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1 **Evaluating the construction and evolution of upper crustal magma reservoirs with coupled**

2 **U/Pb zircon geochronology and thermal modeling: A case study from the Mt. Capanne**

3 **pluton (Elba, Italy)**

4

5 Mélanie Barboni[1], Catherine Annen[2] and Blair Schoene[3]

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7 1 Department of Earth, Planetary and Space Sciences, University of California Los Angeles

8 Phone number: +1 (609) 510 4782; Fax number: +1 (310) 825 2279; Email: mbarboni@epss.ucla.edu

9 2 School of Earth Sciences, University of Bristol (UK)

10 3 Department of Geosciences, Princeton University

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14

15 **Abstract**

16

17 Evaluating mechanisms and rates for magma transport and emplacement in the upper crust is

18 important in order to predict the thermal and rheological state of the crust, and understand the

19 relationship between plutonism and volcanism. U-Pb geochronology on zircon is commonly used

20 to constrain magma emplacement and storage time in the crust, but interpreting complex zircon

21 age populations in terms of in-situ crystallization versus crystallization at a deeper level is not

22 trivial. This study focuses on the Mt. Capanne pluton in Elba (Italy), a well-documented example

23 of arc-related laccolith emplaced in the upper continental crust. Previous studies proposed that the

24 Mt. Capanne intrusion was accreted in less than 10,000 years by distinct and mappable magma

25 pulses. Here, we couple high-precision ID-TIMS U-Pb zircon geochronology with numerical

26 thermal simulations to evaluate emplacement rates, test different emplacement models, inform

27 zircon age interpretations and evaluate the potential for melt storage during construction of the

28 Mt. Capanne pluton. Our results require that the Mt. Capanne intrusion was built in at least

29 300,000 years by multiple magma injections. A variety of emplacement scenarios show that melt

30 was preserved for < 60'000 years after each pulse and that the maximum eruptible volumes were

31 approximately equal to the volume of each pulse. Our results also require that the majority of

32 zircon crystallization occurred in zircon saturated reservoirs at deeper crustal levels prior to final

33 magma emplacement and cooling, which has implications for using zircon U-Pb geochronology

34 to infer upper crustal magma residence times.

35

36 **1. Introduction**

37

38   The flux of magma to the upper crust plays an important role in how continental crust is made

39 and the relationship between volcanic and plutonic systems (e.g. Lipman, 2007; Bartley, 2008;

40 Glazner et al., 2004; Deering et al., 2011; Miller and Miller, 2002; Miller et al., 2011; Bachmann

41 et al., 2007). Low upper crustal temperatures and the associated brittle rheology of host rocks

42 limit the rate at which large magma bodies can be emplaced (Clemens, 1992; Coleman et al.,

43 2004), which has led to the hypothesis that many igneous bodies grow incrementally by accretion

44 of smaller sills and dikes (e.g. Coleman et al., 2004; Lipman, 2007; Menand, 2011). Therefore,

45 geochronology that constrains magma emplacement rates into the upper crust is important for

46 building models linking magma reservoirs with volcanic and plutonic products (e.g. Barboni and

47 Schoene, 2014).

48   Plutons are time-integrated records of magma reservoirs residing beneath volcanic systems (e.g.

49 Bachmann et al., 2007; de Silva and Gosnold, 2007; Bartley, 2008; Menand et al., 2015), and

50 deciphering intrusion geometries and emplacement modes is critical to testing models for

51 volcanic-plutonic systems (Farina et al., 2010). However, interpreting plutonic records in the field

52 is rarely straightforward, as critical information such as contacts between different sills or pulses

53 and original magmatic textures (Bartley, 2008) can be obscured. Quantifying models for upper

54 crustal pluton construction thus involves a combination of thermal and mechanical models tested

55 by field observation, geophysics, petrology and geochronology.

56   Heat transfer calculations using a range of "typical" magma emplacement rates show that in the

57 cool shallow crust successive magma pulses separated by long time intervals solidify before the

58 next one is emplaced (Annen, 2009; Schöpa and Annen, 2013; de Saint Blanquat et al., 2010).

59 This has led some authors to consider that upper crustal magma chambers with volumes

60 equivalent to plutons are rare and short-lived (Glazner et al., 2004; Coleman et al., 2004; de Saint

61 Blanquat et al., 2010). However, further evidence from thermal models (Annen, 2009; Gelman et

62 al., 2013) has shown that high magma emplacement rates can result in magma chambers

63 equivalent in size to large-volume ignimbrites associated with caldera collapse (Lipman, 2007;

64 Bachmann and Bergantz, 2008). Testing model results with examples from the geologic record

65 requires estimates of magma flux in the crust derived from geochronology (e.g. Caricchi et al.,

66 2014). U-Th-Pb and U-series geochronology of magmatic accessory minerals have been used to

67 infer rates of emplacement and melt storage in the crust (e.g. Coleman et al., 2004; Schmitt et al.,

68 2011; Schoene et al., 2012; Barboni and Schoene., 2014). However, an increasing number of

69 studies from both plutonic and volcanic rocks reveal complexities in zircon age populations that

70 are difficult to interpret in terms of emplacement time (e.g. Lissenberg et al., 2009; Schoene et al.,

71 2012). In essence, the ability of zircon to retain age information at magmatic temperatures –

72 which itself makes zircon such an attractive geochrometer in magmatic systems – also increases

73 its propensity to record protracted crystallization and recycling that obscure the connection

74 between zircon date and magma emplacement rates.

75   In this study, we couple high-precision U-Pb zircon geochronology with thermal modeling to

76 test models of pluton construction. We use differing interpretations of zircon dates to model

77 magma emplacement rates, and use the model results to in turn place constraints on zircon age

78 interpretations. Our case study is the Miocene Mt. Capanne intrusion located on Elba Island

79 (Italy), which is a well-documented example of an upper-crustal laccolith (e.g. Westerman et al.,

80 2004; Rocchi et al., 2010). Previous work has proposed that different mappable magma batches

81 contributed to pluton construction (Farina et al., 2010), therefore providing an excellent

82 opportunity to test and refine the incremental emplacement paradigm for upper crustal plutons

83 and to measure the potential for such systems to generate and store eruptible liquid.

84

85 **2. Geological background**

86

87   Elba Island formed behind the eastwards-progressing compressive front of the Apennine

88 orogeny (Malinverno and Ryan, 1986) during the stacking of five tectonic complexes in the early

89 Miocene. The arc-related Elba intrusive complex was emplaced as a nested "Christmas-tree"

90 laccolith at ca. 6 km depth within the tectonic complexes in what is now western and central Elba

91 (Fig. 1; Rosenbaum and Lister, 2004; Gasparon et al., 2009; Bussy, 1991; Westerman et al.,

92 2004; Rocchi et al., 2010). Crosscutting relationships show the following sequence of intrusion

93 (Westerman et al., 2004; Farina et al., 2010; Rocchi et al., 2010; Fig.1): The Capo Bianco aplite,

94 the Portoferraio porphyry, the San Martino porphyry, the ca. ~200 km^3 Mt. Capanne granitic

95 pluton, and lastly late dykes of intermediate compositions (Orano dyke swarm; Fig.1; Dini et al.,

96 2008).

97   Early intrusions such as the Capo Bianco aplite and the Portoferraio porphyry have been

98   interpreted as anatectic crustal melts.   Large chemical variability within the later intermediate to

99   felsic pluton facies and within individual megacrystic K-feldspars have been used to generate

100   models whereby the magma mixing and mingling occurred at lower crustal depths synchronous

101   with upper crustal emplacement of the Mt. Capanne pluton (Dini et al., 2002; Dini et al., 2004;

102   Farina et al., 2010; Gagnevin et al., 2004; Gagnevin et al., 2005; Gagnevin et al., 2008;

103   Westerman et al., 2004). Several mixing models have been proposed to explain variation

104   observed in the Elba magmatic system.   Liquid-liquid mixing of mantle and crustal melts has

105   been used to explain textures and chemical/isotopic zoning in plagioclase and K-feldspar within

106   the Mt. Capanne granite (e.g. Bussy, 1991; Gagnevin et al., 2004; Dini et al., 2002). Previously

107   hybridized products, represented in the field by abundant mafic microgranular enclaves in the Mt.

108   Capanne facies, were also proposed as potential mixing sources (e.g. Bussy, 1991; Dini et al.,

109   2002). Melt-solid interaction such as assimilation and fragmentation of cumulates has also been

110   used to explain isotopic variability and observed feldspar xenocrysts (Bussy, 1991). Farina et al.

111   (2012), however, proposed that much of the chemical and isotopic variability observed is related

112   to progressive lower- to mid-crustal anatexis of isotopically heterogeneous sources, and that

113   hybridization was most important in generating the intermediate Orano dykes and mafic enclaves

114   of the Mt. Capanne granite.

115

116   **3. Model for the Mt. Capanne pluton construction**

117

118   The calc-alkaline Mt. Capanne pluton has monzogranitic composition (SiO_2 between 66 and 70

119   wt%) and slightly peraluminous character (ASI=1.11) (Dini et al., 2002; Farina et al., 2012).

120   Farina et al. (2010) distinguish three geochemically- and texturally-distinct facies within the Mt.

121 Capanne pluton that correlate with the abundance of K-feldspar megacrysts. The Sant'Andrea

122 facies (SA) contains the highest content of megacrysts and mafic enclaves and is mostly

123 preserved along the pluton margin and at high elevation (Fig.1), suggesting it forms the roof of

124 the pluton (Farina et al., 2010; Westerman et al., 2015). The San Piero (SP) is the structurally

125 lowest facies and contains a low abundance of K-feldspar megacrysts and mafic enclaves. The

126 two facies display subtle but systematic geochemical differences such as higher SiO_2 contents and

127 biotite Mg# in the SA compared to the SP (Farina et al., 2010). The San Francesco facies (SF) is

128 intermediate between the SA and SP in geochemical signature, K-feldspar megacryst content, and

129 structural level. Westerman et al. (2015) interpreted the three facies as three distinct magma

130 batches that were emplaced from the top down (i.e., under accretion) in the order SA, SF, SP.

131 Injection of the SF and SP successively deformed the preexisting sheets into the geometry

132 observed today (Farina et al., 2010; Westerman et al., 2015; Fig.1). Construction by under-

133 accretion is supported by the absence of feeder dikes and contractional strain in the roof (Farina

134 et al., 2010). The original diameters and thicknesses of the SA, SF and SP sills are estimated at

135 9.5x0.25, 9.0x0.65 and 8.0x1.5 km, respectively (Farina et al., 2010), yielding to volumes of

136 about 17, 41 and 75 km^3 (assuming a cylinder geometry; Table 2). Although the dimensions of

137 SA and SF are derived from field observations, the thickness of the SP facies has been estimated

138 through a magnetic data model (Dini et al., 2008). Only the top of the SP is outcropping and the

139 buried portion may be composed of another facies, and the possibility that the Mt. Capanne

140 intrusion is thicker than proposed by Dini et al. (2008) cannot be excluded at present.

141 A striking feature of the Mt. Capanne pluton is the absence of clear contacts between the

142 different pulses of Farina et al., (2010). This led these authors to propose that melt was preserved

143 between injections, and using a simple numerical model, concluded that the whole Mt. Capanne

144   intrusion was built in less than 10,000 years. Barboni and Schoene, (2014) showed that one

145   facies of the Cappane (SA) intruded and cooled to below its solidus in <40 ka, but could not

146   further test the Farina et al. (2010) model for the whole pluton. A recent study by Gagnevin et al.

147   (2011) presented U-Pb dates on zircon by Secondary Ion Mass Spectrometry (SIMS) from the

148   Mt. Capanne pluton, and found no age differences within the pluton. Those data are consistent

149   with rapid intrusion of the Mt. Capanne pluton but large uncertainties on single zircons ($\geq \pm 0.15$

150   Ma) prevent a rigorous testing of the intrusion model of Farina et al. (2010).

151

152   **4. ID-TIMS U-Pb geochronology**

153

154   *4.1. sample description*

155

156   In this study, we carry out U-Pb geochronology on zircon using Isotope Dilution Thermal

157   Ioniazation Mass Spectrometry (ID-TIMS), which provides the temporal resolution necessary to

158   test incremental emplacement models for the Mt. Capanne pluton. Sample locations are shown in

159   Fig.1 and representative CL images of zircon are presented in Fig. 2. Additional CL images are

160   given in Supplementary Materials. Detailed descriptions of hand samples, zircon populations, and

161   field photos are given in the Supplementary Materials. One sample each of the Portoferraio

162   (MB11-11) and San Martino (MB11-14) porphyries, as well as six samples from the Mt. Capanne

163   intrusion and one sample from the Orano dykes were collected for U-Pb ID-TIMS analysis.

164   Following the nomenclature of Farina et al., (2010), we collected two samples from the San Piero

165   facies (MB11-1 and MB11-2, elevation of 150 and 350 m respectively), two from the San

166   Francesco facies (MB12-4 and MB12-8, elevation of 608 and 1000 m respectively) and two from

167   the Sant'Andrea facies (MB11-6 and MB12-9, elevation of 0 and 50 m respectively). Unfolding

168   the sills to estimate the geometry at the time of emplacement following the model of Farina et al.

169   (2010), the SP samples would have been close to the same structural level. On the other hand, the

170   SA and SF samples represent a range of depths within the sheets. MB11-6 would have been ca.

171   150 m higher than MB12-9, which is located close from the contact with the SF facies (Fig.1).

172   MB12-4 would have been ca. 100 m higher than MB12-8 in the SF sheet. The Orano sample was

173   collected from a dyke crosscutting the Sant'Andrea facies (Fig.1; Supplement Fig.1).

174

175   *4.2 ID-TIMS U-Pb geochronology*

176

177   A total of 164 zircons were measured for U-Pb ID-TIMS geochronology. CL imaging was

178   performed on each grain before dissolution to identify old metamorphic cores and characterize

179   growth zoning. When visible cores were present, zircons were broken so that only the tips were

180   dissolved and analyzed (Fig. 2). Many zircons showed complex magmatic textures, but our dating

181   of ~200 zircons from Elba (including the data presented in Barboni and Schoene, 2014) illustrates

182   qualitatively that intragrain complexity does not correlate with date (Fig. 2; Supplementary

183   Material). Fig. 1 presents the $^{206}Pb/^{238}U$ dates for each sample. A detailed methodology section

184   and data tables can be found in the Supplementary Material. All uncertainties in the text, figures,

185   tables and supplements are reported to the 2-sigma level and include internal uncertainties only.

186   Fourteen zircons were analyzed from the Portoferraio porphyry and the results show a spread

187   of $^{206}Pb/^{238}U$ dates ranging from 7.942±0.008 to 8.009±0.012 Ma (Δt=67±14 ka). A cluster of 9

188   zircons yield a weighted mean of 8.001±0.002 Ma (MSWD of 2.3), which does not overlap with

189   the youngest zircon measured in the sample (7.942±0.008 Ma; Fig.1). Sixteen zircons were

190   analyzed for the San Martino porphyry (data published in Barboni and Schoene, 2014). $^{206}Pb/^{238}U$

191   ages spread between 7.437±0.011 and 7.947±0.005 Ma, with most of the ages ranging between

192   7.437±0.011 to 7.541±0.006 Ma (Δt=105±12 ka). Weighted means yield unreasonably high

193   MSWDs of >100 (Wendt and Carl, 1991). Three grains are distinctively older (7.783, 7.947 and

194   9.149 Ma).

195   Thirty-two zircons were analyzed for the Sant'Andrea facies of the Mt. Capanne pluton

196   (twenty for MB11-6; previously published in Barboni and Schoene, 2014; and twelve for MB12-

197   9; Fig.1). Both samples show a large spread in $^{206}Pb/^{238}U$ dates with data spanning over 0.3 Ma

198   (Δt=331±8 ka; Fig.1), from 7.236±0.005 to 7.567±0.006 Ma (ignoring older outliers at 7.65 and

199   7.87 Ma; Fig.1). MB12-9 yields younger dates compared to MB11-6 (youngest zircons of

200   7.236±0.005 and 7.323±0.019 Ma, respectively).

201   Forty-three zircons were analyzed for the San Francesco Facies (twenty-seven for MB12-4 and

202   sixteen for MB12-8; Fig.1). Most $^{206}Pb/^{238}U$ ages span between 7.166±0.007 and 7.404±0.005

203   Ma (Δt=238±9 ka), with four older outliers in sample MB12-4 (from 7.563±0.005 to 9.316±0.006

204   Ma) and one in MB12-8 (7.715±0.028 Ma). The youngest zircons from both samples overlap

205   within uncertainties at 7.166±0.007 Ma (MB12-4) and 7.171±0.005 Ma (MB12-8).

206   Thirty-seven zircons were analyzed from the San Piero facies (fifteen for MB11-1 and twenty-

207   two for MB11-2). The SP samples display the largest spread in $^{206}Pb/^{238}U$ ages within the Mt.

208   Capanne pluton (Δt=531±9 ka), between 7.007±0.007 and 7.538±0.005 Ma (excluding older

209   outlier at 7.72, 7.81, 12.06 and 12.74 Ma; Fig.1; Supplement Table 1). The youngest zircon from

210   MB11-1 overlaps within uncertainties with the youngest zircon from MB11-2 (7.007±0.007 and

211   7.009±0.004 Ma, respectively).

212   Twenty-six zircons were measured for the Orano dyke sample (Fig.1). Similar to the Mt.

213   Capanne intrusion samples, a large spread in $^{206}Pb/^{238}U$ ages is observed (Δt=423±9 ka), ranging

214   from 7.080±0.005 to 7.503±0.007 Ma (with two older out layers at 7.73 and 7.90 Ma).

215

216   *4.3 U-Pb results: Summary*

217

218   All the samples measured in this study display a large spread in ^{206}Pb/^{238}U dates of ca. 200-

219   400 ka (with average uncertainties of ±8 ka), raising the question of the significance of any single

220   date or series of dates in terms of magma emplacement and solidification. We suggest two end-

221   member interpretations of the zircon record given the constraint that all analyzed zircons show

222   magmatic zoning (Fig. 2) and therefore crystallized in the presence of melt: (1) the youngest date

223   represents the best estimate for intrusion and the older dates correspond to zircon recycling from

224   a deeper level of the system, and (2) the oldest grain represents post-emplacement zircon

225   saturation and all other dates represent in situ growth. Below we use numerical thermal modeling

226   to test these possibilities.

227

228   **5. Thermal model setup**

229

230   We numerically simulated the assembly of the Mt. Capanne pluton by addition of sills and

231   calculated the evolution of temperature and melt fraction in the igneous body and country rock

232   system. The equation of heat:

234

$$\rho c \frac{\partial T}{\partial t} + \rho L \frac{\partial f}{\partial t} = k \nabla^2 T \qquad (1)$$

238

239   where ρ is density, c is specific heat, T is temperature, L is latent heat of crystallization or fusion,

240   f is melt fraction, and k is thermal conductivity, was solved with an explicit finite difference

241   scheme on a 2D numerical grid using cylindrical coordinates. The numerical domain extends

242   from the surface to a depth of 13 km and radially to a distance of 10 km from the central axis of

10

243 symmetry. We used $\rho = 2700$ kg/m^3 (Rocchi et al., 2010), $c = 1200$ J/kg K (Robertson, 1988) and

244 $L = 3.5 \times 10^5$ J/kg (Hale et al., 2007). The conductivity k varies with temperature as in

245 Whittington et al. (2009). More information on the numerical method can be found in Annen et al.

246 (2008).

247 The top of the pluton was emplaced at 6 km depth (Rocchi et al., 2010 Farina et al., 2010). The

248 initial system temperature as a function of depth is determined by linear geothermal gradients of

249 either 25˚C/km (150˚C at 6 km depth) or 40 ˚C/km (240˚C/km at 6 km depth). Early and distant

250 intrusions such as the Portoferraio and San Martino porphyries do not significantly affect crustal

251 temperature at the time of Mt. Capanne emplacement, supported by the lack of contact

252 metamorphism associated with those earlier sills.

253 Solving eq. 1 and calculating melt fraction with time requires knowledge of the temperature-

254 melt fraction relationship. We used the Rhyolite-MELTS phase equilibria package (Gualda et al.,

255 2012) with the chemical composition of the SA, SF and SP facies as inputs (see Supplementary

256 material for details on the MELTS model). Inaccuracies in Rhyolite-MELTS results have been

257 reported for felsic, hydrated melts (Gardner et al., 2014), and so we compared a series of

258 Rhyolite-MELTS outputs (by varying, e.g., pressure and water content) to petrological

259 observations, modal proportions and microprobe mineral measurements made on Mt. Capanne

260 granite thin sections (e.g., Barboni and Schoene, 2014). The runs that did not closely match

261 observed records were discarded. The remaining runs that were used in our numerical simulations

262 (Fig. 3) are in good agreement with experimental data acquired on similar granitic compositions

263 (Naney, 1983; Whitney, 1988).

264 According to Rocchi et al., (2010) and Barboni and Schoene, (2014), the magma was rich in

265 feldspar and quartz at the time of emplacement. The zircon saturation temperature was estimated

266 at about 805 ˚C for all three Mt. Capanne facies at the emplacement level (see Supplementary

11

267   Material for details on the Zr saturation model). In a first series of simulations, we test the

268   hypothesis that the magma is emplaced above zircon saturation temperature and that zircons are

269   crystallised after emplacement. Accordingly, in those simulations the magma is emplaced with

270   20% crystals and emplacement temperatures of 878, 906, and 856 ◦C for SA, SF and SP

271   respectively (Fig.3). We determined the period τ during which zircon can crystallize by

272   calculating the time spent by the magma between the saturation temperature and the solidus (688,

273   676 and 666 ˚C for SA, SF and SP facies respectively). We infer from those simulations (c.f.

274   section 5.1 below) that zircon saturation preceded emplacement because the range of observed

275   zircon dates is far longer than the time that liquid is present as permitted by the numerical

276   models. In a second series of simulations, the magma is emplaced at 800˚C with a crystal fraction

277   of 40%. In this case τ is the time spent by the magma above solidus.

278   The results are reported in Table 2 and 3 as τ_{sample}, which is τ at an estimated sample

279   paleodepth (Fig. 4b) and τ_{batch}, which is the maximum τ within a given batch, so that:

280    $\tau_{sample} = \tau(z = z_{sample})$ (2)

281    $\tau_{batch} = Max\left[\tau(z_u < z < z_l)\right]$ (3)

282   with z, the depth, z_{sample} the depth of a sample, z_u the depth of a batch upper boundary and z_l

283   the depth of a batch lower boundary.

284   Since cooling times are the longest close to the batch center, τ_{batch} is significantly longer than

285   τ_{sample} if a sample has been collected far away from the batch center. This is the case for SP (Fig.

286   4b).

287   We tested two scenarios for the construction of the Mt. Capanne pluton. In the first scenario,

288   (3-batch scenario) we followed Farina et al., (2010) in assuming that SA, SF, and SP facies each

289   correspond to a single magma batch that are respectively 250, 650 and 1500 m thick (Fig.4a,

290 Table 2) with emplacement times determined by samples MB11-6 (SA), MB12-4 (SF) and

291 MB11-2 (SP). In the second scenario, the magma emplacement sequence is determined by the

292 zircon dates from samples MB11-6, MB12-9, MB12-8, MB12-4, and MB11-2, such that each

293 sample is treated as an individual batch of magma (Fig.4b, Table 3). In other words, the second

294 scenario assumes multiple pulses per facies, each one of them represented by one of our samples.

295 The thicknesses of those pulses were approximated on the basis of the cross-section after

296 removing the deformation of successive pulses (unfolding the cross-section on Fig.1). We did not

297 include MB11-1 because in the unfolded intrusion it is located at the same vertical level than

298 MB11-2 and hence should belong to the same sill. In all cases, we used a diameter for the

299 intrusions of 9 km (Farina et al., 2010).

300

301 **6. Numerical simulation results**

302

303 *6.1 Testing the significance of zircon date spectra*

304

305 The numerical simulations were used to test the hypothesis that magma emplacement is

306 recorded by the oldest zircon ages from each pulse, outliers excluded (Table 1), and that the range

307 of zircon ages reflects in-situ crystallization. We decided to consider as outliers the grains that

308 were older than the main population by a large gap in dates (Fig.1; Table 1).

309 As a preliminary test, we emplaced the entire Mt. Cappane pluton instantly and observed

310 whether the cooling time between zircon saturation and solidus within the pluton matched the

311 zircon age spectra. In this scenario (using an intrusion temperature of 906 ˚C and composition

312 equivalent to the SF), the maximum predicted range in zircon dates is 78 ka and 52 ka for a

313 geotherm of 40 and 25 ˚C/km, respectively (Fig.5a). This is much shorter than the observed

314   zircon age range (Δt=560±10 ka for the all Mt. Capanne intrusion; Fig.1 and Table 1), and is thus

315   insufficient to explain the zircon dataset.

316   In the 3-batch scenario, the oldest zircon date of two samples within a facies was initially

317   taken as the emplacement age for the facies and emplacement is by underaccretation (Table 2).

318   By contrast, in the 5-batch scenario, successive batches are injected randomly within the intrusive

319   body rather than below, as dictated by the zircon dates (Fig.4a ; Table 3), and thus there is no

320   relationship between facies and timing. In this set of models, magmas were emplaced at low

321   crystallinity (20%) to test the duration of liquid residence from above zircon saturation to the

322   solidus. Table 2 and 3 reports τ_{batch} the longest magma residence time between zircon saturation

323   and solidus temperature for each of the 3 and 5 batches, respectively. For both scenarios, the

324   maximum zircon crystallization time predicted by our simulation is less than 60,000 years in the

325   SP facies (Table 3; Fig.5) and is much shorter than the range of observed zircon dates (minimum

326   0.3 Ma; Fig. 1) even when a steep 40˚C/km geothermal gradient is considered. The modeled

327   maximum zircon crystallization time in Sant'Andrea facies is 750 years for a 3-batch scenario and

328   1100 years in a 5-batch scenario and incommensurate with the observed spread in SA zircon

329   dates (Δt=331±8 ka; Fig.1). This discrepancy between the model results and zircon dates suggests

330   that our working hypothesis – that the oldest zircon dates record emplacement and that the range

331   of dates records continuous in situ crystallization – is not correct. The alternate hypothesis, that

332   most of the zircons crystallized at depth and were recycled (antecrystic, using terminology of

333   Miller et al., 2007), is more accurate.

334

335   *6.2. Testing for the presence of melt between batches*

336

337   Farina et al. (2010) argue that retaining melts between the three injections is necessary in order

338   to erase contacts between the sheets. We tested their hypothesis in the light of our new temporal

339   constraints. Based on the result described above, we now test the other end-member assumption

340   that magma is emplaced at or below zircon saturation temperature (Figs. 6 and 7) and that the

341   youngest zircon date from each facies or sample corresponds to the pulse emplacement time

342   (Table 2 and 3). This results in emplacement by underaccretion for both construction scenarios.

343   In these sets of models, magmas were emplaced at high crystallinity (40%) to be in line with the

344   Zr-saturation temperature (ca. 805°C; Supplement Material) The simulations unequivocally show

345   that for both the 3- and 5-batch scenarios, no melt remains in the system between the successive

346   batches even with a high initial geotherm of 40 °C/km (Table 2 and 3; Fig. 6 and 7). The

347   maximum volumes of melts present in the system do not exceed the volume of the last pulse

348   (Fig.6A and 7), which indicates that remelting of former pulse is absent or very limited. For the

349   3-batch model, the geotherm is only slightly perturbed at the time of emplacement of San

350   Francesco and San Piero (Fig.6B and 6B). Our simulations also show that increasing the number

351   of batches (while still respecting the final volume and duration of intrusion of the Mt. Capanne

352   pluton) would only give shorter liquid residence time, and would not satisfy the hypothesis of

353   residual melt persistence. We concur with Farina et al. (2010) that fast emplacement of Mt.

354   Capanne over less than 10,000 year is necessary for maintaining melt between pulses but our

355   zircon ages indicate much longer emplacement timescale. Therefore, the integration of thermal

356   models and zircon ages does not support the hypothesis that the absence of mappable contacts

357   between facies in the pluton is due to the presence of melt between pulses.

358

359   *6.3. The size of magma reservoirs*

360

361   Both for the 3-pulse and 5-pulse scenarios each pulse completely solidifies before the next one

362   so that the maximum volume of melt corresponds to the volume of individual pulses. According

363   to our geochronologic data, and assuming that the youngest zircon has been sampled and dates

364   emplacement, the minimum number of pulses is 4. The youngest dates of MB12-4 and MB12-8

365   overlap and those two samples may belong to the same pulse. The largest possible pulse has the

366   inferred thickness (1.5 km) and diameter (8 km) of the San Piero facies, which corresponds to a

367   volume of about 75 km^3. However, pulses may have been much more numerous, in which case

368   any magma reservoir would have been of smaller volume.

369

370   **7. Discussion**

371

372   *7.1 Constraints on pluton assembly provided by combined zircon geochronology and thermal*

373   *modeling*

374

375   *7.1.1 Zircon sources and crystallization histories*

376

377   The ID-TIMS U-Pb geochronology presented here illustrates that temporal resolution of tens

378   of thousands of years is necessary to resolve the intrusion history of the Mt. Capanne pluton.

379   Previous U-Pb data obtained by SIMS (Gagnevin et al., 2011) was consistent with a rapid

380   emplacement of the pluton, but due to inherently larger uncertainties associated with that method

381   ($\geq$ ±150 ka in Gagnevin et al., 2011) were unable to differentiate between the ages of different

382   magma pulses and therefore could not test the top-down laccolith emplacement model (Farina et

383   al., 2010). The drawback of ID-TIMS geochronology is the larger volume of zircon analyzed,

384   which can integrate protracted zircon growth histories into a single precise crystallization date.

385   We show in this study that careful CL-imaging followed by microsampling can avoid analysis of

386   complexities such as inherited cores (Fig.2; Supplementary Figure 2) in an effort to date the

387   youngest zone of a zircon. However, we observe that removing and selectively analyzing zircon

388   tips does not necessarily yield the youngest dates within a sample (Fig. 2; Supplementary Figure

389   2), suggesting that complexities in zircon saturation and nucleation at small spatial scales and/or

390   grain armoring affects the zircon growth record.

391   Experimental data for zircon saturation show that granodioritic to granitic melts reach zircon

392   saturation at temperatures well above the solidus and therefore could carry significant amounts of

393   early-crystallized zircon during remobilization and transport of magma (Watson and Harrison,

394   1983; Boehnke et al., 2013; Harrison et al., 2007; Miller et al., 2007). As a consequence, the

395   physical integrity and also age information in zircon can survive transport, reheating, and

396   reincorporation in subsequent batches of magma, and interpreting zircon dates in terms of

397   magmatic processes is difficult (Lissenberg et al., 2009; Miller et al., 2007; Schoene et al., 2012).

398   One approach to this problem is to target zircon populations included within specific phases

399   versus the bulk rock, and combine those data with petrologic observations and zircon saturation

400   and phase equilibria modeling to estimate the solidification age of certain pulses (see Barboni and

401   Schoene, 2014, for an example using the SA). Building on that approach for the entire pluton, we

402   estimated zircon saturation temperatures for our samples by modeling the Zr and bulk

403   composition evolution of the melt given by our Rhyolite-MELTS results (see Supplement for

404   detailed methodology and figures) and using the zircon saturation models of Boehnke et al.,

405   (2013). Our results suggest that saturation was reached in the Mt. Capanne magmas at

406   temperatures of ca. 805°C, well above the modeled solidi of 688-666 ˚C. Textures revealed by

407   CL imaging (Fig. 2) also record resorption events within the Mt. Capanne zircons (see also

408   Gagnevin et al., 2011), suggesting that zircon saturation was not constant over the time span of

17

409   200 to 400 ka recorded by zircon in our samples. This conclusion is supported by the results of

410   Barboni and Schoene, (2014), who show that at least 100 ka of zircon crystallization is recorded

411   in the SA prior to its emplacement, in that zircon dates from that pulse predate the intrusion of the

412   demonstrably cross-cut San Martino porphyry by ca. 100 ka.

413   Our thermal modeling and geochonology combine these data to test whether the observed range

414   of zircon dates (~300 ka) from each sample could represent post-emplacement cooling. Because

415   the maximum melt residence time determined in our models is ~58 ka for any batch of magma, it

416   is unavoidable that at least ca. 200 ka of pre-intrusion zircon crystallization (i.e. zircons carried

417   from depth) occurred and is recorded within the Mt Capanne pluton. Our results therefore limit

418   the duration of a magma reservoir in the shallow Elba magmatic system and suggest that most of

419   the zircons were recycled from a deeper crustal reservoir.

420

421   7.1.2 Construction of Mt. Capanne pluton

422

423   Farina et al., (2010) hypothesized that the SA, SF and SP facies correspond to distinct magma

424   batches injected in the upper crust and contacts between them are absent because melt was

425   preserved between magma pulses, which required pluton emplacement in less than 10 ka.

426   However, the difference between the youngest zircons dated in this study from the SA (MB11-6)

427   and the SP (MB11-2) exceeds 300 ka. A possibility is that the pluton was emplaced rapidly ca.

428   7.3 Ma (the youngest SA zircon) and that older SA zircons were inherited from deeper in the

429   crust whereas SP zircons <7.3 Ma crystallized in situ post emplacement. We tested this

430   hypothesis but found that the crystallization time of the SP in such a model is limited to 58 ka,

431   requiring the SP to intrude at least 240 ka after the SA, containing a substantial amount of

432   inherited zircon (Fig. 5 and 6). For this reason, our zircon U-Pb data and thermal modeling show

433   that the conclusion of Farina et al. (2010), that the Mt. Capanne pluton must have been emplaced

434   in <10 ka, is incorrect; this incorrect assertion stems from the assumption that melt was present

435   between pulses, explored below.

436   Our thermal modeling results therefore argue that the timing of magma emplacement for a given

437   pulse (as represented by a handsample) is closer to the youngest zircon date, and that the intrusion

438   time is constrained by the youngest zircon date and the limits of the thermal model. Though the

439   exact number of pulses is not determined by our data, we can reach several important conclusions

440   and highlight remaining uncertainties. The SA was constructed by under-accretion of at least two

441   different pulses 150 vertical meters apart represented by samples MB11-6 and MB12-9 (Fig.4b).

442   Our two samples from the SF, MB12-4 and MB12-8, have youngest zircons that are nearly

443   indistinguishable though MB12-4 was structurally 100 m higher than MB12-8. The large gap in

444   dates between the youngest and the second youngest zircon in MB12-4 imposes significant

445   uncertainty on whether the youngest zircon is in fact representative of the magma solidus.

446   Therefore any conclusion as to whether the SF intruded as one or more than one pulse based on

447   zircon dates is speculative. Similarly, zircon dates from the SP samples are very similar and the

448   youngest dates overlap within uncertainty. However, the SP outcrops sampled were emplaced at a

449   similar structural level, and may represent only one of potentially many sills. Therefore, while

450   collecting more samples within the Mt. Capanne cross-section would allow better estimation of

451   the number of pulses, our main conclusions would not likely change. These are that our zircon

452   data coupled with thermal modeling require that the Mt. Capanne pluton intruded in at least 4

453   pulses (potentially many more) over ~ 250 ka and that the maximum liquid residence time is ~60

454   ka. Our data support previous models for pluton assembly by underaccretion (Farina et al., 2010),

455   similar to some other recently studied intrusions (de Saint-Blanquat et al., 2006; Michel et al.,

456   2008; Barboni et al., 2013).

457

7.2 Effect of unknown pluton geometry on the numerical simulation results

459

460   Increasing the volume of magma underplated beneath the exposed pluton (i.e. increasing the

461   thickness of the San Piero facies) could effect the melt residence time in the deepest part of the

462   intrusion. In this case, the outcropping part of the Mt. Capanne would represent only the roof of a

463   larger magmatic system extending at depth. This possibility is in contradiction with Dini et al.

464   (2008), who used a detailed magnetic susceptibility survey of the Mt. Capanne pluton to resolve

465   the laccolith pluton shape with a maximum thickness of ca. 2.5 km (thickness used in our

466   simulation), but we consider the possibility nonetheless. Our geochronologic data for the SA

467   facies requires solidification prior to the intrusion of the SF and SP facies, consistent with the

468   results from Barboni and Schoene (2014), and without subsequent remobilization. An early SA

469   crystallization is also suggested by our Orano Dyke zircon dates, which are younger than those

470   from the SA facies it crosscuts (Supplement Fig.1), but much older that the youngest San Piero

471   zircon (7.080±0.005 Ma for Orano versus 7.007±0.007 Ma for SP; Fig.1). If the San Piero facies

472   was much thicker than predicted by Dini et al., (2008), its thermal effect did not significantly

473   reheat the upper part of the intrusion.

474   Another unknown that could affect our numerical results is the possibility that part of the

475   intrusion roof (represented in our case by the SA facies) was eroded away. Our models show that

476   the maximum melt residence time for the SA facies is ca. 1 ka, which is much shorter than the

477   prediction from Barboni and Schoene (2014) based on the information recorded by the SA K-

478   feldspar megacrysts (10-40 ka). This suggests a SA facies thicker than observed today, which

479   potentially biases our thermal model outputs by underestimating the original volume of the pulse.

480

481 *7.3 Absence of internal contacts within the Mt. Capanne pluton*

482

483   Integrating age data with numerical modeling shows that for the simulations we ran, melt was

484   not preserved between magma batches and therefore the absence of internal contacts within the

485   Mt. Capanne intrusion is not related to the presence of residual melt. Alternative hypotheses that

486   could explain the lack of internal contacts within an incrementally built granitic pluton include

487   (1) remelting of previously emplaced pulses by a new injection that obscures contacts (Bartley,

488   2008), and (2) sustained amphibolite facies conditions triggering subsolidus textural change and

489   erasing contacts (e.g. Hanson and Glazner, 1995). Farina et al. (2010) discarded the latter

490   hypothesis based on lack of contact metamorphism in the Mt. Capanne host rock and absence of

491   macro- or microscopic recrystallization evidence in the Mt. Capanne granite. The results of

492   Barboni and Schoene (2014), which show core-to-rim younging in zircon included within

493   megacrystic K-feldspar, require rapid cooling and solidification of early pulses without

494   substantial textural modification. Numerical models also predict only slightly perturbed

495   geotherms by successive injections at the depth and of the size of the Mt. Capanne pluton.

496   Another hypothesis for obscuring internal contacts is that (3) contacts between magma of similar

497   composition and texture, as is the case in the Mt. Capanne intrusion, could be difficult to identify

498   in the field if there is no major changes in mineralogy, mineral modal proportions or mineral size.

499   Chilled margins (i.e. reduction of the mineral size approaching the contact with the cold facies)

500   are usually the best way to identify contacts between various injections. However, if the

501   temperature gradient between the new injection and the already solidified pulse is not large

502   enough (as is usually the case for intermediate to felsic melts), then chilled margins may not be

503   expected. While our thermal models preclude large scale reheating or remelting of previous

504   sheets, heating and or physical abrasion (plucking, remobilization) of contacts at a centimeter to

505   meter scale are possible and would act to obscure pulse contacts. Though our geochronological

506   data were able to identify at least 4 pulses, it is possible that the Mt. Capanne pluton is composed

507   of many more sheets with gradational composition whose contacts could be obscured by these

508   processes. Other field examples where 100 m to km scale 3D cross-sections are visible show that

509   it is possible to identify subtle contacts within similar composition sheets (e.g. Torres de Paines

510   laccoliths; Michel et al., 2008; Himalayan leucogranites; Searle et al., 2010), but such

511   relationships are elusive at the outcrop level (Bartley, 2008). We suspect the Mt. Capanne pluton

512   is one of these cases where the compositions and textures of the different increments are too

513   similar to generate obvious contacts in the field.

514

515   *7.4 Eruptible volumes for the upper-crustal Mt. Capanne reservoir and implication for modern*

516   *arc volcanism.*

517

518   A difficulty in understanding active volcanic systems is that very little information is available

519   about the longevity and size of subvolcanic reservoirs. "Fossilized" reservoirs such as the Mt.

520   Capanne pluton can be used to constrain emplacement rates and reservoir lifespan, and contrast

521   volcanic and plutonic records. Calc-alkaline magmatism in Elba occurred in a similar tectonic

522   context as modern arc systems (Rosenbaum and Lister, 2004; Gasparon et al., 2009). Our thermal

523   models show that small upper-crustal systems such as the Mt. Capanne pluton do not contain

524   magma chambers on timescales of hundreds of ka, regardless of the intrusion mechanism. For the

525   scenarios modeled, each pulse injected in the Mt. Capanne system solidifies before the next one

526   intrudes, and therefore the maximum eruptible volume for the system is the volume of each

527   injection. Those volumes range from 2 to 60 km^3, depending upon the crystallinity of the magma

528   at time of melt extraction and eruption (eruption between 40% and 60% crystals; e.g. Bachmann,

22

529   2004) and are similar to those observed in recent arc eruptions (Mt. Pinatubo 1991, 8-10 km^3,

530   Wolf et Hoblitt, 1996; Mt. Saint Helens 1980, 1.25 km^3, Tilling, 1984). If magma was indeed

531   emplaced at about 40% crystals, then our results show that melt remained eruptible for only a

532   very short period of time (<50 ka, but for most pulses in less than several ka), which is in line

533   with the conclusions of Barboni and Schoene (2014) and Cooper and Kent (2014). Volatiles

534   would also have a strong effect on the eruptibility of the system but their nature and role are

535   unfortunately currently poorly understood in Elba.

536

537   **8. Conclusions**

538

539   Our study on the Mt. Capanne intrusion from Elba island shows that coupling a large dataset of

540   high-precision ages with thermal modeling can help assess the emplacement history and thermal

541   evolution of incrementally built upper-crustal reservoirs. Our results suggest that the Mt. Capanne

542   intrusion was built in minimum 250,000 years by multiple magma increments in the crust.

543   Numerical models of sill accretion constrained by U-Pb ID-TIMS dates indicate that no melt was

544   preserved between individual injections. The thermal contribution of each pulse is not large

545   enough to generate long-lasting magma reservoirs and the maximum volumes that can be erupted

546   correspond to the volume of each pulse injected. These results provide interesting insight into

547   understanding active volcanism in modern arcs. Elba magmatism was very similar, both in

548   tectonic context and magma volumes, to some modern arc volcanoes (e.g. Mt. St. Helen; Mt.

549   Pinatubo) and would have produced similar eruptible volumes (< 10 km^3). While active magma

550   chambers can only be assessed indirectly, information recorded in a "fossilized" reservoir such as

551   the Mt. Capanne can give insight into time-integrated rates of magma recharge and duration of

552   potential eruption windows in active system.

553   We also show that absence of contacts within intermediate to granitic intrusions does not

554   require melt preservation in the contact zones between magma sheets, as was previously proposed

555   by Farina et al. (2010) for the Mt. Capanne intrusion. Our thermal models unambiguously

556   indicate that every new magma increment will have a very short liquid residence time in the

557   upper crust, with no melt remaining in-between pulses. Contacts between sheets of similar texture

558   and composition might be unidentifiable at the outcrop scale, as suggested by Bartley et al.,

559   (2008). In such cases, the use of high-precision dating on zircon can discriminate between

560   different magma injections (Schoene et al., 2012).

561   Complexities in U-Pb age populations resulting from zircon recycling introduce complexities

562   in resolving incremental emplacement in evolved melts. However, coupling zircon ages with

563   thermal modeling aids interpretation of complex age spectrums and identifying zircon inherited

564   from deeper crustal levels. Our results suggest that for the Mt. Capanne pluton, the majority of

565   the zircon record is inherited from a deeper level of the system and that only a small portion of

566   the ages record in-situ crystallization.

567

573

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Figure captions

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Figure 1. Study area and ID-TIMS U-Pb geochronology. A) Geological map of Elba with sample locations and cross-section of the Mt. Capanne pluton (modified after Westerman et al., 2004 and Farina et al., 2010). Numbers I-V refer to tectonic complexes (as described in Westerman et al., 2004). B) Rank-order plot of $^{206}Pb/^{238}U$ zircon dates from the Elba intrusives (with youngest zircon age indicated for each samples with 2-sigma uncertainties). Individual bars correspond to single zircons or zircon fragments with height of bars representing 2-sigma uncertainties. See Table S1 for full U-Pb data table.

741

Figure 2. Cathodoluminescence images of selected zircons from the Elba intrusive rocks, with ID-TIMS $^{206}Pb/^{238}U$ dates and 2-sigma uncertainties. Sample name and facies labeled in each panel. White dashed line indicates where grains were fractured and solid line points to which fragment was analyzed. See Table S1 for full U-Pb data table.

746

Figure 3. Melt fraction and proportion of crystallizing phases versus temperature used in the numerical simulations for the three Mt. Capanne facies, as predicted by Rhyolite-MELTS. The modal mineralogy observed in thin section is plotted on the left (colour boxes); colour curves represent modal proportions predicted by MELTS. The zircon saturation temperatures were determined for the evolving melt composition using MELTS and mineral-melt Zr partitioning (Supplementary Methods).

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754

755   Figure 4. Setup for the numerical simulation for the 3-pulse (A) and 5-pulse (B) scenario.

756   Successive magma pulses have the geometry of sills. The colors represent the different facies

757   (Fig. 1), whose thicknesses are determined by field relations; see text. The stars show the

758   approximate position of the U-Pb geochronology samples.

759

760   Figure 5. Numerical thermal model results for simulations where the oldest zircon dates

761   approximate intrusion of magma pulse for the 1-pulse (A), 3-pulse (B) and 5-pulse (C) scenarios.

762   Here magma emplacement temperature is above zircon saturation temperature (see text). The

763   colours and contour lines show the Log10 of the time (i.e., 4 = 10,000 years) spent by the magma

764   between zircon saturation (~805 ˚C) and the solidus on a cross section through the intrusion.

765   Initial geothermal gradient is 40 °C/km.

766

767   Figure 6. Numerical thermal model results for simulations where the youngest zircon dates

768   approximate intrusion of magma pulse for the 3-pulses scenario. Magma emplacement

769   temperature is below zircon saturation temperature at ~40% crystals. (A) Volumes of melt over

770   time. The spikes correspond to intrusion of SF and SP. SA is intruded at time 0 and the magma is

771   too short-lived to be visible on the diagram. (B) and (C) Snapshot of temperatures on a cross

772   section of the system at time 70,300 years (B) and 229,500 years (C) just before the emplacement

773   of SF (B) and SP (C). Curves are labelled in ˚C. The dashed line show the contour of already

774   emplaced pulses and the arrows show the level of the next pulse. In both cases, temperatures at

775   the time and depth of the new pulse are several hundred degrees below the wet granite solidus

776   (Withney, 1988) and no melt remains in the system between pulses. Initial geothermal gradient is

777   40 °C/km.

778

779

780   Figure 7. Numerical thermal model results for simulations where the youngest zircon dates

781   approximate intrusion of magma pulse for the 5-pulses scenario. Curves showing volume of

782   magma with >50% and >0% melt in the entire modelled magmatic systems are shown as a

783   function of time. Each spike corresponds to a pulse but the first pulse emplaced at time 0 is not

784   visible because it is too short-lived. No melt is retained between pulses. Initial geothermal

785   gradient is 40 °C/km.

786

A

B

7.942±0.008 Ma

8.006±0.005 Ma

7.996±0.004 Ma

7.963±0.009 Ma

8.000±0.005 Ma

MB11-11
Portoferraio porphyry

200µm

7.360±0.004 Ma

7.282±0.006 Ma

7.248±0.009 Ma

San Francesco - MB12-9

100µm

7.179±0.005 Ma

7.307±0.006 Ma

7.278±0.003 Ma

San Francesco - MB12-8

100µm

100µm

7.085±0.006 Ma

7.503±0.007 Ma

7.352±0.005 Ma

7.355±0.004 Ma

Orano Dyke- MB11-5

7.338±0.013 Ma

7.204±0.005 Ma

7.009±0.004 Ma

7.192±0.007 Ma

7.335±0.008 Ma

100µm

San Piero - MB11-1

7.174±0.004 Ma

7.204±0.004 Ma

7.071±0.004 Ma

7.156±0.005 Ma

San Piero - MB11-2

100µm

7.361±0.014 Ma

7.473±0.007 Ma

Sant'Andrea - MB11-6

50µm

100µm

7.525±0.007 Ma

San Martino porphyry MB11-14

7.563±0.005 Ma

7.259±0.007 Ma

7.353±0.006 Ma

San Francesco - MB12-4

100µm

A

B

Table 1 Zircon dates used in the thermal model

Facies	sample	Youngest zircon (Ma)	2-sigma (Ma)	Oldest zircon (Ma)	2-sigma (Ma)	Total age dispersion (ka)
SA	MB11-6	7.323	0.019	7.567	0.006	244 ± 20
SA	MB12-9	7.236	0.005	7.406	0.005	170 ± 7
SF	MB12-4	7.166	0.007	7.471	0.009	305 ± 11
SF	MB12-8	7.172	0.005	7.404	0.003	232 ± 5
SP	MB11-2	7.007	0.007	7.411	0.005	404 ± 9

Table 2 Three batches emplacement

Pulse	Pulse thickness (m)	Facies	Volume (km^3)
1	250	SA	17
2	650	SF	41
3	1500	SP	75

Case 1: Magma emplaced above ziron saturation temperature (20% crystals); the oldest zircon dates emplacement.

Pulse	Ages (Ma)	Sample	Emplacement time year	τ_{sample} (year) Geotherm = 25°C/km (1)	τ_{sample} (year) Geotherm = 40°C/km (1)
1	7.567	MB11-6	0	523	732
2	7.471	MB12-4	96317	1759	3576
3	7.411	MB11-2	156817	5673	20975

Pulse	Ages (Ma)	Sample	τ_{batch} (year) Geotherm = 25 °C/km (2)	τ_{batch} (year) Geotherm = 40°C/km (2)	Volumetric emplacement rate (km^{3}yr^{-1})
1	7.567	MB11-6	567	775	1.25E-04
2	7.471	MB12-4	4217	6150	4.26E-04
3	7.411	MB11-2	32895	52060	4.78E-04

Case 2: Magma emplaced below zircon saturation temperature (40% crystals); the youngest zircon dates emplacement

Pulse	Ages (Ma)	Sample	Emplacement time year	τ_{sample} (year) Geotherm = 25°C/km (1)	τ_{sample} (year) Geotherm = 40°C/km (1)
1	7.236	MB12-9	0	141	165
2	7.166	MB12-4	70300	440	1098
3	7.007	MB11-2	229500	555	1593

Pulse	Ages (Ma)	Sample	τ_{batch} (year) Geotherm = 25 °C/km (2)	τ_{batch} (year) Geotherm = 40°C/km (2)	Volumetric emplacement rate (km^{3}yr^{-1})
1	7.236	MB12-9	574	763	8.47E-05
2	7.166	MB12-4	4185	5433	5.83E-04
3	7.007	MB11-2	24490	32144	3.27E-04

(1)   time spent by the magma between zircon saturation temperature and solidus at the sample paleodepth
(2)   maximum time spent by the magma between zircon saturation temperature and solidus anywhere within a batch (see text)

Since cooling times are the longest close to the batch center, τ_{batch} is significantly longer than τ_{sample} if a sample has been collected far away from the batch center.

Table 3 Five batches emplacement

Case 1: Magma emplaced above zircon saturation temperature; the oldest zircon dates emplacement

Pulse	Facies	sample	Ages (Ma)	Pulse thickness (m)	Volume (km^3)	Sample depth (m)
1	SA	MB11-6	7.567	150	9	6050
2	SF	MB12-4	7.471	200	6	6300
3	SP	MB11-2	7.411	1500	13	6950
4	SA	MB12-9	7.406	100	27	6200
5	SF	MB12-8	7.404	450	75	6600

Pulse	Facies	sample	Ages (Ma)	Emplacement time year	τ_{sample} (year) Geotherm = 25°C/km (1)	τ_{sample} (year) Geotherm = 40°C/km (1)
1	SA	MB11-6	7.567	0	236	310
2	SF	MB12-4	7.471	96300	271	2132
3	SP	MB11-2	7.411	156800	44396	58548
4	SA	MB12-9	7.406	161900	803	1133
5	SF	MB12-8	7.404	163700	21050	30012

Pulse	Facies	sample	Ages (Ma)	τ_{batch} (year) Geotherm = 25 °C/km(2)	τ_{batch} (year) Geotherm = 40°C/km(2)	Volumetric emplacement rate (km^{3}yr^{-1})
1	SA	MB11-6	7.567	236	314	6.63E-05
2	SF	MB12-4	7.471	8486	15112	1.35E-04
3	SP	MB11-2	7.411	52167	65686	4.78E-04
4	SA	MB12-9	7.406	803	1133	3.71E-05
5	SF	MB12-8	7.404	37200	48670	1.65E-04

(1) time spent by the magma between zircon saturation temperature and solidus at the sample paleodepth
(2) maximum time spent by the magma between zircon saturation temperature and solidus anywhere within a batch (see text)

Since cooling times are the longest close to the batch center, $\mathbf{\tau}_{batch}$ is significantly longer than $\mathbf{\tau}_{sample}$ if a sample has been collected far away from the batch center.

Table 3 (cont) Five batches emplacement

Case 2: Magma emplaced below zircon saturation temperature; the youngest zircon dates emplacement

Pulse	Facies	sample	Ages (Ma)	Pulse thickness (m)	Volume (km^3)	Sample depth (m)
1	SA	MB11-6	7.323	150	9	6050
2	SA	MB12-9	7.236	100	6	6200
3	SF	MB12-4	7.166	200	13	6300
4	SF	MB12-8	7.172	450	27	6600
5	SP	MB11-2	7.007	1500	75	6950

Pulse	Facies	sample	Ages (Ma)	Emplacement time year	τ_{sample} (year) Geotherm = 25°C/km (1)	τ_{sample} (year) Geotherm = 40°C/km (1)
1	SA	MB11-6	7.323	0	248	299
2	SA	MB12-9	7.236	89600	98	122
3	SF	MB12-4	7.166	159900	405	500
4	SF	MB12-8	7.172	165500	2518	3297
5	SP	MB11-2	7.007	333200	814	1424

Pulse	Facies	sample	Ages (Ma)	τ_{batch} (year) Geotherm = 25 °C/km(2)	τ_{batch} (year) Geotherm = 40°C/km(2)	Volumetric emplacement rate (km^{3}yr^{-1})
1	SA	MB11-6	7.323	248	299	4.49E-05
2	SA	MB12-9	7.236	98	122	6.70E-05
3	SF	MB12-4	7.166	409	503	8.13E-05
4	SF	MB12-8	7.172	2636	3438	1.63E-04
5	SP	MB11-2	7.007	24314	30783	2.25E-04

(1)   time spent by the magma above solidus at the sample paleodepth

(2)   maximum time spent by the magma above solidus anywhere within a batch (see text)

Since cooling times are the longest close to the batch center, τ_{batch} is significantly longer than τ_{sample} if a sample has been collected far away from the batch center.

S1. Hand sample and zircon description:

Portoferraio and San Martino Porphyries:

 The Portoferraio sample was collected near the "Aquavita" locality (Fig.1 of the main text). Latitude and Longitude (WGS84) are N 42°49'21.6''/E 10°17'13.6''. It is a biotite-bearing monzogranite containing quartz phenocrysts set in a very fine matrix (Supplement Fig.1A). Zircons are very abundant, included both in the matrix and as inclusions in biotite. The present a euhedral and prismatic shape and range in size from 50-300μm in length, but mostly 70-200 μ m. Cathodoluminescence (CL) imaging of zircon shows oscillatory zoning typical of igneous zircon, with some grains displaying rounded cores and truncated oscillatory zoning or sector zoning (Fig.2 of the main text).

 Barboni and Schoene, (2014), described the San Martino (SM) porphyry sample (MB11-14). It was collected near the "La Focce" locality (Fig.1 of the main text). Latitude and longitude (WGS84) are: N 42°74'65.4'' /E 10°25'02.8''. It is a biotite-bearing monzogranite containing prominent sanidine megacrysts set in in a fine-grained groundmass (Supplement Fig.1B). The zircon grains are euhedral and prismatic ranging in size from 50-400 μ m in length, but mostly 100-250 μ m. Cathodoluminescence (CL) imaging of zircon shows oscillatory zoning typical of igneous zircon, though some grains contain rounded cores with truncated oscillatory zoning or sector zoning (Fig.2 of the main text).

Orano Dyke:

 We collected the Orano sample from a dyke that was crosscutting the Sant'Andrea facies of the Mt. Capanne intrusion, West of the town of "Chiessi (Fig.1 of the main text; supplement Fig.3C). Latitude and longitude (WGS84) are N 42°75'89.8''/E 10°29'68.2''. It is a quartz monzodiorite containing resorbed xenocrysts of quartz and K-feldspar, as well as mafic microgranular enclaves (MME) and xenoliths (insert in Supplement Fig.3C). Zircon is located in the groundmass and in inclusion in biotite. Although the largest enclaves and xenocrysts from the sample prior to crushing and zircon extraction, some smaller ones were unavoidable during crushing. The zircons therefore represent a mixed population including grains from the host granite, the MME and smaller megacrysts. The zircon grains are euhedral and prismatic ranging in size from 50-200 μ m in length, but mostly 50-150 μ m. Cathodoluminescence (CL) imaging of zircon shows oscillatory zoning typical of igneous zircon, though some grains contain rounded cores with truncated oscillatory zoning or sector zoning (Fig.2 of the main text).

Mt. Capanne pluton:

 The Sant'Andrea (SA) facies rock samples were collected on the Sant'Andrea beach for MB11-6 (Fig. 1 of the main text; WGS84 latitude and longitude of N 42°80'80.1'' /E 10°14'09.1''; described in Barboni and Schoene, 2014), and in the Pomonte quarry for MB12-9 (Fig. 1 of the main text; WGS84 latitude and longitude of N 42°75'08.4'' /E 10°12'93.9''). Both are biotite-bearing monzogranites that contains numerous mafic microgranular enclaves (MME) and K-feldspar megacrysts (Supplementary Fig.1D). Modal proportions are the following: 38% An$_{35-12}$ plagioclase, 27% quartz, 22% orthoclase (Or$_{65-81}$), 13% biotite and accessories (apatite, zircon, tour-

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maline, allanite, titanite and oxides). Zircon is located both in the matrix and included in plagioclase, orthoclase and biotite. Although the largest MME and K-feldspar were removed from the sample prior to crushing and zircon extraction, some smaller ones were unavoidable during crushing. The zircons therefore represent a mixed population including grains from the host granite, the MME and smaller megacrysts. Zircons are euhedral and prismatic, mostly elongate; grain size ranges from 50-500 μm in length, but are mostly 100-300 μm. Cathodoluminescence (CL) imaging of zircon shows oscillatory zoning typical of an igneous origin. Most of the Sant'Andrea zircon grains have rounded cores with truncated oscillatory zoning or sector zoning, sometimes showing a patchy texture (Fig.2 of the main text).

The San Francesco (SF) facies rock samples were collected near the contact with the San Piero facies on the road above the "Torre Giovanni" for sample MB12-8 (Fig. 1 of the main text; WGS84 latitude and longitude of N 42°76'93.2" /E 10°18'77.9"), and 50m bellow the summit of the Mt.Capanne for sample MB12-4 (Fig. 1 of the main text; WGS84 latitude and longitude of N 42°77'09.5" /E 10°16'89.5"). Both samples are biotite-bearing monzogranites that are very similar in compositions and modal proportion as the Sant'Andrea samples described above, at the exception of a lower content of MME and K-feldspar megacrysts and a slightly lower SiO_2 wt% composition (Supplement Fig.1E). Zircons from both samples present similar characteristics that the one from the two SA samples.

The San Piero (SP) facies rocks were collected in the San Piero quarry for MB11-1 (Fig. 1 of the main text; WGS84 latitude and longitude of N 42°74'67.2" /E 10°20'88.5"), and on the road bellow the "Torre Giovanni" (close to the contact with the San Francesco facies) for MB11-2 (Fig. 1 of the main text; WGS84 latitude and longitude of N 42°76'23.4" /E 10°20'07.6"). Both samples are monzogranites and did not contain any MME or K-feldspar megacrysts (Supplement Fig.1F). Zircons from both samples present similar characteristics that the one from the SA and SF samples.

S2. Methodology

2.1 U-Pb methodology

All samples were processed and analyzed at Princeton University. Zircon separates were prepared by standard density and magnetic mineral separation methods (crushing and milling; sieving to <500 μm; concentration via hand-panning; magnetic separation; hand-picking). All the zircons were dated by removing grains that were imaged by CL from the epoxy mount, in order to document any correlations between internal textures and dates and also to target the simplest zircons (representative images are shown in fig.2 of the main text). However, there was no obvious correlation between the dates of the grains and the amount of core material observed in the zircon, the type of zoning (sector vs. oscillatory), the number of growth episodes, nor the brightness of the zoning. When xenocrystic cores were identified, we cut the zircon following the CL imaging in order to insolate and date only the tips (representative images are shown in fig.2 of the main text).

Analyses were performed following the same procedure as described in Barboni and Schoene, (2014) and is repeated here. Annealing was performed by loading the zircons of each sample in quartz crucibles, which were heated at 900°C for ca. 48h. Zircons were removed from Epoxy grainmount following CL imaging, loaded into 200 μl savillex capsules, leached in HF + trace HNO_3 for ca. 12 hours at 190°C and rinsed with water, 6N HCl
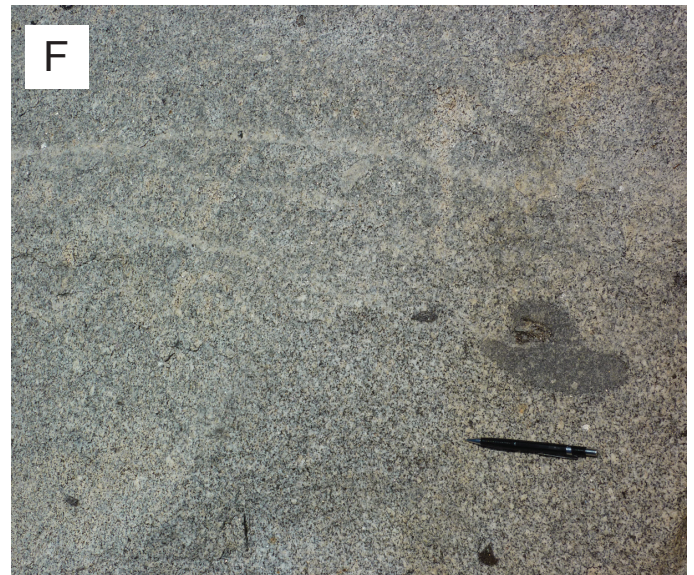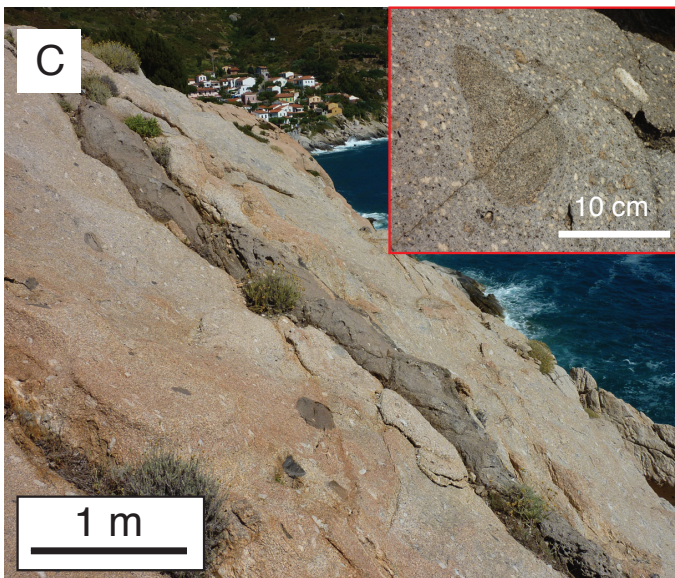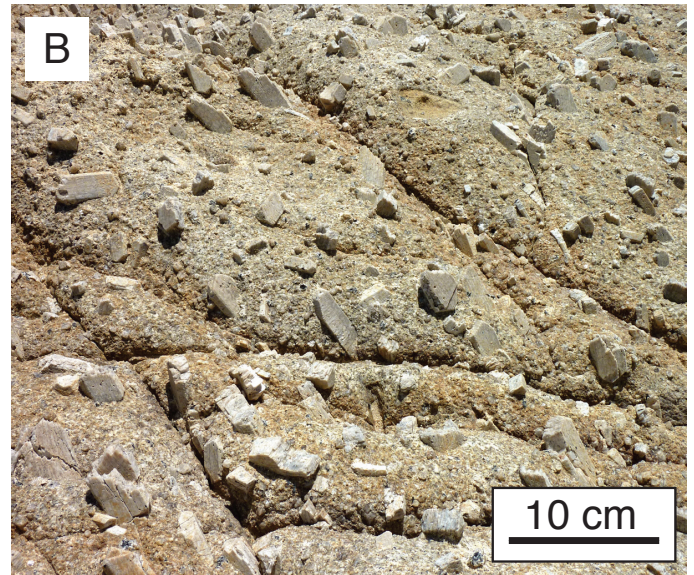
Supplementary Fig.1. A) Portoferraio Porphyry (sample MB11-11). B) San Martino Porphyry (sample MB11-14). C) Orano dyke crosscutting the Sant'Andrea facies of the Mt. Capanne intrusions (sample MB11-5). D) Mafic enclaves and K-feldspar megacrysts in the Sant'Andrea facies of the Capanne intrusions. F) San Francesco facies of the Capanne intrusion. D) San Piero facies of the Capanne intrusion.

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and HF. Each grain was spiked with ca. 0.006 g of the EARTHTIME ^{205}Pb-^{233}U-^{235}U tracer solution (Condon et al., in press; Mclean et al., in press). Zircons were subsequently dissolved in ca. 70 μl 40% HF and trace HNO$_3$ at 210°C for 48+ hours, dried down and redissolved in 6N HCl overnight. Samples were then dried down and redissolved in 3N HCl and put through a modified single 50 μl column HCl-based anion exchange chemistry (Krogh, 1973). U and Pb were collected in single beakers, dried down with a drop of 0.02 M H3PO4, and analyzed on a single outgassed Re filament in Si-gel emitter (modified from Gerstenberg and Haase, 1997).

Measurements were performed on an IsotopX Phoenix62 thermal ionization mass spectrometer at Princeton University. Pb was measured in dynamic mode on an axial ion-counting Daly photomultiplier. Deadtime for the Daly was determined at 40.5 ns by repeated measurements of NBS-981 and NBS-982 for up to 2.5 Mcps. Lead mass fractionation was calibrated by repeated NBS-981 measurements (mean α ^{208}Pb-^{206}Pb = 0.18 ± 0.04 %/amu, 2-sigma standard deviation) on mixed Pb-U aliquots of <100 pg Pb to closely imitate sample running behavior. Baseline measurements were made at each half-mass and the average intensity bounding each measured peak was subtracted. Isobaric interferences on ^{205}Pb were monitored by measuring mass 203, but repeated analyses of unspiked zircon show that the intensity of non-205Pb ions under mass 205 is trivial for this study. As a result, no corrections were applied, and the decay of mass 203 over the duration of the analysis relative to Pb is used as an indicator of declining isobaric interferences under all Pb masses. Data culling was done using decreasing 203/205 and increasing 206/204 ratios over the course of an analysis. U was measured in static mode on Faraday cups on 10^{12} ohm resistors as UO$_2$+. ^{233}UO$_2$ and ^{235}UO$_2$ were corrected for an oxygen isotopic composition of 0.002055 (see discussion in Condon et al., in press). Because ^{18}O/^{16}O typically grows at the beginning of an analysis before stabilizing, early blocks of data were deleted. Baselines were measured at ± 0.5 mass units for 15 seconds every 10 ratios. Correction for mass-fractionation of U was done using the EARTHTIME ^{205}Pb-^{233}U-^{235}U tracer solution assuming a sample ^{238}U/^{235}U ratio of 137.818±0.021 (Hiess et al., 2012). All data reduction, error propagation and plotting of U-Pb data was done using the U-Pb_Redux software package (Bowring et al., 2011; McLean et al., 2011). All reported uncertainties are 2-sigma and include internal sources of uncertainty only. Including systematic sources of uncertainty such as tracer composition and decay constants should be carried out for comparison with U-Pb data collected using a different tracer or with other isotopic systems, and can be done by accessing data from this study on the Geochron data storage website, given the uncertainties for tracer composition reported in Condon et al. (in press) and uncertainties for decay constants discussed in Schoene et al. (2006).

21 procedural blanks were measured over the course of this study, spiked with the same tracer. The amount of Pbc in the total procedural blanks (0.5-3.6 pg; avg. 1.1 pg) agreed well with that found in zircon analyses, and therefore all common Pb is assumed to derive from procedural blanks. After 2-sigma outlier rejection, the composition of 19 ^{205}Pb-^{233}U-^{235}U -spiked blanks was: ^{206}Pb/^{204}Pb = 18.50±0.10, ^{207}Pb/^{204}Pb = 15.56±0.21, ^{208}Pb/^{204}Pb = 37.48±0.34 (2-sigma standard deviation), and these uncertainties were propagated into each U-Pb analysis.

An important consideration in U-Pb geochronology of ca. 7 Ma zircons is the correction for initial secular disequilibrium in the U-Pb decay chain. During zircon crystallization, intermediate daughters products can be incorporated or excluded from the crystal depending on the zircon/magma distribution coefficient for each element. Our primary concern is the exclusion of ^{230}Th ($t_{1/2}$ = 75,380 years), a long-lived intermediate daughter product of ^{238}U, as initial depletion leads to a deficiency of ^{206}Pb and therefore apparent ^{206}Pb/^{238}U dates that are too young. This effect is generally corrected by using a model Th/U$_{zircon}$ calculated from the blank-subtracted ^{208}Pb/^{206}Pb$_{zircon}$ measured by ID-TIMS and an estimate of the Th/U$_{magma}$ at the time of the zircon crystallization.

We calculated the Th/U$_{magma}$ for each dated zircon by using the model Th/U$_{zircon}$ and Th/U zircon/melt distribution coefficients (D) experimentally determined by Rubatto and Hermann (2007) for hydrous granitic melt at 800°C (DTh = 41±4; DU =167±17). Uncertainties on the distribution coefficients were not propagated into our age uncertainties because this uncertainty is regarded as systematic for each grain, assuming a restricted temperature and compositional range of the magma. Additionally, the effect of changing intensive variables on the ratio of partition coefficients (DTh/U) is far less than the absolute values of each, further supporting the systematic nature of this uncertainty. As such, the differences between dated grains are insensitive to the disequilbrium correction. Our calculated values for Th/U$_{magma}$ are reported in Supplementary Table 1, and while these are not meant to be robust estimates of magma composition, they do illustrate that they yield Th/U$_{magma}$ ratios that are reasonable for the Elba samples.

2.2 Ryholite-MELTS model

The crystallization sequence of the Sant'Andrea, San Francesco and San Piero magmas was simulated using the modeling package Rhyolite-MELTS optimized for silica-rich, fluid-bearing magmatic systems (Gualda et al., 2012). We assumed closed system crystallization at isobaric conditions, regulated by the QFM oxygen fugacity buffer. Starting liquid equivalent to the whole-rock compositions of the Sant'Andrea facies sample PP-334 (Dini et al., 2002), San Francesco facies sample PP-364 (Dini et al., 2002) and San Piero facies sample MB11-2 (this study) were used. All these samples are close to the average composition of all samples reported for each facies in the literature (Dini et al., 2002; Farina et al., 2010). Other compositions do not significantly change the results.

We performed multiple runs for pressures ranging from 2 to 5 kbar and water contents between 1 and 6 wt%, with temperatures decreasing from 1200 to 500°C for each of the Capanne facies. Each run with different condi-tions was discarded if not closely matching observed petrological observations or modal proportions and micro-probe mineral measurements (Bussy, 1991) made on Sant'Andrea granite thin sections. We noticed that MELTS could not produce results bellow a pressure of 2.3 kbar. As our study tries to model the cooling evolution of the Capanne granite at emplacement level (ca. 2 Kbar; Bussy, 1991), we narrowed our selection to runs computed for 2.3 kbar. Our best-fit models for the three samples were performed with initial water content of 2 wt% (Supple-ment Fig.2A-2C). Though this water content best fit the observed mineral assemblages, we note that the absolute temperatures calculated (Supplementary Table 2) are very sensitive to the assumed water content. Uncertainties in these temperatures are therefore on the order of ±20°C for water contents of 1.5-2.5 %, with the added constraint that zircon saturation (807±11 °C, see Supplementary Methods section 2.3) must have occurred at <40% crystal content as indicated by pre-emplacement zircon crystallization and the megacryst inclusion history reported by Barboni and Schoene, (2014). Orthopyroxene was intentionally excluded as they were not observed, and MELTS produced them at the expense of biotite. The MELTS raw data are presented in Supplementary Table 2.

2.3 Zr-saturation temperature

Zircon saturation temperature was estimated using the same technique as described in Barboni and Schoene, (2014). Published saturation experiments (Watson and Harrison, 1983; Boehnke et al., 2013) were integrated with our MELTS model. We assumed an initial melt Zr concentration equal to bulk rock and calculated liquid Zr con-

tent during crystallization using bulk partition coefficients (from the GERM database: http://earthref.org/GERM/) for the saturated phases predicted by MELTS. The major element composition of the coexisting liquid was used to determine the M parameter used in the zircon saturation calculation (Supplementary Table 3 and Supplementary Fig. 2). We then calculated the Zr concentration required for saturation in the evolving liquid using Watson and Harrison (1983) and Boehnke et al. (2013), yielding temperatures of ca. 805 °C for all three Capanne facies, ~10-50 °C hotter than that predicted using only bulk rock chemistry alone (Watson and Harrison, 1983; Supplement Fig.2). Uncertainties of ±11 °C in this temperature were calculated by calculating the maximum and minimum temperature permitted by the calibration uncertainties reported in Boehnke et al. (2013).

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MB11-1 San Piero

7.819±0.005 Ma
7.022±0.018 Ma
7.110±0.005 Ma
7.350±0.005 Ma
7.473±0.005 Ma
7.070±0.012 Ma
7.387±0.008 Ma
100μm
7.035±0.006 Ma
100μm
7.518±0.010 Ma

MB11-2 San Piero

7.378±0.008 Ma
7.160±0.007 Ma
7.270±0.004 Ma
7.270±0.004 Ma
7.007±0.008 Ma
7.171±0.005 Ma
7.411±0.005 Ma
7.042±0.018 Ma
100μm
100μm

MB11-5 Orano Dyke

7.365±0.021 Ma
7.307±0.007 Ma
7.172±0.014 Ma
7.350±0.007 Ma
7.429±0.012 Ma
7.345±0.005 Ma
7.080±0.005 Ma
100μm
7.361±0.006 Ma
7.906±0.009 Ma
7.212±0.014 Ma
7.299±0.011 Ma
7.328±0.008 Ma
100μm
100μm

Supplementary Fig.2. CL images of the zircon measured in this study with u-Pb ages (2-sigma uncertainties)

8

MB11-6 Sant Andrea

7.438±0.009 Ma

7.437±0.010 Ma

50μm

7.378±0.005 Ma

50μm

7.551±0.019 Ma

7.391±0.016 Ma

7.484±0.005 Ma

100μm

7.466±0.007 Ma

7.323±0.019 Ma

100μm

7.567±0.006 Ma

7.402±0.006 Ma

100μm

7.376±0.013 Ma

7.521±0.005 Ma

7.648±0.005 Ma

7.495±0.010 Ma

100μm

MB11-11 Portoferraio Porphyry

7.978±0.011 Ma

8.001±0.005 Ma

7.994±0.018 Ma

7.999±0.005 Ma

100μm

7.997±0.004 Ma

8.009±0.012 Ma

7.999±0.005 Ma

100μm

8.008±0.007 Ma

MB11-14 San Martino Porphyry

100μm

7.437±0.011 Ma

7.541±0.006 Ma

7.783±0.005 Ma

7.501±0.011 Ma

7.504±0.006 Ma

7.522±0.012 Ma   7.504±0.008 Ma

7.504±0.006 Ma

100μm

7.510±0.005 Ma

100μm

Supplementary Fig.2. CL images of the zircon measured in this study with u-Pb ages (2-sigma uncertainties)

9

MB12-4 San Francesco

7.410±0.020Ma
7.291±0.014 Ma
7.388±0.006 Ma
7.400±0.004 Ma
7.276±0.007 Ma
7.358±0.009 Ma
7.328±0.005 Ma
7.423±0.005 Ma
7.418±0.008 Ma
7.471±0.009 Ma
7.438±0.006 Ma
7.166±0.007 Ma
8.458±0.007 Ma
7.291±0.006 Ma
7.354±0.014 Ma
7.408±0.005 Ma
7.272±0.005 Ma
200μm

MB12-8 San Francesco

7.239±0.008 Ma
7.715±0.028 Ma
7.260±0.004 Ma
7.224±0.008 Ma
7.347±0.004 Ma
7.220±0.012 Ma
7.257±0.005 Ma
7.363±0.005 Ma
7.309±0.004 Ma
7.172±0.005 Ma
7.404±0.003 Ma
7.300±0.006 Ma
200μm
200μm
200μm

MB12-9 Sant'Andrea

7.279±0.010 Ma
7.406±0.005 Ma
7.395±0.007 Ma
7.329±0.005 Ma
7.403±0.006 Ma
7.283±0.007 Ma
7.355±0.005 Ma
7.236±0.005 Ma
7.288±0.011 Ma
200μm
200μm
200μm

Supplementary Fig.2. CL images of the zircon measured in this study with u-Pb ages (2-sigma uncertainties)

Supplementary Table 2: U-Pb isotopic data

Sample	Th/U zircon	Th/U melt	Pb*/Pbc	Pbc (pg)	$^{206}Pb/^{204}Pb$	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	% err	$^{207}Pb/^{235}U$	% err	$^{206}Pb/^{238}U$	% err	corr. coef.	$^{207}Pb/^{206}Pb$	±	$^{207}Pb/^{235}U$	±	$^{206}Pb/^{238}U$	±	$^{206}Pb/^{238}U$	±
			Compositional parameters				Radiogenic Isotope Ratios							Dates (Ma)							
(a)	(b)	(c)	(d)	(d)	(e)	(f)	(f)	(g)	(f)	(g)	(f)	(g)	(h)	(h)	(g)	(h)	(g)	(i)	(g)	(h)	(g)
MB11-6	Sant'Andrea granite (Capanne pluton) - (N 42°80'01.1" /E 10°14'09.1") n=20; as published in Barboni and Schoene (2014)																				
z11	0.21	0.84	1.5	5.90	115	0.067	0.048482	4.560	0.007598	4.735	0.001137	0.261	0.739	122.9	107.41	7.685	0.362	7.240	0.020	**7.323**	**0.019**
z9	0.17	0.69	1.8	1.43	136	0.056	0.045340	4.109	0.007142	4.254	0.001143	0.190	0.840	-37.4	99.74	7.227	0.306	7.279	0.015	**7.361**	**0.014**
z2	0.16	0.65	1.8	2.04	139	0.053	0.046022	3.863	0.007265	3.994	0.001145	0.170	0.856	-1.2	93.13	7.350	0.292	7.295	0.013	**7.376**	**0.013**
z7	0.13	0.53	6.4	0.99	449	0.043	0.046038	1.099	0.007270	1.143	0.001145	0.072	0.708	-0.4	26.50	7.355	0.084	7.297	0.006	**7.378**	**0.005**
z15	0.16	0.65	1.4	3.49	113	0.051	0.047116	4.793	0.007453	4.961	0.001147	0.216	0.860	55.1	114.34	7.540	0.373	7.309	0.017	**7.392**	**0.016**
z13	0.14	0.57	1.9	3.49	145	0.046	0.046807	3.584	0.007414	3.706	0.001149	0.163	0.850	39.4	85.74	7.500	0.277	7.320	0.013	**7.401**	**0.012**
z7_2	0.18	0.73	7.9	1.16	538	0.058	0.046618	0.901	0.007385	0.938	0.001149	0.080	0.543	29.7	21.60	7.471	0.070	7.320	0.006	**7.402**	**0.006**
z23	0.28	1.14	2.7	2.97	189	0.090	0.047055	2.642	0.007489	2.754	0.001154	0.141	0.835	52.0	63.07	7.576	0.208	7.354	0.011	**7.437**	**0.010**
z3	0.16	0.65	3.2	3.64	233	0.052	0.046744	2.124	0.007441	2.198	0.001155	0.121	0.703	36.2	50.85	7.527	0.165	7.356	0.009	**7.438**	**0.009**
z11_2	0.16	0.65	2.4	3.65	175	0.052	0.046846	2.888	0.007482	2.991	0.001158	0.139	0.825	41.4	69.08	7.569	0.226	7.381	0.011	**7.463**	**0.010**
z22	0.25	1.02	5.7	2.09	388	0.081	0.046349	1.178	0.007406	1.244	0.001159	0.100	0.710	15.8	28.31	7.492	0.093	7.384	0.008	**7.466**	**0.007**
z6	0.12	0.49	3.8	1.21	275	0.039	0.046040	1.854	0.007363	1.914	0.001160	0.092	0.764	-0.3	44.70	7.449	0.142	7.391	0.007	**7.473**	**0.007**
z18	0.16	0.67	7.9	2.41	542	0.053	0.046263	0.884	0.007410	0.922	0.001162	0.066	0.647	11.3	21.27	7.496	0.069	7.402	0.005	**7.484**	**0.005**
z19	0.07	0.29	5.6	2.62	404	0.023	0.043999	1.465	0.007058	1.471	0.001163	0.137	0.202	-110.7	36.08	7.141	0.105	7.413	0.011	**7.495**	**0.010**
z4	0.14	0.57	10.7	1.75	730	0.045	0.046928	0.661	0.007539	0.685	0.001165	0.058	0.517	45.6	15.80	7.626	0.052	7.424	0.004	**7.507**	**0.004**
z21	0.24	0.98	8.8	1.75	587	0.077	0.046743	0.802	0.007524	0.836	0.001167	0.066	0.590	36.1	19.20	7.611	0.063	7.439	0.005	**7.521**	**0.005**
z16	0.23	0.94	1.3	3.72	101	0.075	0.046618	5.557	0.007533	5.763	0.001172	0.254	0.865	29.7	133.20	7.620	0.438	7.468	0.020	**7.551**	**0.019**
z16_2	0.56	2.28	7.2	2.47	446	0.181	0.046765	1.063	0.007574	1.109	0.001175	0.074	0.666	37.3	25.44	7.661	0.085	7.485	0.006	**7.568**	**0.006**
z20	0.17	0.70	17.9	1.19	1202	0.056	0.046207	0.407	0.007563	0.439	0.001187	0.063	0.580	8.4	9.79	7.650	0.033	7.566	0.005	**7.648**	**0.005**
z17	0.24	0.96	4.6	2.31	319	0.076	0.046835	1.526	0.007892	1.588	0.001222	0.102	0.668	40.8	36.50	7.982	0.126	7.791	0.008	**7.873**	**0.008**
MB11-14	San Martino porphyry (N 42°74'65.4" /E 10°25'02.8") n=15; as published in Barboni and Schoene (2014)																				
z23	0.35	1.43	4.6	0.87	309	0.112	0.044224	1.927	0.007038	2.043	0.0011543	0.144	0.830	-98.2	47.34	7.122	0.145	7.354	0.011	**7.437**	**0.011**
z18	0.19	0.78	10.6	0.67	715	0.062	0.046483	0.689	0.007410	0.720	0.0011562	0.060	0.597	22.8	16.54	7.497	0.054	7.367	0.005	**7.449**	**0.004**
z25	0.38	1.55	8.7	1.58	563	0.122	0.046755	0.969	0.007456	1.012	0.0011566	0.102	0.475	36.7	23.20	7.543	0.076	7.369	0.008	**7.452**	**0.008**
z16	0.30	1.18	7.7	1.17	511	0.096	0.046252	0.961	0.007388	1.003	0.0011585	0.071	0.639	10.8	23.12	7.474	0.075	7.382	0.005	**7.464**	**0.005**
z17	0.27	1.10	2.2	1.89	161	0.086	0.046485	3.487	0.007462	3.622	0.0011642	0.193	0.750	22.8	83.68	7.549	0.272	7.418	0.015	**7.501**	**0.014**
z21	0.16	0.65	9.7	0.60	665	0.052	0.046413	0.797	0.007451	0.838	0.0011643	0.080	0.590	19.1	19.15	7.537	0.063	7.419	0.006	**7.501**	**0.006**
z12	0.26	1.05	5.6	0.98	379	0.083	0.045513	1.358	0.007309	1.390	0.0011647	0.086	0.446	-28.1	32.91	7.394	0.102	7.421	0.007	**7.504**	**0.006**
z8	0.21	0.85	3.5	2.32	247	0.068	0.047013	2.006	0.007550	2.089	0.0011647	0.113	0.790	49.9	47.90	7.637	0.159	7.421	0.009	**7.504**	**0.008**
z14	0.17	0.69	12.3	2.66	830	0.055	0.046555	0.569	0.007482	0.597	0.0011657	0.067	0.498	26.4	13.66	7.569	0.045	7.428	0.005	**7.510**	**0.005**
z22	0.29	1.18	18.0	0.94	1166	0.095	0.046696	0.435	0.007506	0.461	0.0011658	0.057	0.517	33.7	10.42	7.593	0.035	7.429	0.004	**7.511**	**0.004**
z26	0.32	1.31	7.2	1.44	473	0.105	0.045889	1.175	0.007387	1.213	0.0011676	0.160	0.317	-8.2	28.38	7.473	0.090	7.443	0.007	**7.522**	**0.012**
z10	0.29	1.19	5.5	0.97	367	0.094	0.045939	1.414	0.007398	1.474	0.0011681	0.092	0.701	-5.6	34.13	7.485	0.110	7.440	0.012	**7.525**	**0.007**
z24	0.31	1.27	11.8	0.87	766	0.101	0.046337	0.698	0.007478	0.722	0.0011705	0.079	0.379	15.2	16.77	7.565	0.054	7.459	0.006	**7.541**	**0.006**
z11	0.08	0.31	8.7	1.17	612	0.025	0.046824	0.790	0.007799	0.820	0.001208	0.068	0.592	40.2	18.89	7.888	0.064	7.701	0.006	**7.783**	**0.005**
z7	0.04	0.15	9.1	2.14	642	0.012	0.046786	0.747	0.007957	0.761	0.0012335	0.063	0.556	38.3	17.88	8.048	0.061	7.865	0.005	**7.947**	**0.005**

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Supplementary Table 2: U-Pb isotopic data (cont.)

	Compositional parameters						Radiogenic Isotope Ratios							Dates (Ma)							
Sample	$\frac{Th}{U}$ zircon	$\frac{Th}{U}$ melt	$\frac{Pb^*}{Pbc}$	Pbc (pg)	$\frac{206Pb}{204Pb}$	$\frac{208Pb}{206Pb}$	$\frac{207Pb}{206Pb}$	% err	$\frac{207Pb}{235U}$	% err	$\frac{206Pb}{238U}$	% err	corr. coef.	$\frac{207Pb}{206Pb}$	±	$\frac{207Pb}{235U}$	±	$\frac{206Pb}{238U}$	±	$\frac{206Pb}{238U}$	±
(a)	(b)	(c)	(d)	(d)	(e)	(f)	(f)	(g)	(f)	(g)	(f)	(g)		(h)	(g)	(h)	(g)	(i)	(g)	(h)	(g)
MB11-1	San Piero granite (Capanne pluton) - (N 42°74'67.2" /E 10°20'88.5") n=16																				
z17	0.19	0.78	18.1	0.52	1208	0.063	0.046512	0.445	0.006972	0.488	0.0010879	0.064	0.459	24.3	10.68	7.059	0.033	6.927	0.005	7.009	0.005
z2	0.16	0.67	1.3	1.87	105	0.053	0.046180	5.490	0.006935	5.693	0.00109	0.253	0.857	7.0	132.15	7.023	0.398	6.940	0.019	7.022	0.018
z10	0.22	0.90	6.2	0.83	423	0.072	0.045444	1.280	0.006637	1.336	0.0010919	0.084	0.641	-31.8	31.04	6.923	0.092	6.953	0.006	7.035	0.006
z5	0.14	0.57	2.3	0.95	174	0.045	0.046070	3.341	0.006965	3.451	0.0010973	0.163	0.756	1.3	80.50	7.053	0.242	6.987	0.012	7.070	0.012
z8	0.27	1.09	6.7	1.70	452	0.087	0.046787	1.055	0.007114	1.109	0.0011035	0.074	0.659	38.4	25.26	7.203	0.079	7.027	0.005	7.110	0.005
z11	0.19	0.78	4.7	0.81	329	0.060	0.046196	1.613	0.007106	1.682	0.0011164	0.093	0.744	7.8	38.81	7.194	0.120	7.109	0.007	7.192	0.007
z9	0.23	0.94	18.8	1.79	1238	0.075	0.046454	0.398	0.007157	0.444	0.0011182	0.066	0.484	21.2	9.55	7.246	0.031	7.122	0.005	7.204	0.005
z7	0.16	0.65	33.2	2.45	2221	0.052	0.046603	0.245	0.007311	0.320	0.0011385	0.111	0.604	28.9	5.87	7.401	0.022	7.253	0.008	7.335	0.008
z1	0.20	0.83	1.8	2.57	136	0.066	0.046727	3.869	0.007333	4.012	0.0011389	0.179	0.840	35.3	92.64	7.423	0.296	7.256	0.014	7.338	0.013
z4	0.16	0.65	14.0	1.68	945	0.052	0.046675	0.503	0.007337	0.545	0.0011408	0.064	0.507	32.6	12.05	7.427	0.039	7.268	0.005	7.350	0.005
z13	0.13	0.53	3.1	3.60	228	0.043	0.047016	2.166	0.007428	2.247	0.0011465	0.111	0.789	50.1	51.73	7.519	0.168	7.305	0.009	7.387	0.008
z16	0.24	0.98	16.6	0.56	1092	0.077	0.046453	0.451	0.007424	0.494	0.0011599	0.063	0.481	21.2	10.84	7.515	0.036	7.390	0.005	7.473	0.005
z14	0.28	1.14	4.7	0.81	318	0.092	0.046708	1.872	0.007511	1.949	0.0011669	0.136	0.591	34.3	44.82	7.602	0.147	7.436	0.011	7.518	0.010
z15	0.27	1.10	19.2	0.63	1254	0.087	0.046451	0.437	0.007489	0.478	0.001170	0.067	0.436	21.1	10.51	7.580	0.035	7.455	0.005	7.538	0.005
z18	0.34	1.39	15.4	0.76	987	0.112	0.046317	0.513	0.007746	0.557	0.0012137	0.063	0.537	14.1	12.34	7.840	0.042	7.737	0.005	7.819	0.005
z12	0.11	0.45	17.5	0.78	1176	0.034	0.068451	0.287	0.017678	0.321	0.0018736	0.059	0.591	882.2	5.95	17.798	0.056	11.983	0.007	12.067	0.007
MB11-2	San Piero granite (Capanne pluton) - (N 42°76'23.4" /E 10°20'07.6") n=22																				
z7	0.38	1.53	8.6	1.83	312	0.122	0.046548	1.600	0.006975	1.700	0.001088	0.110	0.712	26.0	39.00	7.060	0.120	6.925	0.008	7.007	0.008
z25	0.14	0.57	1.5	1.17	102	0.046	0.046467	5.800	0.006995	6.000	0.001093	0.260	0.864	21.0	140.00	7.080	0.420	6.960	0.020	7.042	0.018
z26	0.09	0.37	12.8	0.95	935	0.029	0.046383	0.570	0.007012	0.610	0.001098	0.061	0.463	16.0	14.00	7.099	0.042	6.989	0.004	7.072	0.004
z21	0.1	0.41	17.6	1.13	1077	0.032	0.046684	0.490	0.007084	0.540	0.001102	0.082	0.520	32.0	12.00	7.172	0.038	7.016	0.006	7.099	0.006
z3	0.22	0.9	9.2	1.67	378	0.071	0.046905	1.300	0.007165	1.300	0.001109	0.085	0.643	44.0	31.00	7.254	0.096	7.060	0.006	7.143	0.006
z12	0.14	0.57	30.3	0.63	3230	0.045	0.046583	0.180	0.007129	0.250	0.001111	0.075	0.608	27.9	4.30	7.218	0.015	7.074	0.005	7.156	0.005
z2	0.25	1.02	8.5	1.82	321	0.081	0.046803	1.500	0.007167	1.600	0.001111	0.099	0.686	39.0	36.00	7.260	0.110	7.078	0.007	7.160	0.007
z8	0.19	0.76	31.6	2.05	1030	0.06	0.046386	0.460	0.007114	0.510	0.001113	0.069	0.550	18.0	11.00	7.203	0.036	7.089	0.005	7.171	0.005
z17	0.15	0.61	16.4	0.76	1451	0.049	0.046639	0.340	0.007155	0.380	0.001113	0.057	0.482	30.8	8.10	7.244	0.026	7.092	0.004	7.174	0.004
z10	0.2	0.82	13.8	0.58	1583	0.064	0.046658	0.320	0.007189	0.370	0.001118	0.058	0.494	31.8	7.80	7.278	0.025	7.122	0.004	7.204	0.004
z16	0.18	0.73	24.0	0.77	2081	0.059	0.046532	0.280	0.00717	0.350	0.001118	0.069	0.771	25.3	6.60	7.259	0.024	7.123	0.005	7.205	0.005
z22	0.14	0.57	16.0	0.90	1200	0.044	0.046801	0.400	0.007237	0.440	0.001122	0.060	0.499	39.1	9.60	7.326	0.031	7.147	0.004	7.230	0.004
z24	0.18	0.73	14.3	0.91	1056	0.057	0.046403	0.460	0.007189	0.500	0.001125	0.061	0.485	18.0	11.00	7.278	0.035	7.164	0.005	7.247	0.004
z14	0.13	0.53	17.3	0.8	1458	0.043	0.046327	0.380	0.007199	0.430	0.001128	0.066	0.525	14.6	9.10	7.288	0.029	7.184	0.005	7.266	0.005
z23	0.16	0.65	8.4	0.58	980	0.052	0.046554	0.540	0.007235	0.590	0.001128	0.060	0.520	25.0	13.00	7.325	0.042	7.188	0.005	7.270	0.004
z5	0.16	0.67	19.7	2.52	535	0.053	0.046903	0.880	0.007334	0.930	0.001135	0.074	0.637	44.0	21.00	7.424	0.068	7.228	0.006	7.311	0.005
z20	0.18	0.73	24.8	1.10	1511	0.057	0.046665	0.350	0.007296	0.400	0.001135	0.080	0.480	31.0	8.40	7.386	0.028	7.231	0.006	7.314	0.006
z4	0.16	0.65	24.4	0.87	1872	0.051	0.046593	0.270	0.007302	0.320	0.001137	0.061	0.477	28.4	6.40	7.392	0.021	7.245	0.005	7.328	0.004
z19	0.19	0.78	7.3	1.73	298	0.06	0.046508	1.700	0.007335	1.800	0.001145	0.110	0.683	23.0	42.00	7.430	0.130	7.295	0.009	7.378	0.008
z13	0.13	0.49	18.5	0.47	2634	0.041	0.046713	0.210	0.007404	0.270	0.00115	0.062	0.544	34.6	5.00	7.495	0.018	7.330	0.005	7.411	0.005
z1	0.13	0.53	6.7	1.29	363	0.042	0.046709	1.300	0.007713	1.400	0.001198	0.080	0.715	34.0	32.00	7.810	0.110	7.638	0.007	7.720	0.006
z6	0.24	0.97	17.2	1.16	979	0.077	0.05307	0.430	0.014471	0.470	0.001978	0.064	0.497	331.8	9.90	14.593	0.067	12.658	0.008	12.740	0.008

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Supplementary Table 2: U-Pb isotopic data (cont.)

	Compositional parameters						Radiogenic Isotope Ratios							Dates (Ma)							
Sample	$\frac{Th}{U}$ zircon	$\frac{Th}{U}$ melt	$\frac{Pb*}{Pbc}$	Pbc (pg)	$\frac{^{206}Pb}{^{204}Pb}$	$\frac{^{208}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{206}Pb}$	% err	$\frac{^{207}Pb}{^{235}U}$	% err	$\frac{^{206}Pb}{^{238}U}$	% err	corr. coef.	$\frac{^{207}Pb}{^{206}Pb}$	±	$\frac{^{207}Pb}{^{235}U}$	±	$\frac{^{206}Pb}{^{238}U}$	±	$\frac{^{206}Pb}{^{238}U}$	±
(a)	(b)	(c)	(d)	(d)	(e)	(f)	(f)	(g)	(f)	(g)	(f)	(g)		(h)	(g)	(h)	(g)	(i)	(g)	(h)	(g)
MB11-5	Orano Dykes (N 42°75'89.8''/E 10°29'68.2'') n=26																				
z24	0.19	0.73	7.6	0.93	519	0.060	0.046667	0.964	0.007063	1.010	0.001099	0.069	0.608	31.1	23.11	7.151	0.071	6.998	0.005	7.080	0.005
z2	0.11	0.45	22.9	1.46	1562	0.036	0.046652	0.326	0.007069	0.378	0.001100	0.088	0.455	31.5	7.83	7.157	0.025	7.002	0.006	7.085	0.006
z8	0.31	0.22	1.8	1.68	133	0.099	0.047198	4.064	0.007240	4.157	0.001113	0.189	0.847	59.3	96.86	7.329	0.303	7.217	0.014	7.172	0.014
z23	0.30	1.22	2.2	0.87	158	0.097	0.041980	4.060	0.006472	4.221	0.001119	0.195	0.834	-228.8	102.31	6.555	0.275	7.130	0.015	7.212	0.014
z18	0.33	1.35	3.0	0.72	211	0.108	0.045500	2.808	0.007084	2.933	0.001130	0.157	0.799	-29.9	68.07	7.173	0.209	7.201	0.012	7.284	0.011
z29	0.35	1.43	2.6	1.63	183	0.112	0.045646	3.051	0.007122	3.178	0.001133	0.157	0.811	-22.1	73.86	7.210	0.228	7.216	0.012	7.299	0.011
z6	0.27	1.41	4.9	1.30	332	0.088	0.045199	1.522	0.007063	1.591	0.001134	0.092	0.711	-44.9	37.02	7.151	0.113	7.219	0.007	7.307	0.007
z21	0.26	1.06	3.0	0.99	215	0.084	0.043481	2.895	0.006795	3.002	0.001135	0.140	0.775	-141.1	71.71	6.881	0.206	7.228	0.011	7.311	0.010
z17	0.21	0.86	4.8	1.03	335	0.069	0.044983	1.643	0.007046	1.713	0.001137	0.105	0.676	-57.7	40.04	7.134	0.121	7.246	0.008	7.328	0.008
z14	0.14	0.57	11.0	1.21	755	0.045	0.046482	0.687	0.007298	0.727	0.001140	0.070	0.497	21.6	16.50	7.388	0.053	7.262	0.005	7.344	0.005
z15	0.14	0.57	11.0	0.92	752	0.045	0.046444	0.681	0.007293	0.723	0.001140	0.070	0.511	19.6	16.38	7.383	0.052	7.263	0.005	7.345	0.005
z16	0.35	1.43	9.0	1.30	586	0.113	0.046772	0.869	0.007349	0.925	0.001141	0.093	0.557	36.5	20.81	7.439	0.068	7.268	0.007	7.350	0.007
z1b	0.27	1.08	2.9	3.40	202	0.086	0.047080	2.458	0.007401	2.585	0.001141	0.380	0.409	53.3	58.65	7.492	0.193	7.268	0.028	7.350	0.028
z20	0.28	1.14	7.5	0.93	503	0.089	0.045566	1.036	0.007162	1.088	0.001141	0.074	0.638	-26.4	25.11	7.250	0.078	7.269	0.006	7.352	0.005
z27	0.11	0.45	23.6	0.84	1608	0.034	0.046539	0.317	0.007318	0.363	0.001142	0.055	0.500	24.6	7.64	7.408	0.025	7.272	0.004	7.355	0.004
z1t	0.20	0.81	5.4	3.75	375	0.064	0.046746	1.276	0.007360	1.333	0.001143	0.084	0.669	36.3	30.55	7.450	0.098	7.279	0.006	7.361	0.006
z10	0.16	0.72	1.2	1.13	97	0.051	0.040770	6.951	0.006421	7.180	0.001143	0.281	0.856	-302.0	177.73	6.504	0.465	7.280	0.022	7.365	0.021
z5	0.24	1.11	4.1	1.68	286	0.078	0.045511	1.819	0.007170	1.897	0.001143	0.108	0.722	-28.2	44.09	7.259	0.137	7.281	0.008	7.366	0.008
z26	0.14	0.57	15.9	0.53	1081	0.044	0.046567	0.480	0.007337	0.527	0.001144	0.086	0.452	26.0	11.54	7.427	0.038	7.287	0.006	7.370	0.006
z11	0.18	2.80	4.0	3.37	283	0.057	0.046795	1.715	0.007376	1.791	0.001144	0.104	0.703	38.8	41.04	7.467	0.133	7.268	0.008	7.370	0.008
z3	0.25	1.04	2.7	3.12	192	0.082	0.046490	2.726	0.007387	2.828	0.001153	0.155	0.687	23.1	65.42	7.477	0.210	7.347	0.012	7.429	0.012
z25	0.05	0.20	6.0	1.03	431	0.016	0.046083	1.193	0.007359	1.233	0.001159	0.077	0.701	0.9	28.77	7.449	0.091	7.389	0.006	7.470	0.006
z19	0.20	0.82	11.7	0.96	788	0.064	0.045868	0.633	0.007333	0.676	0.001161	0.067	0.524	-10.4	15.30	7.424	0.049	7.396	0.005	7.479	0.005
z22	0.17	0.69	4.3	1.46	304	0.057	0.046201	1.661	0.007411	1.729	0.001165	0.094	0.740	7.0	39.99	7.502	0.129	7.422	0.007	7.503	0.007
z9	0.05	0.64	14.2	1.99	994	0.018	0.046247	0.489	0.007645	0.531	0.001200	0.066	0.510	10.5	11.77	7.738	0.040	7.629	0.005	7.729	0.005
z28	0.39	1.59	3.7	1.07	249	0.125	0.045977	2.084	0.007772	2.173	0.001227	0.115	0.766	-4.7	50.28	7.865	0.170	7.824	0.009	7.906	0.009
MB11-11	Portoferraio Porphyry (N 42°49'21.6''/E 10°17'13.6'') n=14																				
z11	0.49	2.00	7.7	1.05	482	0.160	0.0450387	1.177	0.007647	1.134	0.001233	0.095	0.425	-29.4	27.45	7.740	0.090	7.860	0.008	7.942	0.008
z19	0.63	2.57	6.3	2.30	387	0.204	0.045738	1.607	0.007787	1.533	0.001236	0.113	0.642	7.8	36.84	7.881	0.126	7.881	0.009	7.963	0.009
z16	0.33	1.35	3.6	0.69	245	0.106	0.0445817	2.522	0.007604	2.427	0.001238	0.132	0.720	-54.1	58.96	7.697	0.193	7.896	0.011	7.978	0.011
z13	0.22	0.90	1.6	1.47	122	0.070	0.0478542	4.754	0.008179	4.572	0.001241	0.223	0.849	115.6	107.31	8.276	0.391	7.911	0.019	7.994	0.018
z7	0.38	1.55	11.7	0.52	748	0.122	0.0465837	0.687	0.007963	0.652	0.001241	0.054	0.509	51.7	15.54	8.059	0.054	7.913	0.004	7.996	0.004
z22	0.15	0.57	17.5	0.78	1183	0.047	0.0464617	0.534	0.007944	0.495	0.001241	0.049	0.584	45.1	11.78	8.039	0.042	7.916	0.004	7.997	0.004
z18	0.14	0.57	7.0	1.14	483	0.046	0.0449932	1.139	0.007694	1.085	0.001242	0.068	0.757	-32.2	26.14	7.787	0.088	7.917	0.006	7.999	0.005
z8	0.28	1.14	7.1	1.59	474	0.092	0.0464122	1.084	0.007937	1.035	0.001242	0.068	0.658	42.7	24.67	8.032	0.086	7.917	0.006	7.999	0.005
z20	0.18	0.73	6.5	1.07	445	0.057	0.0462939	1.194	0.007918	1.164	0.001242	0.061	0.489	36.8	27.73	8.013	0.095	7.917	0.005	8.000	0.005
z15	0.18	0.73	6.3	1.04	436	0.059	0.046678	1.220	0.007985	1.178	0.001242	0.066	0.615	56.3	27.96	8.080	0.098	7.919	0.006	8.001	0.005
z2	0.22	0.90	8.5	0.92	570	0.072	0.046565	0.896	0.007970	0.855	0.001243	0.061	0.595	50.5	20.34	8.066	0.071	7.924	0.005	8.006	0.005

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Supplementary Table 2: U-Pb isotopic data (cont.)

Sample	Compositional parameters						Radiogenic Isotope Ratios							Dates (Ma)							
	Th/U zircon	Th/U melt	Pb*/Pbc	Pbc (pg)	206Pb/204Pb	208Pb/206Pb	207Pb/206Pb	% err	207Pb/235U	% err	206Pb/238U	% err	corr. coef.	207Pb/206Pb	±	207Pb/235U	±	206Pb/238U	±	206Pb/238U	±
(a)	(b)	(c)	(d)	(d)	(e)	(f)	(f)	(g)	(f)	(g)	(f)	(g)		(h)	(g)	(h)	(g)	(i)	(g)	(h)	(g)
MB11-11	Portoferraio Porphyry (N 42°49'21.6"/E 10°17'13.6") *(cont.)*																				
z21	0.17	0.69	5.3	1.23	370	0.055	0.0461816	1.386	0.007907	1.444	0.001243	0.083	0.705	30.8	33.04	8.002	0.115	7.926	0.007	8.008	0.007
z1	0.19	0.78	3.4	3.34	243	0.062	0.0464509	2.024	0.007957	2.104	0.001243	0.146	0.596	45.8	48.12	8.052	0.168	7.927	0.012	8.009	0.012
z3	0.37	1.51	8.4	2.77	543	0.119	0.0494844	0.814	0.017911	0.851	0.002627	0.054	0.657	181.2	18.96	18.030	0.152	16.830	0.009	16.913	0.009
MB12-4	San Francesco granite (Cappane pluton) - (N 42°77'09.5"/E 10°16'89.5") n=27																				
z1	0.16	0.66	5.3	4.27	369	0.053	0.046504	1.319	0.007127	1.378	0.001112	0.100	0.610	51.4	31.26	7.216	0.099	7.084	0.007	7.166	0.007
z28	0.18	0.73	4.3	1.89	300	0.058	0.046940	1.619	0.007284	1.688	0.001127	0.097	0.722	72.2	38.27	7.374	0.124	7.176	0.007	7.259	0.007
z36	0.09	0.37	8.3	0.73	581	0.030	0.046585	0.865	0.007242	0.899	0.001129	0.065	0.514	54.0	20.42	7.332	0.065	7.191	0.005	7.272	0.005
z38	0.21	0.86	5.9	0.95	403	0.069	0.046002	1.334	0.007156	1.399	0.001129	0.102	0.625	24.0	31.86	7.244	0.100	7.194	0.008	7.276	0.007
z32	0.14	0.57	5.8	1.07	403	0.046	0.045232	1.271	0.007045	1.329	0.001131	0.080	0.711	-16.8	30.52	7.133	0.094	7.204	0.006	7.286	0.006
z27	0.14	0.57	2.0	1.32	149	0.046	0.045860	3.815	0.007151	3.957	0.001132	0.188	0.821	17.4	90.97	7.240	0.285	7.209	0.015	7.291	0.014
z37	0.10	0.41	6.5	1.08	460	0.034	0.046898	1.082	0.007310	1.126	0.001132	0.079	0.599	69.8	25.47	7.400	0.082	7.210	0.006	7.291	0.006
z39	0.10	0.41	7.8	0.87	547	0.033	0.046441	0.947	0.007241	0.988	0.001132	0.078	0.537	46.7	22.41	7.331	0.072	7.212	0.006	7.294	0.006
z35	0.13	0.53	13.4	0.46	916.5	0.043	0.046318	0.614	0.007256	0.656	0.001137	0.065	0.534	40.1	14.58	7.346	0.047	7.246	0.005	7.328	0.005
z21	0.22	0.90	5.6	0.55	386.7	0.070	0.046616	1.332	0.007316	1.394	0.001139	0.093	0.662	56.8	31.60	7.406	0.102	7.255	0.007	7.338	0.007
z26	0.19	0.78	11.6	1.14	783.7	0.062	0.046482	0.683	0.007295	0.726	0.001139	0.071	0.515	49.7	16.23	7.385	0.053	7.256	0.005	7.338	0.005
z9	0.19	0.78	7.8	1.49	533.9	0.062	0.046629	0.907	0.007333	0.956	0.001141	0.088	0.527	57.2	21.51	7.423	0.070	7.271	0.007	7.353	0.006
z11	0.18	0.73	1.7	1.53	128.9	0.058	0.046990	4.128	0.007391	4.284	0.001141	0.196	0.844	75.6	97.49	7.481	0.319	7.272	0.015	7.354	0.014
z24	0.21	0.86	3.6	0.40	253.7	0.069	0.046402	2.118	0.007302	2.205	0.001142	0.117	0.764	45.4	50.35	7.392	0.162	7.276	0.009	7.358	0.009
z29	0.12	0.49	5.3	2.38	376.9	0.039	0.046791	1.285	0.007390	1.339	0.001147	0.080	0.701	64.3	30.35	7.481	0.099	7.305	0.006	7.388	0.006
z23	0.23	0.94	7.1	0.47	477.7	0.075	0.046253	1.164	0.007309	1.223	0.001147	0.088	0.644	37.7	27.73	7.399	0.090	7.306	0.007	7.388	0.006
z22	0.30	1.22	21.8	0.48	1404	0.098	0.046526	0.404	0.007364	0.440	0.001149	0.060	0.371	51.6	9.61	7.455	0.031	7.318	0.004	7.400	0.004
z25	0.19	0.78	10.2	0.43	691.2	0.063	0.046553	0.800	0.007375	0.839	0.001150	0.071	0.485	53.0	18.99	7.466	0.062	7.326	0.005	7.408	0.005
z7	0.11	0.43	1.1	1.99	93.77	0.034	0.046630	6.504	0.007390	6.703	0.001150	0.266	0.872	57.0	153.51	7.481	0.499	7.328	0.022	7.410	0.020
z8	0.22	0.90	3.8	0.89	266.1	0.072	0.046522	1.933	0.007381	2.011	0.001151	0.108	0.736	51.5	45.93	7.471	0.149	7.335	0.008	7.418	0.008
z19	0.14	0.57	5.8	0.70	405.6	0.045	0.046319	1.292	0.007353	1.317	0.001152	0.065	0.399	41.1	30.70	7.444	0.097	7.340	0.005	7.423	0.005
z12	0.18	0.73	4.7	2.56	326.9	0.058	0.046939	1.463	0.007467	1.527	0.001155	0.086	0.751	72.6	34.57	7.559	0.115	7.356	0.007	7.438	0.006
z30	0.18	0.73	8.6	0.85	587.3	0.058	0.046480	0.859	0.007424	0.978	0.001160	0.116	0.954	48.0	20.39	7.515	0.073	7.389	0.009	7.471	0.009
z34	0.22	0.9	12.7	0.80	845	0.072	0.046838	0.595	0.007573	0.638	0.001174	0.071	0.496	66.0	14.11	7.665	0.048	7.481	0.005	7.563	0.005
z40	0.16	0.65	8.5	0.82	585.2	0.052	0.046054	1.012	0.007525	1.076	0.001186	0.091	0.681	25.4	24.12	7.617	0.081	7.561	0.007	7.643	0.007
z31	0.14	0.56	11.0	0.67	748.3	0.046	0.053683	0.640	0.009709	0.708	0.001313	0.077	0.849	378.5	14.30	9.816	0.069	8.377	0.007	8.458	0.007
z18	0.09	0.37	10.8	0.98	752.2	0.028	0.048976	0.620	0.009761	0.660	0.001446	0.062	0.605	167.7	14.39	9.867	0.064	9.232	0.006	9.316	0.006

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Supplementary Table 2: U-Pb isotopic data (cont.)

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	Compositional parameters					Radiogenic Isotope Ratios									Dates (Ma)							
Sample	Th/U zircon	Th/U melt	Pb*/Pbc	Pbc (pg)	206Pb/204Pb	208Pb/206Pb	% err	207Pb/206Pb	% err	207Pb/235U	% err	206Pb/238U	% err	corr. coef.	207Pb/206Pb	±	207Pb/235U	±	206Pb/238U	±	206Pb/238U	±
(a)	(b)	(c)	(d)	(d)	(e)	(f)	(g)	(f)	(g)	(f)	(g)	(f)	(g)	(g)	(h)	(g)	(h)	(g)	(i)	(g)	(h)	(g)
MB12-8	San Francesco granite (Cappane pluton) - (N 42°76'93.2" /E 10°18'77.9") n=16																					
z2	0.17	0.67	9.4	1.65	640	0.054	0.798	0.045977	0.844	0.007052	0.064	0.001113	0.064	0.633	24.1	19.0	7.140	0.059	7.089	0.005	7.172	0.005
z1	0.19	0.77	6.7	2.69	459	0.062	1.064	0.046177	1.111	0.007090	0.064	0.001114	0.064	0.682	34.5	25.3	7.179	0.079	7.097	0.005	7.180	0.005
z21	0.26	1.06	2.4	0.63	176	0.083	3.077	0.046673	3.198	0.007204	0.169	0.001121	0.169	0.739	59.0	73.0	7.293	0.232	7.138	0.013	7.220	0.012
z20	0.22	0.90	5.0	0.65	347	0.072	1.589	0.045618	1.673	0.007045	0.106	0.001121	0.106	0.774	4.0	38.1	7.133	0.118	7.142	0.008	7.224	0.008
z13	0.26	1.06	5.6	1.33	377	0.085	1.526	0.046175	1.598	0.007149	0.112	0.001124	0.112	0.642	34.2	36.4	7.238	0.115	7.157	0.008	7.239	0.008
z10	0.11	0.45	11.7	0.93	807	0.036	0.656	0.046767	0.693	0.007258	0.072	0.001126	0.072	0.449	64.7	15.5	7.348	0.050	7.174	0.005	7.257	0.005
z16	0.14	0.57	6.9	0.86	476	0.045	1.029	0.046607	1.071	0.007237	0.059	0.001127	0.059	0.683	56.5	24.4	7.327	0.078	7.178	0.004	7.260	0.004
z22	0.13	0.53	25.1	0.63	1699	0.044	0.302	0.046632	0.341	0.007251	0.046	0.001129	0.046	0.395	56.2	7.2	7.341	0.023	7.193	0.003	7.274	0.003
z14	0.13	0.53	15.4	0.40	1052	0.041	0.512	0.046609	0.539	0.007254	0.047	0.001129	0.047	0.358	56.7	12.1	7.344	0.038	7.194	0.003	7.277	0.003
z11	0.14	0.57	7.9	0.82	546	0.046	0.954	0.046558	1.001	0.007269	0.079	0.001133	0.079	0.584	53.7	22.6	7.359	0.073	7.218	0.006	7.300	0.006
z4	0.17	0.68	4.9	1.28	343.2	0.0541	1.444	0.0465217	1.501	0.007270	0.086	0.001134	0.086	0.678	51.9	34.3	7.360	0.110	7.224	0.007	7.307	0.006
z15	0.22	0.90	20.4	0.53	1348	0.0711	0.389	0.0466782	0.428	0.007297	0.060	0.001134	0.060	0.420	59.9	9.2	7.387	0.030	7.226	0.004	7.309	0.004
z5	0.22	0.90	9.3	0.99	621.8	0.0717	0.772	0.0464455	0.811	0.007298	0.053	0.001140	0.053	0.613	47.8	18.4	7.388	0.059	7.264	0.004	7.347	0.004
z17	0.17	0.65	7.0	0.63	482.1	0.0535	1.095	0.0462571	1.142	0.007284	0.065	0.001143	0.065	0.685	37.7	26.0	7.374	0.083	7.281	0.005	7.363	0.005
z18	0.10	0.41	19.6	0.73	1345	0.0327	0.375	0.0465314	0.407	0.007368	0.038	0.001149	0.038	0.429	52.0	8.9	7.459	0.029	7.322	0.003	7.404	0.003
z19	0.22	0.90	0.9	1.43	76	0.0719	8.111	0.0461928	8.413	0.007619	0.358	0.001197	0.358	0.879	32.3	193.4	7.711	0.646	7.633	0.029	7.715	0.028
MB12-9	San Francesco granite (Cappane pluton) - (N 42°76'93.2" /E 10°18'77.9") n=12																					
z12	0.21	0.82	18.7	0.61	1240	0.0684	0.419	0.046551	0.465	0.007204	0.070	0.001123	0.070	0.478	53.2	10.0	7.294	0.032	7.155	0.005	7.236	0.005
z13	0.23	0.94	2.5	2.72	184	0.0751	2.735	0.046815	2.843	0.007257	0.133	0.001125	0.133	0.835	67.0	64.8	7.346	0.208	7.166	0.010	7.248	0.010
z16	0.30	1.22	3.0	0.49	208.9	0.0983	2.663	0.045715	2.775	0.007114	0.140	0.001130	0.140	0.801	8.8	63.9	7.202	0.199	7.197	0.011	7.279	0.010
z18	0.21	0.86	4.8	1.19	334.2	0.0673	1.464	0.046972	1.528	0.007313	0.086	0.001130	0.086	0.734	74.0	34.6	7.403	0.112	7.200	0.006	7.282	0.006
z5	0.16	0.67	18.0	1.37	1209	0.053	0.407	0.046247	0.466	0.007203	0.099	0.001130	0.099	0.520	37.9	9.7	7.293	0.033	7.200	0.007	7.283	0.007
z6	0.11	0.44	3.0	3.72	218.3	0.0347	2.699	0.045296	2.798	0.007060	0.151	0.001131	0.151	0.739	-12.1	64.6	7.148	0.199	7.205	0.012	7.288	0.011
z3	0.09	0.38	19.3	1.65	1324	0.0305	0.386	0.046560	0.442	0.007298	0.072	0.001137	0.072	0.609	53.7	9.1	7.388	0.031	7.247	0.005	7.329	0.005
z4	0.17	0.70	11.2	1.54	756.3	0.0554	0.689	0.046360	0.738	0.007293	0.073	0.001142	0.073	0.585	43.4	16.4	7.383	0.053	7.273	0.005	7.355	0.005
z19	0.16	0.65	10.4	1.07	706.3	0.0526	0.707	0.046598	0.741	0.007332	0.058	0.001142	0.058	0.484	54.3	16.8	7.422	0.054	7.278	0.004	7.360	0.004
z1	0.14	0.55	8.4	2.55	579.7	0.0441	0.859	0.046106	0.908	0.007292	0.098	0.001148	0.098	0.503	30.0	20.4	7.382	0.066	7.313	0.007	7.395	0.007
z14	0.30	1.22	9.3	0.63	607.4	0.0976	0.855	0.046740	0.901	0.007397	0.079	0.001149	0.079	0.525	61.6	20.3	7.488	0.067	7.321	0.006	7.403	0.006
z15	0.13	0.53	19.1	0.69	1298	0.0422	0.387	0.046593	0.433	0.007376	0.061	0.001149	0.061	0.518	54.1	9.2	7.467	0.031	7.323	0.005	7.406	0.005

(a) z1, z2 etc. are labels for single zircon grains or fragment of grain; all zircons annealed and chemically abraded after Mattinson (2005).
(b) Model Th/U ratio calculated from radiogenic 208Pb/206Pb ratio and 207Pb/235U age
(c) Th/U melt was calculated using the model Th/U zircon of (b) and kd's from Rubatto and Herman (2007)
(d) Pb* and Pbc represent radiogenic and common Pb, respectively
(e) Measured ratio corrected for spike and fractionation only
(f) Corrected for fractionation, spike and common Pb, which was assumed to be blank: 206Pb/204Pb = 18.50±0.10; 207Pb/204Pb = 15.56±0.21; 208Pb/204Pb = 37.48±0.34 (2-sigma standard deviation)
    206Pb/238U and 207Pb/206Pb ratios corrcted for initial disequilibrium in 230Th/238U using Th/U melt from (c)
(g) Errors are 2-sigma, propagated using the alogorithmy of McLean et al., (2011) and Crowley et al., (2007).
(h) Calculations are based on the decay constants of Jaffey et al., (1971). 206Pb/238U and 207Pb/206Pb ages corrected for initial disequilibrium in 230Th/238U using Th/U melt from (c)
(i) Raw 206Pb/238U ages before correction for initial disequilibrium in 230Th/238U

Supplementary Table 2 Rhyolite-MELTS modeling results: melt composition

San Francesco (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	wt% SiO2 melt	wt% TiO2 melt	wt% Al2O3 melt	wt% FeO melt	wt% MgO melt	wt% CaO melt	wt% Na2O melt	wt% K2O melt	wt% H2O melt
1006	67.44	0.58	16.03	1.94	1.21	2.51	3.50	4.08	1.99
996	67.50	0.58	16.09	1.88	1.13	2.51	3.51	4.10	2.00
986	67.56	0.58	16.14	1.82	1.05	2.51	3.53	4.11	2.01
976	67.69	0.59	16.12	1.76	0.97	2.48	3.52	4.16	2.03
966	67.99	0.61	15.96	1.70	0.89	2.36	3.45	4.26	2.10
956	68.28	0.62	15.80	1.65	0.82	2.25	3.37	4.37	2.16
946	68.56	0.64	15.64	1.58	0.75	2.15	3.29	4.48	2.22
936	68.82	0.66	15.49	1.52	0.69	2.06	3.20	4.59	2.29
926	69.09	0.68	15.35	1.45	0.64	1.98	3.10	4.69	2.35
916	69.34	0.70	15.21	1.38	0.59	1.91	3.00	4.80	2.42
906	69.58	0.71	15.07	1.31	0.54	1.84	2.89	4.90	2.48
896	69.89	0.68	14.93	1.22	0.50	1.78	2.79	5.00	2.55
886	70.20	0.64	14.80	1.13	0.47	1.72	2.67	5.10	2.62
876	70.49	0.61	14.67	1.04	0.44	1.67	2.56	5.20	2.69
866	70.77	0.57	14.54	0.96	0.41	1.62	2.45	5.30	2.76
856	71.05	0.54	14.42	0.88	0.38	1.58	2.33	5.39	2.82
846	71.31	0.51	14.30	0.80	0.36	1.54	2.22	5.47	2.89
836	71.56	0.48	14.18	0.74	0.34	1.50	2.11	5.55	2.95
826	71.80	0.45	14.06	0.67	0.32	1.47	2.00	5.63	3.02
816	72.03	0.43	13.95	0.61	0.30	1.44	1.89	5.70	3.08
806	72.05	0.40	13.93	0.56	0.29	1.41	1.79	5.82	3.18
796	71.84	0.37	14.02	0.51	0.27	1.39	1.71	5.97	3.33
786	71.60	0.34	14.12	0.49	0.27	1.40	1.69	5.91	3.58
776	71.30	0.30	14.22	0.49	0.25	1.41	1.67	5.85	3.85
766	70.93	0.26	14.35	0.53	0.21	1.43	1.66	5.77	4.14
756	70.53	0.22	14.48	0.56	0.18	1.45	1.65	5.68	4.46
746	70.02	0.19	14.70	0.57	0.16	1.49	1.63	5.59	4.78
736	69.54	0.17	14.89	0.55	0.14	1.51	1.63	5.49	5.16
726	68.08	0.16	16.28	0.50	0.13	1.68	1.29	5.44	5.18
716	65.94	0.15	16.85	0.42	0.12	2.58	1.12	5.25	5.28
706	64.78	0.16	17.93	0.33	0.11	2.73	0.94	5.13	5.34
696	63.63	0.15	18.86	0.27	0.10	2.94	0.81	4.99	5.41
686	62.44	0.15	19.69	0.22	0.09	3.21	0.71	4.84	5.49
676	58.24	0.13	19.39	0.23	0.09	4.67	0.70	4.18	6.33

Supplementary Table 2 Rhyolite-MELTS modeling results: melt composition

Sant'Andrea (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	wt% SiO2 melt	wt% TiO2 melt	wt% Al2O3 melt	wt% FeO melt	wt% MgO melt	wt% CaO melt	wt% Na2O melt	wt% K2O melt	wt% H2O melt
968	69.08	0.39	15.89	1.68	0.85	2.20	3.09	4.25	1.99
958	69.25	0.39	15.85	1.62	0.79	2.15	3.06	4.31	2.02
948	69.55	0.40	15.69	1.56	0.72	2.04	2.98	4.41	2.08
938	69.85	0.41	15.55	1.50	0.66	1.94	2.90	4.51	2.13
928	70.13	0.42	15.40	1.43	0.61	1.85	2.80	4.61	2.19
918	70.41	0.44	15.26	1.37	0.56	1.77	2.71	4.70	2.24
908	70.67	0.45	15.13	1.30	0.51	1.69	2.61	4.80	2.30
898	70.93	0.46	15.00	1.22	0.47	1.63	2.51	4.89	2.36
888	71.19	0.47	14.88	1.15	0.44	1.56	2.40	4.98	2.41
878	71.43	0.48	14.75	1.08	0.40	1.51	2.29	5.07	2.47
868	71.67	0.49	14.64	1.01	0.37	1.45	2.19	5.16	2.53
858	71.90	0.50	14.52	0.94	0.35	1.40	2.08	5.24	2.58
848	72.13	0.51	14.41	0.87	0.32	1.36	1.97	5.32	2.64
838	72.39	0.49	14.30	0.79	0.30	1.32	1.86	5.40	2.69
828	72.23	0.45	14.40	0.73	0.29	1.27	1.77	5.58	2.81
818	72.05	0.42	14.51	0.67	0.27	1.24	1.68	5.77	2.93
808	71.86	0.40	14.62	0.62	0.26	1.20	1.59	5.94	3.05
798	71.65	0.37	14.75	0.57	0.25	1.18	1.52	6.05	3.21
788	71.40	0.34	14.89	0.54	0.24	1.17	1.49	6.01	3.44
778	71.14	0.31	15.05	0.51	0.23	1.17	1.46	5.95	3.69
768	70.82	0.27	15.22	0.51	0.22	1.17	1.43	5.88	3.96
758	70.43	0.23	15.43	0.54	0.19	1.16	1.41	5.80	4.24
748	70.01	0.20	15.66	0.56	0.16	1.16	1.39	5.71	4.55
738	69.48	0.18	16.05	0.53	0.14	1.16	1.34	5.62	4.84
728	68.86	0.17	16.56	0.50	0.13	1.16	1.27	5.53	5.12
718	67.44	0.16	17.61	0.41	0.12	1.49	1.07	5.41	5.16
708	66.37	0.17	18.69	0.32	0.11	1.62	0.90	5.30	5.19
698	65.37	0.16	19.66	0.26	0.10	1.76	0.78	5.18	5.24
688	64.04	0.16	20.33	0.21	0.09	2.19	0.68	5.02	5.31

Supplementary Table 2 Rhyolite-MELTS modeling results: melt composition

San Piero (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	wt% SiO2 melt	wt% TiO2 melt	wt% Al2O3 melt	wt% FeO melt	wt% MgO melt	wt% CaO melt	wt% Na2O melt	wt% K2O melt	wt% H2O melt
1076	68.21	0.58	14.87	2.81	1.72	1.95	2.23	4.84	2.01
1066	68.29	0.58	14.94	2.73	1.60	1.96	2.24	4.86	2.02
1056	68.37	0.59	15.01	2.65	1.49	1.96	2.25	4.88	2.03
1046	68.45	0.59	15.07	2.57	1.39	1.97	2.26	4.91	2.04
1036	68.53	0.59	15.13	2.49	1.29	1.97	2.27	4.93	2.05
1026	68.61	0.59	15.20	2.40	1.20	1.98	2.28	4.96	2.06
1016	68.69	0.60	15.25	2.31	1.11	1.98	2.29	4.98	2.07
1006	68.77	0.60	15.31	2.22	1.03	1.98	2.30	5.00	2.08
996	68.85	0.60	15.37	2.12	0.96	1.98	2.31	5.02	2.08
986	68.93	0.60	15.42	2.03	0.89	1.98	2.32	5.05	2.09
976	69.01	0.61	15.48	1.93	0.83	1.98	2.33	5.07	2.10
966	69.09	0.61	15.53	1.83	0.77	1.98	2.34	5.09	2.11
956	69.17	0.61	15.58	1.74	0.71	1.98	2.35	5.11	2.12
946	69.25	0.61	15.63	1.64	0.66	1.97	2.36	5.13	2.13
936	69.33	0.61	15.67	1.54	0.61	1.97	2.37	5.15	2.14
926	69.41	0.62	15.72	1.45	0.57	1.96	2.38	5.17	2.14
916	69.62	0.63	15.65	1.36	0.53	1.90	2.32	5.24	2.18
906	69.89	0.64	15.52	1.27	0.49	1.81	2.24	5.35	2.23
896	70.15	0.65	15.40	1.18	0.45	1.73	2.15	5.45	2.28
886	70.40	0.67	15.28	1.10	0.42	1.65	2.06	5.55	2.33
876	70.68	0.65	15.16	1.01	0.39	1.58	1.96	5.65	2.39
866	70.97	0.61	15.05	0.92	0.37	1.52	1.86	5.75	2.44
856	71.25	0.58	14.94	0.84	0.35	1.46	1.76	5.84	2.49
846	71.51	0.55	14.84	0.77	0.32	1.41	1.67	5.93	2.54
836	71.76	0.52	14.74	0.70	0.31	1.36	1.57	6.01	2.59
826	71.99	0.49	14.64	0.63	0.29	1.31	1.47	6.09	2.63
816	71.84	0.46	14.74	0.58	0.27	1.27	1.38	6.27	2.74
806	71.63	0.42	14.88	0.54	0.27	1.27	1.33	6.25	2.94
796	71.41	0.39	15.02	0.51	0.26	1.27	1.29	6.21	3.16
786	71.16	0.36	15.18	0.48	0.25	1.27	1.25	6.17	3.38
776	70.89	0.32	15.35	0.46	0.25	1.27	1.22	6.11	3.63
766	70.52	0.28	15.56	0.49	0.21	1.27	1.18	6.04	3.88
756	70.13	0.24	15.79	0.52	0.18	1.26	1.15	5.96	4.15
746	69.70	0.21	16.05	0.54	0.16	1.26	1.12	5.87	4.44
736	69.10	0.19	16.56	0.51	0.14	1.26	1.05	5.78	4.68
726	68.36	0.17	16.47	0.49	0.12	1.52	1.12	5.60	5.10
716	67.03	0.17	17.57	0.38	0.11	1.77	0.92	5.50	5.14
706	65.87	0.17	18.56	0.30	0.11	1.98	0.77	5.37	5.19
696	64.75	0.17	19.46	0.25	0.10	2.18	0.66	5.23	5.25
686	63.54	0.16	20.22	0.20	0.09	2.50	0.58	5.06	5.33
676	58.87	0.13	19.55	0.22	0.09	4.36	0.58	4.34	6.20

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: modal proportions

San Francesco (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	% liquid	% crystal	% Kfd	% qz	% plag	% biotite	% illmnite	% cpx
1006	1.00	0.00	-	-	-	-	-	0.23
996	1.00	0.00	-	-	-	-	-	0.62
986	0.99	0.01	-	-	-	-	-	1.01
976	0.98	0.02	-	-	0.74	-	-	1.44
966	0.95	0.05	-	-	3.12	-	-	1.94
956	0.93	0.07	-	-	5.42	-	-	2.42
946	0.90	0.10	-	-	7.62	-	-	2.85
936	0.87	0.13	-	-	9.74	-	-	3.26
926	0.85	0.15	-	-	11.77	-	-	3.64
916	0.83	0.17	-	-	13.71	-	-	4.00
906	0.81	0.19	-	-	15.56	-	-	4.33
896	0.78	0.22	-	-	17.39	-	0.08	4.59
886	0.76	0.24	-	-	19.13	-	0.17	4.81
876	0.74	0.26	-	-	20.79	-	0.26	5.02
866	0.73	0.27	-	-	22.36	-	0.33	5.20
856	0.71	0.29	-	-	23.84	-	0.40	5.37
846	0.69	0.31	-	-	25.26	-	0.46	5.52
836	0.68	0.32	-	-	26.59	-	0.52	5.66
826	0.66	0.34	-	-	27.86	-	0.57	5.78
816	0.65	0.35	-	-	29.07	-	0.62	5.89
806	0.63	0.37	-	0.55	30.36	-	0.67	5.99
796	0.60	0.40	0.34	1.70	31.56	-	0.72	6.08
786	0.56	0.44	3.10	3.16	31.44	-	0.79	6.15
776	0.51	0.49	5.39	4.90	31.61	0.43	0.87	5.84
766	0.47	0.53	7.25	6.83	31.99	1.23	0.95	5.24
756	0.43	0.57	8.92	8.53	32.33	1.87	1.01	4.75
746	0.38	0.62	9.22	12.65	33.72	4.44	0.63	-
736	0.35	0.65	10.74	13.73	33.85	4.57	0.68	-
726	0.23	0.77	15.79	17.83	35.53	4.68	0.74	-
716	0.10	0.90	22.79	21.31	35.03	3.56	1.18	-
706	0.08	0.92	23.84	22.06	35.33	3.39	1.18	-
696	0.06	0.94	24.43	22.51	35.56	3.28	1.18	-
686	0.05	0.95	24.79	22.81	35.75	3.20	1.18	-
676	0.00	1.00	26.44	24.36	35.74	3.27	1.20	-

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: modal proportions

Sant'Andrea (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	% liquid	% crystal	% Kld	% qz	% plag	% biotite	% illmnite	% cpx
968	1.00	0.00	-	-	-	-	-	0.94
958	0.99	0.01	-	-	0.98	-	-	1.34
948	0.96	0.04	-	-	3.16	-	-	1.78
938	0.94	0.06	-	-	5.26	-	-	2.20
928	0.91	0.09	-	-	7.28	-	-	2.59
918	0.89	0.11	-	-	9.21	-	-	2.95
908	0.87	0.13	-	-	11.06	-	-	3.29
898	0.85	0.15	-	-	12.83	-	-	3.61
888	0.83	0.17	-	-	14.52	-	-	3.90
878	0.81	0.19	-	-	16.13	-	-	4.18
868	0.79	0.21	-	-	17.66	-	-	4.43
858	0.78	0.23	-	-	19.12	-	-	4.66
848	0.76	0.24	-	-	20.50	-	-	4.88
838	0.74	0.26	-	-	21.84	-	0.05	5.03
828	0.71	0.29	-	1.29	23.45	-	0.13	5.18
818	0.68	0.32	-	2.53	24.96	-	0.20	5.30
808	0.66	0.35	-	3.70	26.39	-	0.26	5.41
798	0.62	0.38	0.89	4.94	27.29	-	0.33	5.51
788	0.58	0.42	3.60	6.41	27.22	-	0.40	5.58
778	0.54	0.46	6.03	7.77	27.23	-	0.46	5.64
768	0.50	0.50	8.11	9.28	27.40	0.27	0.52	5.48
758	0.46	0.54	9.79	10.99	27.77	0.91	0.58	5.00
748	0.43	0.57	11.32	12.52	28.10	1.45	0.63	4.61
738	0.38	0.62	11.53	16.34	29.34	3.73	0.24	-
728	0.34	0.66	13.63	17.95	29.76	3.84	0.29	-
718	0.18	0.83	21.99	22.39	29.53	2.65	0.75	-
708	0.14	0.86	23.47	23.52	29.98	2.52	0.76	-
698	0.12	0.88	24.38	24.24	30.30	2.43	0.77	-
688	0.00	1.00	25.64	25.32	30.52	2.38	0.78	-

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: modal proportions

San Piero (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	% liquid	% crystal	% Kld	% qz	% plag	% biotite	% illmnite	% cpx
1076	1.00	0.00	-	-	-	-	-	0.26
1066	0.99	0.01	-	-	-	-	-	0.78
1056	0.99	0.01	-	-	-	-	-	1.27
1046	0.98	0.02	-	-	-	-	-	1.76
1036	0.98	0.02	-	-	-	-	-	2.23
1026	0.97	0.03	-	-	-	-	-	2.69
1016	0.97	0.03	-	-	-	-	-	3.13
1006	0.96	0.04	-	-	-	-	-	3.57
996	0.96	0.04	-	-	-	-	-	3.99
986	0.96	0.05	-	-	-	-	-	4.40
976	0.95	0.05	-	-	-	-	-	4.80
966	0.95	0.05	-	-	-	-	-	5.19
956	0.94	0.06	-	-	-	-	-	5.57
946	0.94	0.06	-	-	-	-	-	5.93
936	0.94	0.06	-	-	-	-	-	6.29
926	0.93	0.07	-	-	-	-	-	6.63
916	0.92	0.08	-	-	-	-	-	7.00
906	0.90	0.10	-	-	-	-	-	7.36
896	0.88	0.12	-	-	-	-	-	7.70
886	0.86	0.14	-	-	-	-	-	8.00
876	0.84	0.16	-	-	-	-	0.06	8.24
866	0.82	0.18	-	-	-	-	0.14	8.43
856	0.80	0.20	-	-	-	-	0.22	8.60
846	0.79	0.21	-	-	1.20	-	0.29	8.76
836	0.77	0.23	-	-	4.32	-	0.36	8.89
826	0.76	0.24	-	-	7.05	-	0.42	9.02
816	0.73	0.27	0.03	1.20	9.45	-	0.49	9.13
806	0.68	0.32	3.08	2.90	11.58	-	0.59	9.21
796	0.63	0.37	5.80	4.48	13.49	-	0.68	9.29
786	0.59	0.41	8.24	5.95	15.22	-	0.75	9.35
776	0.55	0.45	10.42	7.39	16.58	0.07	0.82	9.35
766	0.50	0.50	11.96	9.63	17.55	1.23	0.91	8.47
756	0.46	0.54	13.35	11.56	18.41	2.17	0.97	7.75
746	0.42	0.58	14.60	13.27	19.06	2.97	1.03	7.15
736	0.37	0.63	14.08	18.53	20.28	6.45	0.42	-
726	0.23	0.77	21.84	21.97	24.53	5.24	1.06	-
716	0.15	0.85	25.46	24.33	26.30	4.76	1.16	-
706	0.12	0.88	26.82	25.38	27.32	4.57	1.16	-
696	0.10	0.90	27.64	26.05	27.96	4.43	1.17	-
686	0.08	0.92	28.33	26.67	30.74	4.34	1.17	-
676	0.00	1.00	31.08	29.32	31.08	4.51	1.20	-

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: feldspar compositions

San Francesco (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Plagioclase

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% CaO	wt% Na2O	wt% K2O	% ab	% an	% or
976	58.79	26.01	7.74	6.85	0.62	0.59	0.37	0.04
966	59.12	25.77	7.47	6.98	0.66	0.61	0.36	0.04
956	59.44	25.55	7.21	7.10	0.70	0.62	0.35	0.04
946	59.73	25.35	6.97	7.21	0.74	0.62	0.33	0.04
936	60.00	25.16	6.75	7.31	0.78	0.63	0.32	0.04
926	60.24	24.98	6.55	7.40	0.83	0.64	0.31	0.05
916	60.47	24.82	6.37	7.48	0.87	0.65	0.30	0.05
906	60.68	24.67	6.19	7.55	0.91	0.65	0.30	0.05
896	60.86	24.53	6.04	7.61	0.96	0.66	0.29	0.05
886	61.03	24.41	5.90	7.66	1.01	0.66	0.28	0.06
876	61.19	24.29	5.76	7.70	1.05	0.67	0.28	0.06
866	61.33	24.19	5.64	7.74	1.10	0.67	0.27	0.06
856	61.46	24.09	5.53	7.77	1.15	0.67	0.26	0.07
846	61.58	24.00	5.43	7.80	1.20	0.67	0.26	0.07
836	61.69	23.91	5.33	7.82	1.25	0.67	0.25	0.07
826	61.79	23.83	5.25	7.84	1.29	0.68	0.25	0.07
816	61.88	23.76	5.17	7.85	1.34	0.68	0.25	0.08
806	61.95	23.70	5.10	7.84	1.41	0.68	0.24	0.08
796	61.98	23.66	5.06	7.82	1.48	0.67	0.24	0.08
786	61.81	23.80	5.21	7.79	1.39	0.67	0.25	0.08
776	61.65	23.92	5.35	7.77	1.30	0.67	0.26	0.07
766	61.51	24.04	5.48	7.75	1.23	0.67	0.26	0.07
756	61.39	24.13	5.59	7.73	1.16	0.67	0.27	0.07
746	61.25	24.24	5.71	7.71	1.09	0.67	0.27	0.06
736	61.16	24.31	5.79	7.71	1.03	0.67	0.28	0.06
726	61.07	24.39	5.87	7.70	0.98	0.66	0.28	0.06
716	61.21	24.30	5.76	7.78	0.95	0.67	0.27	0.05
706	61.18	24.33	5.80	7.79	0.90	0.67	0.28	0.05
696	61.16	24.35	5.82	7.80	0.86	0.67	0.28	0.05
686	61.15	24.37	5.84	7.82	0.82	0.68	0.28	0.05
676	61.15	24.38	5.84	7.85	0.78	0.68	0.28	0.04

K-feldspar

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% CaO	wt% Na2O	wt% K2O	% ab	% an	% or
796	65.56	19.08	0.44	3.79	11.13	0.33	0.02	0.64
786	65.55	19.04	0.41	3.66	11.34	0.32	0.02	0.66
776	65.54	19.00	0.39	3.53	11.54	0.31	0.02	0.67
766	65.52	18.97	0.36	3.41	11.73	0.30	0.02	0.68
756	65.51	18.94	0.34	3.30	11.91	0.29	0.02	0.69
746	65.50	18.91	0.31	3.19	12.09	0.28	0.02	0.70
736	65.49	18.88	0.29	3.10	12.24	0.27	0.01	0.71
726	65.48	18.85	0.27	3.00	12.40	0.27	0.01	0.72
716	65.49	18.83	0.25	2.96	12.47	0.26	0.01	0.73
706	65.48	18.81	0.24	2.88	12.60	0.25	0.01	0.73
696	65.47	18.78	0.22	2.80	12.72	0.25	0.01	0.74
686	65.46	18.76	0.21	2.73	12.85	0.24	0.01	0.75
676	65.45	18.74	0.19	2.66	12.96	0.24	0.01	0.76

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: feldspar compositions

Sant'Andrea (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Plagioclase

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% CaO	wt% Na2O	wt% K2O	% ab	% an	% or
958	59.21	25.71	7.39	7.01	0.67	0.61	0.35	0.04
948	59.52	25.49	7.14	7.13	0.71	0.62	0.34	0.04
938	59.81	25.29	6.91	7.24	0.75	0.63	0.33	0.04
928	60.07	25.10	6.69	7.34	0.80	0.63	0.32	0.05
918	60.32	24.93	6.49	7.43	0.84	0.64	0.31	0.05
908	60.54	24.77	6.31	7.50	0.88	0.65	0.30	0.05
898	60.74	24.62	6.14	7.57	0.92	0.65	0.29	0.05
888	60.93	24.49	5.98	7.63	0.97	0.66	0.29	0.05
878	61.10	24.36	5.84	7.69	1.01	0.66	0.28	0.06
868	61.25	24.25	5.71	7.74	1.05	0.67	0.27	0.06
858	61.40	24.14	5.59	7.78	1.09	0.67	0.27	0.06
848	61.52	24.05	5.48	7.81	1.14	0.67	0.26	0.06
838	61.64	23.96	5.39	7.84	1.18	0.68	0.26	0.07
828	61.71	23.90	5.32	7.82	1.25	0.68	0.25	0.07
818	61.77	23.83	5.25	7.81	1.34	0.67	0.25	0.08
808	61.84	23.77	5.18	7.79	1.42	0.67	0.25	0.08
798	61.82	23.77	5.19	7.76	1.46	0.67	0.25	0.08
788	61.64	23.92	5.35	7.73	1.37	0.67	0.26	0.08
778	61.47	24.05	5.50	7.70	1.28	0.66	0.26	0.07
768	61.33	24.17	5.63	7.68	1.21	0.66	0.27	0.07
758	61.19	24.27	5.75	7.66	1.14	0.66	0.27	0.06
748	61.08	24.36	5.85	7.64	1.07	0.66	0.28	0.06
738	60.97	24.45	5.94	7.63	1.01	0.66	0.28	0.06
728	60.89	24.52	6.02	7.62	0.96	0.66	0.29	0.05
718	60.99	24.45	5.94	7.69	0.93	0.66	0.28	0.05
708	60.94	24.50	5.99	7.69	0.88	0.66	0.29	0.05
698	60.91	24.53	6.02	7.70	0.84	0.66	0.29	0.05
688	60.87	24.56	6.06	7.71	0.80	0.67	0.29	0.05

K-feldspar

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% CaO	wt% Na2O	wt% K2O	% ab	% an	% or
798	65.55	19.08	0.45	3.75	11.18	0.33	0.02	0.65
788	65.53	19.04	0.42	3.61	11.40	0.32	0.02	0.66
778	65.52	19.00	0.39	3.49	11.60	0.31	0.02	0.67
768	65.51	18.97	0.36	3.37	11.79	0.30	0.02	0.68
758	65.49	18.94	0.34	3.26	11.97	0.29	0.02	0.70
748	65.48	18.91	0.32	3.16	12.13	0.28	0.02	0.71
738	65.47	18.88	0.30	3.06	12.29	0.27	0.01	0.72
728	65.46	18.85	0.28	2.97	12.44	0.26	0.01	0.72
718	65.47	18.83	0.26	2.92	12.52	0.26	0.01	0.73
708	65.46	18.81	0.24	2.84	12.66	0.25	0.01	0.74
698	65.45	18.78	0.23	2.76	12.78	0.24	0.01	0.74
688	65.44	18.76	0.21	2.68	12.91	0.24	0.01	0.75

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: feldspar compositions

San Piero (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Plagioclase

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% CaO	wt% Na2O	wt% K2O	% ab	% an	% or
916	59.47	25.50	7.16	7.02	0.86	0.61	0.34	0.05
906	59.75	25.29	6.93	7.12	0.91	0.62	0.33	0.05
896	60.01	25.11	6.71	7.21	0.96	0.62	0.32	0.05
886	60.24	24.94	6.52	7.29	1.01	0.63	0.31	0.06
876	60.45	24.78	6.34	7.35	1.07	0.64	0.30	0.06
866	60.64	24.65	6.18	7.41	1.12	0.64	0.30	0.06
856	60.81	24.52	6.04	7.45	1.18	0.64	0.29	0.07
846	60.97	24.40	5.90	7.49	1.24	0.65	0.28	0.07
836	61.11	24.29	5.78	7.52	1.30	0.65	0.28	0.07
826	61.24	24.19	5.67	7.54	1.37	0.65	0.27	0.08
816	61.32	24.11	5.59	7.52	1.46	0.65	0.27	0.08
806	61.02	24.34	5.84	7.45	1.35	0.64	0.28	0.08
796	60.76	24.54	6.07	7.38	1.26	0.64	0.29	0.07
786	60.51	24.72	6.27	7.32	1.17	0.63	0.30	0.07
776	60.29	24.88	6.46	7.27	1.10	0.63	0.31	0.06
766	60.08	25.04	6.64	7.21	1.03	0.62	0.32	0.06
756	59.91	25.18	6.79	7.16	0.96	0.62	0.32	0.05
746	59.76	25.29	6.92	7.13	0.91	0.62	0.33	0.05
736	59.60	25.41	7.06	7.09	0.85	0.61	0.34	0.05
726	59.88	25.22	6.83	7.22	0.84	0.63	0.33	0.05
716	59.79	25.29	6.92	7.21	0.80	0.62	0.33	0.05
706	59.69	25.37	7.00	7.19	0.75	0.62	0.33	0.04
696	59.63	25.41	7.05	7.18	0.72	0.62	0.34	0.04
686	59.59	25.45	7.09	7.18	0.68	0.62	0.34	0.04
676	59.58	25.47	7.11	7.20	0.65	0.62	0.34	0.04

K-feldspar

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% CaO	wt% Na2O	wt% K2O	% ab	% an	% or
816	65.47	19.13	0.50	3.71	11.19	0.33	0.02	0.65
806	65.45	19.08	0.47	3.55	11.45	0.31	0.02	0.66
796	65.44	19.04	0.44	3.40	11.68	0.30	0.02	0.68
786	65.42	19.00	0.41	3.27	11.90	0.29	0.02	0.69
776	65.41	18.97	0.39	3.14	12.10	0.28	0.02	0.70
766	65.39	18.93	0.36	3.03	12.28	0.27	0.02	0.71
756	65.38	18.90	0.34	2.92	12.46	0.26	0.02	0.72
746	65.37	18.88	0.32	2.82	12.61	0.25	0.02	0.73
736	65.36	18.85	0.30	2.73	12.77	0.24	0.01	0.74
726	65.38	18.83	0.28	2.72	12.79	0.24	0.01	0.75
716	65.37	18.81	0.26	2.64	12.92	0.23	0.01	0.75
706	65.36	18.78	0.24	2.56	13.06	0.23	0.01	0.76
696	65.35	18.76	0.23	2.48	13.18	0.22	0.01	0.77
686	65.34	18.74	0.21	2.41	13.29	0.21	0.01	0.78
676	65.34	18.72	0.20	2.34	13.40	0.21	0.01	0.78

Supplementary Table 2 (cont) Rhyolite-MELTS modeling results: biotite compositions

San Francesco (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% FeO	wt% MgO	wt% K2O	wt% H2O
776	42.93	12.14	1.40	28.02	11.22	4.29
766	42.82	12.11	1.98	27.62	11.19	4.28
756	42.68	12.07	2.74	27.09	11.15	4.27
746	42.51	12.02	3.61	26.49	11.11	4.25
736	42.40	11.99	4.23	26.07	11.08	4.24
726	42.34	11.97	4.55	25.85	11.06	4.23
716	42.41	12.00	4.15	26.12	11.08	4.24
706	42.57	12.04	3.33	26.68	11.12	4.25
696	42.67	12.07	2.79	27.06	11.15	4.26
686	42.75	12.09	2.39	27.33	11.17	4.27
676	42.73	12.08	2.49	27.26	11.16	4.27

Sant'Andrea (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% FeO	wt% MgO	wt% K2O	wt% H2O
768	42.86	12.12	1.79	27.75	11.20	4.28
758	42.73	12.09	2.47	27.28	11.17	4.27
748	42.56	12.04	3.36	26.67	11.12	4.25
738	42.46	12.01	3.90	26.29	11.09	4.24
728	42.35	11.98	4.48	25.90	11.07	4.23
718	42.49	12.02	3.74	26.40	11.10	4.25
708	42.62	12.06	3.03	26.89	11.14	4.26
698	42.72	12.08	2.55	27.23	11.16	4.27
688	42.77	12.10	2.24	27.44	11.18	4.28

San Piero (P = 2.3 Kbar; initial water content = 2 wt%; OPX out; Qz-Fa-Mag buffer)

Temperature (°C)	wt% SiO2	wt% Al2O3	wt% FeO	wt% MgO	wt% K2O	wt% H2O
776	42.95	12.15	1.32	28.07	11.22	4.29
766	42.85	12.12	1.86	27.70	11.20	4.28
756	42.71	12.08	2.57	27.21	11.16	4.27
746	42.54	12.03	3.48	26.58	11.12	4.25
736	42.44	12.00	3.98	26.24	11.09	4.24
726	42.31	11.97	4.68	25.76	11.06	4.23
716	42.50	12.02	3.69	26.44	11.11	4.25
706	42.62	12.06	3.03	26.89	11.14	4.26
696	42.71	12.08	2.57	27.21	11.16	4.27
686	42.77	12.10	2.24	27.44	11.18	4.28
676	42.74	12.09	2.44	27.30	11.17	4.27

Supplementary Table 3a Zircon saturation temperature modeling (Sant'Andrea granite)
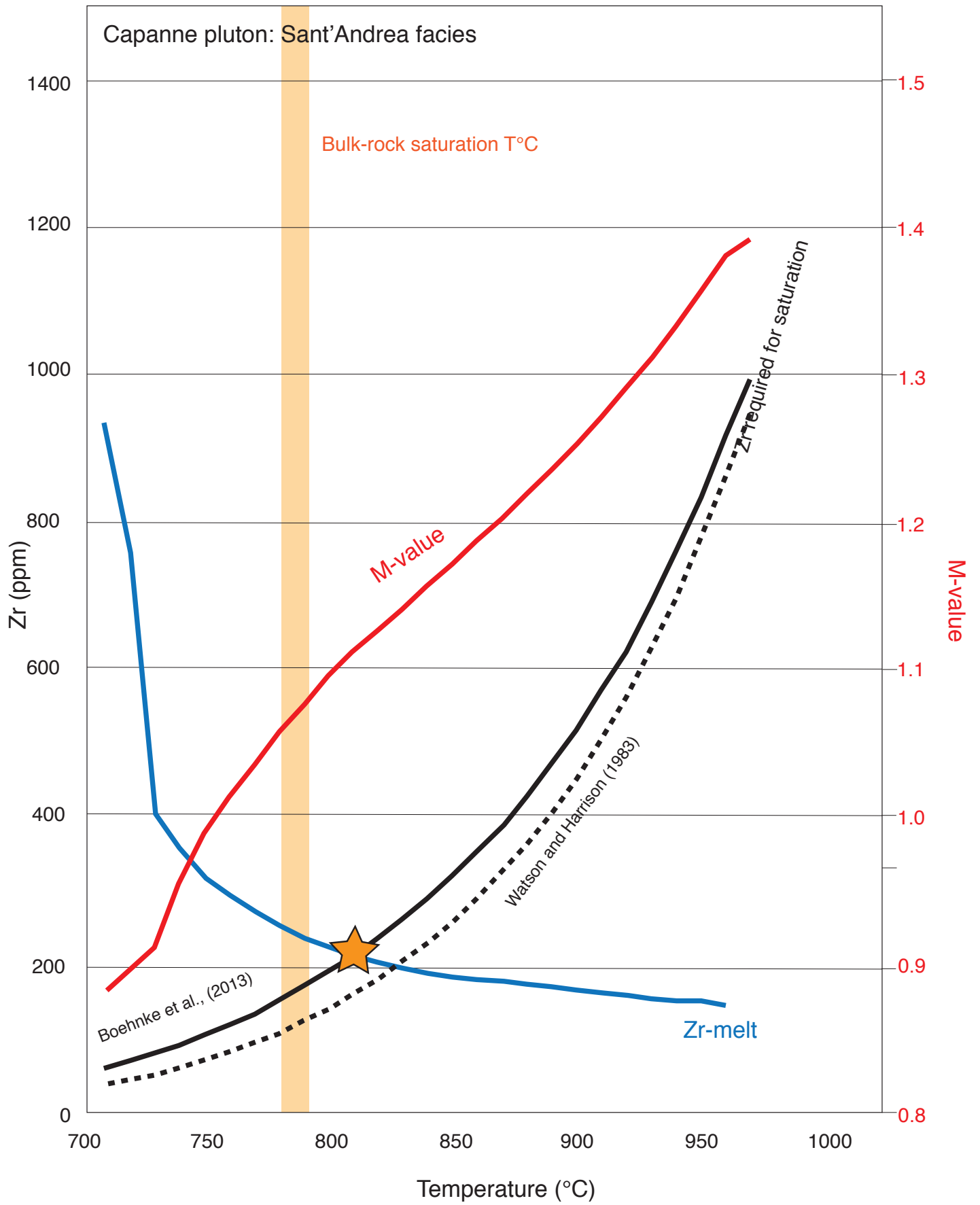
T°C	M values	Zr for saturation (ppm)	Zr for saturation (ppm)	Zr melt (ppm)
MELTS outputs	*Calculated from MELTS compositions*	*Watson and Harrison (1983)*	*Boehnke et al., (2013)*	*using kd's and MELTS outputs*
968	1.39	949	1000	-
958	1.38	864	924	145
948	1.36	777	840	149
938	1.34	698	764	152
928	1.31	627	695	156
918	1.29	563	632	160
908	1.27	505	575	163
898	1.26	453	523	167
888	1.24	406	476	171
878	1.22	363	433	174
868	1.20	325	393	178
858	1.19	290	357	181
848	1.17	258	324	185
838	1.16	230	293	188
828	1.14	204	265	196
818	1.13	181	240	204
808	1.11	160	216	212
798	1.10	142	195	223
788	1.08	124	174	238
778	1.06	109	155	255
768	1.04	95	138	274
758	1.02	83	123	296
748	0.99	72	108	319
738	0.96	61	94	359
728	0.91	52	81	404
718	0.92	46	74	761
708	0.88	39	64	931
698	0.86	33	56	1087
688	0.92	31	54	-

Kd K-fld	0.03	*Kd from EarthRef.org*
Kd plag	0.05	*Initial melt Zr = bulk rock Zr content (sample PP-334 from Dini et al., 2002)*
Kd quartz	0	
Kd bt	0.432	
Kd cpx	0.278	
Kd illmenite	0.568	

Supplementary Table 3b Zircon saturation temperature modeling (San Francesco granite)

T°C	M values	Zr for saturation (ppm)	Zr for saturation (ppm)	Zr melt (ppm)
MELTS outputs	*Calculated from MELTS compositions*	*Watson and Harrison (1983)*	*Boehnke et al., (2013)*	*using kd's and MELTS outputs*
1006	1.53	1454	1493	-
996	1.53	1342	1402	160
986	1.53	1237	1315	161
976	1.52	1132	1222	163
966	1.50	1021	1114	167
956	1.47	920	1016	171
946	1.45	830	927	176
936	1.43	748	847	181
926	1.42	674	773	185
916	1.40	607	706	189
906	1.38	546	645	193
896	1.37	490	588	200
886	1.35	440	536	205
876	1.34	395	489	210
866	1.32	353	445	212
856	1.31	316	405	218
846	1.30	282	369	224
836	1.28	252	335	227
826	1.27	224	304	233
816	1.26	199	276	236
806	1.25	177	250	243
796	1.24	157	226	255
786	1.23	138	204	272
776	1.22	122	184	297
766	1.20	107	165	321
756	1.19	94	148	349
746	1.18	82	132	396
736	1.16	72	118	428
726	1.07	58	96	639
716	1.27	60	108	1421
706	1.21	50	92	1761
696	1.19	43	81	2320
686	1.20	38	73	2763

Kd K-fld	0.03	*Kd from EarthRef.org*
Kd plag	0.05	*Initial melt Zr = bulk rock Zr content (sample PP-364 from Dini et al., 2002)*
Kd quartz	0	
Kd bt	0.432	
Kd cpx	0.278	
Kd illmenite	0.568	

Supplementary Table 3c Zircon saturation temperature modeling (San Piero granite)

T°C	M values	Zr for saturation (ppm)	Zr for saturation (ppm)	Zr melt (ppm)
MELTS outputs	*Calculated from MELTS compositions*	*Watson and Harrison (1983)*	*Boehnke et al., (2013)*	*using kd's and MELTS outputs*
1076	1.33	2070	1787	-
1066	1.33	1928	1690	136
1056	1.33	1793	1597	136
1046	1.33	1666	1508	137
1036	1.33	1546	1422	137
1026	1.33	1433	1339	138
1016	1.33	1326	1260	138
1006	1.33	1225	1184	139
996	1.33	1131	1112	139
986	1.33	1042	1042	140
976	1.33	959	976	140
966	1.33	882	913	140
956	1.33	809	853	141
946	1.32	741	796	141
936	1.32	678	741	142
926	1.32	619	689	142
916	1.30	558	631	144
906	1.28	500	573	146
896	1.26	447	520	149
886	1.24	400	472	151
876	1.23	358	428	153
866	1.21	319	388	156
856	1.19	285	352	158
846	1.17	253	319	161
836	1.16	225	289	165
826	1.14	200	261	169
816	1.13	177	236	176
806	1.11	157	212	189
796	1.09	138	190	202
786	1.07	121	170	216
776	1.05	106	151	232
766	1.03	92	134	253
756	1.00	80	119	274
746	0.98	69	105	297
736	0.93	59	90	343
726	1.01	55	89	540
716	0.99	48	79	794
706	0.97	41	69	985
696	0.96	36	62	1169
686	0.99	32	57	1421

Kd K-fld	0.03	*Kd from EarthRef.org*
Kd plag	0.05	*Initial melt Zr = bulk rock Zr content (sample MB11-2)*
Kd quartz	0	
Kd bt	0.432	
Kd cpx	0.278	
Kd illmenite	0.568	

Capanne pluton: Sant'Andrea facies

Bulk-rock saturation T°C

Zr required for saturation

M-value

Watson and Harrison (1983)

Boehnke et al., (2013)

Zr-melt

Zr (ppm)

M-value

Temperature (°C)

Supplementary Fig. 3a. Zr saturation model (Sant'Andrea facies)

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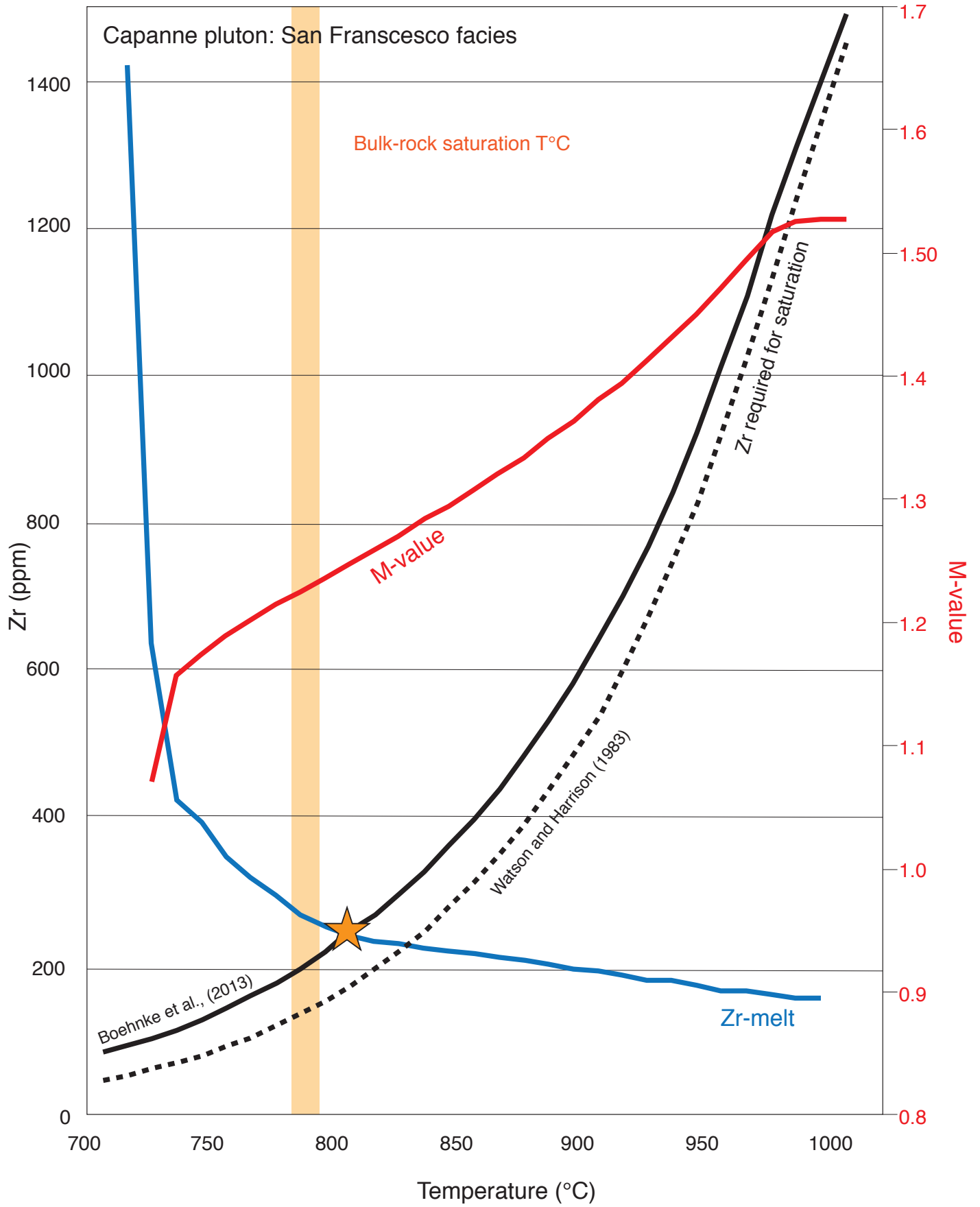
Supplementary Fig. 3b. Zr saturation model (San Francesco facies)
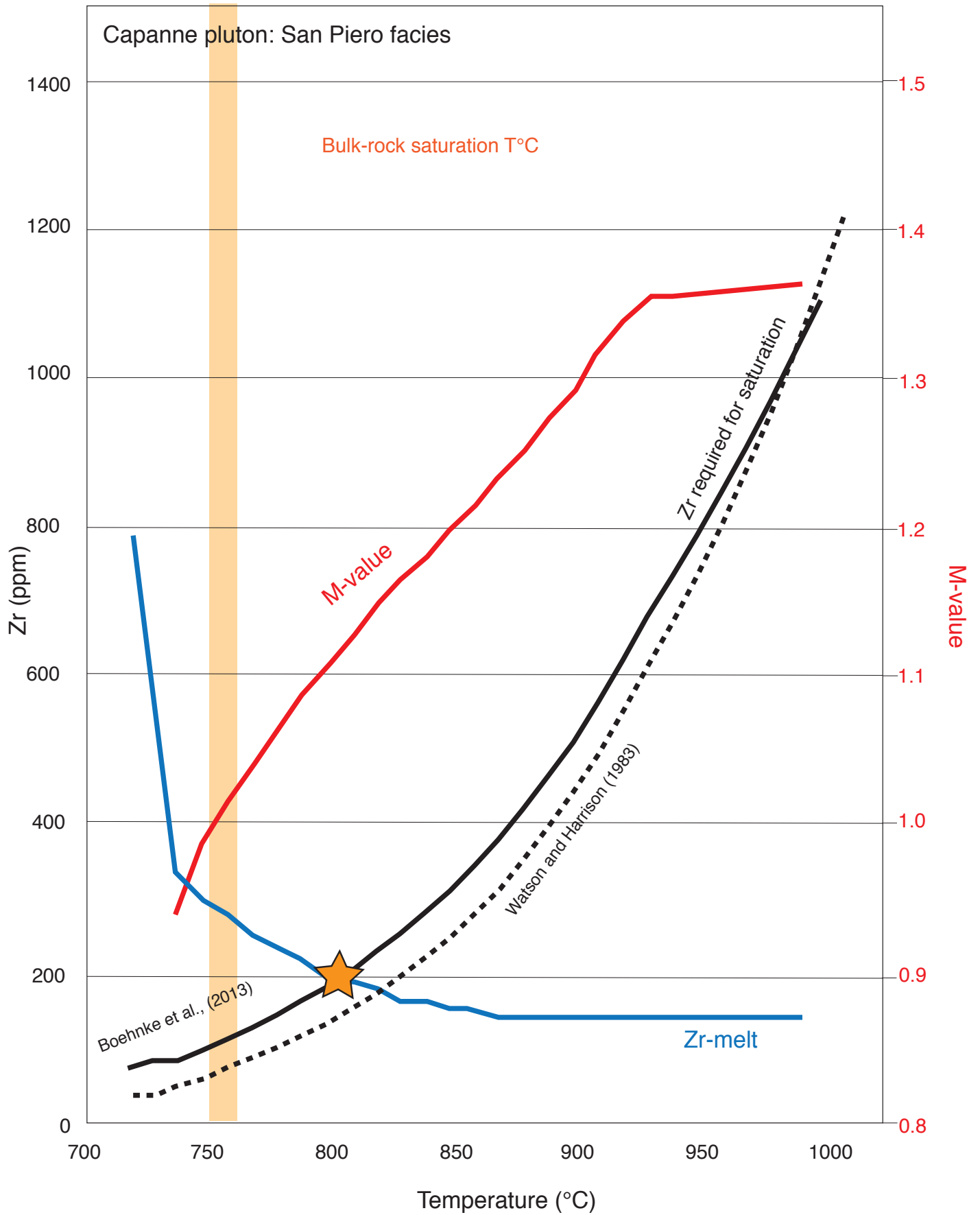
Supplementary Fig. 3c. Zr saturation model (San Piero facies)

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