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The Late Holocene to Pleistocene tephrostratigraphic record of Lake Ohrid (Albania)

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Abstract: Abstract

We present in this work a tephrostratigraphic record from a sediment piston core (JO-2004) from Lake Ohrid. Five tephra layers were recognised, all from explosive eruptions of south Italy volcanoes. A multidisciplinary study was carried out, including stratigraphy, AMS 14C chronology and geochemistry. The five tephra layers were correlated with terrestrial proximal counterparts and with both marine and lacustrine tephra layers already known in the central Mediterranean area. The oldest is from Pantelleria Island (P11, 131 ka BP). Other three tephra layers are from Campanian volcanoes: X6, Campanian Ignimbrite-Y5 and SMP1-Y3 (107, 39 and 31 ka BP respectively). The youngest tephra layer corresponds to the FL eruption from Etna Volcano (3.3 ka BP). In three cases these recognitions confirm previous findings in the Balkans, while two of them were for the

first time recognised in the area, with a significant enlargement of the previous assessed dispersal areas.

Résumé

Une étude tephrostratigraphique a été réalisée dans la carotte sédimentaire JO-2004 prélevée dans le Lac d'Ohrid. Cette étude bénéficie d'un cadre chronologique établi par sept datations SMA 14C et par des analyses chimiques des éléments majeurs. Cinq niveaux de tephra ont été détectés et corrélés aux dépôts terrestres proximaux ainsi qu'aux tephra identifiés dans des carottes marines et lacustres de la Méditerranée Centrale. Leur origine a été attribuée au volcanisme explosif du Sud de l'Italie et corrélée à l'activité de l'île de Pantelleria (P11, 131 ka BP), à la région Campanienne (X6, 107 ka; Ignimbrite Campanienne -Y5, 39 ka; SMP1-Y3; 31 ka) et à l'éruption FL de l'Etna (3,3 ka BP). Ces résultats sont en accord avec des travaux précédemment publiés dans la région des Balkans et ont permis d'identifier pour la première fois deux tephra (X6 et P11), en élargissant significativement leurs secteurs de dispersion en Méditerranéenne Centrale.

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27 enlargement of the previous assessed dispersal areas.

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40 Méditerranéenne Centrale.

42 **Keywords:** tephrostratigraphy, tephrochronology, Italian volcanoes, Lake Ohrid, Albania

43 **1. Introduction:**

44 Tephrostratigraphy is a powerful tool that is widely applied to volcanology, Quaternary
45 science, palaeoceanography or archaeology. This is particularly true in the central
46 Mediterranean region, which bore witness to frequent and powerful volcanic explosive activity
47 during both Holocene and Late Pleistocene [5, 6, 7, 10, 18, 25, 28, 29, 31, 35, 36, 37, 39, 44,
48 47]. Some of the tephra layers generated during these explosive eruptions have regional or
49 extra-regional relevance (e.g. Y3, Y5, Y6, Y7, X5 and X6 tephra layers) [8, 10, 20, 32, 39, 42,
50 49], since they covered very wide areas facilitating correlations between different geological
51 archives. Many other tephra layers are less dispersed but are frequently recognised in marine
52 and lacustrine cores drilled in the central Mediterranean area [4, 14, 16, 17, 28, 30, 40, 46, 47].
53 Owing to its position downwind of the Italian volcanoes, the Balkans were affected by tephra
54 deposition during Holocene and late Pleistocene [41, 46] (Fig. 1), but tephrostratigraphic
55 studies are few and limited to the last 40 ka. This paper deals with the study of a long core (JO
56 2004; 9.88 m), collected on the Albanian side of Lake Ohrid, which records the last 130-140 ka
57 of sedimentation [13]. Our aim is to provide a tephrostratigraphic reconstruction of the core JO
58 2004, and to provide the correlation of its tephra layers with marine, lacustrine or terrestrial
59 deposits in the central Mediterranean. The correlation among the different archives provides an
60 updated framework of the tephra dispersion in the central Mediterranean area, and particularly
61 in the Balkans.

62 Few tephra studies were carried out in the Balkans [41, 46], although their downwind position
63 from the Italian volcanoes makes the area particularly subjected to distal ash deposition. On the
64 other hand, the recognition of ash layers from Italian volcanoes in the Balkans contributes to
65 shed light into the complex and poorly understood dynamics of dispersal of ash particles during
66 and after explosive eruptions.

68 **2. Site description**

69 The Ohrid Lake is one of the oldest lake in Europe [38], and is located at the border between
70 Albania and Macedonia ($40^{\circ}54'-41^{\circ}10'$ N; $20^{\circ}38'-20^{\circ}48'$ E) (Fig. 1). The lake is at 705 m
71 a.s.l., and has a surface of about 360 km². It is surrounded by two principals mountain chains:
72 the Galiçica Mountains to the east (more than 1750 m a.s.l.), and the Mokra Mountains to the
73 west (around 1500 m a.s.l.; Fig. 1). The Lake Ohrid has a NS orientation, and is located in a
74 graben which formed during the extension of the Albanian area during the Pleistocene [1, 46].
75 Carbonate rocks of Triassic and Jurassic age crop out to the north and to the east, while
76 ophiolitic rocks of Jurassic age crop out to the south-west. The southern end of the basin
77 connects with a small graben filled by continental mudstones and sandstones of Pliocene age,
78 overlain by fluvio-lacustrine sediments of Holocene age [24]. The Lake Prespa, located 20 km
79 to the south-east and 150 m above the Lake Ohrid, is the principal sub-aquatic inflow of Lake
80 Ohrid through a karstic system located below the Galiçica Mountain Chain. The Black Drin
81 River is the only surface outflow to the north part of the Lake Ohrid [2, 21, 38].

83 3. Materials and methods.

84 Two series of piston cores (JO 2004-1 and JO 2004-1a) were drilled in the south west part of
85 the Lake Orhid ($40^{\circ} 55,000'$ N ; $20^{\circ} 40,297'$ E ; Fig. 1). The uppermost roughly 10 m of
86 sediments were recovered using a cable-operated piston-core (63 mm in diameter and 3 m-
87 long; Niederreiter Corer). In order to obtain a continuous sediment record, four sections
88 (labelled A, B, C and D respectively from the top to the base) were cored from a first drilling
89 site (JO 2004-1), and three sections (labelled A, B and C) with a planed depth offset of 1.5 m
90 from a second drilling site located at about 5 m of distance from the first (JO 2004-1a; Fig. 2).
91 The overlapping sections were correlated using marker layers clearly identified in both cores
92 and the resulting composite profile checked for consistency using the magnetic susceptibility
93 record (Fig. 2b).

94 The magnetic susceptibility of core JO 2004 has not permitted the identification of any tephra
95 layer, due to the high noise induced by the magnetic minerals from the drainage basin bedrocks

96 [46]. Tephra layer were identified by continuously sampling the composite profile at 1 cm-
97 interval, and washing and sieving each sample at 125, 63 and 40 μm using distilled water. The
98 different grain size fractions were dried in a laboratory heater at a temperature of 50°C over 24
99 h. The three sediment fractions were carefully inspected under the stereo-microscope, looking
100 for volcanic particles (i.e. glass shards, pumice, magmatic crystals, volcanic lithics). At least
101 400 particles were counted under the stereo-microscope to obtain the glass abundance.

102 In samples with volcanic glass in excess of 10 %, glass shards and micro-pumice fragments
103 were picked and sealed in resin beads. They were then polished to avoid compositional
104 variations caused by surface alteration processes.

105 Major element compositions of glass was obtained using an EDAX-DX micro-analyser (EDS
106 analyses) mounted on a Philips SEM 515 at Dipartimento di Scienze della Terra (University of
107 Pisa). Operating conditions were: 20 kV acceleration voltage, 100 s live counting, 10^{-9} Å beam
108 current, beam diameter ≈ 500 μm , 2100 shots per second, ZAF correction. The ZAF correction
109 procedure does not include natural or synthetic standards for reference, and requires the
110 analyses normalization at a given value (which is chosen at 100%). Instrument calibration and
111 performance are described in Marianelli and Sbrana [19].

112 The composition of glass was classified using the Total Alkali vs. Silica diagram (TAS, [12],
113 Fig. 3a).

114 Seven ^{14}C radiocarbon datings were available from literature [13] (Table 3). Raw radiocarbon
115 measurements were converted into calibrated ages using the INTCAL04 method [33] and the
116 polynomial equation of Bard et al. [3] for ^{14}C ages older than 26 cal ka BP.

4. Results

117
118
119 Five tephra layers were recognised along the composite profile, and labelled JO-941 (938 – 942
120 cm), JO-575 (571 – 577 cm), JO-244 (235 – 252 cm), JO-187 (185.5 – 188.5 cm) and JO-42
121 (36.5 – 45.5 cm), respectively (Fig. 2a and b).

123 4.1. Cryptotephra JO-941 (938 – 942 cm)

124 The deepest tephra is dispersed in the sediment (cryptotephra), and glass shards were
125 recognised in all the three sieving classes. The peak of abundance of glass particles is at 941
126 cm (60 %; Fig. 2c), and comprises transparent, brown-honey, cusped, thin glass shards (Fig.
127 4a). The groundmass is glassy, and EDS analyses show a homogeneous rhyolitic composition
128 (Fig. 3a and b, Table 1). In the diagram Comendite-Pantellerite (FeO vs. Al₂O₃; [15]) all the
129 analysed samples plot into the pantelleritic field.

130

131 4.2. Cryptotephra JO-575 (571 – 577 cm)

132 This cryptotephra mainly comprises white to light-brown, elongated and cusped glass shards
133 and rare, white micro-pumice fragments (Fig. 4b). The peak abundance of glass shards is
134 between 574 and 575 cm (95 %; Fig. 2c). The groundmass is glassy (Fig. 4b), and the
135 composition shows a small variability within the trachy-phonolitic field (Fig. 3a and c; Table
136 1).

137

138 4.3. Tephra layer JO-244 (235 – 252 cm)

139 This tephra layer is composed of two distinct parts with different colours. The first one
140 (between 244 and 244.5 cm) is Yellowish Gray (5Y 7/2; [9]), while the second one (between
141 247 and 248 cm) is Moderate Olive Brown (5Y 4/4; [9]). The tephra comprises white, vesicular
142 micro-pumices and elongated glass shards with thin septa. Most of the glass shards are
143 transparent, with few dark-brown in colour (Fig. 4c). The abundance of glass shards and micro-
144 pumice has its maximum (100 %) between 244 and 244.5 cm (Fig. 2c). The groundmass is
145 glassy (Fig.4c), and the glass composition is trachy-phonolitic (Fig. 3a and d; Table 1).

146

147 4.4. Tephra layer JO-187 (185.5 – 188.5 cm)

148 This tephra layer is Yellowish Gray in colour (5Y 4/1; [9]), and comprises transparent, tubular,
149 elongated micro-pumice fragments and transparent, brownish glass shards (Fig. 4d). The

150 maximum abundance (99%) is at 187 cm (Fig. 2c). The groundmass is glassy (Fig. 4d), and the
151 glass composition is homogeneous and trachytic (Fig. 3a and e; Table 1).

152

153 4.5. Cryptotephra JO-42 (36.5 – 45.5 cm)

154 This cryptotephra has a peak abundance of glass particles (80%) at 42 cm of depth (Fig. 2c),
155 and comprises dark-brown, blocky, tachylitic fragments with few spherical vesicles (Fig. 4e).
156 The groundmass comprises small crystals of plagioclase, clinopyroxene and minor olivine (Fig.
157 4e). The glass composition ranges between mugearites and benmoreites (Fig. 3a and f).

159 5. Discussion

161 5.1. Correlation of tephra layers

162 The K- to Na-alkaline affinity of glass compositions of the five tephra layers recognised in the
163 core JO 2004 indicate that all of them were from explosive eruptions of Italian volcanoes, since
164 during late Quaternary the products of the Aegean arc were characterised by calc-alkaline
165 affinity [10, 30, 42]. Two of them (JO-941 and JO-42) present peculiar glass composition that
166 indicate a source from Pantelleria Island and from Mount Etna, respectively. The other three
167 tephtras display trachytic to phonolitic composition, and can be correlated to the explosive
168 activity of Campanian volcanoes. In the following, the precise correlation of each tephra layer
169 with a specific eruption of these volcanoes will be discussed in detail. For comparison, the
170 average compositions of the correlated tephra layers are reported in Table 2.

172 *Cryptotephra JO-941*

173 The pantelleritic glass composition of cryptotephra JO-941 (Table 1) indicates it was generated
174 from Pantelleria Island. The Island of Pantelleria produced several large explosive eruptions
175 with pantelleritic composition [18]. Among them, the most dispersed are the Green Tuff (45-50
176 ka BP), the Ignimbrite Q (113.9 ± 3.6 ka BP), the Ignimbrite P (133.1 ± 3.3 ka BP), the Welded

177 tuff S (162-164 ka BP) and the Welded tuff M (174.8 ± 2.8 ka BP; [18]). Two other $^{40}\text{Ar}/^{39}\text{Ar}$
178 datings are available for the Ignimbrite P (126.8 ± 1.5 ka BP) and for the Welded tuff S (174.5
179 ± 1.5 ka BP; La Felice, pers. com.). Pantelleritic tephra layers have been found in the Ionian
180 Sea core KET 8222 [30] (Table 2) and named P11 (estimated age at about 131 ka BP, 555 cm
181 depth) and P12 (estimated age at about 164 ka BP, 765 cm depth), which have similar ages of
182 Ignimbrite P and Welded tuff S. The composition of P11 and P12 is quite similar, and the two
183 tephra layers are hardly distinguishable on the basis of major elements.

184 The glass composition of sample JO-941 matches well that of both tephra layers P11 and P12
185 (Tables 1 and 2, Fig. 3b). Indeed, the tephra layer P11 have been recognised over a wide area
186 of the Ionian sea while the dispersal of P12 is more limited [30]. Nevertheless, stratigraphic
187 and paleoclimatic considerations support the correlation of the JO-941 cm tephra with P11
188 marine tephra layer, and then with Ignimbrite P deposits on Pantelleria Island. This is because
189 both carbonate and pollen curves carried out on JO 2004 core sediments [13] unequivocally
190 indicate that this tephra were emplaced close to the inception of the Last Interglacial. The onset
191 of the Last Interglacial may have been recorded at different times in different archives [43],
192 but, in any case, the age of 164 cal ka BP (which corresponds to P12 tephra layer) is too old of
193 some ten thousand years with respect to that commonly accepted for the inception of Last
194 Interglacial at Mediterranean latitudes (e.g. 126.8 and 120.3 ka BP ; [43]).

195 The recognition of tephra layer P11 is the first in the Balkans, and significantly enlarges its
196 dispersal well beyond the Ionian sea (Fig. 5a).

198 *Cryptotephra JO-575*

199 This low alkali ratio (LAR) trachytic tephra layer occurs between the calibrated ^{14}C age of
200 $44,812 \pm 1055$ cal yrs BP [13] (Table 3) and the P11 tephra layer.

201 Composition of the tephra layer JO-575 shows a good match with marine tephra C-31 (KET
202 8222 and DED 8708 deep sea cores, Fig. 3c and Table 2), which has an interpolated age of 107
203 ka BP [30]. Paterne had related the C-31 tephra with the LAR- trachyte X6 from 22M-60 core

204 [10]. So, the glass composition of JO-575 tephra layer is correlated to the X6 tephra layer. This
1 205 X6 tephra layer is also dated at 107 ka BP by interpolation from $^{40}\text{Ar}/^{39}\text{Ar}$ age of the X5 tephra
2
3 206 layer (105 ± 2 ka) by Kraml [11] using the sediment rate.
4
5 207 Keller in 1978 [10] attributed the X6 eruption to the Campanian volcanic zone. The X6 tephra
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7 208 layer was for the first time described in Ionian sea cores [10], and successively in Tyrrhenian
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9
10 209 sea core [30] as well in the Lago Grande di Monticchio succession [48]. This is the first
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12 210 recognition of X6 tephra layer in the Balkans, and considerably enlarges its dispersal area to
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14
15 211 the east (Fig. 5b).

20 213 *Tephra layer JO-244*

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22 214 This tephra layer is 11 cm thick (Fig. 2) and comprises both glass shards and micro-pumice
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24
25 215 fragments. When plotted on TAS diagram (Fig. 3a) the glass composition has a narrow
26
27 216 variability within the trachytic and phonolitic fields. However, the tephra layer shows a
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29
30 217 variable alkali ratio passing from the base to the top. In particular, the basal part shows the
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32 218 coexistence of glasses with two different alkali ratio (Table 1, Fig. 3d), whereas upper part has
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34
35 219 a very homogeneous LAR-trachytic glass composition (Table 1).

36
37 220 The glass composition indicates the Campanian area as source for this tephra that, on the basis
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39
40 221 of the peculiar variability in alkali ratio and the thickness, can be confidently correlated to the
41
42 222 Campanian Ignimbrite eruption from Campi Flegrei. The geochemical comparison of major
43
44 223 element shown in Table 2 is applied with the ML-2 layer [20] and the TM-18 layer [47] among
45
46
47 224 the many analyses available. The Campanian Ignimbrite eruption was dated at $39,280 \pm 110$ yrs
48
49 225 BP ($^{40}\text{Ar}/^{39}\text{Ar}$ technique; [6]), and correspond to the Y5 tephra layer, widely dispersed in the
50
51
52 226 central and eastern Mediterranean and in mainland Europe [8, 10, 20, 23, 27, 28, 32, 39, 45, 46,
53
54 227 47]. The recognition in Lake Ohrid succession confirms the previous finding of Wagner et al.
55
56 228 [46] (Fig. 5c).

57 229 60 61 230 *Tephra layer JO-187*

231 The JO-187 tephra is chronologically constrained between the Campanian Ignimbrite (≈ 39 ka
232 BP) and the ^{14}C age of $9,407 \pm 121$ cal yrs BP obtained at 100 cm depth (Table 3). The
233 homogeneous trachytic composition (Table 1, Fig. 2e) of this tephra layer suggests it was
234 originated from the Campanian area, and shows a good match with the composition of SMP1-e
235 eruption from Campi Flegrei [7]. The SMP1-e eruption corresponds to the Y3 tephra layer
236 (Table 2 ; [7, 39, 49]), which is widely dispersed in the central Mediterranean area [10, 22, 23,
237 39, 47, 49] with an estimated age between 30 to 31 cal ka BP [49]. The recognition in Lake
238 Ohrid succession confirms the previous finding of Wagner et al. (2008) [46] (Fig. 5d).

240 *Cryptotephra JO-42*

241 This cryptotephra is stratigraphically younger than the ^{14}C age of $6,680 \pm 66$ cal yrs BP (Table
242 3), and the peculiar mugearitic-benmoreitic composition easily indicates the Mount Etna as the
243 source. The shallow position within the core and the glass composition indicates a correlation
244 with the FL eruption from Mount Etna, dated at $3,370 \pm 70$ cal yr BP [5, 46]. The recognition
245 in Lake Ohrid succession confirms the previous finding in the same lake (Macedonian side) of
246 Wagner et al. [46] and of Sulpizio et al. [41] which recovered the Etna FL tephra layer in the
247 Lake Shkodra successions (Albania) (Fig. 5e).

249 5.2. Significance of tephra layer recognition in Lake Ohrid

250 The recognition of tephra layers in the Lake Ohrid has relevance for both volcanology and
251 Quaternary sciences.

252 From a volcanological point of view, the five tephra layers recognised in the sediments testify
253 for episodes of ash deposition in very distal areas with respect to the Italian volcanoes (Fig. 5),
254 irrespective if they are from large (P11, X6, Y5 and Y3 tephra layers) or intermediate (FL
255 tephra layer) explosive eruptions.

256 Three out of five tephra layers were already recognised in Lake Ohrid sediments (Y5, Y3, and
257 FL) but from a core located in the Macedonian side of the lake [46]. Their recognition in core

258 JO 2004, confirm their deposition was not sporadic but probably they affected all the lake area
1 259 and its drainage basin. Two of them (P11 and X6) were recognised for the first time in the
2
3 260 Balkan area, significantly enlarging to the North-East their dispersal that was previously
4
5 261 limited to Ionian and Tyrrhenian seas [10, 30] or Lago Grande di Monticchio [48]. These new
6
7
8 262 findings represent the most distal recovering of these two eruptions, that is more than 1,000 km
9
10 263 from Pantelleria Island and more than 500 km from the Campanian area (Fig. 5).

12
13 264 The paucity of accurate studies on distal ash deposits mainly relies in their poor preservation
14
15 265 and in their dispersal behaviour. The accumulation of volcanic ash in distal zones often
16
17
18 266 represents a hazard, since most of the attention and mitigation procedures are usually devoted
19
20 267 to proximal areas. Deposition of ash in distal sites can cause damage to infrastructures,
21
22 268 disturbance to communications, water pollution and breathing problems. Therefore the
23
24
25 269 recognition and the collection of very distal samples can improve hazard mitigation plans and
26
27 270 procedures over very large area far from the volcanic sources.

28
29
30 271 Form a Quaternary science point of view, the lake Ohrid represents an exceptional natural
31
32 272 archive. Previous works [46] analysed and discussed only the last 40 ka of sedimentation and
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34
35 273 paleoclimatic record of Lake Ohrid. The cores JO 2004 offer the opportunity to study about
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37 274 130 ka of the sedimentary record, which encompass the last interglacial. In this scenario, the
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40 275 presence of two important regional markers like the P11 and X6 tephra layers allow the
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42 276 physical correlation of the deep part of the cores JO 2004 to other important archives of the
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44
45 277 central Mediterranean area.

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47 278 The available ^{14}C datings (Table 3) and the tephra layers allow the drawing of a sedimentation
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49 279 curve (Fig. 6). The sediment curve based on the seven ^{14}C dating and on the tephrochronology,
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51
52 280 shows three main different rates of sedimentation. The first one between 0 and 100 cm of depth
53
54 281 is about 0.10 mm yr^{-1} , the second one, between 100 and 575 cm of depth is around 0.05 mm yr^{-1}
55
56
57 282 and the third one between 575 and 988 cm of depth is about 0.15 mm yr^{-1} (Fig. 6).

58
59 283 These variable sedimentation rates reflect different paleo-environmental information. Below
60
61
62 284 the X6 tephra layer, there is the transition between the last-glacial and the last-interglacial

285 phases (Eemian, transition from marine isotopic stage 5 and 6, around 125 ka BP; [13]), which
1 286 was characterised by a high sedimentation rate (0.15 mm yr^{-1} ; Fig. 6). Between 100 and 575 cm
2
3 287 depth, there is a glacial period record with a low sedimentation rate (0.05 mm yr^{-1}) and low
4
5 288 sediment dynamic. The upper 100 cm of core sediments (younger than 10 ka BP), correspond
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7
8 289 to the current interglacial period, which is characterised by a high sedimentation rate (0.11 mm
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10 290 yr^{-1}).

13 291

15 292 6. Conclusions

17 293 The study of the JO 2004 cores yields some important results for the tephostratigraphy and
18
19 294 tephrochronology of the Balkans. Five tephra layers were recognised and described, and two of
20
21
22 295 them were for the first time discovered in the area. The tephra layer P11 is the oldest in the
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24
25 296 whole recognised succession and testifies for ash deposition at more than 1,000 km from its
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27 297 source on Pantelleria Island. Similarly, the recognition of tephra layer X6 enlarges to the east
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29
30 298 its dispersal, since it was previously described only in Ionian and Tyrrhenian Sea cores and in
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32 299 the Lago Grande di Monticchio. The other three tephra layers (FL, Y3 and Y5) were already
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34
35 300 recognised in Lake Ohrid succession, and the new findings testify for their extensive deposition
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37 301 in the area.

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39 302 The recognition of the two deeper tephra layers (X6 and P11) is especially important, since
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42 303 they allow the establishment of a chronology for the part of the core older than 40 ka BP, and
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44 304 its physical link to other archives of the central Mediterranean area.

45
46
47 305 In perspective, this work will allow to obtain a better estimation of the distal tephra dispersion
48
49 306 from Italian volcanoes. These results must be integrated in the mitigation and rescue plans
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51
52 307 which concern the population of Central Mediterranean area.

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483 **Figure captions**

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3 485 **Figure 1: Location map of the study area. The Italian volcanoes active in the investigated time span and the**
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5 486 **location of cores used in this study are also shown: CVZ = Campanian Volcanic Zone (Campi Flegrei,**
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7 487 **Somma-Vesuvius, Ischia and Procida), PRG = Lake of Pergusa, LGM = Lago Grande di Monticchio. In the**
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9 488 **framework in the upper right angle, the location of the JO 2004 core is shown.**

10
11 489 *Carte de localisation du site d'étude. Les principaux volcans Italiens actifs lors de la période étudiée et les sites*
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13 490 *des carottes utilisées dans cet article sont indiqués: CVZ = Campanian Volcanic Zone (Champs Phlégréens,*
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15 491 *Somma-Vesuvius, Ischia et Procida), PRG = lac de Pergusa, LGM = Lago Grande di Monticchio. En haut à*
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17 492 *droite, la position du site de forage de la carotte JO 2004.*

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21 494 **Figure 2: Composite stratigraphy of the core JO 2004 (depth in cm): (a) lithostratigraphy (modified from**
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23 495 **[13]), (b) magnetic susceptibility curve and (c) relative glass shards abundance.**

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25 496 *Stratigraphie recomposée de la carotte JO 2004 (profondeur en cm) : (a) lithostratigraphie (modifiée à partir de*
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27 497 *[13]), (b) courbe de susceptibilité magnétique et (c) abondance relative des esquilles de verres volcaniques.*

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31 499 **Figure 3: Comparison of the compositions of the identified tephra layers and analyses from literature using**
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33 500 **the Total Alkali vs. Silica (TAS) diagram [12]. a) General classification using average glass analyses of the**
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35 501 **five identified tephra layers; b) plot of analyses of JO-941 cryptotephra and KET 8222-563 and 555 cm**
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37 502 **tephra from [30]; c) plot of analyses of JO-575 cryptotephra and KET 8222-350, 340 cm and DED 8708-**
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39 503 **1209 cm tephra from [26, 30]; d) plot of analyses of JO-244 tephra layer and TM-18 layer from [47] and**
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41 504 **ML-2 tephra layer from [20]; e) plot of analyses of JO-187 tephra layer and TM-15 tephra layer from [47]**
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43 505 **and MD90-917 920 cm tephra layer from [49] ; f) plot of analyses of JO-42 cryptotephra and SK13 514 cm**
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45 506 **and PRG06-03 390 cm from [41], Ohrid 310-315 cm tephra layer from [46] and Pergusa Type A and B from**
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47 507 **[34].**

48
49 508 *Comparaison entre les compositions chimiques des niveaux de tephra identifiés et ceux issus de la littérature dans*
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51 509 *un diagramme Total Alcalin vs. Silice (TAS) [12]. a) Diagramme général des moyennes des analyses sur les*
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53 510 *verres des cinq niveaux de tephra ; b) analyses du cryptotephra JO-941 et des niveaux de tephra KET 8222-563 et*
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55 511 *555 cm d'après [30]; c) analyses du cryptotephra JO-575 et des niveaux de tephra KET 8222-350, 340 cm et DED*
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57 512 *8708-1209 cm d'après [26, 30]; d) analyses du niveau de tephra JO-244 et des niveaux de tephra TM-18 d'après*
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59 513 *[47] et ML-2 d'après [20]; e) analyses du niveau de tephra JO-187 et des niveaux de tephra TM-15 d'après [47]*

514 et MD 90-917 d'après [49]; f) analyses du cryptotephra JO-42 et des niveaux de tephra de SK13 514 cm et
515 PRG06-03 390 cm d'après [41], Ohrid 310-315 cm d'après [46] et Pergusa Type A et B d'après [34].

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4 517 **Figure 4: Scanning Electron Microscope (SEM) pictures of volcanic glass fragments from a) JO-941**
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6 518 **sample, b) JO-575 sample, c) JO-244 sample, d) JO-187 sample and e) JO-42 sample.**

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8 519 *Images au Microscope Electronique à Balayage (MEB) des échardes de verres volcaniques des niveaux a) JO-*
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10 520 *941, b) JO-575, c) JO-244, d) JO-187 et e) JO-42.*

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14 522 **Figure 5: Dispersal areas of the five tephra layers recognized in core JO 2004. Y5 modified from [32] and**
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16 523 **[8] ; Etna FL modified from [41].**

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18 524 *Cartes de dispersion des cinq éruptions identifiées dans la carotte JO 2004. Y5 est modifié à partir de [32] et*
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20 525 *[8] ; Etna FL est modifié à partir de [41].*

21 526
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24 527 **Figure 6: Sedimentation curves for core JO 2004 calculated using the available calibrated ^{14}C (cross) and**
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26 528 **ages of tephra layers (diamonds). P11=JO-941, X6=JO-575, Y5=JO-245, Y3=JO-187, Etna FL=JO-42.**

27 529 **Numbers in italic underlined indicate the calculated sedimentation rate (mm.yr^{-1}) for each segment of the**
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29 530 **curve.**

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31 531 *Courbe de sédimentation de la carotte JO 2004 calculée à partir des âges ^{14}C calibrés (croix) et des datations des*
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33 532 *niveaux de tephra (losanges). P11=JO-941, X6=JO-575, Y5=JO-245, Y3=JO-187, Etna FL=JO-42. Les chiffres*
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35 533 *soulignés en italiques représentent le taux de sédimentation (mm.an^{-1}) pour chaque section de la courbe.*

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41 535 **Table 1: Composition of major elements of the five tephra layers recognised in core JO 2004.**
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43 536 *Compositions des éléments majeurs des cinq niveaux de tephra identifiés dans la carotte JO 2004.*

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47 538 **Table 2: Comparison of average and standard deviation of analyses from literature used for comparison:**
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49 539 **KET 8222 340 cm, 350 cm, 555 cm, 563 cm, 765 cm, DED 8708 1209 cm from [26] and [30]; ML-2 from**

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51 540 **[20]; TM-15 and TM-18 from [47]; MD90-917 920cm from [49]; tephra Ohrid 310-315 cm from [46] ;**
52
53 541 **Pergusa type A and B from [34] and PRG06-03 390 cm and SK13 514 cm from [41].**

54
55 542 *Comparaison des moyennes et des écarts types des analyses issues de la littérature: KET 8222 340 cm, 350 cm,*
56
57 543 *555 cm, 563 cm, 765 cm, DED 8708 1209 cm d'après [26] et [30]; ML-2 d'après [20]; TM-15 et TM-18 d'après*
58
59 544 *[47]; MD90-917 920 cm d'après [49]; tephra Ohrid 310-315 cm d'après [46]; Pergusa type A et B d'après [34]*
60
61 545 *et PRG06-03 390 cm et SK13 514 cm d'après [41].*

547 **Table 3: Conventional ^{14}C ages from JO 2004 core determined by UMS-ARTEMIS (Pelletron 3MV) AMS**
1
2 548 **facilities (CNRS-CEA Saclay, France, [13]). Ages were calibrated using INTERCAL04 [33] for ^{14}C age**
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4 549 **younger than 26 cal ka BP and Bard polynomial equation for age older than 26 cal ka BP [3].**

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6 550 *Tableau des âges AMS ^{14}C de la carotte JO 2004 obtenus par UMS-ARTEMIS (Pelletron 3MV) CNRS-CEA*
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8 551 *Saclay, France, [13]. Les âges ont été calibrés avec INTERCAL04 [33] pour les datations d'âge inférieur à 26 cal*
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10 552 *ka BP et avec le polynôme de Bard pour les datations d'âge supérieur à 26 cal ka [3].*

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Figure 1
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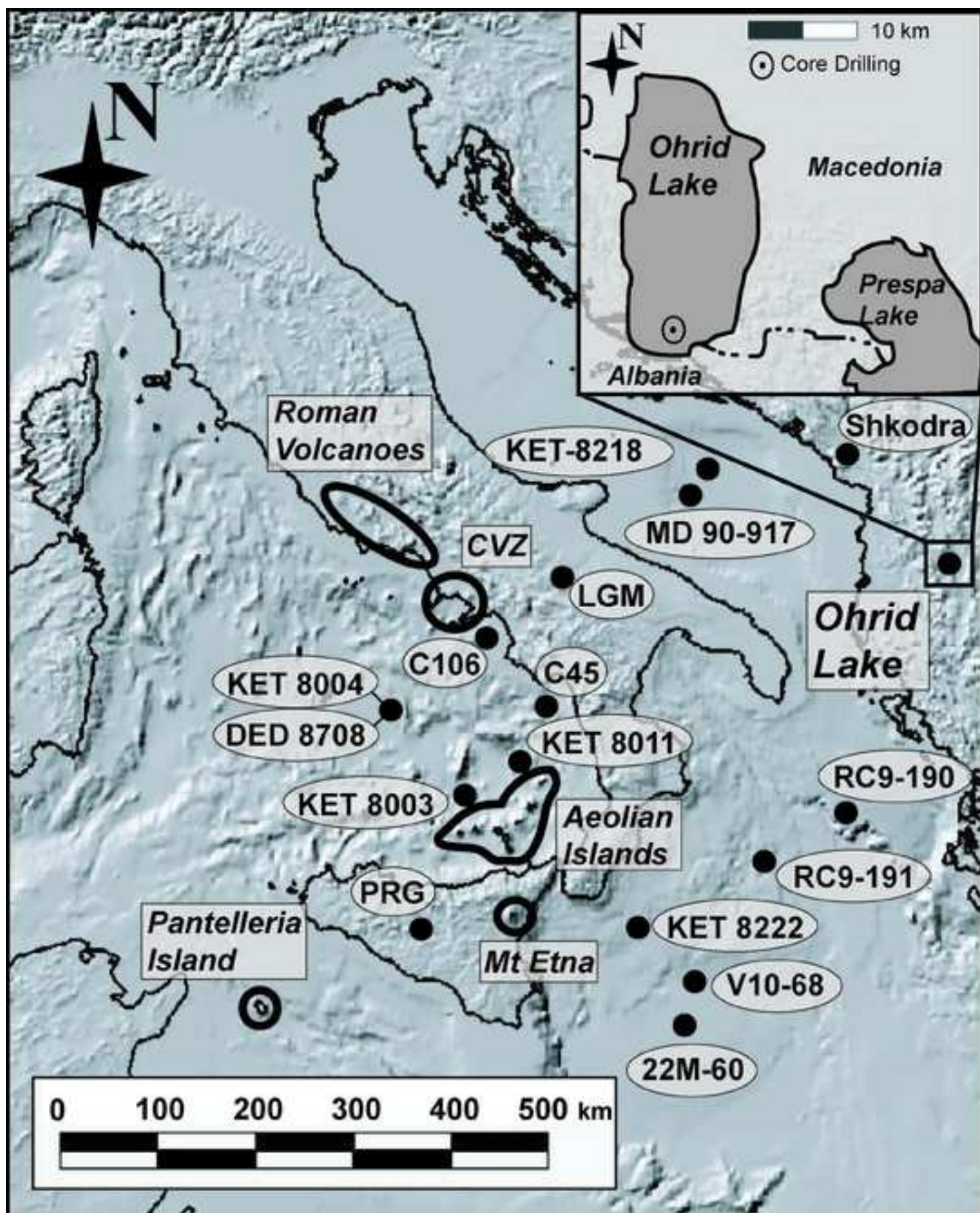


Figure 2
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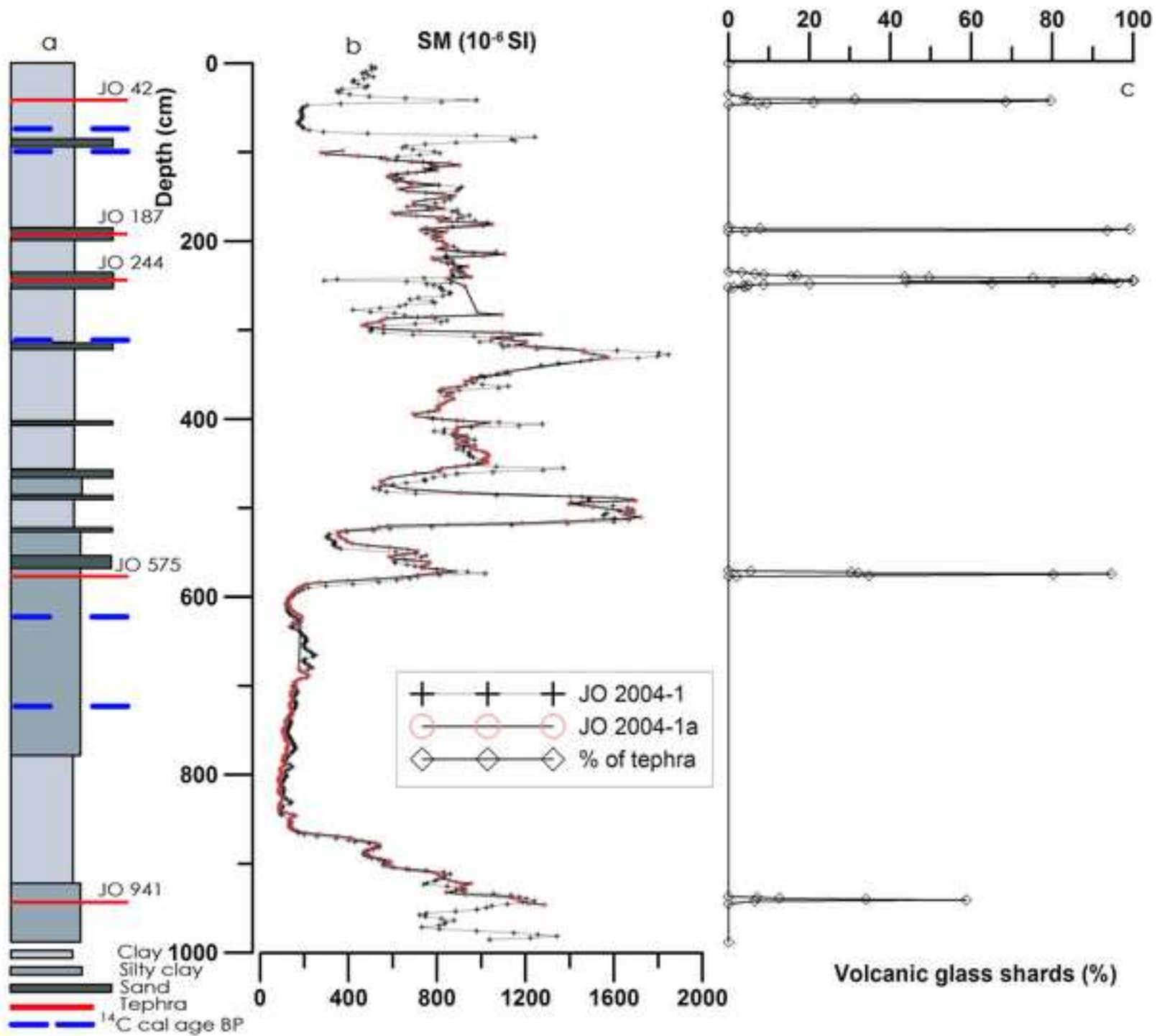


Figure 3
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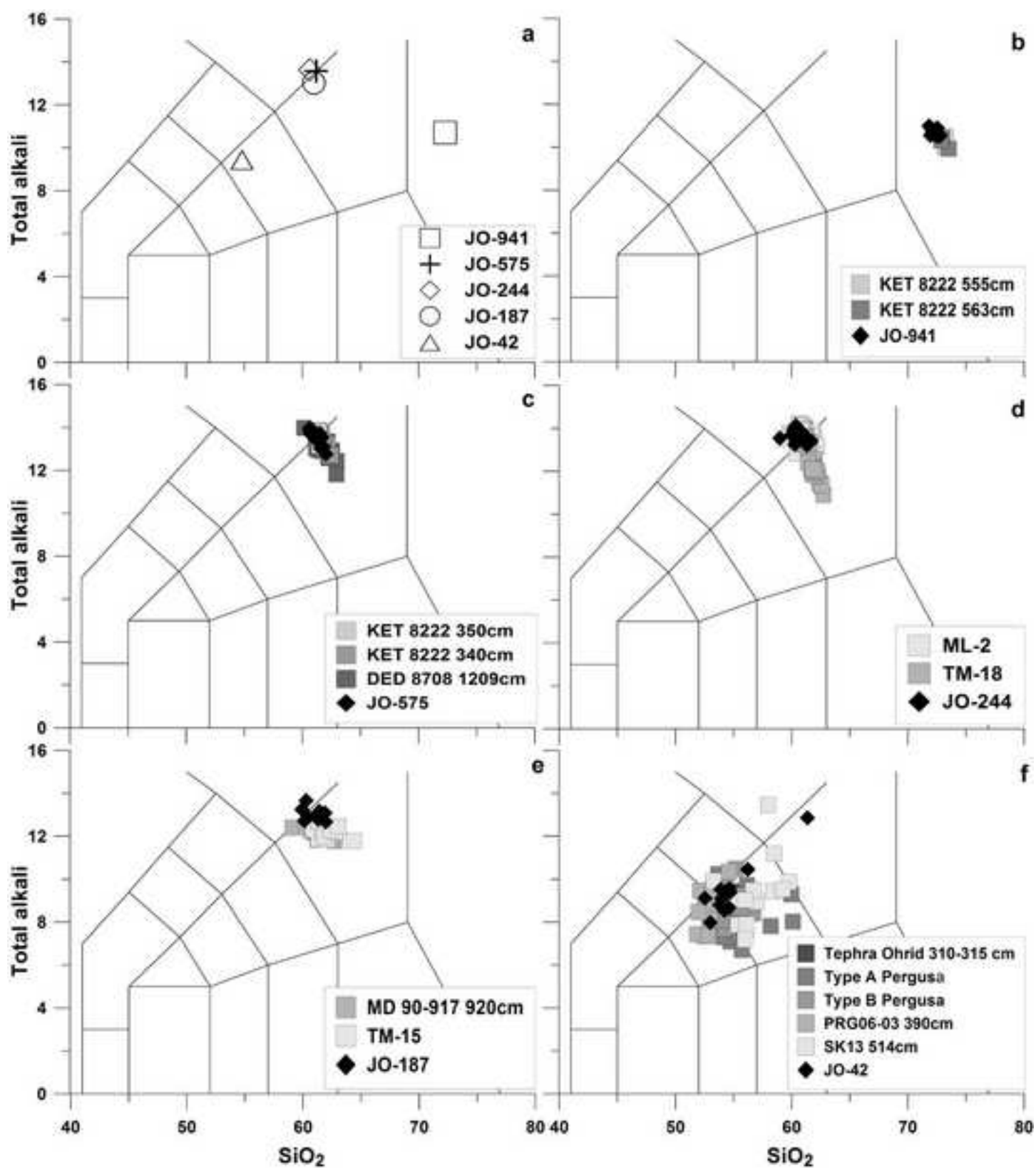


Figure 4
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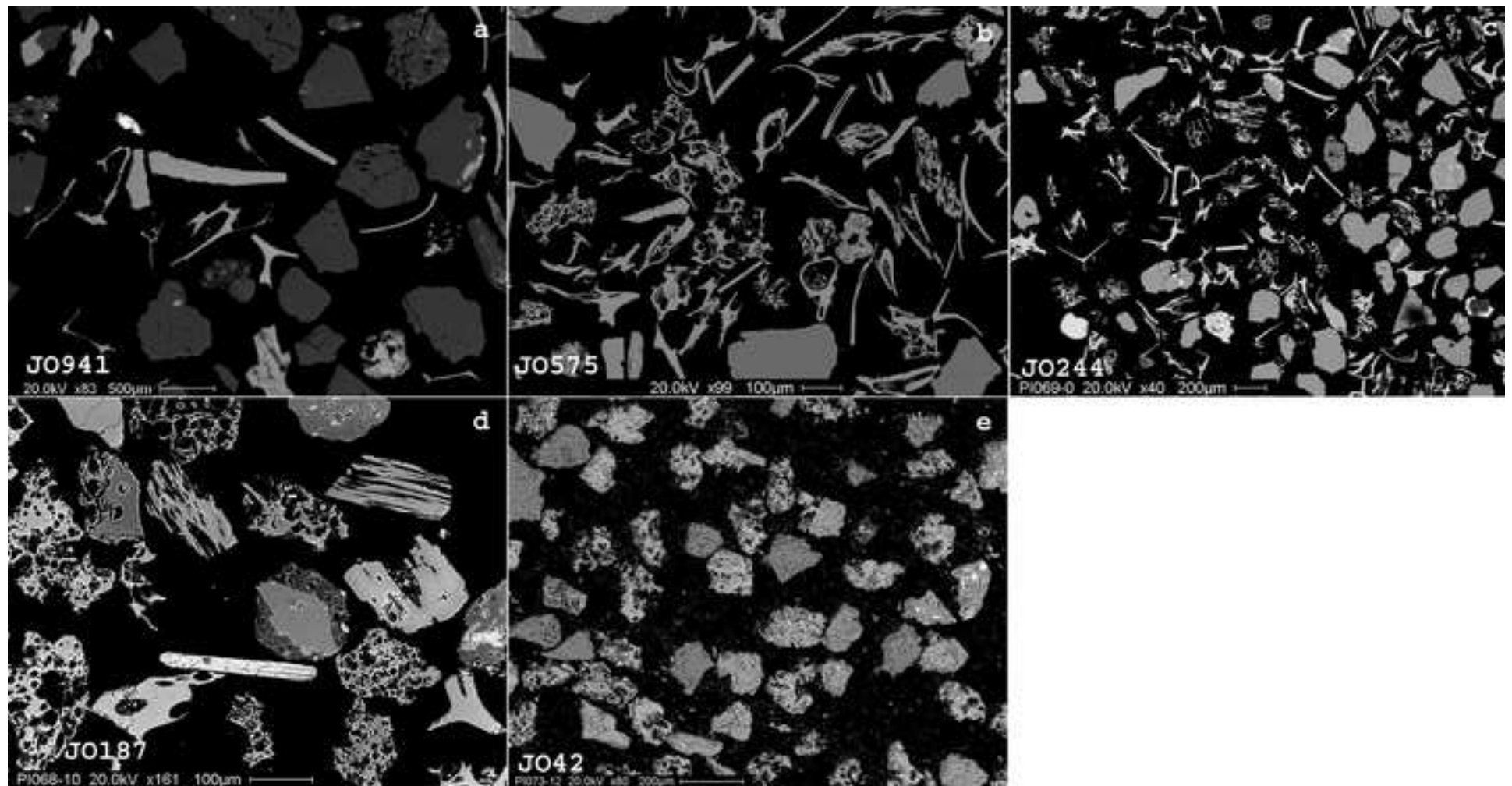


Figure 5

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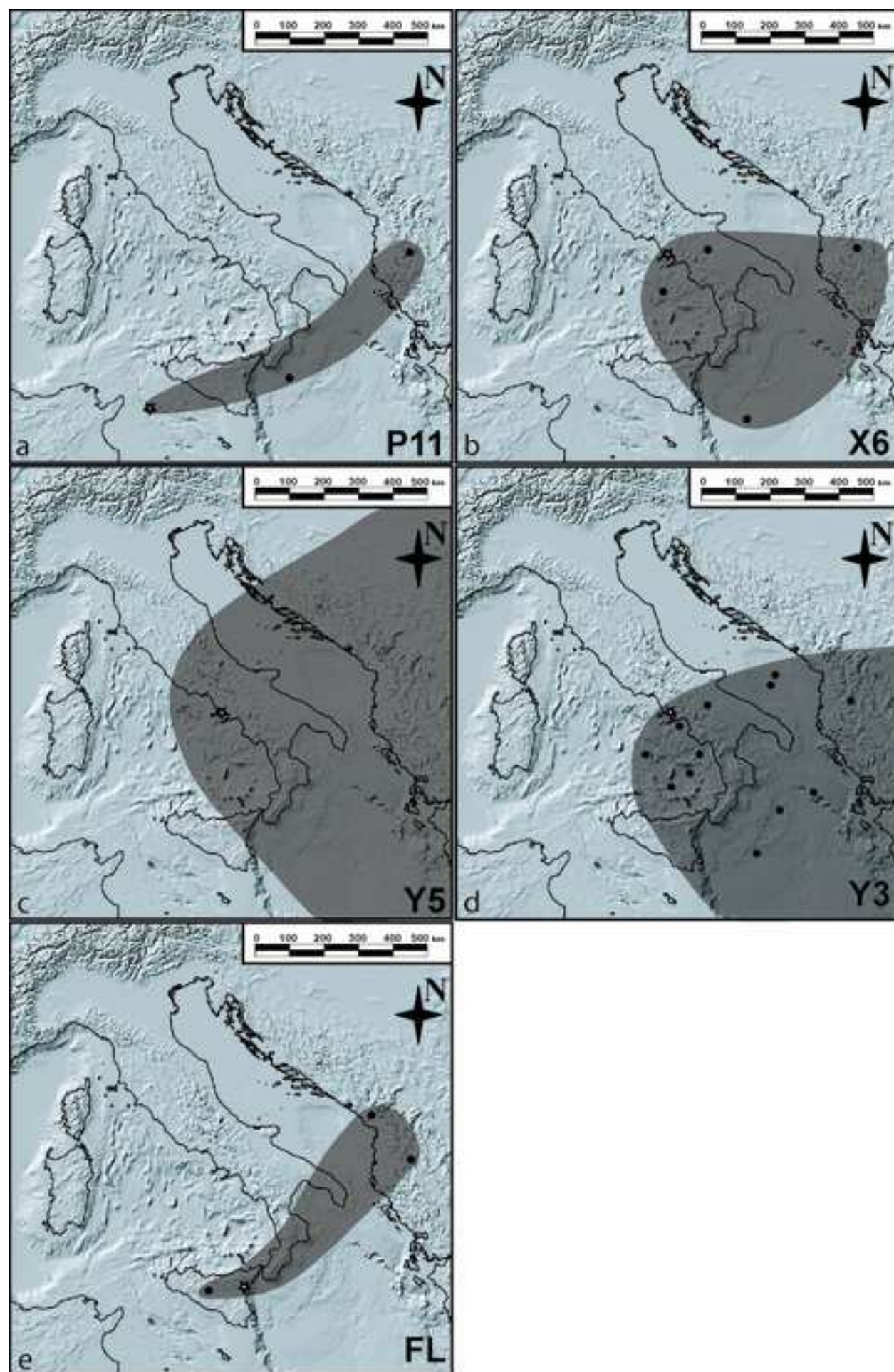
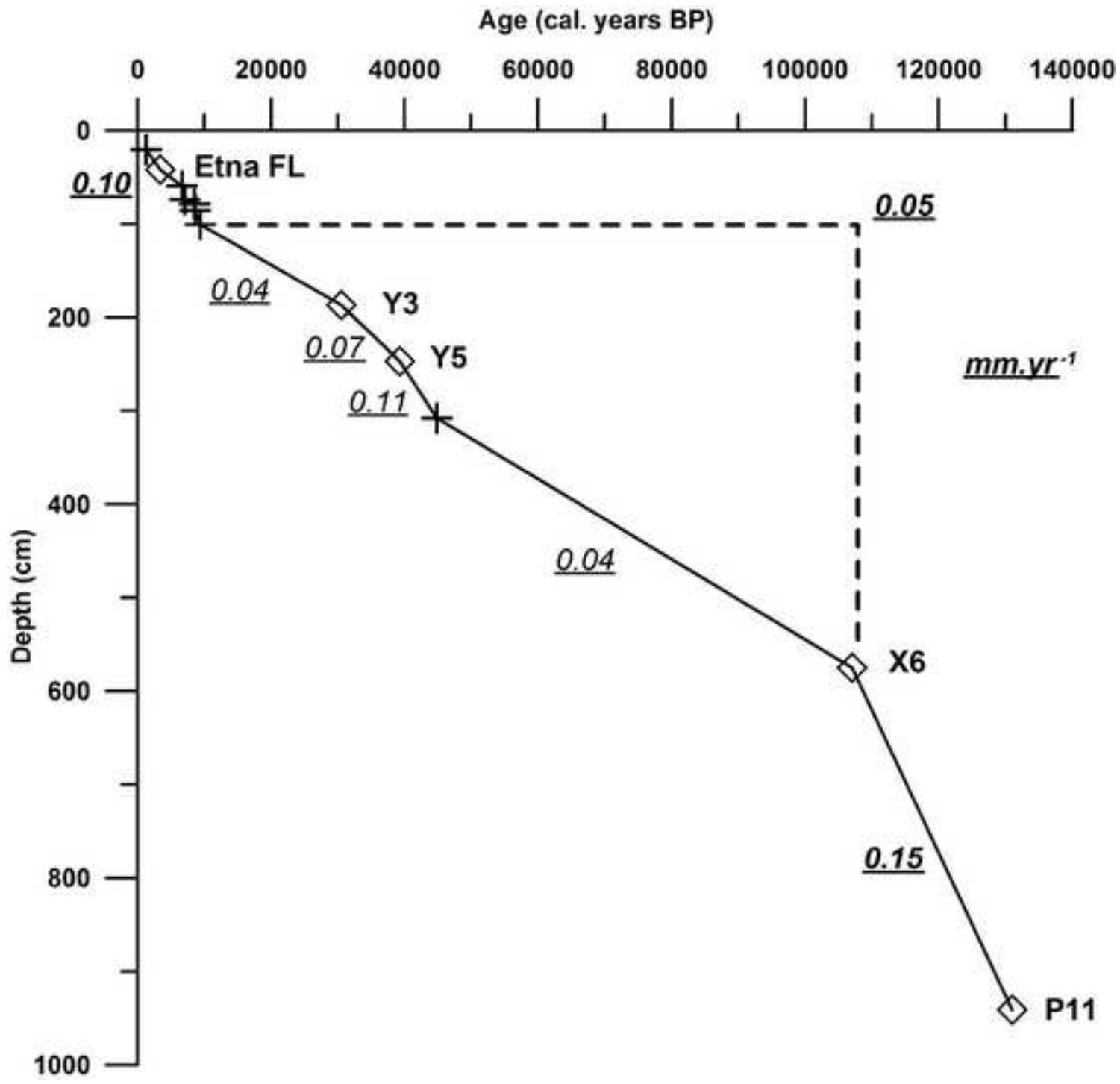


Figure 6
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JO941	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O
JO941-1	71.81	0.50	8.37	6.89	0.37	0.00	0.32	6.63	4.36
JO941-2	72.30	0.44	8.55	6.79	0.25	0.11	0.19	6.35	4.43
JO941-3	72.13	0.51	8.34	6.83	0.39	0.00	0.29	6.49	4.34
JO941-4	72.52	0.32	8.63	6.69	0.24	0.80	0.34	5.93	4.59
JO941-5	72.53	0.23	8.54	6.67	0.16	0.00	0.23	6.53	4.37
JO941-6	71.93	0.45	8.49	6.97	0.49	0.12	0.31	6.30	4.25
JO941-7	72.77	0.29	8.60	6.72	0.20	0.00	0.21	6.16	4.37
JO941-8	72.30	0.35	8.62	6.83	0.23	0.08	0.22	6.41	4.29
JO941-9	72.07	0.27	8.61	6.91	0.23	0.10	0.32	6.44	4.37
JO941-10	72.24	0.32	8.53	6.85	0.38	0.00	0.32	6.18	4.42
JO941-11	72.30	0.45	8.54	6.64	0.26	0.10	0.36	6.21	4.50
JO941-12	72.61	0.17	8.68	6.63	0.18	0.00	0.34	6.33	4.32
JO941-13	72.11	0.49	8.57	6.81	0.34	0.04	0.26	6.28	4.42
Mean	72.28	0.37	8.54	6.79	0.29	0.10	0.29	6.33	4.39
Sd	0.28	0.11	0.10	0.11	0.10	0.21	0.06	0.18	0.09

JO575	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O
JO575-1	60.59	0.53	18.42	3.24	0.39	0.27	1.78	7.29	6.66
JO575-2	61.01	0.59	18.86	2.85	0.31	0.38	1.54	6.82	6.93
JO575-3	60.90	0.44	18.46	3.13	0.20	0.31	1.84	7.08	6.76
JO575-4	60.90	0.46	18.84	2.93	0.21	0.26	1.68	7.28	6.57
JO575-5	60.71	0.50	18.63	3.08	0.40	0.47	1.63	6.85	6.94
JO575-6	61.69	0.50	18.53	2.78	0.23	0.46	1.69	5.80	7.74
JO575-7	61.48	0.36	18.74	2.80	0.13	0.36	1.84	5.62	8.11
JO575-8	61.16	0.46	18.69	3.00	0.30	0.30	1.65	6.86	6.85
JO575-9	60.69	0.61	18.54	3.21	0.40	0.39	1.59	7.20	6.56
JO575-10	61.67	0.43	18.64	2.93	0.30	0.50	1.59	6.02	7.49
JO575-11	61.68	0.64	18.79	2.82	0.42	0.35	1.50	6.33	6.81
JO575-12	61.13	0.50	18.90	3.10	0.38	0.30	1.51	6.70	6.73
JO575-13	61.83	0.52	18.69	2.95	0.27	0.43	1.56	5.56	7.54
JO575-14	61.58	0.49	19.07	2.69	0.28	0.52	1.76	5.53	7.49
JO575-15	61.11	0.37	18.85	3.00	0.24	0.43	1.59	6.73	6.87
JO575-16	60.65	0.46	18.74	3.13	0.36	0.30	1.70	7.22	6.58
JO575-17	60.73	0.35	18.92	3.02	0.34	0.35	1.73	7.08	6.60
JO575-18	61.43	0.36	18.66	2.87	0.20	0.46	1.74	6.00	7.70
JO575-19	62.04	0.38	18.96	2.86	0.24	0.42	1.61	5.87	6.89
JO575-20	60.92	0.41	18.87	3.09	0.20	0.38	1.45	6.96	6.89
Mean	61.20	0.47	18.74	2.97	0.29	0.38	1.65	6.54	7.04
Sd	0.45	0.08	0.17	0.15	0.08	0.08	0.11	0.63	0.46

JO244	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O
JO244-1	60.87	0.46	19.19	2.97	0.20	0.38	1.59	6.62	7.08
JO244-2	61.16	0.33	19.08	2.93	0.20	0.34	1.81	5.98	7.49
JO244-3	60.68	0.42	19.04	2.94	0.21	0.38	1.88	6.25	7.51
JO244-4	60.60	0.52	19.17	2.85	0.25	0.35	1.69	6.53	7.24
JO244-5	60.57	0.51	19.11	2.90	0.31	0.51	1.68	6.58	7.17
JO244-6	59.96	0.36	19.47	3.14	0.23	0.40	1.92	6.10	7.60
JO244-7	61.00	0.38	19.10	2.86	0.18	0.28	1.78	6.48	7.22

JO244-8	60.62	0.55	19.09	2.99	0.26	0.47	1.75	6.37	7.31
JO244-9	60.34	0.37	19.84	2.97	0.20	0.40	1.73	6.21	7.28
JO244-10	61.67	0.44	19.08	2.65	0.15	0.36	1.68	6.07	7.34
JO244-11	58.97	0.45	19.68	3.48	0.07	0.80	2.60	5.08	8.46
JO244-12	60.93	0.36	19.00	2.99	0.21	0.22	1.73	6.42	7.35
JO244-13	60.86	0.45	19.08	2.87	0.21	0.32	1.70	6.37	7.39
JO244-14	60.78	0.45	18.97	2.93	0.19	0.42	1.80	6.33	7.39
JO244-15	61.31	0.26	19.25	2.92	0.19	0.34	1.80	5.65	7.57
JO244-16	60.16	0.49	19.13	2.98	0.28	0.42	1.87	6.13	7.84
JO244-18	60.76	0.29	18.94	2.96	0.28	0.37	1.83	6.39	7.49
JO244-19	60.35	0.46	18.97	2.97	0.20	0.40	1.72	6.31	7.82
Mean	60.64	0.42	19.18	2.96	0.21	0.40	1.81	6.22	7.48
Sd	0.58	0.08	0.25	0.16	0.05	0.12	0.21	0.37	0.32

JO244-17	60.26	0.38	18.80	3.33	0.07	0.96	2.66	3.34	9.92
JO244-20	60.38	0.28	19.14	3.24	0.00	0.69	2.60	3.15	10.22
Mean	60.32	0.33	18.97	3.29	0.04	0.83	2.63	3.25	10.07
Sd	0.08	0.07	0.24	0.06	0.05	0.19	0.04	0.13	0.21

JO188	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O
JO188-1	61.22	0.42	18.77	3.18	0.11	0.67	2.26	3.62	9.39
JO188-2	60.43	0.52	18.89	3.40	0.09	0.77	2.63	3.44	9.48
JO188-3	60.11	0.49	18.71	3.74	0.12	0.93	2.87	3.13	9.59
JO188-4	61.30	0.33	18.70	3.31	0.06	0.69	2.49	2.96	9.82
JO188-5	60.25	0.50	18.85	3.27	0.28	0.64	2.03	4.32	9.35
JO188-6	61.88	0.31	18.53	2.90	0.12	0.47	2.22	3.83	9.26
JO188-7	59.89	0.53	18.75	3.64	0.10	0.87	2.63	2.95	10.30
JO188-8	61.40	0.35	18.68	3.07	0.17	0.42	2.16	4.38	8.79
JO188-9	61.47	0.32	18.70	3.09	0.00	0.72	2.32	3.53	9.42
JO188-10	61.94	0.26	18.81	2.98	0.06	0.64	2.19	3.77	8.90
Mean	60.99	0.40	18.74	3.26	0.11	0.68	2.38	3.59	9.43
Sd	0.75	0.10	0.10	0.27	0.07	0.16	0.26	0.50	0.43

JO42	SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O
JO42-1	52.98	1.79	17.85	8.38	0.25	3.27	6.79	5.30	2.68
JO42-2	54.60	1.63	18.10	7.39	0.22	2.39	6.14	5.65	3.03
JO42-3	53.79	1.67	17.76	8.52	0.00	2.72	5.90	5.57	3.23
JO42-4	54.69	1.86	18.00	7.45	0.28	2.03	5.45	5.72	3.67
JO42-5	53.96	1.70	17.41	7.92	0.14	2.99	6.05	5.94	3.15
JO42-7	52.51	2.23	16.55	9.77	0.25	2.84	5.86	5.18	3.94
JO42-8	53.88	1.83	17.81	8.41	0.09	2.57	5.24	5.97	3.56
JO42-9	61.35	0.53	18.75	3.06	0.24	0.54	2.18	3.96	8.90
JO42-11	54.20	1.84	17.05	8.13	0.24	2.98	6.23	5.23	3.32
JO42-12	56.22	1.50	19.13	5.45	0.09	1.12	5.24	6.53	3.93
JO42-13	54.61	1.86	17.53	7.68	0.18	2.38	5.28	5.67	3.89
Mean	54.80	1.68	17.81	7.47	0.18	2.35	5.49	5.52	3.94
Sd	2.38	0.42	0.72	1.80	0.09	0.83	1.20	0.65	1.70

P₂O₅	ClO	Total	Total Alkali
0.00	0.76	100.01	10.99
0.00	0.61	100.02	10.78
0.00	0.68	100.00	10.83
0.00	0.66	100.72	10.52
0.00	0.75	100.01	10.90
0.00	0.69	100.00	10.55
0.00	0.67	99.99	10.53
0.00	0.67	100.00	10.70
0.00	0.68	100.00	10.81
0.00	0.76	100.00	10.60
0.00	0.64	100.00	10.71
0.00	0.74	100.00	10.65
0.00	0.68	100.00	10.70
0.00	0.69	-	10.71
0.00	0.05	-	-

P₂O₅	ClO	Total	Total Alkali
0.00	0.82	99.99	13.95
0.00	0.71	100.00	13.75
0.00	0.87	99.99	13.84
0.00	0.88	100.01	13.85
0.00	0.78	99.99	13.79
0.00	0.57	99.99	13.54
0.00	0.57	100.01	13.73
0.00	0.73	100.00	13.71
0.00	0.81	100.00	13.76
0.00	0.44	100.01	13.51
0.00	0.65	99.99	13.14
0.00	0.75	100.00	13.43
0.00	0.64	99.99	13.10
0.00	0.59	100.00	13.02
0.00	0.80	99.99	13.60
0.00	0.85	99.99	13.80
0.00	0.88	100.00	13.68
0.00	0.57	99.99	13.70
0.00	0.73	100.00	12.76
0.00	0.82	99.99	13.85
0.00	0.72	-	13.58
0.00	0.13	-	-

P₂O₅	ClO	Total	Total Alkali
0.00	0.65	100.01	13.70
0.00	0.68	100.00	13.47
0.00	0.68	99.99	13.76
0.00	0.80	100.00	13.77
0.00	0.65	99.99	13.75
0.00	0.82	100.00	13.70
0.00	0.71	99.99	13.70

0.00	0.61	100.02	13.68
0.00	0.66	100.00	13.49
0.00	0.58	100.02	13.41
0.00	0.41	100.00	13.54
0.00	0.79	100.00	13.77
0.00	0.75	100.00	13.76
0.00	0.75	100.01	13.72
0.00	0.71	100.00	13.22
0.00	0.71	100.01	13.97
0.00	0.70	100.01	13.88
0.00	0.81	100.01	14.13
0.00	0.69	-	13.69
0.00	0.10	-	-

0.00	0.30	100.02	13.26
0.00	0.30	100.00	13.37
0.00	0.30	-	13.66
0.00	0.00	-	-

P ₂ O ₅	ClO	Total	Total Alkali
0.00	0.36	100.00	13.01
0.00	0.35	100.00	12.92
0.00	0.31	100.00	12.72
0.00	0.33	99.99	12.78
0.00	0.51	100.00	13.67
0.00	0.49	100.01	13.09
0.00	0.35	100.01	13.25
0.00	0.59	100.01	13.17
0.00	0.44	100.01	12.95
0.00	0.44	99.99	12.67
0.00	0.42	-	13.02
0.00	0.09	-	-

P ₂ O ₅	ClO	Total	Total Alkali
0.38	0.33	100.00	7.98
0.51	0.31	99.97	8.68
0.51	0.32	99.99	8.80
0.54	0.30	99.99	9.39
0.44	0.31	100.01	9.09
0.54	0.33	100.00	9.12
0.38	0.26	100.00	9.53
0.00	0.49	100.00	12.86
0.51	0.27	100.00	8.55
0.44	0.34	99.99	10.46
0.57	0.35	100.00	9.56
0.44	0.33	-	9.46
0.16	0.06	-	-

Table / Tableau 2

		SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
KET 8222 563cm	mean	73.09	0.39	8.88	7.05	-	0.09	0.27	5.81	4.42	-
n=13	<i>sd</i>	0.36	0.08	0.13	0.12	-	0.06	0.11	0.37	0.16	-
KET 8222 555cm	mean	72.95	0.31	8.89	7.23	-	0.05	0.20	5.90	4.48	-
n=13	<i>sd</i>	0.47	0.05	0.05	0.33	-	0.03	0.04	0.36	0.10	-
KET 8222 765cm	mean	72.97	0.50	9.02	7.34	-	0.10	0.20	5.44	4.42	-
	<i>sd</i>	0.49	0.06	0.16	0.28	-	0.07	0.02	0.30	0.06	-
		SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
KET8222 350cm	mean	61.47	0.52	19.20	3.20	-	0.40	1.66	6.27	7.30	-
n=11	<i>sd</i>	0.06	0.04	0.10	0.22	-	0.06	0.10	0.53	0.77	-
KET8222 340cm	mean	61.98	0.47	19.18	3.06	-	0.42	1.70	6.08	7.11	-
n=14	<i>sd</i>	0.27	0.10	0.13	0.15	-	0.09	0.10	0.68	0.46	-
DED 8708 1209cm	mean	61.81	0.48	18.18	3.04	0.33	0.31	1.71	5.72	7.29	0.02
n=19	<i>sd</i>	0.68	0.10	0.31	0.23	0.12	0.07	0.32	0.91	0.86	0.04
		SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
TM-18	mean	61.69	0.42	19.11	2.93	0.24	0.35	1.73	5.66	6.83	0.05
n=43	<i>sd</i>	0.46	0.02	0.21	0.09	0.02	0.02	0.07	0.71	0.29	0.03
ML-2	mean	61.01	0.48	18.18	3.02	0.21	0.44	2.12	5.64	8.05	0.07
n=105	<i>sd</i>	0.42	0.04	0.19	0.21	0.06	0.15	0.32	1.21	1.02	0.04
		SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
TM-15	mean	62.22	0.38	18.36	3.27	0.13	0.61	2.19	3.85	8.36	0.12
n=20	<i>sd</i>	0.78	0.03	0.21	0.29	0.04	0.15	0.22	0.44	0.55	0.06
MD90-917 920cm	mean	61.41	0.36	18.72	3.17	0.08	0.70	2.44	3.52	9.14	-
n=20	<i>sd</i>	0.86	0.12	0.17	0.38	0.08	0.21	0.33	0.40	0.40	-
		SiO ₂	TiO ₂	Al ₂ O ₃	FeO _{tot}	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SK13 514cm	mean	56.81	1.21	20.52	4.86	0.09	1.38	5.27	6.22	3.10	0.24
n=14	<i>sd</i>	1.78	0.44	2.39	2.49	0.09	1.27	1.83	1.04	1.26	0.22
Tephra Ohrid 310-315 cm	mean	54.25	1.76	17.48	8.15	0.00	2.85	6.02	5.40	3.29	0.48
n=15	<i>sd</i>	0.73	0.22	0.51	0.53	0.00	0.33	0.50	0.41	0.34	0.10
PRG06-03 390 cm	mean	52.82	2.04	16.86	9.43	0.23	3.21	6.13	4.99	3.58	0.47
n=11	<i>sd</i>	0.82	0.17	0.47	0.90	0.10	0.42	1.03	0.37	0.67	0.07
Type A Pergusa	mean	55.61	1.58	16.97	7.25	0.15	3.98	5.62	6.02	2.37	-
n=14	<i>sd</i>	2.28	0.20	0.78	1.35	0.09	0.57	0.95	1.13	0.34	-
Type B Pergusa	mean	54.91	1.61	17.65	6.83	0.15	3.90	5.65	5.79	3.06	-
n=11	<i>sd</i>	0.91	0.23	0.49	1.16	0.09	0.47	1.04	0.88	0.25	-

SO ₃	ClO	F	Total Alkali
-	-	-	10.23
-	-	-	-
-	-	-	10.38
-	-	-	-
-	-	-	9.86
-	-	-	-

SO ₃	ClO	F	Total Alkali
-	-	-	13.56
-	-	-	-
-	-	-	13.19
-	-	-	-
0.11	0.97	-	13.02
<i>0.08</i>	<i>0.28</i>	-	-

SO ₃	ClO	F	Total Alkali
-	0.78	0.19	12.49
-	<i>0.05</i>	<i>0.17</i>	-
-	0.71	-	13.70
-	<i>0.20</i>	-	-

SO ₃	ClO	F	Total Alkali
-	0.52	0.00	12.21
-	<i>0.11</i>	<i>0.00</i>	-
-	0.44	-	12.66
-	<i>0.09</i>	-	-

SO ₃	ClO	F	Total Alkali
-	0.30	-	9.32
-	<i>0.11</i>	-	-
-	0.31	-	8.69
-	<i>0.06</i>	-	-
-	0.24	-	8.57
-	<i>0.06</i>	-	-
-	0.46	-	8.39
-	<i>0.09</i>	-	-
-	0.45	-	8.86
-	<i>0.43</i>	-	-

Table / Tableau 3

Laboratory number (Artemis-Saclay)	Sample	Mean composite Depth (cm)	¹⁴ C age	error	age cal final	erreur 1 s	Methods
SacA 8010	JO2004-1A020	20.5	1285	30	1253	30	intcal04 Reimer et al., 2004
SacA 8011	JO2004-1A059	59.5	5840	35	6680	66	intcal04 Reimer et al., 2004
2653	JO2004-1A074	74	6130	80	7048	156	intcal04 Reimer et al., 2004
2654	JO2004-1A078	78.5	7800	80	8550	139	intcal04 Reimer et al., 2004
SacA 8012	JO2004-1A085	85.5	7850	40	8622	52	intcal04 Reimer et al., 2004
SacA 8013	JO2004-1A100	100.5	8275	40	9407	121	intcal04 Reimer et al., 2004
2655	JO2004-1B113	307.6	39100	1200	44812	1055	Bard et al., 1998