C5	C5	C5	C5	C5	C1b	C5
textura	Ok	ok	exsolution	ok	exsinCalcita	ok	ok	ok	ok	ok	ok	exsinCalcita	ok
Complexo Mineral	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita	Salitre Dolomita
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	1.41	0.69	1.08	4.69	0.88	2.12	2.63	1.90	2.69	4.47	2.05	0.67	4.12
MnO	0.90	0.38	0.44	1.35	0.35	1.94	1.29	1.02	1.86	0.95	2.03	0.42	0.81
MgO	20.17	20.46	20.72	18.36	21.76	20.29	20.31	20.84	19.96	12.68	20.22	21.82	16.62
CaO	33.47	31.85	32.78	32.43	32.60	32.29	31.88	31.19	31.66	34.24	32.43	34.02	36.28
Na <sub>2</sub> O	0.30	0.20	0.34	0.26	0.37	0.32	0.33	0.25	0.24	0.33	0.33	0.17	0.30
SrO	1.11	0.89	0.49	0.06	0.92	0.10	0.19	0.13	0.00	0.40	0.18	0.99	1.02
BaO	0.00	0.01	0.04	0.00	0.00	0.01	0.03	0.05	0.07	0.12	0.14	0.14	0.39
La <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.01	0.09	0.00	0.05	0.18
Ce <sub>2</sub> O <sub>3</sub>	0.05	0.04	0.07	0.00	0.00	0.15	0.00	0.13	0.03	0.00	0.07	0.05	0.12
Pr <sub>2</sub> O <sub>3</sub>	0.08	0.00	0.02	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.10	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.10	0.02	0.10
Dy <sub>2</sub> O <sub>3</sub>	0.03	0.24	0.12	0.07	0.04	0.12	0.11	0.13	0.12	0.00	0.25	0.09	0.18
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.02	0.07	0.05	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Cl	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	57.42	54.65	56.05	57.23	56.88	57.21	56.68	55.58	56.52	53.31	57.45	58.34	59.83
TotalETR	0.24	0.52	0.49	0.36	0.30	0.38	0.42	0.43	0.28	0.20	0.54	0.42	0.90
CO <sub>2</sub>	50.46	48.68	49.89	49.51	50.84	50.37	50.04	49.41	49.71	44.54	50.54	51.89	50.63
H <sub>2</sub> O													
Total2	108.06	103.80	106.36	107.06	108.02	107.81	107.13	105.29	106.48	97.97	108.46	110.55	111.06



## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	Fsalt0287	Fsalt0287	FVL184	SL109C	SLE360	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SLE360	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C2	C2	C1a	C5	C1b	C5	C5	C5	C5	C5	C5	C1b	C5
textura	Ok	ok	exsolution	ok	exsinCalcita	ok	ok	ok	ok	ok	ok	exsinCalcita	ok
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0342	0.0174	0.0264	0.1161	0.0211	0.0514	0.0643	0.0472	0.0662	0.1221	0.0497	0.0159	0.0995
Mn	0.0222	0.0096	0.0108	0.0337	0.0086	0.0477	0.0319	0.0257	0.0464	0.0263	0.0497	0.0101	0.0198
Mg	0.8727	0.9176	0.9053	0.8094	0.9344	0.8793	0.8858	0.9205	0.8759	0.6172	0.8727	0.9180	0.7158
Ca	1.0409	1.0266	1.0293	1.0275	1.0060	1.0055	0.9993	0.9900	0.9984	1.1982	1.0059	1.0286	1.1231
Na	0.0169	0.0115	0.0194	0.0149	0.0204	0.0178	0.0184	0.0144	0.0139	0.0208	0.0183	0.0095	0.0169
Sr	0.0186	0.0155	0.0083	0.0009	0.0154	0.0017	0.0032	0.0023	0.0000	0.0075	0.0030	0.0162	0.0171
Ba	0.0000	0.0001	0.0005	0.0000	0.0000	0.0001	0.0003	0.0006	0.0008	0.0015	0.0016	0.0016	0.0044
La	0.0001	0.0000	0.0000	0.0005	0.0000	0.0000	0.0001	0.0000	0.0001	0.0010	0.0000	0.0006	0.0019
Ce	0.0005	0.0004	0.0007	0.0000	0.0000	0.0016	0.0000	0.0014	0.0003	0.0000	0.0007	0.0005	0.0012
Pr	0.0009	0.0000	0.0002	0.0000	0.0000	0.0005	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0010	0.0002	0.0010
Dy	0.0002	0.0023	0.0011	0.0007	0.0003	0.0011	0.0010	0.0012	0.0011	0.0000	0.0023	0.0008	0.0016
Yb	0.0000	0.0000	0.0002	0.0006	0.0004	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000
C	1.9997	1.9990	1.9961	1.9992	1.9989	1.9986	1.9986	1.9985	1.9977	1.9860	1.9973	1.9994	1.9976
Cl	0.0000	0.0006	0.0004	0.0003	0.0000	0.0000	0.0005	0.0003	0.0000	0.0000	0.0001	0.0002	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0076	4.0032	4.0064	4.0057	4.0088	4.0071	4.0070	4.0049	4.0048	4.0065	4.0062	4.0033	4.0046

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O	0.00	0.01	0.01										
FeO	9.71	1.37	2.29	2.10	1.54	2.55	2.48	0.91	0.92	1.84	1.13	4.96	2.39
MnO	1.03	0.90	1.09	1.50	1.06	1.28	1.28	0.83	0.94	1.64	0.94	1.52	1.35
MgO	14.77	17.41	16.63	19.10	17.58	19.03	19.05	20.37	20.56	19.49	19.87	17.15	19.11
CaO	31.23	27.97	28.83	28.48	31.72	28.03	27.83	27.87	28.15	28.38	28.00	28.99	28.92
Na <sub>2</sub> O	0.34	1.15	0.92	0.02	0.02	0.00	0.01	0.00	0.03	0.00	0.01	0.14	0.01
SrO	0.11	3.81	5.27	0.05	0.09	0.11	0.22	0.88	1.09	0.04	1.06	0.11	0.15
BaO	0.55	2.04	2.92	0.05	0.01	0.00	0.00	0.00	0.01	0.00	0.14	0.07	0.00
La <sub>2</sub> O <sub>3</sub>	0.05	1.66	0.37	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.04	6.65	0.97	0.02	0.00	0.02	0.01	0.02	0.01	0.03	0.03	0.00	0.05
Pr <sub>2</sub> O <sub>3</sub>	0.00	1.26	0.12	0.00	0.01	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.01	4.20	0.71	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.23	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yb <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	57.86	63.05	59.29	51.39	52.05	51.05	50.96	50.89	51.74	51.41	51.20	52.94	52.08
TotalETR	0.32	14.42	2.72	0.08	0.01	0.08	0.07	0.03	0.06	0.06	0.11	0.04	0.07
CO <sub>2</sub>	47.76	49.22	47.31	45.50	45.75	45.20	45.08	45.57	46.19	45.72	45.48	45.63	45.97
H <sub>2</sub> O													
Total2	105.83	118.37	107.97	96.92	97.82	96.30	96.10	96.46	97.97	97.17	96.74	98.60	98.07

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.2487	0.0335	0.0592	0.0564	0.0413	0.0690	0.0674	0.0244	0.0243	0.0492	0.0304	0.1327	0.0637
Mn	0.0268	0.0224	0.0284	0.0408	0.0287	0.0350	0.0351	0.0226	0.0252	0.0444	0.0257	0.0411	0.0363
Mg	0.6750	0.7612	0.7658	0.9167	0.8390	0.9190	0.9217	0.9760	0.9716	0.9301	0.9539	0.8186	0.9072
Ca	1.0254	0.8789	0.9542	0.9822	1.0881	0.9731	0.9679	0.9596	0.9562	0.9736	0.9661	0.9944	0.9865
Na	0.0203	0.0655	0.0550	0.0015	0.0012	0.0000	0.0006	0.0001	0.0019	0.0000	0.0008	0.0088	0.0004
Sr	0.0020	0.0648	0.0943	0.0009	0.0016	0.0020	0.0041	0.0163	0.0199	0.0007	0.0198	0.0020	0.0027
Ba	0.0066	0.0235	0.0353	0.0006	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0018	0.0009	0.0000
La	0.0006	0.0180	0.0042	0.0003	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0002	0.0001	0.0000
Ce	0.0004	0.0714	0.0110	0.0002	0.0000	0.0002	0.0002	0.0003	0.0002	0.0003	0.0003	0.0000	0.0006
Pr	0.0000	0.0134	0.0013	0.0000	0.0001	0.0000	0.0004	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
Nd	0.0001	0.0440	0.0078	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0001
Dy	0.0000	0.0021	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0001	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9982	1.9711	1.9952	1.9998	1.9997	1.9994	1.9980	1.9994	1.9995	1.9988	1.9993	1.9945	1.9984
Cl	0.0012	0.0005	0.0001	0.0000	0.0000	0.0004	0.0001	0.0000	0.0001	0.0000	0.0000	0.0005	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0079	3.9803	4.0173	4.0001	4.0002	3.9992	3.9979	3.9995	4.0002	3.9987	3.9997	4.0019	3.9984

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	SL109C	AT139	AT139	AT139	AT139	AT139	AT139	AT135	AT46	AT49	AT135	AT46	TAPS
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C3	C3	C3	C3	C3	C3	C4a	C1b	C1b	C4a	C1b	C1a
textura	ok	ok	ok	ok	ok	ok	ok	ok	intersticial_exs	intersticial_exs	exsolution	ok	exsolution
Complexo	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita
K <sub>2</sub> O		0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.00	0.00	0.00
FeO	2.73	0.12	2.97	2.79	0.13	2.04	2.16	2.42		6.96	2.40	2.40	1.71
MnO	1.51	0.15	0.70	0.65	0.10	1.17	1.08	0.60		0.82	0.52	0.53	0.51
MgO	17.92	16.56	17.82	18.83	19.76	19.91	22.53	20.03		16.42	20.16	19.15	21.10
CaO	29.65	39.98	31.34	31.73	38.61	32.17	32.41	31.76		30.43	31.58	30.06	32.39
Na <sub>2</sub> O	0.05	0.29	0.34	0.31	0.37	0.31	0.32	0.31		0.24	0.37	0.70	0.24
SrO	0.32	0.54	1.41	1.38	0.54	1.05	0.86	0.64		0.48	0.88	1.67	1.08
BaO	0.00	0.34	0.00	0.00	0.58	0.34	0.39	0.00		0.00	0.00	0.00	0.00
La <sub>2</sub> O <sub>3</sub>	0.02	0.08	0.06	0.02	0.00	0.00	0.00	0.04		0.00	0.02	0.04	0.01
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.18	0.10	0.04	0.02	0.04	0.01	0.05		0.11	0.00	0.01	0.04
Pr <sub>2</sub> O <sub>3</sub>	0.03	0.03	0.00	0.14	0.08	0.02	0.03	0.00		0.04	0.04	0.06	0.00
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.00	0.06	0.48	0.00	0.00	0.00		0.03	0.04	0.16	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.19	0.06	0.11	0.09	0.31	0.18	0.06		0.00	0.10	0.22	0.03
Yb <sub>2</sub> O <sub>3</sub>	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.01
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
Total1	52.33	58.30	54.77	55.80	60.11	57.03	59.76	55.87		55.45	55.92	54.60	57.08
TotalETR	0.09	0.59	0.31	0.56	0.99	0.61	0.41	0.19		0.46	0.33	0.68	0.18
CO <sub>2</sub>	45.66	50.32	47.24	48.54	52.93	49.88	52.84	49.19		47.07	49.31	47.69	50.50
H <sub>2</sub> O													
Total2	98.06	108.95	102.16	104.84	114.01	107.47	113.01	105.17		102.87	105.54	102.92	107.71

## Dados de Química Mineral de Carbonatos – Dolomita (cont.)

Amostra	SL109C	AT139	AT139	AT139	AT139	AT139	AT139	AT135	AT46	AT49	AT135	AT46	TAPS
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C3	C3	C3	C3	C3	C3	C4a	C1b	C1b	C4a	C1b	C1a
textura	ok	ok	ok	ok	ok	ok	ok	ok	intersticial_exs	intersticial_exs	exsolution	ok	exsolution
Complexo	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0731	0.0029	0.0771	0.0702	0.0030	0.0500	0.0501	0.0602	0.1810	0.0595	0.0616	0.0414	0.0106
Mn	0.0411	0.0036	0.0184	0.0167	0.0024	0.0291	0.0253	0.0151	0.0217	0.0132	0.0138	0.0126	0.0085
Mg	0.8557	0.7176	0.8238	0.8463	0.8145	0.8708	0.9307	0.8882	0.7613	0.8926	0.8760	0.9122	0.9404
Ca	1.0175	1.2449	1.0411	1.0249	1.1437	1.0112	0.9623	1.0125	1.0141	1.0049	0.9882	1.0065	1.0123
Na	0.0033	0.0165	0.0201	0.0180	0.0196	0.0175	0.0171	0.0180	0.0146	0.0215	0.0419	0.0133	0.0239
Sr	0.0059	0.0091	0.0253	0.0242	0.0087	0.0178	0.0138	0.0110	0.0086	0.0151	0.0296	0.0181	0.0106
Ba	0.0000	0.0038	0.0000	0.0000	0.0063	0.0039	0.0042	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
La	0.0002	0.0008	0.0007	0.0002	0.0000	0.0000	0.0000	0.0005	0.0000	0.0002	0.0005	0.0001	0.0000
Ce	0.0000	0.0019	0.0011	0.0004	0.0002	0.0004	0.0001	0.0005	0.0012	0.0000	0.0001	0.0005	0.0000
Pr	0.0003	0.0003	0.0000	0.0015	0.0008	0.0002	0.0003	0.0000	0.0005	0.0004	0.0006	0.0000	0.0008
Nd	0.0000	0.0001	0.0000	0.0007	0.0048	0.0000	0.0000	0.0000	0.0004	0.0004	0.0018	0.0000	0.0000
Dy	0.0000	0.0018	0.0006	0.0010	0.0008	0.0030	0.0016	0.0006	0.0000	0.0009	0.0021	0.0003	0.0010
Yb	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9970	1.9970	1.9995	1.9978	1.9981	1.9980	1.9992	1.9983	1.9991	1.9996	1.9980	1.9994	1.9990
Cl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9989	4.0043	4.0088	4.0059	4.0063	4.0056	4.0069	4.0073	4.0056	4.0095	4.0178	4.0058	4.0103

## Dados de Química Mineral de Carbonatos – Dolomita / Fe-Dolomita

Amostra	AT46	4s22	AT49	AT135	AT135	AT135	AT135	AT49	4s22	AT135	AT135	C83H	C85D
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C3	C1b	C4a	C4a	C4a	C4a	C1b	C3	C4a	C4a	C4a	C5
textura	interstici-	exsoluti-	interstici-	ok	ok	exsoluti-	exsoluti-	interstici-	exsoluti-	exsoluti-	ok	ok	dolomita1
Comple-	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomi-	Dolomi-	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomi-	FeDolomi-	FeDolomi-
ta				ta	ta						ta	ta	ta
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
FeO	1.38	0.98	2.30	2.87	2.35	3.73	2.85	1.78	1.49	4.99	6.78	10.94	8.60
MnO	0.50	0.34	0.67	0.83	0.49	0.99	0.64	0.56	0.39	0.48	0.58	0.54	0.40
MgO	20.90	20.74	20.47	19.77	20.36	17.76	20.11	21.06	20.59	16.34	16.34	13.83	14.82
CaO	32.15	30.41	32.43	31.54	31.67	31.08	31.91	32.59	31.14	34.56	33.80	27.75	26.98
Na <sub>2</sub> O	0.26	0.28	0.30	0.26	0.25	0.25	0.35	0.22	0.42	0.30	0.28	0.00	0.03
SrO	1.14	0.94	0.50	1.43	1.14	0.52	1.46	0.88	1.82	0.32	0.41	0.01	0.04
BaO	0.03	0.04	0.07	0.07	0.07	0.09	0.11	0.14	0.20	0.48	0.53	0.07	0.09
La <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.03	0.13	0.12	0.04	0.04	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.07	0.00	0.00	0.01	0.02	0.14	0.00	0.09	0.30	0.08	0.22	0.06	0.00
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.05	0.02	0.01	0.01	0.00	0.00	0.06	0.04	0.00		0.01
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.06	0.00	0.00	0.14	0.00	0.06	0.00	0.00	0.00		0.04
Dy <sub>2</sub> O <sub>3</sub>	0.23	0.28	0.05	0.06	0.09	0.14	0.09	0.13	0.19	0.01	0.00		0.00
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.04	0.05	0.04	0.00	0.00	0.06	0.00	0.00	0.00	0.02		0.02
Cl	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	56.42	53.74	56.77	56.83	56.39	54.58	57.45	57.34	56.49	57.66	59.07	53.25	51.09
TotalETR	0.54	0.42	0.39	0.26	0.23	0.61	0.24	0.43	0.90	0.47	0.47	0.10	0.07
CO <sub>2</sub>	50.02	48.04	50.17	49.50	49.58	47.27	50.10	50.68	49.45	48.93	49.54	43.97	42.97
H <sub>2</sub> O													
Total2	106.91	102.19	107.30	106.58	106.18	102.32	107.79	108.33	106.40	106.86	108.83	97.23	94.12

## Dados de Química Mineral de Carbonatos – Dolomita / Fe-Dolomita (cont.)

Amostra	AT46	4s22	AT49	AT135	AT135	AT135	AT135	AT49	4s22	AT135	AT135	C83H	C85D
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C1b	C3	C1b	C4a	C4a	C4a	C4a	C1b	C3	C4a	C4a	C4a	C5
textura	interstici-	exsoluti-	interstici-	ok	ok	exsoluti-	exsoluti-	interstici-	exsoluti-	exsoluti-	ok	ok	dolomita1
Comple-	al_exs	on	al_exs			on	on	al_exs	on	on			
xo	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira	Araxá	Araxá
Mineral	Dolomita	Dolomita	Dolomita	Dolomi-	Dolomi-	Dolomita	Dolomita	Dolomita	Dolomita	Dolomita	Dolomi-	FeDolomi-	FeDolomi-
	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta
Proporção atômica para 6 O													
Fe <sup>2+</sup>	0.0338	0.0250	0.0561	0.0710	0.0580	0.0967	0.0696	0.0429	0.0370	0.1247	0.1672	0.3044	0.2417
Mn	0.0123	0.0086	0.0166	0.0207	0.0121	0.0259	0.0159	0.0136	0.0098	0.0121	0.0145	0.0153	0.0113
Mg	0.9116	0.9420	0.8907	0.8719	0.8964	0.8201	0.8758	0.9066	0.9089	0.7283	0.7190	0.6863	0.7424
Ca	1.0081	0.9927	1.0140	0.9993	1.0023	1.0313	0.9989	1.0083	0.9876	1.1074	1.0691	0.9900	0.9715
Na	0.0146	0.0164	0.0170	0.0150	0.0143	0.0147	0.0195	0.0122	0.0242	0.0176	0.0158	0.0000	0.0020
Sr	0.0194	0.0166	0.0084	0.0246	0.0195	0.0093	0.0248	0.0147	0.0312	0.0056	0.0071	0.0002	0.0007
Ba	0.0003	0.0005	0.0008	0.0008	0.0008	0.0011	0.0013	0.0016	0.0023	0.0056	0.0061	0.0009	0.0012
La	0.0000	0.0001	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0014	0.0013	0.0004	0.0005	0.0000
Ce	0.0007	0.0000	0.0000	0.0001	0.0002	0.0016	0.0000	0.0009	0.0032	0.0008	0.0023	0.0007	0.0000
Pr	0.0000	0.0000	0.0006	0.0002	0.0001	0.0002	0.0000	0.0000	0.0007	0.0004	0.0000	0.0000	0.0001
Nd	0.0000	0.0000	0.0006	0.0000	0.0000	0.0015	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0005
Dy	0.0021	0.0027	0.0005	0.0005	0.0009	0.0014	0.0009	0.0012	0.0018	0.0001	0.0000	0.0000	0.0000
Yb	0.0000	0.0004	0.0004	0.0004	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0002	0.0000	0.0002
C	1.9985	1.9982	1.9992	1.9989	1.9991	1.9987	1.9988	1.9985	1.9986	1.9976	1.9967	1.9985	1.9717
Cl	0.0000	0.0002	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001	0.0005	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0050	4.0057	4.0070	4.0060	4.0061	4.0048	4.0081	4.0042	4.0088	4.0059	4.0045	3.9983	3.9969

## Dados de Química Mineral de Carbonatos – Fe-Dolomita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C85D	C87G	C83H	C83H	C87G	C87G	C85D
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C5	C5	C4a	C4a	C5	C5	C5
textura	camada-	camada-	camada-	camada-	camada-	camada-	dolomi-	dolomi-	camada-	camada-	dolomi-	dolomi-	dolomi-
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDo-	FeDo-	FeDolomita	FeDolomita	FeDo-	FeDo-	FeDo-
							lomita	lomita			lomita	lomita	lomita
K <sub>2</sub> O													
FeO	8.52	12.46	10.95	13.67	8.47	9.27	7.74	13.12	12.89	7.67	6.36	10.64	8.33
MnO	0.41	0.45	0.29	0.37	0.34	0.52	0.39	0.58	0.19	0.34	0.64	0.46	0.37
MgO	15.66	12.87	13.91	12.26	15.43	14.61	15.59	12.52	12.78	15.86	15.15	17.99	15.29
CaO	28.23	27.34	27.82	27.65	28.16	28.30	27.25	27.10	28.13	29.21	29.46	23.87	27.48
Na <sub>2</sub> O	0.00	0.03	0.00	0.00	0.00	0.00	0.17	0.05	0.05	0.02	0.00	0.00	0.16
SrO	0.05	0.07	0.08	0.09	0.16	0.17	0.19	0.20	0.25	0.27	0.31	0.34	0.36
BaO	0.22	0.42	0.59	0.38	0.20	0.17	0.07	0.02	0.00	0.29	0.19	0.08	0.21
La <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.01	0.01
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.08	0.02	0.08	0.02	0.01	0.00	0.07	0.00	0.08	0.07	0.03
Pr <sub>2</sub> O <sub>3</sub>							0.00						0.00
Nd <sub>2</sub> O <sub>3</sub>							0.01						0.00
Dy <sub>2</sub> O <sub>3</sub>							0.00						0.00
Yb <sub>2</sub> O <sub>3</sub>							0.00						0.00
Cl	0.00	0.00	0.00	0.02	0.01	0.00	0.02	0.02	0.02	0.00	0.02	0.00	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	53.16	53.67	53.71	54.49	52.90	53.09	51.52	53.61	54.37	53.72	52.29	53.46	52.25
Total- IETR	0.00	0.02	0.08	0.02	0.08	0.02	0.10	0.00	0.07	0.02	0.16	0.08	0.10
CO <sub>2</sub>	44.82	43.60	44.13	43.85	44.50	44.29	43.66	43.46	44.20	45.38	44.18	45.37	43.94
H <sub>2</sub> O													
Total2	97.98	97.28	97.85	98.34	97.41	97.39	95.25	97.06	98.58	99.10	96.49	98.84	96.24



## Dados de Química Mineral de Carbonatos – Fe-Dolomita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C85D	C87G	C83H	C83H	C87G	C87G	C85D
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C5	C5	C4a	C4a	C5	C5	C5
textura	camada-	camada-	camada-	camada-	camada-	camada-	dolomi-	dolomi-	camada-	camada-	dolomi-	dolomi-	dolomi-
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDo-	FeDo-	FeDolomita	FeDolomita	FeDo-	FeDo-	FeDo-

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.2328	0.3501	0.3036	0.3815	0.2329	0.2562	0.2171	0.3692	0.3570	0.2071	0.1761	0.2869	0.2322
Mn	0.0113	0.0129	0.0080	0.0106	0.0095	0.0144	0.0112	0.0166	0.0054	0.0094	0.0180	0.0124	0.0103
Mg	0.7627	0.6447	0.6875	0.6098	0.7567	0.7196	0.7793	0.6282	0.6308	0.7628	0.7481	0.8648	0.7596
Ca	0.9881	0.9840	0.9885	0.9884	0.9924	1.0022	0.9790	0.9772	0.9984	1.0098	1.0455	0.8246	0.9813
Na	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0109	0.0031	0.0034	0.0013	0.0000	0.0000	0.0106
Sr	0.0009	0.0013	0.0014	0.0018	0.0030	0.0033	0.0038	0.0040	0.0047	0.0051	0.0060	0.0064	0.0070
Ba	0.0028	0.0055	0.0076	0.0049	0.0026	0.0022	0.0009	0.0002	0.0000	0.0036	0.0025	0.0010	0.0028
La	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0010	0.0001	0.0001
Ce	0.0000	0.0001	0.0010	0.0003	0.0010	0.0002	0.0002	0.0000	0.0008	0.0000	0.0009	0.0008	0.0004
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9991	1.9999	1.9979	1.9976	1.9988	1.9985	1.9985	1.9970	1.9989	1.9989	1.9984	1.9974	1.9997
Cl	0.0000	0.0002	0.0001	0.0010	0.0006	0.0000	0.0009	0.0010	0.0008	0.0000	0.0012	0.0000	0.0006
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9994	4.0009	3.9979	3.9975	3.9983	3.9986	4.0035	3.9985	4.0003	3.9994	3.9978	3.9976	4.0047

## Dados de Química Mineral de Carbonatos – Fe-Dolomita (cont.)

Amostra	C85D	C85D	C85D	C87G	C83H	C87G	C83H	C83H	C83H	C83H	C85D	C85D rim	C1SH1
Método Unidade	EPMA C5	EPMA C5	EPMA C5	EPMA C5	EPMA C4a	EPMA C5	EPMA C4a	EPMA C4a	EPMA C4a	EPMA C4a	FEG C5	FEG C5	EPMA C4a
textura	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	camadaem- nors	dolomi- ta1	camadaem- nors	camadaem- nors	camadaem- nors	camadaem- nors	intermedi- ario	ok	ok
Com- plexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Catalão
Mineral	FeDolo- mita	FeDolo- mita	FeDolo- mita	FeDolo- mita	FeDolomita	FeDolo- mita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolo- mita	FeDolo- mita
K <sub>2</sub> O													
FeO	6.47	10.06	7.36	7.57	5.73	6.15	7.45	5.33	6.88	5.38	10.60	8.38	9.17
MnO	0.66	0.49	1.48	0.54	0.22	0.60	0.25	0.21	0.33	0.31	0.99		0.47
MgO	16.11	13.33	14.38	16.18	15.71	16.39	14.40	16.13	16.93	16.56	12.04	13.06	14.39
CaO	27.57	27.37	27.45	27.45	30.02	27.57	30.94	31.25	29.13	28.44	26.07	25.98	28.38
Na <sub>2</sub> O	0.20	0.15	0.19	0.00	0.02	0.02	0.02	0.05	0.06	0.03			0.04
SrO	0.39	0.39	0.39	0.41	0.46	0.56	0.65	0.69	0.70	0.83	0.28	0.22	0.18
BaO	0.33	0.19	0.05	0.29	0.89	0.10	0.60	0.57	0.44	0.73			0.07
La <sub>2</sub> O <sub>3</sub>	0.00	0.02	0.01	0.07	0.14	0.00	0.15	0.03	0.07	0.00			0.00
Ce <sub>2</sub> O <sub>3</sub>	0.01	0.03	0.04	0.03	0.03	0.03	0.14	0.17	0.00	0.03	0.00	0.00	0.06
Pr <sub>2</sub> O <sub>3</sub>	0.05	0.00											
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.02											
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.00											
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00											
Cl	0.01	0.00	0.01	0.02	0.00	0.02	0.01	0.01	0.00	0.00			0.02
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Total1	51.89	52.03	51.39	52.61	53.21	51.44	54.59	54.57	54.55	52.34	49.98	47.64	52.77
Tota- IETR	0.12	0.11	0.05	0.10	0.17	0.03	0.28	0.20	0.07	0.03	0.00	0.00	0.06
CO <sub>2</sub>	44.06	42.86	43.01	44.48	44.88	43.97	45.27	46.10	46.26	44.48	40.83	39.88	44.03
H <sub>2</sub> O													
Total2	96.06	94.95	94.41	97.10	98.11	95.41	99.90	100.70	100.82	96.82	90.81	87.52	96.80

## Dados de Química Mineral de Carbonatos – Fe-Dolomita (cont.)

Amostra	C85D	C85D	C85D	C87G	C83H	C87G	C83H	C83H	C83H	C83H	C85D	C85D rim	C1SH1
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	EPMA
Unidade	C5	C5	C5	C5	C4a	C5	C4a	C4a	C4a	C4a	C5	C5	C4a
textura	dolomi- ta1	dolomi- ta1	dolomi- ta1	dolomi- ta1	camadaem- nors	dolomi- ta1	camadaem- nors	camadaem- nors	camadaem- nors	camadaem- nors	intermedi- ario	ok	ok
Com- plexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Catalão
Mineral	FeDolo- mita	FeDolo- mita	FeDolo- mita	FeDolo- mita	FeDolomita	FeDolo- mita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolomita	FeDolo- mita	FeDolo- mita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.1797	0.2869	0.2086	0.2081	0.1564	0.1710	0.2014	0.1413	0.1821	0.1481	0.3180	0.2575	0.2550
Mn	0.0186	0.0142	0.0426	0.0149	0.0060	0.0170	0.0067	0.0056	0.0088	0.0086	0.0301	0.0000	0.0131
Mg	0.7978	0.6775	0.7266	0.7936	0.7644	0.8119	0.6939	0.7626	0.7990	0.8120	0.6439	0.7152	0.7129
Ca	0.9811	0.9995	0.9966	0.9674	1.0498	0.9816	1.0712	1.0620	0.9879	1.0024	1.0021	1.0226	1.0109
Na	0.0126	0.0100	0.0124	0.0000	0.0011	0.0014	0.0009	0.0031	0.0038	0.0016	0.0000	0.0000	0.0023
Sr	0.0074	0.0077	0.0077	0.0079	0.0087	0.0108	0.0122	0.0126	0.0129	0.0157	0.0058	0.0047	0.0034
Ba	0.0043	0.0026	0.0007	0.0037	0.0113	0.0013	0.0075	0.0071	0.0054	0.0095	0.0000	0.0000	0.0009
La	0.0000	0.0003	0.0001	0.0008	0.0016	0.0000	0.0017	0.0004	0.0008	0.0000	0.0000	0.0000	0.0000
Ce	0.0001	0.0003	0.0005	0.0004	0.0004	0.0004	0.0016	0.0020	0.0000	0.0004	0.0000	0.0000	0.0008
Pr	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9979	1.9947	1.9899	1.9976	1.9995	1.9947	1.9973	1.9966	1.9990	1.9979	2.0000	2.0000	1.9984
Cl	0.0005	0.0000	0.0004	0.0011	0.0000	0.0010	0.0005	0.0008	0.0000	0.0000	0.0000	0.0000	0.0009
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0036	4.0031	4.0026	3.9972	3.9995	3.9960	3.9972	3.9974	4.0008	4.0003	4.0000	4.0000	3.9994

## Dados de Química Mineral de Carbonatos – Fe-Dolomita (cont.)

Amostra	C1SH1	C1SH1	C1SH1	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Comple- xo	Catalão	Catalão	Catalão	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta
K <sub>2</sub> O				0.00	0.00	0.00	0.00	0.00	0.00	0.00			
FeO	10.54	8.38	5.52	12.22	16.76	16.41	16.60	15.46	5.99	15.91	14.21	12.50	13.16
MnO	0.34	0.47	0.47	0.61	1.01	1.23	0.81	0.59	4.02	0.93	2.17	0.95	0.90
MgO	13.33	15.44	16.85	8.58	9.66	9.77	9.98	10.56	12.78	10.20	10.59	12.40	10.12
CaO	27.88	28.84	28.96	25.38	29.32	29.76	30.27	29.88	34.44	27.31	26.96	26.73	25.74
Na <sub>2</sub> O	0.03	0.02	0.00	0.35	0.32	0.32	0.33	0.36	0.31	0.01	0.00	0.11	0.07
SrO	0.25	0.31	0.36	0.19	0.16	0.10	0.04	0.12	0.27	0.00	0.00	0.10	0.15
BaO	0.07	0.25	0.08	0.12	0.29	0.10	0.07	0.01	0.22	0.10	0.05	0.00	0.15
La <sub>2</sub> O <sub>3</sub>	0.00	0.03	0.05	0.00	0.01	0.05	0.00	0.04	0.00	0.20	0.14	0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.03	0.00	0.01	0.00	0.00	0.00	0.02	0.15	0.16	0.20	0.12	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>				0.00	0.00	0.02	0.01	0.02	0.01	0.03	0.05	0.04	0.00
Nd <sub>2</sub> O <sub>3</sub>				0.06	0.06	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.01
Dy <sub>2</sub> O <sub>3</sub>				0.18	0.11	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Yb <sub>2</sub> O <sub>3</sub>				0.01	0.05	0.07	0.00	0.01	0.05			0.00	0.00
Cl	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.00	0.00	0.00	0.01	0.00	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	52.46	53.76	52.31	47.44	57.52	57.87	58.23	57.18	58.20	54.85	54.25	52.80	50.30
TotalETR	0.03	0.03	0.06	0.32	0.36	0.27	0.40	0.47	0.51	0.51	0.36	0.11	0.02
CO <sub>2</sub>	43.25	45.14	45.00	37.59	44.92	45.22	45.69	45.25	47.67	43.06	42.89	42.91	40.04
H <sub>2</sub> O													
Total2	95.72	98.90	97.31	85.35	102.79	103.31	104.27	102.71	106.22	98.01	97.24	95.82	90.36

## Dados de Química Mineral de Carbonatos – Fe-Dolomita (cont.)

Amostra	C1SH1	C1SH1	C1SH1	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5
textura	Ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Comple- xo	Catalão	Catalão	Catalão	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre
Mineral	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta	FeDolomi- ta

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.2953	0.2272	0.1502	0.3978	0.4569	0.4441	0.4445	0.4181	0.1536	0.4521	0.4056	0.3538	0.3938
Mn	0.0096	0.0129	0.0129	0.0201	0.0278	0.0338	0.0219	0.0162	0.1044	0.0266	0.0628	0.0273	0.0272
Mg	0.6657	0.7461	0.8173	0.4980	0.4694	0.4715	0.4763	0.5091	0.5844	0.5165	0.5392	0.6256	0.5398
Ca	1.0009	1.0016	1.0097	1.0583	1.0237	1.0321	1.0390	1.0354	1.1322	0.9939	0.9863	0.9695	0.9869
Na	0.0021	0.0011	0.0000	0.0263	0.0200	0.0198	0.0203	0.0225	0.0181	0.0004	0.0000	0.0072	0.0051
Sr	0.0048	0.0059	0.0067	0.0042	0.0029	0.0018	0.0007	0.0023	0.0049	0.0000	0.0000	0.0019	0.0032
Ba	0.0010	0.0032	0.0011	0.0018	0.0037	0.0012	0.0009	0.0001	0.0026	0.0013	0.0007	0.0000	0.0020
La	0.0000	0.0004	0.0006	0.0000	0.0001	0.0006	0.0000	0.0005	0.0000	0.0024	0.0017	0.0000	0.0000
Ce	0.0004	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0018	0.0018	0.0025	0.0014	0.0000	0.0000
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0002	0.0001	0.0004	0.0007	0.0004	0.0000
Nd	0.0000	0.0000	0.0000	0.0008	0.0007	0.0000	0.0000	0.0000	0.0000	0.0009	0.0006	0.0000	0.0002
Dy	0.0000	0.0000	0.0000	0.0023	0.0011	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0001	0.0005	0.0007	0.0000	0.0001	0.0005	0.0000	0.0000	0.0000	0.0000
C	1.9787	1.9980	1.9989	1.9977	1.9987	1.9987	1.9982	1.9981	1.9970	1.9970	1.9992	1.9833	1.9558
Cl	0.0001	0.0002	0.0000	0.0000	0.0000	0.0011	0.0055	0.0000	0.0002	0.0002	0.0005	0.0000	0.0003
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9996	3.9996	3.9988	4.0109	4.0081	4.0076	4.0066	4.0086	4.0056	3.9965	3.9983	3.9952	3.9930

## Dados de Química Mineral de Carbonatos – Fe-Dolomita / Norsethita

Amostra	SL109C	SL109C	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Ok	ok	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja
Complexo Mineral	Salitre FeDolomita	Salitre FeDolomita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita
K <sub>2</sub> O													
FeO	13.28	14.57	0.32	0.48	0.27	0.33	0.24	0.29	0.30	0.29	0.43	0.34	0.36
MnO	2.04	1.03	0.18	0.18	0.20	0.23	0.19	0.10	0.23	0.10	0.15	0.21	0.15
MgO	11.14	11.44	12.94	13.63	14.02	14.80	14.01	15.74	15.66	16.13	14.84	15.69	15.96
CaO	26.97	27.17	4.21	2.88	1.31	3.53	4.27	2.14	1.95	1.41	1.63	1.85	1.36
Na <sub>2</sub> O	0.08	0.01	3.25	0.50	0.63	0.38	0.60	0.35	0.52	0.37	0.47	0.60	0.40
SrO	0.10	0.10	7.17	6.11	2.12	3.06	2.67	1.99	2.71	2.56	1.06	2.55	1.91
BaO	0.09	0.08	46.10	49.83	52.05	54.09	55.38	56.17	56.19	56.34	56.42	56.42	56.95
La <sub>2</sub> O <sub>3</sub>	0.08	0.03	0.69	0.06	0.03	0.09	0.08	0.00	0.04	0.05	0.00	0.02	0.02
Ce <sub>2</sub> O <sub>3</sub>	0.13	0.00	1.85	1.12	1.54	1.50	1.50	1.68	1.71	1.59	0.88	1.45	2.00
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.09	0.05	0.04	0.06	0.03	0.04	0.07	0.10	0.07	0.07	0.06
Nd <sub>2</sub> O <sub>3</sub>	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.19	0.00	0.00	0.02	0.00	0.00
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.04	0.02	0.00	0.02	0.03	0.00	0.00	0.00	0.01	0.04	0.02
Cl	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00
F	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	53.89	54.42	76.72	74.80	72.19	78.00	78.94	78.46	79.31	78.84	75.89	79.13	79.11
TotalETR	0.23	0.08	3.24	1.81	2.14	2.10	2.12	2.42	2.45	2.03	1.30	2.10	2.65
CO <sub>2</sub>	42.91	43.46	37.19	35.28	33.48	36.92	36.94	36.96	37.26	37.02	35.16	37.19	36.95
H <sub>2</sub> O													
Total2	96.82	97.93	114.60	110.72	106.23	115.43	116.42	116.16	117.27	116.25	111.47	116.95	116.69

## Dados de Química Mineral de Carbonatos – Fe-Dolomita / Norsethita (cont.)

Amostra	SL109C	SL109C	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Ok	ok	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja
Complexo Mineral	Salitre FeDolomita	Salitre FeDolomita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita	Araxá Norsethita
Proporção atômica para 6 O													
Fe <sup>2+</sup>	0.3760	0.4104	0.0103	0.0168	0.0098	0.0107	0.0079	0.0095	0.0097	0.0095	0.0149	0.0113	0.0120
Mn	0.0585	0.0293	0.0060	0.0062	0.0075	0.0076	0.0065	0.0034	0.0077	0.0034	0.0053	0.0069	0.0050
Mg	0.5627	0.5744	0.7569	0.8410	0.9116	0.8723	0.8261	0.9270	0.9155	0.9489	0.9196	0.9191	0.9402
Ca	0.9786	0.9808	0.1771	0.1277	0.0612	0.1497	0.1811	0.0904	0.0820	0.0596	0.0724	0.0780	0.0575
Na	0.0050	0.0003	0.2474	0.0401	0.0531	0.0292	0.0460	0.0270	0.0394	0.0282	0.0381	0.0459	0.0310
Sr	0.0019	0.0020	0.1632	0.1467	0.0535	0.0701	0.0611	0.0455	0.0616	0.0585	0.0254	0.0580	0.0438
Ba	0.0012	0.0010	0.7088	0.8081	0.8896	0.8383	0.8583	0.8695	0.8633	0.8713	0.9188	0.8688	0.8819
La	0.0010	0.0004	0.0100	0.0009	0.0005	0.0013	0.0012	0.0000	0.0006	0.0007	0.0000	0.0002	0.0003
Ce	0.0016	0.0000	0.0265	0.0169	0.0246	0.0217	0.0216	0.0244	0.0245	0.0230	0.0134	0.0208	0.0290
Pr	0.0000	0.0000	0.0013	0.0008	0.0007	0.0009	0.0005	0.0005	0.0010	0.0014	0.0010	0.0010	0.0009
Nd	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0002	0.0005	0.0000	0.0000	0.0000	0.0024	0.0000	0.0000	0.0003	0.0000	0.0000
Yb	0.0000	0.0000	0.0005	0.0002	0.0000	0.0003	0.0004	0.0000	0.0000	0.0000	0.0002	0.0004	0.0002
C	1.9841	1.9991	1.9925	1.9938	1.9937	1.9937	1.9946	1.9936	1.9945	1.9946	1.9952	1.9951	1.9940
Cl	0.0000	0.0000	0.0003	0.0004	0.0013	0.0000	0.0000	0.0001	0.0000	0.0009	0.0014	0.0000	0.0000
F	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0014	3.9994	4.1079	4.0108	4.0148	4.0042	4.0125	4.0014	4.0080	4.0040	4.0119	4.0129	4.0028

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita
K <sub>2</sub> O													
FeO	0.26	0.25	0.43	0.24	0.31	0.33	0.37	0.30	0.27	0.23	0.23	0.36	0.25
MnO	0.18	0.10	0.29	0.13	0.17	0.09	0.13	0.14	0.12	0.12	0.15	0.13	0.10
MgO	16.87	16.76	15.33	15.99	16.89	16.81	16.98	15.58	10.71	15.72	14.36	15.00	13.33
CaO	1.06	0.46	0.96	1.31	0.36	0.64	0.89	0.75	3.15	0.78	2.11	2.12	4.22
Na <sub>2</sub> O	0.64	0.54	0.46	0.52	0.56	0.57	0.63	0.44	0.56	0.14	0.13	0.07	0.12
SrO	0.81	1.94	1.04	2.03	1.74	1.85	0.76	0.61	7.70	3.48	3.45	3.33	3.24
BaO	57.14	57.20	57.26	57.64	57.72	57.78	57.82	57.99	46.69	53.59	51.14	51.34	50.92
La <sub>2</sub> O <sub>3</sub>	0.01	0.02	0.00	0.03	0.00	0.00	0.07	0.00	0.19	0.00	0.09	0.05	0.07
Ce <sub>2</sub> O <sub>3</sub>	1.85	1.76	1.66	1.70	1.74	1.58	1.72	1.67	0.25	0.17	0.08	0.25	0.14
Pr <sub>2</sub> O <sub>3</sub>	0.06	0.08	0.02	0.02	0.06	0.04	0.02	0.07					
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
Dy <sub>2</sub> O <sub>3</sub>	0.03	0.08	0.00	0.00	0.00	0.00	0.02	0.08					
Yb <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.01	0.00	0.00	0.02	0.01	0.03					
Cl	0.02	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.01	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	78.84	79.04	77.42	79.59	79.48	79.67	79.41	77.47	69.65	74.22	71.74	72.72	72.40
TotalETR	2.57	2.37	2.17	2.06	2.24	2.25	2.40	2.30	0.44	0.17	0.17	0.29	0.22
CO <sub>2</sub>	37.41	37.14	35.71	37.04	37.31	37.49	37.56	35.70	31.62	35.00	33.85	34.64	34.23
H <sub>2</sub> O													
Total2	116.95	116.76	113.64	116.96	117.28	117.82	117.58	113.80	101.33	109.25	105.62	107.40	106.66



## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0085	0.0082	0.0146	0.0077	0.0100	0.0106	0.0121	0.0100	0.0106	0.0080	0.0081	0.0127	0.0090
Mn	0.0061	0.0034	0.0098	0.0042	0.0055	0.0029	0.0043	0.0047	0.0047	0.0044	0.0055	0.0048	0.0036
Mg	0.9818	0.9824	0.9270	0.9397	0.9859	0.9767	0.9844	0.9303	0.7389	0.9805	0.9259	0.9439	0.8502
Ca	0.0445	0.0194	0.0416	0.0552	0.0151	0.0269	0.0372	0.0321	0.1564	0.0348	0.0976	0.0956	0.1933
Na	0.0484	0.0409	0.0359	0.0399	0.0421	0.0432	0.0471	0.0342	0.0506	0.0117	0.0106	0.0055	0.0101
Sr	0.0183	0.0443	0.0244	0.0465	0.0395	0.0419	0.0172	0.0141	0.2066	0.0843	0.0866	0.0815	0.0804
Ba	0.8741	0.8812	0.9101	0.8904	0.8858	0.8824	0.8808	0.9101	0.8467	0.8787	0.8666	0.8491	0.8535
La	0.0002	0.0003	0.0000	0.0004	0.0000	0.0000	0.0010	0.0000	0.0032	0.0000	0.0014	0.0007	0.0012
Ce	0.0264	0.0254	0.0246	0.0246	0.0250	0.0226	0.0244	0.0244	0.0043	0.0025	0.0013	0.0038	0.0023
Pr	0.0008	0.0011	0.0003	0.0003	0.0009	0.0005	0.0003	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000	0.0003	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0001	0.0000	0.0001	0.0000	0.0000	0.0002	0.0001	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9939	1.9934	1.9776	1.9935	1.9949	1.9949	1.9937	1.9522	1.9977	1.9997	1.9988	1.9963	1.9990
Cl	0.0013	0.0000	0.0001	0.0002	0.0003	0.0005	0.0030	0.0001	0.0006	0.0003	0.0000	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0116	4.0089	4.0063	4.0097	4.0103	4.0108	4.0109	4.0054	4.0210	4.0048	4.0037	3.9980	4.0037

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	ok	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita
K <sub>2</sub> O													
FeO	0.32	0.35	0.21	0.27	0.29	0.33	0.40	0.34	0.24	0.39	0.30	0.24	0.43
MnO	0.12	0.13	0.19	0.15	0.13	0.19	0.08	0.12	0.13	0.15	0.15	0.10	0.16
MgO	14.23	15.11	14.63	15.53	15.32	15.75	15.44	14.06	15.99	15.49	15.71	14.98	15.54
CaO	2.68	1.17	1.67	0.31	1.11	0.32	0.75	5.24	0.34	0.61	0.17	0.26	0.60
Na <sub>2</sub> O	0.15	0.17	0.23	0.27	0.14	0.13	0.15	0.05	0.12	0.11	0.03	0.22	0.21
SrO	3.23	2.43	2.42	2.33	2.30	2.13	2.06	2.03	1.92	1.90	1.88	1.75	1.74
BaO	51.86	53.06	51.97	53.10	53.95	53.54	52.87	50.12	53.35	54.28	52.49	53.41	54.47
La <sub>2</sub> O <sub>3</sub>	0.00	0.04	0.09	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.14	0.21	0.12	0.03	0.01	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.07
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.01	0.02	0.02	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	72.74	72.70	71.65	72.00	73.35	72.41	71.79	71.95	72.17	73.05	70.79	70.97	73.31
TotalETR	0.14	0.25	0.20	0.03	0.01	0.00	0.00	0.00	0.05	0.11	0.03	0.00	0.07
CO <sub>2</sub>	34.32	34.18	33.72	33.89	34.43	34.15	33.90	35.02	34.19	34.22	33.46	33.00	34.35
H <sub>2</sub> O													
Total2	107.07	106.90	105.39	105.89	107.78	106.55	105.69	106.97	106.36	107.28	104.26	103.98	107.67

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	ok	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0114	0.0125	0.0077	0.0098	0.0104	0.0120	0.0144	0.0117	0.0087	0.0141	0.0109	0.0088	0.0152
Mn	0.0043	0.0046	0.0069	0.0055	0.0045	0.0070	0.0030	0.0043	0.0048	0.0056	0.0054	0.0038	0.0056
Mg	0.9046	0.9649	0.9457	0.9985	0.9710	1.0070	0.9936	0.8741	1.0203	0.9879	1.0250	0.9906	0.9862
Ca	0.1225	0.0538	0.0773	0.0142	0.0505	0.0147	0.0348	0.2340	0.0158	0.0279	0.0081	0.0123	0.0275
Na	0.0122	0.0144	0.0197	0.0224	0.0116	0.0110	0.0125	0.0037	0.0103	0.0089	0.0029	0.0192	0.0173
Sr	0.0798	0.0603	0.0608	0.0583	0.0566	0.0530	0.0515	0.0491	0.0476	0.0471	0.0476	0.0449	0.0429
Ba	0.8663	0.8905	0.8828	0.8976	0.8991	0.8996	0.8944	0.8191	0.8950	0.9102	0.9002	0.9282	0.9087
La	0.0000	0.0006	0.0014	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0004	0.0000	0.0000
Ce	0.0022	0.0033	0.0019	0.0005	0.0001	0.0000	0.0000	0.0000	0.0004	0.0017	0.0000	0.0000	0.0011
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9977	1.9983	1.9960	1.9959	1.9991	1.9988	1.9985	1.9942	1.9986	1.9992	1.9997	1.9983	1.9970
Cl	0.0005	0.0012	0.0016	0.0009	0.0017	0.0001	0.0000	0.0006	0.0007	0.0007	0.0000	0.0008	0.0009
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0051	4.0053	4.0053	4.0069	4.0046	4.0049	4.0052	3.9971	4.0045	4.0031	4.0010	4.0080	4.0057

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oklimpa	oksuja	oksuja	oksuja	oksuja	oksuja	ok	oksuja	oksuja	oklimpa	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita
K <sub>2</sub> O													
FeO	0.37	0.18	0.35	0.25	0.36	0.41	0.30	0.32	0.34	0.29	0.53	0.30	0.31
MnO	0.17	0.18	0.11	0.14	0.12	0.13	0.09	0.13	0.10	0.12	0.18	0.19	0.13
MgO	15.71	15.99	15.69	14.88	15.75	15.26	15.64	15.51	15.57	15.54	15.40	15.87	15.85
CaO	0.10	0.08	0.17	0.83	0.10	0.25	0.48	0.28	0.26	0.32	0.34	0.01	1.36
Na <sub>2</sub> O	0.17	0.11	0.14	0.20	0.13	0.19	0.19	0.21	0.20	0.20	0.25	0.14	0.22
SrO	1.58	1.54	1.46	1.42	1.25	1.21	0.90	0.88	0.77	0.62	0.60	0.58	0.46
BaO	54.65	54.31	54.73	54.60	54.76	53.55	54.65	55.14	54.75	55.13	56.15	55.75	53.88
La <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.07	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.01	0.02	0.02
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	72.76	72.44	72.67	72.40	72.66	71.02	72.27	72.49	71.99	72.22	73.52	72.86	72.24
TotalETR	0.00	0.00	0.02	0.07	0.11	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.01
CO <sub>2</sub>	34.05	34.07	33.98	33.58	33.96	33.21	33.90	33.77	33.65	33.70	34.08	33.98	34.47
H <sub>2</sub> O													
Total2	106.81	106.51	106.65	105.98	106.64	104.23	106.17	106.26	105.64	105.92	107.61	106.83	106.71

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oklimpa	oksuja	oksuja	oksuja	oksuja	oksuja	ok	oksuja	oksuja	oklimpa	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0133	0.0066	0.0126	0.0092	0.0129	0.0152	0.0110	0.0116	0.0122	0.0107	0.0189	0.0109	0.0111
Mn	0.0063	0.0065	0.0041	0.0053	0.0045	0.0048	0.0034	0.0047	0.0036	0.0046	0.0065	0.0068	0.0045
Mg	1.0076	1.0231	1.0079	0.9642	1.0120	1.0022	1.0066	1.0013	1.0097	1.0052	0.9838	1.0186	1.0027
Ca	0.0047	0.0038	0.0079	0.0385	0.0046	0.0116	0.0222	0.0129	0.0120	0.0147	0.0154	0.0003	0.0620
Na	0.0140	0.0089	0.0118	0.0170	0.0112	0.0158	0.0158	0.0177	0.0171	0.0164	0.0208	0.0119	0.0184
Sr	0.0393	0.0384	0.0363	0.0359	0.0311	0.0308	0.0224	0.0221	0.0195	0.0157	0.0149	0.0146	0.0112
Ba	0.9212	0.9136	0.9239	0.9300	0.9246	0.9243	0.9242	0.9358	0.9335	0.9376	0.9431	0.9408	0.8958
La	0.0000	0.0000	0.0000	0.0012	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ce	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0001
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9995	1.9969	1.9989	1.9929	1.9982	1.9973	1.9978	1.9972	1.9992	1.9968	1.9943	1.9981	1.9966
Cl	0.0002	0.0014	0.0002	0.0003	0.0000	0.0000	0.0015	0.0025	0.0002	0.0002	0.0006	0.0015	0.0012
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0065	4.0012	4.0057	4.0079	4.0038	4.0067	4.0067	4.0056	4.0085	4.0060	4.0060	4.0047	4.0075

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oklimpa	oklimpa	oksuja	ok
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita
K <sub>2</sub> O													
FeO	0.20	0.27	0.25	0.23	0.31	0.30	0.24	0.37	0.36	0.32	0.32	0.27	0.40
MnO	0.11	0.14	0.14	0.11	0.15	0.09	0.15	0.13	0.11	0.11	0.08	0.13	0.10
MgO	15.96	15.95	15.61	15.84	15.42	16.01	15.69	15.53	15.11	15.94	15.56	15.51	15.71
CaO	0.43	0.19	0.25	0.07	0.30	0.19	0.18	0.29	0.28	0.08	0.13	0.26	0.14
Na <sub>2</sub> O	0.17	0.16	0.16	0.19	0.14	0.14	0.12	0.17	0.17	0.15	0.15	0.16	0.20
SrO	0.46	0.45	0.43	0.42	0.40	0.39	0.39	0.37	0.36	0.36	0.35	0.35	0.34
BaO	55.12	55.79	55.50	54.93	54.99	55.15	56.03	55.34	54.72	54.60	56.37	56.63	55.97
La <sub>2</sub> O <sub>3</sub>	0.02	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.04	0.00	0.00	0.00	0.00	0.05	0.07	0.02	0.00	0.14	0.00	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.02	0.00	0.02	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	72.55	72.94	72.39	71.83	71.75	72.32	72.93	72.21	71.12	71.75	72.95	73.31	72.86
TotalETR	0.06	0.00	0.00	0.04	0.00	0.05	0.07	0.02	0.00	0.14	0.00	0.00	0.00
CO <sub>2</sub>	34.12	34.13	33.71	33.65	33.41	33.98	33.87	33.65	32.99	33.72	33.77	33.89	33.92
H <sub>2</sub> O													
Total2	106.68	107.07	106.10	105.49	105.16	106.31	106.81	105.86	104.11	105.48	106.72	107.20	106.78

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oklimpa	oklimpa	oksuja	ok
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0071	0.0095	0.0090	0.0083	0.0114	0.0107	0.0088	0.0134	0.0133	0.0116	0.0116	0.0096	0.0146
Mn	0.0040	0.0050	0.0052	0.0041	0.0057	0.0034	0.0056	0.0049	0.0041	0.0041	0.0028	0.0048	0.0038
Mg	1.0211	1.0193	1.0107	1.0268	1.0074	1.0287	1.0108	1.0070	0.9975	1.0314	1.0052	0.9987	1.0108
Ca	0.0199	0.0087	0.0118	0.0034	0.0141	0.0090	0.0082	0.0134	0.0134	0.0039	0.0059	0.0119	0.0066
Na	0.0140	0.0133	0.0135	0.0161	0.0122	0.0115	0.0098	0.0146	0.0149	0.0127	0.0127	0.0130	0.0167
Sr	0.0113	0.0112	0.0108	0.0106	0.0101	0.0097	0.0097	0.0093	0.0092	0.0090	0.0087	0.0087	0.0084
Ba	0.9268	0.9372	0.9447	0.9359	0.9444	0.9315	0.9490	0.9434	0.9495	0.9284	0.9568	0.9583	0.9467
La	0.0003	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ce	0.0007	0.0000	0.0000	0.0000	0.0000	0.0009	0.0011	0.0003	0.0000	0.0023	0.0000	0.0000	0.0000
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9989	1.9977	1.9996	1.9980	1.9995	1.9998	1.9988	1.9990	1.9946	1.9977	1.9974	1.9985	1.9993
Cl	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0000	0.0002	0.0012	0.0000	0.0014	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0057	4.0045	4.0064	4.0078	4.0053	4.0054	4.0037	4.0072	4.0028	4.0035	4.0049	4.0055	4.0083

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	ok	oksuja	oksuja	oksuja	ok	oksuja	oksuja	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita
K <sub>2</sub> O													
FeO	0.37	0.35	0.26	0.34	0.30	0.24	0.39	0.86	0.87	0.48	0.24	0.28	0.27
MnO	0.19	0.15	0.12	0.13	0.13	0.18	0.14	0.15	0.08	0.13	0.00	0.19	0.10
MgO	15.31	15.45	15.61	15.40	15.53	15.95	15.28	15.76	15.36	15.60	15.92	15.70	15.46
CaO	0.30	0.31	0.29	0.25	0.14	0.14	0.22	2.43	0.17	0.20	0.13	0.06	0.16
Na <sub>2</sub> O	0.09	0.15	0.18	0.14	0.11	0.16	0.12	0.18	0.26	0.20	0.20	0.16	0.11
SrO	0.32	0.30	0.29	0.28	0.27	0.26	0.26	0.23	0.23	0.20	0.18	0.14	0.13
BaO	55.58	56.14	55.87	55.48	54.99	55.14	55.14	52.28	55.72	54.91	54.76	55.65	55.96
La <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.02	0.01	0.07	0.00	0.00	0.00	0.09	0.22	0.25	0.09	0.00	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	72.26	72.94	72.69	72.02	71.49	72.12	71.68	72.18	72.93	71.80	71.43	72.17	72.33
TotalETR	0.02	0.01	0.07	0.00	0.00	0.00	0.09	0.28	0.25	0.09	0.00	0.00	0.00
CO <sub>2</sub>	33.46	33.79	33.82	33.45	33.30	33.84	33.23	35.06	33.84	33.57	33.56	33.62	33.46
H <sub>2</sub> O													
Total2	105.72	106.73	106.52	105.47	104.78	105.96	104.91	107.27	106.80	105.38	104.99	105.79	105.78



## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	ok	oksuja	oksuja	oksuja	ok	oksuja	oksuja	oksuja
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0135	0.0128	0.0095	0.0124	0.0110	0.0087	0.0145	0.0301	0.0315	0.0174	0.0087	0.0102	0.0100
Mn	0.0069	0.0054	0.0043	0.0049	0.0049	0.0067	0.0051	0.0054	0.0029	0.0046	0.0000	0.0071	0.0037
Mg	0.9980	0.9978	1.0071	1.0050	1.0169	1.0287	1.0025	0.9810	0.9910	1.0140	1.0343	1.0184	1.0084
Ca	0.0138	0.0143	0.0133	0.0116	0.0064	0.0063	0.0104	0.1088	0.0079	0.0093	0.0060	0.0028	0.0075
Na	0.0073	0.0128	0.0153	0.0121	0.0095	0.0134	0.0103	0.0146	0.0215	0.0172	0.0165	0.0132	0.0092
Sr	0.0080	0.0076	0.0074	0.0071	0.0068	0.0065	0.0066	0.0055	0.0056	0.0050	0.0046	0.0035	0.0033
Ba	0.9521	0.9529	0.9474	0.9515	0.9467	0.9349	0.9511	0.8553	0.9447	0.9382	0.9352	0.9487	0.9594
La	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000
Ce	0.0003	0.0001	0.0011	0.0000	0.0000	0.0000	0.0015	0.0033	0.0040	0.0014	0.0000	0.0000	0.0000
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9974	1.9982	1.9979	1.9986	1.9977	1.9992	1.9973	1.9983	1.9989	1.9988	1.9971	1.9973	1.9983
Cl	0.0000	0.0000	0.0000	0.0000	0.0020	0.0000	0.0025	0.0004	0.0000	0.0000	0.0002	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0007	4.0054	4.0059	4.0060	4.0039	4.0063	4.0032	4.0050	4.0092	4.0071	4.0067	4.0055	4.0035

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	AC32830	AC32830
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	N2	N2
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	exsinnor	oksuja	ok	exsolution	exsolution
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	CatalãoI	CatalãoI
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita
K <sub>2</sub> O													
FeO	0.26	0.52	0.29	1.34	0.34	0.30	0.50	0.33	0.34	0.32		0.06	0.00
MnO	0.11	0.20	0.10	0.14	0.16	0.06	0.03					0.16	0.16
MgO	15.81	15.52	15.19	15.11	15.43	15.94	15.80	12.54	13.40	12.97	13.07	15.83	15.22
CaO	0.07	3.62	0.07	0.02	0.22	0.20	0.09	1.13	0.40	0.25		0.12	0.52
Na <sub>2</sub> O	0.14	0.17	0.19	0.19	0.13	0.16	0.15	0.08	0.07	0.03	0.09	0.16	0.09
SrO	0.13	0.12	0.05	0.02	0.01	0.01	0.00	2.09	0.27	0.45		0.31	0.27
BaO	55.60	49.10	54.68	55.63	55.80	55.91	55.86	47.27	51.01	49.81	50.07	56.37	55.27
ThO <sub>2</sub>	0.04	0.17	0.01	0.00	0.00	0.00	0.00					0.07	0.00
La <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00					0.00	0.00
Ce <sub>2</sub> O <sub>3</sub>	0.21	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.21	0.25
Pr <sub>2</sub> O <sub>3</sub>													
Nd <sub>2</sub> O <sub>3</sub>													
Dy <sub>2</sub> O <sub>3</sub>													
Yb <sub>2</sub> O <sub>3</sub>													
Cl	0.00	0.01	0.01	0.00	0.02	0.00	0.00					0.00	0.00
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00					0.00	0.00
Total1	72.38	69.43	70.58	72.45	72.10	72.62	72.42	63.44	65.49	63.83	63.23	73.32	71.78
TotalETR	0.21	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.21	0.25
CO <sub>2</sub>	33.73	34.52	32.73	33.53	33.43	33.96	33.78	29.29	29.96	29.06	28.71	34.03	33.25
H <sub>2</sub> O													
Total2	106.14	103.94	103.31	105.98	105.53	106.58	106.21	92.73	95.45	92.89	91.94	107.38	105.06

## Dados de Química Mineral de Carbonatos – Norsethita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	AC32830	AC32830
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	N2	N2
textura	Oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	oksuja	exsinnor	oksuja	ok	exsolution	exsolution
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	CatalãoI	CatalãoI
Mineral	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita	Norsethita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0095	0.0184	0.0110	0.0489	0.0125	0.0107	0.0180	0.0138	0.0139	0.0135	0.0000	0.0023	0.0000
Mn	0.0040	0.0072	0.0039	0.0050	0.0059	0.0023	0.0012	0.0000	0.0000	0.0000	0.0000	0.0060	0.0059
Mg	1.0231	0.9696	1.0127	0.9834	1.0072	1.0245	1.0192	0.9349	0.9768	0.9746	0.9943	1.0152	0.9977
Ca	0.0033	0.1624	0.0031	0.0011	0.0101	0.0092	0.0039	0.0605	0.0210	0.0135	0.0000	0.0057	0.0246
Na	0.0116	0.0135	0.0165	0.0163	0.0110	0.0134	0.0123	0.0078	0.0066	0.0029	0.0089	0.0136	0.0080
Sr	0.0033	0.0030	0.0012	0.0006	0.0002	0.0002	0.0000	0.0606	0.0077	0.0132	0.0000	0.0078	0.0068
Ba	0.9457	0.8064	0.9580	0.9517	0.9577	0.9443	0.9468	0.9263	0.9773	0.9838	1.0012	0.9502	0.9524
La	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ce	0.0033	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0033	0.0041
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9992	1.9755	1.9983	1.9989	1.9993	1.9986	1.9954	2.0000	2.0000	2.0000	2.0000	1.9986	1.9961
Cl	0.0000	0.0010	0.0007	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0042	3.9824	4.0076	4.0079	4.0050	4.0057	4.0056	4.0039	4.0033	4.0014	4.0044	4.0049	3.9995

## Dados de Química Mineral de Carbonatos – Olekminskita

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	exsolution	interst_dol	interst_dol	exsinnor	exsinnor	exsindol	exsinnor	exsinnor	exsinnor	exsinnor	inters- tnor_dol	camadaem- nors	oklimpa
Com- plexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekminskita	Olekmins- kita	Olekmins- kita
K <sub>2</sub> O													
FeO	0.00	0.08	0.07	0.13	0.03	0.20	0.08	0.04	0.29	0.12	0.00	0.06	0.11
MnO	0.03	0.02	0.03	0.00	0.00	0.10	0.05	0.02	0.03	0.04	0.00	0.00	0.00
MgO	1.83	0.02	0.04	0.39	0.04	0.00	0.18	0.04	0.11	0.02	0.04	0.05	0.07
CaO	4.48	14.27	5.06	4.02	4.37	4.63	3.17	3.49	4.16	4.13	3.90	4.30	3.65
Na <sub>2</sub> O	0.32	0.02	0.11	0.10	0.05	0.08	0.07	0.05	0.09	0.13	0.12	0.08	0.06
SrO	52.70	44.96	50.76	44.85	54.88	54.82	41.29	42.31	53.68	52.62	51.05	57.84	58.11
BaO	10.33	11.13	6.84	4.89	4.60	5.32	3.02	3.27	3.35	3.24	2.50	4.14	4.18
La <sub>2</sub> O <sub>3</sub>	0.05	0.00	0.55	0.19	0.24	0.39	0.17	0.25	0.17	0.31	0.11	0.14	0.34
Ce <sub>2</sub> O <sub>3</sub>	0.38	0.00	0.30	0.02	0.24	0.31	0.22	0.17	0.18	0.21	0.33	0.44	0.44
Pr <sub>2</sub> O <sub>3</sub>	0.00												
Nd <sub>2</sub> O <sub>3</sub>	0.00												
Dy <sub>2</sub> O <sub>3</sub>	0.02												
Yb <sub>2</sub> O <sub>3</sub>	0.03												
Cl	0.03	0.01	0.18	0.11	0.19	0.05	0.28	0.15	0.13	0.36	0.12	0.03	0.17
F	0.00	0.00	0.00	0.01	0.00	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.01
Total1	70.14	70.57	63.95	54.83	64.64	66.09	48.74	49.82	62.19	61.17	58.27	67.08	67.15
Tota- IETR	0.92	0.00	0.85	0.22	0.48	0.70	0.39	0.41	0.35	0.52	0.44	0.58	0.78
CO <sub>2</sub>	31.35	33.60	27.94	24.27	28.30	28.93	21.37	21.89	27.50	26.89	25.74	29.46	29.17
H <sub>2</sub> O													
Total2	101.99	104.16	91.96	79.10	92.97	95.09	70.08	71.72	89.71	88.06	84.05	96.61	96.39

## Dados de Química Mineral de Carbonatos – Olekminskita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H	C83H
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a	C4a
textura	exsolution	interst_dol	interst_dol	exsinnor	exsinnor	exsindol	exsinnor	exsinnor	exsinnor	exsinnor	inters- tnor_dol	camadaem- nors	oklimpa
Com- plexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekminskita	Olekmins- kita	Olekmins- kita
Proporção atômica para 6 O													
Fe <sup>2+</sup>	0.0000	0.0028	0.0030	0.0065	0.0014	0.0085	0.0046	0.0024	0.0130	0.0053	0.0000	0.0024	0.0047
Mn	0.0012	0.0008	0.0015	0.0000	0.0000	0.0041	0.0031	0.0013	0.0015	0.0017	0.0001	0.0000	0.0000
Mg	0.1274	0.0014	0.0031	0.0347	0.0032	0.0003	0.0182	0.0035	0.0083	0.0019	0.0037	0.0040	0.0052
Ca	0.2239	0.6665	0.2833	0.2575	0.2370	0.2484	0.2304	0.2485	0.2358	0.2396	0.2354	0.2286	0.1950
Na	0.0293	0.0017	0.0111	0.0110	0.0044	0.0080	0.0086	0.0064	0.0088	0.0134	0.0130	0.0074	0.0060
Sr	1.4258	1.1365	1.5385	1.5564	1.6128	1.5904	1.6244	1.6312	1.6486	1.6516	1.6674	1.6625	1.6814
Ba	0.1888	0.1901	0.1400	0.1147	0.0914	0.1042	0.0802	0.0852	0.0695	0.0687	0.0552	0.0804	0.0817
La	0.0008	0.0000	0.0107	0.0043	0.0046	0.0072	0.0043	0.0060	0.0034	0.0061	0.0023	0.0026	0.0063
Ce	0.0065	0.0000	0.0057	0.0005	0.0044	0.0057	0.0054	0.0041	0.0035	0.0042	0.0067	0.0081	0.0081
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9974	1.9997	1.9936	1.9827	1.9583	1.9763	1.9791	1.9868	1.9889	1.9873	1.9800	1.9937	1.9875
Cl	0.0022	0.0010	0.0163	0.0107	0.0162	0.0042	0.0322	0.0168	0.0120	0.0329	0.0117	0.0021	0.0147
F	0.0000	0.0000	0.0000	0.0009	0.0000	0.0057	0.0075	0.0093	0.0000	0.0000	0.0000	0.0000	0.0016
ΣCation	4.0087	4.0001	3.9922	3.9868	3.9557	3.9777	3.9754	3.9834	3.9910	3.9858	3.9861	3.9946	3.9845

## Dados de Química Mineral de Carbonatos – Olekminskita (cont.)

Amostra	C83H	C83H	C83H	C83H	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	Fsalt0287
Método	EPMA	EPMA	EPMA	FEG	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4	C4	C4	C4	C4	C4	C4	C2
textura	exsinnor	exsinnor	inters-	exsinnor	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution
Comple-	Araxá	Araxá	tnor_dol	Araxá	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Salitre
xo	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-	Olekminski-
Mineral	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta	ta
K <sub>2</sub> O												0.00
FeO	0.02	0.11	0.02		0.00	0.06	0.04	0.00	0.07	0.04	0.05	0.00
MnO	0.04	0.00	0.00		0.00	0.01	0.00	0.02	0.00	0.09	0.08	0.00
MgO	0.02	0.08	0.07	0.53	0.01	0.03	0.00	0.01	0.01	2.87	0.43	0.00
CaO	3.26	3.00	2.99	8.10	2.71	3.70	3.87	4.24	4.41	8.48	8.83	6.51
Na <sub>2</sub> O	0.10	0.09	0.04		0.38	0.27	0.35	0.32	0.28	0.44	0.30	0.38
SrO	51.58	48.41	52.90	47.62	63.55	63.61	64.05	60.10	64.43	52.11	58.80	57.65
BaO	4.83	3.76	2.82	5.62	5.42	1.85	2.22	4.21	1.76	2.56	1.97	5.13
La <sub>2</sub> O <sub>3</sub>	0.28	0.28	0.28		0.14	0.21	0.05	0.18	0.00	0.00	0.01	0.12
Ce <sub>2</sub> O <sub>3</sub>	0.22	0.14	0.25	0.00	0.23	0.10	0.26	0.43	0.09	0.09	0.07	0.28
Pr <sub>2</sub> O <sub>3</sub>					0.08	0.02	0.04	0.06	0.00	0.04	0.03	0.11
Nd <sub>2</sub> O <sub>3</sub>					0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
Dy <sub>2</sub> O <sub>3</sub>					0.03	0.02	0.00	0.06	0.00	0.05	0.00	0.24
Yb <sub>2</sub> O <sub>3</sub>					0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Cl	0.15	0.28	0.41		0.01	0.00	0.01	0.03	0.02	0.01	0.01	0.02
F	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	60.50	56.28	59.77	61.87	72.44	69.84	70.84	69.54	71.08	66.68	70.53	70.12
Tota-												
IETR	0.50	0.42	0.53	0.00	1.01	0.78	0.80	1.50	0.33	0.71	0.51	1.13
CO <sub>2</sub>	26.14	24.36	25.89	28.77	31.22	30.93	31.36	30.71	31.67	33.23	33.36	31.64
H <sub>2</sub> O												
Total2	86.68	80.63	85.64	90.64	104.30	101.24	102.69	101.13	102.99	100.53	104.32	102.48

## Dados de Química Mineral de Carbonatos – Olekminskita (cont.)

Amostra	C83H	C83H	C83H	C83H	C83H	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	C1SH1	Fsalt0287
Método	EPMA	EPMA	EPMA	EPMA	FEG	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C4a	C4a	C4a	C4a	C4a	C4	C4	C4	C4	C4	C4	C4	C2
textura	tnor_dol	exsinnor	exsinnor	tnor_dol	exsinnor	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution
Com- plexo	Araxá	Araxá	Araxá	Araxá	Araxá	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Catalão	Salitre
Mineral	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita	Olekmins- kita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0089	0.0007	0.0056	0.0009	0.0000	0.0000	0.0025	0.0017	0.0000	0.0027	0.0015	0.0019	0.0000
Mn	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0006	0.0000	0.0034	0.0031	0.0000
Mg	0.0106	0.0017	0.0067	0.0055	0.0402	0.0007	0.0023	0.0000	0.0007	0.0006	0.1887	0.0280	0.0000
Ca	0.1727	0.1955	0.1922	0.1797	0.4418	0.1362	0.1877	0.1935	0.2161	0.2186	0.4000	0.4150	0.3226
Na	0.0039	0.0107	0.0107	0.0045	0.0000	0.0343	0.0251	0.0312	0.0299	0.0254	0.0371	0.0253	0.0338
Sr	1.6997	1.6732	1.6805	1.7229	1.4058	1.7269	1.7451	1.7332	1.6590	1.7269	1.3310	1.4964	1.5456
Ba	0.0682	0.1059	0.0882	0.0620	0.1121	0.0994	0.0343	0.0405	0.0785	0.0319	0.0443	0.0338	0.0930
La	0.0042	0.0057	0.0061	0.0057	0.0000	0.0024	0.0036	0.0009	0.0031	0.0000	0.0000	0.0001	0.0020
Ce	0.0033	0.0046	0.0032	0.0051	0.0000	0.0040	0.0017	0.0044	0.0075	0.0015	0.0014	0.0011	0.0048
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0003	0.0007	0.0010	0.0000	0.0006	0.0005	0.0019
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0003	0.0000	0.0008	0.0000	0.0007	0.0000	0.0035
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000
C	1.9736	1.9962	1.9909	1.9856	2.0000	1.9975	1.9981	1.9980	1.9957	1.9989	1.9985	1.9989	1.9972
Cl	0.0615	0.0137	0.0282	0.0394	0.0000	0.0004	0.0000	0.0005	0.0025	0.0019	0.0004	0.0005	0.0013
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9637	3.9966	3.9885	3.9785	4.0000	4.0113	4.0081	4.0110	4.0055	4.0102	4.0147	4.0098	4.0100

## Dados de Química Mineral de Carbonatos – Olekminskita / Parisita

Amostra	SL109C	SL109C	SL109C	AT49	4s22	AT135	AT49	AT46	AT49	C87G	C87G	C87G	C87G
Método Unidade	EPMA C5	EPMA C5	EPMA C5	EPMA C1b	EPMA C3	EPMA C4a	EPMA C1b	EPMA C1b	EPMA C1b	EPMA C5 fi- bro_radia l	EPMA C5 fi- bro_radia l	EPMA C5 fi- bro_radia l	EPMA C5 fi- bro_radia l
textura Comple- xo Mineral	exsolution Salitre Olekmins- kita	exsolution Salitre Olekmins- kita	exsolution Salitre Olekmins- kita	exsolution Tapira Olekmins- kita	exsolution Tapira Olekmins- kita	exsolution Tapira Olekmins- kita	exsolution Tapira Olekmins- kita	exsolution Tapira Olekmins- kita	exsolution Tapira Olekmins- kita	Araxá Parisita	Araxá Parisita	Araxá Parisita	Araxá Parisita
K <sub>2</sub> O	0.00	0.00	0.00	0.11	0.00	0.12	0.03	0.09	0.03				
FeO	0.05	0.78	0.04	0.13	0.00	0.28	0.00	0.05	0.04	0.39	0.20	0.16	1.08
MnO	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.01	0.00
MgO	0.02	0.00	0.02	0.00	0.00	0.92	0.01	0.11	0.02	0.05	0.00	0.00	0.03
CaO	3.29	3.63	5.12	3.02	3.96	7.21	25.02	13.31	15.73	12.02	8.36	6.29	10.47
Na <sub>2</sub> O	0.19	0.26	0.28	0.36	0.27	0.39	0.36	0.59	0.39	0.05	0.00	0.00	0.00
SrO	60.81	53.21	57.02	63.67	61.06	49.22	36.95	47.23	37.22	1.20	1.34	1.79	1.26
BaO	1.05	1.51	1.39	2.91	1.12	4.91	4.61	7.37	5.16	0.00	0.00	0.00	0.00
La <sub>2</sub> O <sub>3</sub>	0.21	0.73	0.02	0.41	0.08	0.34	0.37	0.42	0.21	21.74	25.75	27.28	26.67
Ce <sub>2</sub> O <sub>3</sub>	0.20	0.94	0.21	0.55	0.16	0.28	0.28	0.52	0.06	25.64	27.70	26.90	27.54
Pr <sub>2</sub> O <sub>3</sub>	0.00	0.15	0.00	0.06	0.04	0.10	0.08	0.08	0.05	3.41	4.30	4.45	4.81
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.22	0.01	0.20	0.08	0.23	0.09	0.20	0.00	2.77	4.83	4.34	3.93
Dy <sub>2</sub> O <sub>3</sub>	0.15	0.31	0.22	0.26	0.30	0.48	0.25	0.41	0.16	0.00	0.00	0.00	0.00
Yb <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.02	0.00	0.00	0.00	0.02	0.03	0.04	0.00	0.04	0.00	0.00
Cl	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.05	0.02	0.02	0.01	0.02
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.21	9.17	9.14	9.03
Total1	65.83	61.08	64.12	71.05	66.64	63.54	67.60	69.65	58.87	70.45	72.54	71.58	76.10
Tota- IETR	0.74	2.47	0.62	1.78	0.96	1.89	1.63	1.77	1.02	53.56	62.62	62.97	62.95
CO <sub>2</sub>	29.10	27.21	29.05	31.06	29.80	29.92	37.35	33.69	30.22	24.66	24.03	22.68	26.32
H <sub>2</sub> O													
Total2	95.27	89.10	93.55	102.93	97.16	94.74	105.93	104.15	89.82	97.41	101.88	99.20	107.35



## Dados de Química Mineral de Carbonatos – Olekminskita / Parisita (cont.)

Amostra	SL109C	SL109C	SL109C	AT49	4s22	AT135	AT49	AT46	AT49	C87G	C87G	C87G	C87G
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C5	C1b	C3	C4a	C1b	C1b	C1b	C5	C5	C5	C5
textura	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	exsolution	fi-	fi-	fi-	fi-
Comple-										bro_radia	bro_radia	bro_radia	bro_radia
xo	Salitre	Salitre	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira	Tapira				
Mineral	Olekminskita	Olekminskita	Olekminskita	Olekminskita	Olekminskita	Olekminskita	Olekminskita	Olekminskita	Olekminskita	Araxá	Araxá	Araxá	Araxá
										Parisita	Parisita	Parisita	Parisita
Proporção atômica para 6 O													
Fe <sup>2+</sup>	0.0021	0.0330	0.0018	0.0051	0.0000	0.0115	0.0000	0.0019	0.0015	0.0282	0.0149	0.0124	0.0740
Mn	0.0000	0.0005	0.0003	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000	0.0000	0.0000	0.0006	0.0000
Mg	0.0018	0.0000	0.0014	0.0000	0.0000	0.0668	0.0007	0.0070	0.0013	0.0065	0.0000	0.0000	0.0036
Ca	0.1774	0.1965	0.2752	0.1524	0.2080	0.3772	1.0498	0.6188	0.8159	1.1290	0.7903	0.6236	0.9227
Na	0.0184	0.0258	0.0272	0.0328	0.0254	0.0368	0.0269	0.0498	0.0365	0.0082	0.0000	0.0000	0.0000
Sr	1.7732	1.5610	1.6594	1.7375	1.7379	1.3940	0.8389	1.1884	1.0446	0.0612	0.0686	0.0959	0.0600
Ba	0.0207	0.0299	0.0273	0.0537	0.0215	0.0939	0.0707	0.1253	0.0978	0.0000	0.0000	0.0000	0.0000
La	0.0039	0.0136	0.0004	0.0072	0.0014	0.0060	0.0053	0.0067	0.0037	0.7029	0.8386	0.9306	0.8092
Ce	0.0037	0.0174	0.0038	0.0094	0.0029	0.0050	0.0040	0.0083	0.0011	0.8228	0.8953	0.9105	0.8294
Pr	0.0000	0.0027	0.0000	0.0011	0.0007	0.0017	0.0012	0.0013	0.0009	0.1090	0.1384	0.1498	0.1441
Nd	0.0000	0.0039	0.0002	0.0034	0.0014	0.0040	0.0012	0.0030	0.0000	0.0866	0.1522	0.1434	0.1155
Dy	0.0024	0.0051	0.0035	0.0040	0.0048	0.0076	0.0032	0.0058	0.0025	0.0000	0.0000	0.0000	0.0000
Yb	0.0002	0.0000	0.0004	0.0000	0.0000	0.0000	0.0002	0.0004	0.0006	0.0000	0.0012	0.0000	0.0000
C	1.9981	1.8796	1.9903	1.9955	1.9971	1.9952	1.9966	1.9958	1.9970	2.9511	2.8969	2.8639	2.9556
Cl	0.0000	0.0000	0.0009	0.0000	0.0000	0.0009	0.0005	0.0001	0.0040	0.0031	0.0031	0.0019	0.0028
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.5524	2.5610	2.6719	2.3486
ΣCation	4.0047	3.9071	4.0096	4.0063	4.0065	4.0070	4.0056	4.0156	4.0110	5.9097	5.8011	5.7311	5.9162

## Dados de Química Mineral de Carbonatos – Parisita / Estroncianita

Amostra	C87G	C87G	C87G	C83H	C85D	C85D	C85D	C85D	C85D	C85D	C85D	C85D
Método Unidade	FEG C5	FEG C5	FEG C5	EPMA C4a	EPMA C5	EPMA C5	EPMA C5	EPMA C5	EPMA C5	EPMA C5	EPMA C5	EPMA C5
textura Com- plexo	fi- bro_radi al	fi- bro_radi al	fi- bro_radi al	exsinnor	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst
Mineral	Araxá Parisita	Araxá Parisita	Araxá Parisita	Araxá Estroncia- nita	Araxá Estroncianita	Araxá Estroncianita	Araxá Estroncianita	Araxá Estroncianita	Araxá Estroncianita	Araxá Estroncianita	Araxá Estroncianita	Araxá Estroncianita
K <sub>2</sub> O												
FeO				0.01	0.04	0.05	0.01	0.05	0.00	0.00	0.00	0.02
MnO				0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00
MgO				0.02	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00
CaO	11.08	8.03	5.48	5.12	4.60	3.96	3.63	3.48	3.23	4.09	3.87	3.83
Na <sub>2</sub> O				0.04	0.04	0.02	0.01	0.04	0.06	0.05	0.04	0.04
SrO	1.00	1.29	1.36	56.03	56.94	54.72	56.10	56.68	54.23	55.89	55.04	57.32
BaO				2.10	0.15	0.96	0.14	0.25	0.37	0.32	0.32	0.43
La <sub>2</sub> O <sub>3</sub>	23.11	25.41	26.91	0.05	0.04	0.03	0.04	0.07	0.07	0.02	0.03	0.02
Ce <sub>2</sub> O <sub>3</sub>	26.14	27.83	27.62	0.24	0.06	0.10	0.14	0.20	0.12	0.07	0.08	0.05
Pr <sub>2</sub> O <sub>3</sub>					0.03	0.00	0.00	0.01	0.03	0.01	0.03	0.00
Nd <sub>2</sub> O <sub>3</sub>					0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00
Dy <sub>2</sub> O <sub>3</sub>					0.00	0.00	0.03	0.00	0.03	0.00	0.01	0.00
Yb <sub>2</sub> O <sub>3</sub>					0.02	0.00	0.05	0.02	0.00	0.01	0.00	0.07
Cl				0.02	0.03	0.02	0.04	0.04	0.06	0.03	0.06	0.04
F	0.73	1.27	1.79	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total1	62.06	63.83	63.16	63.65	61.94	59.88	60.13	60.81	58.25	60.49	59.60	61.86
Tota- IETR	49.25	53.24	54.53	0.30	0.16	0.17	0.37	0.36	0.27	0.13	0.18	0.17
CO <sub>2</sub>	24.43	23.41	21.84	28.56	27.94	26.75	26.84	27.03	25.81	27.13	26.61	27.58
H <sub>2</sub> O												
Total2	94.07	95.22	92.97	92.24	89.94	86.67	87.15	87.92	84.13	87.65	86.27	89.53

## Dados de Química Mineral de Carbonatos – Parisita / Estroncianita (cont.)

Amostra	C87G	C87G	C87G	C87G	C83H	C85D	C85D	C85D	C85D	C85D	C85D	C85D	C85D
Método Unidade	EPMA	FEG	FEG	FEG	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
de	C5	C5	C5	C5	C4a	C5	C5	C5	C5	C5	C5	C5	C5
textura	fi- bro_radi al	fi- bro_radi al	fi- bro_radi al	fi- bro_radi al	exsinnor	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst	colo- morf_interst
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá
Mineral	Parisita	Parisita	Parisita	Parisita	Estronci- anita	Estronci- anita	Estronci- anita	Estronci- anita	Estronci- anita	Estronci- anita	Estronci- anita	Estronci- anita	Estronci- anita
Proporção atômica para 11(O,F)/3Metais,3Carbonos													
Fe <sup>2+</sup>	0.0905	0.0000	0.0000	0.0000	0.0006	0.0016	0.0024	0.0005	0.0022	0.0000	0.0000	0.0000	0.0010
Mn	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0006	0.0000	0.0000
Mg	0.0215	0.0000	0.0000	0.0000	0.0013	0.0001	0.0021	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000
Ca	0.9804	1.2151	0.9047	0.6399	0.2810	0.2582	0.2318	0.2119	0.2021	0.1959	0.2364	0.2280	0.2176
Na	0.0000	0.0000	0.0000	0.0000	0.0036	0.0042	0.0025	0.0007	0.0044	0.0066	0.0051	0.0043	0.0037
Sr	0.0654	0.0594	0.0787	0.0860	1.6648	1.7282	1.7348	1.7740	1.7795	1.7787	1.7492	1.7549	1.7644
Ba	0.0000	0.0000	0.0000	0.0000	0.0421	0.0032	0.0205	0.0029	0.0052	0.0082	0.0067	0.0068	0.0090
Th	0.0030	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0014	0.0000	0.0021	0.0014
La	0.7048	0.8725	0.9855	1.0818	0.0010	0.0008	0.0006	0.0008	0.0015	0.0014	0.0004	0.0006	0.0004
Ce	0.7291	0.9796	1.0714	1.1021	0.0046	0.0011	0.0019	0.0029	0.0039	0.0025	0.0014	0.0015	0.0010
Pr	0.1048	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0002	0.0007	0.0001	0.0006	0.0000
Nd	0.0919	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0006	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0006	0.0000	0.0002	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0008	0.0004	0.0000	0.0001	0.0000	0.0011
C	2.7908	3.4146	3.3601	3.2495	1.9979	1.9969	1.9963	1.9983	1.9983	1.9932	1.9992	1.9978	1.9985
Cl	0.0013	0.0000	0.0000	0.0000	0.0019	0.0026	0.0017	0.0037	0.0038	0.0055	0.0024	0.0060	0.0040
F	3.1701	0.2363	0.4223	0.6170	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	5.6701	6.5412	6.4003	6.2865	3.9976	3.9979	3.9967	3.9967	3.9986	3.9940	4.0009	3.9975	3.9985

Dados de Química Mineral de Carbonatos – Estroncianita (cont.)

Amos- tra	C85D	C85D	C85D	C85D	C87G	C87G	C87G	C87G	C87G	C85D	C83H	C83H	C85D
Méto- do	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG
Unida- de	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5 colo- morf_inters t	C5	C4a	C4a	C5 colo- morf_inters t
textura Com- plejo	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estroncia- nita	Araxá Estronci- anita	Araxá Estronci- anita	Araxá Estronci- anita	Araxá Estroncia- nita
Mineral													
K <sub>2</sub> O													
FeO	0.02	0.00	0.04	0.01	0.18	0.02	0.00	0.02	0.02				
MnO	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00				
MgO	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	1.53			
CaO	3.75	3.43	3.47	4.69	4.70	4.70	4.20	3.89	4.32	5.57	5.39	4.85	3.99
Na <sub>2</sub> O	0.01	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.07				
SrO	53.84	57.79	58.71	57.34	56.35	57.01	54.62	58.40	58.35	49.08	49.25	49.54	53.23
BaO	0.31	0.48	0.27	0.34	0.29	0.30	0.31	0.27	0.35		4.26	6.13	
La <sub>2</sub> O <sub>3</sub>	0.04	0.00	0.09	0.12	0.00	0.03	0.04	0.02	0.03				
Ce <sub>2</sub> O <sub>3</sub>	0.12	0.07	0.18	0.13	0.10	0.06	0.07	0.04	0.05	0.00	0.00	0.00	0.00
Pr <sub>2</sub> O <sub>3</sub>	0.09	0.01	0.00	0.00									
Nd <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.00	0.04									
Dy <sub>2</sub> O <sub>3</sub>	0.00	0.04	0.00	0.02									
Yb <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.04	0.00									
Cl	0.07	0.00	0.01	0.00	0.00	0.04	0.14	0.02	0.04				
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Total1	58.16	61.79	62.78	62.65	61.65	62.21	59.41	62.79	63.23	56.18	58.90	60.52	57.22
Total- IETR	0.29	0.18	0.31	0.41	0.10	0.09	0.10	0.06	0.08	0.00	0.00	0.00	0.00
CO <sub>2</sub>	26.00	27.44	27.85	28.26	27.87	28.04	26.65	28.00	28.37	26.89	26.37	26.61	25.74
H <sub>2</sub> O													
Total2	84.27	89.34	90.67	91.08	89.53	90.25	86.04	90.80	91.60	83.07	85.27	87.13	82.96

## Dados de Química Mineral de Carbonatos – Estroncianita (cont.)

Amostra	C85D	C85D	C85D	C85D	C87G	C87G	C87G	C87G	C87G	C85D	C83H	C83H	C85D	
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	FEG	FEG	FEG	FEG	
Unidade	C5	C5	C5	C5	C5	C5	C5	C5	C5	C5	C4a	C4a	C5	
textura	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	interst_exs	exsinor	exsinor	colo- morf_inters t
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	
Mineral	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0008	0.0000	0.0017	0.0005	0.0077	0.0007	0.0001	0.0010	0.0009	0.0000	0.0000	0.0000	0.0000
Mn	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mg	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0008	0.0005	0.1243	0.0000	0.0000	0.0000
Ca	0.2255	0.1957	0.1948	0.2593	0.2641	0.2629	0.2461	0.2176	0.2385	0.3251	0.3208	0.2861	0.2433
Na	0.0011	0.0025	0.0000	0.0014	0.0003	0.0000	0.0008	0.0000	0.0073	0.0000	0.0000	0.0000	0.0000
Sr	1.7538	1.7853	1.7811	1.7158	1.7123	1.7247	1.7318	1.7684	1.7443	1.5506	1.5864	1.5816	1.7567
Ba	0.0067	0.0099	0.0056	0.0070	0.0059	0.0061	0.0067	0.0054	0.0071	0.0000	0.0927	0.1322	0.0000
La	0.0009	0.0000	0.0018	0.0023	0.0000	0.0005	0.0007	0.0004	0.0006	0.0000	0.0000	0.0000	0.0000
Ce	0.0026	0.0014	0.0034	0.0024	0.0019	0.0012	0.0014	0.0007	0.0009	0.0000	0.0000	0.0000	0.0000
Pr	0.0018	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0001	0.0003	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0008	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	1.9941	1.9956	1.9893	1.9912	1.9940	1.9970	1.9895	1.9960	1.9967	2.0000	2.0000	2.0000	2.0000
Cl	0.0063	0.0001	0.0005	0.0000	0.0000	0.0037	0.0125	0.0019	0.0033	0.0000	0.0000	0.0000	0.0000
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	3.9926	3.9961	3.9932	3.9910	3.9936	3.9961	3.9875	3.9949	3.9994	4.0000	4.0000	4.0000	4.0000

## Dados de Química Mineral de Carbonatos – Estroncianita (cont.)

Amostra	C85D	C85D	C87G	C87G	C85D	C87G	C85D	C83H	C85D	C87G	C85D	C1SH1	C1SH1
Método	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	EPMA	EPMA
Unidade	C5	C5	C5	C5	C5	C5	C5	C4a	C5	C5	C5	C4	C4
textura	colo-	colo-	colo-	colo-	colo-	colo-	colo-	colo-	colo-	colo-	colo-	exsolu-	ok
Complexo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Catalão	Catalão
Mineral	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-	Estroncia-
K <sub>2</sub> O													
FeO												0.03	1.12
MnO												0.02	0.05
MgO												0.04	0.04
CaO	3.95	3.84	3.33	3.30	3.28	3.25	2.99	2.90	2.17	2.03	1.70	3.83	4.94
Na <sub>2</sub> O												0.40	0.26
SrO	53.41	52.62	53.44	52.73	51.36	52.79	52.53	48.65	50.18	56.96	56.37	64.99	66.47
BaO								4.36				0.85	0.20
La <sub>2</sub> O <sub>3</sub>										1.01		0.00	0.01
Ce <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.15	0.08
Pr <sub>2</sub> O <sub>3</sub>												0.00	0.00
Nd <sub>2</sub> O <sub>3</sub>												0.00	0.00
Dy <sub>2</sub> O <sub>3</sub>												0.00	0.00
Yb <sub>2</sub> O <sub>3</sub>												0.00	0.03
Cl								0.05				0.00	0.03
F												0.00	0.00
Total1	57.36	56.46	56.77	56.03	54.64	56.04	55.52	55.96	52.35	61.07	58.07	70.31	73.20
Total- IETR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08	0.00	0.69	0.48
CO <sub>2</sub>	25.78	25.36	25.31	24.99	24.39	24.97	24.66	24.19	23.02	26.42	25.28	31.39	33.24
H <sub>2</sub> O													
Total2	83.14	81.82	82.08	81.02	79.03	81.01	80.18	80.14	75.37	87.78	83.35	102.23	106.81

## Dados de Química Mineral de Carbonatos – Estroncianita (cont.)

Amostra	C85D	C85D	C87G	C87G	C85D	C87G	C85D	C83H	C85D	C87G	C85D	C1SH1	C1SH1
Método	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	FEG	EPMA	EPMA
Unidade	C5	C5	C5	C5	C5	C5	C5	C4a	C5	C5	C5	C4	C4
textura	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	colo- morf_inters t	exsoluti- on	ok
Comple- xo	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	Araxá	CatalãoI	CatalãoI
Mineral	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estroncia- nita	Estron- cianita	Estron- cianita

## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0414
Mn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0018
Mg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0028
Ca	0.2404	0.2376	0.2065	0.2073	0.2111	0.2043	0.1903	0.1881	0.1480	0.1203	0.1056	0.1912	0.2330
Na	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0361	0.0222
Sr	1.7595	1.7624	1.7935	1.7927	1.7889	1.7957	1.8097	1.7076	1.8520	1.8266	1.8944	1.7575	1.6976
Ba	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1034	0.0000	0.0000	0.0000	0.0156	0.0034
La	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0206	0.0000	0.0000	0.0002
Ce	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0217	0.0000	0.0025	0.0014
Pr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dy	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Yb	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
C	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	1.9992	2.0000	1.9949	2.0000	1.9984	1.9986
Cl	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0051	0.0000	0.0000	0.0000	0.0001	0.0022
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΣCation	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	3.9983	4.0000	3.9840	4.0000	4.0142	4.0078

## Dados de Química Mineral de Carbonatos – Estroncianita (cont.)

Amostra	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	AT139	AT139	AT139	4s22	4s22
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C5	C5	C5	C5	C3	C3	C3	C3	C3
textura	exsolution	exsolution	intersticial	intersticial	intersticial	intersticial	ok	exsolution	ok	exsolution	exsolution
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita
K <sub>2</sub> O	0.00	0.00	0.00				0.00	0.00	0.00	0.00	0.01
FeO	0.07	0.04	0.05	0.00	0.03	0.00	0.23	0.03	0.28	0.11	0.01
MnO	0.01	0.06	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.02	0.00
MgO	0.03	0.00	0.02	0.00	0.01	0.00	0.02	0.02	0.00	0.00	0.00
CaO	3.24	3.27	7.45	8.95	4.44	3.42	4.00	4.40	2.98	3.04	3.93
Na <sub>2</sub> O	0.30	0.32	0.25	0.01	0.00	0.03	0.30	0.30	0.28	0.27	0.28
SrO	61.60	52.49	56.70	52.07	58.26	59.69	63.91	64.28	65.39	65.17	64.13
BaO	0.41	0.20	0.02	0.68	0.62	0.17	2.19	1.69	1.95	0.24	0.26
La <sub>2</sub> O <sub>3</sub>	0.00	4.31	0.15	0.02	0.00	0.00	0.06	0.11	0.10	0.11	0.02
Ce <sub>2</sub> O <sub>3</sub>	0.00	7.06	0.41	0.09	0.00	0.02	0.00	0.17	0.27	0.19	0.01
Pr <sub>2</sub> O <sub>3</sub>	0.02	0.62	0.07	0.02	0.00	0.03	0.00	0.05	0.00	0.03	0.02
Nd <sub>2</sub> O <sub>3</sub>	0.00	2.37	0.42	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.30
Dy <sub>2</sub> O <sub>3</sub>	0.31	0.12	0.13	0.00	0.00	0.00	0.35	0.51	0.29	0.09	0.41
Yb <sub>2</sub> O <sub>3</sub>	0.07	0.00	0.09	0.00	0.05	0.00	0.00	0.09	0.00	0.00	0.00
Cl	0.01	0.03	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.02
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Total1	65.66	67.77	65.06	61.85	63.39	63.34	70.73	71.01	71.29	69.34	68.70
TotalETR	0.76	14.88	1.75	0.20	0.05	0.21	0.90	1.08	1.03	0.75	1.05
CO <sub>2</sub>	29.31	29.18	30.63	29.41	28.47	28.16	31.53	31.78	31.32	30.63	30.88
H <sub>2</sub> O											
Total2	95.73	100.46	96.88	91.35	91.91	91.68	103.09	103.58	103.25	100.42	100.60



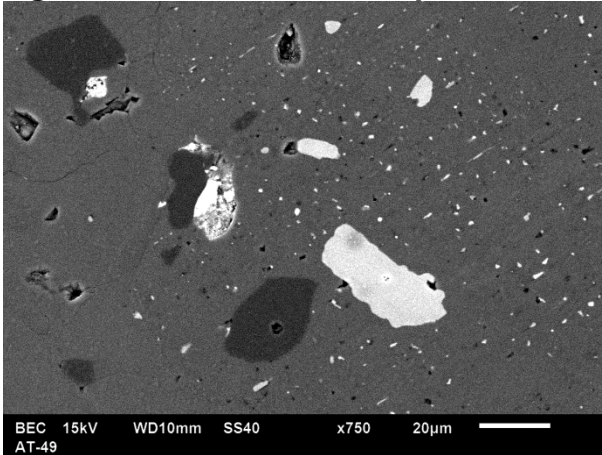
## Dados de Química Mineral de Carbonatos – Estroncianita (cont.)

Amostra	SL109C	SL109C	SL109C	SL109C	SL109C	SL109C	AT139	AT139	AT139	4s22	4s22
Método	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA	EPMA
Unidade	C5	C5	C5	C5	C5	C5	C3	C3	C3	C3	C3
textura	exsolution	exsolution	intersticial	intersticial	intersticial	intersticial	ok	exsolution	ok	exsolution	exsolution
Complexo	Salitre	Salitre	Salitre	Salitre	Salitre	Salitre	Tapira	Tapira	Tapira	Tapira	Tapira
Mineral	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita	Estroncianita

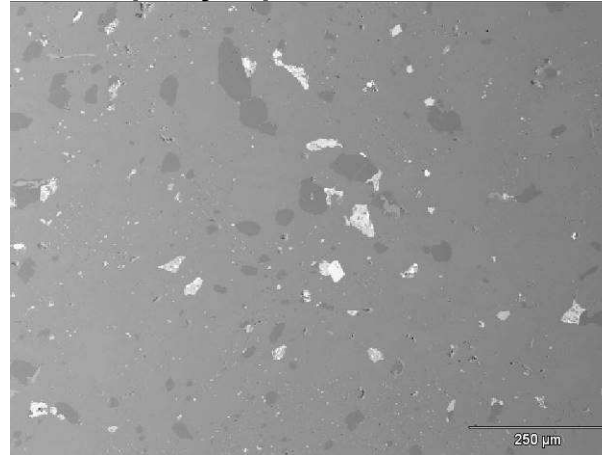
## Proporção atômica para 6 O

Fe <sup>2+</sup>	0.0030	0.0017	0.0020	0.0001	0.0014	0.0001	0.0090	0.0010	0.0111	0.0044	0.0003
Mn	0.0003	0.0022	0.0000	0.0014	0.0013	0.0000	0.0000	0.0000	0.0001	0.0009	0.0000
Mg	0.0022	0.0000	0.0016	0.0000	0.0008	0.0000	0.0011	0.0016	0.0000	0.0000	0.0000
Ca	0.1732	0.1600	0.3804	0.4767	0.2446	0.1906	0.1988	0.2171	0.1493	0.1554	0.1996
Na	0.0286	0.0281	0.0228	0.0007	0.0000	0.0028	0.0273	0.0270	0.0253	0.0253	0.0260
Sr	1.7837	1.3917	1.5670	1.5017	1.7383	1.7978	1.7181	1.7160	1.7710	1.8048	1.7614
Ba	0.0080	0.0035	0.0004	0.0132	0.0125	0.0034	0.0399	0.0305	0.0356	0.0045	0.0048
La	0.0000	0.0726	0.0026	0.0003	0.0000	0.0000	0.0010	0.0018	0.0018	0.0020	0.0004
Ce	0.0000	0.1183	0.0072	0.0017	0.0000	0.0005	0.0000	0.0029	0.0046	0.0034	0.0002
Pr	0.0003	0.0103	0.0012	0.0004	0.0000	0.0005	0.0000	0.0009	0.0000	0.0005	0.0003
Nd	0.0000	0.0387	0.0071	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0051
Dy	0.0050	0.0017	0.0019	0.0000	0.0000	0.0001	0.0052	0.0076	0.0044	0.0013	0.0062
Yb	0.0011	0.0000	0.0013	0.0000	0.0008	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000
C	1.9984	1.8215	1.9929	1.9970	1.9999	1.9971	1.9956	1.9975	1.9971	1.9976	1.9974
Cl	0.0005	0.0022	0.0006	0.0000	0.0000	0.0013	0.0006	0.0010	0.0005	0.0000	0.0014
F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.0000	0.0000
ΣCation	4.0096	3.8208	3.9990	3.9970	3.9997	3.9977	4.0064	4.0072	4.0056	4.0069	4.0063

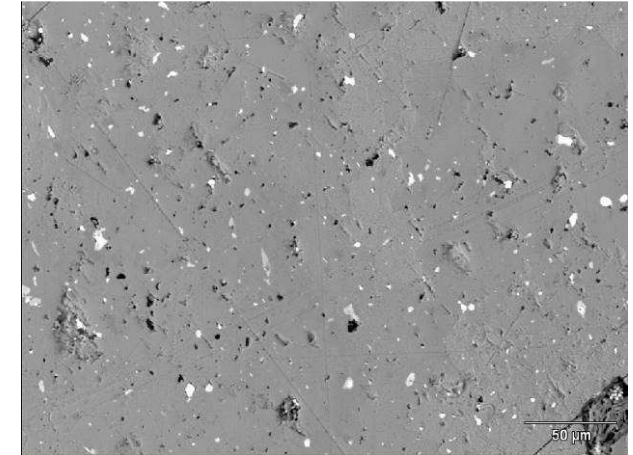
## Imagens de Elétrons Retroespalhados e Mapas de Composição por EDS – C1 e C2



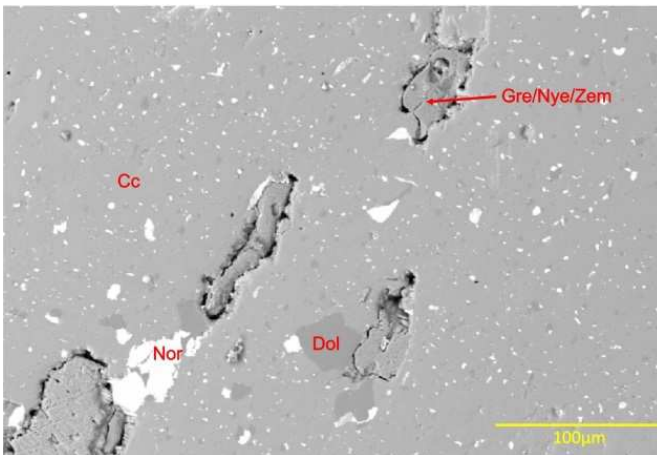
Amostra AT49. Calcita com exsolução de dolomita e olekminskita, notar contato entre calcita com muita exsolução (suja) e sem exsolução (limpa). C1



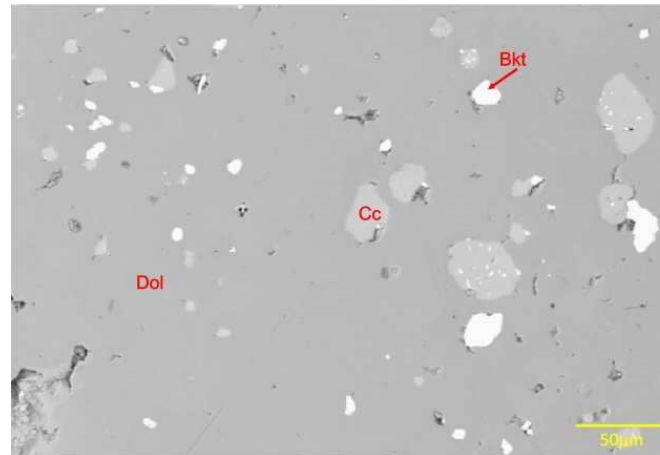
Amostra AT49. Calcita com exsolução de dolomita (mais escuro) e olekminskita (mais claro). C1



Amostra SLE360. Exsoluções de burbankita e olekminskita em calcita. C1

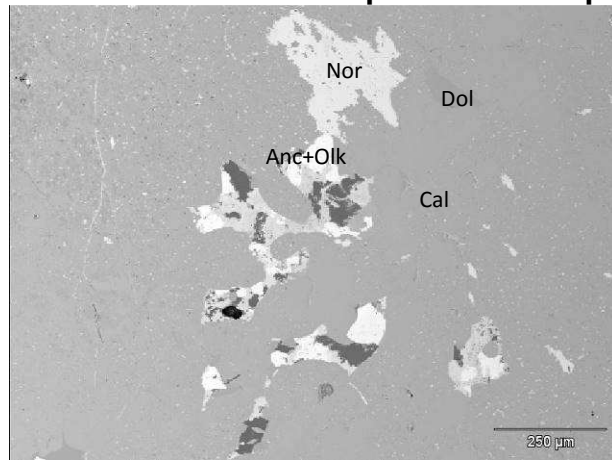


Amostra SLE360. Calcita com exsoluções de dolomita, norsethita e Gregoryita/nyererita/zemkorita. C1

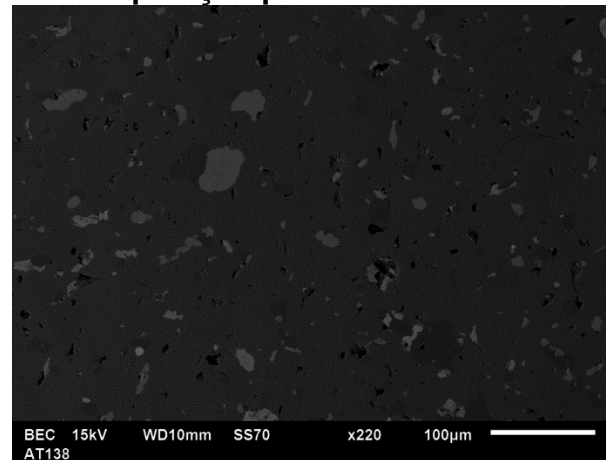


Amostra CB02. Exsoluções de burbankita e calcita em dolomita. C2

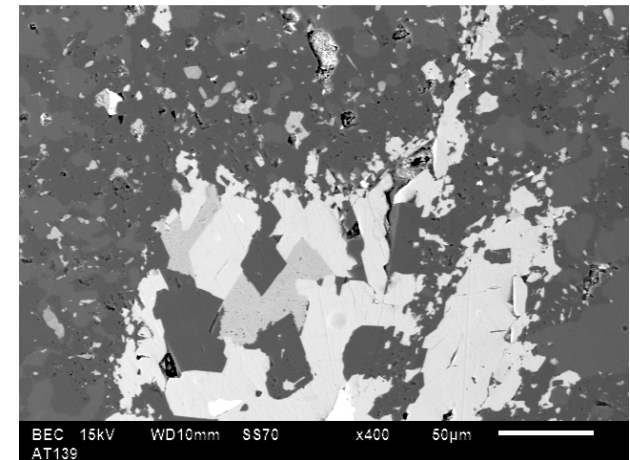
### Imagens de Elétrons Retroespalhados e Mapas de Composição por EDS – C3



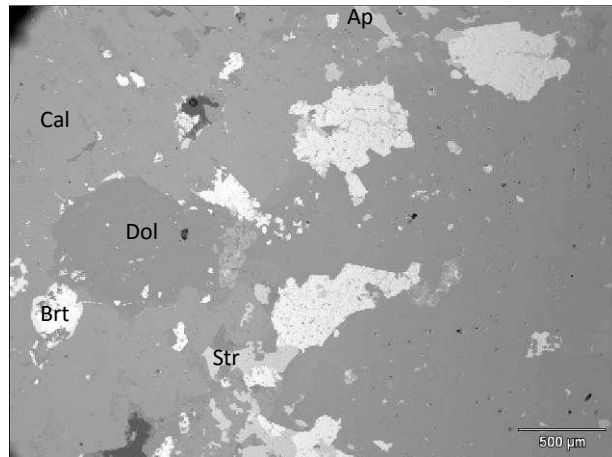
Amostra AT138. Exsolução de dolomita em calcita e de ancylita e olekminskita em norsethita



Amostra AT138. Exsolução de dolomita, olekminskita e baritocalcita em calcita.

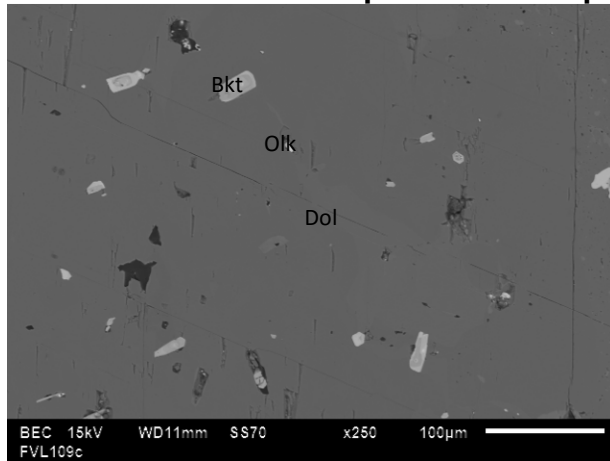


Amostra AT139. Calcita (mais escuro), estroncianita (intermediário) e baritocalcita (mais claro)

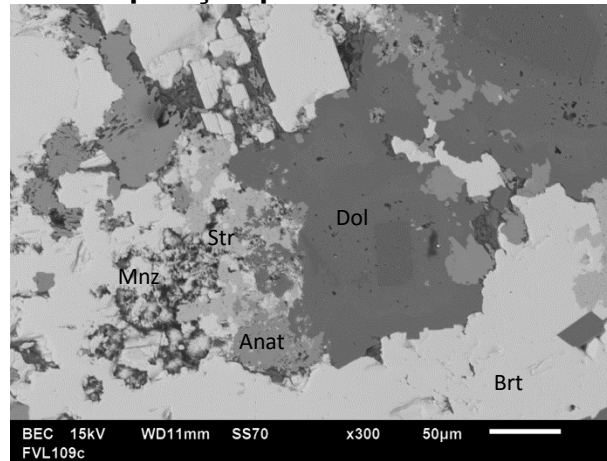


Amostra AT140. Apatita, barita e calcita dominante com bolsões de dolomita e estroncianita

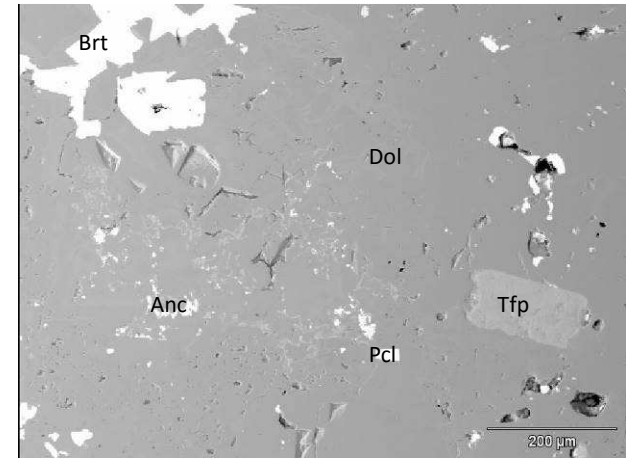
### Imagens de Elétrons Retroespalhados e Mapas de Composição por EDS – C4



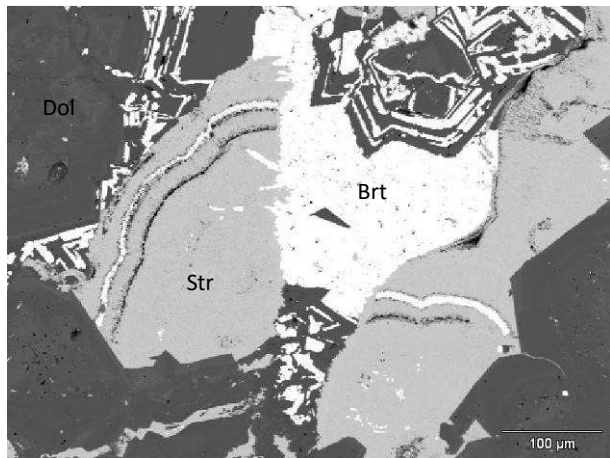
Amostra FVL109c. Exsolução de olekminkita e microinclusão de burbankita em dolomita



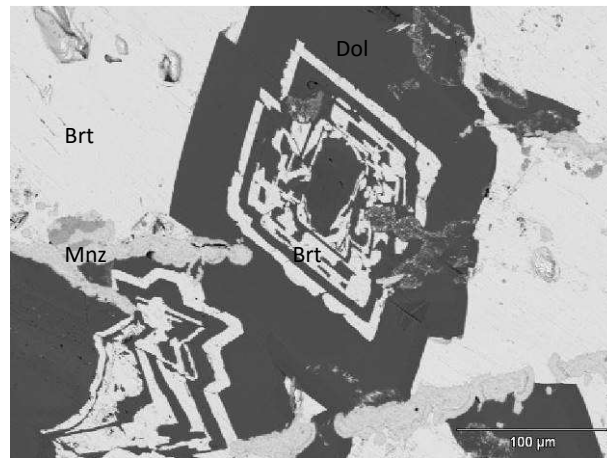
Amostra FVL109c. Dolomita, estroncianita, barita, monazita e anatásio



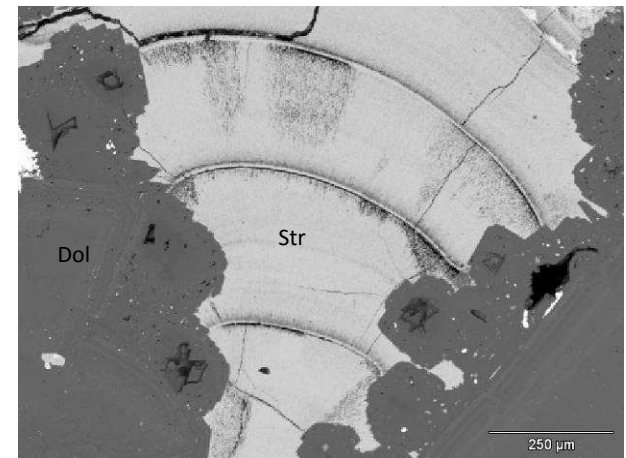
Amostra AT137. Tetraferroflogopita, picrocloro, barita e dolomita com exsolução de ancyllita.



Amostra C85D. Dolomita, Fe-Dolomita, Estroncianita e Barita.

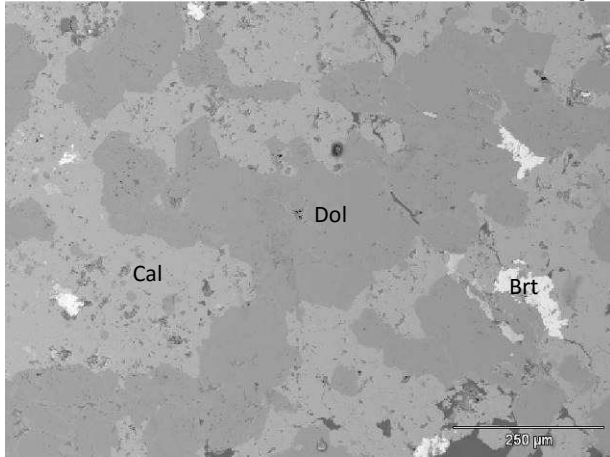


Amostra C85D. Intercalação de barita e dolomita. Monazita coloidal.

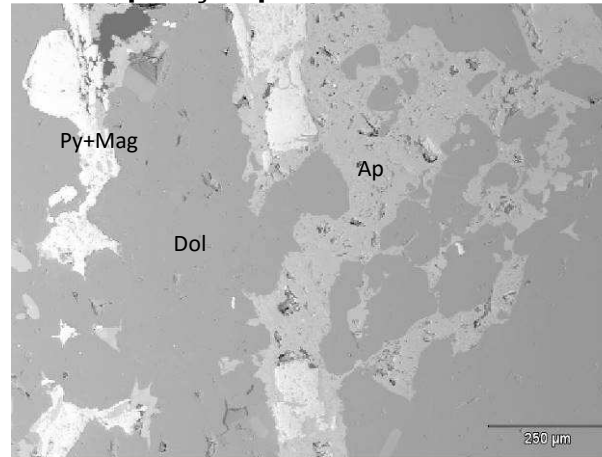


Amostra C87G. Zonação de dolomita fe-dolomita com estroncianita preenchendo espaço entre elas.

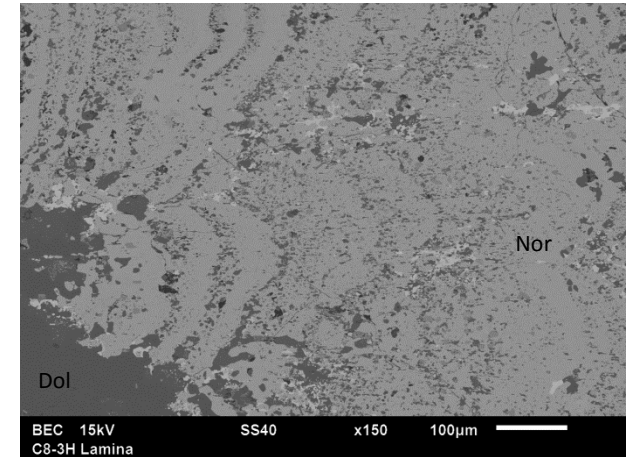
## Imagens de Elétrons Retroespalhados e Mapas de Composição por EDS – C5



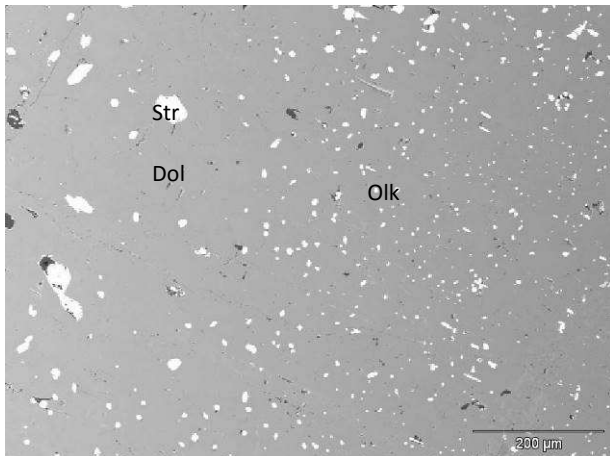
Amostra ASL12. Calcita, dolomita e barita,



Amostra CB15. Magnetita, apatita, flogopita, pirita e dolomita.

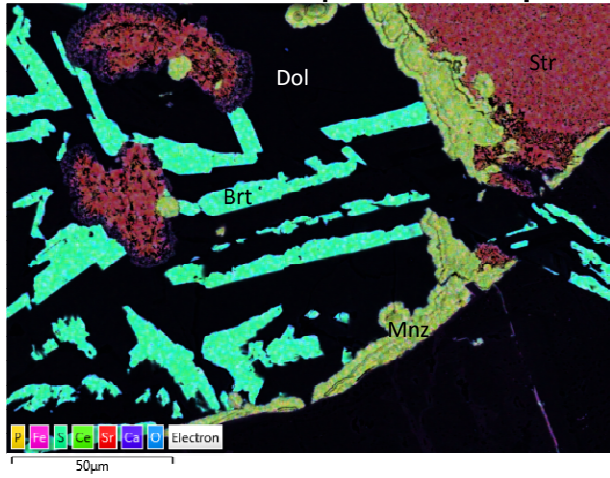


Amostra C83H. Dolomita e norsethita, exsoluções de dolomita, burbankita, benstonita, olekminskita em norsethita

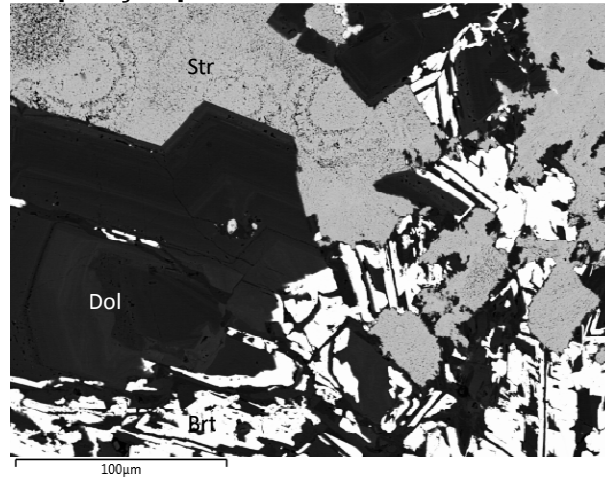


Amostra C815. Exsolução de estroncianita e olekminskita em dolomita.

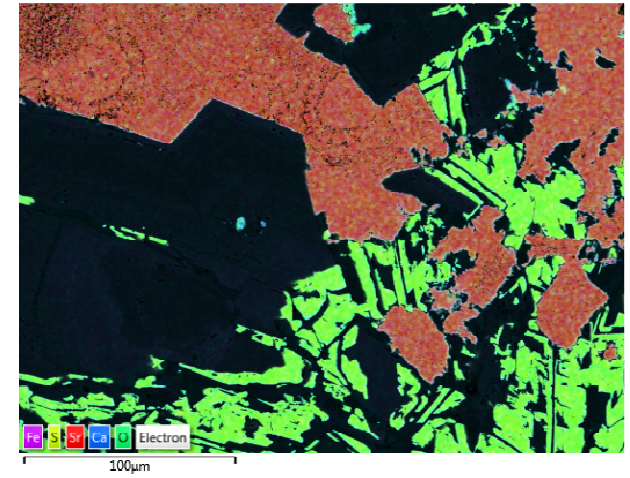
Imagens de Elétrons Retroespalhados e Mapas de Composição por EDS



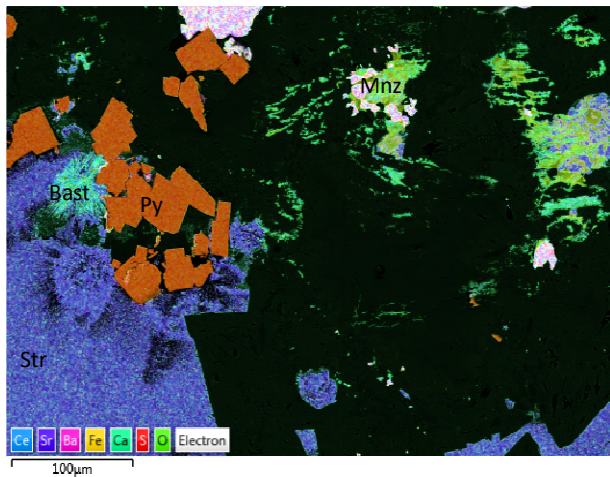
Amostra C85D. Dolomita, Barita, Estroncianita e Monazita. C4.



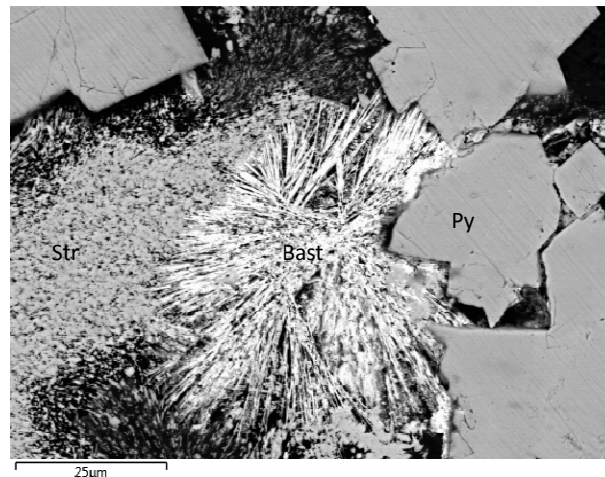
Amostra C85D. Dolomita, Barita, Estroncianita. C4.



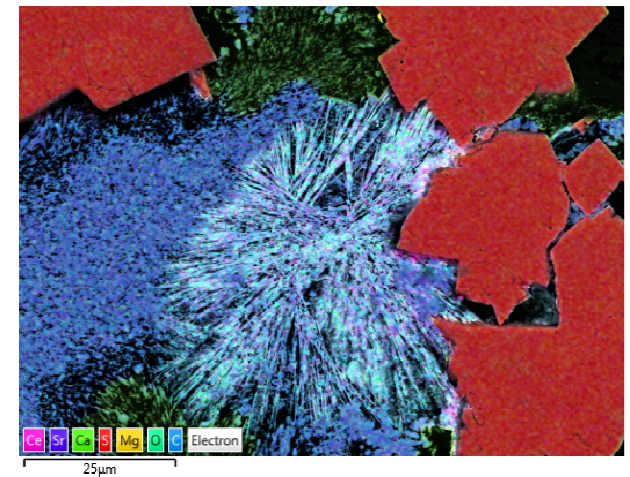
Amostra C85D. Dolomita, Barita, Estroncianita. C4.



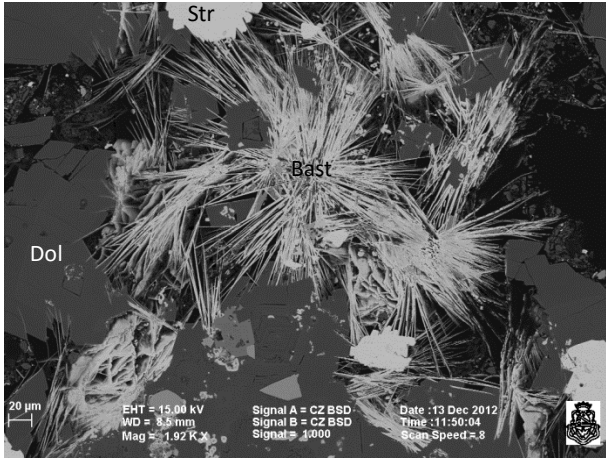
Amostra C87G. Dolomita, Barita, Estroncianita, Batnaesita, Pirita e Monazita. C4.



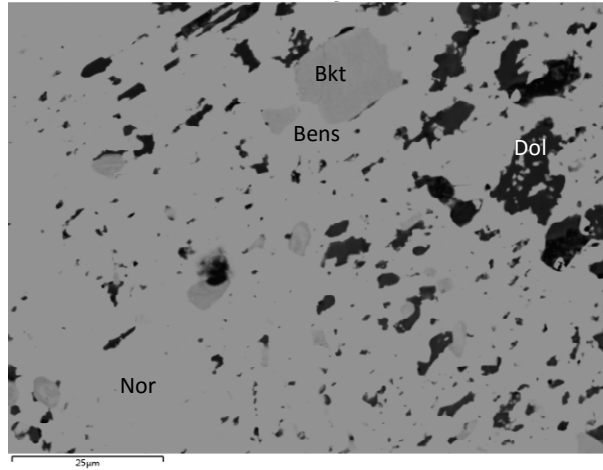
Amostra C87G. Dolomita, Estroncianita, Batnaesita e Pirita. C4.



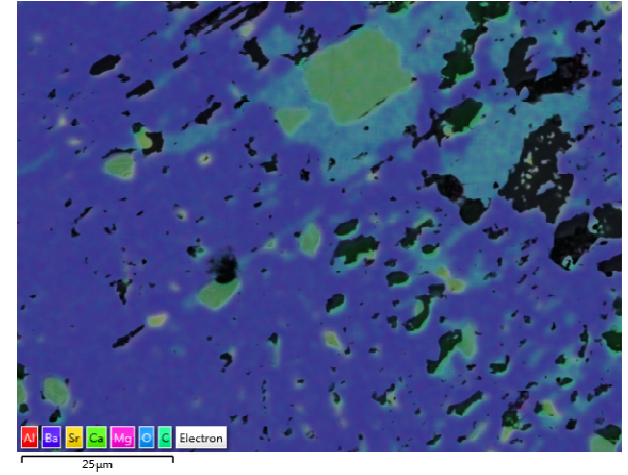
Amostra C87G. Dolomita, Estroncianita, Batnaesita e Pirita. C4.



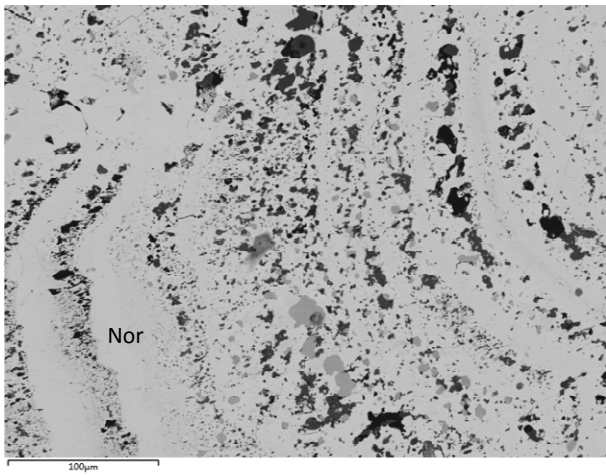
Amostra C87G. Dolomita, Estroncionita, Bastnaesita e Pirita. C4.



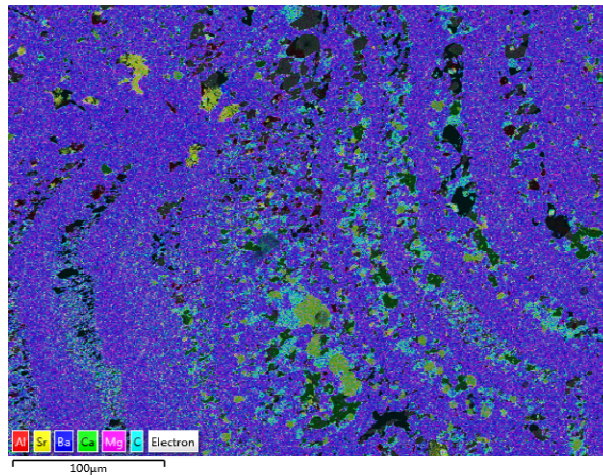
Amostra C83H. Norsethita, burbankita (zonada), benstonita, dolomita. C5.



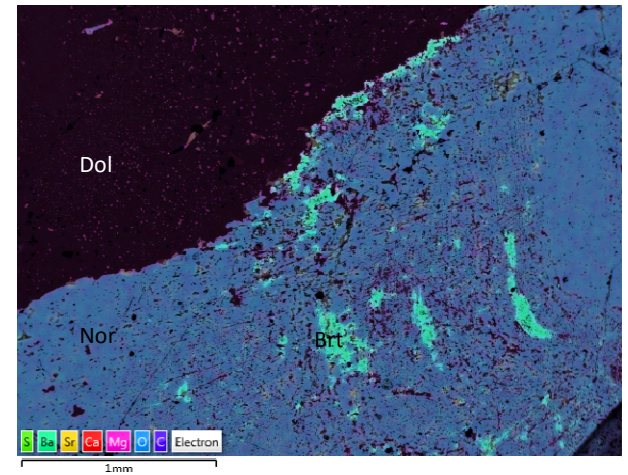
Amostra C83H. Norsethita, burbankita, benstonita, dolomita. C5.



Amostra C83H. Norsethita, burbankita, benstonita, dolomita e barita. C5.

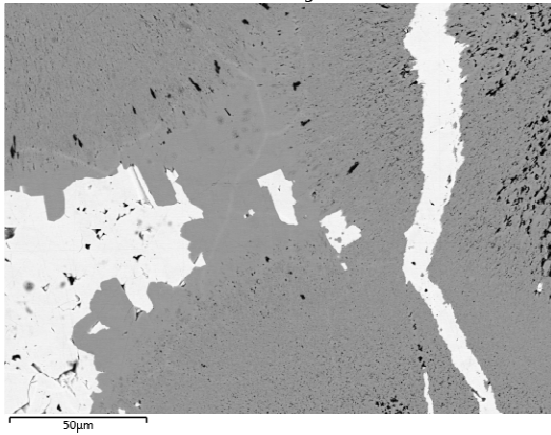


Amostra C83H. Norsethita, burbankita, benstonita, dolomita e barita. C5.



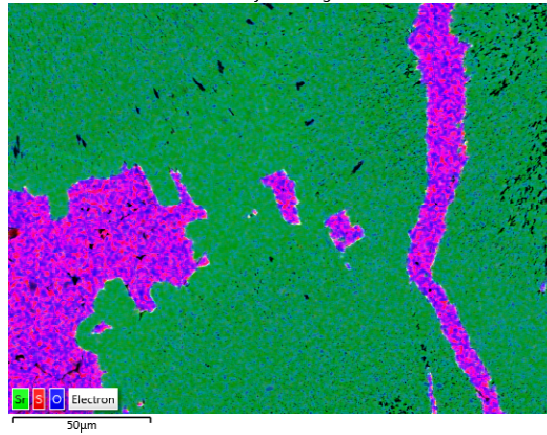
Amostra C83H. Norsethita, burbankita, benstonita, dolomita e barita. C5.

Electron Image 24

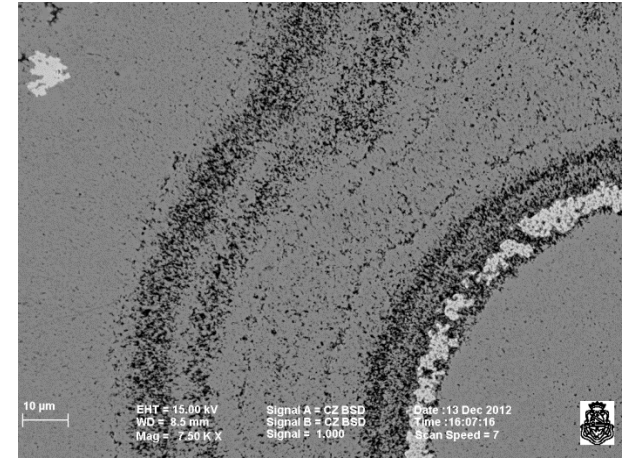


Amostra C85D. Barita, estroncianita e veio de barita (veio sem Sr e outra Barita com pouco Sr)

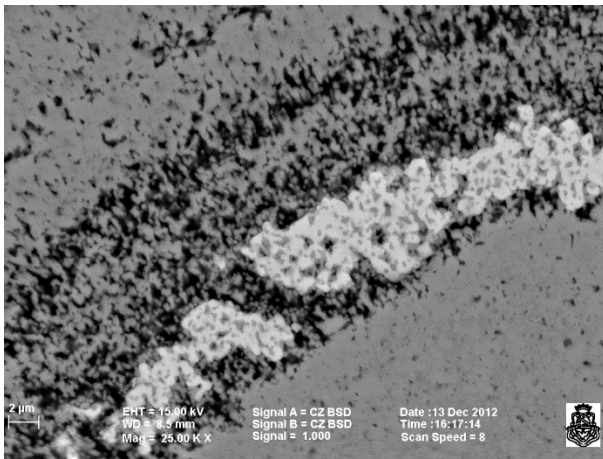
EDS Layered Image 25



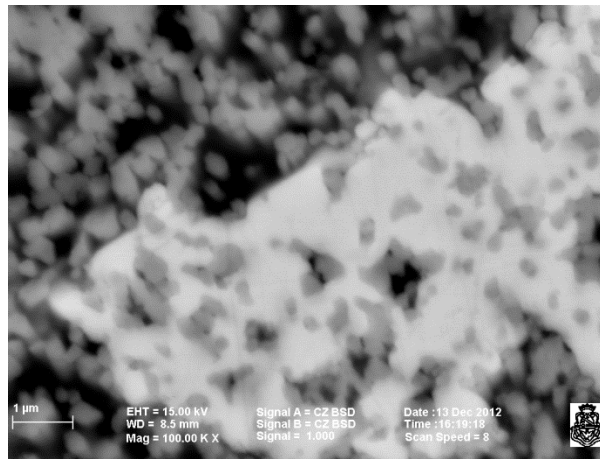
Amostra C85D. Barita, estroncianita e veio de barita



Amostra C85D. Barita e estroncianita

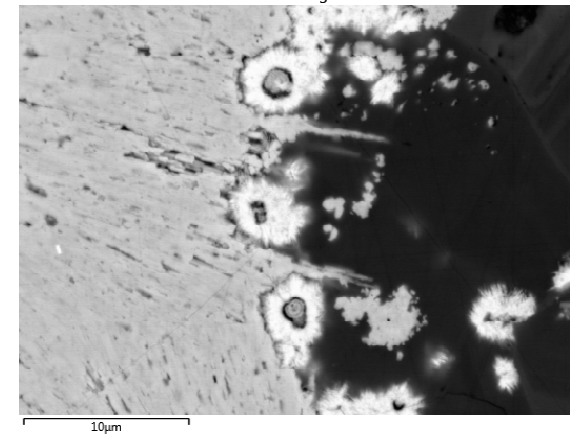


Amostra C85D. Barita e estroncianita



Amostra C85D. Barita e estroncianita

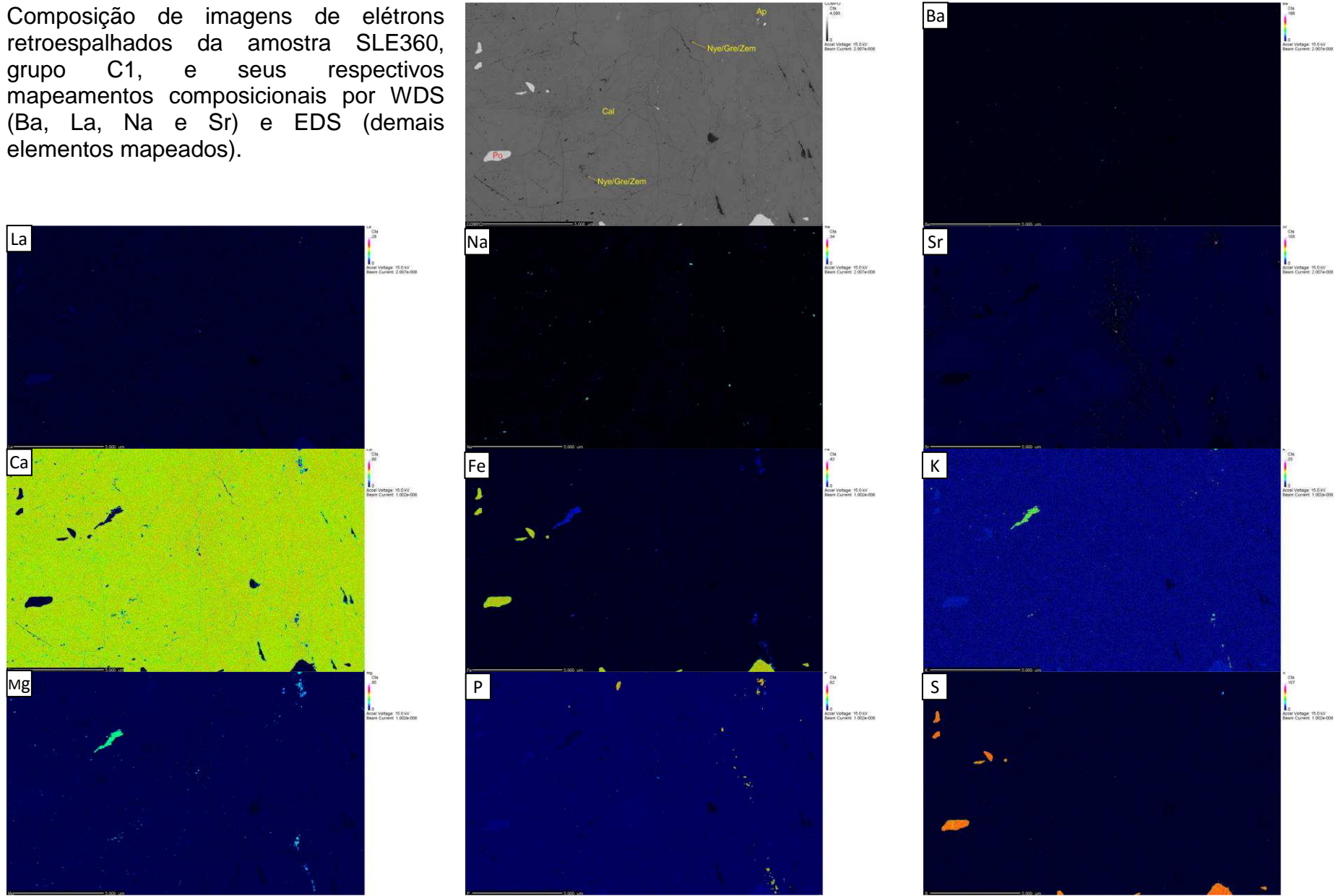
Electron Image 23



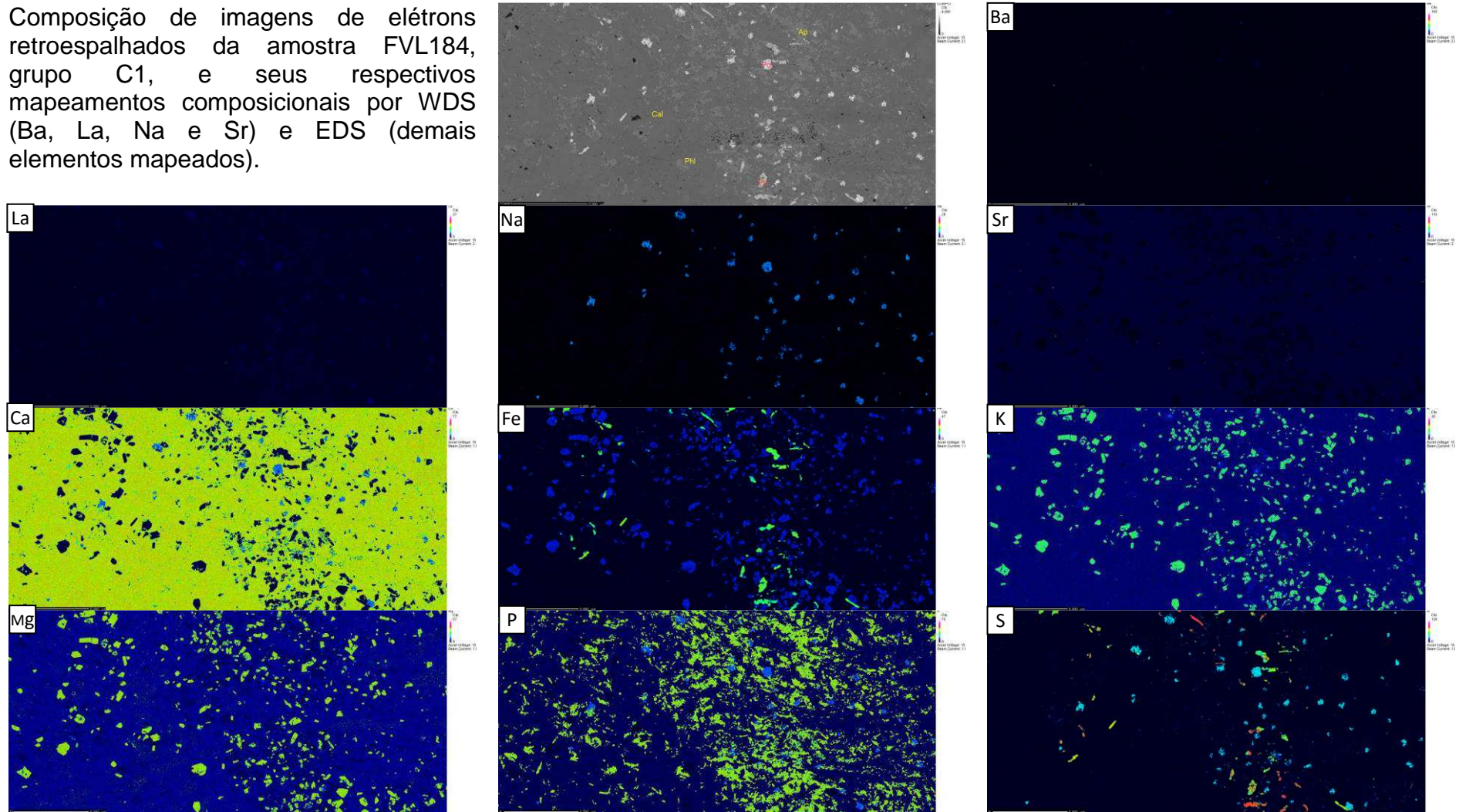
Amostra C85D. Estroncianita, dolomita e monazita



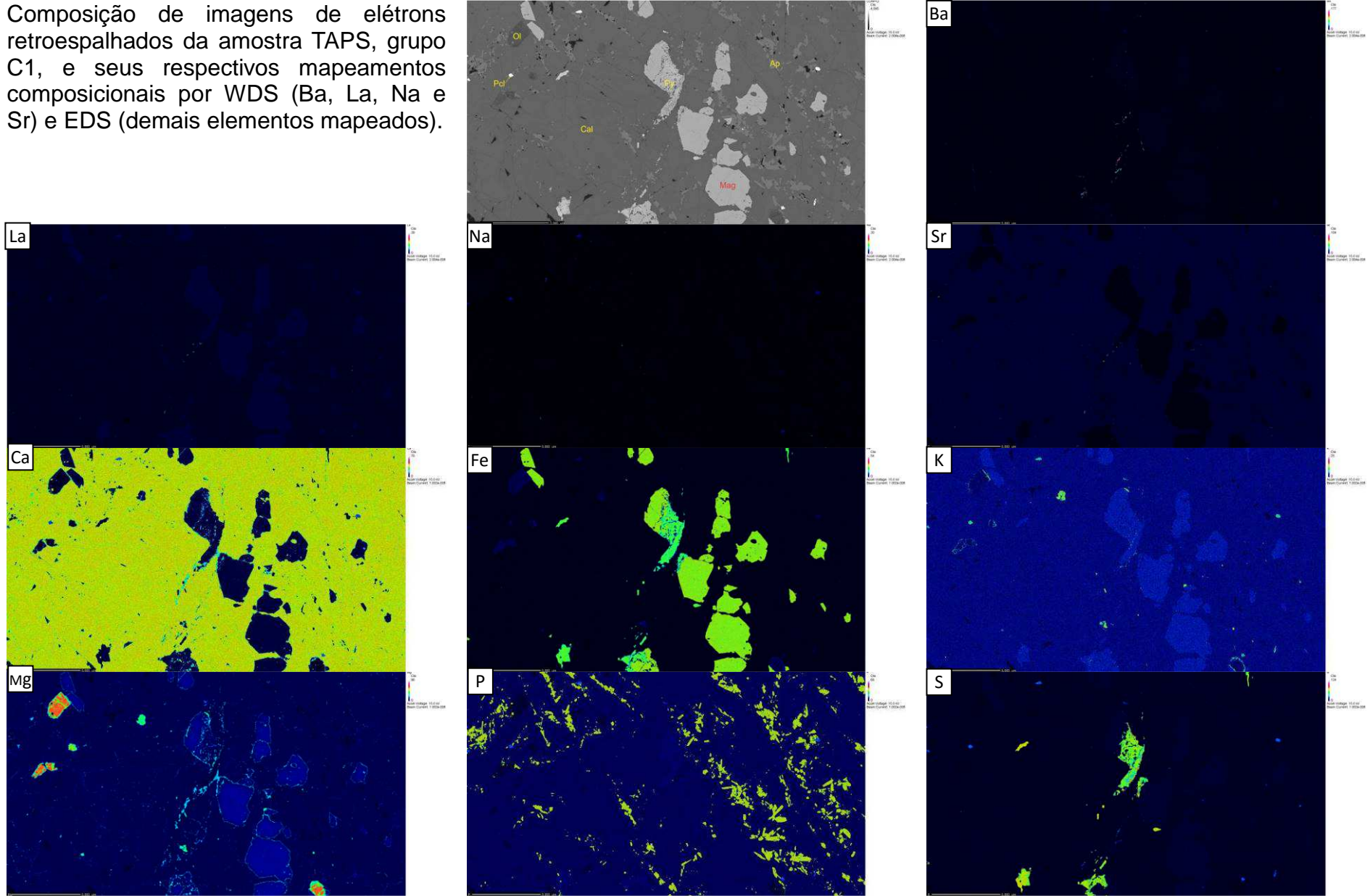
Composição de imagens de elétrons retroespalhados da amostra SLE360, grupo C1, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



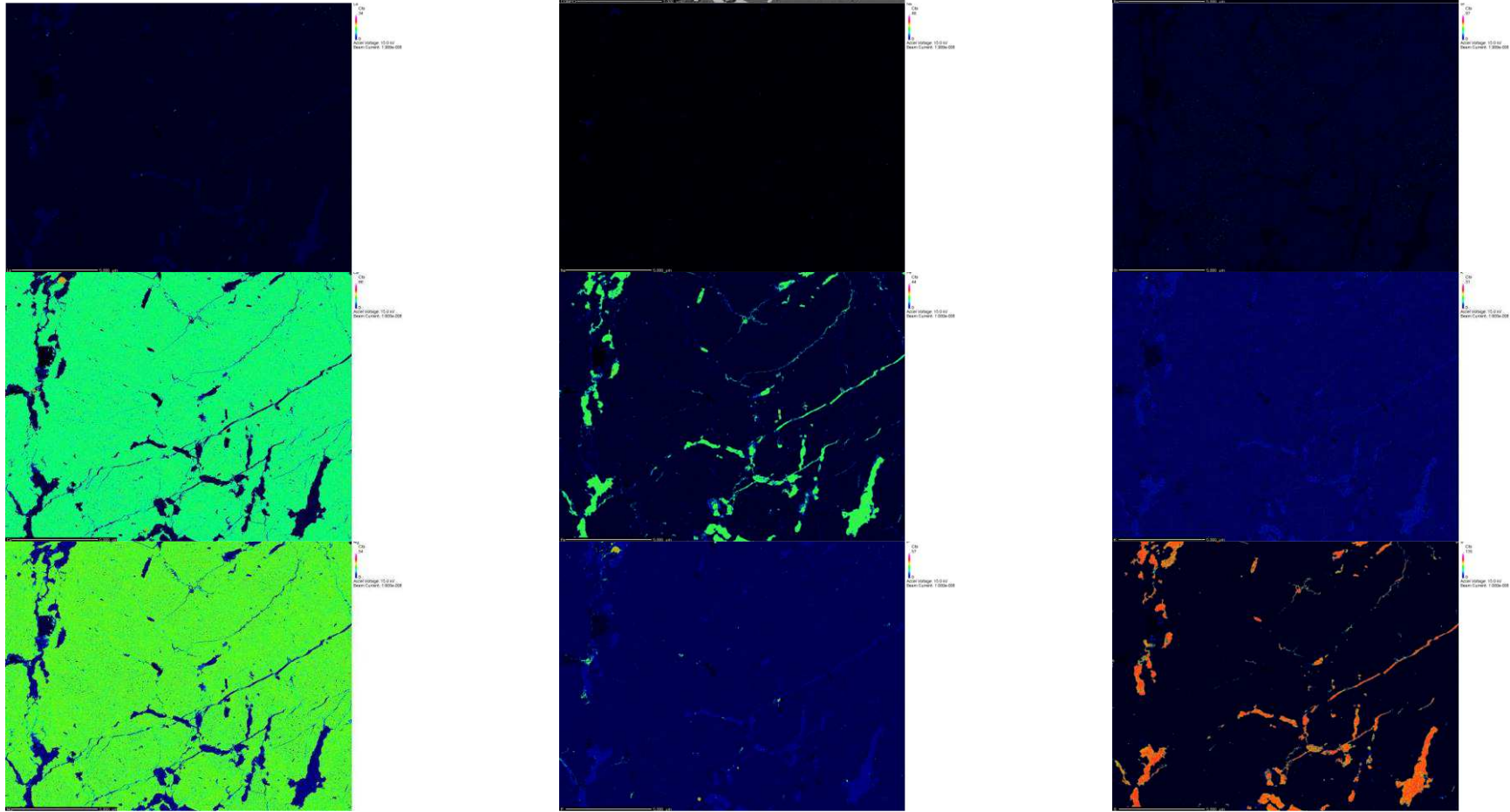
Composição de imagens de elétrons retroespalhados da amostra FVL184, grupo C1, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



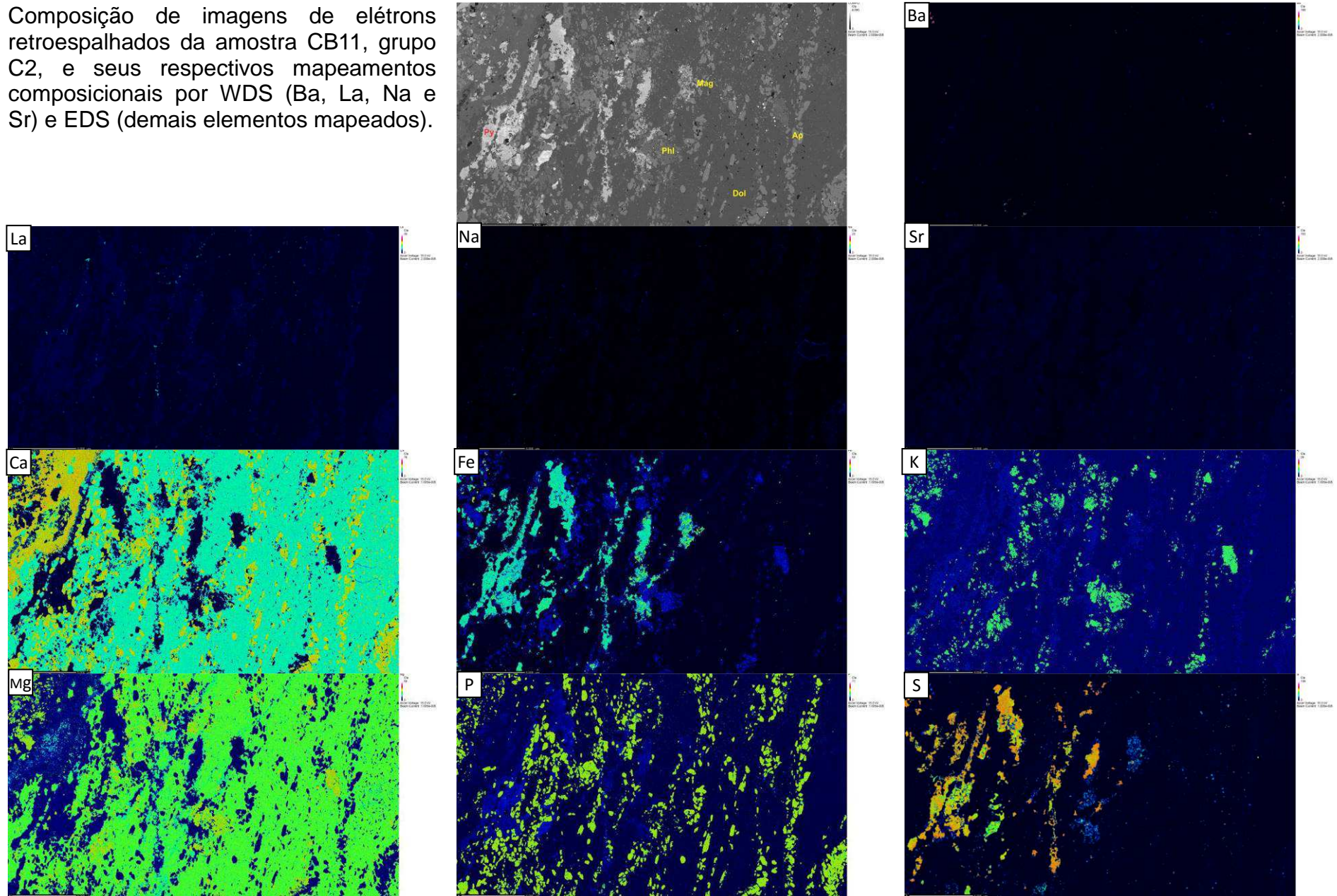
Composição de imagens de elétrons retroespalhados da amostra TAPS, grupo C1, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



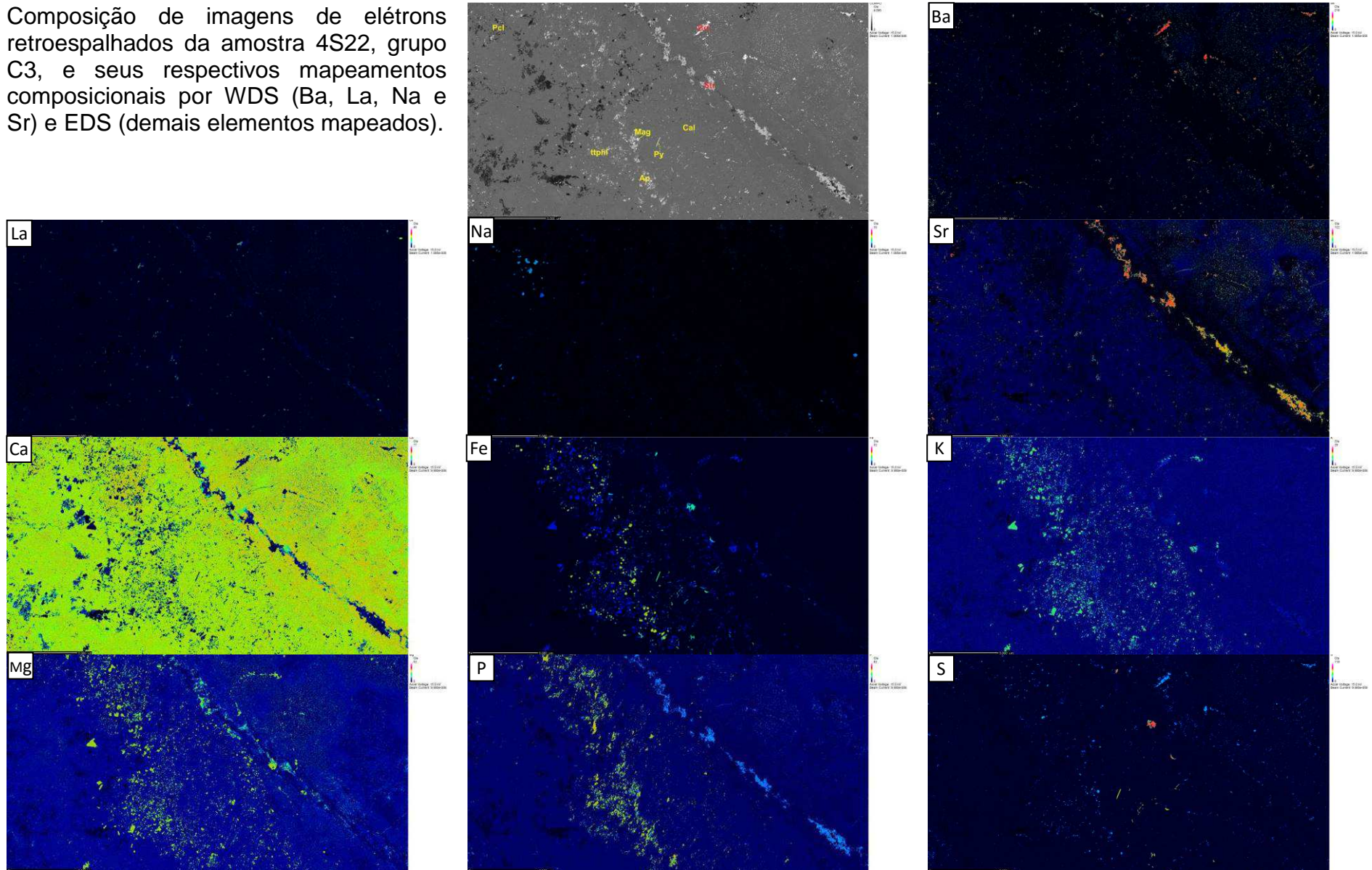
Composição de imagens de elétrons retroespalhados da amostra CB02, grupo C2, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



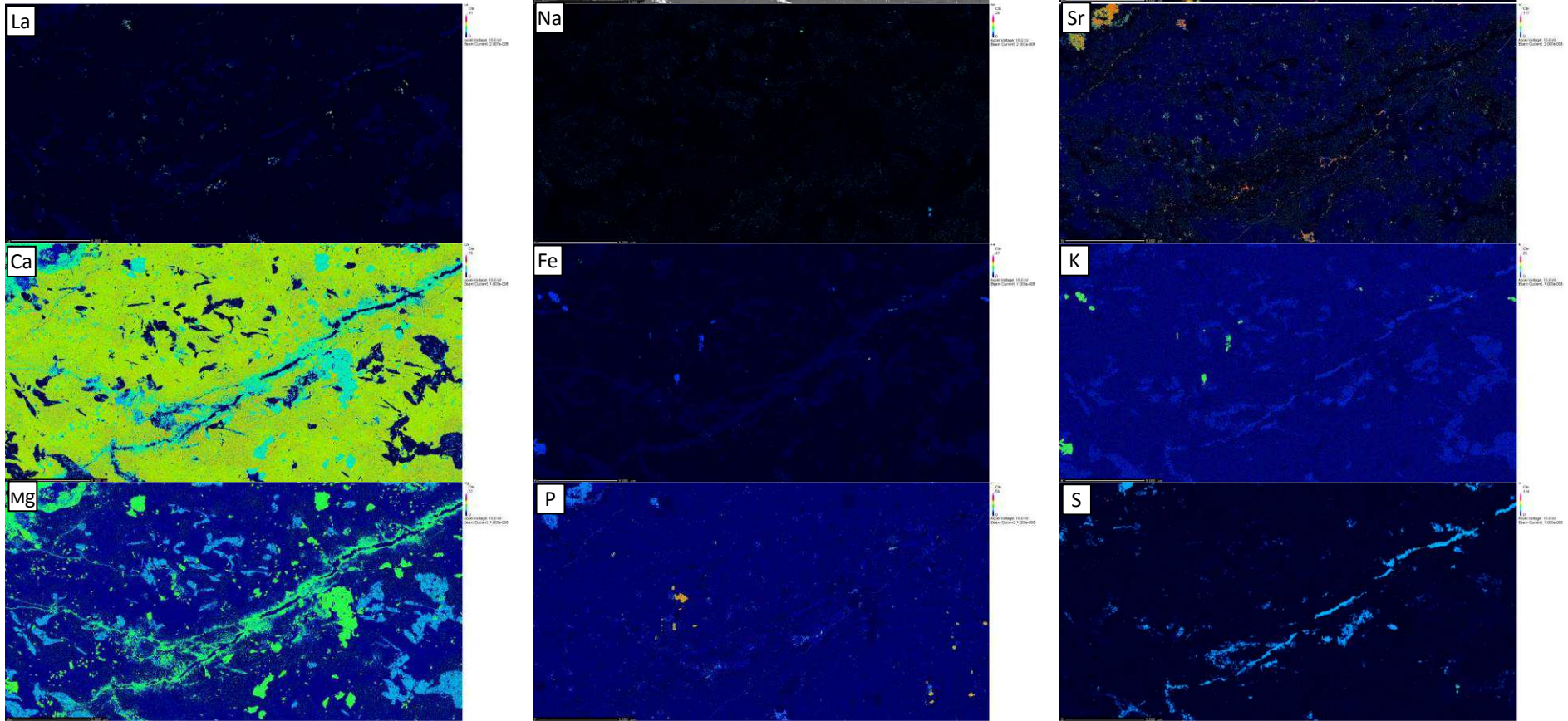
Composição de imagens de elétrons retroespalhados da amostra CB11, grupo C2, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



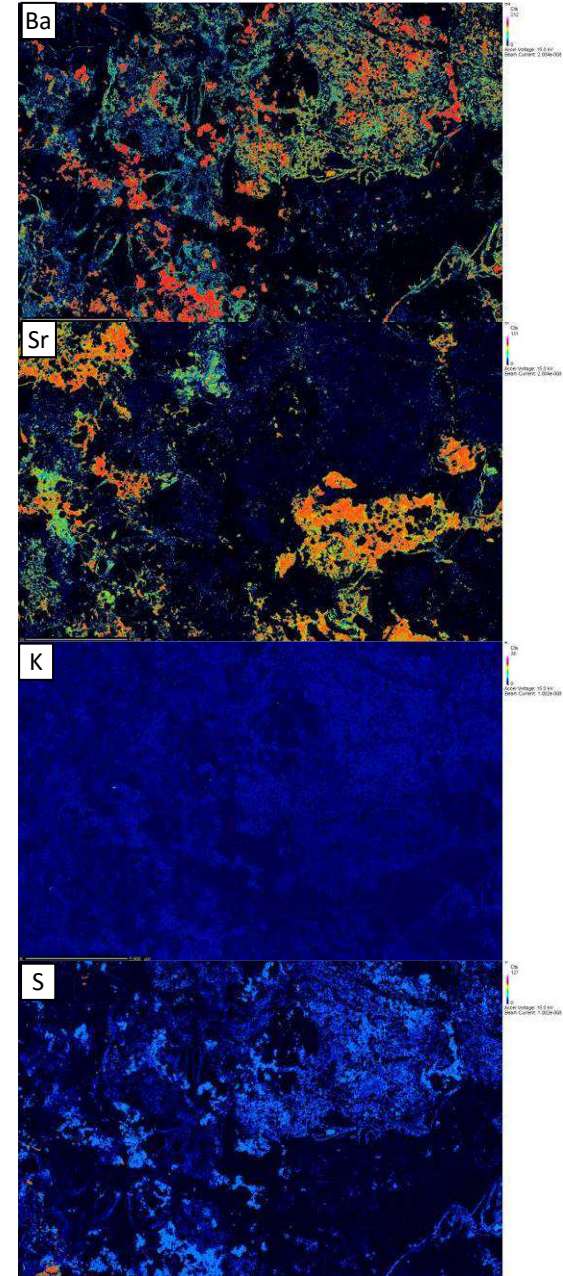
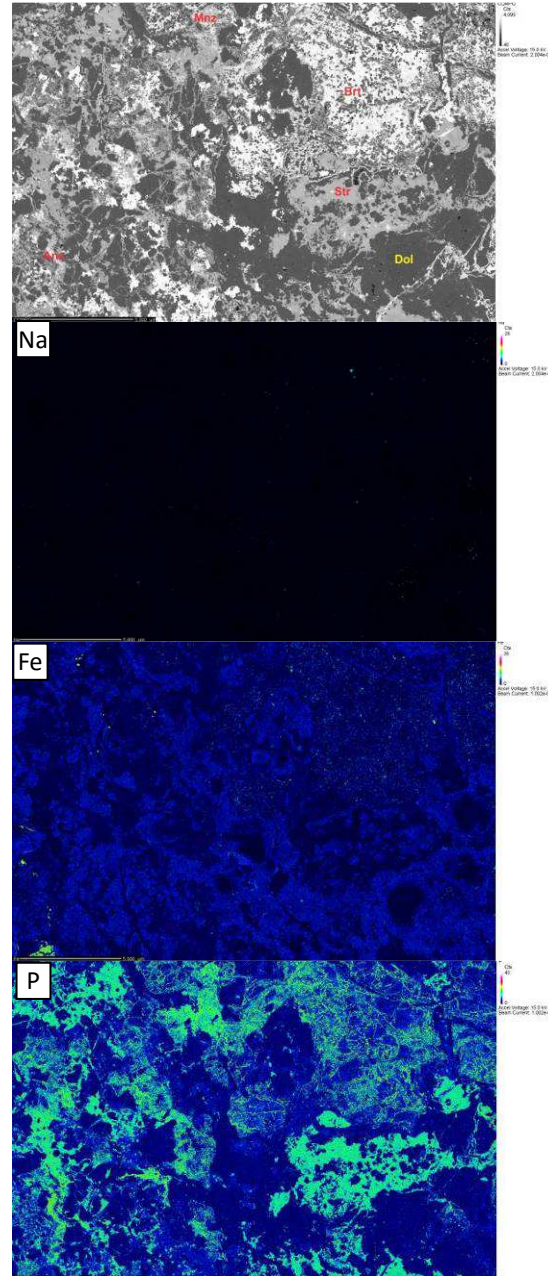
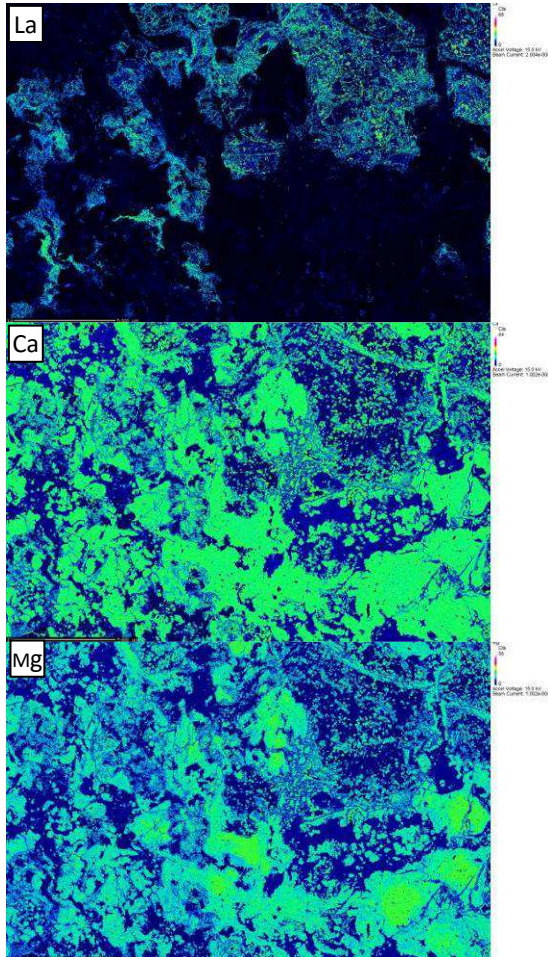
Composição de imagens de elétrons retroespalhados da amostra 4S22, grupo C3, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



Composição de imagens de elétrons retroespalhados da amostra AT139, grupo C3, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).

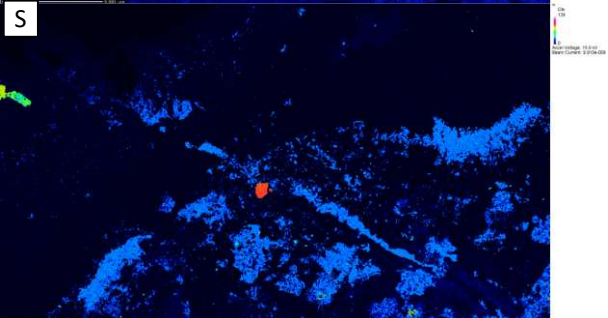
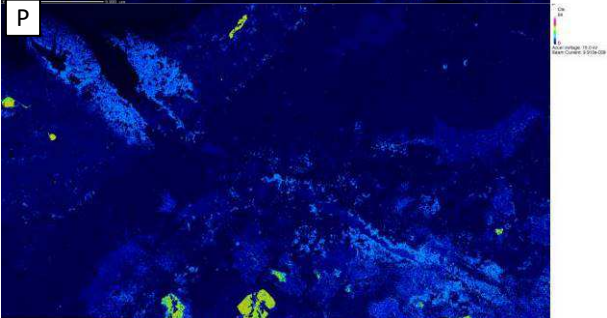
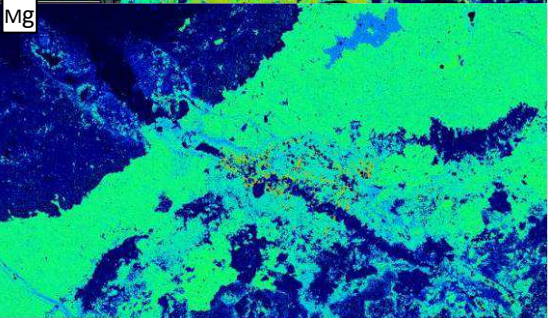
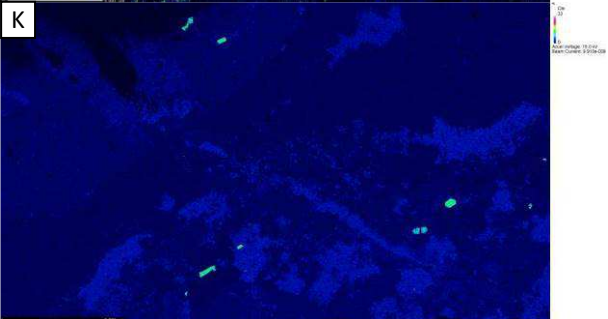
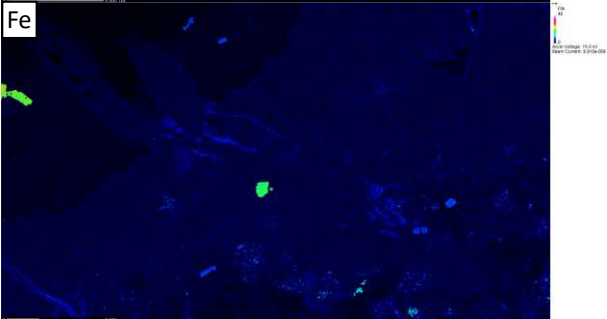
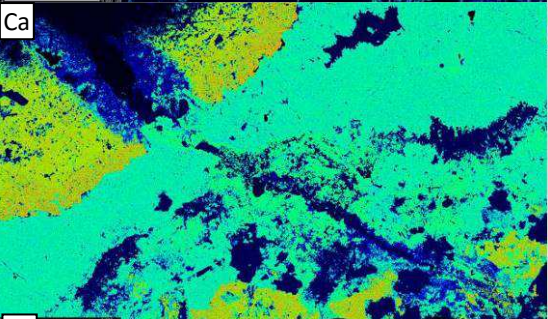
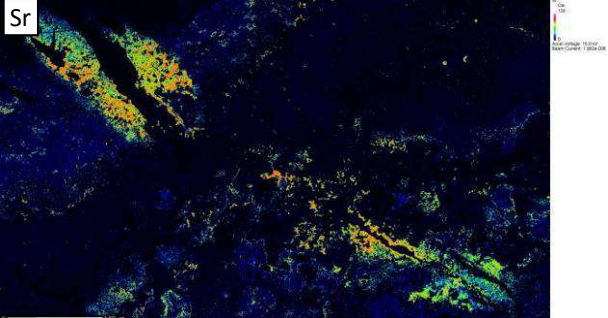
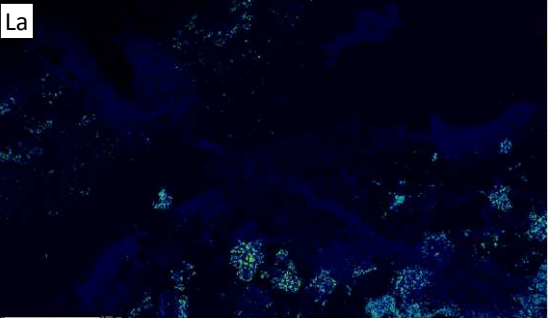
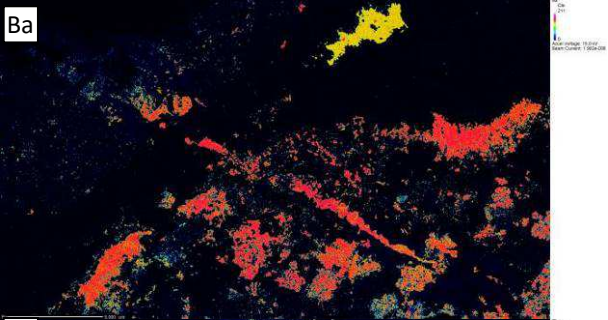
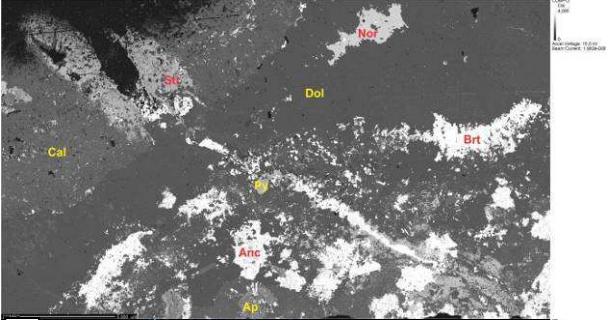


Composição de imagens de elétrons retroespalhados da amostra C85D, grupo C4, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).

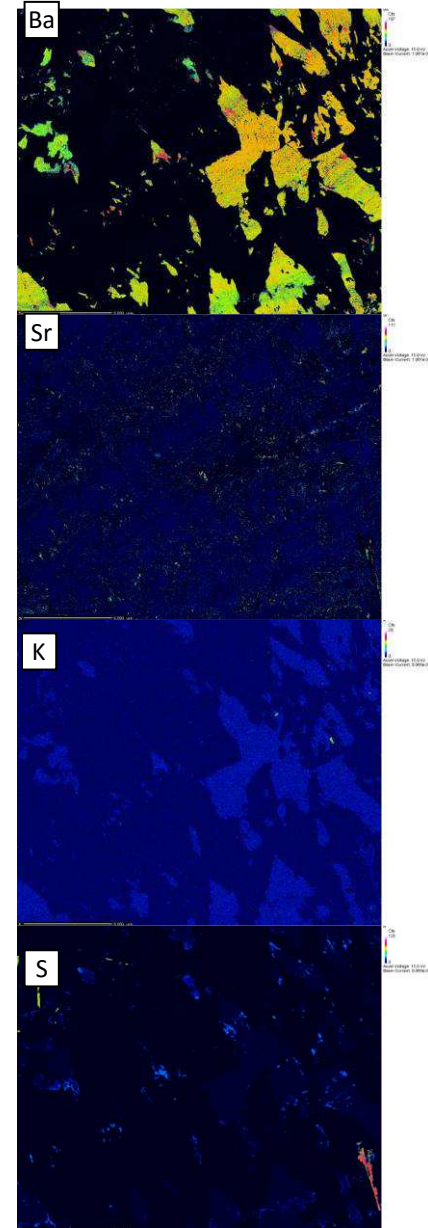
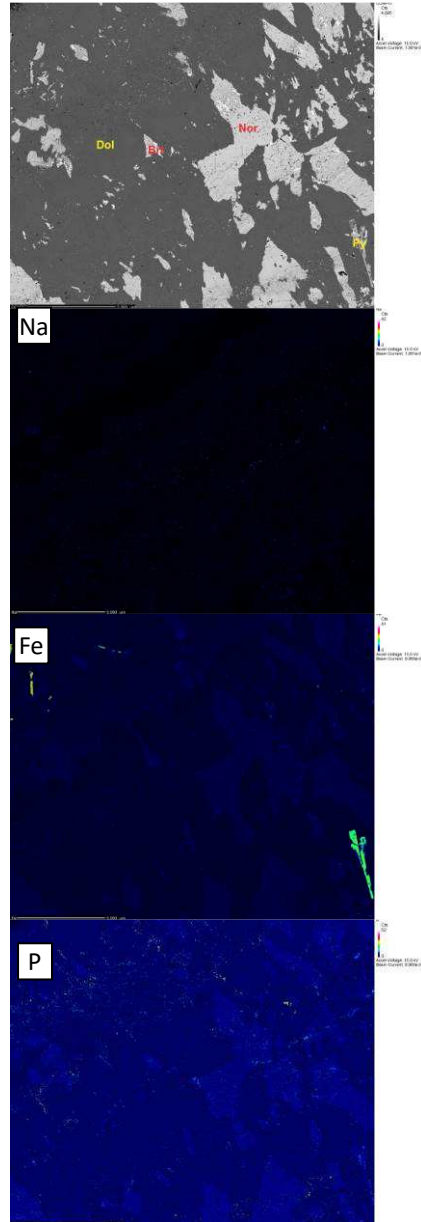
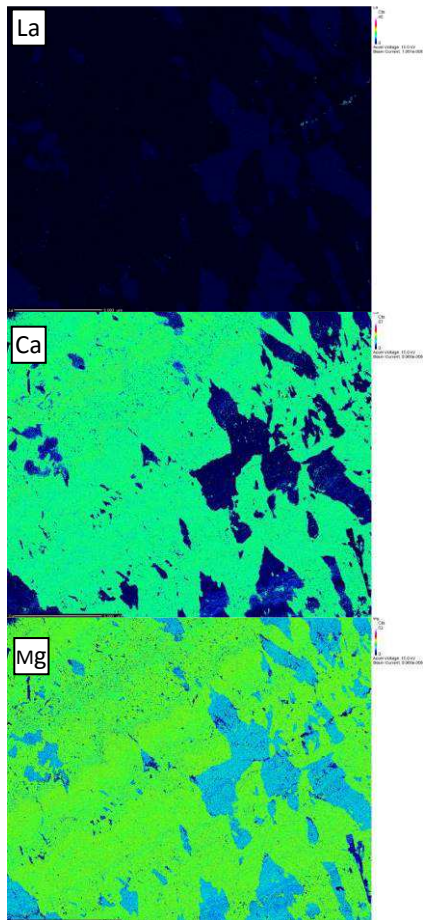




Composição de imagens de elétrons retroespalhados da amostra AT137, grupo C4, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



Composição de imagens de elétrons retroespalhados da amostra C83H, grupo C5, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).



Composição de imagens de elétrons retroespalhados da amostra AT135, grupo C5, e seus respectivos mapeamentos composicionais por WDS (Ba, La, Na e Sr) e EDS (demais elementos mapeados).

