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# Protracted thermal evolution of the Neoproterozoic Araçuaí hot orogen (SE Brazil): consequences for rheology, strain distribution, and deformation analysis

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Abstract:

13 The Araçuaí-Ribeira belt formed during the amalgamation of West Gondwana in the 14 late Neoproterozoic. Its evolution encompasses a main tectono-metamorphic peak at 600-580 15 Ma and a minor one, associated with the final collision with the Western Congo at 540-530 16 Ma. This belt holds characteristics of a hot-orogen: high thermal gradient (>30 °C/km), 17 pervasive partial melting of the middle crust, emplacement of huge volume of magmas 18 resulting from partial melting of the lower crust and underlying mantle, and slow cooling after the peak of temperature. We report 21 new amphibole, biotite and muscovite  ${}^{40}\text{Ar}/{}^{39}\text{Ar}$  ages, 19 20 which complement data already published by our group. Altogether, these data support slow 21 cooling (3-4 °C/Myr) during several tens of million years after the peak temperature 22 (~800 °C at ~600 Ma), followed by faster cooling (>10 °C/Myr) after the final amalgamation 23 of Western Gondwana. We estimate that ~30 Myr were needed to heat the middle crust to the 24 peak of temperature and that anatectic and plutonic bodies remained in the magmatic state 25 over at least 40 Myr. This protracted thermal evolution likely had major effects on the 26 rheology of the middle crust and on the tectonic evolution of this orogen. For instance, correlation of U-Pb zircon crystallization ages and <sup>40</sup>Ar/<sup>39</sup>Ar biotite cooling ages in the 27 28 anatectic core of the orogen denotes a diachronic thermal evolution likely related to a 3D 29 deformation characterized by successive upwelling of anatectic components, along a channel 30 crosscutting pre-existent fabric (channel-flow type). This study also highlights that classical 31 structural analysis techniques relying on changes in pressure or temperature conditions to identify the succession of deformation phases, cannot be used to decipher the tectonic 32 evolution of hot, slowly cooling orogenic belts, where temperature varies weakly over tens of 33 34 millipn years, allowing diachronic episodes of deformation to occur under almost similar 35 pressure and temperature conditions.

- Keywords: Hot orogen, <sup>40</sup>Ar/<sup>39</sup>Ar ages, slow cooling, crust rheology, gravity-induced 3D
  deformation.
- 39 1) Slow cooling of the Neoproterozoic Araçuaí hot orogen
- 40 2) Middle crust partially molten during 40-45 Ma
- 41 3) Rheology of the crust and strain distribution
- 42 4) Thermo-tectonic evolution

### 43 1. Introduction:

Many orogens are characterized by an abnormally high geotherm ( $\geq 30$  °C/km) down to 44 the middle/lower crust (e.g., Peucat et al., 1999; Möller et al., 2000; Collins, 2002; Morisset et 45 al., 2009; Högdahl et al., 2012; Turlin et al., 2018). A common characteristic of these "large-46 47 hot" orogens (Beaumont et al., 2010) is to have cooled very slowly; estimated cooling rates 48 are usually << 10 °C/Myr. Thus, after temperature rose up to the metamorphic peak, it 49 remained high over millions of years. The effects of this peculiar thermal evolution on the 50 mechanical behavior of the lithosphere and on petrologic and geochemical systems are still 51 not fully evaluated (e.g., Jamieson et al., 2011). Such an evolution contrasts with those of 52 "small-cold", "alpine-type" orogens (Beaumont et al., 2010), in which temperature variations 53 during and following orogeny are much faster. Cooling rates are in most cases high (several 54 tens of °C/Myr) and, sometimes, even higher, in particular when fast exhumation follows 55 orogen building (e.g., Zeck et al., 1992; Janots et al., 2009). Rapid temperature variations 56 result in marked changes in the rheology of rocks over short periods of time and successive 57 stages of the orogenic evolution are usually recorded as superimposed deformations occurring 58 at different pressure and temperature conditions. In contrast, in a hot-orogen, temperature 59 decreases very slowly; diachronic deformation episodes may occur under similar temperature 60 conditions and, hence, result in similar rock microstructures and mineralogical assemblages. Consequently, it might be difficult to recognize contemporaneous deformations with 61 62 contrasted kinematics from diachronous deformations separated by 10-15 Myr, for instance.

The processes that result in the formation of "hot orogens" are still poorly understood. Radiogenic heating of a highly thickened continental crust is regarded as the most efficient one (England and Thompson, 1986; Huerta et al., 1998; Vanderhaeghe et al., 2003; Clark et al., 2011; Clark et al., 2015). However, mechanical heating due to shearing or intrusion of multiple batches of mantle-derived magmas may also contribute to generate abnormally high temperatures in the middle to lower crust (Michaut and Jaupart, 2007; Nabelek et al., 2010). At larger scales, it was suggested that slab-retreat might trigger upwelling of asthenospheric
mantle, which may contribute to heating of the overlying plate (e.g., Turlin et al., 2018 and
references therein).

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Three processes may combine to lower the cooling rates in a collision zone:

High temperature in the middle crust decreases its thermal conductivity and hence its
capacity to evacuate heat. A "heat reservoir" may thus form in the middle/lower crust,
allowing for maintenance of an abnormal thermal gradient over long periods of time (Michaut
and Jaupart, 2007; Whittington et al., 2009; Nabelek et al., 2010).

High temperature in the middle to lower crust may trigger widespread partial melting
and emplacement of large volumes of magma in the middle crust. Upon cooling,
crystallization of these magmas releases latent heat of crystallization that compensates, at
least partially, conductive cooling (Michaut and Jaupart, 2011).

- The viscosity of a hot and partially molten middle crust is too low to sustain high topography. When the weight due to orogenic topography exceeds the strength of the hot middle crust, it triggers a gravity-driven flow in the low-viscosity middle to lower crust, which reduces the topography and forms plateaus (e.g., Jamieson et al., 2011 and references therein). This process partly compensates orogenic thickening of the crust through frontal or/and lateral extrusion, limits erosion rates, and, consequently, hinders tectonic exhumation and associated cooling.

88 In Southeast Brazil, the Araçuaí belt (Figure 1) displays evidence of high temperature 89 contractional deformation distributed almost homogeneously all over its internal domain on 90 which focus this study, which is ~200 km large and >500 km long. Pressure-temperature 91 estimates consistently point to synkinematic conditions between ~750 °C/500-600 MPa and 92 ≥800 °C/600-700 MPa (Petitgirard et al., 2009; Cavalcante et al., 2014; Moraes et al., 2015; 93 Richter et al., 2016), supporting a temperature gradient of 30-35 °C/km down to 25 km depth 94 at least. Cavalcante et al. (2018) have also substantiated that anatexis was active in the core of 95 the belt during ~30 Myr. However, cooling rates were poorly constrained. Only two amphibole and three biotite <sup>40</sup>Ar/<sup>39</sup>Ar ages from four samples, suggesting low cooling rate, 96 have been previously published (Petitgirard et al., 2009). Here, we report 21 new <sup>40</sup>Ar/<sup>39</sup>Ar 97 98 ages in amphibole, muscovite and biotite from 16 samples representative of the different 99 tectonic units of the Araçuaí "hot orogen". These new data, combined with previously 100 published U-Pb zircon ages, thermo-barometric data, and structural data from field 101 measurements and Anisotropy of Magnetic Susceptibility (AMS) mapping (Vauchez et al., 2007; Petitgirard et al., 2009; Mondou et al., 2012; Cavalcante et al., 2013, 2014, 2018) 102

103 constrain a protracted tectono-thermal evolution for this orogenic belt and confirm that 104 temperatures in the middle crust remained high over tens of Myr. Based on these results, we 105 discuss the implications of such an evolution for the strain repartition through space and time 106 in this orogenic segment and the difficulties in applying classical tectonic analysis to hot 107 orogens.

### 108 2. Structure of the Araçuaí belt and previous thermo-chronological data

109 The Araçuaí belt (Figure 1) is a segment of a large orogenic system formed between the 110 São Francisco, Salvador, and Congo cratons during the convergence between the South 111 America and Africa proto-continents, which resulted in the formation of Western Gondwana 112 (Hasui et al., 1975; Almeida, 1977; Trompette et al., 1992; Pedrosa-Soares et al., 2007). The 113 bulk orogenic system comprises the Araçuaí-Ribeira and Cabo Frio-West Congo belts (Monié 114 et al., 2012; Egydio-Silva et al., 2018). The convergence lasted at least one hundred millions 115 years and diachronic orogenic climaxes have been substantiated for the Araçuaí-Ribeira 116 orogen (600-570 Ma; e.g., Nalini et al., 2000b; Mondou et al., 2012; Gonçalves et al., 2014; 117 Cavalcante et al., 2018) and for the West Congo belt (540-530 Ma; e.g., Monié et al. 2012). 118 The latter event involved thrusting of the "Cabo Frio Tectonic Domain" upon the eastern 119 Ribeira belt in the Rio de Janeiro province (Schmitt et al., 2004).

120 On the South American side, the Araçuaí-Ribeira belt molds the eastern to southeastern 121 boundary of the São Francisco craton (Vauchez et al., 1994; Egydio-Silva et al., 2018; Figure 122 1). The Ribeira belt forms the southern segment of the orogen. It is characterized by a 123 transpressional tectonic regime, which combined orogen-parallel transcurrent motion with 124 orogen-normal thrusting (Vauchez et al., 1994; Egydio-Silva et al., 2002). Seismic anisotropy 125 measurements (Heintz et al., 2003; Assumpção et al., 2006) suggest that orogen-parallel 126 shearing involved the whole lithosphere (Vauchez et al., 2012). Northward, the connection 127 with the Aracuaí belt is characterized by a curvature of the orogenic fabric from NE-SW to N-128 S (Figure 1) and a progressive transition in strain regime to dominant westward thrusting of 129 allochtonous units onto the São-Francisco craton in the Araçuaí belt (Vauchez et al., 1994; 130 Oliveira et al., 2000; Egydio-Silva et al., 2005; Vauchez et al., 2007; Egydio-Silva et al., 131 2018). These longitudinal variations in orogenic fabric and kinematics are likely related to the 132 termination of the São Francisco craton (Vauchez et al. 1994). Finally, the northern 133 termination of the Araçuaí belt is characterized by dominant northward thrusting of the 134 orogenic units onto the Salvador craton (e.g., Uhlein et al., 1998).

The central Araçuaí belt (Figure 2), where all samples used in this study were collected (location of selected samples in Supplementary Material #1), is composed by four allochthonous domains docked against the São Francisco craton (Oliveira et al., 2000; Vauchez et al., 2007). These domains are from West to East:

139 - The para-autochthonous metasedimentary cover of the craton. Several U-Pb and 140  $^{207}$ Pb/ $^{206}$ Pb ages in zircons > 2 Ga obtained in this domain (e.g., Noce et al., 2000; Silva et al., 141 2002) support that these rocks belong to the craton. Approaching the contact with the 142 allochthonous units, these rocks display a tectonic fabric parallel to the mylonitic fabric of the 143 westernmost allochtonous unit, suggesting that they have been both strongly deformed under 144 high temperature conditions during the Neoproterozoic orogeny. The foliation gently dips 145 eastward and the lineation trends dominantly EW (Figure 2), metapelites contain acicular 146 sillimanite, garnet, and K-feldspar and coarse-grained quartzites contain crystals of sillimanite 147 frequently included in overgrown quartz grains. Shear criteria, although infrequent, 148 consistently point to a top-to-west sense of shear.

149 - The Western Mylonitic Unit (WMU, Figure 2) is thrust westward onto the para-150 autochthonous cover of the craton. This unit comprises mylonites derived from 151 metasediments, which display a foliation that gently dips eastward and bears an EW-trending 152 lineation formed under HT-LP conditions (Petitgirard et al., 2009). The similarity of 153 lithologies and deformation conditions with those of the para-autochthonous cratonic 154 formations hinders a precise definition of the basal contact of the WMU. The main 155 differences between the two units are the presence in the WMU of numerous top-to-west 156 shear criteria (Figure 3a-d), the absence of quartzites, the alternation of metapelites with 157 amphibolites, and the presence of large volumes (up to 40% locally) of anatectic 158 leucogranites in decimetric veins parallel to the mylonitic foliation (Figure 3b-d). There is no 159 evidence of strain localization at the base of the unit; strain is rather homogeneously 160 distributed across the WMU. Indeed, the microstructure of the HT mylonites is similar across 161 the whole unit, varying only as a function of mineralogy. Petitgirard et al. (2009) have 162 determined metamorphic conditions for the WMU mylonites based on garnet-biotite 163 exchange thermobarometers: core-core analyses (or biotite included in garnet) consistently 164 yield 760-780°C (±30°C) and rim-rim analyses, 730-760°C (±30°C) and pressure in the range 165 500-600 MPa. A few ages have been published for this unit. Using the Pb-evaporation 166 technique Noce et al. (2000) have dated two magmatic bodies (Brasilândia and Guarataia plutons) from this unit (Oliveira et al., 2000), which yielded <sup>207</sup>Pb/<sup>206</sup>Pb zircon ages of 595±3 167

168 and 574±2 Ma respectively, later on confirmed by Tadeschi et al. (2016). Petitgirard et al. 169 (2009) have dated two synkinematic leucocratic granites intercalated in the mylonites: one 170 yielded U-Pb ages of 577  $\pm$  9 Ma for zircon and 572  $\pm$  3 Ma for monazite and the other 171 vielded a zircon U-Pb age of  $578 \pm 3$  Ma (Figure 4; Table 1). These authors have reported <sup>40</sup>Ar/<sup>39</sup>Ar ages of ca. 501 and ca. 495 Ma for amphiboles and ca. 474 and ca. 468 Ma for 172 173 biotites from the WMU and the associated Ibituruna svenite, respectively; these preliminary 174 data are integrated in our database (Table 1, Figure 7) and further commented (see 175 Supplementary Material #2 for amphibole AR-414 from the Ibituruna syenite).

176 - The Central Plutonic Unit (CPU; Figure 2) comprises huge volumes of synkinematic 177 garnet-bearing granodiorites and tonalites emplaced in metasediments (e.g., Mondou et al., 178 2012; Narduzzi et al., 2017). These plutonic bodies (the "São Vitor" and "Galileia" batholiths) 179 display a consistent magmatic fabric (Figure 5) that evolves eastwards from a gently 180 eastward-dipping foliation bearing a dominantly EW-trending lineation to a steeply-dipping 181 to subvertical foliation bearing a lineation that switches from subvertical to subhorizontal 182 over intervals of a few tens of meters. In the easternmost part of the CPU, Mondou et al. 183 (2012) have substantiated the presence of a corridor in which the magmatic foliation is sub-184 horizontal and bears a strong orogen-parallel, NS-trending magmatic lineation. In several 185 places, the granodiorites and tonalites contain elongated dioritic to gabbroic lenses (Vauchez 186 et al., 2007; Gonçalves et al., 2014; Narduzzi et al., 2017) implying in a contribution of 187 mantle-derived magmas to the formation of the batholiths (Figure 5c).

188 Metamorphic conditions in the metasedimentary country rocks of the CPU are still 189 poorly constrained due to poor outcropping conditions, but they tend to decrease eastwards as 190 supported by the occurrence of staurolite and, locally, of muscovite in garnet-sillimanite 191 bearing metapelites of the easternmost part of the CPU. These minerals, indicative of 192 temperatures  $\leq 650$  °C (Nalini et al., 2015), are only present in the easternmost CPU.

Several ages have been obtained for CPU granitoids close to the contact with the WMU (Figure 4). Zircons from a tonalite sill yielded a U-Pb age of  $580 \pm 8$  Ma (Petitgirard et al., 2009). Two leucocratic veins interlayered with mylonitic metasediments yielded zircon U-Pb ages of  $587 \pm 5$  and  $579 \pm 8$  Ma (Mondou et al., 2012). Zircons from a sample of tonalite collected ~80 km south of the previous locations and ascribed to the CPU western boundary yielded an age of  $597 \pm 4$  Ma (Gonçalves et al., 2014). 199 The São Vitor tonalite was first dated at 576  $\pm$  5 and 569  $\pm$  9 Ma (Noce et al., 2000; 200  $^{207}\text{Pb}/^{206}\text{Pb}$  ages on zircons) then, Mondou et al. (2012) obtained one U-Pb and two  $^{207}\text{Pb}/^{206}\text{Pb}$ 201 ages on zircons of 583  $\pm$  4, 583  $\pm$  4, 582  $\pm$  6, and 585  $\pm$  4 Ma, respectively.

The Galileia tonalitic/granodioritic batholith was dated at  $594 \pm 6$  Ma (Nalini et al., 203 2000b;  $^{206}$ Pb/ $^{238}$ U on zircons). Subsequently, Mondou et al. (2012) have dated samples from 204 domains of this batholith presenting contrasted fabrics. U-Pb zircon ages from these domains 205 with different kinematics are fairly consistent between 579 and 583 Ma.

The muscovite-bearing Palmital peraluminous granite was dated at  $582\pm 2$  Ma (Nalini et al., 2000a) and the cordierite-garnet-biotite-bearing Wolf leucogranite at  $582\pm 5$  Ma (Noce et al., 2000) and  $585 \pm 4$  Ma (U-Pb on zircons; Mondou et al., 2012). These two granites (Figures 2, 4) likely result from melting of aluminous metapelites contemporaneous to the melting of the lower crust and underlying mantle that formed the tonalitic/granodioritic magmas.

212 - Intermediate, discontinuous kinzigitic unit (Figures 2 and 6). The steeply dipping, 213 medium temperature, staurolite-bearing metasediments that crop out in the easternmost part 214 of the CPU are separated from the gently dipping Eastern Anatectic Unit (EAU; see below) 215 by a discontinuous unit of partially molten kinzigites with a steeply-dipping foliation 216 (Oliveira et al., 2000; Mondou et al., 2012). In contrast with metasediments of the 217 easternmost CPU, these kinzigites contain biotite, garnet, cordierite, sillimanite, but no 218 staurolite or muscovite. The tectonic contact between these kinzigites and the CPU is 219 therefore characterized by a metamorphic gap, despite the similar subvertical fabric recorded 220 by the two units. This suggests that the intermediate kinzigitic unit, initially equilibrated at 221 deeper levels, has been thrust upon the CPU and that, subsequently, the tectonic contact and 222 associated fabric have been verticalized.

223 - The Eastern Anatectic Unit (EAU, also known as "Carlos Chagas leucogranite"; 224 Figures 2 and 6) is more than 300 km long and 50 to 100 km wide. It comprises peraluminous 225 metatexites, diatexites, and leucogranites containing quartz, K-feldspar, garnet, biotite, 226 sillimanite, ± rutile, ± cordierite (e.g., Cavalcante et al., 2013). Some garnet-bearing 227 leucogranites are almost free of biotite (Figure 6c). Rather than a batholith, the EAU 228 represents the anatectic core of the Araçuaí belt, which was intruded by several late orogenic 229 charnockitic plutons (~520 Ma). This unit is characterized by a widespread, penetrative 230 magmatic fabric marked by a magmatic foliation that dominantly dips gently to moderately in

231 various directions due to open folds that affected an initial low-angle foliation (Cavalcante et 232 al., 2013). Detailed mapping of magnetic foliations and lineations across the EAU revealed a 233 complex flow field, characterized by a western domain where gently dipping foliations bear 234 lineations that progressively rotate from SW in the south to NW in the north (Figure 2) and by 235 an eastern domain where subvertical NS-trending foliations bear sub-horizontal, orogen-236 parallel lineations (Cavalcante et al., 2013). The eastern boundary of the anatectic unit is 237 defined by a progressive transition to migmatitic kinzigites (Figure 6d) in which are 238 intercalated layers of orthopyroxene-bearing granulites.

239 Cavalcante et al. (2014, 2018) using the Ti-in-quartz (TitaniQ), the Zr-in-rutile 240 geothermometers in anatexites and Fe-Mg exchange geothermobarometers in neighbouring 241 kinzigites obtained temperatures of 780-800 °C and pressures in the range of 650-700 MPa; 242 these P-T conditions are interpreted as those under which crystallization of anatexites began 243 during cooling. These thermobarometric estimates are in good agreement with those obtained 244 for the migmatitic kinzigites by Munhá et al. (2005) using Fe-Mg exchange 245 geothermobarometers and, more recently, by Richter et al. (2016) from phase equilibrium 246 modeling. Such P-T conditions are consistent with the presence of cordierite (Harley et al., 247 2002; Pattison et al., 2003; Harley, 2004) in the studied rocks and also of rutile that, 248 according to Le Breton and Thompson (1988), crystallizes at T ≥760 °C. Evidence of 249 destabilization of restitic biotites in several samples further supports temperatures >800 °C 250 (Le Breton and Thompson, 1988; Vielzeuf and Holloway, 1988; Pattison et al., 2003). As 251 highlighted by Cavalcante et al. (2014), such high temperatures probably allowed for melt 252 fractions >30%, which may have drastically reduced the viscosity of the anatectic middle 253 crust (Rosenberg and Handy, 2005; Vanderhaeghe, 2009). Moreover, the contrast in peak 254 equilibrium temperatures supports a major tectonic contact between the central (CPU) and 255 eastern (EAU) units.

256 Vauchez et al. (2007) reported a SHRIMP U-Pb zircon age of  $575 \pm 3$  Ma for a diatexite 257 from the EAU. Additional U-Pb SHRIMP zircon ages from anatectic granite, diatexites, and 258 metatexites substantiate a broad variability in U-Pb zircon ages across the EAU (Cavalcante 259 et al., 2018). Several diatexites and anatectic granites yielded ages in the range 597-593 Ma, 260 whereas the remaining anatectic samples were dated between 589 and 572 Ma. Ages are on 261 average slightly older in the northwest and younger in the southeast, but the trend is not clear-262 cut (Figure 5). Richter et al. (2016) reported a similar age range (595-570 Ma) for samples 263 from the easternmost "Nova Venecia" kinzigitic unit of the Araçuaí belt. These data indicate that anatexis was already underway in the middle crust (~25 km) of the Araçuaí belt by
~600 Ma and that it remained active until at least 570 Ma (Cavalcante et al., 2018).

# 266 3. ${}^{40}Ar/{}^{39}Ar$ ages

267 Ten samples were collected across the CPU: two synkinematic tonalites from the 268 contact between this domain and the WMU, five synkinematic granodiorites/tonalites from 269 the São Vitor and Galiléia complexes showing a well developed magmatic fabric, one 270 synkinematic leucogranite (Wolf granite), one muscovite-bearing peraluminous granite from 271 the Palmital plutonic body, and one orthogneiss from the country rock (Figure 7). The U-Pb 272 zircon ages of six of the selected plutonic rocks are close to 580 Ma (Mondou et al., 2012). 273 Biotite was separated and analyzed for the 10 samples; amphibole was analyzed in four 274 tonalites, and muscovite in the peraluminous Palmital granite (see Table 1).

Six samples from the EAU were selected among the 12 recently dated by Cavalcante et al. (2018): four anatectic granites, one diatexite and one metatexite (Figure 4, Table 1). Their U-Pb zircon ages range between 597 and 572 Ma. All selected samples display a welldeveloped magmatic foliation and are free of solid-state deformation (Cavalcante et al., 2013). Only biotite was dated since amphibole was not found in anatexites.

The location of the samples for which  ${}^{40}$ Ar/ ${}^{39}$ Ar ages were obtained in this study is shown on Figure 7, which also integrates  ${}^{40}$ Ar/ ${}^{39}$ Ar ages obtained previously (Table 1, 2 amphibole and 3 biotite ages from Petitgirard et al., 2009). Samples from the CPU were analyzed at Geosciences Montpellier (University of Montpellier, France) and those from the EAU at the Geochronological Research Center of the University of São Paulo (Brazil).  ${}^{40}$ Ar/ ${}^{39}$ Ar diagrams are shown on Figures 9 and 10. Full analytical data are available in the Supplementary Material #3 and #4.

287 In the CPU, <sup>40</sup>Ar/<sup>39</sup>Ar cooling ages on amphibole, muscovite, and biotite show a larger dispersion than the U-Pb ages on zircon; they range from about 550 to 470 Ma (Figure 7). 288 289 This dispersion reflects both the difference of closure temperatures between amphibole and 290 micas and the variability from sample to sample. Amphiboles from tonalite/granodiorite 291 samples provide nearly undisturbed age spectra with plateau ages ranging from  $549.2 \pm 5.6$ 292 Ma to 500±5 Ma (Figure 8). Biotites from the São Vitor and Galileia tonalites/granodiorites yielded  ${}^{40}\text{Ar}/{}^{39}\text{Ar}$  ages between 489.5  $\pm$  5.4 Ma and 474.5  $\pm$  4.4 Ma; those of the Wolf 293 294 leucogranite  $491.9 \pm 5.8$  Ma and those from the Palmital granite and one orthogneiss sample 295 overlap at 484.1  $\pm$  4.7 Ma. Muscovite from the Palmital granite yield plateau age of 487.6  $\pm$ 4.5 Ma for more than 90% of the released <sup>39</sup>Ar (Figure 8). Two samples of tonalite collected 296

close to the contact between the WMU and the CPU yield older cooling ages for amphibole ( $549.2 \pm 5.6$  and  $541.6 \pm 7.7$  Ma) and biotite ( $532.2 \pm 5.4$  and  $507.5 \pm 5.3$  Ma). Although these ages are reliable from the analytical point of view, their geological significance remains unclear since for neighboring samples collected on both sides of this contact amphibole and biotite yield younger cooling ages in the range 510-470 Ma.

In the EAU, biotite ages span from  $485.8 \pm 4.4$  Ma to  $458.5 \pm 4.2$  Ma with the oldest age obtained for the northernmost sample and the youngest one for the southernmost sample (Figure 9; Supplementary Material #4). This distribution is correlated with the variation in U-Pb zircon ages across this domain.

# 306 4. Discussion

# 307

### 4.1. Origin and duration of the heating episode

308 Considering the current crustal thickness of ~40 km (Assumpção et al., 2013) and the paleopressures of 0.6-0.7 GPa recorded by rocks currently exposed in the central Araçuaí 309 310 orogen (Petitgirard et al., 2009; Cavalcante et al., 2014; Richter et al., 2016), the orogenic 311 crustal thickness was likely >60 km. Temperatures of 740 to ≥800 °C were recorded at 20-25 312 km depth (Petitgirard et al., 2009; Cavalcante et al., 2014; Richter et al., 2016) suggesting an 313 average thermal gradient >30 °C/km within the upper and middle crust (likely lower in the 314 lower crust). Throughout the orogen, the magmatic bodies are either embedded in metapelitic 315 rocks or formed by local anatexis of metapelitic rocks. This supports that the orogenic middle 316 crust of the Araçuaí belt, down to 25 km depth at least, was mostly composed by metapelites 317 with some amphibolite and quartzite intercalated layers. Although the content in heat-318 producing elements of these metapelites is not known, such a middle crust likely had a rather 319 high radiogenic heat production, which probably contributed significantly to heating (Clark et 320 al., 2011; Clark et al., 2015). In response to heating, it underwent prograde metamorphic 321 reactions that produced free water favoring extensive partial melting (Weinberg and Hasalová, 322 2015).

The presence of diorite/gabbros mingled within the granodioritic/tonalitic bodies of the CPU (Figure 5c) indicates that partial melting also affected the underlying mantle (Mondou et al., 2012; Gonçalves et al., 2014). Heating in the lithospheric mantle may be due to enrichment in heat-producing elements resulting from metasomatic reactions (Neves et al., 2008) during pre-orogenic rifting of the lithosphere along the eastern border of the São Francisco craton (Cunningham et al., 1996; Uhlein et al., 2007). 329 Available U-Pb ages on zircons are remarkably consistent across the various geological 330 units that shape the central part of the Araçuaí orogen. Similar ages have been reported in the 331 northern (Siga Jr et al., 1987) and southern portions of the belt, including its connection with 332 the Ribeira transpressional belt (Silva et al., 2005; Bento dos Santos et al., 2010). Ages 333 obtained in the EAU (Cavalcante et al., 2018) and in the kinzigites that bound it eastwards 334 (Richter et al., 2016; Melo et al., 2017) support that by ~600 Ma the middle/lower crust (0.6-335 0.7 GPa) of the Araçuaí orogen had reached temperatures ~800 °C and was already partially 336 molten, producing garnet-rich aluminous magmas. Following this metamorphic peak, huge 337 volumes of synkinematic granodioritic/tonalitic magmas were emplaced in the CPU. They 338 systematically display a magmatic fabric that, although variable through the whole CPU, is 339 always consistent with the fabric of the country rock, and their ages are in the range 585-575 340 Ma independently of the orientation of their magmatic fabric (Mondou et al., 2012). In this 341 plutonic complex, only a few ages older than 600 Ma have been obtained (Silva et al., 2005).

342 The data support that contractional tectonics and crustal thickening started significantly 343 earlier than 600 Ma. A rough estimate may be obtained based on data from the EAU 344 considering heating rates in the range of 5-20 °C/Myr (Harris et al., 2000 and references 345 therein) or 8-15 °C/Myr, as recently deduced from allanite and monazite dating in the central Alps by Janots et al. (2009). Assuming an initial temperature of ~400 °C at 20-25 km depth 346 347 (McKenzie et al., 2005), heating up to 800 °C would have required between 27 and 50 Myr. 348 This would imply that deformation producing thickening and prograde metamorphism in the 349 Araçuaí belt started before 630 Myr ago. Such a delay between the initiation of the orogeny 350 and the occurrence of widespread partial melting is in agreement with estimates from models 351 for the southern India developed by Clark et al. (2015). It is also consistent with the time 352 intervals (20-60 Myr) between the initiation of collision and melting of the middle/lower 353 crust under peak metamorphism conditions, estimated for the southern Tibet and the High 354 Himalayas or the Canadian Cordillera (e.g., Vanderhaeghe and Teyssier, 2001b and 355 references therein; Zhang et al., 2004; Guo and Wilson, 2012).

The granodioritic/tonalitic bodies of the CPU yield consistent ages in the range 590-570 Ma. These plutonic units display a magmatic fabric parallel to the solid-state fabric of their country rocks, of the mylonites in the WMU, and of the intermediate kinzigitic unit between the CPU and EAU. This supports synkinematic emplacement of huge volumes of granodioritic and tonalitic magmas in the middle crust (Vauchez et al., 2007; Mondou et al., 2012) during the temperature climax, the magmas likely resulting from partial melting of the lower crust, with minor contribution from mantle melting, as evidenced from mixing withdioritic and gabbroic magmas (Gonçalves et al., 2014).

364 Younger ages obtained on several late- and post-collisional granitic bodies (Silva et al., 365 2002, 2005; Mondou et al., 2012) highlight that magmatic pulses occurred over a very long 366 period of time until, at least, 500 Ma. Among the late magmatic bodies, the "Ibituruna" 367 Syenite in the CPU (U-Pb zircon age of 530 Ma; Petitgirard et al., 2009) and the "Padre 368 Paraíso" charnockitic suite in the EAU (U-Pb zircon ages of ~520 Ma; Noce et al., 2000; 369 Mondou et al., 2012) still have a poorly understood origin. Their compositions imply 370 nevertheless that rather high temperature conditions subsisted in the lower crust and 371 underlying mantle up to these late stages of the evolution of the Araçuaí belt. It is worth 372 noticing that the Ibituruna syenite (~530 Ma) has a magmatic fabric (foliation and lineation) 373 parallel to the solid-state fabric in the surrounding HT mylonites (Petitgirard et al., 2009), 374 whereas the charnockites crosscut the tectonic fabric of the Araçuaí belt (e.g., Oliveira et al., 375 2000; Mondou et al., 2012). Interestingly, these late magmatic events in the Aracuaí belt are 376 coeval with the main tectono-metamorphic event in the West Congo belt in Angola (Monié et 377 al., 2012) and in the "Cabo Frio Tectonic Domain" (Schmitt et al., 2004). They might, 378 therefore, record limited reactivation of the Araçuaí belt in response to the formation of the 379 "Congo-Cabo Frio" belt during the final collision between the African and South American 380 proto-continents at 540-530 Ma.

381

### 4.2. Cooling rates

In this section, we will only consider U-Pb and <sup>40</sup>Ar/<sup>39</sup>Ar ages obtained by our group (Table 1; Vauchez et al., 2007: Petitgirard et al, 2009; Mondou et al., 2012; Cavalcante et al., 2018; this work), for which the location of samples, the definition of the rock type and, in case of magmatic rocks, the synkinematic or post-kinematic emplacement and absence of solid-state reworking are well known. This choice does not alter the results, since there is a good agreement between the ages obtained in different studies for rocks from the Araçuaí belt.

Since our goal was to estimate the cooling temperature at the regional scale, to define the minimum starting temperature of the cooling path we have used the equilibrium temperatures estimated for the metamorphic country rocks (~750 °C; Petitgirard et al., 2009) and the U-Pb zircon ages of synkinematic magmas in the WMU (577-578 Ma; Petitgirard et al., 2009). For the anatexites of the EAU, we have considered U-Pb zircon ages obtained across the domain (597-570 Ma; Cavalcante et al., 2018) and the maximum temperatures estimated for the anatectic rocks using the Ti-in-Quartz (~800 °C, Cavalcante et al., 2014) and 395 Zr-in-Rutile thermometers (790 °C, Cavalcante et al., 2018). These temperatures are not 396 necessarily representative of the metamorphic peak conditions, since the magmas were 397 already crystallizing and thus cooling, but they rather provide a robust value for the starting 398 temperatures of the cooling path. Finally, for the youngest anatexites of the EAU (570-578 399 Ma), we have considered that their Ti-in-Zircon temperatures (720-740 °C; Cavalcante et al., 3018) represent the minimum value of the equilibrium temperature at this time.

401 Figure 10 summarizes all ages obtained by our group for the Araçuaí belt. Zircon U-Pb 402 ages from synkinematic leucogranites in mylonites from the WMU, granodiorites/tonalites from 403 the CPU, and anatexites from the EAU spread from ~600 Ma to ~570 Ma with a clear 404 concentration around 580 Ma (19/29 ages between 575-585 Ma, 8/29 between 585 and 600 Ma), 405 supporting that the metamorphic peak, partial melting, and tonalitic/granodioritic magmatism 406 occurred during this period of time. To estimate a mean cooling rate, we use the median value of 407 584 Ma ( $\sigma$  = 7) calculated based on 27 zircon ages (excluding the late Ibituruna svenite AR-414 408 and the orthogneiss AR-722). Temperature and pressure estimates support that, by ~600-580 Ma, metamorphic temperature at 20-25 km depth was in the range of 750 °C (WPU, Petitgirard et al., 409 410 2009) to ≥800 °C (EAU; Cavalcante et al., 2014). These values crudely define the minimum 411 starting temperature of the cooling path (Figure 10).

412 Almost all dated minerals are of magmatic origin, except the recrystallized biotite 413 extracted from orthogneiss AR-722, which has an U-Pb zircon age of  $2103 \pm 11$  Ma (Mondou et al., 2012), but yielded similar <sup>40</sup>Ar/<sup>39</sup>Ar age as the magmatic biotites. <sup>40</sup>Ar/<sup>39</sup>Ar ages on 414 415 amphibole and micas record, therefore, cooling through the respective closure temperatures. A 416 first estimate of the cooling rate was obtained considering closure temperatures of 550  $\pm$ 417 30 °C for amphibole (Dahl, 1996),  $400 \pm 20$  °C for muscovite (Harrison et al., 2009), and 325 418  $\pm$  20 °C for biotite (Harrison et al., 1985). However, for very low cooling rates, the isotopic 419 re-equilibration may continue at temperatures lower than the theoretical closure temperature 420 (Dodson, 1973). We have thus recalculated the closure temperatures for amphibole, 421 muscovite and biotite taking into account the estimated cooling rate (5 °C/Myr for amphibole 422 and 15 °C/Myr for biotite and muscovite) and the grain size (Brandon et al., 1998; McDougall 423 and Harrison, 1999; Braun et al., 2006; Reiners and Brandon, 2006). Depending on grain size, 424 estimated closure temperatures range from 485 to 526 °C for amphibole, 288 to 338 °C for 425 biotite and 416±4 °C for the single analyzed muscovite (Table 1).

426 Cooling rates inferred for various scenarios are shown on Figure 10:

427

428

- The first one (curve 1) is calculated using: 1) average ages computed considering all samples (except the syenite AR-414 and the orthogneiss AR-722 as stated

above), i.e., 584 Ma for U-Pb zircon age, 510 Ma and 487 Ma for <sup>40</sup>Ar/<sup>39</sup>Ar 429 430 amphibole and biotite ages respectively, 2) the average closure temperatures of 431 amphibole (508 °C) and biotite (316 °C). This results in cooling rates of 432 3.9 °C/Myr with an initial temperature (T<sub>i</sub>) of 800 °C (curve 1) between 584 and 433 510 Ma (3.3 °C/Myr with  $T_i = 750$  °C) and of 8.4 °C/Myr between 510 and 487 Ma. 434 - For the second scenario (curve 2), we excluded the two samples that yielded significantly older amphibole and biotite <sup>40</sup>Ar/<sup>39</sup>Ar ages, and used average closure 435 temperatures of 504 °C for amphibole and of 319 °C for biotite. The obtained 436 cooling rates are of 3.5 °C/Myr between 584 and 499 Ma with  $T_i = 800$  °C 437 438 (2.9 °C/Myr with  $T_i = 750$  °C) and of 9.7 °C/Myr between 499 and 480 Ma.

 $\begin{array}{rcl} 439 & - & \mbox{Even considering only the oldest ages obtained for amphibole (average: 546 Ma)} \\ 440 & \mbox{and biotite (average: 520 Ma), cooling rates still remain low (curve 3): 7.6 °C/Myr} \\ 441 & \mbox{between 583 and 546 Ma with } T_i = 800 °C (6.3 °C/Myr with } T_i = 750 °C). Cooling \\ 442 & \mbox{rates below the closure temperature of amphibole range between 16.1 °C/Myr (with 443 & \mbox{AR-590 biotite age of 532 Ma)} and 5.8 °C/Myr (with AR-1057 biotite age of 508 \\ 444 & \mbox{Ma)} and 8.7 °C/Myr for the average age of biotites (520 Ma). \\ \end{array}$ 

445 Local cooling rates for the EAU can be estimated using biotite <sup>40</sup>Ar/<sup>39</sup>Ar ages of the six 446 samples for which Cavalcante et al. (2018) obtained U-Pb zircon ages between 597 and 572 447 Ma (Table 1; Figures 5, 9). Biotite from these samples yield <sup>40</sup>Ar/<sup>39</sup>Ar ages from 486 to 459 448 Ma and closure temperatures from 307 to 338 °C. Considering the oldest anatectic 449 leucogranites of the EAU (AR-1133; curve 4 on Figure 10), which has U-Pb zircon age of 597  $\pm$  3 Ma and <sup>40</sup>Ar/<sup>39</sup>Ar biotite age of 486 $\pm$ 4, the TitaniQ temperature for this unit of 450 451 ~800 °C (Cavalcante et al., 2014) as initial temperature, and 307 °C as the closure 452 temperature of biotite, we obtain an average cooling rate of ~4.4 °C/Myr during the ≥110 Myr 453 that followed the crystallization of zircons. Sample AR-1349, for which an equilibrium 454 temperature of 780-790 °C was estimated using Zr-in-rutile data (Cavalcante et al., 2018), yields U-Pb zircon age of 583 Ma and <sup>40</sup>Ar/<sup>39</sup>Ar biotite age of 476 Ma (closure T: 323 °C), 455 456 pointing to an average cooling rate of ~4.3 °C/Myr. For the youngest anatectic sample (AR-457 1370), the  ${}^{40}$ Ar/ ${}^{39}$ Ar biotite age is 469 Ma with a closure temperature of ~ 316 °C, the U-Pb 458 zircon age is 572 Ma, and a minimum ambient temperature of ~720 °C may be assumed from 459 Ti-in-zircon data (Cavalcante et al., 2018). This points to cooling by ~404 °C in 103 Myr and, 460 therefore, to an average cooling rate of 3.9 °C/Myr. These cooling rates estimated for the EAU rely on <sup>40</sup>Ar/<sup>39</sup>Ar biotite ages and closure temperatures only. They lack intermediate 461

462 constraints and therefore consider a linear cooling between the crystallization of zircons and 463 the closure of the K/Ar system in biotite. Taking into account the difference in cooling rates 464 above and below the closure temperature of amphibole obtained for rocks from the WMU and 465 the CPU, a cooling rate significantly lower than 4 °C/Myr may also be expected for the EAU 466 during the first tens of million years after the peak of metamorphism.

467 In summary, U-Pb, <sup>40</sup>Ar/<sup>39</sup>Ar ages and the metamorphic temperature estimates from the 468 three allochthonous units consistently suggest low cooling rates (~3 to 8 °C/Myr; likely 3-469 5 °C/Myr) during at least the first 40 Myr after initiation of cooling (based on the oldest 470 <sup>40</sup>Ar/<sup>39</sup>Ar ages of amphiboles, Am3 on Figure 10), more probably 70-80 Myr (based on the average amphibole <sup>40</sup>Ar/<sup>39</sup>Ar age, Am1 on Figure 10), or even >100 Myr in the EAU. These 471 472 data also imply that cooling was faster (at least 11-15 °C/Myr) after the closure of the 473 amphibole K/Ar system, and possibly even faster (>20 °C/Myr) approaching the closure 474 temperature of muscovite, although this last inference needs further investigation since it 475 relies on the single muscovite age of our database. Moreover, as discussed above, the 476 estimated cooling rates consider linear trends between the different time markers (crystallization of zircon and the closure of <sup>40</sup>Ar/<sup>39</sup>Ar system in amphibole and biotite). Yet, 477 478 cooling was probably lower right after the metamorphic peak, especially during progressive 479 solidification of magmatic rocks, due to the release of the latent heat of crystallization 480 (Michaut and Jaupart, 2011), and has progressively increased through time. However, 481 although no evidence has been found yet, episodes of reheating cannot be ruled out.

482 The present estimates of cooling rates in the Araçuaí belt are in rather good agreement 483 with those proposed by Bento dos Santos et al. (2010; 2014) for anatexites, granulites, and charnockites from the northern Ribeira belt. These authors propose a two-step thermal 484 485 evolution with initial cooling rates of 1-5 °C/Myr during 50-90 Myr, followed by faster cooling by 8-30 °C/Myr and possibly up to 100 °C/Myr, based on diffusion of Fe<sup>2+</sup> and Mg 486 487 between garnet and biotite inclusions. Although the approaches are different, estimates 488 obtained in both areas consistently point to a very slow cooling during several tens of million 489 years after the major high temperature deformation that shaped the Araçuaí and the northern 490 Ribeira belts.

<sup>40</sup>Ar/<sup>39</sup>Ar ages of 498-493 Ma for amphibole and of 487 to 466 Ma for biotite obtained
in the West Congo belt in Angola (Monié et al., 2012) are similar to those obtained in the
Araçuaí belt, suggesting that, although the age of the orogenic/metamorphic peak is different
in these two belts (Araçuaí : 600-580 Ma; West Congo ~540-530 Ma), they shared a common
cooling history after the final amalgamation of Western Gondwana.

# 496 497

# **4.3.** Effect of protracted high temperature conditions in the middle crust on its rheology and strain repartition

498 Under "hot orogen" conditions (high temperatures and low cooling rates in the middle 499 and lower crust), we may expect specific rheological behaviors. When the temperature 500 gradient reaches equilibrium, it is almost homogeneous over large distances both laterally and 501 vertically (e.g., Whittington et al., 2009). Rheological contrasts between different crustal rock 502 types are minimized, and strain localization efficiency, which is inversely proportional to 503 stress and thus to temperature, becomes much lower. Strain tends to be distributed over large 504 volume of rocks (Vanderhaeghe and Teyssier, 2001b; Vauchez et al., 2007). Consequently, 505 transitions between orogenic domains should be much smoother than under lower temperature 506 conditions (Vanderhaeghe and Teyssier, 2001a). This is particularly true when the middle to 507 lower crust undergoes widespread partial melting, because this process may lead to a decrease 508 in viscosity by several orders of magnitude (e.g., Rosenberg and Handy, 2005; Rosenberg et 509 al., 2007; Cavalcante et al., 2014). The presence of even a small proportion of melt in a rock 510 significantly modifies its viscosity. For instance, Rosenberg and Handy (2005) pointed out 511 through reinterpretation of experimental data on partially molten systems that the strength of a 512 rock undergoes a drastic drop during the first ~7% of partial melting. They also argued that, 513 symmetrically, the strength of magmas deforming during crystallization remains low until 514 they reach a proportion of solid-phase of  $\sim 90\%$  and then increases rapidly up to the solidus. 515 When cooling is slow, as it is the case in the Araçuaí orogen, high melt fractions subsist for 516 long times and, by consequence, partially crystallized magmatic bodies or partially molten 517 anatexites may accommodate most of the strain, either gravity-induced or due to far-field 518 forces, during most of the duration of the continental collision.

519 The three main allochthonous units of the Aracuaí orogen are characterized by the 520 presence of large volumes of synkinematic magmas intermingled with metasedimentary 521 rocks: leucogranites interlayered with mylonites in the western unit, granodiorites/tonalites in 522 the central unit, and anatexites in the eastern unit. Such large volumes of magmas in the 523 middle crust certainly had a major impact on the rheology of the orogenic lithosphere. Using 524 the cooling rates discussed in the previous section, we may roughly estimate the time lapse 525 between emplacement and solidification of the magmas. For instance, the oldest anatectic 526 granite of the EAU, emplaced at ~597 Ma in the middle crust at a minimum temperature of 527 800 °C yields a mean cooling rate of ~4 °C/Myr, suggesting that the solidus temperature 528 (~630 °C) was attained at least 40-45 Myr after its emplacement, i.e., at about 550-555 Ma. 529 Time lapses in the range of 30-40 Myr are obtained considering the synkinematic 530 leucogranites of the WMU and the tonalite and granodiorites of the CPU emplaced at ~580 531 Ma in mylonites or metasediments equilibrated at ~750 °C, which yield cooling rates of 3-532 4 °C. The consistent estimates for the different units of the Araçuaí belt support that the large 533 volumes of magmas emplaced or formed in the three allochthonous units allowed for 534 magmatic flow and hence maintained low strengths in the middle crust for ~40 Myr after 535 initiation of cooling. Considering the suggestion by Ackerson et al. (2018) that granitic and 536 granodioritic magmas may contain a significant volume of interstitial magma down to 537 temperatures as low as ~500 °C, the above value may be still an underestimate. Indeed, in the 538 Grenville Province in North America, cooling rates in the range 2.3-4.4 °C/Myr and 539 maintenance of supra-solidus conditions over  $\geq$ 70 Myr have been substantiated (Turlin et al., 540 2018). The presence today, as deduced from seismic profiles (Nelson et al., 1996), of a 541 partially molten middle crust beneath Tibet, which results from partial melting initiated 20-25 542 Myr ago (Zhang et al., 2004; Guo and Wilson, 2012), illustrates that a long-lived partially 543 molten crust may have been present in orogens of a variety of ages.

544 Viscosity increase upon cooling may generate a strength inversion between the 545 magmatic bodies and their country rocks. Nabelek and Liu (2004) suggested, for instance, 546 inversion of shear strength between a mica schist and a dry granite at a temperature of ca. 547 530 °C depending weakly on strain rate. Based on the cooling rates estimated from our data, 548 strength inversion between metapelitic country rocks and magmatic bodies might have 549 occurred as late as 60 Myr after emplacement of the magmatic bodies. The magmatic bodies 550 were therefore the most deformable part of the middle crust during several tens of million 551 years and, considering their large volume, likely accommodated most of the strain imposed by 552 both plate tectonics and gravity. Upon cooling and crystallization of the magmas, the strength 553 of the magmatic rocks became higher than the strength of the metasedimentary country rocks 554 and the late pulses of deformation must have been accommodated mostly in metasediments.

555 The viscosity increase during cooling in a hot orogen may also lead to a progressive 556 decrease of the contribution of gravity-driven forces to regional deformation so that the strain 557 regime becomes dependent on far-field forces only. Strengthening of the middle crust may 558 also have allowed more effective transmission of tectonic forces toward the external domains 559 of the orogen, which are, in the present case, the remobilized eastern border of the São 560 Francisco craton.

### 561 **4.4. Tectonic evolution of the Araçuaí belt**

562 The slow cooling rates estimated in this study and their possible rheological 563 consequences require reconsidering the tectonic evolution of the Araçuaí belt. As stated above, 564 a characteristic of this orogenic segment is that strain was almost evenly distributed across the 565 tectonic units described previously and occurred under high temperature conditions in the 566 presence of syntectonic magmas. However, detailed mapping revealed that the tectonic fabric 567 is variable across the belt. In the CPU and EAU in particular, the foliation and lineation form 568 a complex pattern supporting a 3D deformation (Mondou et al., 2012; Cavalcante et al., 2013). 569 Even if domains with different tectonic fabrics display consistent HT conditions of 570 deformation and similar U-Pb ages of synkinematic magmas, the question of their 571 contemporaneity remains open, since the present study substantiates that HT conditions were 572 maintained during several tens of Myr. In partially molten rocks a new deformation event 573 tends to erase evidence of any previous one. Fast diffusion, allowing for easy grain boundary 574 migration, may have the same effect in HT metamorphic rocks. Under such conditions, it is 575 difficult to establish a reliable chronology since classical techniques of structural analysis are 576 therefore less efficient than in faster cooling orogenic belts.

577 Interestingly, despite the homogeneity of rock types, equilibrium temperatures, and 578 systematic deformation in the magmatic state throughout the whole EAU, geochronological 579 data denote a diachronous tectonothermal evolution within this unit. There is a correlation 580 between the southeastward decrease in zircon ages evidenced by Cavalcante et al. (2018) and the variation in <sup>40</sup>Ar/<sup>39</sup>Ar biotite ages across the EAU. Samples with the oldest U-Pb ages 581 582 were the first ones to reach the closure temperature of biotite and samples with the youngest U-Pb ages also yield the youngest  ${}^{40}$ Ar/ ${}^{39}$ Ar biotite ages (Figure 11). Only the  ${}^{40}$ Ar/ ${}^{39}$ Ar age 583 of biotite from the anatectic granite AR-535 does not follow this tendency, displaying a 584 younger than expected biotite <sup>40</sup>Ar/<sup>39</sup>Ar age. This might be due to the vicinity of a large 585 586 massif of charnockite emplaced at ~520 Ma. The presence of this hot magmatic body may 587 have reduced the cooling rate in the surrounding rocks during its solidification. There is no 588 evidence of a correlation between U-Pb and Ar/Ar ages in the WMU and CPU, suggesting 589 that the EAU underwent a specific thermotectonic evolution.

590 The variations in U-Pb and Ar/Ar ages support that, although not far from each other, 591 some parts of the EAU started to crystallize and cooled down well before other parts. This 592 might be due to diachronic migration of granites generated in the anatectic middle crust. 593 However, considering the complex strain pattern mapped across the EAU (Cavalcante et al., 594 2013), the variation in thermal evolution in the EAU is in good agreement with a "channel595 flow like" deformation during which, due to gravity forces, some parts of the anatectic core of 596 the belt were thrust upwards before or more efficiently than other parts (Cavalcante et al. 597 2018). The western EAU anatexites, in an initially shallower position, crystallized zircon and 598 reached the closure temperature of biotite before the initially deeper eastern EAU. The 599 regional variation in ages may also mean that the transcurrent fabric mapped in the eastern 600 EAU (Cavalcante et al., 2013; Figure 2) has been formed after the gently-dipping foliations of 601 the western part of the EAU, even if strain was, in both cases, accommodated by magmatic 602 flow in the anatexites.

603 The "channel-flow like" interpretation for the deformation of the EAU is in agreement 604 with the large-scale structure of the belt and with the crosscutting relationships of the contacts 605 between the different units (Figure 12), which suggest diachronic deformations under supra-606 solidus temperature across the belt. The anatexites of the EAU cover discordantly the other 607 allochthonous units. In the northernmost part of the Araçuaí belt, they are directly atop the 608 para-autochthonous HT metasediments of the São Francisco craton (Figure 12a), while in the 609 central part of the Araçuaí belt, the EAU is thrust over the subvertical contact between the 610 western CPU and the higher temperature intermediate kinzigitic unit (Figure 12b). This 611 supports earlier thrusting of the intermediate kinzigitic unit over the CPU, then verticalization 612 of the contact and, finally, thrusting of the anatexites of the EAU onto the steeply-dipping 613 structures of the central and intermediate units. No evidence of significant solid-state 614 deformation associated with thrusting of the EAU over the other units has ever been observed 615 in the various EAU anatexites, which are solely characterized by a strong magmatic fabric. 616 This suggests that these events, although diachronic, occurred before full solidification of the 617 magmatic bodies in the different units and that, at all times, deformation was concentrated in 618 the partially molten (or crystallized) rocks.

#### 619 5. Conclusions

21 new <sup>40</sup>Ar/<sup>39</sup>Ar ages of amphibole, muscovite and biotite from 16 samples collected in 620 the central (CPU) and eastern (EAU) units of the Araçuaí belt, together with <sup>40</sup>Ar/<sup>39</sup>Ar and U-621 622 Pb ages and P-T data previously published by our group (Vauchez et al., 2007; Petitgirard et 623 al., 2009; Mondou et al., 2012, Cavalcante et al., 2013, 2014, 2018) provides constrains on 624 the thermal history of the middle crust in the central part of the Araçuaí hot orogen. U-Pb 625 zircon ages support that by ~600 Ma the middle to lower crust, heated to temperatures of 626 ~800 °C, was already partially molten and that production of anatectic magmas persisted until 627 ~570 Ma at least (Cavalcante et al., 2018). Most of the granodioritic/tonalitic magmatism of

- the CPU, as well as the synkinematic leucogranites within the mylonitic metasediments of the
  WMU, has been emplaced during this period (Nalini et al., 2000a,b; Noce et al., 2000;
  Petitgirard et al, 2009; Mondou et al., 2012; Gonçalves et al., 2014).
- 631 Altogether these data point to a protracted orogenic evolution marked by:
- Initiation of crustal thickening and heating of the middle crust at about 630 Ma,
- 633 Heating of the middle crust to ≥800 °C and initiation of pervasive partial melting at
  634 ~600 Ma,

# 635 - Partial melting remained active until at least ~570 Ma; it affected the middle and 636 lower crust and also the mantle,

- 637 Slow cooling (3-5 °C/Ma) of the middle crust, which reached temperatures of
  638 ~500 °C at 510-500 Ma and of ~300 °C at ~480 Ma.
- Magmatic rocks maintained high melt fractions for several tens of Myr (>40 Myr)
  during which they accommodated most of the imposed deformation by magmatic
  flow. A rough estimate suggests that they reached the solidus temperature
  (~630 °C) at ~545-555 Ma.
- The anatexites of the EAU underwent a diachronic evolution: those from the northwestern part crystallized and cooled down earlier than those from the southeastern part. However, estimated cooling rates across the EAU are similar.
  This diachronic evolution is consistent with a "channel flow like" tectonic model compatible with the 3D deformation of anatexites substantiated by Cavalcante et al. (2013, 2018).
- 649 Such a protracted thermal evolution had major effects on the rheology of the orogenic 650 crust, on the strain repartition across the belt, and thus on the tectonic evolution of the 651 Araçuaí belt. During progressive heating of the orogenic crust (prograde metamorphism), 652 deformation was already active and crustal thickening was accommodated in the 653 metasedimentary sequence, but the microstructures recording these early stages of 654 deformation are impossible to differentiate from those formed at the peak of metamorphism in 655 presence of melt and during subsequent deformation under almost stable temperature 656 conditions. Initiation of partial melting at ~600 Ma and syntectonic injection of large volumes 657 of granodioritic/tonalitic magmas between 590 and 570 Ma strongly decreased the viscosity 658 of the middle crust, allowing gravity-induced deformation to combine with far-field 659 compressive forces to produce a 3D deformation regime (Cavalcante et al., 2013). This may 660 explain that northwestwards, the tectonic flow recorded in the middle crust rotate from

dominantly eastward onto the São Francisco craton to northward onto the Salvador craton(e.g., Uhlein et al., 1998).

663 Similar <sup>40</sup>Ar/<sup>39</sup>Ar cooling ages are obtained for biotite in both the Araçuaí belt in Eastern 664 Brazil and the West-Congo belt in Angola (Monié et al., 2012) despite the large differences in 665 the age of the orogenic climax and in tectonic evolution. This suggests that the late thermal 666 evolution in the Araçuaí-Ribeira orogeny is shared by the West-Congo - Cabo Frio belt 667 during the final stages of continental amalgamation. This might explain the late emplacement 668 of some atypical magmatic bodies (syenites, charnockites) in the Araçuaí belt.

669

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Sample number and type	<b>U/Pb</b> <i>Myr</i> (*= <sup>207</sup> Pb/ <sup>206</sup> Pb)	<sup>40</sup> A	ar/ <sup>39</sup> Ar M	<i>Ayr</i>	Closing 7		°C	Cooling
JI 31	Zr	Am	Bt	Ms	Am	Bt	Ms	rate °C/My
western mylonitic unit	All de	ata from	(1)					
AR-684 leucocratic melt	577±9							
AR-935 leucocratic melt	578±3*							
AR-562 Mylonite		501±5	474±5		488±7	310±11		~3/8
AR-86 leucocratic melt			468±4			318±12		
AR-414 Ibituruna syenite	530±1	505±5			485±6			
Contact zone Derribadinha	All data from (2)	r	This worl	k				
AR-264 Tonalite	581±4							
AR-590 Tonalite		549±6	532±5		513±7	288±9		7/13
AR-940 leucocratic melt	587±5							
AR-87 leucocratic melt	579±8							
AR-1057 Tonalite	583±4*	542±8	508±5		521±8	293±8		5.6/6.6
Central plutonic unit	All data from (2)	-	This work	k				
AR-1009 SV To/Gd		501±9	490±5		526±6	321±9		
AR-800 SV To/Gd	582±6*		485±5			320±10		4.4
AR-968 SV To/Gd	585±7							
AR-957 Wolf leucogranite	585±4		492±6			326±5		4.6
AR-787 Galiléia To/Gd	582±6							
AR-705 Galiléia To/Gd	579±4		475±4			311±9		4.4
AR-815 Galiléia To/Gd	583±4							
AR-717 Galiléia To/Gd	581±4*	500±5	481±5		517±4	311±9		2.9/12
AR-747 Galiléia To/Gd			482±4			325±6		
AR-722 orthogneiss	2103±11		484±5			307±5		
AR-648 Palmital granite			484±5	488±5		306±6	416±4	M-B:27
Eastern anatectic unit	All data from (3) except AR548		This work	k				
AR-408 Diatexite	597±8							
AR-455 Anatectic granite	594±4							
AR-1133 Anatectic granite	597±3		486±4			307±5		4.4
AR-1145 Diatexite	593±3		477±4			328±3		4.1
AR-1315 Anatectic granite	597±4							
AR-664 Anatectic granite	589±6		474±4			307±5		4.1
AR-1349 metatexite	583±5		476±4			323±3		4.3
AR-1358 Anatectic granite	585±4							
AR-535 Anatectic granite	575±3		459±4			338±7		3.3
AR-1119 Diatexite	578±4							
AR-1332 Anatectic granite	572±9							
AR-548 Anatectic granite	575±4 (4)	4	72±4 (1)			315±5		3.9
AR-1370 Anatectic granite	572±4		469±4			316±4		3.9

Table 1: Summary of U-Pb and <sup>40</sup>Ar/<sup>39</sup>Ar ages obtained from rocks collected in the Central Araçuaí belt. Samples are organized from West to East. (1) is for ages published in Petitgirard et al. (2009), (2) for those published in Mondou et al., (2012), (3) for those

published in Cavalcante et al., 2018 and (4) for those published in Vauchez et al., 2007. The last column shows individual cooling rates calculated for samples for which U-Pb and <sup>40</sup>Ar/<sup>39</sup>Ar ages of amphibole and/or biotite have been obtained, and for which an initial temperature of the country-rock may be inferred (for sample AR-562 and AR-590 an age of 578 Ma and 582 Ma respectively has been assumed taking into account their vicinity and similarity with dated samples). Cooling rates are indicated as: above closing T of amphibole/ between amphibole and biotite closing T. For sample AR-648, MB is for cooling rate between muscovite and biotite closing T.



Figure 1: Schematic map of the neoproterozoic tectonic belts in eastern Brazil. The Brasilia belt is docked against the western and southwestern boundaries of the São Francisco (SF) craton. The Araçuaí and Ribeira belts formed along the eastern and southeastern boundary of the craton. The transition between these two orogenic segments, marked by a clear change in tectonic regime from contractional to transpressional, is correlated with the southern termination of the craton. The eastern part of the São Francisco craton was strongly remobilized during the formation of the Araçuaí belt. Deformation in the Cabo Frio tectonic domain (CF) is younger than in the Araçuaí-Ribeira belt and likely represents the westernmost part of the early Cambrian Angola-Congo orogen. The underlying tectonic map is from (Cordani et al., 2016). The area delimited by doted white lines shows the location of Figure 2. Insert at the lower right corner is a reconstitution of the Ribeira-Araçuaí and Congo orogens before the South Atlantic opening (Vauchez et al., 2007).



Figure 2: Simplified map of the central Araçuaí belt modified from Vauchez et al., 2007 showing (1) the para-autochthonous cover of the São Francisco cratons and the three allochthonous units: the western mylonitic unit (WMU, 2), the Central Plutonic Unit (CPU, 3-7) and the Eastern Anatectic Unit (EAU, 8-9). In the CPU, (3) is for metasediments, (4) for the "São Vitor" tonalite/granodiorite, (5) for the "Galileia" tonalite/granodiorite, (6) for the "Palmital" aluminous granite, (7) for the "Wolff" leucogranite. In the EAU: (8) anatexites and (9) kinzigites. (10) is the late "Padre Paraíso" charnockite. (11) foliation and lineation either measured in the field or inferred from AMS (Petitgirard et al., 2009; Mondou et al., 2012; Cavalcante et al., 2013).



Figure 3: Typical outcrops of the Western Mylonitic Unit (a-c) and of its boundary with the Central Plutonic Unit (d). For the four pictures West is on the right. a-c show metasediments injected by leucocratic granite and shear criteria that indicate top-to-west sense of shear. In (a) lenses are leucogranite. (d) shows intercalations of leucogranite, migmatitic metasediments, tonalite (To) free of solid-state deformation and several asymmetric black lenses resulting from the disruption of an amphibolite layer.



Figure 4: Location and U-Pb ages (Ma) of zircons used in this study. Results (and references) are summarized in table 1.



Figure 5: Pictures of outcrops typical of the Central Plutonic Unit. Tonalites/Granodiorites showing a well-developed magmatic foliation, gently-dipping in the western CPU (a-b) and that progressively becomes subvertical eastward (c-d). In (c) the subvertical magmatic foliation is underlined by elongated dioritic lenses and in (d) by lenses and discontinuous layers of biotite rich granite.



Figure 6: Pictures of outcrops typical of the Eastern Anatectic Unit: metatexites (a), diatexites (b) and garnet-rich leucocratic granite (c), all displaying a well-developed foliation, which is magmatic in the leucosome and solid-state in the restitic parts (when present). (d) shows the anatectic kinzigites (kz) at the eastern boundary of the EAU, in which leucogranitic melt focus and forms lenses and veins. Dark lenses in the leucogranite contains garnet + biotite  $\pm$  cordierite.



Figure 7 : Location and <sup>40</sup>Ar/<sup>39</sup>Ar ages of amphibole, biotite and muscovite used in this study. Numbers in black are ages obtained in this study and those in white are previously published <sup>40</sup>Ar/<sup>39</sup>Ar ages (4 samples). Diagrams for newly dated samples are shown on Figures 8 and 9. Analytical data are available in supplementary material #3 and #4.





Figure 8: <sup>40</sup>Ar/<sup>39</sup>Ar diagrams for amphibole, muscovite and biotite from samples collected in the Central Plutonic Unit. Diagrams are organized by mineral and for samples from West to East. Analytical data and methodology are available in supplementary material #3.



Figure 9: <sup>40</sup>Ar/<sup>39</sup>Ar diagrams for biotite from samples collected in the Eastern Anatectic Unit. Diagrams are displayed for samples from North to South. Analytical data and methodology are available in supplementary data #4.



Figure 10: Figure 10: Diagram summarizing data and inferred thermochronological evolutions for the studied domain of the Araçuaí belt. Open symbols represents the whole set of data taken into account in this study. Symbols filled in grey represent either data for specific samples (zircons, muscovite) or average values computed for amphibole and biotite. Temperatures for zircons data have been roughly estimated from (a) the peak temperature (800 °C) and the oldest age (597 Ma) of the Eastern Anatectic Unit, (b) The Zn-in rutile temperature (780-790 °C) obtained for sample AR-1349 (583 Ma), (c) equilibrium temperatures (~750 °C) and ages (577-578 Ma) obtained for samples from the Western Mylonitic Unit, and (d) Ti-in-zircon temperature obtained for several samples from the EAU. Zm is average U-Pb age of zircons from synkinematic magmatic/anatectic rocks, Am are average <sup>40</sup>Ar/<sup>39</sup>Ar ages of amphiboles with Am1 for all dated samples and Am2 and Am3 without and for the two oldest samples, respectively. Similarly, Bm are average <sup>40</sup>Ar/<sup>39</sup>Ar ages of biotites with Bm1 for all dated samples and Bm2 and Bm3 without and for the two oldest samples, respectively. Line (1) represents the thermochronological evolution based on average values for all dated samples, (2) excludes the two oldest amphiboles and biotites, (3) is the cooling evolution based on the mean ages of the two oldest amphiboles and biotites, and (4) links the oldest zircons ages of the Eastern Anatectic unit to average age of biotites.



Figure 11: U-Pb zircon ages versus <sup>40</sup>Ar/<sup>39</sup>Ar biotite ages in the Eastern Anatectic Unit. Numbers are for the cooling rate calculated for each sample (Table 1). This figure shows a tendency of the age of closure of the <sup>40</sup>Ar/<sup>39</sup>Ar system in biotite to be correlated with zircon crystallization ages. Samples showing earlier crystallization of zircon also show earlier closure of the Ar/Ar system in biotite. This suggests a diachronous thermal evolution across the EAU.



Figure 12: Schematic map and cross-section showing the Eastern Anatectic Unit thrust upon the Central and Western Units and even, in the northernmost part of the map, directly onto the paraautochthonous metasedimentary cover of the São Francisco craton. The cross-section also shows that the gently dipping basal contact of the Eastern unit crosscuts steeply dipping tectonic contacts and foliation in the eastern part of the CPU, suggesting that the tectonic emplacement of the EAU is later than the formation of this subvertical fabric, although it occurred before the anatexites reached solid-state.



Supplementary material #1: Location of samples from which zircons and/or amphibole, biotite and muscovite have been dated. Results (and references for data already published) are summarized in Table 1, Figure 4 for zircons and Figure 7 for <sup>40</sup>Ar/<sup>39</sup>Ar ages. In the main text, sample numbers are preceded by AR- (for instance 562 is AR-562). Legends of the map as in Figure 2.

Supplementary material #2:

# <sup>40</sup>Arl<sup>39</sup>Ar data and diagram for sample AR-414 (Petitgirard et al., 2009).

Amphibole from this sample (Ibituruna syenite) did not yield a plateau age but a total gas age of 495.4  $\pm$  4.3 Ma that should be considered as a minimum age for its closure for argon. Apparent ages slightly increase with increasing degassing temperatures up to apparent ages in the range 500-510 Ma corresponding to almost constant <sup>37</sup>Ar/<sup>39</sup>Ar (Ca/K) and <sup>38</sup>Ar/<sup>39</sup>Ar (Cl/K) compositions. We thus preferred taking into account the integrated age of 505  $\pm$  5 Ma for the amphibole from this sample.

A	R414 Ibituruna	Syenite Amp	hibole	Data f	rom Petitgire	ard et al 2	009		
Step	<sup>40</sup> Ar/ <sup>39</sup> Ar	$Ar = \frac{^{38}Ar}{^{39}Ar} = \frac{^{37}Ar}{^{39}Ar}$		<sup>36</sup> Ar/ <sup>39</sup> Ar (E-3)	F <sup>39</sup> Ar released	% <sup>40</sup> Ar*	<sup>40*/39</sup> Ar <sub>K</sub>	Age (Ma)	±1 SD (Ma)
1	51.133	0.085	0.2841	133.399	0.99	22.90	11.71	186.1	2.2
2	44.631	0.074	0.1807	93.225	1.49	38.26	17.08	265.4	2.2
3	41.129	0.048	0.0574	30.448	3.08	78.08	32.12	470.5	0.6
4	34.864	0.040	0.0072	3.000	15.41	97.40	33.96	494.1	0.2
5	33.716	0.053	0.1632	0.863	30.92	99.21	33.45	487.6	0.3
6	34.722	0.115	0.9239	1.309	54.47	98.99	34.39	499.6	0.4
7	34.715	0.189	1.8392	0.875	77.15	99.52	34.59	502.1	0.2
8	35.299	0.218	2.2291	1.184	91.93	99.33	35.11	508.7	0.2
9	35.967	0.224	2.5280	3.007	94.47	97.90	35.27	510.7	0.4
10	35.832	0.247	2.7335	2.467	98.33	98.37	35.31	511.2	0.3
11	37.297	0.250	2.6180	13.641	98.63	89.56	33.46	487.7	1.7
12	41.118	0.249	2.6689	22.207	100.00	84.38	34.76	504.3	1.1



Petitgirard, S., Vauchez, A., Egydio-Silva, M., Bruguier, O., Camps, P., Monié, P., Babinski, M. and Mondou, M., 2009. Conflicting structural and geochronological data from the Ibituruna quartz-syenite (SE Brazil): Effect of protracted "hot" orogeny and slow cooling rate? Tectonophysics 477, 174-196.

Ar- Ar results for samples from the Central Plutonic Unit

# Method:

These samples were collected for laser probe single grain <sup>40</sup>Ar-<sup>39</sup>Ar studies at Geosciences Montpellier (Université de Montpellier, France). They were hand crushed and cleaned using ethanol and distilled water. Single grains of amphibole and mica about 500  $\mu$ m in diameter were handpicked under binocular microscope and ultrasonically cleaned in acetone and distilled water. The grains were then packaged in aluminium foils and irradiated along with several flux monitors of MMhb-1 hornblende and TCR2-sanidine at McMaster Reactor (Canada) with an integrated power of 60 MWH. K<sub>2</sub>SO<sub>4</sub> and CaF<sub>2</sub> salts were also irradiated to determine the correction factors for interference reactions from K and Ca. <sup>40</sup>Ar-<sup>39</sup>Ar laser degassing was carried out at Geosciences Montpellier (France) using a 50W CO<sub>2</sub> laser. The gas cleaning was achieved in a low volume UHV gas purification system including a cold trap and two Ti/Zr getters. Argon isotope measurements were performed on a MAP215-50 noble gas mass spectrometer directly connected to the UHV purification system. Blank analyses were performed every three runs to eliminate the background contribution on the gas released from the sample itself. Individual grains were stepwise heated by increasing the laser beam intensity in successive increments until the final fusion. A plateau age is defined by three or more contiguous heating steps comprising 50% or more of the  ${}^{39}Ar_{K}$  released and overlapping at the two-sigma confidence level. Because of the high radiogenic content of the dated minerals and the clustering of data points near the <sup>39</sup>Ar-<sup>40</sup>Ar abscissa, <sup>36</sup>Ar-<sup>40</sup>Ar versus <sup>39</sup>Ar-<sup>40</sup>Ar correlation plots do not provide meaningful information about the age and initial <sup>36</sup>Ar-<sup>40</sup>Ar values.

# Results:

Step	<sup>40</sup> Ar/ <sup>39</sup> Ar	<sup>38</sup> Ar/ <sup>39</sup> Ar	<sup>37</sup> Ar/ <sup>39</sup> Ar	<sup>36</sup> Ar/ <sup>39</sup> Ar (E-3)	F <sup>39</sup> Ar released	% <sup>40</sup> Ar*	<sup>40*/39</sup> Ar <sub>K</sub>	Age (Ma)	±1 SD (Ma)
AR-590	Derribadinha :	tonalite Amph	ibole						
1	1190.597	0.088	0.00163	115.344	0.01	97.14	1156.5	4440.84	959.0
2	525.881	0.414	37.06841	395.543	0.05	78.30	421.95	2871.623	139.9
3	40.087	0.055	0.07051	11.151	12.52	91.75	36.78	529.416	2.8
4	38.401	0.053	0.00000	3.618	16.75	97.17	37.32	536.056	3.8
5	38.749	0.053	0.00000	3.893	23.39	96.99	37.58	539.361	2.4
6	37.889	0.054	0.00000	1.733	36.33	98.61	37.36	536.607	1.5
7	38.485	0.05	0.00000	2.784	39.29	97.82	37.65	540.157	2.3
8	39.338	0.052	0.88118	4.345	41.82	96.86	38.13	546.099	2.4
9	40.045	0.053	0.22236	5.34	45.71	96.06	38.47	550.377	3.4
10	38.602	0.197	9.80187	4.637	58.67	98.32	38.2	546.953	1.8
11	38.792	0.22	8.05135	4.118	66.52	98.38	38.36	549.036	2.3
12	38.736	0.234	8.42765	3.584	89.15	98.86	38.5	550.762	1.2
13	37.921	0.149	4.41234	3.567	92.30	98.05	37.29	535.727	3.7

14	38.258	0.119	3.12708	2.99	100.00	98.26	37.67	540.452	2.3
AR-590	Derribadinha ta	onalite Biotite	?						
1	260.267	0.279	0.85808	821.286	0.12	6.77	17.64	273.22	249.9
2	47.308	0.078	0.30582	47.638	0.99	70.26	33.24	484.733	8.4
3	37.783	0.055	0.00454	4.487	0.05	96.45	36.44	525.151	1.9
4	38.096	0.056	0.02386	5 614	9.95	95.61	36.42	524 927	24
5	37 547	0.054	0.00000	1 838	14.51	98.51	36.99	531.976	1.9
6	26.078	0.051	0.00804	0.005	23.02	00.24	26.70	528 225	28
0	27.216	0.051	0.00094	1.252	30.26	08 80	26.00	520.525	2.0
/	37.310	0.052	0.00000	1.552	39.65	98.89	30.90	530.885	1.5
8	37.577	0.052	0.02104	1.507	44.11	98.78	37.12	533.591	2.0
9	37.213	0.052	0.00000	1.592	50.89	98.69	36.73	528.715	2.5
10	37.553	0.053	0.01094	1.671	54.61	98.65	37.04	532.675	2.6
11	37.395	0.054	0.00957	1.835	58.77	98.51	36.84	530.104	2.1
12	37.339	0.054	0.00419	1.298	71.42	98.93	36.94	531.374	1.7
13	38.200	0.054	0.02762	2.665	77.27	97.90	37.40	537.086	2.2
14	37.479	0.053	0.00051	1.614	82.08	98.69	36.99	531.947	1.5
15	37.740	0.053	0.00000	1.817	87.03	98.54	37.19	534.458	2.2
16	37.682	0.054	0.01606	1.812	93.55	98.54	37.13	533.775	1.7
17	37.827	0.052	0.00000	2.458	100.00	98.04	37.09	533.182	2.3
					100.00				
AR-1052	7 São Vitor tona	lite Amphibo	le	I-0.009621					
1	1318.154	5.167	0.01591	4055.33	0.01	9.09	119.79	1383.1	7131.5
2	137.46	1.089	0.00341	248.554	0.06	46.56	64	865.6	1790.6
3	87.653	1.146	0.00438	857.07	0.10	-188.96	-165.63	0.0	0.0
4	73.132	0.824	0.00216	49.913	0.19	79.81	58.37	804.0	1148.4
5	26.992	0.121	0.00062	0.002	0.47	99.94	26.98	416.3	14.2
6	33.716	0.136	0.00121	0.003	0.62	99.95	33.7	506.6	23.1
7	33.403	0	0.00064	0.002	0.90	99.95	33.39	502.5	11.7
8	36.065	0.038	0.00015	0	2.13	99.96	36.05	537.2	6.9
9	36.223	0.103	0.00001	0	24.26	99.96	36.21	539.2	8.1
10	36.476	0.083	0.00003	0	29.92	99.96	36.46	542.5	4.1
11	30.01 26.221	0.11	0.00000	0	07.39	99.90	30.39	544.2	10.1
12	36 788	0.073	0.00003	0	75.42	99.90 99.96	36.77	546.5	8.0
14	36.393	0.09	0.00003	0	82.57	99.96	36.38	541.4	2.8
15	36.267	0.055	0.00001	0	100.00	99.96	36.25	539.8	6.7
AR-1052	7 São Vitor tona	lite Biotite		J= 0.009621					
1	110.008	0.856	51.77421	633.621	0.02	-66.68	-75.92	0.0	0.0
2	55.347	0.118	42.76951	156.805	0.05	22.05	12.55	205.7	635.9
3	19.962	0	27.29096	4.961	0.12	99.92	20.9	330.5	253.3
4	30.371	0.041	1.20390	11.343	0.44	89.21	27.12	418.2	54.5
5	32.03	0.03	0.00003	2.986	1.30	97.2	31.13	472.7	20.0
6	34.103	0.024	5.91843	19.592	2.40	84.28	28.85	442.0	16.0
7	33.375	0.021	0.00001	0	5.04	99.95	33.36	502.2	4.0
8	55.621 22.972	0.021	0.00001	U 0 172	10.01	99.95	33.01 22.01	508.0	2.4
9 10	33.812 33.672	0.022	0.00001	0.173	10.01	99.8 00.05	33.81 33.66	506.1	8.U 2.1
10	33.630	0.019	0.00001	0	14.42	99.95 99.95	33.60	505.6	2.1 4 1
12	33.621	0.013	0.00001	0	20.48	99.95	33.61	505.4	4.8
13	33.401	0.025	0.68492	0	25.61	99.95	33.45	503.4	3.8
14	33.81	0.019	0.00001	0	29.71	99.95	33.79	507.9	2.6

15	33.405	0.016	0.15295	0	33.97	99.95	33.4	502.8	3.5
16	33.596	0.018	0.00995	0	36.51	99.95	33.58	505.1	1.9
17	33.77	0.019	0.47576	0	39.37	99.95	33.8	508.0	1.9
18	33.827	0.028	0.09567	0	48.56	99.95	33.82	508.2	5.0
19	33.52	0.018	0.00001	0	53.17	99.95	33.5	504.1	3.1
20	33 961	0.019	0.00000	0	61 48	99.95	33.95	509.9	2.6
20	33.56	0.021	0.00000	0.725	6/ /0	00.32	33.33	501.8	5.0
21	33.04	0.021	0.00001	0.725	68.08	00.05	33.02	500.6	2.5
22	22 805	0.021	0.00001	0	72.10	99.95	22.92	509.0	2.0
23	22.495	0.019	0.00001	0	72.19	99.95	22 51	504.1	4.0 0.5
24	22,807	0.021	0.39021	0 776	/0.51	99.95	22.51	504.1	0.J
25	33.807	0.018	0.03891	0.776	81.48	99.28	33.57	504.9	0.2
26	33.809	0.02	0.11646	0.905	85.65	99.19	33.54	504.5	4.8
27	33.911	0.02	0.00000	0	92.58	99.95	33.9	509.2	1.4
28	33.821	0.019	0.00001	0	94.72	99.95	33.81	508.0	3.3
29	33.943	0.02	0.00001	0.354	98.05	99.65	33.82	508.2	5.8
30	33.419	0.023	0.00001	0	100.00	99.95	33.4	502.8	1.4
AR-100	9 São Vitor tona	lite Amphibo	le	J=0.009621					
1	240.903	2.011	0.00999	0.029	0.02	99.99	240.88	2163.5	187.3
2	110.055	0	0.00470	0.014	0.07	99.98	110.04	1302.6	104.3
3	31.356	0.142	0.00148	0.004	0.21	99.95	31.34	475.4	36.4
4	26.766	0	0.00195	0.006	0.31	99.94	26.75	413.1	43.5
5	13.629	0.094	0.00048	0.001	0.75	99.88	13.61	222.0	12.5
6	32,837	0.098	0.00007	0	3 84	99.95	32.82	495.1	57
7	32.942	0.092	0.00001	0	30.41	99.95	32.93	496.5	21.6
8	33 752	0.116	0.00001	0	56.55	00.05	33.74	507.1	10.3
0	33 243	0.110	0.00001	0	60.02	00.05	33.74	500.4	10.5
10	22 177	0.104	0.00002	0	80.86	99.95	22.16	400.6	4.0 7 7
10	33.177	0.094	0.00001	0	09.00	99.95	55.10	499.0	1.1
11	26.04	0.126	0 00008	0 22	02.20	02.12	22 57	504.0	516
11	36.04	0.126	0.00008	8.32	92.38	93.13	33.57	504.9	54.6
11 12	36.04 35.724	0.126 0.111	0.00008 0.00749	8.32 9.601	92.38 100.00	93.13 92.02	33.57 32.87	504.9 495.7	54.6 19.3
11 12	36.04 35.724	0.126 0.111	0.00008 0.00749	8.32 9.601	92.38 100.00	93.13 92.02	33.57 32.87	504.9 495.7	54.6 19.3
11 12 <i>AR-100</i>	36.04 35.724 9 São Vitor tono	0.126 0.111 alite Biotite	0.00008 0.00749	8.32 9.601 J= 0.009621	92.38 100.00	93.13 92.02	33.57 32.87	504.9 495.7	54.6 19.3
11 12 <i>AR-100</i> 1	36.04 35.724 9 São Vitor tono 17.141	0.126 0.111 alite Biotite 0.063	0.00008 0.00749 0.00031	8.32 9.601 J=0.009621 48.478	92.38 100.00 0.21	93.13 92.02 16.34	33.57 32.87 2.8	504.9 495.7 48.0	54.6 19.3 246.5
11 12 <i>AR-100</i> 1 2	36.04 35.724 9 São Vitor tono 17.141 19.604	0.126 0.111 alite Biotite 0.063 0.054	0.00008 0.00749 0.00031 2.54802	8.32 9.601 J= 0.009621 48.478 27.182	92.38 100.00 0.21 0.64	93.13 92.02 16.34 59.92	33.57 32.87 2.8 11.77	504.9 495.7 48.0 193.5	54.6 19.3 246.5 112.0
11 12 <b>AR-100</b> 1 2 3	36.04 35.724 9 <i>São Vitor tono</i> 17.141 19.604 30.648	0.126 0.111 alite Biotite 0.063 0.054 0.027	0.00008 0.00749 0.00031 2.54802 0.23931	8.32 9.601 J=0.009621 48.478 27.182 2.129	92.38 100.00 0.21 0.64 12.46	93.13 92.02 16.34 59.92 97.96	33.57 32.87 2.8 11.77 30.03	504.9 495.7 48.0 193.5 457.8	54.6 19.3 246.5 112.0 4.8
11 12 <b>AR-100</b> 1 2 3 4	36.04 35.724 9 <i>São Vitor tono</i> 17.141 19.604 30.648 33.241	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846	8.32 9.601 J=0.009621 48.478 27.182 2.129 3.592	92.38 100.00 0.21 0.64 12.46 21.69	93.13 92.02 16.34 59.92 97.96 96.89	33.57 32.87 2.8 11.77 30.03 32.22	504.9 495.7 48.0 193.5 457.8 487.1	54.6 19.3 246.5 112.0 4.8 5.9
11 12 <b>AR-100</b> 1 2 3 4 5	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002	8.32 9.601 J=0.009621 48.478 27.182 2.129 3.592 0	92.38 100.00 0.21 0.64 12.46 21.69 26.50	93.13 92.02 16.34 59.92 97.96 96.89 99.95	33.57 32.87 2.8 11.77 30.03 32.22 32.22	504.9 495.7 48.0 193.5 457.8 487.1 487.1	54.6 19.3 246.5 112.0 4.8 5.9 2.4
11 12 <b>AR-100</b> 1 2 3 4 5 6	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79	504.9 495.7 48.0 193.5 457.8 487.1 487.1 481.4	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6
11 12 <b>AR-100</b> 1 2 3 4 5 6 7	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427	8.32 9.601 J= 0.009621 48.478 27.182 2.129 3.592 0 3.662 3.193	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86	504.9 495.7 48.0 193.5 457.8 487.1 487.1 481.4 482.4	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61	504.9 495.7 48.0 193.5 457.8 487.1 487.1 481.4 482.4 482.4 492.3	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.023	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J=0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10	36.04 35.724 <b>9 São Vitor tono</b> 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.023 0.024	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11	36.04 35.724 <b>9 São Vitor tono</b> 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.023 0.024 0.024 0.018	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54	504.9 495.7 48.0 193.5 457.8 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.22	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.22	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AP 800</b>	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070	8.32 9.601 J=0.009621 48.478 27.182 2.129 3.592 0 3.662 3.193 0.356 0 0.609 1.025 1.045	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5
11 12 AR-1002 1 2 3 4 5 6 7 8 9 10 11 12 AR-800	36.04 35.724 9 São Vitor tonu 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonul	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J= 0.009621\\ \hline \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.22	504.9 495.7 48.0 193.5 457.8 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5
11 12 AR-100 1 2 3 4 5 6 7 8 9 10 11 12 AR-800 1 2	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonal 24.463 27.11	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070	8.32 9.601 $J=0.009621$ 48.478 27.182 2.129 3.592 0 3.662 3.193 0.356 0 0.609 1.025 1.045 $J=0.009621$ 0.001	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.22 24.45	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 2	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonol 24.463 27.11 21.022	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.038 0 0.038 0 0.012	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.000042 0.00006	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J= 0.009621\\ 0.001\\ 0\\ 0\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.93 99.94	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.22 24.45 27.09 21.02	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 482.2	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 2.2
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3	36.04 35.724 9 São Vitor tona 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonal 24.463 27.11 31.993 22.50	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.013	0.00008 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.000042 0.00006 0.00000	$\begin{array}{c} 8.32\\ 9.601\\ \hline \\ J=0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J=0.009621\\ 0.001\\ 0\\ 0\\ 0\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.93 99.94 99.95 99.94	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.54 32.22 24.45 27.09 31.98	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 487.1 487.1 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 405.7	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3 4	36.04 35.724 9 São Vitor tona 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonal 24.463 27.11 31.993 32.104	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 bite Biotite 0.038 0 0.013 0.01	0.00008 0.00749 0.00749 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.000042 0.00006 0.00000 0.03448	$\begin{array}{c} 8.32\\ 9.601\\ \hline \\ J=0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J=0.009621\\ 0.001\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01 40.98	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.93 99.94 99.95 99.95	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.22 24.45 27.09 31.98 32.09	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 487.1 487.1 487.1 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 485.4	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2 1.0
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3 4 5	36.04 35.724 9 São Vitor tonu 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonul 24.463 27.11 31.993 32.104 31.991	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.013 0.01 0.01	0.00008 0.00749 0.00749 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.000042 0.00006 0.00000 0.03448 0.32973	8.32 9.601 J=0.009621 48.478 27.182 2.129 3.592 0 3.662 3.193 0.356 0 0.609 1.025 1.045 J=0.009621 0.001 0 0 0 0 0 0	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01 40.98 65.29	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.94 99.95 99.94	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.22 24.45 27.09 31.98 32.09 31.98	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 485.4 483.9	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2 1.0 2.8
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3 4 5 6	36.04 35.724 <b>9 São Vitor tonu</b> 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 <b>São Vitor tonal</b> 24.463 27.11 31.993 32.104 31.991 31.174	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.013 0.01 0.01	0.00008 0.00749 0.00749 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.00004 0.00006 0.00000 0.03448 0.32973 1.67359	$\begin{array}{c} 8.32\\ 9.601\\\\\hline J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\\\\hline J= 0.009621\\ 0.001\\ 0\\ 0\\ 0\\ 0\\ 0.101\\ 0.53\\\\\hline \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01 40.98 65.29 73.66	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.94 99.95 99.94 99.95 99.94 99.95	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.22 24.45 27.09 31.98 32.09 31.98 31.16	504.9 495.7 48.0 193.5 457.8 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 485.4 483.9 485.4 483.9 473.1	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2 1.0 2.8 7.9
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3 4 5 6 7	36.04 35.724 9 São Vitor tono 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonal 24.463 27.11 31.993 32.104 31.991 31.174 32.499	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.013 0.01 0.01 0.01 0.014	0.00008 0.00749 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.000042 0.000042 0.00006 0.00000 0.03448 0.32973 1.67359 0.30455	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J= 0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J= 0.009621\\ 0.001\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0.101\\ 0.53\\ 1.315\\ \hline \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01 40.98 65.29 73.66 87.06	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.93 99.94 99.95 99.94 99.95 99.94 99.95 99.94 99.85 99.83	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.54 32.22 24.45 27.09 31.98 32.09 31.98 31.16 32.12	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 487.1 487.1 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 485.4 483.9 473.1 485.9	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2 1.0 2.8 7.9 4.3
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3 4 5 6 7 8	36.04 35.724 9 São Vitor tonu 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 São Vitor tonul 24.463 27.11 31.993 32.104 31.991 31.174 32.499 31.573	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.013 0.01 0.01 0.014 0.015	0.00008 0.00749 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.000042 0.00006 0.00000 0.03448 0.32973 1.67359 0.30455 0.92221	$\begin{array}{r} 8.32\\ 9.601\\ \hline \\ J=0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J=0.009621\\ \hline 0.001\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0.101\\ 0.53\\ 1.315\\ 1.489\\ \hline \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01 40.98 65.29 73.66 87.06 91.94	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.93 99.94 99.95 99.94 99.95 99.94 99.95 99.94 99.85 98.83 98.78	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.54 32.54 32.22 24.45 27.09 31.98 32.09 31.98 31.16 32.12 31.21	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 485.4 483.9 473.1 485.9 473.6	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2 1.0 2.8 7.9 4.3 11.6
11 12 <b>AR-100</b> 1 2 3 4 5 6 7 8 9 10 11 12 <b>AR-800</b> 1 2 3 4 5 6 7 8 9	36.04 35.724 <b>9 São Vitor tonu</b> 17.141 19.604 30.648 33.241 32.232 32.84 32.752 32.715 32.546 32.668 32.741 32.509 <b>São Vitor tonal</b> 24.463 27.11 31.993 32.104 31.991 31.174 32.499 31.573 31.366	0.126 0.111 alite Biotite 0.063 0.054 0.027 0.033 0.025 0.028 0.028 0.028 0.028 0.028 0.023 0.024 0.018 0.025 lite Biotite 0.038 0 0.013 0.01 0.01 0.01 0.014 0.015 0.014	0.00008 0.00749 0.00749 0.00031 2.54802 0.23931 0.56846 0.00002 0.48662 0.70427 0.20325 0.00001 0.08151 1.23529 0.40070 0.00042 0.00006 0.00000 0.03448 0.32973 1.67359 0.30455 0.92221 2.65175	$\begin{array}{c} 8.32\\ 9.601\\ \hline \\ J=0.009621\\ 48.478\\ 27.182\\ 2.129\\ 3.592\\ 0\\ 3.662\\ 3.193\\ 0.356\\ 0\\ 0.609\\ 1.025\\ 1.045\\ \hline \\ J=0.009621\\ \hline 0.001\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0.101\\ 0.53\\ 1.315\\ 1.489\\ 0\\ \end{array}$	92.38 100.00 0.21 0.64 12.46 21.69 26.50 34.88 43.07 64.36 69.86 82.04 84.66 100.00 0.24 1.91 24.01 40.98 65.29 73.66 87.06 91.94 96.19	93.13 92.02 16.34 59.92 97.96 96.89 99.95 96.77 97.23 99.68 99.95 99.42 99.31 99.09 99.93 99.93 99.94 99.95 99.94 99.95 99.94 99.95 99.94 99.95 99.94 99.95 99.94 99.95 99.94 99.95	33.57 32.87 2.8 11.77 30.03 32.22 32.22 31.79 31.86 32.61 32.53 32.48 32.54 32.54 32.54 32.22 24.45 27.09 31.98 32.09 31.98 31.16 32.12 31.21 31.6	504.9 495.7 48.0 193.5 457.8 487.1 487.1 487.1 481.4 482.4 492.3 491.2 490.6 491.4 487.2 381.1 417.9 483.9 485.4 483.9 473.1 485.9 473.6 479.0	54.6 19.3 246.5 112.0 4.8 5.9 2.4 6.6 6.6 3.6 1.3 4.4 20.1 2.5 11.0 2.6 3.2 1.0 2.8 7.9 4.3 11.6 2.1

11	29.15	0.004	5.97273	0	100.00	99.95	29.7	453.4	2.3
AR-705	Galiléia tonalit	e Biotite		I = 0.009143					
1	47.49	0.035	0.09484	69.249	0.96	56.89	27.02	398.3	9.4
2	34.542	0.019	0.04145	5.079	7.90	95.62	33.03	476.1	1.7
3	34.124	0.019	0.03185	3.779	13.88	96.69	32.99	475.6	2.0
4	34.076	0.018	0.02898	4.019	17.51	96.48	32.88	474.1	2.4
5	35.064	0.017	0.00153	7.771	26.51	93.41	32.75	472.6	1.3
6	33.221	0.017	0.00252	1.093	61.59	98.98	32.88	474.2	1.1
7	33.451	0.016	0.00933	1.446	78.28	98.68	33.01	475.8	1.7
8	33.74	0.015	0.00433	2.203	84.24	98.03	33.07	476.6	1.8
9	33.62	0.015	0.04585	1.566	89.05	98.59	33.15	477.6	3.5
10	33.468	0.019	0.00000	3.643	90.78	96.74	32.38	467.8	3.9
11	33.088	0.016	0.00000	3.046	95.39	97.23	32.17	465.2	2.4
12	33.857	0.021	0.01916	3.274	97.83	97.1	32.88	474.1	2.7
13	34.062	0.022	0.30465	1.224	100.00	98.96	33.71	484.7	3.7
AR-957	Galiléia tonali	te Biotite		I = 0.009621					
1	90.921	0.123	0.00007	220.372	0.47	28.36	25.79	399.8	45.0
2	28.051	0.133	0.00002	38.963	1.93	58.9	16.52	266.1	16.0
3	26.711	0.083	0.00001	0	5.44	99.94	26.7	412.4	11.3
4	31.753	0.099	0.00000	0	13.66	99.95	31.74	480.7	10.7
5	32.575	0.081	0.00001	0	19.06	99.95	32.56	491.6	4.1
6	31.829	0.095	0.00000	0	32.63	99.95	31.81	481.7	8.0
7	32.456	0.095	0.00000	0	41.55	99.95	32.44	490.1	2.4
8	32.39	0.087	0.74200	0.619	46.68	99.56	32.26	487.7	6.4
9	32.439	0.088	2.72211	0	51.05	99.95	32.69	493.3	6.8
10	32.654	0.063	0.00000	0	58.09	99.95	32.64	492.7	4.2
11	32.703	0.104	0.19190	0	61.17	99.95	32.71	493.6	1.7
12	32.701	0.069	0.00000	0	71.31	99.95	32.69	493.3	2.6
13	32.35	0.1	0.00001	0	77.13	99.95	32.33	488.7	4.4
14	32.634	0.087	1.00316	0.444	79.83	99.78	32.58	491.9	8.7
15	32.839	0.062	0.00003	0	80.90	99.95	32.82	495.1	1.0
16	31.988	0.12	0.18118	0	100.00	99.95	31.99	484.1	1.0
AR-747	Galiléia tonalit	e Biotite		J=0.009143					
1	57.422	0.03	0.01364	91.03	1.61	53.13	30.51	443.9	7.1
2	39.955	0.022	0.02162	25.911	4.52	80.8	32.28	466.6	2.8
3	35.88	0.016	0.00738	9.687	9.02	91.98	33	475.7	3.3
4	34.273	0.015	0.00168	2.766	20.32	97.57	33.44	481.3	0.9
5	34.296	0.015	0.00014	2.832	31.62	97.51	33.44	481.3	1.1
6	33.764	0.015	0.01223	0.697	40.13	99.35	33.54	482.6	2.4
7	33.859	0.015	0.00433	1.196	56.64	98.91	33.49	481.9	1.1
8	33.859	0.015	0.00036	1.196	73.15	98.91	33.49	481.9	1.1
9	34.115	0.015	0.00573	1.423	81.64	98.72	33.68	484.3	2.2
10	34.308	0.015	0.00025	2.258	84.00	98.01	33.63	483.6	1.9
11	33.948	0.016	0.00000	1.262	86.30	98.86	33.56	482.8	2.7
12	34.072	0.016	0.00000	2.071	89.38	98.16	33.44	481.3	1.2
13	34.353	0.016	0.00000	2.806	90.79	97.54	33.51	482.1	1.5
14	33.582	0.014	0.01767	1.878	91.79	98.31	33.01	475.9	2.1
15	33.964	0.016	0.09576	2.674	93.24	97.65	33.17	477.8	2.6
16	34.171	0.015	0.04058	2.497	95.25	97.8	33.42	481.0	1.7
17	34.185	0.013	0.03524	2.226	95.88	98.04	33.51	482.2	2.4
18	35.065	0.012	0.04808	3.948	96.45	96.64	33.89	486.9	2.7
19	34.571	0.016	0.37912	3.552	100.00	97	33.54	482.6	2.1
1									

AR-722	Orthogneiss Bio	tite		J = 0.009143					
1	159.363	0.099	0.00000	464.193	1.87	13.92	22.18	333.1	21.7
2	34.741	0.014	0.00000	6.242	14.58	94.65	32.88	474.2	2.6
3	34.216	0.014	0.00000	1.643	47.17	98.54	33.72	484.7	3.5
4	33.938	0.014	0.01015	0.977	60.65	99.11	33.63	483.7	1.7
5	33.969	0.014	0.01127	0.317	68.16	99.68	33.86	486.6	8.2
6	34.18	0.013	0.00113	1,167	73.52	98.95	33.82	486.1	3.3
7	33.726	0.016	0.00313	0.389	79.06	99.61	33.6	483.3	3.3
8	33 956	0.014	0.00000	0.523	82.42	99.5	33 79	485.6	3.1
9	34 568	0.015	0.04584	1 497	85.25	98.68	34 11	489.8	3.2
10	34 858	0.015	0.04797	4 659	87.71	96.02	33.47	481.7	3.2
11	34 272	0.01	0.00315	2 179	90.25	98.08	33.61	483.5	2.2
12	34 487	0.01	0.00000	2.001	92 79	98.24	33.88	486.8	3.1
13	34 305	0.008	0.04174	1.852	93.90	98.37	33.75	485.1	3.2
14	33 628	0.013	0.00000	0	95.50	99.95	33.61	483.5	3.4
15	35 277	0.015	0.00000	5 575	96.17	95 29	33.61	483.5	3.1
16	33.888	0.015	0.00000	0.891	100.00	18	33.61	183.0	2.1 2.4
10	55.000	0.015	0.00000	0.071	100.00	.10	55.01	+00.+	2.4
AD 717	Calilóia tonalito	Amphiholo		I 0 000140					
1	24.57	0.007	2 01000	J = 0.009143	0.24	00.15	24.24	402.6	17
1	34.37	0.087	2.01000	0.741	9.54	99.15	25.07	492.0 501.7	1./
2	33.003	0.1	3.03176 2.97121	5 705	45.25	99.90	24.00	500.8	1.0
5	24.742	0.098	2.0/151	5.795	40.31	95.65	24.99	300.8 400.2	1.9
4	34.743	0.099	3.01849	0.501	/1.53	99.96	34.87	499.3	0.8
5	35.207	0.097	3.19382	1.54	/4.55	99.34	35.05	501.5	3.4
6	34.857	0.094	3.1/43/	0.909	//.8/	99.87	34.88	499.4	3.6
/	33.844	0.093	3.06684	1.285	81./6	99.51	33./5	485.1	1.4
8	34.243	0.096	3.08908	1.2	84.98	99.6	34.17	490.5	2.8
9	34.695	0.089	3.04323	0	86.34	99.96	34.98	500.6	2.8
10	34.46	0.087	3.50846	0	87.96	99.95	34.79	498.2	2.2
11	34.269	0.101	4.06140	0.423	89.99	99.95	34.52	494.9	3.4
12	34.294	0.086	4.88181	1.663	100.00	99.59	34.26	491.6	1.8
AD 717	Calilóin ton alito	Distita		$I_{-0.000142}$					
AK-/1/		0.051	0.01228	J= 0.009143	2 5 2	17	22.44	160 6	1 0
1	69.019	0.031	0.01228	125.755	5.52 5.10	4/	32.44 22.21	408.0	4.8
2	41.094	0.034	0.00000	32.570	J.10	94.46	52.51 22.01	407.0	4.2
5	39.081	0.029	0.00000	20.301	16.72	84.40	33.01 22.4 <b>2</b>	4/3.8	1.4
4	37.388	0.03	0.00000	13.371	16.72	89.39	33.42	481.0	1.4
5	30.138	0.028	0.00294	9.623	22.38	92.09	33.28	4/9.2	1.5
0	30.239	0.027	0.00000	9.562	20.30	92.10	33.4 22.25	480.7	5.0 1.2
/	33.741	0.027	0.01162	8.044	30.38	95.51	22.22 22.49	480.1	1.5
8	34.784	0.027	0.00000	4.304	40.40	90.25	33.48	481.8	1.8
9	34.724	0.026	0.00451	4.722	40.91	95.94	22.25	4/9./	2.1
10	34.831	0.024	0.00000	4.944	56.90	95.70	33.33 22.4	480.2	2.5
11	34.462	0.026	0.00000	3.546	50.80	96.91	33.4	480.8	3.9
12	34.525	0.025	0.01044	3.976	59.00	96.55	33.34	480.0	3.0
13	34.477	0.025	0.00000	3.118	62.83	97.28	33.54	482.5	2.7
14	34.058	0.027	0.00000	1.788	67.39	98.4	33.51	482.2	2.7
15	34.103	0.028	0.00000	1.581	69.44	98.58	33.62	483.6	4.0
16	33.701	0.026	0.00000	0.809	73.23	99.24	33.45	481.4	1.6
1/	33.807	0.026	0.00000	0.726	/6.31	99.32	33.58	483.0	2.0
18	34.128	0.026	0.00000	1.843	/8.69	98.36	33.57	482.9	2.2
19	33.742	0.023	0.007/8	1.58	81.84	98.57	33.26	47/9.0	2.4
20	33.921	0.026	0.05392	1.562	83.39	98.6	33.45	481.4	2.1
21	34.031	0.026	0.13242	1.878	84.41	98.35	33.47	481.7	3.2
22	34.255	0.027	0.07780	2.209	86.16	98.07	33.59	483.2	2.2
23	34.088	0.025	0.00000	1.579	89.48	98.59	33.61	483.4	2.0

24	34.182	0.023	0.00000	1.897	91.45	98.31	33.61	483.4	1.7
25	34.433	0.026	0.00000	3.116	92.87	97.28	33.5	482.0	1.8
26	34.898	0.026	0.06806	5.072	93.74	95.68	33.39	480.7	3.5
27	34.888	0.026	0.07908	3.617	100.00	96.91	33.81	486.0	1.0
AR-648	Palmital granit	te Muscovite	J= 0.009143						
1	44.588	0.045	0.00000	33.342	0.32	77.87	34.72	497.4	15.8
2	41.464	0.014	0.08912	25.844	1.44	81.56	33.82	486.1	4.0
3	34.49	0.012	0.00096	1.894	38.29	98.33	33.91	487.3	0.9
4	34.152	0.011	0.00000	0.74	63.38	99.31	33.92	487.3	2.3
5	34.333	0.013	0.03045	1.628	67.35	98.56	33.84	486.3	3.7
6	34.304	0.015	0.00066	1.067	71.51	99.04	33.97	488.0	1.9
7	34.057	0.011	0.00000	0	79.71	99.95	34.04	488.9	2.2
8	34.116	0.012	0.01782	0.308	87.49	99.69	34.01	488.5	1.2
9	33.864	0.011	0.04417	0.046	88.52	99.92	33.84	486.3	3.3
10	34.07	0.012	0.00000	0.058	94.25	99.9	34.04	488.8	0.9
11	33.329	0.009	0.01615	0	96.75	99.95	33.31	479.7	1.4
12	34.258	0.011	0.00364	0	99.74	99.95	34.24	491.4	1.5
13	34.001	0.014	0.00000	0	100.00	99.95	33.99	488.2	11.5
AR-648	Palmital granite	e Biotite		J=0.009143					
<b>AR-648</b> 1	Palmital granite 52.46	e <b>Biotite</b> 0.026	0.00710	J= 0.009143 63.792	4.90	64.04	33.59	483.2	3.9
AR-648	Palmital granite 52.46 40.419	e <i>Biotite</i> 0.026 0.018	0.00710 0.00657	J= 0.009143 63.792 23.181	4.90 17.64	64.04 83.02	33.59 33.55	483.2 482.7	3.9 1.7
AR-648	Palmital granita 52.46 40.419 37.645	e <i>Biotite</i> 0.026 0.018 0.017	0.00710 0.00657 0.00113	J= 0.009143 63.792 23.181 13.793	4.90 17.64 28.62	64.04 83.02 89.13	33.59 33.55 33.55	483.2 482.7 482.7	3.9 1.7 2.0
AR-648 1 2 3 4	Palmital granita 52.46 40.419 37.645 38.948	e Biotite 0.026 0.018 0.017 0.016	0.00710 0.00657 0.00113 0.00414	J= 0.009143 63.792 23.181 13.793 17.756	4.90 17.64 28.62 32.78	64.04 83.02 89.13 86.49	33.59 33.55 33.55 33.69	483.2 482.7 482.7 484.4	3.9 1.7 2.0 2.8
AR-648 1 2 3 4 5	Palmital granita 52.46 40.419 37.645 38.948 36.093	e Biotite 0.026 0.018 0.017 0.016 0.017	0.00710 0.00657 0.00113 0.00414 0.00274	J= 0.009143 63.792 23.181 13.793 17.756 8.039	4.90 17.64 28.62 32.78 47.76	64.04 83.02 89.13 86.49 93.38	33.59 33.55 33.55 33.69 33.7	483.2 482.7 482.7 484.4 484.6	3.9 1.7 2.0 2.8 1.3
AR-648 1 2 3 4 5 6	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814	4.90 17.64 28.62 32.78 47.76 54.41	64.04 83.02 89.13 86.49 93.38 93.53	33.59 33.55 33.55 33.69 33.7 33.56	483.2 482.7 482.7 484.4 484.6 482.8	3.9 1.7 2.0 2.8 1.3 1.6
AR-648 1 2 3 4 5 6 7	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172	4.90 17.64 28.62 32.78 47.76 54.41 65.86	64.04 83.02 89.13 86.49 93.38 93.53 95.64	33.59 33.55 33.55 33.69 33.7 33.56 33.89	483.2 482.7 482.7 484.4 484.6 482.8 486.9	3.9 1.7 2.0 2.8 1.3 1.6 2.7
AR-648 1 2 3 4 5 6 7 8	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5
AR-648 1 2 3 4 5 6 7 8 9	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.85 35.43 35.595 35.949	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.014	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.7	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4
AR-648 1 2 3 4 5 6 7 8 9 10	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.015 0.014 0.013	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017 0.07064	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.7	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8
AR-648 1 2 3 4 5 6 7 8 9 10 11	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.479	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.015 0.014 0.013 0.016	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.00000 0.02017 0.07064 0.02246	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.78 33.7 33.19 33.39	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5
AR-648 1 2 3 4 5 6 7 8 9 10 11 12	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.479 35.548	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.014 0.015 0.014 0.013 0.016 0.015	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017 0.07064 0.02246 0.00000	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.19 33.39 33.5	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9
AR-648 1 2 3 4 5 6 7 8 9 10 11 12 13	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.949 35.756 35.479 35.548 35.359	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.015 0.014 0.013 0.016 0.015 0.016	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017 0.07064 0.02246 0.00000 0.00000	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866 5.228	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88 88.15	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25 95.59	33.59 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.19 33.39 33.5 33.8	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1 485.8	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9 1.6
AR-648 1 2 3 4 5 6 7 8 9 10 11 12 13 14	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.479 35.548 35.359 35.204	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.015 0.014 0.013 0.016 0.015 0.016 0.015 0.016	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017 0.07064 0.02246 0.00000 0.00000 0.00000 0.01110	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866 5.228 4.678	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88 88.15 91.77	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25 95.59 96.03	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.19 33.39 33.5 33.8 33.8 33.8	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1 485.8 485.9	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9 1.6 2.2
AR-648 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.479 35.548 35.359 35.204 32.629	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.014 0.013 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.015 0.016	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017 0.07064 0.02246 0.00000 0.00000 0.00000 0.001110 0.01785	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866 5.228 4.678 0	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88 88.15 91.77 94.27	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25 95.59 96.03 99.95	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.19 33.39 33.5 33.8 33.81 32.62	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1 485.8 485.9 470.8	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9 1.6 2.2 2.1
AR-648 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.949 35.756 35.479 35.548 35.359 35.204 32.629 32.112	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.014 0.015 0.014 0.013 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.015 0.016	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.02017 0.07064 0.02246 0.00000 0.00000 0.00000 0.01110 0.01785 0.03756	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866 5.228 4.678 0 0	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88 88.15 91.77 94.27 96.17	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25 95.59 96.03 99.95 99.95	33.59 33.55 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.19 33.39 33.5 33.8 33.81 32.62 32.1	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1 480.7 482.1 485.8 485.9 470.8 464.3	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9 1.6 2.2 2.1 3.8
AR-648 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.479 35.548 35.359 35.204 32.629 32.112 36.991	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.015 0.014 0.013 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.017	0.00710 0.00657 0.00113 0.00414 0.00274 0.02312 0.00000 0.00000 0.02017 0.07064 0.02246 0.00000 0.00000 0.00000 0.01110 0.01785 0.03756 0.00000	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866 5.228 4.678 0 0 0 10.295	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88 88.15 91.77 94.27 96.17 96.92	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25 95.59 96.03 99.95 99.95 91.73	33.59 33.55 33.69 33.7 33.56 33.89 33.78 33.7 33.19 33.39 33.5 33.8 33.5 33.8 33.81 32.62 32.1 33.93	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1 480.7 482.1 485.8 485.9 470.8 464.3 487.5	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9 1.6 2.2 2.1 3.8 4.5
AR-648 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	Palmital granita 52.46 40.419 37.645 38.948 36.093 35.885 35.43 35.595 35.949 35.756 35.479 35.548 35.359 35.204 32.629 32.112 36.991 126.985	e Biotite 0.026 0.018 0.017 0.016 0.017 0.014 0.015 0.015 0.014 0.013 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.015 0.016 0.017 0.014 0.015 0.016 0.015 0.015 0.016 0.017 0.016 0.017 0.016 0.017 0.016 0.017 0.016 0.017 0.016 0.017 0.016 0.017 0.016 0.017 0.016 0.017 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.016 0.015 0.015 0.015 0.015 0.016 0.015 0.015 0.015 0.015 0.016 0.015 0.015 0.016 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.015 0.016 0.015 0.012 0.014 0.015 0.012 0.014 0.015 0.012 0.014 0.015 0.012 0.014 0.015 0.015 0.012 0.014 0.015 0.012 0.012 0.012 0.012 0.012 0.014 0.015 0.072	0.00710 0.00657 0.00113 0.00414 0.02312 0.00000 0.02017 0.07064 0.02246 0.00000 0.00000 0.01110 0.01785 0.03756 0.00000 0.00000	J= 0.009143 63.792 23.181 13.793 17.756 8.039 7.814 5.172 6.099 7.55 8.661 7.019 6.866 5.228 4.678 0 0 0 10.295 320.696	4.90 17.64 28.62 32.78 47.76 54.41 65.86 71.54 75.61 77.47 80.25 82.88 88.15 91.77 94.27 96.17 96.92 100.00	64.04 83.02 89.13 86.49 93.38 93.53 95.64 94.89 93.75 92.81 94.11 94.25 95.59 96.03 99.95 91.73 25.36	33.59 33.55 33.69 33.7 33.56 33.89 33.78 33.78 33.77 33.19 33.39 33.5 33.8 33.8 33.81 32.62 32.1 33.93 32.2	483.2 482.7 482.7 484.4 484.6 482.8 486.9 485.5 484.6 478.1 480.7 482.1 485.8 485.9 470.8 464.3 487.5 465.6	3.9 1.7 2.0 2.8 1.3 1.6 2.7 2.5 2.4 3.8 2.5 2.9 1.6 2.2 2.1 3.8 4.5 11.8

Ar- Ar results for samples from the Eastern Anatectic Unit

### Method:

Samples from the Eastern Anatectic Unit were processed and analysed at the Geochronological Research Center of the University of São Paulo (Brazil). Separation and concentration consisted of hand crushing of centimetre-scale sample chips using steel pestle and mortar to reduce size to mm-scale, sieving for size fractions of #250-500, and final magnetic purification through a isodynamic Frantz® separator. Biotite was loaded into a 21-pit aluminum disk along with the Fish Canyon sanidine standard (FCs) arranged in a cross-like geometry. Neutron-flux irradiation was performed in the cadmium lined in-core (CLICIT) facility at the Oregon State University TRIGA reactor for 14 hours. After radioactive cooling (approximately 4 weeks), each sample was loaded on a Cu-disk as multigrain aliquots containing two or three irradiated biotite flakes and progressively step-heated by a solid state Nd:YVO<sub>4</sub> (532 nm) Verdi 6W Coherent laser. Data reduction including correction for nuclear interferences, background (blank) and mass discrimination, as well J-value determination and graphical representation were made using the Ar-ArCALC v2.5.2 software (Koppers, 2012). The ages were calculated relative to the age of 28.01  $\pm$  0.04 Ma for the FCs standard (Phillips and Matchan, 2013a; Phillips and Matchan, 2013b), assuming the <sup>40</sup>K decay constant of Steiger and Jäger (Steiger and Jäger, 1977). The J-factor value for this irradiation is 0.00406  $\pm$  0.00002.

Results:
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Step	<sup>39</sup> Ar released %	<sup>40</sup> Ar/ <sup>39</sup> Ar	1σ	<sup>37</sup> Ar/ <sup>39</sup> Ar	1σ	<sup>36</sup> Ar/ <sup>39</sup> Ar	1σ	<sup>39</sup> Ar <sub>K</sub> (%)	<sup>40</sup> Ar*(%)	<sup>40</sup> Ar*/ <sup>39</sup> Ar <sub>K</sub>	2σ	Age (Ma)	2σ
AR-53	5 Anatectic g	ranite bio	tite	•									
1	2.1	75.104	0.426	0.0949	0.0321	0.0037	0.0071	2.09	98.53	74.00	4.30	475.06	24.30
2	18.0	72.939	0.018	0.0183	0.0059	-0.0006	0.0007	15.81	100.23	73.11	0.45	470.01	2.54
3	42.8	71.218	0.091	0.0171	0.0022	0.0003	0.0003	24.87	99.88	71.13	0.26	458.80	1.49
4	63.1	71.345	0.044	0.0118	0.0033	0.0012	0.0006	20.45	99.50	70.99	0.39	457.97	2.23
5	76.3	71.988	0.118	0.0203	0.0057	0.0033	0.0010	13.12	98.65	71.02	0.64	458.14	3.67
6	87.6	71.965	0.087	0.0785	0.0042	0.0008	0.0007	11.28	99.70	71.75	0.48	462.30	2.72
7	91.2	73.069	0.295	-0.1005	0.0072	0.0055	0.0016	3.70	97.75	71.42	1.11	460.44	6.30
8	97.5	72.664	0.144	-0.0329	0.0081	0.0027	0.0023	6.25	98.90	71.86	1.40	462.94	7.98
9	99.1	75.197	0.942	-0.0306	0.0213	0.0148	0.0063	1.67	94.14	70.79	4.17	456.83	23.78
10	100.0	82.607	0.533	-0.1886	0.0588	0.0009	0.0122	0.77	99.67	82.32	7.39	521.44	40.64
AR-60	64 Anatectic g	ranite bioti	te										
1	2.8	74.623	0.162	0.0167	0.0195	0.0100	0.0034	2.74	95.98	71.63	2.04	461.60	11.59
2	23.2	73.705	0.100	0.0305	0.0007	-0.0020	0.0005	20.57	100.81	74.30	0.35	476.74	1.97
3	42.6	74.270	0.041	-0.0067	0.0049	-0.0007	0.0009	19.21	100.27	74.47	0.54	477.71	3.03
4	61.5	73.577	0.084	0.0019	0.0048	0.0008	0.0003	19.04	99.68	73.34	0.23	471.35	1.30
5	74.3	73.410	0.062	0.0058	0.0020	-0.0025	0.0010	12.68	101.02	74.16	0.64	475.97	3.60
6	85.2	73.691	0.098	-0.0301	0.0032	0.0012	0.0016	11.24	99.51	73.33	0.96	471.26	5.41
7	95.4	74.157	0.092	0.0581	0.0035	-0.0031	0.0009	9.94	101.24	75.08	0.58	481.15	3.24
8	97.3	73.385	0.774	-0.0296	0.0281	-0.0071	0.0049	2.05	102.88	75.50	3.35	483.48	18.83
9	99.6	78.937	0.837	-0.1303	0.0543	0.0023	0.0083	2.10	99.12	78.23	5.23	498.79	29.13
10	100.0	68.647	0.102	-0.1451	0.0947	0.0889	0.0156	0.44	61.33	42.09	9.31	285.31	58.38
AR11.	33 Anatectic g	granite biot	ite										
1	2.0	68.546	0.747	-0.0401	0.0538	0.0601	0.0021	1.85	73.83	50.60	1.62	337.89	9.85
2	14.1	76.158	0.025	-0.0042	0.0058	0.0021	0.0024	12.37	99.16	75.52	1.42	483.60	7.99
3	32.7	75.626	0.023	-0.0028	0.0024	-0.0009	0.0007	18.45	100.34	75.88	0.43	485.65	2.41
4	51.4	75.885	0.092	-0.0048	0.0024	-0.0025	0.0003	18.80	101.00	76.64	0.28	489.91	1.56
5	71.8	75.560	0.031	-0.0080	0.0008	-0.0011	0.0007	19.26	100.41	75.87	0.43	485.59	2.41
6	89.9	76.085	0.096	0.0030	0.0023	0.0001	0.0007	19.18	99.95	76.05	0.48	486.58	2.67

7	92.0	76.922	0.539	-0.0123	0.0164	0.0013	0.0057	2.09	99.49	76.53	3.57	489.26	20.02
8	94.5	77.429	0.277	0.0212	0.0221	-0.0021	0.0049	2.56	100.79	78.04	3.01	497.74	16.76
9	95.1	96.414	1.689	-0.0442	0.1504	-0.0416	0.0288	0.47	112.86	108.81	17.61	661.62	89.66
10	100.0	76.783	0.074	-0.0160	0.0135	0.0044	0.0026	4.72	98.28	75.46	1.56	483.27	8.78
AR-1145 Diatexite biotite													
1	3.8	76.081	0.461	0.0267	0.0152	0.0062	0.0045	3.76	97.58	74.24	2.84	476.40	15.99
2	19.7	74.885	0.098	0.0021	0.0036	0.0010	0.0008	16.04	99.61	74.59	0.49	478.38	2.78
3	41.7	74.068	0.056	0.0071	0.0018	-0.0005	0.0008	21.89	100.20	74.22	0.47	476.27	2.66
4	58.6	74.312	0.095	0.0352	0.0001	0.0008	0.0009	16.87	99.67	74.07	0.58	475.44	3.25
5	74.1	74.438	0.092	-0.0017	0.0032	-0.0002	0.0002	15.51	100.06	74.49	0.22	477.79	1.23
6	88.0	74.188	0.079	-0.0054	0.0063	0.0006	0.0003	13.97	99.75	74.00	0.26	475.07	1.45
7	94.9	74.099	0.070	-0.0330	0.0026	-0.0007	0.0024	6.67	100.29	74.31	1.46	476.81	8.26
8	97.2	78.537	0.256	0.0831	0.0015	0.0071	0.0031	2.62	97.31	76.43	1.91	488.71	10.68
9	99.1	75.991	0.233	-0.0308	0.0168	-0.0055	0.0056	1.92	102.16	77.63	3.37	495.42	18.82
10	100.0	103.780	3.899	-0.0479	0.2651	-0.0895	0.0691	0.22	125.76	130.51	42.35	768.85	203.22
AR-1349 Metatexite biotite													
1	2.6	75.148	0.048	0.0038	0.0193	0.0088	0.0044	2.41	96.52	72.53	2.61	466.73	14.82
2	18.7	73.699	0.043	-0.0035	0.0039	0.0003	0.0007	16.17	99.86	73.60	0.45	472.77	2.57
3	40.0	74.334	0.030	-0.0001	0.0033	0.0006	0.0003	21.43	99.77	74.16	0.18	475.97	1.04
4	57.9	73.908	0.031	0.0006	0.0036	0.0015	0.0008	17.85	99.41	73.47	0.48	472.07	2.73
5	74.3	73.914	0.012	-0.0028	0.0015	-0.0012	0.0005	16.36	100.50	74.28	0.29	476.65	1.64
6	86.4	74.232	0.069	-0.0049	0.0037	0.0003	0.0009	12.17	99.87	74.13	0.58	475.81	3.27
7	95.2	73.989	0.040	0.0236	0.0022	-0.0006	0.0006	9.04	100.24	74.17	0.39	475.98	2.18
8	97.6	73.159	0.180	-0.0378	0.0181	-0.0065	0.0038	2.19	102.65	75.09	2.30	481.21	12.97
9	100.0	78.291	0.116	-0.0526	0.0121	0.0012	0.0018	2.37	99.52	77.91	1.12	497.00	6.22
AR-1368 Anatectic granite biotite													
1	3.1	68.182	0.009	-0.0421	0.0207	-0.0045	0.0055	3.11	101.96	69.52	3.30	449.57	18.87
2	22.3	71.413	0.029	-0.0048	0.0052	-0.0005	0.0011	19.35	100.20	71.56	0.69	461.21	3.92
3	44.1	72.785	0.110	-0.0071	0.0048	-0.0005	0.0006	21.88	100.21	72.94	0.41	469.04	2.35
4	58.8	72.960	0.067	-0.0014	0.0039	0.0001	0.0009	14.26	99.98	72.94	0.56	469.08	3.18
5	69.9	72.692	0.061	-0.0072	0.0089	-0.0033	0.0005	11.30	101.34	73.67	0.30	473.16	1.71
6	79.9	73.675	0.053	-0.0049	0.0073	0.0025	0.0007	9.95	99.00	72.94	0.40	469.06	2.29
7	88.5	72.897	0.099	0.0083	0.0088	0.0034	0.0007	9.67	98.63	71.90	0.45	463.14	2.53
8	95.2	73.578	0.007	-0.0601	0.0050	0.0050	0.0019	5.59	97.95	72.07	1.11	464.11	6.28
9	99.2	71.936	0.090	-0.0225	0.0173	0.0015	0.0032	4.26	99.39	71.49	1.92	460.85	10.90
10	100.0	72.199	0.996	-0.1665	0.0926	0.0304	0.0163	0.63	87.41	63.10	9.86	412.45	57.65

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