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Garnet as a monitor for melt-rock interaction: textural, mineralogical and compositional evidence of partial melting and melt-driven metasomatism

Abridged title : Garnet as a monitor for melt-rock interaction

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28

29 **ABSTRACT**

30 In this study, we focus on a partially melted garnet-bearing granulite from the Salvador-
31 Esplanade belt (Salvador da Bahia, Brazil), and examine the behavior of major and trace
32 elements during partial melting and melt-driven metasomatism. Phase equilibria modeling and
33 U-Th-Pb geochronology shows that the sample underwent partial melting during the heating
34 segment of the decompression path from ~ 1.2 GPa and 675-700°C to ~ 0.8 GPa and 790°C at ca.
35 2.06 Ga. During the last stage of decompression, from 0.8 to ~ 0.5 GPa, physical segregation of
36 melt resulted in the establishment of chemical potential gradients and mass transfer between
37 the host-granulite and the leucosome. Modelling shows that H₂O, CaO, K₂O and Na₂O diffuse from
38 the melt into the host residue, whereas SiO₂ is transferred from the host-granulite into the
39 adjacent leucosome. Opposed senses of diffusional transfer resulted in the formation of a
40 quartz-rich anhydrous leucosome and a quartz-undersaturated selvage in the host-granulite.
41 Compositional maps show that garnets exhibit unusual and contrasting major and trace element
42 distribution depending on their textural position. The largest garnets located in the quartz-
43 undersaturated selvage preserve their original Ca and trace element growth zoning. A transition
44 from bell-shaped profiles for Y and HREEs to bowl-shape profiles for LREEs is consistent with a
45 typical Rayleigh fractionation model, fast intergranular element mobility and rock-wide
46 equilibrium during prograde partial melting. In contrast, smaller garnets away from the
47 leucosome show evidence of prograde growth zoning modified by intragranular diffusion, as
48 evidenced by a network of open channels and healed-cracks that act as connecting pathways
49 between the matrix and garnet core. This results in either subtle modification of both major and
50 trace elements adjacent to the inner core inclusions, or a complete re-equilibration. The
51 recognition that the initial Ca growth zoning, including the inner core compositions, was later
52 modified by intragranular diffusion implies that misleading thermobarometric results and
53 tectonic interpretations would be obtained if the garnet core composition was used to
54 fingerprint the early garnet nucleation stage. This study further demonstrates that at high

55 temperature ($> 750^{\circ}\text{C}$) and in the presence of melt, REE are not less vulnerable to diffusive
56 resetting than divalent cations like Ca^{2+} .

57 keywords : garnet zoning, partial melting, chemical potential, diffusion metasomatism, LA-ICP-

58 MS

59

60 1. INTRODUCTION

61 Partial melting is a fundamental process for differentiating (Brown, 2010) and weakening
 62 the deep crust (Piazolo, Daczko, Silva & Raimondo, 2020; Rosenberg & Handy, 2005), which in
 63 turn exerts a first-order control on deformation style, lateral redistribution of mass, crustal
 64 thickness and surface topography (Beaumont, Jamieson, Nguyen & Medvedev, 2004; Hollister &
 65 Crawford, 1986; Jamieson, Unsworth, Harris, Rosenberg & Schulmann, 2011; Rabin, Trap, Carry,
 66 Fréville & Cenki-Tok, 2015; Royden et al., 1997; Vanderhaeghe, 2012). Exhumed migmatites
 67 preserve, through their mineralogy and structure, a wealth of information that can be used to
 68 decipher the thermo-mechanical behavior of orogenic continental crust. With this motivation,
 69 the petrological analysis of partially melted felsic rocks is now commonplace in metamorphic
 70 petrology, thanks to extended experimental work (e.g. Clemens, 1984; Grant, 1985; Le Breton,
 71 1988; Thompson, 1982; Vielzeuf & Holloway, 1988; Vielzeuf & Montel, 1994) and thermodynamic
 72 phase relation modeling (Holland & Powell, 2001a; Spear, Kohn & Cheney, 1999; Vielzeuf &
 73 Schmidt, 2001; White, Powell & Holland, 2001; White & Powell, 2010). Despite this progress,
 74 modeling phase relations in migmatites is not trivial because they are subject to redistribution
 75 and transfer of the highly mobile melt component at various scales, from grain- to crustal-scale
 76 (Etheridge, Daczko, Chapman & Stuart, 2020; Sawyer, 2001). Therefore, phase relation modeling
 77 in migmatites requires the consideration of not only changes in environmental variables like
 78 pressure and temperature, but also the variation of the equilibrium volume and composition of
 79 the system (i.e. open system processes).

80 Modeling the role of melt transfer (loss and gain) on phase relations has been extensively
 81 investigated (Alessio, Hand, Morrissey, Kelsey & Payne, 2017; Bartoli, 2017; Dumond, Goncalves,
 82 Williams & Jercinovic, 2015; White et al., 2001; Yakymchuk & Brown, 2014;). Among the many
 83 benefits of open system forward modeling is the application of a melt-reintegration approach
 84 that consist of recovering the bulk composition prior to any melt transfer. This method allows
 85 investigating the prograde evolution of melt-bearing systems that tend to be obliterated by
 86 continuous re-equilibration up to peak metamorphic conditions. Another complexity arising from

the segregation of melt from the solid residue is that the system becomes physically and chemically differentiated into melt-rich domains (leucosome) and solid-rich domains (melanosome). The thermodynamic system is therefore composed of two sub-systems that will interact, with changing pressure and temperature conditions, due to the establishment of chemical potential gradients of components at the interface between both sub-systems (White & Powell, 2010). The diffusion of components (H_2O , SiO_2 , ...) between the two sub-systems produces significant variations in composition, mineral reactions and assemblages (Fitzsimons, 1996; White & Powell, 2010). Despite this conceptual framework being generally accepted, melt-rock interaction in segregated migmatites remains rarely identified via textural, geochemical and/or mineralogical evidence, nor investigated via thermodynamic modeling (Kriegsman & Hensen, 1998; Lin & Sawyer, 2019; White & Powell, 2010).

In migmatites, garnet is very common as a peritectic phase and has the ability to preserve zoning of divalent cations (Fe, Mg, Ca and Mn) that reflects changing P-T conditions and/or bulk rock chemistry, either due to garnet fractionation or mass transfer during melt segregation, transport and interaction with the garnet-bearing residual rock (e.g. Caddick, Konopásek & Thompson, 2010; Konrad-Schmolke, O'Brien, de Capitani & Carswell, 2008). To retrieve the maximum information related to garnet chemical evolution, the characterization of major element zoning can be complemented with trace elements (Hyppolito et al., 2019; Raimondo et al., 2017). Trivalent cations, like rare-earth elements, have lower diffusion coefficients than major divalent cations. They are therefore more resistant to diffusional modification and allow the preservation of prograde and high temperature processes (Carlson, 2012; Gaidies et al., 2020; George & Gaidies, 2017; Moore, Carlson & Hesse, 2013; Rubatto et al., 2020), including those involved during partial melting (Dumond et al., 2015).

The trace element characteristics of garnet can be linked to the evolution of accessory phases used for geochronology (e.g. monazite, zircon and rutile) to better constrain tectonometamorphic histories (Dumond et al., 2015; Hermann & Rubatto, 2003; Mahan, Goncalves, Williams & Jercinovic, 2006; Prent et al., 2019; Pyle & Spear, 2003; Tomkins & Pattison, 2007; Weller, Jackson, Miller, St-Onge & Rayner, 2020). They also provide insight into

the mechanisms controlling the uptake (interface- vs diffusion-controlled growth) and mobility of trace element during metamorphism and metasomatism (George, Gaidies & Boucher, 2018; Konrad-Schmolke, Zack, O'Brien & Jacob, 2008; Moore et al., 2013; Raimondo et al., 2017; Skora et al., 2006). With the recent development of in-situ laser ablation - inductively coupled plasma - mass spectrometry (LA-ICP-MS), it is now possible to rapidly and quantitatively map the 2D distribution of trace elements across major and accessory minerals of interest (George et al., 2018; Raimondo et al., 2017; Ubide, McKenna, Chew & Kamber, 2015). Yet, despite the known benefits of analyzing trace elements in garnet for the purposes listed above, there remains a limited number of studies using this approach to understand the grain-scale controls on garnet crystallization (Gaidies et al. 2020; George et al., 2018; Rubatto et al. 2020).

In this contribution, we report the integrated petrological and geochemical characterization of a high-grade rock that preserves evidence of changes in P-T conditions, partial melting and melt-driven metasomatism. The selected sample, from the São Francisco craton in Brazil, is a layered composite rock that consists of a garnet-bearing quartz-saturated host granulite, a quartz-feldspathic leucosome, that may correspond to crystallized segregated melt or differentiated melt residue (Guernina & Sawyer, 2003), and a quartz-undersaturated garnet-bearing selvage formed at the interface between the host-granulite and leucosome. Petrological analysis and thermodynamic modeling (using P-T- μ -X phase diagrams, where μ = chemical potential and X = composition) shows that the distinct mineralogy of the selvage is the result of mass transfer driven by chemical potential gradients established between the host-granulite and the segregated melt during decompression. In addition, garnets show a consistent change in grain size, morphology, major and trace element composition and zoning patterns across the gneissic layering, as revealed by quantified LA-ICP-MS raster maps. The strong correlation between textural position and zoning pattern in garnet gives insight into the grain-scale petrogenetic processes involved in partially-molten granulites. We distinguish the role of (1) intergranular mobility of elements and accessory phases during metamorphic garnet growth; and (2) post-growth intragranular diffusion of major and trace elements during melt-driven metasomatism.

143 2. GEOLOGICAL SETTING

144 2.1. São Francisco craton and the Salvador-Esplanade belt

145 The São Francisco Craton, located in the east-central part of Brazil, consists of an Archean to
 146 Paleoproterozoic crystalline basement mostly overlain by Meso to Neoproterozoic sediments in
 147 its western part (Figure S1). The craton is bounded by Neoproterozoic marginal fold belts (Figure
 148 S1). The eastern part of the craton, where most of the metamorphic rocks are exposed, is
 149 subdivided into four major geological units: three Archean blocks (Gavião, Jequié and Serrinha)
 150 and two Paleoproterozoic belts: the Itabuna-Salvador-Curaçá Orogen (ISCO) and the Salvador-
 151 Esplanada belt (SEB) (Figure S1) (Barbosa & Sabaté, 2004, see references therein). The
 152 southernmost part of the Salvador-Esplanada belt, where this study has been conducted, trends
 153 broadly North-East and consists mostly of mafic to felsic granulites and migmatites.

154

155

156 2.2. Farol da Barra: metamorphism and age constraints

157 In the Salvador da Bahia city, high grade metamorphic and magmatic rocks of the SEB are
 158 exposed in a horst that is bound on the western side by the Recôncavo sedimentary basin and on
 159 the eastern side by the Atlantic coastal margin. The studied area is located at the Barra lighthouse
 160 (Farol da Barra; 13°00'41"S; 38°31'57"W, Figure 1a). Four distinct lithologies are identified
 161 (Souza Barbosa & Gomes, 2010; Souza-Oliveira et al., 2014) (Figure 1a): (1) orthopyroxene-
 162 bearing granulites that constitute most of the basement of the city of Salvador da Bahia and are
 163 interpreted to be derived from late Archean tonalitic magmatic rocks (2) garnet-bearing
 164 granulites and sapphirine-bearing Al-Mg granulites interpreted as meta-sediments (3)
 165 granulitized ultramafic and mafic rocks that occur as centimeter to meter-scale boudins within
 166 the paraderived granulites; and (4) monzonitic to syenitic intrusives dykes, oriented ~N10°
 167 (Figure 1a), that are either deformed or undeformed with sharp intrusive contacts.

168 Metamorphic conditions have been estimated at 0.75-0.9 GPa and 840-900°C in the
 169 sapphirine-bearing granulites (Fujimori, 1988). The age of the granulitic metamorphism has been

170 constrained by SHRIMP U-Pb dating at 2089 ± 11 Ma on zircon overgrowths from the
 171 orthopyroxene-bearing granulites (Da Silva, McNaughton, 1997). On the same samples, zircon
 172 cores yielded an age of 2561 ± 7 Ma interpreted as the crystallization age of the protolith
 173 magmatic rocks. The later syenitic to monzonitic magmatism has been dated by Pb-Pb
 174 evaporation on zircon at 2064 ± 6 Ma (Souza et al., 2010).

175

176 **2.3. Farol da Barra: structural relationships**

177 The Barra lighthouse outcrop is characterized by a complex ductile finite strain pattern
 178 that results from the superposition of two main phases of deformation (D_1 and D_2) (Figure 1b).
 179 The overall geometry consists of meter to decameter lenses, in which D_1 structures are best
 180 preserved, surrounded by D_2 -East-West striking high strain zones (Figures 1b and S2). The first
 181 deformation phase (D_1) is characterized by a gently dipping gneissic foliation (S_1) that strikes NE-
 182 SW (Figure 1b and S2). This foliation is associated with isoclinal folds with axial planes parallel
 183 to S_1 (Figure 1b). The S_1 foliation bears a sub-horizontal L_1 stretching and mineral lineation
 184 plunging $0-20^\circ$, marked by the preferred orientation of feldspars, quartz ribbons, mafic mineral
 185 and elongated ultramafic to mafic boudins. The second deformation phase (D_2) is characterized
 186 by heterogeneous deformation that progressively steepens and transposes the previous D_1 fabric
 187 along upright D_2 folds and steeply dipping high strain zones ($> 55^\circ$) that forms an anastomosing
 188 network of conjugated shear zones trending approximately east-west (Figures 1b and S2). An L_2
 189 lineation is defined by stretched quartz, feldspars and by the preferred orientation of biotite
 190 with a moderate plunge of 10 to 35° towards the NE.

191 Kinematic analysis in the low D_2 strain domains show that the two sets of ductile
 192 conjugate shear zones consist of a dominant $108/72$ SSW dextral shear zone and minor sinistral
 193 $021/79$ ESE shear zones (Figure S2). This pattern of D_2 finite strain is consistent with a NNW-SSE
 194 shortening and a bulk dextral sense of shear. The NW-SE cross-section from the Santa Maria Forte
 195 towards the Cristo hill (Figure 1b) shows that the studied area (the Barra lighthouse) corresponds
 196 to a major localized D_2 high strain zone within a preserved D_1 low strain domain characterized by
 197 gently dipping foliation. Whereas the D_1 domains (Santa Maria fort, Hispaniola hospital, and
 8

Cristo Hill) consist mainly of orthopyroxene-bearing granulites, the Barra lighthouse D₂ high strain zone is characterized by the abundance of garnet-bearing granulite. This apparent relationship between deformation and lithology is beyond the scope of this contribution and will not be discussed further.

3. TEXTURAL AND MINERALOGICAL CHARACTERISATION

3.1. Outcrop and sample descriptions

The studied sample is located in a S₂ high strain zone that surrounds a large decametric lense of low strain rocks where an earlier fabric (S₁) is preserved (Figure 1). The S₂ granulite-grade gneissic foliation is steeply dipping (072/80S) and contains a gently plunging mineral lineation (09—>075) defined by the preferred orientation of biotite and sillimanite. The gneissic foliation is marked by a compositional banding with centimeter-wide quartzo-feldspathic leucosomes in a garnet-bearing granulite (Figure 2a). Leucosomes are usually less than a three centimeters in width and are systematically surrounded by a centimeter thick dark and coarse-grained quartz-undersaturated selvage developed at the expense of the surrounding garnet-bearing granulite (Figure 2b).

The studied sample 06SB06 encompasses the three lithologies described above: the host quartz-saturated granulite, a 1 cm-wide quartz-undersaturated selvage and a thin leucosome (Figure 2b). The peak-metamorphic assemblage of the quartz-saturated granulite consists of garnet, sillimanite, plagioclase, biotite, quartz and K-feldspar (Figure 3a). Garnet is interpreted as a peritectic phase produced during biotite dehydration melting via the reaction:

Spinel is locally observed in the matrix but it is always surrounded by a thin corona of sillimanite and it is never in contact with quartz. The preferred orientation of large sillimanite blades (up to 5 mm), K-feldspar and biotite, that occurs either as small flakes or large resorbed grains,

225 defines the main S_2 foliation observed at the outcrop scale. Garnet contains numerous quartz
226 inclusions and polyphase aggregates of plagioclase + quartz with minor biotite inclusions that all
227 show a preferred orientation at high angle with respect to the S_2 foliation (Figure 3a). This
228 alignment is interpreted as a relict of the former shallow dipping S_1 foliation. Peak metamorphic
229 garnet in contact with sillimanite is partially resorbed and surrounded by a moat of retrograde
230 cordierite (Figure 3b), consistent with the classic reaction

232 which proceeds during decompression and/or cooling.

233 The selvage, in direct contact with the leucosome, is composed of the same peak
234 metamorphic assemblage, consisting of prismatic sillimanite, plagioclase, garnet, biotite and K-
235 feldspar, except it lacks quartz. Biotite is more abundant than in the quartz-saturated granulite.
236 Garnet cores contain numerous quartz inclusions, in association with plagioclase, suggesting that
237 the onset of partial melting and crystallization of peritectic garnet occurred under quartz-
238 saturated conditions. Garnet porphyroclasts are partially broken-down into cordierite and
239 sillimanite is strongly resorbed and replaced by cordierite + spinel symplectites (Figure 3c) via
240 the reaction

242 The leucosome consists mainly of quartz and thin elongated K-feldspar ribbons.

243 Plagioclase is very rare and occurs as late myrmekite intergrowths next to K-feldspar.

244 Mineral compositions are available in Dataset S1. Biotite has X_{Mg} of 0.67-0.69 and 0.71-
245 0.73 for the small flakes and large grains respectively, with a constant Ti content of 0.25 to 0.30
246 pfu. Plagioclase in the matrix has a variable range in anorthite content from 0.43 to 0.52. Spinel
247 is very homogeneous in composition with a X_{Mg} of 0.31. Garnet compositions are described in
248 Section 4.

249

250 **3.2. Evolution of garnet morphology and inclusions**

251 One of the most conspicuous observations is the evolution of garnet size, distribution of

inclusions and composition across the quartz-undersaturated selvage and the granulite perpendicular to the gneissic layering. Although no quantitative textural analysis has been conducted, it appears that garnet grain size decreases and the number of garnet grains increases away from the leucosome, with the biggest garnet grains observed in the quartz-undersaturated selvage (Figures 4 and 5). Furthermore, the amount, shape and composition of inclusions in garnet varies greatly and continuously across the gneissic foliation. To describe this evolution, seven garnets (A to G) were selected (see location in Figure 4).

In the quartz-undersaturated selvage, most garnets contain a few rounded inclusions of quartz in their core (garnet A, Figure 5a). Away from the leucosome, but still in the selvage, the largest garnet porphyroblast (b) contains in its core a small polymineralic inclusion, that consists of plagioclase and quartz, surrounded by rounded isolated quartz inclusions (Figure 5b). Inclusion-rich garnet cores are surrounded by a large rim free of inclusions except for numerous and homogeneously distributed crystallized granitic melt inclusions that are less than 20 microns in diameter (Figures 5a-b and 6). The inclusions have been identified as crystallized melt based on the main microstructural criteria summarized in Cesare, Acosta-Vigil, Bartoli & Ferrero (2015) : (1) the development of a perfect negative crystal shape (Figure 6a); (2) its polycrystalline nature that consists of biotite, plagioclase, quartz and apatite for the most common phases (nanogranitoids) (Figure 6b-c); and (3) the development of cracks (decrepitation) during decompression filled with minerals similar to those in the melt inclusion (Figure S6). The presence of these crystallized melt inclusions attest to the growth of the garnet rim in the presence of melt.

In the quartz-saturated granulite, the abundance of polymineralic inclusions of plagioclase and quartz observed in garnets increases away from the leucosome (Figures 4 and 5c-g). The garnet core, defined as the garnet containing plagioclase-quartz polymineralic inclusions surrounded by isolated quartz grains can be as large as 1mm and represent up to 50% of the garnet volume. Polymineralic inclusions have rounded (Figure 5c-d-f) to very irregular shapes with straight boundaries (Figure 5e). These facets are inferred to be parallel to crystallographic orientations of the garnet host and result from post-entrapment readjustment of the inclusion

and host by dissolution-reprecipitation processes (e.g. Frezotti, 2001). Plagioclase in the polymineralic inclusions are chemically zoned with a composition varying almost continuously from pure anorthite $An_{95}Ab_{05}$ to $An_{58}Ab_{41}$. Highest amounts of albite are measured in the vicinity of rounded quartz inclusions within plagioclase and the garnet host (Figure S3). All garnets have an inclusion-free rim without any melt-inclusions, as for the garnet located in the quartz-undersaturated selvage (Figure 5). This difference in the ability for garnet rims to entrap melt inclusions may be related to a slowdown of radial growth rate as garnet continuously grows.

X-ray computed microtomography and sequential cuts through a single garnet crystal has been performed to highlight the volume, shape and potential connectivity of the polyphased inclusions with the matrix. The selected garnet is located in the quartz-saturated granulite where the amount of polyphase quartz-plagioclase is most abundant. The X-ray tomography reveals the very irregular shape of the polyphased inclusions as well as the “spongy” texture of the garnet core (Figure 7). Although all thin-section photomicrographs of garnet presented in Figure 5 suggest that polyphase inclusions are completely enclosed in the garnet, the 2D cuts rather suggest that they are connected to the matrix through small pathways (Figure 7d-f and Movie S1).

3.3. Microtextures in the quartz-undersaturated selvage

Microtextures in the quartz-undersaturated selvage have been revealed using a cold cathode cathodoluminescence detector on an optical microscope. The matrix consists mainly of K-feldspar grains (in blue in the CL images) that form a fine-grained mosaic texture with straight boundaries and triple junctions at 120° (Figure 8a-b). K-feldspar is characterized by a core with fine-grained perthite textures surrounded by a K-feldspar rim (Figure 8a). These boundaries are coated with thin plagioclase films or elongated grains (brown color in Figure 8a-b) that can be connected to form a branching array. Terminations of the films and elongated grains are characterized by small dihedral angles ($< 20^\circ$). The connection of these films also leads to the formation of plagioclase pools along grain boundaries (Figure 8a-b) or at K-feldspar triple

junctions. Where plagioclase films are abundant, K-feldspar grains show very irregular resorbed grain boundaries (Figure 8b) and plagioclase films are connected to myrmekites pools (Figure 8a-b). Finally, a large plagioclase ($\pm$ quartz) moat surrounds sillimanite and garnet porphyroblasts (Figure 8b).

311

312 4. GARNET COMPOSITION

To investigate the link between the textural and mineralogical features of melt-rock interaction and their compositional characteristics, major element data from multiple garnet grains were obtained by EMPA, and trace element data by LA-ICP-MS. X-ray maps and linear spot traverses were acquired to reveal the evolution of major element zoning patterns across the quartz-undersaturated selvage and granulite. Trace element mapping was performed to better inform the paragenetic context, particularly with regard to accessory minerals, and evaluate the record of geochemical mobility during garnet growth and dissolution. Major and trace element data are provided in Datasets S1 and S2, respectively, and presented in Figures 9, 10, 11, 12 and 13. . Raw trace element maps from which the profiles were extracted are available as “.csv” text file images (Dataset S3-S5). LA-ICP-MS analytical methods are provided in Appendix S1.

323 4.1. Major element zoning

Garnets are almandine - pyrope - grossular solid solutions with minor amounts of spessartine (< 0.015) (Dataset S1). All garnets are zoned and their composition varies with respect to their location and distance from the leucosome. In the quartz-undersaturated selvage, a polymineralic inclusion-free garnet porphyroblast in direct contact with the leucosome (Garnet A; Figure 5a) is characterized by bell-shaped zoning in grossular, with a maximum content of 0.12 in the core that decreases continuously towards the rims down to 0.03 (Figure 9a). Almandine and pyrope content increase towards the rim from 0.56 to 0.61 and 0.30 to 0.35, respectively, which results in a constant $X_{Mg} [=Mg/(Fe+Mg)]$ of 0.34-0.35. Garnet B has equivalent zoning, except that close to the polymineralic inclusions, grossular content decreases

333 from a 700 μm wide and uniform plateau at 0.12 down to 0.08 (Figure 9b). This decrease in
 334 grossular content is mimicked by an increase of XMg from 0.35 to 0.38. It is noteworthy that the
 335 depleted grossular core also corresponds to the domain containing smoothed and rounded
 336 inclusions of quartz (light gray area in Figure 9b). The outer rim of Garnet B is characterized by
 337 grossular content and XMg value of 0.03 and ~0.35-0.36, respectively (Figure 9b). The resorbed
 338 outer left rim, in contact with cordierite and biotite, shows a sharp decrease in XMg down to
 339 0.28 over a distance not greater than 100 μm (Figure 5b and 9b).

340 Garnets from the quartz-saturated granulite (Garnets C-G) show zoning profiles
 341 comparable in shape to Garnet B from the quartz-undersaturated selvage, except that the
 342 endmember modal abundances are significantly different (compare Figure 9b and Figure 9c-g).
 343 Garnet cores in direct contact with the polymineralic inclusions are characterized by low
 344 grossular values (0.03-0.04) that are similar in composition to garnet rims in contact with the
 345 matrix. Grossular content then increases towards the rim to a maximum value that is
 346 systematically located at the transition between the inclusion-bearing and inclusion-free garnet
 347 (Figure 9c-g). The maximum grossular content varies from grain to grain, from 0.095 (Garnet E)
 348 down to 0.045 (Garnet F). Finally, the inclusion-free rims show a decrease in grossular content
 349 towards the matrix to a minimum value of 0.03, equivalent to the core compositions. XMg ratio
 350 profiles for all samples are relatively flat, with values evolving from 0.36-0.37 (Garnet C) to
 351 0.41-0.44 (Garnet G) with increasing distance from the leucosome. The smallest garnet grain
 352 analyzed (Garnet F) does not follow this trend, showing a lower XMg value of 0.36 and a near-
 353 constant grossular content of 0.03-0.04. Garnet E profile shows on its left side a sharp decrease
 354 in XMg from 0.40 to 0.36, over a distance less than 100 μm , that is interpreted as late Fe-Mg
 355 exchange during partial garnet breakdown into cordierite, comparable to Garnet B.

356

357

358 4.2. Trace element zoning

359 Similar to their major element characteristics, the analyzed garnets show significant

360 variations in trace element composition and zoning patterns depending on their location with
 361 respect to the leucosome. We will focus on Garnets A and B, located in the quartz-
 362 undersaturated selvage, and Garnet G, located in the quartz-present host granulite.

363 Garnet A is located directly adjacent to the leucosome, and contains the least inclusions
 364 in its core except for a few rounded quartz grains. Figures 10a, 11 and Figure S4 illustrate the
 365 key features of the trace element zoning. Y, Zr, V and heavy rare-earth elements (HREEs), from
 366 Dy to Lu, show a symmetrical bell-shaped profile without sharp discontinuities except for an
 367 abrupt increase at the rim. In contrast, light rare-earth elements (LREEs), from La to Gd, show a
 368 bowl-shaped zoning profile with a broad flat core that is mimicked by Li, P and Sc. Notably, the
 369 radial positions of broad peaks along the zoning profile are correlated for all REEs and Y (Figure
 370 11), and there is no difference in gradient with decreasing atomic number.

371 Garnet B is the largest analyzed grain, with a small polyphase plagioclase + quartz
 372 inclusion in its core. It is located a few millimeters from Garnet A within the quartz-
 373 undersaturated selvage but further displaced from the leucosome. Trace element map and
 374 profile are shown in Figure 10b, 12 and S4. Its zoning pattern shows the same symmetrical bell-
 375 shape profile for Y, Zr and the heaviest HREE (from Yb to Er), but with elevated concentrations
 376 compared to Garnet A (e.g. Y ~360 vs 270 ppm; Yb ~75 vs 45 and Lu ~15 vs 6 ppm). In contrast,
 377 rim compositions are strictly identical for all elements in both samples (compare Figures 11 and
 378 12 and S4). Because Garnets A and B are located in the same petrographic setting, we suggest
 379 that the difference in absolute concentrations reflects a sectioning effect (i.e. Garnet A is not
 380 sectioned through its core) rather than a geological process. The outer rim of Garnet B is
 381 characterized by a sharp increase in Y, Zr and HREEs, and LREEs and P have the same overall
 382 bowl-shaped zoning as Garnet A despite a more irregular profile that includes several narrow
 383 peaks. Concentrations in La, Ce and P are significantly enriched next to the polyphase inclusion
 384 and the matrix on the left side of the profile (Figure 12). The major difference in comparison to
 385 Garnet A corresponds to a broad depletion in Dy, Ho and Tb adjacent to the polyphase inclusion
 386 located at the garnet core. This feature closely matches the grossular zoning profile (Figure 9b),

387 and corresponds to the domain containing rounded inclusions of quartz.

388 Garnet G is derived from the quartz-present host granulite and is located furthest from
389 the leucosome (Figures 4 and 5). It is the smallest analyzed grain and contains a large irregular
390 polyphase inclusion in its core. Trace element map and profile are shown in Figure 10c, 13 and
391 S4. Y and HREEs, from Lu to Tb, show a broad bell-shaped profile, but with maximum
392 concentrations on average two to three times lower than the larger Garnets A and B (Figure 13).
393 In contrast, rim compositions for all elements are once again similar for all samples. La, Ce and
394 P show bowl-shaped profiles with a large flat core surrounded by an enriched rim. Sm (and to a
395 lesser extent Gd) are no longer characterized by a typical bowl-shaped profile but rather mimic
396 the grossular zoning, with a depleted core next to the polyphase inclusion (Figure 13). This
397 similarity continues along the profile, with an identical location for the maximum Sm
398 concentration and a core composition adjacent to the polyphase inclusion that is equivalent to
399 the rim composition (2 to 3 ppm on average; Figure 13).

400

401 **5. PETROLOGICAL MODELING**

402 We use computed phase diagram sections to constrain (1) the pressure and temperature
403 of garnet nucleation and growth, partial melting, and retrogression; and (2) the most likely
404 processes responsible for the formation of the quartz-undersaturated selvage. For this purpose,
405 the model system $\text{Na}_2\text{O}-\text{CaO}-\text{K}_2\text{O}-\text{FeO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2-\text{H}_2\text{O}$ was chosen to calculate phase
406 relationships using Perple_X 6.6.6 software (Connolly, 2005), with the thermodynamic database
407 of (Holland & Powell (1998), as revised in 2002). TiO_2 and Fe_2O_3 were not considered in the
408 modeling because (1) the bulk rock content of TiO_2 is less than 0.6 wt%; and (2) there is no Fe^{3+} -
409 bearing phase like hematite or magnetite and the amount of Fe^{3+} in garnet based on structural
410 formulae is negligible. Solution models and end-member phases considered in the modeling are
411 listed in Table S1.

412

413 5.1. P-T conditions of garnet nucleation and growth

414 Deciphering the P-T conditions of the early garnet growth and prograde path relies
 415 essentially on the observation of garnet inclusions and the valid interpretation of garnet
 416 composition and zoning. Garnet cores are characterized by the occurrence of quartz and
 417 polyphase plagioclase-quartz inclusions, whereas the inner rim of the largest garnet grains show
 418 abundant crystallized melt inclusions. We therefore suggest that the onset of garnet growth may
 419 have occurred under sub-solidus conditions.

420 Garnet core compositions are typically used to retrieve the approximate P-T conditions of
 421 garnet nucleation. However we will show later that major and trace element zoning patterns
 422 and more particularly garnet core compositions have been modified, most likely as a result of
 423 post-growth re-equilibration during partial melting and retrogression. The biggest garnets located
 424 in the quartz under-saturated selvage (garnet A and B, Figure 4-5) show the least modified
 425 zoning profile, with typical bell-shape zoning in grossular (Figure 9a,b) and trace elements
 426 (Figure 11-12). Although these large garnets A and B are located in the quartz-undersaturated
 427 selvage, the presence of quartz inclusions within their cores suggests that the onset of garnet
 428 growth occurred under quartz-saturated conditions. We therefore suggest that the loss of SiO₂
 429 and the formation of the quartz-undersaturated layer is a post-garnet growth process. Hence, to
 430 retrieve the P-T conditions of early garnet growth and constrain the prograde path, we have
 431 computed a P-T phase diagram section with a XRF bulk composition corresponding to the quartz-
 432 saturated domain composition (Table 1 and Figure 14). The phase diagram section has been
 433 contoured for grossular content, XMg (= MgO/MgO+FeO) in garnet and garnet modes (Figure 14).

434 The amount of water is known to be a critical variable when modeling phase relations in
 435 melt-bearing systems (e.g. White et al., 2001). A classic strategy to estimate the amount of
 436 water in melt-bearing systems consists of adding enough water to the system such that the
 437 solidus is water-saturated. However, if we follow this approach, high-grossular garnet core
 438 compositions cannot be reproduced. Therefore, the system was kept water-undersaturated, such
 439 that measured garnet core compositions (i.e. the highest grossular values) are predictable, and

the amount of major rock-forming phases are consistent with observed mineral modes. The amount of water was adjusted and fixed at 1.67 mol% (0.025 mol or 0.46 wt%). With this low water condition, partial melting was restricted to temperatures higher than ~750°C (Figure 14)

The maximum grossular content of ~0.12, coupled with the corresponding XMg (0.35-0.38), allow estimating the minimum P-T conditions of garnet growth at ~1.2 GPa, 675°C (black circles with letters in Figure 14). This corresponds to sub-solidus conditions where garnet is in equilibrium with plagioclase, biotite, kyanite and muscovite. Although these last two phases have never been observed as inclusions in garnet, the predicted plagioclase composition (An₇₆-Ab₂₃) is consistent with the high anorthite compositions measured in plagioclase inclusions. Furthermore, melt-inclusions are absent in the high grossular cores (Figure 5), whereas they are abundant in the low-grossular rims. This observation is consistent with an early garnet nucleation and growth under sub-solidus conditions with peak metamorphism and garnet rim crystallization occurring in melt-present conditions.

In Figure 14, we report the composition of Garnet C to G, located in the quartz-saturated domain, with the highest grossular content and corresponding XMg values (grey circles with letters in Figure 14). The maximum grossular content, preserved in the inner rim at the transition between the inclusion-bearing and inclusion-free domains, varies from grain to grain from 0.095 (Garnet E) down to 0.04 (Garnet F) and XMg from 0.36 (Garnet C) to 0.43 (Garnet G) (Figure 9). The inferred P-T conditions vary from ~1.3 GPa and 720°C to 0.85 GPa and 780°C corresponding approximately to the P-T conditions of garnet nucleation and peak metamorphism / partial melting, respectively (see Section 5.2 below). We suggest that this could reflect the progressive and incomplete re-equilibration of garnet during a prograde (heating/decompression) path from ~1.2 GPa and 675°C down to 0.8 GPa and 790°C. During this P-T evolution minor garnet growth is expected (volume % = 14-16, Figure 14).

5.2. P-T conditions of peak metamorphism, partial melting and retrogression

The computed P-T phase diagram in Figure 14 shows the classic phase relations for partially melted aluminous-rich pelites (e.g. White et al., 2001), with the divariant muscovite-dehydration melting equilibrium at high pressure ($1.2 > P > 0.9$ GPa) and the biotite-dehydration melting equilibrium that produces garnet and cordierite at lower pressure ($0.8 > P > 0.6$ GPa). Between these two divariant narrow fields lies a trivariant assemblage with garnet, biotite, sillimanite, K-feldspar, quartz and melt in equilibrium, between 770 and 820 °C (Figure 14). This calculated assemblage is consistent with the observed assemblage in the quartz-saturated granulite. Garnet core and rim compositions in direct contact with the polyphased plagioclase-quartz inclusions (ca. 3% grossular and $X_{Mg} = 0.36-0.44$) give consistent P-T conditions of 0.8 ± 0.05 GPa and 790 ± 20 °C (white circles with letters in Figure 14), with the predicted X_{Mg} of biotite (0.70) consistent with the measured biotite composition. We interpret these estimates to reflect partial melting during the development of the steeply dipping S_2 granulite-grade gneissic foliation. As discussed in Section 7.2, however, the garnet trace element distribution indicates that core compositions may have been affected by post-growth re-equilibration.

Retrogression in the quartz-saturated domain is characterized by the local development of cordierite at the expense of garnet and sillimanite (Figure 4b), through reaction (1). This local and partial retrogression is also evidenced by the sharp decrease in X_{Mg} from 0.40 to 0.36, at constant grossular content (~ 0.30) (Figure 9e, outer rim of Garnet E). Figure 14 shows that the development of cordierite and the decrease in X_{Mg} , at almost constant grossular content, would require further isothermal decompression at or below 0.7 GPa in the garnet + cordierite + sillimanite + K-feldspar + plagioclase + quartz stability field.

5.3 Formation of the quartz-undersaturated selvage via melt-driven metasomatism

In migmatites, the formation of quartz-undersaturated assemblages has been interpreted as characteristics of advance quartz-consuming reactions during partial melting coupled with local melt extraction (Fitzsimons, 1996; Owen, 1991). Alternative models consist of producing

the quartz-depleted selvage by small-scale silica metasomatism between the host rock and a quartz vein (Penniston-Dorland & Ferry, 2008) or a silica-rich leucosome formed after melt segregation and transport (Dunkley, Clarke & Harley, 1999). In the later case, selvage formation is a post-anatectic process rather than being directly related to partial melting of the host-rock (Lin & Sawyer, 2019). In the following section, we model and show that element exchange (diffusion-metasomatism) between the segregated melt (leucosome) and the host granulite is likely to be responsible for the formation of the quartz-depleted selvage during post-peak decompression.

Following the approach of White and Powell (2010), we investigate through phase equilibria modeling the melt-driven metasomatism and more particularly the role of diffusion, between melt-rich domains (leucosome) and the host granulite, on the formation of the selvage. Our conceptual model is similar to Lin & Sawyer (2019) and requires a first stage of partial melting and melt segregation to produce two subsystems corresponding to the quartz-saturated domain (~residue) and the melt domain. At the P-T conditions of partial melting and melt segregation (i.e. 0.8 GPa and 790°C), chemical potentials are the same in the solid phases and the melt of both domains, if thermodynamic equilibrium is maintained. The second stage corresponds to decompression into the cordierite-bearing stability field below 0.7 GPa. As pressure decreases, chemical potential evolve independently in both subsystems. Therefore, diffusion of components is driven by the chemical potential gradient established at the interface between the quartz-saturated residue and the leucosome.

In order to determine the direction of diffusion, we have computed the chemical potentials of H₂O, SiO₂, CaO and K₂O for the quartz-saturated and melt domains along an isothermal decompression path from 0.8 to 0.5 GPa at 790°C (Figure 15). The chemical potentials in the melt domain were determined using the chemical composition of melt produced at 0.8 GPa and 790°C (Table 1). Chemical potential of the selected components were computed separately for each sub-systems (segregated melt and residue) by assuming that during decompression these two sub-systems are closed and chemically isolated from each other (Figure 15). This implies that there is no interaction or mass transfer between the two

subsystems. This ideal chemical isolation model is in a strict sense impossible because the two sub-systems are physically in contact and therefore chemical interactions are expected at some scale and chemical potential will continuously evolve with ongoing decompression due to diffusive mass transfer (White & Powell, 2010). However, our approach can be used at first order to determine the direction of transport of the four selected species if chemical interaction at the interface is permitted. During decompression, the chemical potentials of H_2O , CaO , K_2O and Na_2O (Na_2O not shown in Figure 15) become higher in the melt segregated domain (leucosome) than in the residue. In contrast, the chemical potential of SiO_2 is lower in the melt than in the residue. This suggests that species such as H_2O , CaO , K_2O and Na_2O will diffuse from the melt into the host residue whereas SiO_2 is transferred from the host residue into the adjacent melt domain.

To model the effect of metasomatism and pressure on phase relations, a P-X phase diagram section was computed at 790°C (Figure 16). The initial amounts of CaO and Na_2O are very low (< 1.3 and 0.6 wt%, respectively) and do not significantly influence the phase relations. Therefore, variations in Na_2O and CaO content are not considered. The bulk composition for $X = 0$ corresponds the quartz-saturated host-rock composition prior to any mass transfer. The bulk composition for $X=1$ is obtained assuming a gain in H_2O of 200% ($\text{H}_2\text{O} = 0.075$ mol) and a SiO_2 loss of 55% ($\text{SiO}_2 = 0.342$ mol). These values are arbitrary. Bulk compositions used are provided in Table 1.

Figure 16 shows the location of the two main low variance ($V=2$) retrogression equilibria that have been observed in the quartz-saturated domain and quartz-absent selvage: $\text{Grt} + \text{Sil} + \text{Qz} \pm \text{Bt} = \text{Crd} + \text{L}$ (2) and $\text{Grt} + \text{Sil} \pm \text{Bt} = \text{Crd} + \text{Spl} + \text{L}$ (3) at 0.72 GPa and 0.55 GPa respectively. These divariant equilibria together with their related trivariant assemblage are used to locate the quartz-out, cordierite-in and spinel-in boundaries (Figure 16). The formation of selvage assemblage ($\text{Crd} + \text{Spl} + \text{Sil} + \text{L} \pm \text{Grt/Bt}$) requires a decompression below 0.55 GPa and a bulk composition with X ranging from ~ 0.65 to 0.8 . Taking a value of $X = 0.7$, mass transfer required to produce the selvage from the host quartz-saturated granulite corresponds to a relative gain of

about 140 % of H₂O coupled with a relative loss of 47% of SiO₂. The P-X phase diagram is also contoured for garnet mode (Figure 16). As expected, decompression is associated with garnet breakdown, but at pressures above the cordierite-in boundary ($P > 0.72$ GPa), mass transfer (SiO₂ loss coupled with H₂O gain) induces a slight increase in garnet mode, from 12 to 17 vol%. This mineralogical evolution is consistent with the observation of a higher modal abundance of garnet in the metasomatic selvage with respect to the host granulite.

Based on the estimation of mass transfer required to produce the quartz-undersaturated selvage, a P-T phase diagram section has been computed with an estimated selvage composition (Figure 17 and table 1). This composition corresponds to $X = 0.70$ in Figure 16. Figure 17 shows the location in a P-T space of the two main low-variance retrogression reactions (2) and (3) and the position of the quartz-out, cordierite-in and spinel-in lines. Once again, the selvage formation is consistent with a decompression from about 0.8 GPa down to 0.5 GPa at temperatures greater than 750 °C.

6. U-TH-PB MONAZITE AND ZIRCON GEOCHRONOLOGY

Monazite and zircon geochronology were acquired to establish a temporal framework for melt-rock interactions and the relationship of garnet growth and dissolution to the accessory mineral evolution. Chemical zoning in monazite and zircon were first characterised via X-ray mapping and cathodoluminescence respectively. In situ U-Th-Pb monazite and zircon ages were then acquired by laser ablation inductively coupled plasma-mass spectrometry (LA-ICP-MS). Sample preparation and operational procedures for all techniques are described in Hurai, Paquette, Huraiová & Kronečný (2010) and Paquette et al. (2014) and presented in Appendix S2. U-Th-Pb geochronological data are provided in Dataset S6.

572 6.1. Textural features and dates

573 Monazite is abundant in both quartz saturated and undersaturated domains but is totally
 574 absent in the leucosome. The analyzed monazites range in size from 50 to 250 μm and occur in
 575 the matrix, at grain boundaries and included in sillimanite and plagioclase (M1-2-13), in the
 576 vicinity of garnet and within the retrograde cordierite moat (M3-6-4-8-9-10-11-12) (Figure 18a).
 577 Monazite grains M3, M6 and M12, located in cordierite moats, have an unusual worm-like shape
 578 that mimics the embayed garnet rim (Figure 18c). Only one grain (M7) was found included in a
 579 garnet rim.

580 All monazite grains are chemically homogeneous (Y-poor) (Figure 18b,c) except for two
 581 grains (M9 and M10) that show a subtle zoning with high Th domains. Grains located in the
 582 cordierite moat show discrete and discontinuous micron-scale Y-rich rims (Figure 18c) whereas
 583 those included in other phases are devoid of such overgrowths (Figure 18b). These observations
 584 suggest that the crystallization of the low Y grains might precede or be coeval with the peak
 585 assemblage garnet (rim), sillimanite, biotite, plagioclase, K-feldspar $\pm$ quartz. The crystallization
 586 of discrete Y-rich monazite overgrowths in the vicinity of garnet porphyroblasts partially
 587 retrogressed into cordierite has been previously interpreted as an indicator of accessory phase
 588 growth during garnet breakdown (Mahan et al., 2006). We suggest that Y overgrowths are also
 589 contemporaneous with cordierite crystallization and selvage formation.

590 Ten homogeneous Y-poor grains were analyzed for a total of 39 analyses (Dataset S6). The
 591 Y-rich overgrowths were not analyzed due to their small size in order to avoid mixing during
 592 ablation. In a $^{206}\text{Pb}/^{238}\text{U}$ versus $^{208}\text{Pb}/^{232}\text{Th}$ diagram all analyses are concordant or sub-concordant
 593 (Figure 19a). Excluding six analyses (see Dataset S6) gives a concordia age of 2061 ± 6 Ma
 594 ($\text{MSWD}(\text{C}+\text{E}) = 1.3$). The weighted mean of $^{208}\text{Pb}/^{232}\text{Th}$ dates gives an age of 2069 ± 8 Ma ($\text{MSWD} =$
 595 1.6) (Figure 19b). The $^{208}\text{Pb}/^{232}\text{Th}$ dates show no systematic variation with textural location (see
 596 Figure 18a and Dataset S6), and more specifically, monazite included in garnet (M7) is not
 597 statistically different from matrix grains (Figure 19). The date of 2.06 Ga is interpreted as the
 598 age of partial melting at 0.8 ± 0.05 GPa and 790 ± 20 °C, before decompression responsible for

599 partial garnet breakdown and crystallization of small Y-rich overgrowths.

600 Zircons are rare and do not exceed 50 μm in diameter. They are translucent with a
 601 rounded shape typical of zircons recrystallized under granulite facies conditions. Fourteen
 602 analyses were performed on fourteen grains (Dataset S6). They do not show significant zoning in
 603 cathodoluminescence. A first group of 7 analyses are concordant and gives a concordia age of
 604 2072 ± 7 Ma (MSWD(C+E) = 2.3) (Figure 19c). A second group of 4 analysis are discordant and
 605 when plotted together with the previous 7 analysis, it defines a discordia with an upper
 606 intercept at 2073 ± 11 Ma (MSWD = 2.0). The last group, consists of 4 analyses that do not match
 607 the previous tow identified clusters (white ellipses in Figure 19), with $^{207}\text{Pb}/^{206}\text{Pb}$ dates that
 608 range from 2.07 to 2.33 Ga and one concordant analysis at 2192 ± 15 Ma. The 2.07 Ga date is
 609 similar to that obtained for monazite and is interpreted as the age of partial melting. The
 610 remaining three analyses are interpreted as inherited ages.

611

612 7. DISCUSSION

613 Petrological and micro-textural analysis carried out across the interface between the
 614 leucosome and the host-granulite shows a systematic and consistent evolution in mineral
 615 paragenesis, micro-textures, garnet grain size and composition (major and trace element) with
 616 the distance from the leucosome. The studied sample is therefore used to discuss small-scale
 617 melt-rock interaction processes. In this section, we will first summarize the petrological model
 618 of formation of the migmatite and more particularly the quartz-undersaturated selvage at the
 619 interface between the segregated melt (leucosome) and the partially melted host granulite.
 620 Based on this petrological evolution, we will discuss the significance of major and trace element
 621 zonation observed in garnet.

622

7.1. Petrological model of migmatite and quartz-undersaturated selvage formation through diffusion metasomatism

The phase relation modeling performed suggests that the onset of garnet crystallization occurred under subsolidus conditions at high pressure ($P \sim 1.2$ GPa) and temperatures of 675 to 700°C. These P-T conditions, that were estimated using the maximum grossular content of garnet cores and anorthite content of plagioclase inclusions, are consistent with a steady state geotherm considering average crustal thermal parameters (thermal conductivity $k = 3 \text{ W.m}^{-1}.\text{K}^{-1}$, heat production $A = 0.75 \text{ } \mu\text{W.m}^{-3}$, a mantle heat flow $Q = 30 \text{ mW}^{-2}$, a density $\rho = 2.7 \text{ kg.m}^{-3}$) at a depth of 45 km (1.2 GPa). We suggest that the gently dipping gneissic foliation (S_1) that trends NE-SW (Figures 2b and S1) may be occurred at to these conditions and may correspond to a crustal thickening event. This interpretation is also supported by the observation of quartz and plagioclase inclusions trails, defining a S_1 foliation, in the high-grossular garnet cores (Figure 3a).

Partial melting occurred at 0.8 GPa and 790°C at $\sim 2.06\text{-}2.07$ Ga. The former presence of melt at peak metamorphic conditions can reliably be inferred from the occurrence of peritectic garnet, produced by biotite-dehydration melting (1) (Figures 4-5) and the presence of crystallized melt inclusions within the garnet (Figure 6). Interstitial elongated films along grain boundaries and pools at the triple junction (Figure 8) are alternative criteria diagnostic of the former presence of melt and melt movement at the grain scale (Holness & Sawyer, 2008; Sawyer, 2001; Stuart, Piaolo & Daczko, 2018; Vernon, 2011). The interstitial plagioclase may represent the plagioclase component crystallized from the melt (Hasalová, Schulmann, Lexa, Štípská & Hroda, 2008; Stuart et al., 2018). The corroded K-feldspar grains and the crystallization of plagioclase and myrmekite (figure 8) are interpreted as the result of K-feldspar dissolution during the interaction between the host rock and a migrating melt (Hasalová et al., 2008). We suggest that the connection between the leucosome and the host-granulite via the grain boundary melt array favored efficient small-scale mass transfer in and out of the host-granulite to produce the quartz-undersaturated selvage.

650 Thermodynamic modeling shows that decompression from 0.8 to 0.5 GPa at 790°C
 651 coupled with melt segregation are responsible for the establishment of chemical potential
 652 gradients between the leucosome and the host-granulite. Chemical potential gradients drive
 653 diffusive metasomatism of species between the two reservoirs and the formation of the quartz-
 654 undersaturated selvage at the interface. The modeling suggests that, during post-peak
 655 decompression from 0.8 to ~0.5 GPa at 790°C, species like H₂O, CaO and Na₂O will be transferred
 656 from the leucosome to the host-rock while SiO₂ had an opposite diffusion direction, going from
 657 the host-rock to the leucosome. Phase diagrams in figure 16 and 17 show that mass transfer
 658 coupled with decompression resulted in the partial transformation of the quartz-saturated peak
 659 metamorphic assemblages (Grt, Bt, Sil, Qz + L) into a quartz-undersaturated assemblage with
 660 cordierite and spinel (see location of Qz-out, Crd-in and Spl in Figure 16). Formation of the
 661 quartz-undersaturated selvage via melt-driven metasomatism (ie. SiO₂ loss), is well supported by
 662 the absence of quartz in the matrix and the observation of quartz only as inclusions in garnet
 663 cores. This observation rules out the possibility that the gneissic layering and more particularly
 664 the quartz-absent selvage is inherited from the sedimentary protolith. The phase diagram shows
 665 that further mass transfer and decompression below 0.5 GPa could result in the formation of
 666 corundum-bearing assemblage.

667 Several other petrological and micro-textural observations provide support for the
 668 modeled mass transfer direction and the formation of the selvage:

669 (1) The quartz-undersaturated selvage, where local mass-transfer is inferred as the
 670 dominant process, is characterized by larger garnet grain sizes. This is consistent with modeled
 671 garnet modes in Figure 16, that show an isobaric and isothermal increase in garnet abundance at
 672 0.8 GPa, only due to mass transfer (SiO₂ gain and H₂O loss).

673 (2) Diffusion of water from the melt into the host-granulite will favor the crystallization
 674 of anhydrous products in the melt, producing almost an anhydrous leucosome, while the
 675 adjacent host granulite is hydrated, as demonstrated by the slight enrichment of the selvage in
 676 hydrous-phases like biotite and cordierite. This observation is very consistent with results from

White and Powell (2010) who also predicted that the diffusion of H_2O into the residue will be responsible for the formation of anhydrous leucosomes during an isobaric cooling under granulite facies conditions.

(3) Diffusion of other mobile species like CaO , Na_2O and K_2O , from the leucosome into the selvage is indirectly supported by the mineralogical composition of the leucosome that consists mostly of quartz with very minor K-feldspar and almost no plagioclase. It is well known that leucosomes in migmatites do not have the expected minimum granitic composition (Ashworth & McLellan, 1985) due to post-anatectic magmatic differentiation processes. However, following Olsen and Grant (1991), who performed a mass-balance (isocon) analysis on leucosomes, we suggest that the quartz-rich and K-feldspar and plagioclase-poor leucosomes most likely formed by loss of Na_2O and CaO by diffusion.

(4) Diffusion of K_2O into the host-rock is likely to be responsible for the formation of the distinct inclusion-free outer-rim of K-feldspar located in the selvage (Figure 8).

(5) The introduction of a Na_2O/CaO -rich fluid or melt into the selvage, is consistent with the observation of plagioclase films and pools along K-feldspar grain boundaries (Figure 8). The formation of myrmekite in the selvage is also consistent with a fluid or melt mediated Na-Ca replacement of K-feldspar by plagioclase (Yuguchi & Nishiyama, 2008).

Melt segregation and the development of the selvage defines a steeply deeping S_2 gneissic layering that transposes the previous S_1 fabric (Figure 3 and Figure S1). Kinematic analysis of the D_2 high strain is consistent with NNW-SSE shortening and a bulk dextral sense of shear. We conclude that melt transfer and metasomatism may have been enhanced by D_2 transpressive deformation.

699

7.2. Major and trace element behavior during partial melting and retrograde melt-rock interaction

The studied sample preserves mineralogical and textural evidence of prograde partial melting and melt segregation, near-isothermal decompression and melt-driven metasomatism. With respect to other phases, garnet has the tremendous advantage to preserve records of these

705 various processes via its chemical zoning in major and trace elements, because of the slow rates
 706 of intracrystalline diffusion (e.g. Carlson, 2006). However, in order to interpret accurately these
 707 zoning patterns in terms of large-scale and long-term geological/geodynamic processes, we have
 708 to understand the small-scale processes that control the behavior of major and trace elements
 709 during garnet nucleation, growth, breakdown and re-equilibration (George & Gaidies, 2017 and
 710 references therein). Although the zoning features varies from garnet to garnet, they show
 711 systematic variations and similarities that can be correlated with the P-T-X evolution and
 712 petrographic setting. Via a qualitative analysis of zoning profiles, and previous work by others
 713 cited below, we suggest these features reflect the superposition of at least three grain-scale
 714 processes that control the intra- and intergranular mobility of chemical components (major and
 715 trace elements).

716

717 *Evidence of fast intergranular mobility of elements, including REE, and rock-wide equilibrium*

718 The P-T evolution of the studied sample occurred at high temperature ($> 650^{\circ}\text{C}$) and in
 719 the presence of melt, from peak-metamorphic conditions (0.8 GPa; 790°C) to the conditions of
 720 selvage formation (~ 0.5 GPa; 800°C). Therefore, the high mobility of major and to a lesser
 721 extent trace elements is expected. We report below evidence of fast intergranular mobility of
 722 elements, including REE, and rock-wide equilibrium.

723 Rock-wide equilibrium and by extension fast inter-granular transport of major and trace
 724 elements during peak metamorphic conditions and subsequent melt-driven metasomatism is best
 725 demonstrated using garnet rim compositions. Although the analyzed garnets are located in
 726 different petrographic settings (within the quartz-undersaturated selvage or in the host-
 727 granulite displaced from the leucosome) and vary markedly in grain size and morphology, their
 728 outermost rims share consistent major element (grossular content = 3%; Figure 9) and trace
 729 element compositions (Y and REEs; Figure 11-13). This consistency in major element composition
 730 of the rims permits an accurate estimation of peak metamorphic conditions at 0.8 GPa and
 731 790°C (Figure 14).

732 The length scale of equilibration during garnet growth, which is related to the degree of
 733 mobility of major and trace elements through the intergranular matrix, can be evaluated using
 734 the REE zoning pattern (Moore et al., 2013; Skora et al., 2006). In both studies, these authors
 735 have shown a dependency of REE distribution on atomic number in large and early nucleating
 736 garnets. Such garnets are characterized by pronounced central peaks for Y and HREEs (Lu to Er),
 737 central peaks and annular maxima for MREEs (Ho, Dy), and well defined annular maxima for
 738 LREEs (Tb to Nd). This distribution is driven by diffusion-limited uptake that evolves during
 739 garnet growth. With increasing temperature, intergranular diffusivities increase progressively as
 740 garnet grows, but with more rapid diffusion for HREEs compared to LREEs (Moore et al., 2013;
 741 Skora et al., 2006). However, this dependency of REE distribution with atomic number is less
 742 valid at high temperature. Numerical modeling of garnet zoning along a temperature-time path
 743 performed by Moore et al. (2013) demonstrates that a uniform bell-shaped distribution for all
 744 REEs is consistent with garnet nucleation and growth at high temperature, whereas at lower
 745 temperature a sharp central peak with an annular maximum would be expected (see Figure 19
 746 and Figure 20b in Moore et al. (2013)). From these previous studies, we can conclude that a
 747 uniform distribution for all REEs is the result of rapid intergranular diffusion that strongly
 748 minimizes the development of concentration gradients in the matrix surrounding the growing
 749 garnet.

750 All studied garnets are characterized by a bell-shape distribution for Y and REEs, ranging
 751 from Lu to Dy ($\pm$ Tb), with a strong correlation between the radial positions of all peaks. This
 752 distribution is consistent with a progressive depletion of the matrix in Y and REEs (Lu-Dy) due to
 753 Rayleigh fractionation with an unchanging mineral assemblage (Moore et al., 2013; Otamendi et
 754 al., 2002). Although the inferred P-T path in Figure 14 suggests that the onset of garnet growth
 755 may have occurred under sub-solidus conditions prior to muscovite dehydration, we instead
 756 suggest that the majority of garnet growth occurred via biotite dehydration melting in the
 757 trivariant NaCaKFMASH stability field Bio - L - Gt - Kf - sill - pl - q at a temperature greater than
 758 $\sim 760^\circ\text{C}$. The uniform bell-shaped distribution for REEs, ranging from Lu to Dy, is consistent with

759 rapid intergranular diffusivities.

760 All garnet grains are characterized by (1) the absence of progressive outwards migration
761 of REE peak locations with decreasing atomic number; and (2) the lack of a central peak for
762 LREEs between La and Gd. Instead, they show a large LREE-depleted core of constant
763 composition surrounded by an enriched rim. This transition from bell- to bowl-shaped profiles
764 with decreasing atomic number is similar to an example reported by Raimondo et al. (2017) from
765 a metasomatic shear zone in central Australia. Both observations (1) and (2) are once again
766 indicative of fast intergranular mobility and rock-wide equilibrium during garnet growth, without
767 significant differences in diffusivity between HREEs and LREEs. However, we will see below that
768 the bowl-shaped profile could also be related, or at least accentuated, by a post-growth
769 modification.

770 Following Raimondo et al. (2017) and Konrad-Schmolke et al. (2008), we suggest that the
771 REE zoning reflects a typical Rayleigh fractionation model. As garnet nucleates and grows at high
772 temperature ($T > 750^{\circ}\text{C}$), the matrix is progressively depleted in HREEs on a large scale due to the
773 presence of melt along grain boundaries that favor fast element mobility and rock-wide
774 equilibration. Simultaneously, the matrix is passively enriched in LREE on a rock-wide scale due
775 to the low garnet/matrix partition coefficients for LREEs (Moore et al., 2013). The rapid
776 intergranular mobility for all REEs with respect to garnet growth, without any dependence on
777 atomic number, precludes the establishment of diffusion gradients in the matrix, resulting in
778 smooth core-to-rim zoning and a transition from bell-shaped HREE to bowl-shaped LREE profiles.

779 Small garnets located in the quartz-saturated host granulite (e.g. Garnet G) are
780 characterized by a significantly HREE-depleted composition compared to large garnets located in
781 the quartz-undersaturated selvage adjacent to the leucosome (Garnets A and B), whereas their
782 LREE content remains similar. This discrepancy in REE concentrations could be related to a later
783 nucleation of garnets located in the quartz-present host granulite. Assuming a rapid
784 intergranular mobility and rock-wide equilibration for REEs, the early nucleation and enhanced
785 growth of garnet in proximity to the leucosome may have induced a bulk-rock HREE depletion at

786 the scale of the distance between Garnet A and Garnet G (~7 cm). In contrast, the small
 787 garnet/matrix LREE partitioning coefficient has a negligible effect on the bulk rock composition,
 788 resulting in an approximately constant LREE concentration for garnet regardless its nucleation
 789 and growth history.

790

791 *Post-growth intragranular diffusion of major and trace elements*

792 Calcium maps and profiles from Garnets B-G reveal that their prograde growth zoning is
 793 modified bear the inner core inclusions. This post-growth modification resulted in chemical re-
 794 equilibration of the grossular content to varying degrees, depending on the location of the
 795 garnet with respect to the quartz-undersaturated selvage and the host granulite. In the quartz-
 796 saturated host granulite, the smallest garnets (which also contain the biggest polyphase
 797 inclusions) show a complete (Garnet F) or partial re-equilibration (Garnets C, D, E, G) of the
 798 garnet core in contact with the inclusions, with grossular content decreasing to 3%,
 799 corresponding to the rim composition. This suggests that post-growth modification occurred near
 800 peak P-T conditions (0.8 GPa; 790°C). Located in the quartz-undersaturated selvage, the largest
 801 analyzed grain (Garnet B) also shows post-growth modification of bell-shaped Ca zoning, but
 802 chemical re-equilibration at peak-metamorphic conditions was only partial, with a minimum
 803 grossular content of 8% in the garnet core.

804 The modification of garnet cores in contact with polyphase inclusions and their strong
 805 similarity with matrix compositions requires a pervasive connectivity to permit such rock-wide
 806 re-equilibration to proceed. Both X-ray tomography (Figure 7) and LA-ICP-MS mapping (e.g.
 807 linear features highlighted in Li map; Figure 10) reveal the presence of a network of open
 808 channels and re-healed cracks that may have acted as potential connecting pathways. These
 809 features confirm that the garnet core was not isolated or armored from the matrix, but was
 810 rather freely accessible to the extent that fluid access along these discrete open fractures or
 811 larger conduits (Figure 7) may favor cation transport and garnet re-equilibration.

812 Furthermore, we suggest that REEs are also susceptible to the post-growth re-equilibration
 813 process. In contact with the polyphase inclusions in Garnet B, the bell-shaped HREE profile is
 814 modified with a decrease in Ho, Dy and Tb that correlates with the Ca zoning (Figure 12). The
 815 remaining HREEs are apparently unaffected by this modification, whereas the modification of
 816 LREEs such as Sm, Gd, La and Ce is more challenging to interpret. This is largely because the
 817 bowl-shaped profile for Sm and Gd, as described above, could also be enhanced by a depletion
 818 in LREEs next to the inner core inclusions. However, Grain G does show a pronounced depletion
 819 in LREEs at the garnet core, resulting in zoning that closely mimics the Ca distribution (compare
 820 Figs 9g and 13). Unlike Grain B, the absence of significant depletion in Ho, Dy and Tb, coupled
 821 with its lower HREE content and well-preserved bell-shaped HREE profile, may support the
 822 interpretation that Grain G represents a late nucleating garnet in the host granulite at peak
 823 metamorphic condition. Post-growth modification proceeded at a lower temperature where only
 824 LREE remained mobile, in the presence of F, Cl and/or P complexes (Ague, 2017; Migdisov,
 825 Williams-Jones & Wagner, 2009; Williams-Jones, Migdisov & Samson, 2012). Alternatively, it may
 826 suggest that selective REE mobility is coupled to Ca substitution via retrograde garnet-
 827 plagioclase exchange that favors LREE over HREE according to kinetic controls and element
 828 compatibility.

829

830 *Role of changes in accessory phases and major rock-forming minerals*

831 In the studied sample, the LREE + P whole rock budget is largely controlled by the
 832 stability of monazite. As such, an approximately constant LREE concentration for garnet
 833 whatever its nucleation and growth history, coupled with a smooth bowl-shaped LREE + P profile
 834 prior to post-growth modification (i.e. Garnet A; Figure 13), suggests that monazite did not grow
 835 on the prograde path. Bulk rock fractionation of this kind is incompatible with garnet-monazite
 836 partitioning relationships if their growth was coeval (Warren et al., 2019). Rather, the apparent
 837 lack of monazite competition for LREE + P throughout the garnet growth history necessitates
 838 that monazite first appeared at peak conditions, consistent with the U-Pb age interpretation

839 documented previously and further explained below.

840 Superimposed on the bowl-shaped LREE profile, the rims of Garnets B and G show a
 841 sharp coincident enrichment in Ce, La and P where garnet is in contact with the matrix
 842 assemblage consisting of plagioclase and biotite. The same sharp enrichment is observed next to
 843 polyphase plagioclase and quartz inclusions located in garnet cores. There are two possibilities
 844 for explaining LREE enrichment. We suggest that these sharp enrichments may reflect
 845 modification of garnet zoning during post-peak breakdown of monazite. This interpretation is
 846 consistent with the pervasive occurrence of thin Y-rich overgrowths on monazite located in the
 847 matrix (Figure 18c), which may represent dissolution-precipitation events during the retrograde
 848 evolution. Plagioclase breakdown may also contribute to the LREE enrichment since garnet rims
 849 are locally enriched in large ion lithophile elements (LILEs) such as Ba and Sr, further suggesting
 850 that post-peak garnet-plagioclase exchange is responsible for the modified grossular zoning and
 851 that monazite ages reflect the timing of partial melting prior to breakdown on the retrograde
 852 path.

853 The outermost rims of garnets are characterized by a sharp increase in Y and HREEs along
 854 grain boundaries (Figures 10-13). This local enrichment is interpreted to be the result of partial
 855 garnet breakdown during decompression via reactions (2) and (3) and back-diffusion of elements
 856 that strongly partition into garnet with respect to the matrix. Notably, the absence of sharp
 857 HREE and Y enrichment in core domains, despite an apparently pervasive matrix connectivity
 858 during post-growth re-equilibration and simultaneous monazite replacement, confirms that
 859 garnet resorption must have post-dated these events.

860 Similar to the HREEs, Zr zoning is radial in all garnets except for sharp spikes adjacent to
 861 grain boundaries (figure S4). There are no satellite peaks or annular maxima indicative of zircon
 862 breakdown, nor are there any pronounced depletions indicative of sudden zircon crystallization.
 863 This suggests that zircon grew on the prograde P-T path, with the bulk rock Zr budget
 864 progressively depleted as zircon and garnet grew under rock-wide equilibrium. The distribution
 865 of U-Pb dates supports this interpretation, with concordant zircon analyses at 2.07 Ga being

866 similar to the 2.06 Ga monazite age inferred to represent peak metamorphism and partial
867 melting. Rimward spikes in Zr are coincident with the HREE and Y enrichment noted above and
868 slope away from the grain boundary, thus most likely due to garnet resorption rather than zircon
869 breakdown.

870

871

872 CONCLUSIONS

873 The petrological and geochemical investigations of this partially melted granulite highlight the
874 complexity of processes involved during partial melting at a scale ranging from a few microns to
875 centimeters. This study confirms and shows that partially melted rocks are open systems in
876 which changes in P-T conditions, deformation and mass transfer, that we have defined as melt-
877 driven metasomatism, are preserved in the mineralogical assemblage and the major and trace
878 element distribution revealed by X-ray microprobe and LA-ICPMS mapping respectively. One of
879 the main challenges is to be able to distinguish the mineralogical records of a process like
880 metasomatism from those related to changes in P-T conditions.

881 A first key observation and interpretation is that melt segregation and extraction coupled with
882 changes in P-T conditions (due to decompression in this example) induce local disequilibrium
883 between the segregated melt and the residual host-rock. The establishment of chemical
884 potential gradients at the interface of these two sub-systems drives diffusive mass transfer. Our
885 thermodynamic modeling shows that while H_2O , Na_2O , CaO and K_2O are transferred from the
886 melt to the host rock, SiO_2 diffuses in the opposite direction. This combined mass transfer
887 results in the formation of a quartz-rich and almost anhydrous leucosome and a quartz-
888 undersaturated selvage at the expense of the host-granulite. Depending on the initial bulk-rock
889 composition, P-T conditions of melt extraction and shape of the P-T path, the element that will
890 diffusive (or not) in or out the melt domain and the residue will vary. We suggest that the variety
891 of mineralogical compositions encountered in selvages surrounding leucosomes in migmatites

892 relates directly to these environmental variables and the induced melt-driven metasomatism.

893 Garnets show a complex major and trace element distribution that varies consistently with the
 894 petrographic setting. We suggest that preserved chemical zoning reflects the superposition of
 895 changes in P-T conditions and melt-driven metasomatism. Major and trace element zoning was
 896 first acquired during prograde and peak metamorphism garnet growth in a temperature range of
 897 675 and 790°C. Garnet grew mostly as a peritectic phase during biotite-dehydration melting
 898 reaction. Calcium, Y and HREEs (from Lu to Dy), are characterized by a bell-shape distribution
 899 and LREEs (from La to Gd) show a bowl-shape. The chemical zoning is consistent with a typical
 900 Rayleigh fractionation model with fast intergranular element mobility of all elements, including
 901 REEs, and rock-wide equilibration. The fast mobility is enhanced by the presence of melt along
 902 grain boundaries.

903 The post-peak melt-driven metasomatism event is responsible for the modification of the
 904 prograde zoning growth. Both Calcium and REE's are susceptible to the post-growth alteration
 905 and results in a complete or partial re-equilibration through diffusion of garnet composition at
 906 the P-T-X conditions of metasomatism (0.8 to 0.5 GPa; 790°C). Garnet cores in contact with
 907 polyphased inclusions were affected by the post-growth modification due to the presence of a
 908 network of open channels and cracks that act as connecting pathways between the matrix and
 909 garnet core. Once again, at these high temperature conditions and in the presence of melt (and
 910 fluid), divalent cation (Ca^{2+}) and REE are characterized by fast inter-granular and intragranular
 911 element mobility and rock-wide equilibration. We conclude that in this peculiar case (high
 912 temperature and melt/fluid-bearing open system), REE are not less vulnerable to diffusive
 913 resetting than divalent cations.

914 Besides the interpretations regarding the formation of the quartz-undersaturated selvage and
 915 the mobility of major and trace elements at high temperature conditions, this contribution
 916 shows that an inaccurate interpretation of chemical zoning in garnet could result in misleading
 917 thermobarometric results. Indeed, if the modified garnet core compositions (i.e. low calcium
 918 content) were used as the chemical fingerprint of the early garnet nucleation stage it would

919 have resulted in erroneous low-pressure condition estimates for garnet nucleation.

920

921

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935

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937

938

939 FIGURE CAPTIONS

940

941

942 Figure 1. (a) Aerial photograph of the Farol da Barra outcrop in the city of Salvador da Bahia,
943 with a corresponding structural and geological map (right-hand side). (b) Simplified structural
944 cross section including the studied area, showing the finite strain pattern consisting of a gently
945 dipping S1 fabric and steeply dipping D2 high strain zones. On both figures, the location of the
946 studied sample 06SB06 is shown as a red star.

947

948 Figure 2. (a) Photograph of the studied outcrop showing the steeply dipping S2 gneissic foliation.
949 The leucosome is surrounded by a melanocratic quartz-undersaturated selvage. (b) Polished slice

950 of the studied sample 06SB06 showing the location of the three thin sections.

951

952 Figure 3. (a) Photomicrograph of the metamorphic assemblage in the quartz-saturated granulite.

953 (b) Cordierite development at the contact between garnet and sillimanite in the quartz-

954 saturated granulite. (c) Spinel and cordierite symplectite developed at the expense of garnet

955 and sillimanite in the quartz-undersaturated selvage.

956

957 Figure 4. Thin-section scans under crossed-polarized light showing the location of the seven

958 analyzed garnets (A to G). Garnets A and B are located in the quartz-undersaturated selvage.

959 Notice the change in grain size and proportion of inclusions with increasing distance from the

960 leucosome.

961

962 Figure 5. Photomicrographs of the seven analyzed garnets. (a) Garnet A; (b) Garnet B; (c) Garnet

963 C; (d) Garnet D; (e) Garnet E; (f) Garnet F; (g) Garnet G. The size of the scale bar shown is 50

964 μm for all cases, and dashed lines correspond to the location of major element profiles shown in

965 Figure 9.

966

967 Figure 6. Backscattered electron images of crystallized melt inclusions in the outer rim of Garnet

968 B located in the quartz-undersaturated selvage. (a), garnet negative crystal shape crystallized

969 melt inclusion; (b) polyphase xenomorph crystallized melt inclusion; and (c) radial crack

970 attesting to melt inclusion decrepitation

971

972 Figure 7. (a) Backscattered electron image of a representative garnet in the quartz-saturated

973 granulite. (b) 3D reconstruction from a computed X-ray microtomography of garnet. (c-f)

974 sequential slices of the 3D reconstructed garnet (in red) showing the channels (white arrows)

975 connecting the irregular inclusions (transparent) to the outside matrix.

976

977 Figure 8. (a) Cathodoluminescence images of K-feldspar texture (blue) with plagioclase films and
978 pool (brown) along grain boundaries. Plagioclase films are connected to myrmekite pools (m).

979 (b) Extensive replacement of K-feldspar by plagioclase and myrmekites.

980

981 Figure 9. Garnet composition (black square = molar amount of grossular and white square =
982 XMg). The location of each line profile is shown in figure 5. The dark and light gray stripes
983 correspond to plagioclase-quartz inclusions and domains with minute inclusions of quartz,
984 respectively.

985

986 Figure 10. LA-ICP-MS trace element maps of (a) garnet A; (b) Garnet B; (c) Garnet G.

987 Concentrations values are in ppm. The line profiles shown in Figure 11-13 are located in each
988 case on the Phosphorus (P) map.

989

990 Figure 11. LA-ICP-MS trace element line profile of Garnet A. . See Figure 10a for traverse
991 location.

992

993 Figure 12. LA-ICP-MS trace element line profile of Garnet B. See Figure 10b for traverse
994 location.

995

996 Figure 13. LA-ICP-MS trace element line profile of Garnet G. See Figure 10c for traverse
997 location.

998

999 Figure 14. P-T phase diagram section computed for with quartz-saturated granulite composition
1000 (see Table 1). Circles with letters indicate the P-T conditions corresponding to measured garnet
1001 compositions. The letters refer to garnet grain labels in Figure 5.

1002

1003 Figure 15. Evolution of chemical potential of H₂O, SiO₂, CaO and K₂O for the quartz-saturated
1004 domain (black line) and melt (dashed line) along a decompression path from 0.8 to 0.5 GPa at
1005 790° C.

1006

1007 Figure 16. P-X phase diagram section computed at 790° C with X=0 corresponding to the quartz-
1008 saturated domain and X=1 corresponding to a 55% loss of SiO₂ and 200% gain of H₂O. See Table 1
1009 for compositions.

1010

1011 Figure 17. P-T phase diagram section computed with a modeled quartz-undersaturated selvage
1012 composition produced after a 47% loss of SiO₂ and 140% gain of H₂O. See Table 1 for
1013 compositions.

1014

1015 Figure 18. (a) Full thin-section X-ray Al map of sample 06SB06a showing the petrographic setting
1016 of dated monazites. (b) Y map of monazite included in garnet and plagioclase. (c) Y map of
1017 monazite in the cordierite-bearing matrix. Note the presence of thin Y-rich overgrowths.

1018

1019 Figure 19. (a) Monazite U-Th-Pb concordia diagram. (b) Monazite Th-Pb ages. (c) Zircon U-Pb
1020 concordia diagram

1021

1022 **TABLE CAPTIONS**

1023 Table 1. Bulk geochemical compositions used in phase diagrams shown in figures 14-17

1024

1025 DATASETS AND SUPPORTING INFORMATION

1026 Figure S1. Simplified geological map of the São Francisco Craton modified after Barbosa et al.
1027 (2003).

1028

1029 Figure S2. (a) Simplified structural map of the southwestern part of the city of Salvador da
1030 Bahia. (b) Simplified structural cross-section. (c) Equal-area Schmidt lower hemisphere
1031 projection of poles to S_1 and S_2 foliations (dashed lines = conjugated shear zones associated the
1032 S_2 mylonitic foliation).

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1034

1035

1036 Figure S3. (a) Backscattered image of a polyphased plagioclase and quartz inclusion in a garnet.
1037 (b) anorthite vs albite content in mole of plagioclase. Grey and black diamonds are plagioclase
1038 composition in contact with quartz and garnet respectively. (c) Profile showing the evolution of
1039 plagioclase composition in contact with quartz and garnet. See location of the profile in figure a.

1040

1041 Figure S4. LA-ICP-MS Zr line profile of garnet A, B and G

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1045

1046 Movie S1. 3D reconstruction from computed X-ray microtomography of garnet (see Figure 7).

1047

1048 Table S1. Solid solution models used in Figures 14-17

1049

1050 Dataset S1. Electron microprobe analysis of biotite, plagioclase, spinel and garnet. Garnet
1051 compositions include the seven profiles collected from Garnets A-G in Figure 9 (see Figure 5 for
1052 the line profile locations).

1053

1054 Dataset S2. LA-ICP-MS trace element data of line profiles collected from Garnets A, B and G (see
1055 Figures 11-13).

1056

1057 Dataset S3. Raw LA-ICPMS trace element data of garnet A (see map in Figure 10a)

1058

1059 Dataset S4. Raw LA-ICPMS trace element data of garnet B (see map in Figure 10b)

1060

1061 Dataset S5. Raw LA-ICPMS trace element data of garnet A (see map in Figure 10c)

1062

1063 Dataset S6. LA-ICP-MS isotopic U-Th-Pb data of monazite and zircon

Figure 1

figure 1. (a) Aerial photograph of the Farol da Barra outcrop in the city of Salvador da Bahia, with a corresponding structural and geological map (right-hand side). (b) Simplified structural cross section including the studied area

180x188mm (300 x 300 DPI)

figure 2

Figure 2. (a) Photograph of the studied outcrop showing the steeply dipping S2 gneissic foliation. The leucosome is surrounded by a melanocratic quartz-undersaturated selvage. (b) Polished slice of the studied sample 06SB06 showing the location of the three thin sections.

80x115mm (300 x 300 DPI)

Figure 3

Figure 3. (a) Photomicrograph of the metamorphic assemblage in the quartz-saturated granulite. (b) Cordierite development at the contact between garnet and sillimanite in the quartz-saturated granulite. (c) Spinel and cordierite symplectite developed at the expense of garnet and sillimanite in the quartz-undersaturated selvage.

180x173mm (300 x 300 DPI)

Figure 4

Figure 4. Thin-section scans under crossed-polarized light showing the location of the seven analyzed garnets (A to G).

85x160mm (300 x 300 DPI)

Figure 5

Figure 5. Photomicrographs of the seven analyzed garnets. (a) Garnet A; (b) Garnet B; (c) Garnet C; (d) Garnet D; (e) Garnet E; (f) Garnet F; (g) Garnet G. The size of the scale bar shown is 50 μm for all cases, and dashed lines correspond to the location of major element profiles shown in Figure 9.

180x206mm (300 x 300 DPI)

Figure 6

Figure 6. Backscattered electron images of crystallized melt inclusions in the outer rim of Garnet B located in the quartz-undersaturated selvage. (a), garnet negative crystal shape crystallized melt inclusion; (b) polyphase xenomorph crystallized melt inclusion; and (c) radial crack attesting to melt inclusion decrepitation

80x220mm (300 x 300 DPI)

Figure 7

Figure 7. (a) Backscattered electron image of a representative garnet in the quartz-saturated granulite. (b) 3D reconstruction from a computed X-ray microtomography of garnet. (c-f) sequential slices of the 3D reconstructed garnet (in red) showing the channels (white arrows) connecting the irregular inclusions (transparent) to the outside matrix.

180x140mm (300 x 300 DPI)

Figure 8

Figure 8. (a) Cathodoluminescence images of K-feldspar texture (blue) with plagioclase films and pool (brown) along grain boundaries. Plagioclase films are connected to myrmekite pools (m). (b) Extensive replacement of K-feldspar by plagioclase and myrmekites.

180x92mm (300 x 300 DPI)

Figure 9

Figure 9. Garnet composition (black square = molar amount of grossular and white square = XMg). The location of each line profile is shown in figure 5. The dark and light gray stripes correspond to plagioclase-quartz inclusions and domains with minute inclusions of quartz, respectively.

180x260mm (300 x 300 DPI)

figure 10a

Figure 10. LA-ICP-MS trace element maps of (a) garnet A; (b) Garnet B; (c) Garnet G. Concentrations values are in ppm. The line profiles shown in Figure 11-13 are located in each case on the Phosphorus (P) map.

210x297mm (300 x 300 DPI)

Figure 10b

Figure 10. LA-ICP-MS trace element maps of (a) garnet A; (b) Garnet B; (c) Garnet G. Concentrations values are in ppm. The line profiles shown in Figure 11-13 are located in each case on the Phosphorus (P) map.

210x297mm (300 x 300 DPI)

Figure 10c

Figure 10. LA-ICP-MS trace element maps of (a) garnet A; (b) Garnet B; (c) Garnet G. Concentrations values are in ppm. The line profiles shown in Figure 11-13 are located in each case on the Phosphorus (P) map.

210x297mm (300 x 300 DPI)

Figure 11

Figure 11. LA-ICP-MS trace element line profile of Garnet A. . See Figure 10a for traverse location.

176x158mm (300 x 300 DPI)

Figure 12

Figure 12. LA-ICP-MS trace element line profile of Garnet B. See Figure 10b for traverse location.

185x165mm (300 x 300 DPI)

Figure 13

Figure 13. LA-ICP-MS trace element line profile of Garnet G. See Figure 10c for traverse location.

145x161mm (300 x 300 DPI)

Figure 14

Figure 14. P-T phase diagram section computed for with quartz-saturated granulite composition (see Table 1). Circles with letters indicate the P-T conditions corresponding to measured garnet compositions. The letters refer to garnet grain labels in Figure 5.

180x204mm (300 x 300 DPI)

Figure 15

Figure 15. Evolution of chemical potential of H₂O, SiO₂, CaO and K₂O for the quartz-saturated domain (black line) and melt (dashed line) along a decompression path from 0.8 to 0.5 GPa at 790°C.

180x191mm (300 x 300 DPI)

Figure 17

Figure 16

Figure 16. P-X phase diagram section computed at 790°C with X=0 corresponding to the quartz-saturated domain and X=1 corresponding to a 55% loss of SiO₂ and 200% gain of H₂O. See Table 1 for compositions.

171x212mm (300 x 300 DPI)

Figure 17

Figure 17. P-T phase diagram section computed with a modeled quartz-undersaturated selvage composition produced after a 47% loss of SiO₂ and 140% gain of H₂O. See Table 1 for compositions.

179x103mm (300 x 300 DPI)

Figure 18. (a) Full thin-section X-ray Al map of sample 06SB06a showing the petrographic setting of dated monazites. (b) Y map of monazite included in garnet and plagioclase. (c) Y map of monazite in the cordierite-bearing matrix. Note the presence of thin Y-rich overgrowths.

180x171mm (300 x 300 DPI)

Figure 19. (a) Monazite U-Th-Pb concordia diagram. (b) Monazite Th-Pb ages. (c) Zircon U-Pb concordia diagram

180x139mm (300 x 300 DPI)

Figure 1

Figure S1. Simplified geological map of the São Francisco Craton modified after Barbosa et al. (2003).

180x240mm (300 x 300 DPI)

Figure S1

Figure S2. (a) Simplified structural map of the southwestern part of the city of Salvador da Bahia. (b) Simplified structural cross-section. (c) Equal-area Schmidt lower hemisphere projection of poles to S₁ and S₂ foliations (dashed lines = conjugated shear zones associated the S₂ mylonitic foliation).

180x197mm (300 x 300 DPI)

Figure S3

Figure S3. (a) Backscattered image of a polyphased plagioclase and quartz inclusion in a garnet. (b) anorthite vs albite content in mole of plagioclase. Grey and black diamonds are plagioclase composition in contact with quartz and garnet respectively. (c) Profile showing the evolution of plagioclase composition in contact with quartz and garnet. See location of the profile in figure a.

80x102mm (300 x 300 DPI)

Figure S4. LA-ICP-MS Zr line profile of garnet A, B and G

80x156mm (300 x 300 DPI)

Table 1

P-T pseudosection Figure 14		P-μ diagrams in Figure 15		P-X diagram in Figure 16		P-T pseudosection in Figure 17
06SB06 – qtz-saturated granulite		melt produced @ 0.8 GPa and 790°C		X = 0	X = 1	selvage composition after H ₂ O and SiO ₂ transfer (X=0.70)
	wt%		wt%	wt%	wt%	wt%
SiO ₂	64.22		69.12	64.22	36.25	48.21
Al ₂ O ₃	22.93		13.94	22.93	39.84	32.61
FeO	5.76		0.42	5.76	10	8.19
MgO	2.89		0.15	2.89	5.02	4.11
CaO	1.25		0.74	1.25	2.17	1.77
K ₂ O	1.86		6.51	1.86	3.23	2.64
Na ₂ O	0.64		2.28	0.64	1.11	0.91
H ₂ O	0.46		6.85	0.46	2.38	1.56
	mol		mol	mol	mol	mol
SiO ₂	1.053		1.565	1.053	0.342	0.556
Al ₂ O ₃	0.222		0.186	0.222	0.222	0.222
FeO	0.079		0.008	0.079	0.079	0.079
MgO	0.071		0.005	0.071	0.071	0.071
CaO	0.022		0.018	0.022	0.022	0.022
K ₂ O	0.019		0.094	0.019	0.019	0.019
Na ₂ O	0.010		0.050	0.010	0.010	0.010
H ₂ O	0.025		0.517	0.025	0.075	0.060

Table S1

solid solution models	abbreviation in Perple_X	abbreviation used	references
Biotite	Bio(TCC)	Bio	Tajcmanova et al. (2009)
Orthopyroxene	Opx(HP)	Opx	Powell & Holland (1999)
Melt	melt(HP)	L	White et al. (2001)
K-feldspar	San	Kf	Waldbaum & Thompson (1968)
Plagioclase	Pl(h)	pl	Newton et al. (1981)
Garnet	Gt(WPH)	Gt	White et al. (2007)
Spinel	Sp(HP)	Sp	
Sapphirine	Sapp(KWP)	Spr	Kelsey et al. (2014)
White mica	Mica(CHA)	Mu	Auzanneau et al. (2009)
Cordierite	hCrd	Crd	Holland et al. (1996)

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Profit gamet D																																			
Pt	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Dist	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	
SiO2	38.58	37.97	38.08	38.87	38.64	38.86	38.10	38.53	37.96	38.12	38.45	38.25	38.00	38.65	38.67	38.92	38.08	38.02	39.02	38.83	38.11	38.70	38.58	38.43	38.58	38.15	38.02	38.47	37.45	39.28	38.01	38.20	38.61	39.02	
Al2O3	21.90	21.95	21.89	21.68	21.96	21.64	21.83	21.89	21.78	22.12	21.80	21.73	21.81	21.87	21.79	21.71	21.87	21.81	21.82	21.55	21.75	21.72	21.74	21.83	21.84	21.80	21.77	21.80	21.45	21.81	22.05	21.67	22.08		
FeO	27.73	27.20	27.60	27.71	27.28	27.56	27.58	27.36	26.75	27.50	27.64	26.76	27.01	27.14	27.15	26.98	27.08	26.51	26.81	26.83	26.43	26.46	26.31	26.19	26.78	26.23	26.82	26.69	26.55	27.02	26.65	27.05	26.92		
MgO	10.16	10.27	10.17	10.11	9.95	10.11	10.04	9.93	9.81	9.85	9.75	9.53	9.51	9.53	9.51	9.51	9.35	9.27	9.13	9.29	9.10	9.25	9.20	9.14	9.34	9.28	9.27	9.46	9.32	9.49	9.60	9.70	9.75	9.81	
MnO	0.61	0.61	0.73	0.65	0.58	0.64	0.70	0.64	0.66	0.69	0.68	0.66	0.60	0.56	0.56	0.64	0.65	0.69	0.53	0.65	0.62	0.61	0.59	0.64	0.52	0.57	0.71	0.56	0.57	0.59	0.58	0.58	0.61	0.59	
CaO	1.14	1.12	1.20	1.29	1.29	1.40	1.51	1.65	1.73	1.84	2.06	2.25	2.28	2.53	2.62	2.70	2.84	2.98	2.99	3.11	3.13	3.12	3.24	3.29	3.19	3.02	3.07	2.97	2.86	2.77	2.73	2.50	2.37	2.24	
Total	100.12	99.11	99.67	100.59	99.48	100.21	99.77	99.99	98.68	100.11	100.39	99.17	99.21	100.27	100.29	100.45	99.79	99.28	100.29	100.26	99.14	99.95	99.81	99.62	99.66	99.59	99.07	100.08	98.19	100.45	99.75	99.68	100.26	100.66	
Mg	Si	2.968	2.949	2.948	2.976	2.987	2.987	2.949	2.969	2.961	2.940	2.960	2.972	2.956	2.972	2.974	2.986	2.950	2.956	2.996	2.988	2.965	2.984	2.979	2.973	2.978	2.958	2.959	2.966	2.950	3.005	2.952	2.968	2.980	
	Al	1.986	2.009	1.997	1.982	1.981	1.960	1.992	1.988	2.002	2.011	1.978	1.989	1.999	1.982	1.975	1.964	1.990	1.998	1.975	1.954	1.995	1.974	1.979	1.989	1.987	1.992	1.997	1.981	1.978	1.963	1.992	1.988	1.981	1.988
	Fe	1.785	1.767	1.787	1.774	1.763	1.771	1.785	1.763	1.745	1.774	1.780	1.739	1.757	1.746	1.746	1.731	1.755	1.724	1.721	1.727	1.720	1.711	1.709	1.702	1.691	1.736	1.707	1.729	1.759	1.699	1.751	1.722	1.739	1.720
	Mg	1.165	1.189	1.174	1.154	1.146	1.158	1.148	1.140	1.141	1.133	1.119	1.103	1.103	1.092	1.090	1.081	1.074	1.045	1.066	1.056	1.063	1.059	1.054	1.074	1.072	1.078	1.087	1.095	1.082	1.109	1.117	1.117	1.117	1.117
Mn	Mn	0.039	0.04	0.048	0.042	0.038	0.041	0.046	0.041	0.044	0.045	0.044	0.043	0.039	0.036	0.036	0.041	0.043	0.046	0.035	0.043	0.041	0.04	0.038	0.042	0.034	0.037	0.047	0.036	0.038	0.038	0.038	0.038	0.04	0.038
	Ca	0.094	0.093	0.1	0.106	0.107	0.115	0.126	0.136	0.144	0.152	0.17	0.187	0.19	0.208	0.236	0.262	0.288	0.248	0.246	0.256	0.261	0.258	0.268	0.273	0.263	0.251	0.256	0.245	0.241	0.227	0.226	0.195	0.183	
	MgRat	0.40	0.40	0.40	0.39	0.39	0.40	0.39	0.39	0.40	0.39	0.39	0.39	0.39	0.39	0.38	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.39	0.38	0.39	0.38	0.39	0.39	0.39
		Alm	0.58	0.57	0.58	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.57	0.56	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Pyr		0.38	0.39	0.38	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.34	0.35	0.34	0.35	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.37	
Sps		0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Grs	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06

Pitt gamet E																																					
1	2	3	4	5	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	26	27	28	29	30	31	32	33	34	36	37	39				
Dist	0	26	51	77	102	153	178	204	229	254	280	306	357	382	407	433	458	484	509	534	560	585	636	661	686	712	737	762	788	813	839	889	915	966			
SiO2	38.68	39.07	38.44	39.02	38.81	39.16	38.55	38.64	38.22	38.37	38.70	38.59	38.87	38.86	38.49	38.49	38.61	38.14	38.51	38.40	38.98	38.42	39.31	38.71	39.30	38.99	38.58	39.04	39.05	38.87	39.18	38.67	38.42	38.76			
Al2O3	21.80	21.88	22.01	21.94	22.12	22.14	21.91	21.91	21.90	22.11	22.03	22.14	22.08	22.22	21.98	22.18	22.15	22.00	21.92	21.99	21.81	22.40	22.08	22.06	22.26	22.07	21.86	22.10	22.07	22.19	22.29	21.99	22.11	22.11			
FeO	28.65	28.04	27.73	27.37	27.49	26.93	27.02	26.94	26.38	26.42	26.52	26.43	26.25	25.96	26.33	25.71	26.22	25.85	26.17	25.86	25.83	25.72	25.89	25.41	25.75	25.42	25.62	25.78	25.46	25.49	25.72	26.31	25.98	25.75			
MgO	9.30	9.68	9.79	9.85	9.83	9.90	9.87	9.96	9.86	9.88	9.89	9.70	9.96	9.79	10.09	10.09	10.26	10.14	10.23	10.04	10.03	9.95	9.93	10.09	9.97	10.11	10.11	10.10	10.26	10.32	10.68	10.88	10.93				
MnO	0.57	0.64	0.57	0.55	0.67	0.53	0.56	0.52	0.46	0.45	0.58	0.49	0.52	0.51	0.43	0.57	0.46	0.50	0.47	0.44	0.50	0.53	0.49	0.55	0.46	0.50	0.45	0.53	0.42	0.42	0.42	0.49	0.47				
Ca	1.28	1.41	1.53	1.65	1.85	2.15	2.40	2.42	2.61	2.72	2.75	2.78	2.74	2.75	2.70	2.77	2.67	2.73	2.78	2.77	2.95	2.99	3.11	3.21	3.19	3.23	3.17	3.10	2.96	2.89	2.73	2.14	1.99	1.68			
Total	100.27	100.72	100.07	100.38	100.77	100.80	100.30	100.41	99.44	99.95	100.47	100.12	100.42	100.09	100.01	99.81	100.31	99.49	99.99	99.72	100.04	99.72	100.83	99.83	100.92	100.33	100.05	100.34	100.20	100.01	100.54	100.52	99.76	99.63			
Si	2.984	2.991	2.963	2.990	2.968	2.984	2.962	2.984	2.957	2.952	2.964	2.963	2.972	2.976	2.958	2.958	2.956	2.944	2.960	2.956	2.987	2.957	2.989	2.971	2.984	2.974	2.958	2.983	2.982	2.974	2.981	2.950	2.951	2.967			
Al	1.982	1.974	2.000	1.981	1.993	1.988	1.984	1.984	1.981	1.997	2.005	1.988	2.004	1.989	2.006	1.991	2.008	1.998	2.002	1.985	1.995	1.970	2.001	1.975	1.997	1.974	2.002	1.995	1.968	1.989	1.990	1.988	2.004	1.991	1.998		
Fe	1.848	1.795	1.787	1.753	1.758	1.716	1.736	1.728	1.707	1.700	1.698	1.697	1.678	1.663	1.693	1.652	1.679	1.669	1.682	1.664	1.655	1.655	1.646	1.631	1.635	1.622	1.643	1.647	1.626	1.631	1.636	1.678	1.669	1.652			
Mg	1.069	1.104	1.124	1.125	1.120	1.125	1.130	1.139	1.137	1.134	1.128	1.110	1.136	1.118	1.153	1.156	1.164	1.181	1.161	1.174	1.146	1.151	1.128	1.136	1.142	1.134	1.156	1.151	1.150	1.170	1.171	1.174	1.247	1.249			
Mn	0.037	0.041	0.037	0.036	0.043	0.034	0.036	0.034	0.03	0.029	0.038	0.032	0.034	0.033	0.028	0.037	0.03	0.033	0.03	0.03	0.028	0.032	0.034	0.032	0.035	0.03	0.033	0.029	0.034	0.027	0.027	0.027	0.032	0.03			
Ca	0.106	0.115	0.126	0.136	0.152	0.175	0.197	0.199	0.217	0.224	0.226	0.228	0.234	0.226	0.222	0.228	0.219	0.226	0.229	0.228	0.242	0.247	0.253	0.264	0.259	0.264	0.26	0.254	0.242	0.237	0.222	0.175	0.164	0.138			
MgRat	0.37	0.38	0.39	0.39	0.39	0.40	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43			
Alm	0.60	0.59	0.58	0.58	0.57	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.53	0.53	0.53	0.54	0.53	0.53	0.54	0.54	0.54	0.54			
Pyr	0.35	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.36	0.37	0.37	0.38	0.38	0.38	0.38	0.37	0.38	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.39	0.40	0.41				
Sps	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			
Grs	0.04	0.04	0.04	0.04	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.07	0.06	0.05	0.05			

Profit gamet F																																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	27	28	29	30	31	32	33	34	35	
Dist	0	20	41	61	81	101	121	142	162	182	202	223	243	263	283	304	324	344	364	385	405	425	1221	1242	1263	1284	1305	1326	1347	1368	1389	1410	1430	1451	
SiO2	38.69	38.58	38.29	38.52	38.53	38.37	38.58	38.60	38.37	38.55	38.89	38.54	38.13	38.42	37.98	38.61	38.66	38.48	38.36	38.53	38.36	38.56	38.62	38.66	38.90	38.80	38.65	38.63	38.76	39.11	39.09	38.75	38.93	39.16	
Al2O3	22.04	22.10	22.21	22.25	21.85	22.23	22.07	21.99	22.31	22.03	21.96	22.04	21.90	21.94	22.30	21.95	22.03	21.92	22.10	21.96	21.92	21.99	22.10	22.06	22.10	21.89	22.22	21.87	21.94	22.04	22.02	21.94	21.78	21.84	22.01
FeO	28.93	29.38	28.86	28.97	28.78	28.78	29.10	28.74	28.86	28.78	28.78	29.04	29.06	28.97	29.05	29.01	29.08	28.83	29.45	29.24	29.12	29.13	28.84	28.87	28.92	28.76	29.10	28.99	28.87	29.02	28.97	29.13	29.04	29.02	
MgO	8.98	9.10	9.16	9.19	9.00	9.18	9.24	9.00	9.03	8.92	8.98	9.05	9.04	9.14	9.09	8.92	9.18	9.07	8.95	9.10	9.04	9.06	9.23	9.21	9.07	9.14	9.16	9.05	9.17	9.06	9.21	9.13	9.15	9.18	
MnO	0.65	0.64	0.64	0.72	0.69	0.66	0.69	0.68	0.61	0.66	0.64	0.65	0.59	0.61	0.68	0.66	0.67	0.70	0.69	0.62	0.69	0.67	0.75	0.69	0.64	0.71	0.61	0.65	0.69	0.69	0.65	0.69	0.71	0.75	
CaO	1.11	1.33	1.35	1.44	1.41	1.48	1.56	1.63	1.64	1.65	1.68	1.65	1.70	1.61	1.61	1.58	1.50	1.51	1.46	1.44	1.37	1.48	1.48	1.46	1.50	1.47	1.49	1.46	1.47	1.48	1.49	1.43	1.48	1.50	
Total	100.40	101.12	101.12	101.10	100.26	100.85	101.24	100.65	100.82	100.60	100.93	100.97	100.43	100.69	100.69	100.72	101.11	100.51	101.00	100.89	100.50	100.88	101.03	100.66	101.13	100.78	101.25	100.72	100.99	101.40	101.34	100.93	101.15	101.56	
Si	2.983	2.962	2.976	2.954	2.978	2.954	2.957	2.972	2.950	2.970	2.984	2.962	2.951	2.961	2.930	2.973	2.966	2.968	2.953	2.965	2.963	2.966	2.963	2.972	2.978	2.982	2.959	2.974	2.973	2.987	2.979	2.983	2.983		
Al	2.002	2.000	2.003	2.011	1.990	2.017	1.994	1.995	2.022	2.000	1.986	1.996	1.997	1.993	2.028	1.992	1.992	1.992	2.005	1.991	1.996	1.993	1.998	1.999	1.994	1.983	2.006	1.990	1.992	1.993	1.975	1.973	1.972	1.979	
Fe	1.865	1.886	1.847	1.858	1.860	1.853	1.865	1.850	1.856	1.854	1.846	1.866	1.881	1.867	1.874	1.868	1.864	1.860	1.896	1.881	1.881	1.874	1.850	1.837	1.852	1.849	1.864	1.866	1.852	1.854	1.851	1.873	1.861	1.851	
Mg	1.032	1.041	1.045	1.051	1.037	1.047	1.056	1.033	1.035	1.025	1.026	1.037	1.043	1.050	1.046	1.023	1.050	1.043	1.026	1.043	1.041	1.039	1.056	1.055	1.035	1.046	1.064	1.038	1.048	1.032	1.049	1.047	1.046	1.043	
Mn	0.042	0.041	0.041	0.047	0.045	0.043	0.045	0.045	0.039	0.043	0.043	0.042	0.042	0.039	0.04	0.044	0.043	0.044	0.046	0.045	0.041	0.045	0.043	0.049	0.045	0.042	0.046	0.04	0.043	0.045	0.045	0.042	0.045	0.046	0.048
Ca	0.092	0.109	0.11	0.119	0.117	0.123	0.128	0.135	0.145	0.135	0.137	0.138	0.136	0.141	0.133	0.133	0.133	0.125	0.12	0.119	0.114	0.122	0.122	0.12	0.123	0.121	0.123	0.121	0.125	0.121	0.122	0.118	0.122	0.123	
MgRat	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.35	0.36	0.36	0.35	0.36	0.36	0.36	0.36	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	
Alm	0.62	0.61	0.61	0.60	0.61	0.60	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.60	0.60	0.61	0.60	0.61	0.61	0.60	0.61	0.60	0.61	0.61	0.60	
Pyr	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.33	0.34	0.34	0.34	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	
Sps	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.02	0.02	
Grs	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	

profil gamet G																																					
Pt	1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	18	19	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	37	38			
Dist	0	20	41	61	81	101	122	142	162	183	203	223	243	304	325	345	365	406	426	447	467	507	528	548	568	589	609	629	649	670	690	1094	1114	1133			
SiO ₂	39.80	39.51	38.41	38.64	38.58	38.58	38.94	39.17	39.71	39.45	39.43	38.80	37.05	39.05	39.51	39.63	39.07	38.79	42.21	39.71	39.81	39.27	39.88	39.64	39.17	40.69	39.24	39.67	39.59	40.20	39.85	39.62	39.24	39.42			
Al ₂ O ₃	22.34	22.22	22.16	22.36	21.98	22.48	22.27	22.15	22.33	22.23	22.23	22.16	21.66	22.13	22.05	22.13	22.17	22.29	22.45	22.22	22.52	22.24	22.38	22.92	22.31	22.38	22.92	22.28	22.62	22.37	22.40	22.39	22.30	22.24	22.10		
FeO	26.69	26.46	26.24	26.76	25.95	26.50	26.22	26.30	26.19	26.04	25.89	26.05	25.14	25.68	25.70	25.48	25.68	25.78	24.97	25.59	25.90	26.23	25.82	25.99	25.85	25.83	26.13	26.14	26.29	26.11	26.10	26.40	26.74	26.61			
MgO	11.25	11.17	10.96	11.12	11.20	10.90	10.93	10.89	10.64	10.78	10.73	10.59	10.66	10.91	10.62	10.49	10.57	10.53	10.31	10.82	10.73	10.73	11.01	11.03	10.95	9.85	11.10	11.39	11.86	11.33	11.19	11.21	11.24	11.01			
MnO	0.44	0.53	0.40	0.45	0.46	0.49	0.57	0.54	0.51	0.52	0.45	0.52	0.48	0.46	0.56	0.48	0.45	0.47	0.45	0.47	0.45	0.43	0.51	0.44	0.44	0.42	0.52	0.47	0.47	0.54	0.46	0.48	0.52	0.52			
CaO	1.10	1.22	1.32	1.37	1.42	1.56	1.64	1.72	1.83	1.98	2.02	2.00	1.95	2.16	2.28	2.25	2.22	2.25	2.06	2.09	2.14	1.85	1.79	1.77	1.62	1.44	1.31	1.23	1.01	1.05	1.14	1.02	1.02	1.06			
Total	101.62	101.11	99.49	100.61	99.58	100.47	100.57	100.76	101.21	101.01	100.76	100.11	96.95	100.38	100.71	100.48	100.15	100.03	102.28	101.14	101.45	101.02	101.36	101.18	100.41	101.15	100.58	101.51	101.60	101.63	101.13	101.04	101.07	100.72			
Si	2.990	2.985	2.954	2.944	2.962	2.943	2.963	2.975	2.986	2.985	2.988	2.967	2.929	2.972	2.996	3.006	2.981	2.966	3.114	2.992	2.994	2.971	2.998	2.989	2.976	3.025	2.978	2.977	2.972	3.009	3.000	2.991	2.970	2.991			
Al	1.978	1.978	2.009	2.008	1.989	2.017	1.997	1.982	1.986	1.982	1.985	1.997	2.018	1.985	1.971	1.980	1.993	2.002	1.938	1.993	1.987	2.008	1.980	1.982	2.004	2.050	1.993	2.001	1.979	1.976	1.987	1.984	1.989	1.976			
Fe	1.677	1.672	1.687	1.705	1.666	1.691	1.668	1.671	1.653	1.647	1.641	1.666	1.662	1.634	1.630	1.617	1.638	1.640	1.540	1.612	1.629	1.659	1.623	1.639	1.642	1.620	1.659	1.641	1.650	1.635	1.643	1.666	1.693	1.689			
Mg	1.259	1.258	1.265	1.256	1.252	1.281	1.240	1.240	1.232	1.196	1.216	1.212	1.207	1.256	1.238	1.200	1.187	1.201	1.200	1.134	1.215	1.202	1.210	1.234	1.239	1.240	1.100	1.256	1.274	1.327	1.265	1.265	1.281	1.268	1.245		
Mn	0.028	0.034	0.026	0.029	0.03	0.032	0.037	0.035	0.033	0.033	0.029	0.033	0.032	0.03	0.036	0.031	0.029	0.031	0.028	0.03	0.029	0.027	0.032	0.028	0.028	0.027	0.033	0.03	0.03	0.034	0.029	0.031	0.033	0.033			
Ca	0.088	0.099	0.109	0.112	0.116	0.128	0.133	0.14	0.148	0.161	0.164	0.164	0.165	0.176	0.185	0.183	0.181	0.184	0.163	0.169	0.172	0.15	0.144	0.143	0.132	0.115	0.107	0.099	0.081	0.084	0.092	0.083	0.083	0.086			
Mg/Rat	0.43	0.43	0.43	0.42	0.44	0.42	0.43	0.43	0.42	0.43	0.43	0.42	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.40	0.43	0.44	0.45	0.44	0.43	0.43	0.43	0.42		
Alm	0.55	0.55	0.55	0.55	0.54	0.55	0.54	0.54	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.53	0.54	0.55	0.54	0.54	0.54	0.57	0.54	0.54	0.54	0.53	0.54	0.54	0.55	0.55	0.55		
Pyr	0.41	0.41	0.41	0.40	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.39	0.40	0.40	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.38	0.41	0.42	0.43	0.42	0.42	0.42	0.41	0.41	0.41		
Sps	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			
Grs	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03		

[illegible]

44	45	46	47	48	50	51	52	53	54	56	57	59	60	61	62	64	65	66	68	70	71	72	73	74	76	77	79	80	81	82	83	84	85	86		
1071	1096	1121	1145	1170	1220	1245	1269	1294	1319	1369	1393	1443	1468	1493	1517	1567	1592	1616	1666	2132	2158	2183	2208	2233	2283	2308	2359	2384	2409	2434	2459	2484	2509	2534		
38.09	38.48	38.53	38.78	38.42	39.66	38.57	37.13	38.87	36.38	38.84	38.36	39.75	38.89	38.72	38.99	38.79	38.72	38.98	38.83	38.75	38.73	38.62	38.79	38.63	39.66	38.64	38.77	38.79	39.06	38.88	38.83	38.74	38.77	39.01		
21.13	21.72	21.72	21.85	21.85	22.35	22.00	20.71	21.83	20.32	21.84	21.75	21.78	22.10	21.84	21.75	21.69	21.96	21.80	21.85	21.78	21.92	21.84	21.62	21.71	21.43	22.14	21.67	21.77	21.61	21.84	21.55	21.72	21.83	21.62	21.51	
26.92	26.83	27.09	26.72	26.79	26.93	26.39	26.57	26.43	26.19	26.88	26.36	26.46	26.70	26.50	26.39	26.50	26.30	26.48	26.37	26.23	26.59	26.39	26.40	26.16	25.95	26.40	26.21	26.42	26.43	26.29	26.36	25.85	26.40	26.21		
8.28	8.33	8.24	8.24	8.28	8.12	8.31	7.58	8.26	7.71	8.26	8.22	8.51	8.66	8.65	8.77	8.94	9.09	9.02	9.19	9.11	9.02	9.00	8.79	8.73	8.55	8.72	8.53	8.79	8.47	8.57	8.60	8.47	8.57	8.41		
0.59	0.53	0.55	0.53	0.50	0.46	0.59	0.55	0.47	0.54	0.52	0.52	0.48	0.56	0.51	0.54	0.46	0.45	0.45	0.49	0.42	0.47	0.48	0.45	0.42	0.50	0.44	0.41	0.47	0.41	0.46	0.51	0.51	0.45	0.48		
4.42	4.25	4.24	4.30	4.36	4.34	4.44	4.20	4.29	4.29	4.47	4.32	4.08	4.08	3.98	3.83	3.44	3.44	3.42	2.96	3.18	3.49	3.69	3.93	4.14	4.37	4.33	4.40	4.49	4.40	4.48	4.50	4.34	4.40	4.40		
99.44	100.14	100.36	100.42	100.20	101.89	100.29	96.74	100.15	95.42	100.91	99.56	101.38	100.73	100.11	100.20	100.09	99.61	100.20	99.62	99.61	100.14	99.68	100.07	99.51	101.16	100.21	100.09	100.57	100.61	100.23	100.52	99.74	100.21	100.05		
2.975	2.975	2.976	2.985	2.969	3.002	2.972	2.983	2.995	2.967	2.978	2.978	3.016	2.982	2.985	2.999	2.984	2.993	2.994	2.996	2.990	2.981	2.988	2.989	2.994	3.012	2.979	2.988	2.980	2.995	2.995	2.984	2.992	2.988	3.009		
1.945	1.979	1.977	1.983	1.960	1.994	1.998	1.961	1.982	1.953	1.984	1.993	1.977	1.974	1.977	1.966	1.991	1.968	1.978	1.981	1.993	1.981	1.961	1.972	1.959	1.981	1.968	1.977	1.957	1.973	1.956	1.967	1.986	1.964	1.955		
1.759	1.734	1.749	1.721	1.731	1.705	1.700	1.785	1.703	1.787	1.724	1.711	1.679	1.712	1.708	1.697	1.705	1.700	1.701	1.702	1.693	1.712	1.708	1.701	1.696	1.648	1.702	1.689	1.698	1.684	1.693	1.694	1.670	1.702	1.689		
0.964	0.96	0.948	0.945	0.953	0.916	0.955	0.908	0.948	0.937	0.944	0.951	0.962	0.99	0.994	1.005	1.025	1.047	1.033	1.057	1.048	1.035	1.038	1.010	1.009	0.968	1.002	0.98	1.007	0.968	0.983	0.985	0.975	0.984	0.966		
0.039	0.035	0.036	0.035	0.033	0.03	0.038	0.037	0.031	0.037	0.034	0.034	0.031	0.036	0.033	0.035	0.03	0.03	0.029	0.032	0.028	0.031	0.031	0.029	0.027	0.032	0.029	0.027	0.031	0.027	0.03	0.033	0.034	0.029	0.032		
0.37	0.352	0.351	0.355	0.363	0.354	0.368	0.362	0.354	0.375	0.367	0.359	0.332	0.335	0.329	0.316	0.284	0.285	0.282	0.245	0.263	0.288	0.306	0.331	0.329	0.343	0.343	0.355	0.357	0.363	0.37	0.361	0.37	0.37	0.359	0.363	0.363
0.35	0.36	0.35	0.36	0.36	0.35	0.36	0.34	0.36	0.34	0.35	0.36	0.36	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.37	0.37	0.36	0.37	0.37	0.37	0.37	0.36		
0.56	0.56	0.57	0.56	0.56	0.57	0.56	0.58	0.56	0.57	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.55	0.56	0.55	0.55	0.55	0.55	0.55	0.56	0.55	0.55	0.55	0.55	0.55		
0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.29	0.31	0.30	0.31	0.31	0.31	0.32	0.32	0.32	0.34	0.34	0.35	0.35	0.34	0.34	0.34	0.33	0.33	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
0.12	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	

44	45	46	47	48	49	50	51	52	53	54	56	57	58	59	60	61	62	64	65	66	67	68	69	70	71	72
1307	1328	1349	1369	1390	1410	1431	1451	1472	1493	1513	1554	1575	1595	1616	1637	1657	1678	1719	1739	1760	1781	1801	1822	1842	1863	1883
36.68	38.15	38.59	38.53	38.55	38.10	38.28	38.41	37.59	38.39	38.21	38.45	38.45	36.73	38.43	38.57	38.72	38.06	38.32	38.29	39.36	38.72	38.83	38.58	38.56	38.53	37.92
21.81	21.82	21.46	21.64	21.84	21.72	21.92	21.78	21.34	21.53	21.47	21.32	21.54	20.87	21.61	21.42	21.60	21.38	21.63	21.57	22.07	21.73	21.77	21.75	21.80	21.77	21.64
27.22	27.32	27.38	26.84	27.57	27.35	27.34	27.56	27.08	27.64	27.00	27.12	27.53	27.25	27.24	27.42	27.44	27.67	27.65	27.76	27.69	28.19	28.05	27.99	27.97	28.08	28.32
8.82	8.85	8.86	8.74	8.79	8.73	8.93	8.65	9.05	8.76	8.88	8.72	8.83	7.68	8.75	8.81	8.46	9.01	9.05	9.12	9.08	9.21	9.34	9.31	9.22	9.39	9.45
0.62	0.66	0.60	0.62	0.64	0.62	0.66	0.60	0.56	0.71	0.62	0.64	0.58	0.66	0.60	0.71	0.56	0.68	0.53	0.59	0.69	0.64	0.66	0.69	0.61	0.61	0.67
2.98	2.94	3.08	3.10	3.14	3.28	3.30	3.21	3.19	3.26	3.20	3.19	3.10	3.00	3.01	2.86	2.73	2.81	2.41	2.38	2.27	2.15	2.08	1.93	1.84	1.67	1.48
100.13	99.73	99.97	99.48	100.52	99.80	100.44	100.21	98.81	100.29	99.38	99.43	100.03	96.19	99.63	99.78	99.51	99.61	99.59	99.70	101.15	100.64	100.63	100.26	100.01	100.05	99.48
2.984	2.961	2.987	2.990	2.970	2.959	2.952	2.969	2.949	2.970	2.974	2.992	2.977	2.971	2.983	2.991	3.006	2.965	2.976	2.973	3.000	2.978	2.984	2.976	2.980	2.976	2.955
1.983	1.996	1.958	1.979	1.983	1.988	1.993	1.985	1.974	1.963	1.970	1.955	1.966	1.990	1.976	1.958	1.976	1.963	1.979	1.973	1.982	1.970	1.971	1.978	1.986	1.982	1.987
1.756	1.773	1.772	1.742	1.776	1.777	1.763	1.782	1.777	1.788	1.758	1.765	1.783	1.843	1.768	1.778	1.781	1.802	1.796	1.802	1.765	1.813	1.803	1.806	1.807	1.814	1.845
1.014	1.024	1.023	1.011	1.009	1.011	1.026	0.997	1.058	1.010	1.031	1.015	1.019	0.926	1.012	1.018	0.979	1.045	1.048	1.055	1.032	1.056	1.059	1.071	1.063	1.081	1.097
0.04	0.044	0.039	0.041	0.041	0.041	0.043	0.039	0.037	0.047	0.041	0.042	0.038	0.045	0.039	0.047	0.037	0.045	0.035	0.039	0.045	0.042	0.043	0.045	0.04	0.04	0.044
0.246	0.244	0.256	0.258	0.259	0.273	0.273	0.266	0.268	0.27	0.267	0.266	0.257	0.26	0.25	0.237	0.227	0.234	0.2	0.198	0.185	0.172	0.171	0.16	0.152	0.139	0.124
0.37	0.37	0.37	0.37	0.36	0.36	0.37	0.36	0.37	0.36	0.37	0.36	0.36	0.33	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
0.58	0.58	0.57	0.57	0.58	0.57	0.57	0.58	0.57	0.57	0.57	0.57	0.58	0.60	0.58	0.58	0.59	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.59
0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.32	0.33	0.33	0.33	0.30	0.33	0.33	0.32	0.33	0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01
0.08	0.08	0.08	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.04

35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	
680	700	720	740	760	780	1104	1123	1143	1162	1182	1201	1221	1240	1260	1637	1657	1678	1699	1719	1739	1760	1780	1801	1821	1842	1862	1883	1903	1924	1944	1965	1985	2006	2026	
38.84	39.00	39.07	38.63	39.13	39.36	39.07	39.32	39.69	38.83	39.24	39.30	38.70	39.37	39.69	39.61	39.37	38.26	38.80	38.88	39.48	38.75	39.12	38.53	38.57	38.58	39.21	39.19	38.68	38.55	39.26	38.94	38.46	39.42	39.44	
21.98	21.99	21.89	22.05	21.98	21.97	22.12	22.12	21.97	22.25	22.07	22.23	22.15	21.95	22.08	22.19	21.92	22.27	21.86	21.94	21.92	21.97	21.94	21.94	22.15	21.85	21.97	22.03	22.11	22.17	21.94	22.08	22.14	21.87	21.96	
27.01	27.02	26.65	27.16	26.99	27.11	26.31	26.65	27.02	26.49	26.87	26.61	26.56	26.79	27.01	26.19	26.37	26.54	26.39	26.69	26.36	25.78	26.68	26.21	26.22	26.23	26.19	26.04	25.96	26.33	26.38	26.29	26.19	26.10	26.47	
9.95	9.97	10.01	10.29	10.39	10.50	10.41	10.55	10.56	10.51	10.59	10.59	10.47	10.46	10.51	10.72	10.56	10.56	10.43	10.38	10.28	10.28	10.24	10.18	10.26	10.39	10.35	10.23	10.29	10.24	10.32	10.28	10.37	10.37	10.51	
0.58	0.54	0.60	0.53	0.57	0.63	0.46	0.49	0.58	0.53	0.58	0.56	0.58	0.58	0.51	0.48	0.55	0.52	0.57	0.60	0.51	0.63	0.52	0.51	0.55	0.59	0.50	0.53	0.50	0.50	0.56	0.54	0.46	0.57	0.56	
2.01	1.93	1.84	1.59	1.53	1.34	1.29	1.29	1.32	1.46	1.38	1.38	1.33	1.38	1.24	1.37	1.44	1.73	1.88	2.11	2.29	2.18	2.28	2.34	2.30	2.36	2.32	2.29	2.21	2.18	2.09	2.11	2.02	1.94	1.79	
100.38	100.45	100.07	100.25	100.59	100.91	99.66	100.43	101.22	100.07	100.73	100.67	99.79	100.53	101.04	100.56	100.21	99.88	99.93	100.61	100.86	99.59	100.77	99.72	100.05	99.99	100.55	100.31	99.74	99.97	100.57	100.25	99.84	100.27	100.73	
2.976	2.984	2.995	2.963	2.985	2.992	2.995	2.995	3.003	2.971	2.985	2.987	2.972	3.000	3.006	3.004	3.003	2.941	2.978	2.969	2.999	2.999	2.981	2.966	2.958	2.963	2.988	2.991	2.970	2.959	2.991	2.977	2.959	3.006	2.997	
1.985	1.983	1.978	1.993	1.976	1.969	1.998	1.986	1.959	2.007	1.979	1.991	2.004	1.971	1.971	1.984	1.971	2.018	1.977	1.975	1.962	1.991	1.970	1.991	2.002	1.978	1.973	1.981	2.001	2.006	1.971	1.990	2.008	1.966	1.967	
1.731	1.728	1.708	1.742	1.722	1.723	1.687	1.697	1.710	1.695	1.710	1.692	1.706	1.707	1.711	1.661	1.683	1.706	1.694	1.705	1.675	1.657	1.700	1.687	1.682	1.685	1.669	1.662	1.667	1.690	1.681	1.681	1.685	1.664	1.682	
1.137	1.137	1.144	1.177	1.182	1.190	1.189	1.198	1.202	1.199	1.201	1.199	1.198	1.188	1.187	1.212	1.201	1.210	1.194	1.182	1.164	1.178	1.163	1.168	1.173	1.190	1.175	1.163	1.177	1.172	1.173	1.172	1.189	1.179	1.190	
0.038	0.035	0.039	0.034	0.037	0.04	0.03	0.031	0.037	0.034	0.038	0.036	0.038	0.037	0.033	0.031	0.035	0.034	0.037	0.039	0.033	0.041	0.034	0.033	0.035	0.038	0.033	0.034	0.033	0.032	0.036	0.035	0.03	0.037	0.036	
0.165	0.158	0.151	0.131	0.125	0.109	0.106	0.105	0.107	0.119	0.132	0.113	0.109	0.113	0.1	0.111	0.118	0.143	0.155	0.173	0.187	0.179	0.186	0.193	0.189	0.194	0.189	0.188	0.182	0.18	0.171	0.173	0.167	0.158	0.146	
0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.41	0.41	0.41	0.42	0.42	0.42	0.41	0.41	0.41	0.42	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.41
0.56	0.57	0.56	0.57	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.57	0.55	0.55	0.55	0.55	0.55	0.55	0.54	0.55	0.55	0.55	0.54	0.54	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	
0.37	0.37	0.38	0.38	0.39	0.39	0.40	0.40	0.39	0.39	0.39	0.40	0.39	0.39	0.39	0.40	0.40	0.39	0.39	0.38	0.38	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.39	0.38	0.38	0.38	0.39	0.39	0.39	
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	

40	41	42	43	44	45	48	49	50	51	52	53	54	55	56	57	58	59	60	64	65	66	67	69	71	72	73	75	76	77	78	79	80	81	82
992	1017	1042	1068	1093	1118	1195	1220	1246	1409	1434	1459	1485	1510	1535	1560	1585	1610	1635	1736	1761	1787	1812	1862	1912	1937	1963	2013	2038	2063	2089	2114	2139	2164	2189
39.23	38.99	39.00	39.00	38.10	39.17	39.38	39.30	39.04	39.89	39.78	38.66	39.31	39.08	39.78	39.16	39.64	39.88	39.63	39.99	39.77	40.17	39.79	40.07	40.12	39.74	39.83	39.60	40.00	39.78	39.17	39.90	39.65	39.09	39.81
22.06	22.32	22.11	22.18	21.96	21.96	22.16	22.25	22.34	22.31	22.50	22.27	22.23	22.28	22.29	22.19	22.41	21.99	22.38	22.41	22.00	22.16	22.34	22.23	22.41	22.25	22.07	22.19	22.29	22.21	22.20	22.21	22.20	22.05	
26.00	26.37	26.28	25.71	25.88	25.68	25.58	25.52	26.04	25.81	25.69	26.30	25.56	25.50	25.83	25.89	25.68	25.38	25.86	25.77	25.81	25.13	25.42	24.93	25.53	25.08	25.00	24.61	24.61	24.73	24.65	24.93	24.84	24.41	24.89
11.02	11.13	11.20	11.06	11.31	11.44	11.32	11.51	11.40	11.30	11.48	11.53	11.52	11.67	11.58	11.47	11.31	11.53	11.31	11.45	11.29	11.30	11.21	11.14	11.13	10.81	10.72	10.29	10.25	10.10	10.33	10.37	10.35	10.43	
0.54	0.48	0.52	0.56	0.55	0.50	0.59	0.50	0.51	0.42	0.56	0.41	0.40	0.48	0.46	0.42	0.43	0.49	0.52	0.50	0.54	0.58	0.40	0.46	0.48	0.46	0.51	0.47	0.52	0.57	0.53	0.47	0.55	0.46	0.48
1.57	1.46	1.34	1.32	1.15	1.24	1.20	1.08	1.15	1.26	1.08	0.99	1.08	1.01	1.08	1.06	1.15	1.19	1.15	1.30	1.36	1.48	1.62	1.87	1.92	2.54	2.99	3.40	3.60	3.65	3.67	3.54	3.56	3.50	3.45
100.43	100.75	100.45	99.83	98.94	99.99	100.23	100.20	100.19	101.49	100.83	100.23	99.98	100.25	101.00	100.24	100.49	100.75	100.66	101.42	100.76	101.04	100.86	100.47	101.33	100.97	101.27	100.79	101.23	100.90	100.55	101.51	101.18	100.00	101.11
2.983	2.960	2.969	2.979	2.946	2.985	2.991	2.983	2.974	2.987	3.000	2.947	2.976	2.965	2.996	2.977	2.999	3.005	2.997	2.999	3.006	3.016	2.998	3.026	3.012	2.996	2.997	2.993	3.010	3.008	2.975	2.998	2.991	2.980	3.003
1.978	1.998	1.984	1.997	2.001	1.973	1.984	1.995	1.980	2.013	1.978	2.007	2.001	2.012	1.976	1.992	1.987	1.979	1.978	1.981	1.959	1.980	1.990	1.958	1.961	1.985	1.971	1.996	1.973	1.967	1.987	1.974	1.975	1.995	1.961
1.654	1.674	1.673	1.643	1.673	1.637	1.625	1.620	1.659	1.616	1.620	1.677	1.626	1.618	1.627	1.646	1.625	1.599	1.636	1.616	1.632	1.578	1.602	1.575	1.603	1.581	1.573	1.556	1.548	1.564	1.566	1.566	1.567	1.556	1.571
1.250	1.259	1.271	1.259	1.303	1.300	1.281	1.302	1.295	1.261	1.290	1.311	1.307	1.320	1.300	1.299	1.275	1.295	1.276	1.280	1.272	1.265	1.259	1.254	1.245	1.214	1.202	1.159	1.150	1.139	1.170	1.162	1.166	1.176	1.172
0.035	0.031	0.034	0.036	0.036	0.032	0.038	0.032	0.033	0.027	0.036	0.026	0.026	0.031	0.029	0.027	0.028	0.031	0.033	0.032	0.035	0.037	0.026	0.03	0.03	0.03	0.033	0.03	0.033	0.036	0.034	0.03	0.035	0.029	0.031
0.128	0.119	0.109	0.108	0.095	0.101	0.098	0.088	0.094	0.101	0.087	0.081	0.088	0.082	0.087	0.087	0.094	0.096	0.093	0.104	0.11	0.119	0.13	0.151	0.155	0.205	0.241	0.275	0.29	0.296	0.299	0.285	0.288	0.286	0.279
0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.45	0.44	0.44	0.44	0.44	0.45	0.45	0.44	0.44	0.44	0.45	0.44	0.44	0.44	0.45	0.44	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.43	0.43	0.43	0.43	0.43
0.54	0.54	0.54	0.54	0.54	0.53	0.53	0.53	0.54	0.54	0.53	0.54	0.53	0.53	0.54	0.54	0.54	0.53	0.54	0.53	0.54	0.53	0.53	0.53	0.52	0.52	0.52	0.51	0.52	0.51	0.52	0.51	0.51	0.51	0.52
0.41	0.41	0.41	0.41	0.42	0.42	0.43	0.42	0.43	0.42	0.43	0.42	0.43	0.43	0.43	0.43	0.42	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.40	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.39	0.38
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.07	0.08	0.09	0.10	0.10	0.10	0.09	0.09	0.09

78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1990	2016	2042	2068	2094	2120	2171	2197	2223	2249	2275	2301	2326	2352	2378	2404	2430	2456	2481	2507	2533	2559
38.45	38.56	38.45	38.80	38.06	38.48	38.55	38.53	38.28	37.81	38.40	37.99	38.19	38.38	38.25	38.47	38.17	38.17	38.28	38.09	38.38	37.83
21.61	21.61	21.74	21.54	21.60	21.57	21.73	21.74	21.54	21.58	21.54	21.73	21.65	21.68	21.59	21.89	21.83	21.50	21.54	21.71	21.72	21.41
27.77	28.27	27.97	28.14	28.10	27.71	28.28	28.49	28.23	27.94	28.23	28.33	28.19	28.36	28.26	28.49	29.06	28.72	28.94	29.31	28.91	29.44
7.88	7.89	7.97	8.04	8.08	8.12	7.97	8.18	8.30	8.19	8.44	8.30	8.48	8.41	8.54	8.45	8.54	8.70	8.71	8.89	8.81	9.44
0.79	0.76	0.69	0.73	0.74	0.71	0.80	0.73	0.76	0.71	0.83	0.68	0.76	0.77	0.72	0.71	0.69	0.86	0.67	0.66	0.69	0.73
3.48	3.40	3.41	3.24	3.18	3.11	3.00	2.88	2.93	2.80	2.65	2.56	2.42	2.37	2.26	2.18	2.08	1.92	1.83	1.57	1.45	1.32
99.98	100.50	100.24	100.49	99.75	99.69	100.34	100.54	100.03	99.02	100.08	99.59	99.69	99.97	99.62	100.20	100.39	99.87	99.97	100.22	99.96	100.17
2.987	2.985	2.980	2.998	2.968	2.993	2.986	2.979	2.975	2.966	2.980	2.964	2.974	2.981	2.979	2.978	2.959	2.972	2.976	2.958	2.979	2.944
1.978	1.971	1.986	1.962	1.985	1.977	1.984	1.981	1.973	1.996	1.971	1.998	1.987	1.984	1.982	1.997	1.995	1.973	1.974	1.986	1.987	1.963
1.804	1.830	1.813	1.819	1.832	1.802	1.832	1.842	1.835	1.833	1.832	1.849	1.836	1.842	1.841	1.845	1.884	1.870	1.881	1.903	1.876	1.915
0.912	0.911	0.921	0.926	0.939	0.941	0.92	0.942	0.962	0.958	0.976	0.966	0.984	0.973	0.991	0.975	0.987	1.010	1.010	1.028	1.020	1.095
0.052	0.05	0.045	0.048	0.049	0.047	0.052	0.048	0.05	0.047	0.054	0.045	0.05	0.05	0.048	0.047	0.046	0.057	0.044	0.043	0.045	0.048
0.29	0.282	0.283	0.268	0.266	0.259	0.249	0.239	0.244	0.235	0.22	0.214	0.202	0.197	0.189	0.181	0.173	0.16	0.152	0.13	0.121	0.11
0.34	0.33	0.34	0.34	0.34	0.34	0.33	0.34	0.34	0.34	0.35	0.34	0.35	0.35	0.35	0.35	0.34	0.35	0.35	0.35	0.35	0.36
0.59	0.60	0.59	0.59	0.59	0.59	0.60	0.60	0.59	0.60	0.59	0.60	0.60	0.60	0.60	0.61	0.61	0.60	0.61	0.61	0.61	0.61
0.30	0.30	0.30	0.30	0.30	0.31	0.30	0.31	0.31	0.31	0.32	0.31	0.32	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.35
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02
0.10	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04	0.04

87	88	89	91	92	93	94	95	96	97	98	99	100	101	102	103	104	106	107	108	109	110	111	113	114	115	116	117	120	121	122	123	124	125	126
2559	2584	2609	2659	2684	2709	2734	2759	2784	2809	2834	2859	2884	2909	2934	2959	2984	3034	3059	3084	3109	3134	3159	3209	3234	3259	3284	3309	3385	3410	3435	3460	3485	3510	3535
38.58	38.66	38.51	38.42	38.64	38.95	38.41	38.99	40.14	37.30	38.17	38.12	38.74	38.83	38.74	38.84	39.08	39.26	39.11	38.81	38.99	38.59	38.59	38.83	38.77	38.56	38.86	38.01	38.69	38.58	38.49	31.57	38.32	38.85	38.56
21.73	21.55	21.69	21.53	21.97	21.80	21.59	21.61	22.30	20.75	21.79	21.35	21.58	21.45	21.66	21.81	21.70	21.62	21.79	21.75	21.61	21.78	21.72	21.56	21.78	21.89	21.62	21.38	21.84	22.00	21.73	17.73	21.75	22.15	21.85
26.19	25.91	26.35	26.00	26.33	26.11	26.36	26.45	26.45	26.04	25.95	26.75	26.89	26.77	26.97	27.15	26.96	26.66	27.44	26.86	27.23	27.71	27.15	27.66	27.43	27.50	28.03	27.97	28.23	28.27	28.51	28.41	28.65	29.02	28.79
8.58	8.42	8.44	8.55	8.45	8.35	8.36	8.24	8.18	8.82	7.56	8.63	8.40	8.38	8.36	8.37	8.08	8.24	8.24	8.43	8.43	8.42	8.47	8.67	8.43	8.53	8.50	8.78	8.52	8.75	8.82	8.32	9.02	8.77	8.85
0.52	0.40	0.47	0.54	0.51	0.56	0.56	0.55	0.54	0.48	0.45	0.48	0.52	0.47	0.46	0.53	0.49	0.52	0.48	0.52	0.63	0.56	0.53	0.60	0.60	0.55	0.55	0.59	0.59	0.55	0.53	0.55	0.56	0.60	0.68
4.61	4.52	4.49	4.47	4.39	4.35	4.35	4.36	4.36	4.34	4.26	4.16	4.23	4.17	4.06	4.07	4.04	3.87	3.86	3.76	3.48	3.65	3.30	3.26	3.21	3.04	2.97	2.79	2.30	2.09	1.87	1.59	1.43	1.36	1.29
100.22	99.47	99.95	99.51	100.29	100.11	99.63	100.19	101.97	97.74	98.17	99.49	100.37	100.07	100.24	100.57	100.34	100.17	100.92	100.14	100.37	100.70	99.76	100.59	100.23	100.06	100.52	99.52	100.16	100.23	99.96	88.16	99.73	100.76	100.03
2.974	2.996	2.977	2.982	2.975	2.999	2.981	3.005	3.027	2.959	2.998	2.968	2.987	3.000	2.989	2.990	3.009	3.022	2.998	2.994	3.003	2.972	2.990	2.990	2.992	2.981	2.995	2.966	2.990	2.978	2.983	2.853	2.976	2.985	2.986
1.975	1.969	1.977	1.969	1.993	1.978	1.974	1.963	1.982	1.940	2.017	1.960	1.961	1.953	1.970	1.961	1.969	1.961	1.969	1.977	1.962	1.978	1.983	1.957	1.981	1.994	1.964	1.967	1.989	2.002	1.985	1.888	1.991	2.006	1.994
1.688	1.680	1.704	1.687	1.695	1.681	1.711	1.705	1.668	1.728	1.705	1.742	1.734	1.730	1.740	1.748	1.736	1.716	1.759	1.733	1.754	1.785	1.759	1.781	1.770	1.777	1.807	1.825	1.825	1.825	1.848	2.147	1.861	1.865	1.865
0.986	0.973	0.973	0.989	0.97	0.958	0.967	0.947	0.919	1.043	0.885	1.002	0.966	0.964	0.961	0.96	0.927	0.946	0.942	0.969	0.968	0.966	0.978	0.995	0.97	0.983	0.976	1.022	0.981	1.006	1.019	1.120	1.044	1.005	1.021
0.034	0.026	0.031	0.035	0.033	0.036	0.037	0.036	0.034	0.033	0.03	0.032	0.034	0.031	0.03	0.034	0.032	0.034	0.031	0.034	0.041	0.037	0.035	0.039	0.039	0.036	0.036	0.039	0.038	0.036	0.035	0.042	0.037	0.039	0.045
0.381	0.375	0.372	0.372	0.362	0.359	0.362	0.36	0.353	0.369	0.358	0.347	0.35	0.345	0.335	0.336	0.333	0.319	0.317	0.31	0.287	0.301	0.274	0.269	0.266	0.252	0.245	0.233	0.19	0.173	0.155	0.154	0.119	0.112	0.107
0.37	0.37	0.36	0.37	0.36	0.36	0.36	0.36	0.36	0.38	0.34	0.37	0.36	0.36	0.36	0.36	0.35	0.36	0.35	0.36	0.36	0.35	0.36	0.36	0.35	0.36	0.35	0.36	0.35	0.36	0.34	0.36	0.35	0.35	
0.55	0.55	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.55	0.57	0.56	0.56	0.57	0.57	0.57	0.57	0.58	0.57	0.58	0.58	0.58	0.58	0.58	0.58	0.59	0.59	0.60	0.60	0.60	0.62	0.61	0.62	0.61	
0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.33	0.30	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.33	0.32	0.33	0.33	0.32	0.34	0.33	0.34
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.09	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.06	0.06	0.05	0.04	0.04	0.04	0.04

71	72	73	74	75	76	77	78	79	80
2047	2067	2088	2108	2129	2149	2170	2190	2211	2231
38.56	39.54	39.40	38.82	39.29	38.72	39.64	39.70	39.25	39.40
22.12	22.06	21.94	21.98	21.89	22.28	22.35	21.88	22.00	21.98
26.08	26.51	26.21	26.18	26.48	26.70	26.56	26.35	26.59	26.31
10.38	10.54	10.64	10.73	10.81	10.77	10.80	10.79	10.87	10.94
0.50	0.58	0.59	0.56	0.57	0.50	0.48	0.55	0.61	0.60
1.80	1.69	1.63	1.48	1.42	1.36	1.23	1.10	1.16	1.14
99.44	100.93	100.41	99.75	100.46	100.32	101.07	100.37	100.47	100.36
2.969	2.998	3.000	2.978	2.993	2.958	2.995	3.018	2.989	2.998
2.007	1.971	1.969	1.987	1.985	2.006	1.990	1.960	1.974	1.971
1.679	1.681	1.669	1.679	1.687	1.706	1.678	1.675	1.694	1.674
1.192	1.191	1.208	1.227	1.227	1.226	1.216	1.222	1.233	1.240
0.033	0.038	0.038	0.036	0.037	0.032	0.031	0.035	0.039	0.038
0.148	0.138	0.133	0.121	0.116	0.111	0.1	0.09	0.095	0.093
0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.43
0.55	0.55	0.55	0.55	0.55	0.56	0.56	0.55	0.55	0.55
0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03

83	84	85	86	87	88	89	90	91	92	93
2214	2239	2265	2290	2315	2340	2365	2391	2416	2441	2466
39.91	39.06	39.25	39.25	39.78	38.97	39.58	39.71	39.53	39.00	39.67
22.15	22.34	22.25	22.11	22.33	22.08	22.24	22.13	22.44	22.18	22.44
24.90	25.10	24.45	25.33	25.26	25.46	25.53	25.33	25.41	25.52	26.02
10.37	10.73	10.63	10.75	10.81	11.10	11.01	11.12	11.07	11.26	11.48
0.46	0.53	0.49	0.43	0.54	0.48	0.54	0.51	0.46	0.57	0.48
3.23	3.08	2.83	2.59	2.43	2.22	2.08	1.75	1.65	1.39	1.23
101.02	100.83	99.91	100.46	101.16	100.32	100.98	100.57	100.55	99.93	101.31
3.010	2.960	2.989	2.982	2.996	2.967	2.989	3.004	2.990	2.975	2.983
1.969	1.996	1.997	1.980	1.982	1.982	1.979	1.973	2.000	1.994	1.989
1.571	1.591	1.557	1.610	1.591	1.621	1.612	1.603	1.607	1.628	1.636
1.166	1.212	1.207	1.217	1.214	1.260	1.239	1.254	1.248	1.281	1.286
0.029	0.034	0.031	0.028	0.034	0.031	0.035	0.033	0.03	0.037	0.03
0.261	0.25	0.231	0.211	0.196	0.181	0.168	0.142	0.134	0.113	0.099
0.43	0.43	0.44	0.43	0.43	0.44	0.44	0.44	0.44	0.44	0.44
0.52	0.52	0.52	0.53	0.52	0.52	0.53	0.53	0.53	0.53	0.54
0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.42	0.42
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.04	0.04	0.03

76 1884	77 1904	78 1924	79 1943	80 1963	81 1983	82 2003	83 2023	84 2042	85 2062
38.96	39.43	38.72	38.81	39.49	39.12	39.34	35.88	39.26	39.11
22.22	22.06	22.04	22.28	22.40	22.17	22.34	22.28	22.26	22.03
26.50	26.81	26.97	26.73	27.05	26.94	26.74	26.60	27.10	26.88
10.30	10.42	10.43	10.31	10.37	10.51	10.50	10.23	10.50	10.42
0.51	0.55	0.57	0.49	0.52	0.50	0.57	0.45	0.53	0.49
1.90	1.88	1.75	1.67	1.64	1.56	1.51	1.06	1.29	1.26
100.39	101.15	100.48	100.29	101.47	100.80	100.99	96.50	100.93	100.20
2.974	2.989	2.962	2.968	2.983	2.976	2.982	2.867	2.982	2.990
1.999	1.971	1.987	2.008	1.994	1.968	1.996	2.098	1.992	1.985
1.692	1.700	1.726	1.709	1.709	1.714	1.695	1.778	1.721	1.719
1.172	1.178	1.190	1.175	1.167	1.192	1.187	1.219	1.189	1.188
0.033	0.035	0.037	0.032	0.033	0.032	0.037	0.03	0.034	0.032
0.155	0.153	0.144	0.137	0.132	0.127	0.123	0.091	0.105	0.103
0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.57	0.57	0.57
0.38	0.38	0.38	0.39	0.38	0.39	0.39	0.39	0.39	0.39
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03

127	128
3561	3586
38.84	38.54
21.80	21.87
29.21	29.49
8.75	8.48
0.67	0.62
1.33	1.27
100.50	100.27
2.995	2.985
1.962	1.997
1.884	1.910
1.006	0.979
0.037	0.041
0.11	0.105
0.35	0.34
0.62	0.63
0.33	0.32
0.01	0.01
0.04	0.04

Garnet A																
pt	Ce	Cr	Dy	Er	Eu	Gd	Ho	La	Li	Lu	Nd	Pr	Sc	Sm	Tb	Tm
0	1.86	0.1519	0.0447	0.0391	0.0038	0.0033	2.772	2.3337	0.2904	2.3333	0.2963	0.0509	2.00217	0.0584	2.071	0.1579
1	1.609	0.1821	0.0595	0.0502	0.0053	0.0050	2.34	0.0296	1.9165	0.0297	0.08675	0.01049	0.1467	2.482	0.9058	
2	1.349	0.318	0.1018	0.0672	0.0624	1.903	0.03015	1.4997	0.20631	0.12261	0.0188	0.2294	2.893	89.444		
3	1.088	0.4338	0.0032	0.0745	0.0745	1.469	0.03029	0.15866	0.15866	0.102712	0.3121	3.304	87.923	181.234	169.682	
4	1.018	0.5897	0.1064	1.3756	0.0867	1.224	0.03516	0.9919	0.17438	0.19828	0.04841	0.3389	5.28	99.82		
5	1.063	0.9153	0.3476	1.7481	0.157	1.011	0.03985	0.9216	0.193	0.23835	0.07052	0.3622	7.355	118.983		
6	1.109	1.125	0.81	0.9761	0.2399	0.816	0.04458	0.27841	0.27841	0.09254	0.38955	9.43	139.907			
7	1.432	1.5906	0.6951	1.432	0.3983	0.3048	0.918	0.24623	0.7896	0.3075	0.07319	0.35825	2.0338	29.519	155.326	
8	2.393	4.8303	2.4033	5.9457	0.9318	1.002	0.50778	0.733	0.45038	1.43719	0.77204	4.6709	60.569	160.112		
9	3.354	8.8359	5.6544	7.426	1.8952	1.085	0.88933	0.6764	0.59826	2.1424	1.18583	7.308	91.62	184.897		
10	4.315	14.841	7.7256	12.887	2.8987	1.169	1.4552	0.986	0.85231	2.74887	1.52021	9.3957	148.124	169.682		
11	5.565	19.4122	9.8832	10.0785	3.6852	1.536	1.25144	0.8906	1.26194	3.12831	1.672	10.2073	134.175	158.809		
12	6.819	22.983	10.8829	11.4047	4.1971	1.907	1.35735	1.0851	1.69867	3.50775	1.6238	11.022	150.225	158.809		
13	8.074	26.537	11.8825	11.6134	4.709	2.279	1.46327	1.2797	1.93541	3.88718	1.97559	11.6366	166.276	153.292		
14	10.063	30.1245	12.8822	11.8045	5.2209	2.665	1.33786	1.558	2.58691	3.54009	1.72663	10.1753	147.884	151.457		
15	12.42	26.5121	11.4688	11.9565	4.7261	3.058	1.20881	1.8375	3.03864	3.18157	1.47137	8.4751	128.951	151.458		
16	14.777	22.7866	10.0173	11.7002	4.2154	3.451	1.07375	2.1171	3.49037	2.82305	1.21612	6.7748	110.017	151.479		
17	15.298	19.0612	8.5659	11.1607	3.7047	3.498	0.97423	2.4541	3.66089	2.62317	1.07616	5.93	97.494	146.5		
18	12.398	16.9492	7.5958	10.6213	3.2682	2.894	0.88051	2.8198	3.69033	2.50287	0.99405	5.5144	88.187	132.71		
19	9.439	15.0647	6.8872	10.0574	2.8689	2.29	0.78678	3.1856	3.71078	2.38257	0.91194	5.0987	78.879	117.789		
20	6.556	14.3442	6.1386	9.4475	2.4696	1.697	0.70645	3.2478	3.69317	2.25589	0.8727	4.7983	72.322	109.672		
21	5.262	13.3785	5.7714	8.8376	2.2471	1.467	0.65129	2.7395	3.56126	2.11721	0.914	4.7143	70.93	94.424		
22	3.969	13.0456	6.0931	8.2574	2.3568	1.238	0.59613	2.2312	3.42934	1.97852	0.9553	4.8304	69.538	64.474		
23	2.675	12.7127	6.3948	8.6784	2.4665	1.008	0.54378	1.7642	3.32224	1.84523	0.99346	4.5553	68.177	74.438		
24	2.15	12.3826	6.6958	8.0995	2.5725	0.992	0.50838	1.6945	4.05312	1.89392	0.92537	4.779	67.866	68.869		
25	1.94	11.6436	6.6346	8.5205	2.5542	1.063	0.46299	1.6248	4.784	1.94261	0.85729	5.0026	67.554	446.986		
26	1.729	11.9069	6.5735	9.4839	2.5359	1.134	0.67159	4.555	5.51488	1.9913	0.78921	5.2263	67.243	262.564		
27	1.557	11.6691	6.5123	9.2605	2.5176	1.155	0.69316	4.251	5.27463	1.97381	0.86347	5.4427	69.041	134.221		
28	1.444	12.15	6.8353	9.4729	2.4928	1.097	0.70615	3.4433	4.63807	1.92931	0.99639	5.6562	71.699	132.141		
29	1.331	13.0253	7.3145	9.8055	2.5961	1.154	1.09554	2.1827	4.0015	1.88462	1.1827	5.8897	74.257	130.062		
30	1.228	13.8586	7.794	9.4782	2.6262	0.97	0.78574	2.1427	3.72349	1.88197	1.20442	6.2508	77.512	128.155		
31	1.255	14.4652	8.3185	9.8928	2.8058	0.751	0.93554	2.1389	4.00254	1.94394	1.19356	6.9524	81.442	128.496		
32	1.281	14.736	8.9131	10.2874	3.1896	0.694	1.2816	1.9527	4.2816	2.09571	1.1827	7.534	85.371	123.717		
33	1.308	14.9981	9.5078	10.427	3.5734	0.311	1.21826	1.2193	4.5367	2.06928	1.17899	8.1364	89.056	128.938		
34	1.137	15.2975	10.0506	10.5667	3.5262	0.249	1.1329	2.0973	4.48767	2.15445	1.26062	8.2401	89.635	118.796		
35	1.002	16.0408	9.9362	10.7083	3.8844	0.238	1.43963	1.2962	4.43963	2.23962	1.35305	8.437	90.215	105.136		
36	0.666	16.7841	9.8217	10.1887	3.8427	0.227	0.9622	0.3031	4.3896	2.32479	1.44008	8.4475	90.794	91.567		
37	0.547	17.5274	9.7073	9.4804	3.801	0.225	1.06405	1.8197	4.40169	2.32347	1.47192	8.565	91.41	82.373		
38	0.578	18.9039	9.7633	9.7633	3.8483	0.238	1.04757	2.294	4.43963	2.32479	1.44008	8.4475	90.794	91.567		
39	0.608	17.5458	10.1785	8.6386	3.9195	0.244	1.38962	1.2747	4.46569	2.26453	1.49968	8.8091	92.666	75.432		
40	0.649	17.4522	10.4031	9.2851	3.9929	0.249	1.52567	1.2994	4.34443	2.29067	1.54262	9.0799	95.612	74.423		
41	0.768	17.4554	11.0531	9.7616	4.0671	0.251	1.7121	1.5771	4.32478	2.3888	1.62316	9.569	95.612	74.423		
42	0.887	17.452	12.0127	10.4274	4.2398	0.189	1.72854	1.8947	3.70513	2.48693	1.70371	10.0067	107.505	109.482		
43	1.006	17.4885	12.98	9.7878	4.3829	0.158	1.80574	2.2051	3.43836	2.57116	1.77768	10.4783	112.856	127.011		
44	1.847	13.8254	13.8254	11.328	4.3218	0.186	1.56967	2.4611	2.55072	2.80207	1.70507	11.5827	137.319	128.496		
45	2.871	18.296	13.7518	8.5088	4.6286	0.1543	1.95333	2.7171	3.70098	2.53029	1.82647	11.5441	114.589	105.627		
46	3.896	18.9999	13.6781	8.7004	4.7354	0.161	1.49013	2.973	3.83229	2.59985	1.85087	12.077	115.456	91.776		
47	4.507	19.6957	13.6487	8.5028	4.8421	0.159	1.55023	3.08918	3.71753	2.69582	1.92562	12.609	122.137	87.744		
48	4.671	20.5477	14.1437	8.7026	4.9528	0.172	1.65201	2.5541	4.18996	2.66742	1.93099	13.1514	121.868	82.013		
49	4.836	21.4547	14.8374	8.6217	5.0644	0.138	1.75379	2.2926	4.37411	2.73731	1.97279	13.8891	125.335	80.282		
50	4.891	22.2618	15.5311	8.5955	5.176	0.107	1.85375	2.5602	4.45731	2.73289	2.01011	13.9355	126.941	78.173		
51	4.165	23.053	15.8445	8.2495	5.2214	0.066	1.89021	2.4008	4.53118	2.58952	2.04256	13.9663	125.529	74.108		
52	3.469	23.2036	15.7461	8.0241	5.1951	0.056	1.94662	2.4214	4.40504	2.43954	2.07501	13.7972	126.118	70.074		
53	2.772	23.4539	15.6477	7.8562	5.1689	0.046	1.98719	1.8224	4.36017	2.39841	2.11059	13.7157	125.48	68.976		
54	2.918	23.1455	15.5745	8.1603	5.1444	0.044	2.11799	1.9554	4.21789	2.27486	2.16345	12.6464	70.949			
55	3.22	22.813	15.6327	7.7377	5.1295	0.044	1.90385	3.2884	4.07582	2.24052	2.21431	13.425	121.847	75.038		
56	3.522	22.0806	15.6908	7.1393	5.1147	0.037	1.86218	3.2514	3.93365	2.20607	2.26617	13.7796	120.031	81.227		
57	4.244	21.3481	15.7489	6.6971	5.0971	0.031	1.9769	3.7065	3.99963	2.23773	2.36647	13.8262	121.548	81.227		
58	2.991	21.6095	16.3126	6.2544	5.3649	0.046	2.12076	3.0689	4.10441	2.28171	2.54139	14.3643	130.288	76.23		
59	2.548	22.0651	16.9705	6.4398	5.6822	0.021	2.28452	3.4314	4.20918	2.32659	2.6883	14.9652	130.699	71.208		
60	2.154	22.5027	17.6286	6.2695	5.6996	0.017	2.46896	3.5445	3.43681	2.41007	2.71377	15.0657	131.681	67.025		
61	1.946	22.5992	18.1489	6.1355	5.1699	0.045	2.41417	3.4314	4.51133	2.50489	2.64516	16.1559	141.695	66.082		
62	1.738	22.3782	18.5448	5.9816	4.3953	0.047	2.46738	3.3183	4.67886	2.60873	2.57294	16.766	143.639	65.139		
63	1.531	18.9408	19.0431	5.6443	4.3738	0.045	2.4521	3.4521	4.78074	2.59917	2.52012	16.981	143.639	65.139		
64	1.519	22.0676	19.1901	5.8371	4.6349	0.044	2.54494	3.0683	4.64671	2.50352	2.59971	16.9815	142.992	66.713		
65	1.533	22.4852	18.6748	6.0299	4.9302	0.353	2.57422	3.9354	4.51267	2.34786	2.5963	16.765	139.528	69.733		
66	1.547	18.5596	19.4545	5.7865	4.9455	0.302	2.56349	3.8026	4.37863	2.3924	2.63289	16.981	143.639	65.139		
67	1.404	23.3204	18.2443	7.0194	6.3008	0.268	2.53808	2.9571	4.00292	2.22103	2.75555	17.2192	139.144	80.988		
68	1.143	23.459	18.6655													

159	2.519	3.5809	3.4181	1.3552	1.0767	1.144	0.65736	1.8774	0.59107	0.4101	0.65394	4.8957	35.966	29.499
160	2.435	4.2408	4.2103	2.0021	1.287	1.161	0.80408	1.289	0.80408	0.62683	0.94732	6.8457	51.802	35.562
161	2.19	6.5052	6.2974	2.649	1.784	1.058	1.27489	1.6131	1.18223	0.84982	1.24767	8.8368	67.985	43.216
162	1.945	8.8242	8.4289	3.1625	2.2909	1.055	1.55843	1.9371	1.0778	0.92298	1.52368	10.8779	90.869	50.869
163	1.646	11.1441	10.5605	3.6218	2.7977	0.808	1.94489	1.983	1.71087	1.16039	1.79613	12.7226	93.4	55.016
164	1.239	12.6919	12.1337	4.0738	3.2921	0.573	2.31643	1.8779	1.81372	1.1745	2.0159	14.5649	98.859	52.033
165	0.831	13.2029	13.4039	4.4212	3.7798	0.339	2.67977	1.7728	1.91857	1.18861	2.23548	16.4071	104.319	49.05
166	0.428	14.95	14.6741	4.5557	4.2674	0.106	3.12995	1.9474	2.27832	1.33334	2.60492	19.0185	120.28	46.168
167	0.413	17.276	16.7356	4.6901	5.039	0.123	3.71115	2.691	3.16658	1.74372	3.27811	23.1932	157.597	52.323
168	0.397	22.2682	20.408	4.8397	6.3879	0.141	4.29335	3.1541	4.05483	2.1541	3.9513	27.8678	194.915	58.477
169	0.382	26.7963	24.0765	6.345	7.7369	0.158	4.87149	4.1813	4.92959	2.56222	4.62066	31.5207	231.984	64.631
170	0.353	31.5244	27.7313	7.8503	9.0768	0.148	5.08746	5.2066	4.59777	2.7682	4.94686	33.7366	246.828	76.554
171	0.317	33.3838	29.9913	9.3556	9.6063	0.126	5.30342	6.2319	4.26895	2.97417	5.27305	35.9524	261.672	91.038
172	0.281	35.2432	32.2513	9.4707	10.1359	0.103	5.51938	7.2572	4.93412	3.18015	5.59925	38.1682	276.517	105.523
173	0.244	37.1026	34.5112	9.8685	10.6654	0.083	5.70257	7.2024	3.99884	3.22717	5.62221	38.6719	283.523	106.29
174	0.206	37.6702	35.6074	8.4652	10.7535	0.064	5.8712	6.6679	4.23965	3.2026	5.51051	38.4152	287.049	84.087
175	0.167	37.6641	36.1868	8.1465	10.6456	0.046	6.02882	6.1334	4.48046	3.18003	5.38882	38.1586	290.575	61.884
176	0.14	37.658	36.7662	8.1324	10.5376	0.032	5.98365	5.7606	4.47782	3.13871	5.21654	37.3997	286.872	41.589
177	0.286	37.1464	36.2216	8.1182	10.3597	0.091	5.55101	5.6586	4.06749	3.06767	4.91606	35.7998	271.065	53.883
178	0.432	35.7883	33.795	8.0991	10.0646	0.151	5.11838	5.5566	4.65717	2.95664	4.61558	34.1999	255.258	66.177
179	0.579	34.4301	31.3684	7.994	9.7695	0.21	4.69814	5.4629	3.27255	2.92565	4.39757	32.6128	240.073	78.47
180	0.542	33.0899	29.0607	7.8889	9.4779	0.205	4.48958	5.5107	3.32696	2.85558	4.39755	31.2458	235.503	74.387
181	0.441	28.7848	26.7845	7.7839	9.2449	0.177	4.28103	5.5586	3.38136	2.7865	4.45992	29.8788	230.934	64.461
182	0.339	31.0246	28.5083	7.872	9.0119	0.149	4.07247	5.6064	3.43576	2.71542	4.5223	28.5117	226.384	54.516
183	0.271	29.9919	28.2322	8.0292	8.7789	0.127	4.12907	5.4291	3.85555	2.77124	4.49427	28.2899	224.325	49.303
184	0.251	30.4222	28.1313	8.1864	8.79	0.128	4.28042	5.1713	4.40591	2.87205	4.43294	28.4773	223.19	50.862
185	0.231	31.3753	28.0931	8.2531	8.8884	0.124	4.43178	4.9136	4.95626	2.97286	4.3736	28.8648	222.056	52.022
186	0.226	32.3283	28.005	8.1938	8.9867	0.127	4.53379	4.979	5.17207	3.07366	4.28699	28.505	222.643	53.993
187	0.361	28.5652	26.0552	8.131	8.7923	0.188	4.59711	5.494	4.92233	3.17444	4.16379	27.862	225.628	61.502
188	0.497	31.7299	28.1429	8.1169	8.8242	0.245	4.60043	6.009	4.67258	3.27523	4.4046	27.219	228.612	69.01
189	0.632	30.9168	28.2206	8.4777	8.6693	0.304	4.49091	6.4943	4.44987	3.34642	3.93415	26.5645	230.18	76.518
190	0.59	28.2194	26.3256	8.3834	8.2556	0.395	4.39379	7.109	4.47161	3.25003	3.97918	25.8901	214.936	80.209
191	0.498	29.8227	27.5016	8.1892	8.483	0.456	4.17857	6.927	4.45935	2.95363	4.02419	25.9476	207.692	82.939
192	0.405	29.4535	26.7841	8.9165	8.4404	0.597	3.96335	7.1433	4.51509	2.75724	4.06921	24.2892	196.448	85.45
193	0.355	29.1643	26.0686	8.4533	8.3798	0.599	3.70556	6.7826	4.5214	2.6396	3.84428	23.5148	192.857	84.948
194	0.352	24.9418	24.9418	8.3696	8.3696	0.484	3.43965	6.2828	4.52339	2.59862	3.54364	22.7359	191.412	80.816
195	0.35	28.2149	28.2149	7.9272	8.3455	0.37	3.16613	5.773	4.52537	2.51972	3.243	21.957	189.967	76.684
196	0.371	27.7223	22.4638	8.329	8.3213	0.266	3.02116	5.4182	4.52974	2.51967	3.1173	21.6492	187.533	74.528
197	0.535	21.8418	21.8418	8.7131	8.2109	0.228	2.43987	5.2438	4.53987	2.60088	3.18499	21.8892	183.947	84.137
198	0.698	27.5337	21.9372	8.0576	8.0002	0.186	3.02134	5.0693	4.544	2.6821	3.27267	22.1292	180.362	93.747
199	0.862	27.5858	22.0325	8.9356	7.7694	0.145	3.00212	4.8763	4.54373	2.74452	3.31705	22.1611	177.067	103.367
200	0.808	22.9849	22.9849	8.8135	7.8608	0.153	3.01112	5.7277	4.59519	2.69052	3.16311	21.8601	169.258	86.427
201	0.708	26.8988	21.8812	8.6915	7.56	0.107	3.00212	4.7691	4.45509	2.64553	3.00917	19.7478	173.935	84.226
202	0.608	26.2591	21.6774	8.3948	7.5171	0.09	2.99311	3.9655	4.41077	2.59603	2.95524	18.5411	172.369	72.825
203	0.619	21.4737	21.4737	8.061	7.7433	0.152	2.85986	3.734	4.50403	2.63892	2.85156	17.9338	169.816	76.106
204	0.739	24.6881	20.7923	7.7272	7.2438	0.291	2.71378	3.5178	4.62642	2.60117	2.87971	17.4537	160.385	78.075
205	0.856	23.6952	19.3462	7.6719	6.9737	0.43	2.5616	3.3015	4.74882	2.60873	2.90786	16.9735	153.97	85.294
206	1.005	18.2002	17.7887	7.8878	6.7036	0.382	2.44528	3.3112	4.59519	2.5428	2.86502	16.4817	155.225	86.427
207	1.462	22.5117	17.6091	7.8103	6.4144	0.632	2.51094	3.541	5.3623	2.40472	2.74919	15.9786	146.106	82.422
208	1.889	23.1025	17.5584	8.3938	6.1067	0.707	2.52565	3.7708	5.72941	2.26684	2.63466	15.4755	142.987	75.072
209	2.316	22.6934	17.5078	9.0046	5.799	0.781	2.51079	3.9548	6.00585	2.17319	2.52948	15.0999	139.906	67.722
210	3.269	24.1221	17.4271	9.6154	5.5655	0.969	2.36438	3.9415	8.89086	2.27054	2.46469	14.7065	136.99	69.593
211	4.3	23.8511	17.2171	10.2262	5.6524	1.174	2.21796	3.9282	5.77586	2.36789	2.3999	14.403	134.073	72.85
212	5.331	23.5801	17.0071	9.5472	5.7393	1.378	2.07155	3.9149	5.66086	2.46524	2.33511	14.0998	131.157	76.106
213	5.067	23.3092	16.7971	8.6746	5.8262	1.309	1.97306	4.0319	6.23456	2.37138	2.30238	14.3438	129.566	75.887
214	3.748	22.3666	16.255	7.802	5.616	1.018	1.88176	4.1685	4.76153	2.24881	2.27446	14.6701	128.174	72.833
215	2.428	21.3232	15.663	7.4618	5.3812	0.726	1.78047	4.3051	4.2885	2.12624	2.24654	14.9965	126.782	69.78
216	1.367	20.2788	15.071	7.5557	5.1063	0.488	1.80212	4.0173	4.06407	2.04078	2.11382	14.3905	123.913	68.442
217	1.158	19.9272	14.7263	7.6495	4.9469	0.424	1.8977	3.3835	4.04231	1.99558	1.99566	13.5874	119.839	78.074
218	0.949	20.1379	14.5832	7.7138	4.8652	0.361	1.99328	2.7497	4.02955	1.93038	1.6775	12.5842	115.765	86.705
219	0.741	20.3485	14.4401	7.6806	4.7835	0.297	2.00564	2.283	4.02111	1.88218	1.53463	11.7032	111.686	95.337
220	0.825	20.1749	14.1625	7.6474	4.6875	0.333	1.82204	2.3685	4.09541	1.85712	1.64059	11.2259	107.593	101.599
221	0.938	18.7313	13.4403	7.6142	4.544	0.377	1.62355	2.454	4.16971	1.83206	1.74605	10.7486	103.5	107.637
222	1.05	17.2877	12.7182	7.8653	4.4006	0.422	1.42955	2.5395	4.24401	1.80599	1.82551	10.7712	99.406	113.975
223	2.344	15.8441	11.996	8.1872	4.2571	1.072	1.3369	2.598	3.99483	1.8213	1.74073	10.2571	96.23	129.991
224	4.442	16.0052	11.3742	8.4882	4.1406	1.134	1.25916	2.654	3.71512	1.83932	1.60839	10.2898	97.329	153.298
225	6.539	16.3178	10.7619	8.5724	4.0267	1.196	1.18142	2.7099	3.4354	1.85734	1.47604	10.3165	96.429	176.605
226	7.721	16.6305	10.1496	8.5092	3.9127	1.704	1.15005	3.3974	3.29117	1.91125	1.38733	10.0834	95.514	194.881
227	6.507	16.3993	9.8694	8.446	3.8942	2.765	1.15021	4.5144	3.23911	1.98957	1.3283	9.6716	94.591	199.995
228	5.292	15.7982	9.8151	8.6614	3.9406	1.825	1.15037	5.6315	3.18705	2.0679	1.26917	9.2598	93.667	205.109
229	4.078	15.1971	9.7609	8.6055	3.987	0.886	1.16117	6.124	3.2976	2.13839	1.23751	9.033	93.419	210.223
230	3.3	14.7414	9.7377	10.5495	4.0016	0.723	1.19982	4.983	3.83352	2.18841	1.27709	9.29	94.938	209.333
231	2.541	14.6603	9.7957	11.4936	3.9333</									

219	24416.02	3635.192	4.9552	1.55963	153.704	90.217	4.9552	17.326	50.476	1.15965	8.2099	3.28502	0.9504	9.5555	3.39712	40.318	11.6459	44.4489	8.4598	72.596	14.1352	349.44
220	22752.54	3571.558	4.7073	1.23074	149.998	89.894	4.7073	15.88	49.183	1.38392	8.2801	3.38392	0.95768	8.9259	3.24772	38.246	11.4447	44.2824	8.3188	71.39	13.5596	333.967
221	21457.992	3511.157	4.4491	1.12875	146.909	90.144	4.4491	14.42	48.875	1.21875	8.2937	3.41903	1.02332	7.5465	3.11765	36.375	11.2499	43.5092	8.1735	70.006	13.0319	320.514
222	22589.998	3471.984	4.1236	1.04286	147.868	94.148	4.1236	12.875	55.038	1.04286	7.9935	3.03526	1.02751	7.2213	3.11456	35.8242	11.0977	41.5189	7.9999	67.458	12.8194	320.329
223	23722.204	3429.992	3.7882	0.96697	152.626	102.329	3.7882	10.329	62.626	0.96697	7.2823	2.65546	1.01146	6.6999	3.11456	34.8242	11.0977	41.5189	7.9999	67.458	12.8194	320.329
224	24826.318	3402.911	3.4779	0.90628	150	102.159	3.4779	9.847	66.76	0.90628	6.7739	2.29936	0.87869	6.6052	3.11003	34.802	10.8256	42.925	7.6644	62.543	12.4108	320.422
225	25314.229	3379.387	3.2171	0.88381	155.97	106.237	3.2171	9.794	78.869	0.88381	6.1936	2.00567	1.00905	7.0766	3.14556	36.0984	11.4281	43.4286	7.7677	64.236	12.5812	331.006
226	25802.129	3352.864	3.0656	1.06134	161.94	110.315	3.0656	9.741	50.977	1.06134	9.1133	2.52779	1.13942	7.548	3.18109	37.3947	12.0036	43.9322	7.871	65.929	12.7517	341.589
227	26290.949	3325.34	2.8954	1.23887	167.91	114.392	2.8954	9.609	43.086	1.23887	10.033	2.64701	1.23887	8.0194	3.21661	38.691	12.6331	44.4358	7.9742	67.622	12.9221	352.172
228	26643.256	3286.35	2.6863	1.22069	165.563	109.288	2.6863	8.814	52.448	1.22069	9.8523	2.83963	1.24406	7.7104	3.19634	38.6977	12.4874	43.3338	7.8061	65.999	12.5508	344.436
229	26899.941	32629.589	1.6554	1.19305	162.813	103.739	1.6554	6.61	62.646	1.19305	9.6184	3.01694	1.20464	7.3636	3.13737	38.642	12.3564	43.1615	7.6248	64.152	12.5059	335.814
230	27336.627	3772.829	1.044	1.1654	160.604	98.19	1.044	5.035	72.843	1.1654	9.8444	3.20346	1.16824	7.0168	3.15039	38.5863	12.1234	42.0043	7.6453	62.336	11.6009	327.192
231	27377.266	3743.392	0.8414	0.92736	167.585	101.297	0.8414	3.826	64.837	0.92736	8.7177	3.4406	1.18183	6.9699	3.12249	38.0305	11.9851	44.202	7.5741	64.016	11.6939	327.071
232	27389.998	3718.233	0.7028	0.56539	176.714	105.76	0.7028	2.675	53.981	0.56539	8.1123	3.20228	6.97	3.05832	37.9965	11.8535	44.4488	7.7534	66.243	11.872	11.872	326.282
233	27382.732	3693.074	0.5642	0.38542	185.942	110.223	0.5642	1.524	43.126	0.38542	7.4474	3.5894	1.22472	6.9701	3.06515	36.7624	11.7219	44.6955	7.9327	68.471	12.05	329.493
234	26834.424	3645.223	0.4134	0.30712	172.135	106.711	0.4134	1.192	37.023	0.30712	7.003	3.61103	1.18774	7.0448	3.07229	35.3432	11.2367	43.2995	7.5944	65.401	11.2718	313.998
235	25079.184	3590.803	0.259	0.28461	151.816	100.891	0.259	1.097	32.296	0.28461	6.6225	3.58856	1.13383	7.1411	3.08981	33.6968	10.649	41.4279	7.1063	60.797	10.2186	293.667
236	23793.943	3536.303	0.1046	0.2621	133.447	95.071	0.1046	1.002	27.569	0.2621	6.242	3.56609	1.07993	7.2374	3.10733	32.0503	10.0613	40.9563	6.6181	56.194	9.9155	273.337
237	24012.475	3573.729	0.0756	0.25579	133.818	96.464	0.0756	0.895	29.401	0.25579	6.2245	3.39926	1.01634	7.2145	3.07159	33.4242	10.1222	39.7621	6.7066	55.129	9.3887	274.887
238	24918.344	3653.018	0.1039	0.25688	146.497	101.154	0.1039	0.782	34.231	0.25688	6.3729	3.15668	1.08383	7.1371	3.0115	36.1787	10.5533	40.9667	7.0587	55.682	9.9615	285.948
239	25824.215	3732.307	0.1322	0.25798	159.156	105.845	0.1322	0.669	39.062	0.25798	6.5213	3.21979	0.88031	7.0598	2.95142	38.9331	10.9544	42.1512	7.4108	56.235	10.6239	297.209
240	26420.816	3768.017	0.2167	0.31132	167.107	109.215	0.2167	0.832	38.078	0.31132	6.8952	2.99634	0.9193	7.0482	3.10048	39.8876	11.2714	43.4309	7.5874	57.381	10.7443	300.996
241	26806.756	3774.324	0.3391	0.39991	171.777	111.696	0.3391	1.182	33.173	0.39991	6.8862	3.28855	1.03049	7.3271	3.39065	39.6277	11.5317	43.7748	7.6457	58.928	10.4995	314.718
242	27196.715	3780.632	0.4405	0.44985	178.483	114.177	0.4405	1.533	28.268	0.44985	7.0772	3.58075	1.14167	7.534	3.68083	39.3678	11.7921	46.1887	7.704	60.474	10.2488	322.84
243	27427.969	3886.362	0.5275	0.58467	180.92	115.838	0.5275	1.727	29.073	0.58467	7.0967	3.76891	1.12096	7.7299	3.73287	39.3813	12.1904	46.6801	7.8717	60.599	10.1949	327.184
244	27507.443	3808.397	0.5388	0.6876	185.096	116.704	0.5388	1.77	35.411	0.6876	6.9503	3.85627	0.97248	7.774	3.55426	39.6595	12.2262	46.4835	8.1455	59.349	10.3336	327.867
245	27586.918	4290.432	0.5501	0.79072	189.073	117.571	0.5501	1.812	41.748	0.79072	6.8038	3.94362	0.82401	8.218	3.37565	39.9376	12.5241	46.2869	8.4192	58.098	10.4722	328.55
246	27659.135	4328.372	0.5519	0.9414	191.484	118.193	0.5519	1.784	46.361	0.9414	7.1635	3.88021	0.77852	8.1515	3.2526	40.1096	13.5582	45.9995	8.3673	57.118	10.353	327.82
247	27727.277	4172.454	0.5405	0.65923	190.969	118.476	0.5405	1.657	46.849	0.65923	8.2258	3.60754	0.87732	7.6539	3.24056	40.1343	13.5001	45.5862	7.8634	56.514	10.0142	325.128
248	27824.322	4006.526	0.5291	0.2543	190.453	118.759	0.5291	1.529	50.917	0.2543	8.2766	3.33488	0.95753	7.1564	3.21852	40.1589	13.582	45.1728	7.3596	55.909	9.6345	322.437
249	27763.684	3871.884	0.4888	0.44004	189.261	118.608	0.4888	1.375	52.442	0.44004	9.5784	3.12754	1.00078	7.0273	3.22211	40.2418	13.5209	44.6386	7.0767	55.192	9.3003	320.119
250	27577.42	3800.86	0.3898	0.59881	186.593	117.574	0.3898	1.167	52.459	0.59881	8.2999	3.0521	0.95734	7.6747	3.27782	40.4433	13.2074	43.8965	7.2432	54.248	9.0585	318.562
251	27391.154	3729.828	0.2948	0.47759	184.125	116.54	0.2948	0.957	52.475	0.47759	9.0244	2.97865	0.9868	8.2685	3.24547	40.6445	12.6049	42.078	6.9589	52.299	8.6268	320.296
252	27355.502	3692.46	0.2088	0.48253	182.334	116.901	0.2088	0.815	51.806	0.48253	6.2005	2.91032	0.86318	8.6003	3.37941	40.9138	12.6638	42.478	7.4614	51.256	8.5734	314.991
253	27795.609	3761.454	0.1808	0.44375	183	121.663	0.1808	0.87	48.968	0.44375	6.8249	2.86134	0.93585	8.0215	3.39421	41.3956	12.4639	42.445	7.1501	51.422	8.2022	311.528
254	28235.719	3830.447	0.1527	0.40496	183.666	126.426	0.1527	0.926	46.131	0.40496	7.4494	2.81235	1.00852	7.4435	3.40902	41.8775	12.224	42.4119	6.8387	50.489	8.0881	308.066
255	28688.775	3877.654	0.1265	0.36895	184.402	130.152	0.1265	0.952	44.447	0.36895	6.9562	2.73802	1.00633	7.0075	3.40696	42.105	12.98	42.4175	6.609	49.766	7.8512	304.852
256	28301.219	3876.706	0.1105	0.34847	185.732	128.158	0.1105	0.817	49.402	0.34847	5.9593	2.52149	1.00041	7.5984	3.31881	40.9053	12.299	42.6044	6.8518	50.376	7.8319	303.032
257	28033.36	3866.023	0.0946	0.32799	186.661	126.15	0.0946	0.681	54.334	0.32799	7.2584	2.30495	0.93979	8.1593	3.22955	39.7057	12.5798	42.8632	7.0928	50.565	7.8126	301.213
258	27787.588	3858.269	0.0801	0.30694	187.551	124.189	0.0801	0.549	58.322	0.30694	6.9444	2.11753	0.8841	8.6555	3.15454	38.6414	12.3701	43.031	7.308	51.342	7.7826	299.381
259	27865.979	3894.735	0.0871	0.27735	184.825	122.936	0.0871	0.471	48.037	0.27735	6.9499	2.36993	0.90284	8.1911	3.29476	39.6209	12.2321	42.3675	7.1335	48.505	7.5901	297.368
260	27944.589	3759.272	0.0756	0.24775	182.098	121.682	0.0756	0.472	59.752	0.24775	6.9555	2.62232	0.85198	8.2689	3.17797	39.8912	12.7039	42.9589	6.9457	47.207	7.2671	295.154
261	28022.758	3967.669	0.1009	0.21816	179.731	120.428	0.1009	0.313	27.468	0.21816	9.661	2.87471	0.94032	7.2604	3.57519	41.58	11.865	40.403	6.7843	42.83	7.2052	293.34
262	26863.846	3791.99	0.1657	0.248	176.442	120.961	0.1657	0.417	37.691	0.248	6.8364	3.12131	0.96847	6.9989	3.54284	40.7318	11.9602	40.1681	6.3509	42.903	6.802	289.027
263	25607.506	3681.908	0.2322	0.27949	173.507	119.181	0.2322	0.526	48.485	0.27949	6.708	3.38774	0.99688	6.743	3.50569	39.8328	11.9433	39.2691	5.9102	42.658	6.3929	284.45
264	24477.145	3630.140	0.2986	0.28686	170.573	115.742	0.2986	0.526	49.969	0.28686	6.9273	3.61547	1.02502	6.9717	3.46955	38.4127	11.4935	42.317	6.4023	5.9188	6.2713	283.598
265	24040.66	331																				

Garnet G		Ce	Di	Er	Eu	Gd	Hf	La	Lu	Nd	P	Pr	Sc	Sm	Tb	Tm	Yb	Y
4	10.0668	9.5112	4.1445	0.51705	0.67797	1.79195	0.60045	0.49354	0.53324	213.374	1.9718	1.65736	0.48899	3.5059	47.833	3.466	46.057	
5	7.3364	10.2024	4.3347	0.45324	10.9318	1.80492	2.7538	0.45384	194.458	2.508	1.91559	0.44973	3.3959	49.609				
6	4.576	10.4936	4.5249	0.45324	10.9318	1.80492	2.7538	0.45384	194.458	2.508	1.91559	0.44973	3.3959	49.609				
7	2.9148	10.7584	4.5247	0.45324	10.9318	1.80492	2.7538	0.45384	194.458	2.508	1.91559	0.44973	3.3959	49.609				
8	2.2872	10.9983	4.2867	0.45324	10.9318	1.80492	2.7538	0.45384	194.458	2.508	1.91559	0.44973	3.3959	49.609				
9	1.6595	11.2382	4.0687	0.47166	11.412	1.80495	0.6438	0.53857	214.25	2.066	1.87929	0.63928	3.6679	51.129				
10	1.4954	11.0473	4.2221	0.4859	11.036	1.80495	0.533	0.56416	213.257	1.892	1.87929	0.63928	3.6679	51.129				
11	1.5959	10.6128	4.5854	0.49723	11.4281	1.80515	0.4797	0.58085	201.865	2.863	1.9341	0.7159	3.8686	54.072				
12	1.6954	10.1783	4.9487	0.50866	11.4066	1.89116	0.4265	0.59753	192.172	3.195	1.9762	0.74733	3.9586	55.81				
13	1.5521	11.0282	5.158	0.52395	11.7237	2.02701	0.4561	0.61801	181.794	3.562	2.04099	0.74478	4.1706	57.202				
14	1.3331	12.2785	5.3103	0.54644	12.1464	2.19492	0.5115	0.63967	171.202	3.96	2.11296	0.73164	4.4205	58.486				
15	1.1141	13.5288	5.4806	0.56693	12.5691	2.36283	0.5669	0.66133	160.61	3.952	2.18473	0.7185	4.6705	59.771				
16	1.2976	13.8309	5.6379	0.615	12.9605	2.59444	0.5369	0.68899	148.063	4.057	2.2684	0.79662	5.0288	61.688				
17	1.533	14.0107	5.7847	0.67942	13.348	2.84193	0.5021	0.71743	135.306	4.317	2.35359	0.8865	5.4011	63.686				
18	1.7655	14.1802	5.9482	0.74093	13.7221	3.03806	0.4645	0.7453	122.523	4.67	2.43716	0.97499	5.7674	65.651				
19	1.683	13.2439	5.7465	0.70467	12.6746	2.37491	0.4308	0.71332	109.034	4.833	2.34676	0.91389	5.4914	64.059				
20	1.6006	12.3076	5.5449	0.66842	11.6271	2.31177	0.3972	0.68134	95.545	4.799	2.25635	0.85779	5.2154	62.487				
29	0.761	12.8623	5.9448	0.49392	10.827	2.30669	0.1943	0.72475	68.717	7.041	2.25646	0.70388	4.2592	62.278				
30	0.6708	14.2536	6.4765	0.5874	12.2554	2.57489	0.1934	0.81018	73.855	7.27	2.49627	0.78682	4.9102	69.17				
31	0.6112	14.4445	6.3801	0.67909	13.3024	2.65226	0.2049	0.80518	73.381	7.233	2.47907	0.84441	5.4234	70.67				
32	0.5516	14.6355	6.2837	0.77079	14.3493	2.77893	0.2164	0.80018	72.907	7.185	2.46187	0.90199	5.9367	72.17				
33	0.4994	14.5998	6.0503	0.76705	14.4072	2.71419	0.2122	0.81231	71.877	6.889	2.41582	0.90521	6.0667	71.432				
34	0.4515	14.4289	5.7363	0.79643	13.8754	2.64343	0.1985	0.83466	70.516	6.47	2.35258	0.87002	5.9684	69.36				
35	0.4037	14.2581	5.4202	0.64882	13.3437	2.52767	0.1848	0.85701	69.155	6.338	2.28934	0.84682	5.87	67.288				
40	0.5192	11.6819	6.5455	0.51475	10.1303	2.32653	0.224	0.97535	68.677	6.693	2.09754	0.83936	6.1005	64.811				
41	0.5421	12.2222	7.5159	0.58915	10.8516	2.63106	0.2186	1.11208	77.03	6.856	2.36666	0.95955	6.9325	74.598				
42	0.4778	14.1379	7.8837	0.5205	12.1357	2.77994	0.1863	1.205	84.405	6.55	2.40522	1.11118	7.0075	79.442				
43	0.4131	15.0518	8.2455	0.4514	13.4216	2.92773	0.154	1.2853	91.776	5.831	2.44288	1.23664	7.0801	84.271				
44	0.3992	15.8624	8.1445	0.39686	14.547	3.05564	0.1461	1.33005	95.896	5.176	2.4907	1.33459	7.1404	86.323				
45	0.4051	14.5006	8.7345	0.51618	10.9627	3.1246	0.7543	1.24405	72.051	6.327	2.44783	1.13988	8.7833	81.121				
54	3.4253	15.7246	8.7356	0.53427	10.9388	3.24549	1.3612	1.22173	86.828	5.225	2.22855	1.32306	9.9996	83.676				
55	4.4455	16.9485	8.7366	0.55235	10.9149	3.36338	1.5962	1.19941	90.044	4.619	2.20326	1.50724	9.8158	86.232				
101	2.29	23.3416	14.8518	0.59589	12.8811	5.05939	2.0186	2.66524	3.848	3.01049	2.40383	17.3873	123.007	13.073				
102	4.077	24.0394	15.3543	0.5442	13.3739	5.18031	1.2329	2.75025	71.287	3.919	3.05974	2.42664	18.2693	130.596				
103	4.5881	21.0243	13.5513	0.57512	12.2115	4.4321	1.4528	2.43386	74.881	3.946	2.61847	2.05696	15.574	112.768				
104	4.7695	18.0092	11.7482	0.60503	11.049	3.68389	1.6777	1.11748	78.475	4.065	2.17719	1.68728	12.8787	94.939				
113	3.2421	19.8861	13.3828	0.22096	12.4212	4.26324	0.815	1.97351	112.602	2.503	3.12121	1.70559	12.3865	116.751				
114	2.4029	20.7583	13.7371	0.22633	13.5825	4.30407	0.6255	1.91423	102.683	3.291	2.98005	1.76173	12.2784	113.958				
115	1.5636	21.0378	14.0913	0.34429	13.7437	4.3449	0.4359	1.85894	98.754	3.717	2.83881	1.74339	11.1164	111.164				
116	0.8924	22.1678	14.1358	0.39505	13.8765	4.39941	0.2801	1.78959	84.748	3.682	2.74448	1.85143	12.0277	108.932				
117	0.8659	21.4213	12.9921	0.40396	13.9004	4.50642	0.2539	1.70093	84.032	3.58	2.62942	1.79836	11.7529	108.858				
118	0.8395	20.6747	11.8484	0.41287	13.9242	4.63123	0.2277	1.61227	73.162	3.419	2.51342	1.74528	11.4781	107.327				
119	0.8035	20.0682	11.124	0.40647	13.874	4.63123	0.2227	1.5798	63.815	3.755	2.95548	1.6875	11.2302	108.416				
120	0.7482	19.7453	11.2498	0.36901	13.6737	4.46813	0.2604	1.66128	86.774	5.562	2.90768	1.62017	11.0369	107.451				
121	0.6929	19.4223	10.7175	0.3821	13.4733	4.30543	0.2677	1.57475	87.745	5.775	2.85969	1.55364	10.7373	111.164				
122	0.7851	18.6491	11.1297	0.32831	13.3371	4.05656	0.3055	1.68943	93.178	5.381	2.79691	1.50236	10.3261	102.818				
123	1.055	17.333	10.3954	0.36629	13.2781	3.7063	0.2761	1.47379	97.206	4.793	2.71567	1.47718	9.4181	95.893				
124	1.3249	16.017	9.8739	0.32465	12.2102	3.24525	0.2461	1.25815	107.234	4.583	2.53462	1.4421	9.2515	91.021				
125	1.418	15.6913	9.3097	0.45058	12.9185	3.18947	0.2915	1.20334	97.649	4.903	2.54763	1.38758	9.1081	86.17				
126	1.3815	16.0911	9.2072	0.50207	12.4407	3.16165	0.3908	1.26635	88.486	5.317	2.45677	1.3154	8.0768	86.396				
127	1.3451	16.491	9.1047	0.55637	11.9432	3.13283	0.4901	1.33236	79.324	5.269	2.46591	1.24323	8.0455	83.353				
128	1.1985	17.0484	9.2195	0.54739	12.5869	3.23067	0.4064	1.21447	72.547	6.304	2.47592	1.26338	7.9409	88.908				
129	1.0048	17.6732	9.4272	0.51362	13.6815	3.38077	0.2446	1.26521	66.79	4.701	2.67176	1.32298	7.805	92.073				
130	0.8111	18.296	9.635	0.47985	14.7762	3.53807	0.0827	1.2164	61.034	4.483	2.86761	1.38258	7.669	95.238				
131	0.8178	18.966	9.776	0.51478	15.24	3.54636	0.0946	1.24075	63.038	4.548	2.96649	1.41834	8.353	97.912				
132	0.8673	19.6433	9.9027	0.56437	15.5691	3.5331	0.144	1.28072	66.7	4.938	3.04467	1.44901	9.2121	100.048				
133	0.9167	20.3206	10.0295	0.61397	15.8982	3.51985	0.1932	1.32069	70.361	5.548	3.12284	1.47968	10.0712	103.148				
134	0.7664	19.2875	9.4835	0.58848	14.7868	3.52727	0.1457	1.28996	70.633	6.185	3.01519	1.3775	9.4556	98.007				
135	0.6049	18.1597	8.9002	0.55883	13.5956	3.53584	0.0928	1.25531	70.716	6.503	2.89724	1.26796	8.7584	92.545				
136	0.4497	17.0254	8.3183	0.52768	12.431	3.52418	0.0448	1.21695	70.646	6.411	2.7699	1.15925	8.0931	86.949				
137	0.3749	15.8204	7.7546	0.47681	11.6143	3.24785	0.06	1.13	68.558	6.108	2.51965	1.06129	7.8466	79.603				
138	0.3001	14.6145	7.1909	0.42595	10.7976	2.97151	0.0751	1.04305	66.47	5.87	2.26939	0.96333	7.6001	72.258				
142	0.4197	13.1693	6.4642	0.58715	9.9512	2.80578	0.2815	1.03404	60.736	6.03	1.9524	1.00539	6.1392	70.997				
143	0.5121	13.5136	6.5556	0.56854	10.4218	3.00894	0.219	1.03845	89.06	5.409	2.0307	0.93023	6.4077	71.511				
144	0.6045	13.8579	6.647	0.54993	10.8925	3.												

Dataset S3

Monazite	Location	Analysis	Pb ppm	Th ppm	U ppm	Measured ratios										Ages (Ma)		Ages (Ma)		Ages (Ma)		Ages (Ma)	
						Th/U	²⁰⁸ Pb/ ²³⁸ U	2σ error	²⁰⁷ Pb/ ²³⁵ U	2σ error	²⁰⁸ Pb/ ²³² Th	2σ error	Error correlation (²⁰⁸ Pb/ ²³⁸ U)/(²⁰⁷ Pb/ ²³⁵ U)	²⁰⁷ Pb/ ²³⁵ Pb	2σ error	²⁰⁸ Pb/ ²³⁸ U	2σ error	²⁰⁷ Pb/ ²³⁵ U	2σ error	²⁰⁸ Pb/ ²³² Th	2σ error		
M3	garnet corona	07220410a	4833	46728	655	71.4	0.37671	0.00970	6.24289	0.16316	0.10860	0.00256	0.99	1959	39	2061	45	2011	23	2084	47		
		08220410a	4344	39967	1042	38.4	0.38194	0.00980	6.27779	0.16158	0.10996	0.00260	1.00	1945	38	2085	46	2015	23	2109	47		
		09220410a	4161	37465	1172	32.0	0.38172	0.00980	6.32455	0.16238	0.11067	0.00262	1.00	1959	38	2084	46	2022	23	2122	48		
		10220410a*	4016	35987	1141	31.6	0.38382	0.00986	6.41352	0.16532	0.11107	0.00262	1.00	1974	38	2094	46	2034	23	2129	48		
		11220410a	3926	37703	685	55.0	0.37378	0.00962	6.16346	0.16048	0.10803	0.00256	0.99	1951	39	2047	45	1999	23	2073	47		
		12220410a	4124	38152	1113	34.3	0.37153	0.00954	6.12666	0.15802	0.10854	0.00258	1.00	1951	38	2037	45	1994	23	2083	47		
		13220410a	4015	37077	1133	32.7	0.36773	0.00944	5.97349	0.15428	0.10842	0.00256	0.99	1924	38	2019	44	1972	22	2081	47		
		14220410a	3877	37583	630	59.6	0.37587	0.00968	5.96853	0.15712	0.10752	0.00254	0.98	1883	40	2057	45	1971	23	2064	47		
		17220410a	1485	60815	1145	53.1	0.37460	0.00966	6.20153	0.16430	0.10731	0.00254	0.97	1958	40	2051	45	2005	23	2060	46		
		19220410a	4190	40269	614	65.5	0.38301	0.00992	6.68575	0.17976	0.10918	0.00260	0.96	2052	40	2090	46	2071	24	2094	47		
M1	matrix	20220410a	3243	30781	422	72.9	0.38657	0.01004	6.63376	0.18068	0.10911	0.00258	0.95	2021	41	2107	47	2064	24	2093	47		
		21220410a	3512	33630	373	90.1	0.37961	0.00996	6.50656	0.18426	0.10740	0.00254	0.93	2019	44	2075	47	2047	25	2062	47		
		22220410a	3392	33417	242	137.9	0.37192	0.00966	6.31423	0.17258	0.10686	0.00254	0.95	2002	42	2038	45	2020	24	2052	46		
		25220410a	2645	25527	396	64.5	0.37782	0.00990	6.32737	0.18052	0.10825	0.00258	0.92	1978	44	2066	46	2022	25	2078	47		
		26220410a	2514	24739	288	85.9	0.37138	0.00972	6.20212	0.17560	0.10655	0.00254	0.92	1973	44	2036	46	2005	25	2046	46		
		28220410a	2666	25695	381	67.5	0.37365	0.00970	6.18806	0.17102	0.10776	0.00256	0.94	1958	42	2047	46	2003	24	2069	47		
		29220410a*	2540	25792	317	81.3	0.36243	0.00946	5.86449	0.16538	0.10310	0.00246	0.93	1917	44	1994	45	1956	24	1983	45		
		30220410a	2554	25329	278	91.2	0.37082	0.00970	6.05440	0.17250	0.10600	0.00252	0.92	1933	45	2033	46	1984	25	2036	46		
		33220410a	2989	29611	301	98.5	0.37283	0.00976	6.30146	0.18120	0.10695	0.00254	0.91	1995	45	2043	46	2019	25	2054	46		
		36220410a	2072	20720	170	121.7	0.37748	0.01000	6.70199	0.20022	0.10664	0.00254	0.89	2082	47	2065	47	2073	26	2048	46		
M12	cordierite	42220410a	3019	30710	319	96.3	0.36237	0.00950	5.96332	0.17478	0.10359	0.00248	0.89	1947	46	1993	45	1971	25	1992	45		
		43220410a	3504	34976	290	120.4	0.38431	0.01006	6.38088	0.18676	0.10619	0.00254	0.89	1963	46	2096	47	2030	26	2040	46		
M7	inclusion in garnet	07220410b	3436	29255	1805	16.2	0.38007	0.00978	6.48405	0.17972	0.10598	0.00256	0.93	2011	42	2077	46	2044	24	2036	47		
		08220410b	3488	28368	1978	14.3	0.38398	0.00988	6.53893	0.18158	0.10883	0.00264	0.93	2008	42	2095	46	2051	24	2088	48		
		09220410b	10440	79551	3740	21.3	0.38353	0.00986	6.53198	0.18114	0.10899	0.00264	0.93	2008	42	2093	46	2050	24	2091	48		
		10220410b	11282	84742	4281	19.8	0.38280	0.00984	6.50028	0.18084	0.10919	0.00264	0.92	2003	42	2089	46	2046	24	2095	48		
M6	garnet corona	11220410b*	8361	67660	3148	21.5	0.36139	0.00932	6.06015	0.17016	0.10287	0.00248	0.92	1980	43	1989	44	1985	24	1979	46		
		15220410b*	3654	31896	1926	16.6	0.36765	0.00948	6.25963	0.17874	0.10388	0.00252	0.90	1995	55	1954	46	1974	29	1998	46		
		16220410b	4026	35564	1642	21.7	0.37599	0.00970	6.31429	0.18170	0.10700	0.00258	0.90	2007	44	2058	45	2020	25	2055	47		
		17220410b*	23039	42916	5258	8.2	0.35764	0.00924	5.89449	0.17014	0.10261	0.00248	0.90	1983	44	1971	44	1960	25	1974	46		
M8	garnet corona	18220410b*	23781	44063	5234	8.4	0.36269	0.00938	6.02281	0.17498	0.10366	0.00250	0.89	1963	45	1995	44	1979	25	1994	46		
		19220410b	29453	52048	7093	7.3	0.36922	0.00954	6.19700	0.18046	0.10588	0.00256	0.89	1982	45	2026	45	2004	25	2034	47		
		20220410b	26864	56458	1094	51.6	0.37686	0.00986	6.42208	0.19650	0.10781	0.00260	0.86	2009	48	2062	46	2035	27	2069	48		
		23220410b	4197	36576	1946	18.8	0.36793	0.00954	6.28375	0.18906	0.10644	0.00258	0.86	2013	47	2020	45	2016	26	2044	47		
M11	garnet corona	24220410b	3815	33360	1753	19.0	0.36885	0.00958	6.29805	0.19142	0.10618	0.00256	0.85	2012	48	2024	45	2018	27	2040	47		
		25220410b	69383	31589	1255	25.2	0.38074	0.00990	6.44913	0.19800	0.10862	0.00262	0.85	1998	48	2080	46	2039	27	2084	48		
		26220410b	68800	32354	981	33.0	0.38095	0.00994	6.48009	0.20158	0.10798	0.00262	0.84	2006	49	2081	46	2043	27	2073	48		
		27220410b	119897	60223	618	97.4	0.36992	0.00972	6.19893	0.19768	0.10755	0.00260	0.82	1979	51	2029	46	2004	28	2065	47		
M2	matrix	28220410b	104613	51524	708	72.7	0.37416	0.00980	6.32158	0.20144	0.10851	0.00262	0.82	1994	51	2049	46	2022	28	2082	48		

Zircon	Analysis	Pb ppm	Th ppm	U ppm	Measured ratios										Ages (Ma)		2σ error		Ages (Ma)		2σ error	
					Th/U	²⁰⁷ Pb/ ²⁰⁹ Pb	2σ	²⁰⁸ Pb/ ²³⁸ U	2σ	²⁰⁷ Pb/ ²³⁵ U	2σ	Error correlation (²⁰⁸ Pb/ ²³⁸ U)/(²⁰⁷ Pb/ ²³⁵ U)	²⁰⁷ Pb/ ²⁰⁹ Pb	2σ error	²⁰⁸ Pb/ ²³⁸ U	2σ error	²⁰⁷ Pb/ ²³⁵ U	2σ error				
	05150311b	105	38	274	0.1	0.12805	0.00274	0.37178	0.00782	6.56623	0.1456	0.95	2071	38	2038	37	2055	20				
	06150311b	59	22	147	0.1	0.12887	0.00284	0.38044	0.00794	6.76245	0.15232	0.93	2083	39	2078	37	2081	20				
	07150311b	51	11	118	0.1	0.13706	0.0031	0.40551	0.0084	7.66637	0.17426	0.91	2190	39	2194	39	2193	20				
	09150311b	73	28	209	0.1	0.13477	0.00306	0.35447	0.00716	6.58908	0.14736	0.90	2161	39	1956	34	2058	20				
	05150311c	111	123	239	0.5	0.14136	0.00312	0.40488	0.00864	7.89667	0.1802	0.94	2244	38	2192	40	2219	21				
	06150311c	49	29	139	0.2	0.1281	0.0034	0.32557	0.00706	5.75444	0.15276	0.82	2072	46	1817	34	1940	23				
	07150311c	18	21	45	0.5	0.12554	0.00314	0.35073	0.00738	6.07523	0.15118	0.85	2036	44	1938	35	1987	22				
	08150311c	57	28	154	0.2	0.12777	0.00302	0.37744	0.00772	6.65346	0.1548	0.88	2068	41	2064	36	2067	21				
	09150311c	135	123	301	0.4	0.14845	0.0035	0.41452	0.00832	8.48907	0.19336	0.88	2328	40	2236	38	2285	21				
	10150311c	91	40	239	0.2	0.12904	0.00312	0.38156	0.00756	6.79173	0.15614	0.86	2085	42	2084	35	2085	20				
	03150311d	320	344	813	0.4	0.12775	0.0028	0.35262	0.00772	6.21268	0.14532	0.94	2067	38	1947	37	2006	20				
	04150311d	229	182	549	0.3	0.12836	0.00288	0.37412	0.00808	6.62303	0.1552	0.92	2076	39	2049	38	2062	21				
	05150311d	151	80	363	0.2	0.12791	0.00294	0.37889	0.00806	6.68385	0.15756	0.90	2069	40	2071	38	2071	21				
	06150311d	170	153	391	0.4	0.12838	0.00316	0.37536	0.00794	6.64614	0.16414	0.86	2076	43	2055	37	2066	22				

APPENDIX S1 : Trace element LA-ICP-MS analytical procedure

LA-ICP-MS trace element maps were acquired using a Resonetics M-50-LR 193 nm excimer laser coupled to an Agilent 7700x Quadrupole ICP-MS housed at Adelaide Microscopy, University of Adelaide. Instrument conditions and mapping protocols similar to that employed in this study are outlined by (Raimondo et al., 2017). Mapping was performed on standard 30 μm -thick polished thin sections by ablating a series of parallel rasters across the sample surface to form a square or rectangular grid. A beam diameter of 16 μm coupled with a laser repetition rate of 10 Hz produced an energy density of $\sim 3.5 \text{ J/cm}^2$ at the target, and a scan speed of 22 $\mu\text{m/s}$ and line spacing of 16 μm were used.

Data acquisition was performed in time-resolved analysis mode as a single continuous experiment. Each analysis comprised a suite of 39 elements (Figures S4-S6 and Datasets S1 and S2); dwell times for major elements were 0.005 s (to reduce excessive count rates) and all other masses were 0.008 s, giving a total sweep time of 0.31 s. Standards were analysed in duplicate at the start and end of each mapping run, and included reference glasses NIST 610 and 612 (Jochum et al., 2011; Pearce et al., 1997) and garnet standard MON-GT (C. Harris & Vogeli, 2010; Chris Harris et al., 2000). Data reduction was performed using the software *lilite* (Hellstrom et al., 2008; Paton et al., 2011; Woodhead et al., 2007), with quantification via the Trace Elements DRS applied using ^{29}Si for internal calibration, applicable to garnet pixels only. Finally, image and data processing was completed using *XMapTools* 2.3.4 (Lanari et al., 2014; Raimondo et al., 2017) and *ImageJ* (Abramoff, Magalhães & Ram, 2004).

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Appendix S2 : U-Th-Pb monazite and zircon geochronology analytical procedures

The identification, distribution and characterization of chemical zoning of monazite was performed in-situ, following the approach of Williams, Jercinovic, Goncalves & Mahan (2006), on a Cameca SX100 ® electron microprobe at the Laboratoire Magmas et Volcans in Clermont-Ferrand (France). All monazite grains were identified through full-thin-section X-ray mapping for Ce L α , P K α along with Al K α , Mg K α to obtain a mineralogically and texturally map in order to reveal the monazite distribution with respect to the leucosome, quartz saturated and undersaturated domains (Figure 18). Analytical conditions were a 15 keV accelerating voltage with a 200 nA beam current, a defocussed beam at 35 μ m, and a counting time of 9 ms per pixel with a 35 μ m pixel setp size. High resolution compositional maps were performed on all the selected grains for Y L α , Ca K α , Th M α and U MB. Analytical conditions were 15 kV, 200 Na with a rastering focussed beam. Counting time varies from 100 to 150 ms, with a step size ranging from 0.4 to 1 μ m. Intensities of all raw compositional were normalized in counts per second and processed all together so that gray levels (i.e. composition) and zoning features can be compared from grain to grain. Zircon were identified via a conventional optical microscope.

U-Th-Pb geochronology of zircon and monazite was conducted by laser ablation inductively coupled plasma spectrometry (LA-ICPMS) at the Laboratoire Magmas et Volcans, Clermont-Ferrand (France). The analyses involve the ablation of minerals with a Resonetics Resolution M-50 powered by an ultra short pulse ATL Atlex Excimer laser system operating at a wavelength of 193 nm (detailed description in Müller, Shelley, Miller & Broude (2009). Spot diameters of 20-26 μ m and 7 μ m associated to repetition rates of 3 Hz and 1 Hz were used for zircon and monazite respectively. The ablated material is carried into helium, and then mixed with nitrogen and argon, before injection into a plasma source of an Agilent 7500 cs ICP-MS equipped with a dual pumping system to enhance the sensitivity.

The alignment of the instrument and mass calibration was performed before every analytical session using the NIST SRM 612 reference glass, by inspecting the signal of ^{238}U and by minimising the ThO $^{+}$ /Th $^{+}$ ratio (<< 1%). The mean sensitivity on ^{238}U at the instrumental conditions reported in Table 1 and using a spot size of 44 μ m is about 15-20,000 cps/ppm. The analytical method for isotope dating of monazite with laser ablation ICPMS is basically similar to that developed for zircon and monazite and reported in Paquette & Tiepolo (2007) and Tiepolo, Bottazzi, Palenzona & Vannucci (2003). The signal of $^{204}(\text{Pb}+\text{Hg})$, ^{206}Pb , ^{207}Pb , ^{208}Pb , ^{232}Th and ^{238}U

masses are acquired. The occurrence of common Pb in the sample can be monitored by the evolution of the $^{204}\text{Pb}+\text{Hg}$ signal intensity, but no common Pb correction was applied owing to the large isobaric interference from Hg. The ^{235}U signal is calculated from ^{238}U on the basis of the ratio $^{238}\text{U}/^{235}\text{U}=137.88$. Single analyses consisted of 20 seconds of background integration with laser off followed by 1 minute integration with the laser firing and a 20 seconds delay to wash out the previous sample (approximately 10 seconds for 6 orders of magnitude) and prepare the next analysis.

Data are corrected for U-Pb and Th-Pb fractionation occurring during laser sampling and for instrumental mass discrimination (mass bias) by standard bracketing with repeated measurements of GJ-1 zircon (Jackson, Pearson, Griffin & Belousova, 2004) or Moacyr monazite (Gasquet, Bertrand, Paquette, Lehmann & Ratzov, 2010) standard. Data reduction was carried out with the software package GLITTER® (Macquarie Research Ltd, 2001; Jackson et al. (2004); Van Achterbergh, Ryan, Jackson & Griffin (2001). For each analysis, the time resolved signal of single isotopes and isotope ratios was monitored and carefully inspected to verify the presence of perturbations related to inclusions, fractures, mixing of different age domains or common Pb. Calculated ratios were exported and Concordia ages and diagrams were generated using Isoplot/Ex v. 2.49 software package by Ludwig (2001). The concentrations in U-Th-Pb were calibrated relative to the certified contents of 91500 zircon standard (Wiedenbeck, Allé, Corfu, Griffin & Meier, 1995) and Moacyr monazite (Seydoux-Guillaume, Wirth, Deutsch & Schärer, 2004).

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