<u>Author comment to the reviews on Leicher et al.</u>

First of all, we would like to express our thanks to the anonymous reviewer and to the second reviewer S. Davies for reviewing the MS. We considered all comments on the tephrostratigraphy of the DEEP site carefully, which significantly improved the established correlations and the general quality and structure of the MS. Below, we will provide a point-to-point reply to the comments.

Anonymous Referee #1

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General comments:

My main comments concern the discussion section i.e. the data analysis. I have some difficulties in taking into account the proposed correlations mainly for the ancient tephras (prior to X-6). The correlation of a tephra with a volcanic source and/or event cannot be solely based on the TAS classification diagram as the authors did. It is known that the sum of alkalis cannot be a diagnostic criterion due to the mobility of the two oxides. Moreover, there is heavy overlap of compositions related to the Italian volcanic rocks. The use of TAS as the only instrument of major element analysis can lead to misinterpretations and ambiguous correlations. I suggest to the authors to perform a more accurate data analysis and to provide significant figures concerning this issue.

We agree with the reviewer that the former way of presenting the proposed correlations using the TAS classification diagram alone is not enough for establishing reliable correlations of tephra layers. We are aware of the mobility of the alkali-oxides and the overlap in the geochemical composition of pyroclasts from Italy's volcanoes. Actually, we established our correlations using also other major elements, but in the original manuscript, we decided to show only the TAS-diagram as a general overview and correlation figure. Therefore, in the revised version, in order to improve and present a more accurate data analysis, we will add other oxides plots to proof the proposed correlations for the tephra older than P-11/OH-DP-06xx. Additional oxide plots also for the younger tephra layers will be given as supplementary material.

The ancient tephras analysed here represent the most original aspect of this paper and therefore deserve a more significant approach. I think that a research paper should provide all the main informations to let the reader follow the discussion and the aimed results in the proper way. This work deals with the correlations of 13 tephras with a number of likely correlatives both at proximal and distal sites. This means a large dataset of major element compositions from literature which the authors should have used in order to make comparison with OH-DP-

tephra and to establish the proposed correlations. A table where at least the average composition of all the many tephras, used in the TAS for comparison e cited in the text must be reported. It is hard for the reader to have such a long text without a reference table.

We will add a table showing the average major element compositions of all tephra layers used in our study and agree that this will help to make the suggested correlations more robust and easier to follow for the reader.

Detailed comments

1. *It is not clear to me if the cryptotephra correlated with the Mercato event has been analysed in terms of major element content. Actually, there are no data in table 1. Is the correlation merely based on similar tephrostratigraphic features in other cores from Lake Ohrid and Lake Prespa? Please, specify.*

   In the meantime, we carried out SEM-EDS analysis on the glass shards and micro-pumices found in the specific depth. We will use this major element data to strengthen the proposed correlation between OH-DP-0027 and the Mercato eruption, so that the correlation is not only based on (tephro-)stratigraphic features from other cores of lakes Ohrid and Prespa.

2. *Please, locate in Fig.1 all the drilling and outcrop sites cited in the text and discussed to establish correlations with OH-DP-tephras. The paper must be easily managed by anybody interested in the field but not necessarily expert of Mediterranean tephrochronology.*

   We will add a map showing all drillings and outcrops cited in the text in order to give the reader a better overview of the Mediterranean area.

3. *Since some of the analysed tephras in this work aim to be good markers beyond Italy and the Balkan region, I suggest to insert a figure where the tephrostratigraphic framework for the area might be sketched. This figure can sum the conclusions of the paper which are too long in the text after all.*
   We appreciate this idea and will add a tephrostratigraphic sketch merging all the used tephra layers in order to highlight the potential of Lake Ohrid linking individual sections to a continuous record. Furthermore, this will help to sum up the proposed correlations and provide the basis for e.g. future paleoclimatic studies, comparing different archives.

4. *The authors report in the text a low and high silica end-member for tephra OH-DP-0115/Y-3. This feature should be displayed in table 1 with two average compositions for the layer.*

   We will add this to Table 1 and highlight the variation in silica in some of the new oxide plots.

5. *Trimodal composition of the CI deposits? I don't see anything of this in your OH-DPO169/Y-5 tephra.*
   We will revise the specific sentences explaining the tri-modal composition of the CI deposits in order to prevent the misunderstanding born from the three different compositions. Our aim was to show that there is a trimodal composition of the CI deposits, but only two of the three populations are found in OH-DP-0169. The differences in composition are described in Civetta et al. (1997); Pappalardo et al. (2002); Marianelli et al. (2006) and can be seen in the alkali ratio. Such differences in the alkali ratio have also been described for the CI-tephra layer equivalents from previous studies at Lake Ohrid (Sulpizio et al., 2010). We will highlight the differences in the alkali ratio of OH-DP-0169 in a specific table. We will further discuss that one pole is missing in the revised version. In short it could be related to either limited number of analysis performed on glass shards of OH-DP-0169 or the relatively low abundance of the third composition of the CI in distal setting, which to great existent (up to 80%), is represented by the component characterized by a low alkali ratio (K_2O/Na_2O=~1.2) .

6. *In Fig. 3g the label for the tephra plotted in the TAS diagram is OH-DP-0617 but actually it should be OH-DP-0624 according to the text.*

   We will correct the labelling.

7. *The authors report a trachy-andesitic to phonolitic trend for tephra OH-DP-1955. Are you sure it can be considered one population instead of two? Such magmatic trend is very unlikely. Moreover, since Sr-isotope ratios of the correlative SC5 tephra infer an origin for these layers from the Roccamonfina volcano, why do the authors discuss a possible origin from Sabatini vents despite geochemical differences? It is a useless part of the discussion.*
   By using oxide plots such as MgO, CaO it becomes obvious that the composition shows a linear magmatic trend rather than two different populations. We will add such specific

plots to rule out these doubts, clarify our description of a magmatic trend, and ensure our correlation with the SC-5 tephra.

We do not think that the discussion of Sabatini products is useless at that point. Our reference to Fall B is in fact intended to clear up any doubts about considering it as possible counterpart of OH-DP-1955. Fall B has in fact an age compatible with OH-DP-1955 and thus avoiding to mention it might be considered a lack of our assessment. This part of the discussion is substantially intended to emphasize our correlation with SC5 while ruling out a correlation with the products of Fall B. Fall B is described having also a phonolitic composition, which makes it somehow similar to OH-DP-0624. However, a closer look offers geochemical differences. The second reviewer S. Davies (see reviewer point 3) also demands such discussion.

8. *Concerning tephra OH-DP-2010/Fall A, the authors cite the Tufi Terrosi Eruptive Cycle of the Sabatini volcanic district as the source for the deposit. Please, report the age of this cycle and the reason why they make this correlation.*

   We will report the age of the Tufi Terrosi Eruptive Cycle and further explain the correlation using oxides plots.

9. *In section 5.14 the authors mention two flux standards: FCs and ACs-2. I suppose the one used to recalculate 40Ar/39Ar ages is the latter one (as it is reported in the caption of table 2). Please, correct the sentence.*

   Flux standards are intercalibrated (FCs at 28.02Ma correspond to ACs-2 at 1.194Ma or FCs at 28.201 is equivalent to ACs2 at 1.201Ma). Therefore, the ages obtained with one of the two standards are comparable to each other. Depending on the source we used for the ages we recalculated all ages used in the MS with respect to the proportionality between these two standards. We added the following important information: All ages are recalculated to an age of 1.194 Ma for ACs, which corresponds to FCs at 28.02Ma.

10. *The exact reference for the TAS diagram is Le Bas et al., 1986 and not Bas et al., 11 Please, note in the Introduction section that the tephrochronological record published for KC01B core in the Ionian Sea (Insinga et al., 2014) extends down to 200 ka, then Middle Pleistocene.*

    We will change the citation to “Le Bas et al., 1986”.

    We will revise the specific sentences in the introduction dealing with KC01B.

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Specific comments

1. *Please consider merging the results (4) and discussion sections (5.1-5.13) so that descriptions of the tephra deposits can be discussed in tandem with the geochemical signatures and potential correlations. This will shorten the paper and allow the Discussion section to focus on the implications of the results.*

   We will merge the two sections in order to get a more compact MS and increase the focus on the results.

2. *I would suggest re-structuring the Discussion to two sub-sections. The first should describe the intricacies of the age-depth model for the Lake Ohrid record. The second section needs to focus on the implications of the tephra results beyond just the development of the Ohrid age-depth model. In its current form, the value of this tephra framework to other studies and researchers is somewhat lost. Some important but brief points are made in the conclusions e.g. clarifying the eruptive order of events, new insights on tephra distribution patterns, potential for linking different palaeo-records, evidence of large-magnitude eruptions and new records of previously unknown events. These points should be expanded in a section on the implications of these discoveries. This sub-section would greatly benefit from a figure of the tephra record or template plotted alongside an appropriate climato-stratigraphical framework extending from MIS1-15. This would represent a focus for discussing the implications of these results. For instance, key marker horizons for different climatic periods could be identified that could aid in the interpretation of other Middle and Late Pleistocene records in the Eastern Mediterranean region and beyond. Other points touched upon in the Conclusions and mentioned above could also use the visualization of the tephra framework as a focus.*

   We will divide the Discussion chapter into two parts in order to strengthen and expand the mentioned implications and conclusions. However, it is not possible for all points mentioned by the reviewer. The main focus of this MS is to establish independent and precise tie points to create a chronology for the DEEP site sequence. With the proposed implications in the conclusions, we tried to highlight the future potential of tephrostratigraphic studies on the DEEP site, because general implications on the older tephra layers are hard to establish with the current knowledge.

The implications transferred from the tephras younger than OH-DP-0499/P-11 are already described in published studies, summarized in Sulpizio et al. (2010). Discussing implications of Middle Pleistocene tephra layers we discovered is premature at that point, since this is the first continuous distal archive being analysed. For instance, implications on the dispersal patterns of these tephras are hardly to establish since some of them are just correlated to single occurrence (e.g. OH-DP-1955/SC5 or OH-DP-201/A11-12). The current state of the art barely allows implications of the eruptive order of tephra layers, since we only presented selected correlations and not the complete tephrostratigraphy of the DEEP site. Additional studies on the geochemical composition of tephras are not discussed in this article. The study of cryptotephras in specific intervals may be necessary to improve our knowledge and allow further implications. However, this is well beyond the scope of this MS.

Adding a figure, showing the framework of current knowledge of Middle Pleistocene tephrostratigraphy, is an excellent suggestion and will help to visualize the links and possible synchronisation of the different archives of the Mediterranean area. We agree that this figure will be helpful and may give more space for implications.

3. *Figure 3 is very difficult to see and interpret. Further figures and additional biplots are needed to support the proposed correlations. In most cases, only the data that support a correlation are provided. Are there other tephras of similar ages and com position that should also be plotted to test other potential correlations? For instance, how does the data for OH-DP-0169 compare with pre-CI data presented in Tomlinson et al. 2012 (Geochmica et Cosmochimia Acta). Further consideration of other potential matches is required and should be shown on plots, where appropriate.*

   We agree with the reviewer request, so we have added an additional oxide-biplot and improved the visual appearance of Figure 3 (please see the reply letter to the anonymous reviewer (general comment).

   For the tephra layers younger than OH-DP-0499/P-11, tephrostratigraphic correlations were well established for lakes Ohrid and Prespa in several studies (e.g. Sulpizio et al. (2010)) and we decided to show only data of the equivalent layers that support the established correlations. This helped to shorten the MS and keep it clearer. However, for the older tephras we will constrain further considerations with alternative tephra deposits more in detail, where appropriate.

4. *Please provide average secondary standard data alongside the WDS data summarized in Table 1 (average) and individual analyses in the supplementary file.*

   We will add this information to Table 1 and the supplement.

5. *It would be useful to provide some context for the cryptotephra discovery (OH-DP-0027). What is the shard concentration and how does the concentration profile vary around the peak concentration? Are the glass shards confined to a few centimetres or dispersed within the profile? This is important to pinpoint the exact stratigraphic position of the tephra for age-modeling purposes.*

   The main focus of this MS was to identify all macroscopic tephra layers of the DEEP site. No detailed high-resolution cryptotephra studies have been performed yet (e.g. glass shard counting). Since many studies have shown, that the XRF-scanning technique is a suitable tool for detecting cryptotephra (Vogel et al., 2010; Damaschke et al., 2013), we identified this cryptotephra layer by analysing XRF-downcore data and comparing this data with homologous data of previous cores from Lake Ohrid. In these previous cores peaks in XRF-scanning data and subsequent cryptotephra investigations revealed occurrence of the Mercato tephra by. A maximum of K in the XRF scanning data of the DEEP site sequence was used to infer the stratigraphic position of OH-DP-0027. The subsequent analyses (microscope, SEM-EDS) were performed on a one cm thick interval, where K showed the maximum. We added this additional information to the MS.

Technical corrections

1. Page 15414 line 4 replace Rosetta stone with template or framework.
   Will change to “template”.
2. Page 15417, line 16 change to “opened lengthwise” and “visually described”
   Will change as suggested.
3. Page 15419 line 1 – grammar - revise sentence.
   Will revise sentence.
4. 15419, line 10 –grammar revise sentence
   Will revise sentence.
5. Page 15420, line 4 – grammar – revise sentence
   Will revise sentence.
6. Page 15423, line 26 – should this be OT0702-3 as shown on figure 3?
   Will change to OT0702-3.
7. Page 15424, line 26 - grammar, revise sentence.
   Will revise sentence.

8. Page 15425, line 3 delete the “in light of new geochemical data”

   Will delate this part and revise the sentence.

9. Figure 3g – should this be OH-DP-0624?

   Will change to OH-0624.

10. Page 15440, line 5-7– grammar please revise.

    Will revise sentence.

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First tephrostratigraphic results of the DEEP site record from Lake Ohrid~~,~~ (Macedonia, Albania)

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Abstract

A tephrostratigraphic record covering the Marine Isotope Stages (MIS) 1–15 was established for the DEEP site record of Lake Ohrid (Macedonia/Albania). Major element analyses (SEM-EDS/WDS) were carried out on juvenile fragments extracted from 12 tephra layers (OH-DP-0115 to OH-DP-2060). The geochemical analyses of the glass shards of all of these layers suggest an origin from the Italian ~~Volcanic Provinces.~~volcanic provinces. They include: the Y-3 (OH-DP-0115, 26.68–29.42 ka cal BP), the Campanian Ignimbrite/Y-5 (OH-DP-0169, 39.6±0.1 ka), and the X-6 (OH-DP-0404, 109±2 ka) from the Campanian volcanoes, the P-11 of the Pantelleria Island (OH-DP-0499, ~~129 ± 6~~133.5±2 ka), the Vico B (OH-DP-0617, 162±6 ka) from the Vico volcano, the Pozzolane Rosse (OH-DP- 1817, 457±2 ka), and the Tufo di Bagni Albule (OH-DP-2060, 527±2 ka) from the Colli Albani volcanic district, and the Fall A (OH-DP-2010, 496±3 ka) from the Sabatini volcanic field. Furthermore, a comparison of the Ohrid record with tephrostratigraphic records of mid-distal archives related to the Mediterranean area~~,~~ allowed the recognition of the equivalents of other less known tephra layers, such as the ~~TM24-a~~TM24a/POP2 (OH-DP-0404, ~~101.8~~102±2 ka) ~~from~~recognised in the Lago Grande di Monticchio and the Sulmona basin, the CF-V5/PRAD3225 (OH-DP-0624, ca. ~~162~~163±22 ka) ~~from~~identified in the Campo Felice basin/Adriatic Sea, the SC5 (OH-DP-1955, 493.1±10.9 ka) ~~from~~recognised in the Mercure basin, and the A11/12 (OH-DP-2017, 511±6 ka) ~~from~~sampled at the Acerno basin, whose specific volcanic sources are still poorly constrained. Additionally, one cryptotephra (OH-DP-0027) was identified by correlation of the potassium XRF intensities from the DEEP site with those from a short ~~cores~~core of a previous ~~studies~~study from Lake Ohrid. In these cores, a maximum in potassium is caused by glass shards, which were correlated with the Mercato tephra (8.43– 8.63 ka cal ~~ka~~ BP) from Somma-Vesuvius. ~~With the~~The presented tephrostratigraphic work~~,~~ allows, for the first time, the extension of a consistent part of the Middle Pleistocene ~~tephrostratigraphic framework~~tephrostratigraphy of Italian volcanoes ~~was for the first time extended~~ as far as to the Balkans. The establishment of the tephrostratigraphic framework for the Lake Ohrid record provides important, independent tie-points for the age-depth model of the DEEP site sequence, which is a prerequisite for paleoclimatic and -environmental reconstructions. Furthermore, this age-depth model will help to improve and re-evaluate the chronology of other, both undated and dated tephra layers from other records. Thus, the Lake Ohrid record is candidate to become the ~~Rosetta stone~~template for the central Mediterranean tephrostratigraphy, especially for the hitherto poorly known and explored lower Middle Pleistocene period.

1 Introduction

Volcanic explosive eruptions produce pyroclastic material, called tephra (gr. τεφρα = ash), which is ejected into the atmosphere and distributed by the prevailing wind systems.

Tephra settles down from the atmosphere in a relatively short time (days-weeks) as isochronous event marker horizons into all kind of geological archives downwind of the volcano. By determining the unique geochemical and physical fingerprint of such a tephra horizon, tephra layers (from different archives) can be identified, characterised~~, identified~~, and correlated with each other in order to obtain a tephrostratigraphic framework. If tephra horizons can be dated directly (e.g., ^{40}Ar/^{39}Ar~~/^{40}Ar~~) or indirectly (e.g., ^{14}C dating on overlying or underlying sediments, varve counting, age modelling) and correlated with tephra horizons in other archives, also the ages can be transferred to ~~the studied~~these other archives.

The Italian volcanism was ~~active~~characterized by an intense explosive activity during the entire Quaternary (Peccerillo, 2005~~), which provides~~). Consequently, the surrounding Mediterranean region became an ideal setting for tephrochronological studies (tephrostratigraphy and tephrochronometry, cf. Sarna-Wojcicki, 2013~~) on~~), which provide a key tool for a wide spectrum of Quaternary science subjects ~~in the Mediterranean region (Giaccio et al., 2014~~(e.g. Lowe, 2011). After Keller et al. (1978) set up the first tephrostratigraphic scheme for the central Mediterranean region, numerous studies on marine and terrestrial archives have spatially and temporally extended and improved this initial stratigraphy for the Holocene and Late Pleistocene (Paterne et al., 1986, 1988, 2008; Vezzoli, 1991; Calanchi et al., 1998; Narcisi and Vezzoli, 1999; Siani et al., 2004; Calanchi and Dinelli, 2008; Zanchetta et al., 2011; Tamburrino et al., 2012; Insinga et al., 2014; Satow et al., 2015; Tomlinson et al., 2015). Despite this ~~immense~~noticeable progress over the last decades, tephrochronological work in the period > 200 ka~~,~~ is still challenging due to incomplete knowledge on the eruption history and limited geochemical analysis. Some records from the Italian Peninsula cover specific intervals of the Early to Middle Pleistocene and can be used as proximal (Karner et al., 2001; Rouchon et al., 2008; Marra et al., 2009, 2014; Palladino et al., 2010; Giaccio et al., 2013a) or ~~mid-~~relatively distal (Karner et al., 1999; Munno and Petrosino, 2007; Roulleau et al., 2009; Russo Ermolli et al., 2010; Giaccio et al., 2013b, 2014, 2015; Petrosino et al., 2014a, b, 2015; Sagnotti et al., 2014) archives of deposits from volcanic complexes. Sediment records spanning continuously > 200 ka are extremely rare in the Mediterranean region. To date, there are only two continuous records covering the entire Middle and parts of the Early Pleistocene of the Mediterranean region, which are the Calabrian Ridge core KC01B (Lourens, 2004; Insinga et al., 2014) and the peat record from Tenaghi Philippon, Greece (Tzedakis, 1993; St. Seymour et al., 2004; Pross et al., 2007). However, both records are limited in the tephrostratigraphy to the Holocene and ~~Late~~upper Middle Pleistocene.

Lake Ohrid is located on the Balkan Peninsula and is one of the oldest lakes of Europe (Wagner et al., 2014). Over 1.2 Ma of continuous sediments were recovered from Lake Ohrid during the ICDP (International Continental Scientific Drilling Program) deep drilling campaign SCOPSCO (Scientific Collaboration on Past Speciation Conditions in Lake Ohrid). Previous tephrochronological studies on sediment cores from Lake Ohrid covered the last 135 ka and revealed the lake’s unique potential as distal tephra archive of Italian volcanoes (e.g. Sulpizio et al., 2010).

Here, we present first tephrostratigraphic and tephrochronological results of the uppermost 247.~~8m~~8 m composite depth (mcd) of the main drill site (DEEP site) in the central part of the lake, which covers continuously the last ~~ca. 640~~637 ka (Francke et al., 2015). The correlation of the discovered tephra layers to known and dated equivalent tephra horizons from proximal and distal archives enables dating of the Lake Ohrid succession. The transfer of these ages to the Lake Ohrid record ~~provide~~provides important, independent tie-points for ~~a tuning based~~an age-depth model complemented by orbital tuning (Francke et al., 2015), which is a precondition for environmental and climate reconstructions. The correlation of tephra layers between different geographical archives, both terrestrial and marine, is crucial for a synchronisation of ~~paleoclimatical~~paleoclimatic and paleoenvironmental changes on a regional and global scale.

2 Regional setting

Lake Ohrid (40°54’–41°10’ N, 20°38’–20°48’ E) is located ~~on~~in the Balkan Peninsula (cf. Fig. 1a) and shared between Albania and the Former Yugoslav Republic of Macedonia (FYROM). The lake is 30 km long, 15 km wide~~ and~~, covers an area of 358 km^2, and is situated at an altitude of 693 m above sea level (a.s.l.). The lake basin has a simple tub-like shape with a volume of 55.4 km^3 and a maximum water depth of 293 m (Lindhorst et al., 2015). ~~Today’s water chemistry~~The lake is oligotrophic~~,~~ today due to the large water volume and the low nutrient availability (Wagner et al., 2010~~) with~~), and has a ~~surface water~~ specific conductivity of ca. 200 µScm^{-1} and a pH of around 8.4 (Matter et al., 2010~~).~~) in the surface waters. The hydrological characteristics are mainly controlled by a relatively low water input of 37.~~9m^{3}s~~9 m^{3}s^{-1}, of which

~50% derives from karst aquifers (Matzinger et al., 2006a, b). The natural catchment area is relatively small with 1042 km^2 (Matzinger et al., 2006b; Wagner et al., 2008). Lake Ohrid is situated within the Lake Ohrid Basin, which is a 40 km long N–S trending graben structure in the Dinarides-Albanides-Hellenides mountain belt. The ~~pull-apart like~~ basin formation ~~of the basin~~ was initiated during a late phase of Alpine orogeny in the Miocene ~~and the following subsidence led to the development of~~as a pull-apart basin in a short transtensional phase and consequently widened by an ~~early lake system (Reicherter~~E-W extensional phase since the Pliocene (Lindhorst et al., ~~2011~~2015). The exact age of the formation of the lake is still unknown and subject of several studies within the SCOPSCO project.

In the N and NE of the basin Palaeozoic metamorphic rocks crop out, which are superimposed by Triassic to Early Jurassic karstified platform carbonates (cf. Fig. 1b) in the E, NW and at the up to 2300 m a.s.l. high ~~Galicica~~Galičica Mountains in the SE (Robertson and Shallo, 2000). Jurassic ophiolites and Tertian conglomerates form the Mocra Mountains of the SW part of the graben shoulder (Robertson and Shallo, 2000). Mesozoic intrusions of rhyolites and diabases are locally preserved in between the limestones and dolomites in the NE ~~locally~~ (Hoffmann et al., 2010). ~~Within this geological setting the youngest active volcanism is reported for Early to Middle Miocene times, when volcanism occurred in central and eastern Macedonia due to extension in the Vardar zone and the Serbo-Macedonian massif. The occurrence of a hydrothermal field near Kosel in the north of the basin is most likely fault related since no other hints for volcanic activity in younger times have been found during detailed field mapping (Reicherter et al., 2011).~~ The plains in the N and S of Lake Ohrid are covered with lacustrine and alluvial plain sediments of Quaternary age (Watzin et al., 2002). The occurrence of a hydrothermal field near Kosel in the north of the Lake Ohrid Basin is most likely fault related since no hints for volcanic activity in younger times have been found during detailed field mapping (Reicherter et al., 2011).

3 ~~Material~~Materials and methods

During ~~an~~the ICDP deep drilling campaign at Lake Ohrid in spring 2013 six parallel holes were drilled at the main drill site, the DEEP site (cf. Fig. 1b), down to a maximum sediment depth of 569 m below lake floor (b.l.f.). The coring location (40 m distance between the individual holes) can be averaged to 41°02’57” N and 20°42’54” E ~~at~~with a water depth of 243 m.

The cores of the DEEP site sequence were opened lengthwise ~~opened, visual~~, visually described, and subsequently scanned by X-ray fluorescence with an ITRAX core scanner (Crtube, 30mA 30 kV, COX Ltd, Sweden) at the University of Cologne. Based on the core description and the XRF data the uppermost 247.8 mcd of the DEEP site sequence were correlated to a composite profile (Francke et al., 2015). The core halves were visually screened for conspicuous horizons showing changes in macroscopic grain size or colour to identify potential tephra layers. Smear slides of these horizons were then checked for the occurrence of glass shards and micro-pumices using a Leitz DM EP polarization microscope.

Once a tephra layer was identified, bulk samples were taken from the respective horizon and embedded in epoxy resin. The epoxy pucks were polished to avoid compositional variations due to topographic effects and carbon-coated to enable conductivity during the following SEM and EDS/WDS-analysis. A first screening of major element compositions of single glass shards and micro-pumice was done using a SEM Philips XL30 equipped with an energy dispersive spectroscope (EDS) EDAX DX4. Operating conditions were adjusted at 20 kV accelerating energy, 200–500 nm beam diameter, 9–10 A beam current, 100 s live time with 2100–2400 shots per second, and ZAF correction (Z: atomic number; A: absorption; and F: fluorescence). The initial calibration, using four reference standards (albite, olivine and the glasses CFA47 and KE12), and the performance of the machine are described in detail by Marianelli and Sbrana (1998). In order to obtain more accurate quantitative analysis and to enlarge the comparability/reproducibility with existing datasets, a second screening of the samples was performed using the more common wavelength dispersive spectrometer (WDS) technique at the Istituto di Geologia Ambientale e Geoingegneria of the Italian National Research Council (IGAG-CNR, Rome). A Cameca SX50 electron microprobe equipped with a five wavelength dispersive spectrometer was set to the following operating conditions: 15 kV; beam current, 15 nA; beam diameter, 10–15 mm; and counting time 20 s per element. Wollastonite (Si and Ca), corundum (Al), diopside (Mg), andradite (Fe), rutile (Ti), orthoclase (K), jadeite (Na), phlogopite (F), potassium chloride (Cl), baritina (S), and metals (Mn) were used as standards. Titanium contents were corrected for the overlap of the Ti and K peaks. Two international secondary standards (Kanui augite and rhyolite RLS132 glasses, from the United States Geological Survey) were analysed prior sample measurements to evaluate the accuracy of the analyses. The mean analytical precision was < 1% for SiO_2 and up to 1, 5, 15, 30, and > 50% for all the elements in concentration range of 15-30, 5-15, 1-5, 1-0.3, and < 0.3 wt %, respectively. All geochemical compositions were recalculated as being 100% water-free. The geochemically classification of the composition of shards and micro-pumice was done with the total alkali vs. silica (TAS) diagram (Le Bas et al., 1986). Identified tephra layers are labelled unambiguously with the site name (OH-DP for Ohrid-DEEP) and the correlated bottom depth of each layer (e.g. "OH-DP-corr. depth in dm").

4 Results and Discussion

The~~ here presented~~ uppermost 247.8 mcd of sediments from the DEEP site sequence mainly consist of fine-grained hemipelagic sediments with some intercalated ~~more ~~coarse-grained beds~~. ~~, which were classified as event layer such as tephra and mass movement deposits. A detailed lithological description and the discussion of sedimentological processes and paleoenvironmental information is given by Francke et al. (2015). Interglacial sediments indicate high amounts of calcite and organic matter, whereas glacial sediments are dominated by clastic, terrigenous components.

In total, ~~32~~34 macroscopic tephra layers were ~~identified~~recognized in the upper 247.8 mcd of the DEEP site sequence (Fig. 2). ~~Here, we present data~~12 out of ~~12~~the 34 macroscopic tephra ~~layers, which could~~and one cryptotephra horizon have been unambiguously correlated with known eruptions~~, and~~ of ~~one cryptotephra, which was already recognized in shorter cores of Lake Ohrid (Vogel et al., 2010; Wagner et al., 2012).~~Italian volcanoes and represent the focus of the present paper. A detailed geochemical description and interpretation of the remaining tephra layers, which are not all ~~analyzed and correlated with known eruptions at present~~analysed yet, and a discussion of potential ages and origins will be given elsewhere, as it is beyond the scope of this paper. ~~Thickness information is given for tephra layers only, because the cryptotephra did not form a visible horizon.~~

~~Cryptotephra OH-DP-0027 was recognized by correlating the XRF potassium curve of the DEEP site record with those of nearby core Co1262 (Wagner et al., 2012) and core Co1202 from the NE part of the lake (Vogel et al., 2010). In cores Co1262 and Co1202 a potassium peak is caused by the presence of glass shards of the cryptotephra OT0702-3 and Co1262-709. A similar peak is found in the DEEP site sequence at 2.773 mcd, and a more detailed inspection of this depth revealed also the occurrence of volcanic particles at this depth. ~~A local~~The discovered volcanic particles of OH-DP-0027 are highly vesicular micro-pumices having spherical or elongated vesicles and glass shards with thick septa or a platy shape.~~

~~Tephra layer OH-DP-0115 (11.492–11.507 mcd) is 1.5 cm thick, brownish-greyish in colour and has sharp upper and lower boundaries. OH-DP-0115 comprises both highly vesicular micro-pumices with elongated vesicles and bubble-wall and -junction glass shards. The glass~~

~~composition is mainly trachytic with a tendency towards the phonolitic field in the TAS-diagram (Fig. 3b, Table 1).~~

~~Tephra OH-DP-0169 (16.783–16.933 mcd) has a thickness of 15 cm, which makes it the thickest tephra layer within the so far studied DEEP site sequence. It can be visually separated in two units. The lower unit (OH-DP-0169a) has a sharp boundary at the bottom, is 2 cm thick and pale yellow in colour, whereas the upper unit (OH-DP-0169b) is 13 cm of pale brown, coarser material. The uppermost centimetres of the upper unit are mixed with lacustrine sediments and have an uneven top boundary, which is probably due to a difficult penetration during coring. Both units comprise elongated vesicle bearing micro-pumices, bubble-wall and -junction shards with thick septa, and have the same trachytic to phono-trachytic glass composition (Fig. 3c, Table 1).~~

~~Tephra layer OH-DP-0404 (40.456–40.486 mcd) is a 3 cm thick dark reddish brown horizon with sharp transitions at the top and bottom. The layer comprises elongated vesicular micro-pumices and thick walled bubble-wall shards. Glass composition analyses reveal a mainly phonolitic composition with some shards scattering around the intersection of tephriphonolitic, trachyandesitic, and trachytic fields in the TAS-diagram (Fig. 3d, Table 1).~~

~~Tephra OH-DP-0435 (43.498–43.513 mcd) is a 1.5 cm thick, greyish brown layer with sharp top and bottom contacts. The horizon comprises highly vesicular micro-pumices and bubble wall shards with thick septa, which mainly have a trachytic glass composition. However, some shards are also plotting in the phonolitic field of the TAS-diagram (Fig. 3e, Table 1).~~

~~The OH-DP-0499 (49.937–49.947 mcd) tephra layer is 1 cm thick, olive brown, and characterised by a sharp bottom and a diffuse top boundary. It comprises elongated vesicular micro-pumices and larger platy bubble wall shards. The glass composition is bimodal with a distinctly separated trachytic and rhyolitic group (Fig. 3f, Table 1). According to the~~ ~~Al_2O_3-FeO_{TOT}~~ ~~diagram (Fig. 4), glass shards have a mainly pantelleritic composition with some shards plotting in the comenditic field. The tephra layer OH-DP-0617 (61.701–61.726 mcd) is a yellowish brown, 2.5 cm thick deposit with sharp bottom and top contacts. The very fine-grained glass shards have various forms, being highly vesicular with circular and oval bubbles. Micropumices with elongated vesicles are rare. The chemical glass composition is a homogenous phonolite (Fig. 3f, Table 1).~~

~~Tephra OH-DP-0624 (62.367–62.413 mcd) is 4.6 cm thick, of olive brown colour and has a sharp bottom and more diffuse top transition. It comprises micro-pumices with elongated~~

~~vesicles, cuspate glass shards, and non-vesicular, blocky, porphyric particles, bearing prismatic microlites and phenocrysts. In the uppermost diffuse part, volcanic fragments are mixed with authigenic siderite crystals. The glass composition spans from the phonotephritic to the phonolitic field of the TAS-diagram (Fig. 3g, Table 1).~~

~~Tephra layer OH-DP-1817 (181.744–181.769 mcd) is a dark brownish layer with a thickness of 2.5 cm and sharp bottom and top contacts. The layer contains mostly non-vesicular, blocky porphyric shards with a high content of microlites and phenocrysts. Vesicular cuspate shards are rare and are also porphyritic. The composition is low evolved plotting in the foiditic field of the TAS-diagram (Fig. 3h, Table 1).~~

~~The tephra layer OH-DP-1955 (195.536–195.566 mcd) is 3 cm thick and has a sharp bottom and a diffuse top boundary. The greyish layer comprises blocky, non-vesicular glass shards and porphyric micro-pumices containing leucite crystals. The composition is mainly phonolitic to trachy-andesitic with some shards plotting in the tephri-phonolitic field (Fig. 3h, Table 1).~~

~~OH-DP-2010 (201.034–201.049 mcd) is a reddish-brown, 1.5 cm thick layer with a sharp lower and an undulated upper boundary. It comprises morphological different volcanic fragments, which range from non-vesicular, microlite-bearing blocky, glass shards, to medium vesicular cuspate glass shards, and elongated vesicular micropumices. The TAS-diagram shows a characteristic tephriphonolitic to phonolitic composition (Fig. 3i, Table 1).~~

~~Tephra layer OH-DP-2017 (201.747–201.782 mcd) is whitish to yellowish, 3.5 cm thick, and has sharp bottom and top boundaries. The horizon contains highly vesicular cuspate glass shards with a varying morphology and septa thickness. The chemical glass composition is homogenous trachytic (Fig. 3j, Table 1). Tephra OH-DP-2060 (206.060–206.080 mcd) is a 2 cm thick, brownish-greyish tephra layer with a sharp bottom and a more diffuse upper boundary. The layer comprises mainly non-vesicular, porphyritic (leucite and sanidine), blocky glass shards. Furthermore, numerous diatoms and weathered calcite were found during microscope analysis. The composition is mainly foiditic (Fig. 3j, Table 1).~~

~~5 Discussion~~

~~A primary~~ origin of the tephra layers from the direct surrounding of Lake Ohrid is highly unlikely, as there is no volcanic activity recorded for the Quaternary~~.~~ (cf. Fig.1). Potential volcanic sources within the Mediterranean area are the Italian ~~Provinces~~provinces, the Hellenic Arc, or the Anatolian provinces. Pyroclastic deposits from the Hellenic Arc and the Anatolian

~~Provinces are~~provinces, mainly high-silica calc-alkaline~~, often have very high silica contents~~ tephra, were primarily dispersed in eastern directions (Druitt et al., 1995, 1999; Aksu et al., 2008; Hamann et al., 2010; Sulpizio et al., 2013; Sumita and Schmincke, 2013; Keller et al., 2014; Tomlinson et al., 2015), and so far have not been found~~ so far~~ in the sediment records of Lake Ohrid (Sulpizio et al., 2010) and nearby Lake Prespa (Damaschke et al., 2013). Furthermore, they were not found in the numerous ~~tephrological studies~~studied tephrochronological successions from the Tyrrhenian, Adriatic, or Western Ionian Sea.

Mainly eastern distribution is also assumed for Italian tephra layers, and some of them were even found in the Eastern Mediterranean and Aegean Sea (Margari et al., 2007; Sulpizio et al., 2010; Karkanas et al., 2015; Satow et al., 2015).

All tephra layers discussed here show an alkaline affinity, which is only known from the Italian ~~Volcanic Provinces~~volcanic provinces in the Mediterranean region (Peccerillo, 2005). The existing records from ~~Lakes~~lakes Ohrid and Prespa only contain tephra~~, only~~ from Italian volcanoes, which ~~were~~was transported by the prevailing westerlies with E–SE ~~direction~~directions in the upper atmospheric wind system. The Quaternary Italian volcanism is classified in several magmatic provinces (Washington, 1906; Peccerillo, 2005), which are mainly located along the Tyrrhenian coast of the Italian Peninsula, in the Tyrrhenian Sea, and in the Sicily channel, between 500 and 1000 km apart of Lake Ohrid (Fig. 1). In the studied succession (< ~~640~~637 ka) explosive volcanic activity of Italian volcanoes is known so far from the Roman ~~Province~~province (Vulsini, Vico, Sabatini, Colli Albani), the Ernici-Roccamonfina area (Mt. Ernici, Roccamonfina), the Campania ~~Province~~province (Somma-Vesuvio, Campi Flegrei, Procida, Ischia), the Pontine Islands (Ventotene~~.~~, Santo Stefano), the Mount Vulture, the Aeolian Arc (Alicudi, Filicudi, Salina, Lipari, Vulcano, Panarea, Stromboli)), and the Sicily ~~Province~~province (Mt. Etna, Ustica, Pantelleria~~) (~~,Fig. 1, Peccerillo, 2005).

The products of these Italian volcanoes span a wide compositional field ranging from subalkaline to alkaline and from mafic to silicic, depending on their geodynamic setting or mantle source (Lustrino et al., 2011). Most of them have a potassium or a high potassium affinity (Roman, Roccamonfina, Campanian, and Pontine Islands) and their large chemical similarity or overlap in composition makes tephrostratigraphic work very challenging (Sulpizio et al., 2010). An origin from one of these provinces is supposed by the (high) alkaline phonolitic and trachytic compositions of most of the tephra layers found in the DEEP site sequence. However, some of the tephra layers in the DEEP site succession show more specific and unique compositions, which allow more straightforward correlations to the Pantelleria Islands and Somma-Vesuvius (Peccerillo, 2005), or the silica undersaturated, low evolved pyroclastic products of Colli Albani (Giaccio et al., 2013a).

~~5.1~~4.1 OH-DP-0027/Mercato

Cryptotephra OH-DP-0027 was recognized by correlating the patterns of the XRF potassium curve of the DEEP site record with those of the nearby core Co1262 (cf. Fig. ~~The~~1, Wagner et al., 2012). In both cores, a potassium peak is observed in the same stratigraphic position~~ and~~, which in core Co1262 is caused by the presence of glass shards of cryptotephra Co1262-709. In the DEEP site sequence, the corresponding peak culminates at about 2.775 mcd. A microscopic inspection of the interval 2.770-2.780 mcd revealed the occurrence of glass shards. Since cryptotephra is dispersed in the sediment and do not form a continuous distinct horizons, the exact depth of the tephra isochron was set to the maximum of the K-peak (2.775 mcd), most likely representing the maximum shard concentration.

The discovered volcanic particles of OH-DP-0027 are highly vesicular micro-pumices having spherical or elongated vesicles and glass shards with thick septa or a platy shape.~~ allow a correlation of OH-DP-0027 with the cryptotephras OT0701~~ The composition of OH-DP-0027 is Na-phonolitic (Table 1, Figure 2a) and thus similar to cryptotephra Co1262-709 (Wagner et al., 2012) and the associated cryptotephra horizons OT0702-3 from Lake Ohrid (Vogel et al., 2010) and ~~Co1262-709 (Wagner et al., 2012) from Lake Ohrid and~~ PT0915~~-~~-2 from Lake Prespa (Damaschke et al., 2013~~) and thus the correlation with~~). Nevertheless, OH-DP-0027 has slightly lower SiO_2 (2-3 wt%), and FeO_{TOT} (~0.5 wt%) contents, but higher Na_2O (~1 wt%) and Al_2O_3 (~2 wt%) contents (cf. Table 1). Despite these geochemical differences, the general geochemical signature (Na-phonolitic, cf. Suppl. I Fig. a), and the stratigraphic position of OH-DP-0027 suggest a correlation with the aforementioned cryptotephra horizons and their supposed origin, the Pomici di Mercato (PdM) eruption from the Somma-Vesuvius volcano~~ (cf. Fig. 3a).~~. The PdM eruption is the only known eruption in the Late Pleistocene and early Holocene having such a composition in the central Mediterranean region (Mele et al., 2010; Santacroce et al., 2008).

The products of the PdM eruption are found as two distinct layers TM6a and TM6b in the Lago Grande di Monticchio record (Wulf et al., 2004). The double ~~layers has been~~layer were interpreted as due to shortly interrupted eruptive phases of the eruption (Mele et al., 2011).

OH-DP-0027 ~~matches~~and the associated Ohrid cryptotephra horizons match better with TM6b~~,~~ (Table1, cf. Suppl. I Figure a), which represents the main Plinian and initial phase of the eruption (Wulf et al., 2004). A correlation with the PdM eruption is also established for a tephra found in the Veliko Jezero on the Island of Mljet (Croatia), where even ~~several~~more than two eruptive phases are indicated (Jahns and van den Bogaard, 1998). Also in sediment cores from the Adriatic Sea, such as ~~the~~ KET8218 (V1, Paterne et al., 1988), IN68-9, IN68-5 and RF95-11 (125, 259, 320 cm respectively, Calanchi and Dinelli, 2008), ~~or~~ AD91-17 (190-191, 195-196 cm, Marchini et al., 2014), or from ~~the Northern Ionian Sea~~ MD90-918 (210/~~223 (~~223cm, Caron et al., 2012) tephra layers were correlated with the PdM eruption~~.~~ (cf. Suppl. I Figure a).

Santacroce et al. (2008) reviewed several existing ^{14}C ages on proximal deposits of the Mercato eruption and suggested a maximum age of 9010–8750 year cal ~~a~~ BP. This age is somewhat younger than the varve age obtained from the Lago Grande di Monticchio record for TM6b (9680±480 ~~cal a~~year BP; Wulf et al., 2004). The most reliable age of 8630~~–~~-8430 year cal~~ a~~ BP comes probably from ^{14}C dating of charcoals collected at the basal part of the proximal fallout deposit (Zanchetta et al~~. (~~., 2011).

~~5.2~~4.2 OH-DP-0115 / Y-3

Tephra layer OH-DP-0115 (11.492–11.507 mcd) is 1.5 cm thick, brownish-greyish in colour and has sharp upper and lower boundaries. OH-DP-0115 comprises both highly vesicular micro-pumices with elongated vesicles and bubble-wall and -junction glass shards. The ~~distinct trachytic~~ glass composition ~~of OH-DP-0115~~is mainly trachytic tending towards the phonolitic field in the TAS-diagram (Fig. 3b, Table 1), which suggests a correlation with the prominent marine tephra layer Y-3 from the Campanian area (cf. Table 1, Suppl. I Fig. b; Keller et al., 1978; Albert et al., 2015). The slightly heterogeneous major element composition, with a low and a high silica end-member (</> 62 wt.% SiO_2) is defined by Albert et al. (2015) as the diagnostic characteristic of the Y~~–~~-3 tephra and perfectly matches the OH-DP-0115 tephra (cf. Fig.3b~~)~~., Tab. 1, Suppl. I Fig. b). The ~~Campi Flegrei (CF) caldera is the~~ most probable source of the Y-3 tephra is the Campi Flegrei (CF) caldera (Di Vito et al., 2008; Zanchetta et al., 2008;

Albert et al., 2015), but to date none of the suggested proximal counterparts~~, indicating a specific eruption,~~ of different eruptions could be unambiguously assigned as its origin (Albert et al., 2015~~).~~). Furthermore, the former most accepted correlation of the Y-3 tephra with the intracaldera VRa and the mid-distal SMP1e/CE1 deposits (Sulpizio et al., 2003; Di Vito et al., 2008) is rejected~~ in the light of~~, because new geochemical data ~~separating~~gained on the Y-3 type locality (marine cores M25/4-12, RC9 191) separate the Y-3 from other CF eruptions of the Tufi Biancastri/NYT series (Tomlinson et al., 2012; Albert et al., 2015).

The Y-3 tephra is known as a widespread stratigraphic marker found in different archives in the Central and Eastern Mediterranean region, such as the Lago Grande di Monticchio (TM15, ~~(TM15,~~ Wulf et al., 2004; Tomlinson et al., 2012), the Southern Adriatic Sea ~~(~~core MD90-917 (920/17, Zanchetta et al., 2008), Lake Ohrid (~~0T0520~~OT0520-2; OT0700-1; OT0702-4; JO 187, summarized in Sulpizio et al., 2010), Lake Prespa (~~PT0704-1~~PT0915-5, Damaschke et al., 2013), and the Tenaghi Philippon peat record in Greece (TP 9.70, Albert et al., 2015). These correlations are validated by the low and high silica end-member (Albert et al., 2015). The correlations of the marine tephra layers C-7 (Tyrrhenian and Adriatic Sea, Paterne et al., 1988~~; Zanchetta et al., 2008~~), A2/B2 (C106/C45, Munno and Petrosino, 2004), and the terrestrial S19 layer (Munno and Petrosino, 2007) with the Y-3 tephra were not revaluated by Albert et al. (2015) due to restricted data sets, but seem to be likely.

Since no proximal equivalents could be unambiguously identified so far, the ages from these proximal correlations (e.g., 31–30 ka cal BP, Zanchetta et al., 2008) have to be rejected (Albert et al., 2015). However, a Bayesian age-depth model based on multiple radiocarbon ages above and below the TP 9.70 tephra of the Tenaghi Phillipon record provides an age of 28.68-29.42 ka cal~~ ka~~ BP (Albert et al., 2015). This is probably the best age estimate, which is supported by radiocarbon ages from other distal archives, for example the ^{14}C-age of 28.78-29.98 ka cal BP obtained at the top of the Ohrid tephra OT07042-4/Y-3 (Vogel et al., 2010). The Y-3 tephra represents an important marker in the Mediterranean area, linking marine and terrestrial archives close to the Marine Isotope Stage 3/2 transition and the North Atlantic Heinrich Stadial 3 (HS3).

~~5.3~~4.3 OH-DP-0169 / Y-5 CI

Tephra OH-DP-0169 (16.783–16.933 mcd) has a thickness of 15 cm, which is the thickest tephra layer found within this part of the DEEP site sequence and can be visually separated into two units.~~The characteristic trachytic to phonotrachytic alkaline composition of OH-DP-0169 (cf. Fig.3c~~ The lower unit (OH-DP-0169a) has a sharp boundary at the bottom, is 2 cm thick and pale yellow in colour, whereas the upper unit (OH-DP-0169b) is 13 cm of pale brown, coarser material. The uppermost centimetres of the upper unit are mixed with lacustrine sediments and have an uneven top boundary, which is probably due to a difficult penetration during coring. Both units comprise elongated vesicle bearing micro-pumices, bubble-wall and -junction shards with thick septa, and have the same trachytic to phono-trachytic glass composition (Fig. 3c, Table 1). The characteristic trachytic to phonotrachytic alkaline composition of OH-DP-0169 (cf. Fig.3c, Suppl. I Fig. c) and its remarkable thickness allow an unambiguous correlation with the Campanian Ignimbrite (CI) eruption (Orsi et al., 1996; Civetta et al., 1997; Pappalardo et al., 2002) and the marine tephra layer Y-5 (Keller et al., 1978; Thunell et al., 1979). The comparison of major element oxides such as Al_2O_3, FeO_{TOT}, and CaO strongly support the correlation with the Y-5/CI deposits and exclude other possible correlation with pre-CI deposits described in Tomlinson et al., 2012 (cf. Suppl. I Fig. c). Additionally, the CI/Y-5 was also recognized in previous studies at lakes Ohrid and Prespa (OT0520-3; OT0700-2; OT0701-1; OT0702-6; JO-244; PT0704-3 summarized in Sulpizio et al., 2010).

The proximal deposits of the CI are described to have a trimodal composition~~due to a strongly zoned, two layered trachytic magma chamber, whose distinct evolved products were tapped during~~ , which resulted from the different ~~phases of the eruption~~timing and ~~their interaction probably produced a third intermediate composition~~dynamic of extraction and mingling of two layered compositionally different magmas (Civetta et al., 1997; Pappalardo et al., 2002; Marianelli et al., 2006). According to Civetta et al. (1997~~) the largest part of~~), OH-DP-0169 belongs to the most evolved composition (K_2O/N_2O 1.1-1.35) and only some shards can be assigned to the intermediate group (K_2O/N_2O 1.37-1.42~~).~~ , cf. Suppl. II). The third, least evolved group (K_2O/Na_2O >2) was not found in OH-DP-0169 most likely due to its relatively low abundance in distal settings and the limited number of analysis of OH-DP-0169. Indeed, the least-evolved group is associated with the less energetic phase of the eruption of the late caldera collapse that generated more dense pyroclastic flows that did not reach great distance from the vent (Civetta et al., 1997). Thus, they are likely less representative in very distal settings also because the intermediate and most evolved group form more than 85 % of the eruptive volume (Civetta et al., 1997).

As the two ~~parts~~optical units of OH-DP-0169 (a+b) cannot be geochemically discriminated based on major elements, the initial Plinian phase (cf. Marianelli et al., 2006) may correspond with the lower, pale yellow and more fine-grained part (OH-DP-0169a), while the main ignimbrite phase probably corresponds with the upper, pale brown and coarser part (OH-DP-0169b).

The CI/Y-5 tephra layer, originating from the Campi Flegrei (e.g. Pappalardo et al., 2002), is the most widely dispersed tephra marker in the Mediterranean region. It was found, for example, in sediment cores from the Lago Grande di Monticchio (TM-18, Wulf et al., 2004), the San Gregorio Magno basin, (S-17, Munno and Petrosino, 2007) the Greek island of Lesvos (ML 2, Margari et al., ~~2007), the~~ 2007), and the Tenaghi Philippon peat record (TP-CI, Lowe et al., 2012). Furthermore, it was identified in the Tyrrhenian ~~Sea~~Ses cores KET- 8022, -8004, -8003, -8011 (C-13, Paterne et al., 1988; Ton-That et al., 2001~~) and in previous studies at Lake Ohrid (OT0520-3; OT0700-2; OT0701-1; OT0702-6; JO-244, summarized)~~, in ~~Sulpizio~~the Adriatic Sea cores PRAD1-2 (PRAD1653, Bourne et al., 2010) and ~~Lake Prespa (PT0704-3, Damaschke et al., 2013~~KET8218 (C-13, Paterne et al., 1988), in the Ionian Sea cores KC01B (I-3, Insinga et al. 2014) and RC9 191/V110 69 (Y-5, Keller et al. 1978), and in the Levantine and Aegean Sea cores (RC 9 183, -181, V10 58 (Y-5) Keller et al., 1978; LC21 (4.925) Lowe et al., 2012, Satow et al., 2015). To date, the most distal finding is in the Russian Plain, 2500 km away from its source (Pyle et al., 2006; Giaccio et al., 2008).

The ages for the CI cluster around 40 ka BP. The varve chronology of Lago Grande di Monticchio yielded an age of 36.77 ~~cal~~ ka BP (Wulf et al., 2006). $^{40}Ar/^{39}Ar$ dating on single sanidine crystals revealed ages of 37.1±0.4 ka ~~BP~~ (Deino et al., 1994), 41.1±2.1 ka ~~BP~~ (Ton-That et al. (2001) and 39.28±0.11 ka ~~BP~~ (De Vivo et al., 2001), with the latter regarded as the best age, as it derives from proximal deposits.

~~5.4~~4.4 OH-DP-0404 / TM24a POP2

Tephra layer OH-DP-0404 ~~has~~(40.456–40.486 mcd) is a 3 cm thick dark reddish brown horizon with sharp stratigraphic contacts at the top and bottom. The layer comprises elongated vesicular micro-pumices and thick walled bubble-wall shards. Glass composition analyses reveal a mainly phonolitic composition with some shards scattering around the intersection of tephriphonolitic, trachyandesitic, and trachytic fields in the TAS-diagram (Fig. 3d, Table 1) The geochemical signature is similar, even if somewhat more variable~~ phonolitic composition~~ ~~as~~, to tephra OT-0702-8 (cf. Fig.3d, Suppl. I Fig. d), found in Ohrid core Co1202 (Vogel et al., 2010), which ~~was~~is correlated with the Monticchio tephra TM24a (Wulf et al., 2004; Wulf et al., 2012). The TM24a tephra was first correlated with the prominent marine X-5 layer (Keller et al., 1978), but this correlation was later revised and the older Monticchio tephra TM25 was correlated with the X~~-~~-5 layer (Wulf et al., 2012). The proximal or the marine tephra counterparts of TM24a remain unknown so far. Based on major element compositions, OH-DP-0404 can be further correlated with the recently found POP2 tephra in the Popoli section from the Sulmona basin~~,~~, (Regattieri et al., 2015), which is also correlated with the TM24a tephra (~~Regattieri et al., 2015).~~cf. Table1, Suppl. I Fig. d). A~~ potential~~ correlation of OH-DP-0404 with marine tephra layers from core CM92-42 (710 cm) and core RF93-77 (797 cm), which were also correlated with the TM24 (Calanchi and Dinelli, 2008), is likely, however, there is no differentiation between the bifurcation of tephra TM24 (a+b) in these marine ~~tephras.~~tephra layers. According to the Monticchio varve record, TM24a has an age of 101.8±5 ka BP (Wulf et al., 2012), which matches~~ very~~ well the age of 102.0±2.4 ka obtained from the age-model of the Sulmona basin (Regattieri et al., 2015).

~~5.5~~4.5 OH-DP-0435 / X-6

~~The~~Tephra OH-DP-0435 (43.498–43.513 mcd) is a 1.5 cm thick, greyish brown layer with sharp top and bottom contacts. The horizon comprises highly vesicular micro-pumices and bubble wall shards with thick septa having a low alkali ratio (LAR) trachytic glass composition with only few shards plotting in the phonolitic field. This geochemical composition and ~~its~~the position below OH-DP-0404/TM24a/POP2 suggest a correlation of OH-DP-0435 with the marine tephra layer X-6 (core 22M-60, Keller et al., 1978). The correlation is supported by the geochemically similarity of OH~~-~~-DP~~-~~-0435 with the Ohrid ~~tephras~~tephra layers OT0702-9 (Vogel et al., 2010) and JO-575 (Caron et al., 2010), which were also correlated with the X-6 layer (cf. Fig.3e; Suppl. I Fig. e). Equivalents of the X-6 tephra are also found in marine cores KET8004 and -8022 of the Tyrrhenian Sea (C-31, Paterne et al., 2008~~; t1, Iorio et al., 2014)~~), the Adriatic Sea cores PRAD1-2 (PRAD-2812, Bourne et al., 2015), and the ~~southern~~ Ionian Sea cores KC01B (I-9, Insinga et al., ~~2014~~2014), and KET82-22 (C-31, Paterne et al., 2008). Furthermore, the X-6 is known from the terrestrial records of the Lago Grande di Monticchio

(TM27, Wulf et al., 2012), the San Gregorio Magno basin (S10, Munno and Petrosino, 2007), the Cilento coastline (SM1-2/SA, Marciano et al., 2008; CIL2, Giaccio et al., 2012), and the Popoli section of the Sulmona basin (POP4, Regattieri et al., 2015). The origin of the X-6 is assigned to an unknown eruption of the Campanian area (Keller et al., 1978; Paterne et al., 2008; Wulf et al., 2012).

Based on $^{40}Ar/^{39}Ar$ dating, the age of tephra layer X-6 is 107±2 ka (Kraml, 1997), which fits to the varve-based age of ca. 108.3±5.4 ka BP of the TM-27 layer in Lago Grande di Monticchio (Wulf et al., 2012) and the interpolated age of 107 ka of the C-~~21~~31 tephra layer (Paterne et al., 2008). More recently, a $^{40}Ar/^{39}Ar$ age of 108.9±1.8 ka was obtained on X-6 equivalent deposits of the Cilento offshore area (t1 tephra, Iorio et al., 2014), which matches well the interpolated age of the Popoli section (109.0±1.5 ka, Regattieri et al., 2015).

~~5.6~~4.6 OH-DP-0499 / P-11

The OH-DP-0499 (49.937–49.947 mcd) tephra layer is 1 cm thick, olive brown, and characterised by a sharp bottom and a diffuse top boundary. It comprises elongated vesicular micro-pumices and larger platy bubble wall shards. OH-DP-0499 has a distinct bimodal glass chemical composition, with a clearly separated trachytic and a rhyolitic group (Fig. 3f, Table 1).~~.~~ The shards can be classified as comendites and pantellerites (cf. Al_2O_3-FeO_{TOT} diagram, Fig.~~ ~~4), which unambiguously ~~assigns~~assign them to an origin from the Pantelleria Island, the only source of these type of magmas in the central Mediterranean region (Peccerillo, 2005). The twofold composition is explained by a chemically zoned magma chamber, in which peralkaline rocks originating from mantle-derived parental magma and trachytic magma differentiated in a low-pressure magma chamber by crystal-liquid fractionation (Civetta et al., 1984).

The stratigraphic position of OH-DP-0499, below the X-6 tephra (OH-DP-0435), infers a definite correlation with the P-11 tephra (cf. Fig. 3f) found in the Ionian Sea core KET82-22 (Paterne et al., 2008), since other widespread eruptions of the Pantelleria Island are much younger (ca. 77 ka, P-10, Paterne et al., 2008; 45.7 ka, Green Tuff, Scaillet et al., 2013). Furthermore, the geochemical fingerprint of OH-DP-0499 is identical to those of the two ~~cryptotephras~~cryptotephra layers OT0702-10 (Vogel et al., 2010) and JO-941 (Caron et al., 2010~~)~~), which were found previously in Lake Ohrid sediments and ~~which were~~ correlated with the P-11~~.~~ (cf. Suppl. I Fig. f). A more proximal core from the Sicily Channel (ODP 963A) comprises three pantelleritic layers (ODP2-4) in a similar stratigraphic position (Tamburrino et al., 2012). ODP2 shows a somewhat different geochemical composition (benmoritic part) compared to OH-DP-0499/P-11~~.~~ (cf. Table1, Suppl. I Fig. f). ODP3 and ODP4 indicate a very similar composition, but ODP3 is formed as a distinct horizon, whereas ODP4 is a cryptotephra (Tamburrino et al., 2012). Due to chronological concerns, Tamburrino et al. (2012) correlated ODP3 with the P-11, which is supported by their climastratographic position at the transition from MIS 6 to 5 (cf. Zanchetta et al., this issue). As only one pantelleritic layer is found in distal archives, ODP2 was precluded due to chemical considerations, ODP4 is a cryptotephra, ~~and~~ a correlation of ODP3 with the P-11 layer is the most likely and supposes that this tephra is the most widespread.

OH-DP-0499 can be further correlated with the ML5 tephra found on Lesovs Island (Margari et al., 2007), as already suggested by Vogel et al. (2010) for the OT0702-10 tephra. The ML5 tephra was previously correlated with the younger Green Tuff/Y-6, but the geochemical data support a correlation with the older P-11 tephra. In more recent studies, Karkanas et al. (2015) correlated a pantelleritic cryptotephra (THP-TII5) found in the Theopetra cave in central Greece with the P-11 and its equivalents. Satow et al. (2015) found a cryptotephra (LC21 10.345) in the Aegean Sea core LC21, which he ascribed to one of the ODP2-4 ~~tephras.~~tephra layers. The position of LC21 10.345 in the *G. ruber* $\delta^{18}O$ record of LC21 implies a correlation with ODP3 and P-11 based on the position in the respective isotope records. Nevertheless, it has to be stated that only the rhyolitic endmember of P-11 was found in the records from LC21 and Theopetra. The typical comenditic trachytic part is not found in these archives, which is probably due to a different dispersal of the twofold zonation of the magma chamber (rhyolitic/trachytic part) tapped at different phases of the eruption. This is also indicated by an internal zonation of the OPD3 layer. Whereas the bottom of ODP3 has a pantelleritic composition, its top shows comenditic trachytic compositions (Tamburrino et al., 2012). This suggests that the rhyolitic pantelleritic part was erupted first and dispersed over a larger area, while the comenditic trachytic part is distributed only in a smaller, northern sector. Changes of the plume direction and dispersal during an eruption are likely due to changes in the aerodynamic characteristics of the erupted material or in the high and low atmosphere dynamics (Sulpizio et al., 2008, 2013).

Proximal counterparts of the P-11 are the ignimbrite deposits of the P-unit on Pantelleria Island (Mahood and Hildreth, 1986; Paterne et al., 2008; Tamburrino et al., 2012). These proximal

P-unit deposits provide inhomogeneous $^{40}Ar/^{39}Ar$ ages between 123±1.6 ka and 135±1.2 ka, with large internal age variations suggesting xenocrystic contamination (Rotolo et al., 2013). The mean age of the P-unit (129±5.9 ka) is in broad accordance with the non-radiometric ages from the distal deposits. The age-depth model of core KET82-22, based on orbital tuning of the oxygen isotope and sapropel stratigraphy, provided an age of 130.6±5 ka for the P-11 tephra (Paterne et al., 2008). This age matches well the age of 128.1 ka of ODP3, which is inferred from correlation of benthic and planktonic foraminifera $\delta^{18}O$ curves of core ODP-963A with the SPECMAP stack curve (Incarbona et al., 2008; Tamburrino et al., 2012). The ~~tentative~~ correlation of LC21 10.345 with P-11 provides an age of 133.5±2 ka, based on the correlation of the surface-water foraminiferal $\delta^{18}O$ record of LC21 to the high resolution U/Th dated Soreq Cave $\delta^{18}O$ record (Grant et al., 2012, Satow et al., 2015).

~~Proximal counterparts of the P-11 are the ignimbrite deposits of the P-unit on Pantelleria Island (Mahood and Hildreth, 1986; Paterne et al., 2008; Tamburrino et al., 2012). These proximal P-unit deposits provided $^{40}Ar/^{39}Ar$ ages between 123±1.6 ka and 135±1.2 ka, with a mean age of 129±5.9 ka (Rotolo et al., 2013) and are in good accordance with the non-radiometric ages from the distal deposits.~~

~~5.7~~4.7 OH-DP-0617 / Vico "Ignimbrite B"

The tephra layer OH-DP-0617 (61.701–61.726 mcd) is a yellowish brown, 2.5 cm thick deposit with sharp bottom and top contacts. The very fine-grained glass shards have various forms, being highly vesicular with circular and oval bubbles. Micropumices with elongated vesicles are rare. The characteristic homogenous phonolitic composition of OH-DP-0617 (Fig. 3f, Table 1) is very similar to the composition of tephra OT0701-6 (cf. Fig. ~~3f~~5a), which was found in the Ohrid core Co1201 (Sulpizio et al., 2010). OT0701-6 was previously correlated with the marine ~~tephras~~tephra C-20 and the proximal deposits of the SA3-b eruption from the Campanian area (Sulpizio et al., 2010). However, the ~~correlation of C-20 with OH-DP-0404 and the~~ stratigraphic position of OH-DP-0617 below the X-6/C-31/OH-DP-0435 and ~~P11~~P-11/OH-DP-0499 tephra ~~suggest~~suggests that and OH-DP-0617 and OT0706-1 rather correlate with the CF-V4 tephra from the Campo Felice Basin (Giraudi et al., 2011). The CF-V4 tephra is correlated with the "Ignimbrite B" of the Vico volcano (Vico B, Ronciglione Formation, Bear et al., 2009), which also has a large geochemical similarity to the Ohrid ~~tephras~~tephra layers OH-DP-0617/OT0701-6~~.~~ (cf. Table 1, Fig. 5a). So far, equivalents of this Vico eruption were not found in other archives. Laurenzi and Villa (1987) $^{40}Ar/^{39}Ar$ dated the Ignimbrite B ~~on~~in a proximal ~~deposits~~setting to 157±3 ka.

~~5.8~~4.8 OH-DP-0624 / CF-V5/ PRAD3225

~~OH-DP-0624 is characterised by a wide spectrum in composition ranging from phonotephritic to phonolitic.~~Tephra OH-DP-0624 (62.367–62.413 mcd) is 4.6 cm thick, of olive brown colour, and has a sharp bottom and more diffuse top transition. It comprises micro-pumices with elongated vesicles, cuspate glass shards, and non-vesicular, blocky, porphyric particles, bearing prismatic microlites and phenocrysts. In the uppermost diffuse part, volcanic fragments are mixed with authigenic siderite crystals. The glass composition spans from the phonotephritic to the phonolitic field of the TAS-diagram (Fig. 3g, Table 1). This characteristic is also observed for tephra OT0701-7 in core Co1201 from Lake Ohrid (Sulpizio et al., 2010). OT0701-7 was first subdivided into three different chemical groups (a-b-c), of which OT0701-7b tentatively was correlated with the tephra layer OT0702-8/TM24a/X-5 (Sulpizio et al., 2010). However, this correlation is not supported by the stratigraphic position of OT0701-7 below OT0701-6, as the latter correlates well with OH-DP-0617. Furthermore, OT0702-8/TM24a is correlated with OH-DP-0404, which is embedded by sediments of interglacial MIS5, whereas glacial sediments encompass OT0701-7 (Sulpizio et al., 2010). Also the glass composition of OT0701-7, showing a linear geochemical trend rather than two different geochemical populations, makes a correlation with OH-DP-0624 more likely~~.~~ (Fig. 5b).

The ~~very characteristic~~peculiar geochemical trend of OH-DP-0624 (cf. Fig. 3g, Fig. 5b) matches the marine tephra PRAD3225 from the Adriatic Sea (Bourne et al., 2015), which is tentatively correlated with the tephra 322 from core RF95-7 and with the TM38 ~~in~~tephra from the Lago Grande di Monticchio record (Wulf et al., 2012). Tephra 322 was assigned to the Vico D eruption (Calanchi and Dinelli ~~(~~, 2008), which is dated to ca. 138 ka (Laurenzi and Villa, 1987). TM38 has an age of 125.6±6.3 ka according to the varve chronology of the Lago Grande di Monticchio record (Wulf et al., 2012). ~~The~~However, the ages of TM38 and 322/Vico D are significantly too young for the stratigraphic position of OH-DP-0624 below the OH-DP-0617/Vico B and dated to ca. 157±3 ka. Another marine counterpart of OH-DP-0624 could be tephra C-42 with its phonotephritic composition (core DED8708, Paterne et al., 2008), but the published average values do not allow a robust correlation.

The most reliable equivalent of OH-DP-6024/OT0701-7/PRAD3225 is probably found in the Campo Felice basin in the Apennine chain. The geochemical composition and the stratigraphic position of the CF-V5 tephra, which was found in this basin directly below the CF-V4 tephra (Giraudi and Giaccio, 2015) correlates well with the composition and stratigraphic position of the OH-DP-6024 directly below the OH-DP-0617 tephra. Giraudi and Giaccio (2015) tentatively suggest that the CF-V5 tephra is an equivalent of the Pitigliano Tuff from the Latera caldera in the Vulsini volcanic complex (Turbeville, 1992a). Although the geochemical dataset is limited, a similar characteristic trend is observed in CF-V5 and OH-DP-0624/OT071-7~~.~~/PRAD3225 (cf. Fig. 5b). $^{40}Ar/^{39}Ar$ dating on proximal deposits of the Pitigliano Tuff provided ages of 158±11 ka and 155±11 ka (Turbeville, 1992b, a) and the overlying Vico Ignimbrite B tephra limits the minimum age to 157±3 ka.

~~5.9~~4.9 OH-DP-1817 / Pozzolane Rosse

Tephra layer OH-DP-1817 (181.744–181.769 mcd) is a dark brownish layer with a thickness of 2.5 cm and sharp bottom and top contacts. The layer contains mostly non-vesicular, blocky porphyric shards with a high content of microlites and phenocrysts, mostly leucite. Vesicular cuspate shards are rare and are also porphyritic. ~~OH-DP-1817~~ OH-DP-1817 has a low evolved K-foiditic composition~~,~~ (Fig. 3h, Table 1), which is only known from the Italian volcanoes of the Colli Albani volcanic district, and more sporadically in Vulture volcano (Peccerillo, 2005). However, as the activity of the Vulture volcano clustered between ~740 to 610 ka and around 140 ka (Villa and Buettner, 2009), the most relevant source of foiditic tephra is the Colli Albani caldera, of which the Middle Pleistocene explosive activity was characterized by very high-energetic events (e.g., Marra et al., 2009). The most widespread ~~eruption~~Colli Albani tephra is from ~~Colli Albani are the products of the~~ the Pozzolane Rosse eruption ~~cycle~~ (Giaccio et al., 2013a) of the Tuscalano-Aretemsio ~~(T-A)~~ phase ~~in the Middle Pleistocene (~~ (~560-360 ka; Marra et al., 2011).

~~A~~A direct chemical correlation of OH-DP-1817 with proximal ~~data of the~~ Pozzolane Rosse ~~eruption~~pyroclasts is difficult~~.~~, because of the lack of a comprehensive geochemical dataset. Marra et al. (2009) describe the proximal type localities (within the Colli Albani volcanic district) of the Pozzolane Rosse pyroclastic products, but only the mean value of one geochemical analysis is published (AH-20-PRa). Another, more comprehensive data set ~~was obtained in modern quarry sections adjacent to~~for the ~~Colli Albani (~~composition of ~~Marra et al., 2011), but~~ the ~~tephra was strongly altered~~proximal Pozzolane Rosse pyroclastics was provided by ~~weathering (e.g. high loss on ignition values, low totals due to loss of alkalis) and~~Freda et al. (2010), who however reported only the ~~XRF data cannot be directly compared to our EDS data.~~composition of the basal sub-Plinian fallout. Therefore, the correlation OH-DP-1817/Pozzolane Rosse (cf. Fig. ~~3h~~3h, 5c, Suppl. I Fig. g) is mainly based on the major element data of the $^{40}Ar/^{39}Ar$ dated distal equivalents of the Pozzolane Rosse units, which ~~are found in~~occur diffusely in the fluvial-lacustrine successions of the Apennine intermountain basins of Paganica-San Demetrio-Castelnuovo and ~~in the~~ Sulmona ~~basin in the Apennine chain~~, east of Colli Albani (Galli et al., 2010; Giaccio et al., 2013a). Giaccio et al. (2013a) separates the Pozzolane Rosse distal equivalents into two sublayers, which differ chemically and morphologically. ~~Most of the shards of~~ OH-DP-1817 ~~match~~matches both compositions of the less evolved composition (group a) of the lower layer and ~~only few analyses are prone to~~ the more evolved composition (group b) of the upper sublayer (cf. Fig. 3h). Besides the ~~chemical~~geochemical correlation, microtextural features, such as the scoria character (dense, few vesicles) of the shards and the huge number of juvenile crystals ~~observed in OH-DP-1817, support a correlation with~~, suggest the components of the lower sub-layer prevail in OH-DP-1817. Giaccio et al. (2013a) correlate the lower sublayer (group a) to the proximal Pozzolane Rosse basal ~~fall-out~~fallout and the upper sublayer to the phoenix cloud of the main pyroclastic flow-forming phase. According to Freda et al. (2011~~)~~), the Pozzolane Rosse eruption sequence encompasses from bottom to top the Vallerano lava flow, the main Pozzolane Rosse pyroclastic units (basal fallout and main pyroclastic flow unit) and the scoria lapilli fallout deposits. ~~Thus, most of the material of the tephra layer OH-DP-1811 can be assigned to the basal fallout of the Pozzolane Rosse eruption.~~ Recently, the products of the Pozzolane Rosse eruption were also found in the Campo Felice basin ~~and correlated with tephra~~ (layer CF-V11) where it marks the local glacier advancement of the MIS 12 glacial (Giraudi and Giaccio, 2015). Pronounced glacial conditions are also recorded in the lacustrine sediments across the Pozzolene Rosse of the Sulmona basin (Regattieri et al., 2016).

The age of the Pozzolane Rosse eruption is well constrained by several $^{40}Ar/^{39}Ar$-ages. The pyroclastic products are dated to 457±4 ka at a proximal site (Karner et al., 2001), which is confirmed by the distal equivalent found in the Sulmona Basin (457±~~4~~2 ka, Giaccio et al., 2013a). These ages are further~~ framed and~~ supported by $^{40}Ar/^{39}Ar$-ages of 457±5 ka from a lava flow below and of 442±2 ka from a relatively thin succession of ~~fall-out~~fallout deposits on top (Marra et al., 2009).

~~5.10~~4.10 OH-DP-1955 / SC5

The tephra layer OH-DP-1955 (195.536–195.566 mcd) is 3 cm thick and has a sharp bottom and a diffuse top boundary. The greyish layer comprises blocky, non-vesicular glass shards and porphyric micro-pumices containing leucite crystals. The composition is mainly phonolitic to trachy-andesitic with some shards plotting in the tephri-phonolitic field (Fig. 3h, Table 1). According to the stratigraphic position, OH-DP-1955 was deposited ~~around or~~ prior to ca. ~~450~~460 ka~~.~~, since it is found below OH-DP-1817/Pozzolane Rosse (457±2 ka). Proximal deposits of the active volcanoes in Italy older than 450 ka are only barely explored. From the more distal archives, the tephra layer SC5 from the Mercure Basin (Giaccio et al., 2014) shows a ~~trachy~~trachytic-andesitic to phonolitic trend similar to that of OH-DP-1955 (cf. Fig. 3h). Oxide plots (cf. Fig 6a, Suppl. I Fig. h) of major element clarify that this composition shows a linear magmatic trend and the occurrence of two different populations of tephra can be ruled out. Investigated sources for OH-DP-1955 and its potential equivalent SC5 are very limited. Sr-isotope ratios of tephra layer SC5 reveal an origin from the Roccamonfina volcano (Giaccio et al., 2014). $^{40}Ar/^{39}Ar$ dating provided an age of 493.1±10.9 ka for the SC5 tephra (Giaccio et al., 2014), which thus represents ~~an unknown~~a poorly known eruption from the Roccamonfina volcano~~, as the oldest known eruption is~~ attributable to the Rio Rava ~~eruption~~stage dated ~~to~~between ~600 and 439 ka (Rouchon et al., 2008). ~~A~~Despite a similar age, a potential correlation of OH-DP-1955 with Fall B (490±4 ka) from the ~~Tuffi~~Tufi Terrosi ~~Eruptive Cycle from~~con Pomici Bianche eruptive cycle (TTPB, 499±3-490±4 ka) of the Sabatini volcanic field ~~despite a similar age is unlikely due to the geochemical difference between the tephras (cf.,~~ (Sottili et al., 2004; Marra et al., 2014~~).~~) is unlikely. The composition of the Fall B deposits is somehow different, having e.g. lower FeO_{TOT} (~1.1 wt.%), and CaO (1.5 wt%.) but higher K_2O (3.4 wt.%) contents (cf. Fig. 6a, Table 1).

~~5.11~~4.11 OH-DP-2010 / Fall A

OH-DP-2010 (201.034–201.049 mcd) is a reddish-brown, 1.5 cm thick layer with a sharp lower and an undulated upper boundary. It comprises morphological different volcanic fragments, which range from non-vesicular, microlite-bearing blocky, glass shards, to medium vesicular cuspate glass shards, and elongated vesicular micropumices. The tephri-phonolitic to phonolitic composition of tephra OH-DP-2010 (Fig. 3i, Table 1) and its characteristic high potassium content suggest an origin from the Roman province. The low Cl content of OH-DP-2010 (cf. Table 1) is typical for Middle Pleistocene Sabatini products (Giaccio et al., 2014; Palladino et al., 2014) and supports an origin from the ~~Tufi Terrosi Eruptive Cycle~~TTPB eruptive cycle of the Sabatini volcanic district (Sottili et al., 2004; Marra et al., 2014). The major element composition and the stratigraphic position suggest that OH-DP-2010 correlates with the proximal and distal products of the oldest eruptive unit Fall A (cf. Fig. ~~3i) of the Tufi Terrosi con Pomici Bianche (Karner et al., 2001; Sottili et al., 2004).~~3i; Fig. 6b). The reddish colour of OH-DP-2010 can be attributed to the reddish, terracotta-like, thermally metamorphosed clay lithics, which are a diagnostic characteristic of the proximal Fall A deposits (Sottili et al., 2004). However, the proximal deposits of Fall A apparently show a smaller compositional range (cf. Marra et al., 2014) than ~~in~~ OH-DP-2010 and other distal archives, such as the Mercure Basin (SC3) and the Sulmona Basin (SUL 5-1c), whose correlation is corroborated by Sr-isotope analyses (Giaccio et al., 2014). Similar major element ~~compositions~~composition (cf. Table 1, Fig. 6b) suppose also a correlation of OH-DP-2010/Fall A with the Acerno tephra A9~~, whose origin has been unknown so far~~ (Petrosino et al., 2014b) and FIC-12.9 from Ficoncella site (Aureli et al., 2015).

Sottili et al. (2004) describe a bifurcation of the Fall A at the type section Isola Farnese at the Sabatini volcanic district with a lower sublayer A1 and an upper sublayer A2 both comprising alternating layers of white pumice and grey scoria clasts. Whereas the white pumices of these eruptive units are more evolved and trachy-phonolitic, the grey scoria clasts have a phono-tephritic to tephri-phonolitic composition (Marra et al., 2014). The reason for the wider compositional spectrum of distal Fall A deposits (e.g. OH-DP-2010, SC3) could be the lack of data for the less evolved, upper grey pumices of the proximal zoned Fall A. A correlation of the older Grottarossa Pyroclastic Sequence (GPRS, Karner et al., 2001) of the Sabatini volcano (Marra et al., 2014) with the chemically similar and less evolved part of OH-DP-2010 can be excluded, since ~~a paleosol separates~~ the GPRS ~~from Fall A in the type section~~and Fall A are temporally well distinct events, as testified by field (Sottili et al., 2004~~). Furthermore, the GPRS products and Fall A occur as two individual layers in the Sulmona Basin. ~~) and $^{40}Ar/^{39}Ar$ chronological evidence (Marra et al., 2014).

According to $^{40}Ar/^{39}Ar$ dating, the lower Fall A1 has an age of 499±3 ka and the upper Fall A2 has an age of 496±3 ka (Marra et al., 2014). However, unpublished age~~-~~–depth interpolations from distal equivalents reveal slightly older ages, with 510±3 ka for SC3 at the Mercure Basin, and with 502±4 ka for the A9 at the Acerno Basin.

~~5.12~~4.12 OH-DP-2017 / A11/A12

~~The trachytic composition of OH-DP-2017~~Tephra layer OH-DP-2017 (201.747–201.782 mcd) is whitish to yellowish, 3.5 cm thick, and has sharp bottom and top boundaries. The horizon contains highly vesicular cuspate glass shards with a varying morphology and septa thickness. The homogenous trachytic composition of OH-DP-2017 (Fig. 3j, Table 1) excludes an origin from Roman and Roccamonfina provinces, which mainly produced phonolites and tephro-phonolites during the Middle Pleistocene (cf. Giaccio et al., 2014). However, two very similar trachytic layers (A11/A12) are found in the Acerno Basin sequence (Petrosino et al., 2014b). They have a similar stratigraphic position and a similar glass chemical composition (cf. Fig. 3j+6c, Table 1) compared with OH-DP-2017 (Petrosino et al., 2014b). An unambiguous correlation of OH-DP-2017 with one of the both layers is not possible~~,~~ due to their indistinguishable major element composition~~.~~ (Table 1). Tephra SC2 from the Sulmona Basin was tentatively also correlated based on chemical affinities and its stratigraphic position with the A11/A12 (Giaccio et al., 2014). However, ~~some ~~differences in the composition (higher FeO_{TOT}, SiO_2) do not support an unambiguous correlation of SC2 with OH-DP-2017 or A11/12 (cf. Fig 6c) and suggest that they may derive from the same source, but from different eruptions.

According to the geochemical characteristics, an origin of A11/12 from the Campanian area was proposed (Petrosino et al., 2014b). ~~While proximal~~Proximal products of the Campanian area date back to ca. 290 ka only (Seiano Ignimbrite, Rolandi et al., 2003~~), distal~~). Distal deposits, such as found in the Montalbano Jonico succession (around 720 ka, V5, V7, Petrosino et al., 2014c) and the Sulmona Basin (ca. 723 ka, SC1-35.30/SUL2-1, Giaccio et al., 2013b~~)~~), suggest also older activity of the Campanian area, which may have produced OH-DP-2017/A11/A12. Although Sr-isotope ratios indicate that tephra layer SC2 originate from the

Ponza Island, the lack of Middle Pleistocene pyroclastic rocks on Ponza Island contradicts this correlation and an origin of SC2 from the Campanian area ~~is~~appears more likely (Giaccio et al., 2014).

Sanidine crystals of the Acerno tephra A11 yielded a $^{40}Ar/^{39}Ar$ age of 514±5.6 ka (Petrosino et al., 2014b). ~~The stratigraphic distance of the Acerno layers A11 and~~As A12 is located only 12 cm ~~only~~below A11, which amounts to an age difference of a few hundred years according to the sedimentation rate between the two tephra (Petrosino et al., 2014b~~). As this~~), the difference in age is negligible ~~compared to the $^{40}Ar/^{39}Ar$ error of 5.6 ka,~~and the age of 514±5.6 ka can be transferred from the A11 to OH-DP-2017 tephra.

~~5.13~~4.13 OH-DP-2060 / Tufo di Bagni Albule

~~The characteristic K-foiditic composition of tephra layer OH-DP-2060~~Tephra OH-DP-2060 (206.060–206.080 mcd) is a 2 cm thick, brownish-greyish tephra layer with a sharp bottom and a more diffuse upper boundary. The layer comprises mainly non-vesicular, porphyritic (leucite and sanidine), blocky glass shards. Furthermore, numerous diatoms and weathered calcite were found during microscope analysis. The characteristic K-foiditic composition (Fig. 3j, Table 1) suggests an origin from the Colli Albani volcanic district. According to the stratigraphic position of OH-DP-2060 with a presumed age older than 510 ka, it can be assigned to the Tufo del Palatino-Tufo di Bagni Albule eruptive cycle of the Colli Albani volcanic district (Karner et al., 2001; Giaccio et al., 2013a). Glass composition data are only published for the upper pyroclastic flow Tufo di Bagni Albule (TBA or Tufo di Acque Albule), which is separated by a paleosol from the lower Tufo del Palatino (TP) ignimbrite (Marra et al., 2009). A geochemical comparison of the TBA with the proximal data of the Via Tiburtina section AH-23 (within the Colli Albani volcanic district, Marra et al., 2009) and the distal equivalent found in the Sulmona Basin (SUL1-6 site 2, Giaccio et al., 2013a) reveals a good correlation with OH-DP-2060 (cf. Table 1, Fig. ~~3j~~6d). A relatively thick, foiditic tephra with Tufo del Palatino-Tufo di Bagni Albule products was also found in a core from the Fucino basin in the Apennine chain (Giaccio et al., 2013a). In the Intra-Apennine Carsoli Basin, a chemically very similar deposit, the so-called the Oricola tuff was found (Stoppa et al., 2005) and later correlated with TBA from the Colli Albani volcanic district based on chronological, isotopic, and major element composition affinities~~ correlated with TBA from the Colli Albani volcanic district~~ (Giaccio et al., 2013a).

The carbonate content of the Oricola tuff (Peccerillo, 2005; Stoppa et al., 2005), which is also noticed in OH-DP-2060, is typical for Colli Albani products, because the magma chambers are situated in Mesozoic limestones (Giordano et al., 2006).

TP and TBA in proximal deposits indicate geochronologically indistinguishable ages of 530±2 and 527±2 ka (Marra et al., 2009), which are in a good agreement with the age obtained for the Oricola tuff (ca. 531 ka, Bosi et al., 1991). As long as no compositional glass data is available for the TP, the TBA is the most likely equivalent of OH-DP-2060 and an age of 527±2 ka can be assumed for this tephra.

~~5.14~~4.14 ~~Recalculation~~Reassessing and ~~chronology~~homogenizing the age of the DEEP site tephra layers

The obtained tephrochronological information from the dated equivalents of the DEEP site tephra layers were used to develop a robust chronology for the DEEP site ~~sequence~~proxy series, for both the sediment core and the borehole ~~sequence~~successions (cf. Baumgarten et al., 2015; Francke et al., 2015). For this purpose, ~~9~~11 out of the presented 13 tephra layers were selected ~~due to~~ based on the strength of correlation and their ~~radiometrically dated ages, except~~geochronological reliability. Except for the Y~~-3, where a~~-3, TM24a/POP2, and P-11 tephra, all ages are radiometric ages, whereas the ages of these three tephra layers were taken from the respective age-depth models. The high number of ^{14}C ages above and below the Y-3 equivalent of the Tenaghi Philippon record (Albert et al. 2015) allow a reliable age interpolation~~.~~, similar to the POP2 tephra from the Sulmona basin, where tephra layers above and below are precisely ^{40}Ar/^{39}Ar dated (Regattieri et al., 2015). The only available ^{40}Ar/^{39}Ar ages of the P-11 tephra scatter between 123±1.6 ka and 135±1.2 ka. Currently, the most reliable age of P-11 is likely that obtained from the age-depth model of core LC21, which is tuned to the extensively U/Th-dated Soreq Cave speleothem record (Satow et al., 2015; Zanchetta et al., 2015).

In order to achieve a homogenous set of ages, all ^{40}Ar/^{39}Ar ages have been ~~calculated based on~~recalculated relative to the same flux standard ~~(~~and the total ^{40}K decay constant of Steiger and Jäger (1977). Since the flux standards Fish Canyon sanidine (FCs) ~~at 28.02 Ma~~ and Alder Creek sanidine ~~ACs-2,~~ (ACs-2) are intercalibrated, all ages were recalculated to an age of 1.194 Ma for ACs, which corresponds to FCs at 28.02 Ma (Nomade et al., 2005~~ and the total ^{40}K decay constant of Steiger and Jäger, 1977).~~). This choice was made because most of the published ages were ~~made~~calculated using these two flux standards. ~~Several~~However, several calibrations of the $^{40}Ar/^{39}Ar$ chronometer are currently in use, which yield ages that can vary by ~1% in the time range of the Pleistocene (e.g. Kuiper et al., 2008; Renne et al., 2010; Phillips and Matchan, 2013). As long as it is not the purpose of this work to decipher, which calibration is the more accurate and that the implied difference in calibrated age is within the current reported fully propagated uncertainties at 2σ level, we decided to keep ages as they were published without necessarily endorsing the flux standards values used. The results are ~~indicted~~indicated in Table~~-~~ 2.

~~Based on the 9 selected tephra layers, which are used as first order tie points, Francke et al. (2015) established an age-depth model including further 44 chronological tie points for the uppermost 247.8 mcd of the DEEP site sequence. Second order tie points are tuned TOC and TOC related proxies (C/N) to local insolation and winter season length patterns (Laskar et al., 2004), third order tie points result from tuning, TIC maxima to LR04 minima (Lisiecki and Raymo, 2005). Finally, the established age-depth model was cross evaluated (logging K vs. composite core K) and fine-tuned with the age model of the borehole logging data (Baumgarten et al., 2015).~~

~~The ages of the tephra layers TM24a/POP2 were not considered in the recalculation (Table 2), because their ages were interpolated from the respective age-depth models and independent, radiometrically dated ages do not exist.~~

The age obtained from the suggested correlation OH-DP-0624/CF-V5 with the Pitigliano Tuff was recalculated, but not included in the age model, as the tephrostratigraphical correlation is not very robust (cf. discussion OH-DP-0624) and the 2σ error bar is relatively large (Table 2). Furthermore, the age of the directly overlying tephra OH-DP-0617/Vico B represents a more reliable tie-point in this part of the sequence. ~~The tephra layers OH-DP-1955/SC5 and OH-DP-2060/Tufo di Bagni Albule were not included in the age-depth modelling, as the results of the geochemical analyses were not available when the age-depth model was established.~~ The original/recalculated age of Fall A 499/496±3 ka was not selected as a first order tie point for the age-depth model shown in Francke et al. (~~this issue), since~~2015), because of the age-depth interpolations of the Acerno Basin and the Mercure Basin: They suggest an older age for distal Fall A~~ and~~, making the published age ~~of~~for the proximal Fall A~~ is~~ questionable.

In order to obtain a first overview of the chronology of the DEEP site sequence, an age-depth plot (Fig. ~~5~~7) with all tephrochronological information was created. The homogenous distribution of ages vs. depth suggests a relatively constant sedimentation rate of the DEEP site ~~sequence~~succession for the upper 247.8 m. ~~Although the ages of OH-DP- 0404/TM24a/POP2 and OH-DP-1955/SC5 were not included~~As shown in ~~the age model, they tentatively support to the age-depth curve (cf.~~ Fig. ~~5). As visualised in Fig. 5~~7, the ~~uncertainties~~unreliability of the ^{40}Ar/^{39}Ar age of Fall A ~~(at~~ 496±~~3ka) become~~3 ka becomes more obvious. The tephra ~~correlation~~ OH-DP-1955/SC5 dated to 493±11 ka is located 5.48- m ~~(2.9 ka)~~ above OH-DP-2010/Fall A ~~and~~, whilst the OH-DP-2017/A11 dated to 514±6 ka is located only 0.73- m ~~(17.9 ka)~~ below this layer. Accepting an age of 496±3 ka for Fall A would imply a ~~dramatic~~distinct change in the sedimentation rates ~~within this periods~~, with interpolated sedimentation rates ~~(~~of 1.~~8m/~~8 m ka^{-1} above and 0.04 m ka^{-1} below~~)~~,, which differ substantially from a mean sedimentation rate of 0.39 m ka^{-1} for the entire sequence. However, there is no lithological evidence ~~for~~justifying such a conspicuous change in sedimentation rate. The radiometric dating of Fall A was done on deposits from Cava Rinaldi, which were correlated with Fall A only using trace element ratios (Zr/Y vs. Nb/Y plot) and chronological constraints, because the deposits have been too altered to use major element compositions (Marra et al., 2014). Although this method is helpful to distinguish between the different Italian provinces and between the different volcanic districts (Marra et al., 2011; Marra et al., 2014), it may be not suitable to distinguish between single eruptions, with similar composition. Moreover, the intense alteration of the deposits makes an unequivocal correlation difficult and the obtained age for Fall A is probably too young. Following the correlation of OH-DP-2010 with distal deposits of the SC3 in the Mercure and the A9 in the Acerno basin, an age of between 502 and 510 ka seems to be more likely and would be consistent with more constant sedimentation rates in the DEEP site record.

4.15 Resulting tephrostratigraphy of the Lake Ohrid record

The Middle Pleistocene Italian tephrostratigraphic framework was extended for the first time beyond Italy to the Balkan region. The 13 identified tephra layers (OH-DP-0027-2060) of the DEEP sequence link the Lake Ohrid record with numerous terrestrial and marine records of the Mediterranean region (Fig. 8) at least back to MIS13. Since the last 160 kyrs are recorded in many archives, tephra layers found in Lake Ohrid of this period were also found in numerous other records and give a dense framework of tie points for this period. However, for the period between MIS 7 and MIS 11, no correlations could be established for the Lake Ohrid sequence so far, but at least 13 tephra layers between OH-DP-0624 (>160 ka) and OH-DP-1817 (<450 ka) indicate activity and widespread eruptions of Italian volcanoes. On the other hand, Lake

Ohrid provides a very long and continuous record of stratigraphically ordered Middle Pleistocene tephra, which represents a reference section for other discontinuous and short successions in which the stratigraphic order of tephra is unknown or not well constrained. In spite of this potential, tephrostratigraphic and volcanologic implications based on the lower part of the record below P-11 are premature, because the succession is not fully analysed and more detailed investigations are needed to complete and improve the tephrostratigraphic framework. Even still at this preliminary stage of the study, the recognition of tephra layers from volcanic provinces, which were thought to be poorly active or even

~~61 Conclusions~~

~~First tephrostratigraphic studies on the DEEP site record from Lake Ohrid correlated 12 tephra layers and one cryptotephra with their counterparts, all originating from the Italian volcanism. The following correlations could be proposed: OH-DP-0027/Mercato tephra, OH-DP-0115/Y-3, OH-DP-0169/Y-5, OH-DP-0404/TM24a/POP2, OH-DP- 0435/X-6, OH-DP-0499/P-11., OH-DP-0617/Vico "Ignimbrite B", OH-DP-0624/CF-V5/Pitigliano Tuff, OH-DP-1817/Pozzolane Rosse, OH-DP-1955/SC5, OH-DP-2010/Fall A, OH-DP-2017/A11/12, and OH-DP-2060/Tufo di Bagni Albule.~~

~~Tephra layers found in the previous studies could be re-identified and were helpful markers for developing the new tephrostratigraphy of the DEEP site record. The existing correlations could be emphasised and some of them corrected to the todays knowledge (e.g. OH-DP-0617/OT0701-6 and OH-DP-0624/OT0701-7). Furthermore, tephrostratigraphy was successfully applied for the sequence older than the already inspected 130 ka of Lake Ohrid's history. The Italian Middle Pleistocene tephrostratigraphic framework, which is based on several records covering specific intervals of time, was extended for the first time beyond Italy to the Balkan region and linked to an at least 640 ka old continuous record. This will provide a unique opportunity to achieve new results in stratigraphy, when the eruptive order of tephra layers found in different archives is unknown. Furthermore, this linkage and synchronization of different archives helps to find the origin of so far unknown tephra layers (e.g.OH-DP-2010/Acero tephra A9/Fall A) or improves suggested correlations (e.g. OH-DP-6024/CF-V5/PRAD3225). The connection to different records within the Mediterranean region reveals the possibility to review different distribution patterns of specific eruptions, which probably changed within an eruption (e.g. OH-DP-0499/P-11/THP-TII-5).~~

~~The recognition of tephras from volcanic provinces, which were thought to be~~ inactive at the time of tephra deposition, such as the ca. 490 ka old OH-DP-1955/SC5 tephra from the Roccamonfina volcano, or the ca. 510 ka old OH-DP-2017/A11/12 tephra from the Campanian Volcanic Zone, provide insights for exploring and improve our knowledge about volcanic activity of the different provinces. Furthermore, their widespread distribution to the Balkan ~~suggest~~suggests that some of them were rather large magnitude eruptions and represent widespread marker horizons.

The connection to different records within the Mediterranean region also reveals the possibility to review different distribution patterns of specific eruptions, which probably will change substantially in the light of the Lake Ohorid data (e.g. OH-DP-0499/P-11/THP-TII-5). Moreover, this established tephrostratigraphic framework can be used as a powerful tool for the synchronization of different archives in order to address at very fine temporal and stratigraphic resolution relevant paleoclimate and paleoenvironmental issues (cf. Zanchetta et al., 2015).

5 Conclusions

The results of the first tephrostratigraphic study of the DEEP site succession from Lake Ohrid allowed us to recognize 34 macroscopic tephra, 12 out of which and one cryptotephra, all originating from the Italian volcanism, were correlated with their proximal or distal counterparts. Tephra layers found in the previous studies have been re-identified and were utilized as helpful markers for setting up the uppermost part of the new tephrostratigraphy of the DEEP site record. In the light of the longer tephra succession presented in this paper, the previously established correlations have been either confirmed or, in some cases, revised (e.g. OH-DP-0617/OT0701-6 and OH-DP-0624/OT0701-7). Furthermore, tephrostratigraphy was successfully applied for the succession older than the already inspected 135 ka of Lake Ohrid's history. On the whole, the following correlations are here proposed: OH-DP-0027/Mercato tephra (8.43-8.63 ka cal BP), OH-DP-0115/Y-3 (28.68-29.42 ka cal BP), OH-DP-0169/Y-5 (39.6±0.1 ka), OH-DP-0404/TM24a/POP2 (102±2.4 ka), OH-DP- 0435/X-6 (109±2 ka), OH-DP-0499/P-11 (133.5±2 ka), OH-DP-0617/Vico "Ignimbrite B" (162±6 ka), OH-DP-0624/CF-V5/Pitigliano Tuff (163±22 ka), OH-DP-1817/Pozzolane Rosse (457±2 ka), OH-DP-1955/SC5 (493.1±10.9 ka), OH-DP-2010/Fall A (496±3 ka), OH-DP-2017/A11/12 (511±6 ka), and OH-DP-2060/Tufo di Bagni Albule (527±2 ka).

The ages of ~~8~~11 of the correlated tephra layers were used to contribute first order tie points to develop a robust age-depth model of the ~~entire DEEP site sequence. This~~uppermost 247.8 mcd of the DEEP succession, which is a fundamental pillar for the development of the different multi-proxy paleoclimatic-environmental and evolutionary studies, which are in progress. Furthermore, this age-depth model has the potential to ~~improve~~refine our ~~tephrochronological~~chronological knowledge of some ~~of the layers found in the Lake Ohrid sequence (e.g. Fall A, Pitigliano Tuff).~~relevant marker tephra found in the Lake Ohrid succession (e.g. Fall A), and to provide a first chronological framework for a number of currently poorly known tephra, which, however, can be potentially found elsewhere and thus indirectly dated by simple geochemical fingerprinting. In this perspective, the data presented in this paper provide a further important step forward for extending back in time, and well beyond the current chronological limit, a robust and reliable Middle Pleistocene tephrostratigraphy in central Mediterranean area.

Appendix A: Supplementary Material

Supplement I: Harker diagrams of established correlations of the Ohrid tephra layers OH-DP-0027-1955.

Supplement II: Full data set of WDS-analysis of Ohrid tephra layers OH-DP-0027-2060

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Table 1. Average major element glass composition (normalised to 100 %) of investigated tephra layers OH-DP-0027–OH-DP-2060 of the DEEP site sequence, the discussed

correlations, and the standards used for evaluation of the accuracy of the analyses. All data of the Ohrid tephra layers were obtained using a WDS, except for OH-DP-0027, which is based on EDS measurements. The "Total" is given as analytical total, and the tephra layers printed in italic are not correlated with the respective Ohrid tephra and are discussed only. The full dataset of OH-DP-0027–OH-DP-2060 is given in the Supplement 2.

Table 2. Depths and ages of tephra layers in the DEEP site succession. $^{40}Ar/^{39}Ar$ ages with 2σ uncertainties (last column) recalculated to ACs at 1.194 Ma for, which corresponds to FCs at 28.02 Ma (Nomade et al., 2005) and the total decay constant of Steiger and Jäger (1977). Tephra layers in bold are not considered for the age-depth modelling (Francke et al., 2015).

Figure 1. (a) Location of Lake Ohrid in the Mediterranean region**,** the Italian volcanoes**,** and the locations of archives mentioned in the text **(**1-Ficoncella Site, 2-Carsoli Basin, 3-Paganica-San Demetrio-Castelnuovo basin, 4-Campo Felice, 5-Fucino Basin, 6-Sulmona Basin, 7-PRAD1-2, 8-CM92-42, 9-RF93-77, 10-RF95-11, 11-Veliko Jezero, Island of Mljet, 12-KET8022, 13-KET8003, 14-KET8011, 15-C-45, 16-KET8004/DED8708, 17-C1202, 18-Cilento coast, 19-C106, 20-SMP1e (CE1/CD1/SMP1), 21-Acerno Basin, 22-San Gregorio Magno basin, 23-Lago Grande di Monticchio, 24-Mercure basin, 25-Montalbano Jonico succession, 26-MD90-917, 27-KET8218, 28-IN68-9, 29-IN68-5, 30-AD91-17, 31-MD90-918, 32-RC9 191, 33-M25/4-12, 34-KET8222, 35-V10 69, 36-ODP 963A, 37-22M-60, 38-KC01B, 39-RC9 18, 40-RC9 181, 41-LC01,-42-V10 58, 43-Lesvos, 44-Tenaghi Philippon, 45-Theopetra Cave, 46-Lake Prespa). **(b)** Geological map of the Lake Ohrid catchment modified after Lindhorst et al. (2015) and the core locations from previous studies (Lz1120, Co1200/1201/1202/1262, and JO2004) and the ICDP main drill site DEEP.

Figure 2. (Litho-) Stratigraphy of the uppermost 247.8 mcd of the DEEP site sequence and the position of recognised tephra layers. Tephra layers coloured in yellow and being labeld are discussed within this paper. The thickness of tephra layers is not to scale and more detailed information about tephra thickness and appearance are provided in the text.

Figure 3. Total alkali-silica diagram after Le Bas et al., 1986 to classify and correlate the DEEP site tephra layers OH-DP-0027–OH-DP-2060 (a–j). The full dataset of the DEEP site record is given in Table 1 and in the supplementary online material. The following references were used: **a) OH-DP-0027/Pomici di Mercato:** Co1262-709 (Wagner et al., 2012), OT0702-3 (Vogel et al., 2010), PT0915-2 (Damaschke et al., 2013TM6a/TM6b (Wulf et al., 2004); MJ1/VJ1 (Jahns and van den Bogaard, 1998); KET8218 V1 (Paterne et al., 1988); IN68-9 125cm, IN68-5 259

cm and RF95-11 320 cm (Calanchi and Dinelli, 2008); 190-191, 195-196 cm AD91-17 (Marchini et al., 2014); 210/223cm MD90-918 (Caron et al., 2012). **b) OH-DP-0115 / Y-3:** OT0520-2; OT0700-1; OT0702-4; JO 187 (Sulpizio et al., 2010), PT0915-5, (Damaschke et al., 2013); TM15 (Wulf et al., 2004); Y-3 M25/4-12, RC9 (Keller et al., 1978; Albert et al., 2015); C7 (Paterne et al., 1988); MD90-917 920/17 (Zanchetta et al., 2008); TP 9.70 (Albert et al., 2015); A2/B2 C106/C45 (Munno and Petrosino, 2004); S19 (Munno and Petrosino, 2007). **c) OH-DP-0169 / CI/Y-5:** OT0520-3, OT0700-2, OT0701-1, OT0702-6, JO-244, PT0704-3 (Sulpizio et al., 2010); Y-5 RC9 191 (Keller et al. 1978); TM-18 (Wulf et al., 2004); S-17 (Munno and Petrosino, 2007)**;** ML 2 (Margari et al., 2007); TP-CI (Lowe et al., 2012); C-13 (Paterne et al., 1988); PRAD1653 (Bourne et al., 2010); I-3, (Insinga et al. 2014); LC21 4.925 (Lowe et al., 2012, Satow et al. 2015); pre-CI deposits (Tomlinson et al., 2012).**d) OH-DP-0404 / TM24a POP2 :** OT-0702-8 (Vogel et al., 2010); TM24a (Wulf et al., 2004; Wulf et al., 2012); POP2 (Regattieri et al., 2015); CM92-42 (710 cm), RF93-77 (797 cm) (Calanchi and Dinelli, 2008). **e) OH-DP-0435 / X-6:** OT0702-9 (Vogel et al., 2010), JO-575 (Caron et al., 2010); X-6 (Keller et al., 1978); C-31 (Paterne et al., 2008); TM27 (Wulf et al., 2012); POP4 (Regattieri et al., 2015); PRAD-2812 (Bourne et al., 2015); I-9 (Insinga et al., 2014); S10 (Munno and Petrosino, 2007); SM1-2/SA (Marciano et al., 2008); CIL2 (Giaccio et al., 2012); t1 (Iorio et al., 2014). **f) OH-DP-0499 / P-11:** OT0702-10 (Vogel et al., 2010), JO-941 (Caron et al., 2010); P-11 (Paterne et al., 2008); ODP2-4 (Tamburrino et al., 2012); ML5 (Margari et al., 2007); THP-TII5 (Karkanas et al., 2015); LC21 10.345 (Satow et al., 2015). **f) OH-DP-0617 / Vico "Ignimbrite B":** OT0701-6 (Sulpizio et al., 2010); CF-V4 (Giraudi et al., 2011); Vico B (Giraudi et al. 2011). **g) OH-DP-0624 / CF-V5/ PRAD3225:** OT0701-7 (Sulpizio et al., 2010); PRAD3225 (Bourne et al., 2015); CF-V5 tephra (Giraudi and Giaccio, 2015); C-42 (Paterne et al., 2008). **h) OH-DP-1817 / Pozzolane Rosse:** AH-20-PRa (Marra et al., 2009); basal fallout (Freda et al., 2010); Paganica-Raiano-Sulmona (Giaccio et al., 2013a); CF-V11 (Giraudi and Giacco, 2015). **h) OH-DP-1955 / SC5:** SC5 (Giaccio et al., 2014); Fall B (Marra et al., 2014). **i) OH-DP-2010 / Fall A:** Proximal Fall A (Marra et al., 2014); SC3 and SUL 5-1c (Giaccio et al., 20149; A9 (Petrosino et al., 2014b); FIC-12.9 (Aureli et al., 2015). **j) OH-DP-2017/ A11/A12:** A11/12 (Petrosino et al., 2014b); SC2 (Giaccio et al., 2014).

Figure 4. Al_2O_3-FeO_{TOT} diagram for classification of comendites and pantellerites according to MacDonald (1974). Tephra OH-DP-0499 and most of the other P-11 equivalents show the typical bimodal chemical composition of P-11, except for the very distal equivalents LC21 10.345 and THP-TII5, which only have a pantelleritic part (see text for data references).

Figure 5. Harker diagrams of tephra layers OH-DP-0617-OH-DP-1817 and their discussed equivalents. For references of correlated tephra layers, see text, additional Harker diagrams for OH-DP-1817 can be found in the Supplement I Fig. g.

Figure 6. Harker diagrams of tephra layers OH-DP-1955-OH-DP-2060 and their discussed equivalents. For references of correlated tephra layers, see text, additional Harker diagrams for OH-DP-1955 can be found in the Supplement I Fig. h.

Figure 7. Age-depth plot for the selected DEEP site tephra layers. The ages of the tephra layers are based on recalculation of existing $^{40}Ar/^{39}Ar$ ages (Table 2) or according to published data for non $^{40}Ar/^{39}Ar$ ages. Chronological tie points were interpolated on a linear basis (blue line). The dotted lines in the insert indicate a suspicious change in the sedimentation rate for a different age of the Fall A tephra.

Figure 8. Tephrostratigraphic framework of Lake Ohrid and selected archives of the last 637 kyrs corresponding to MIS16. The dashed parts of the archive columns indicate the part of the existing record, where no tephrostratigraphic information are available at present. The following archives and tephra layers are presented: Lago Grande di Montichhio (LgdM, Wulf et al. 2004, 2012), Siciliy Channel: ODP963 (Tamburino et al. 2012), Tyrrhenian Sea: KET8004/DED8708, KET8003,-8011,8022 (C-7,-13,-31,-42, Paterne et al., 1988, 2008); C1202 (t1, Iorio et al. 2014); C45/106 (A2/B2, Munno and Petrosino, 2004), Adriatic Sea: KET8218 (V-1, Paterne et al., 1988), IN68-9, IN68-5, RF95-11, CM92-42, RF93-77 (*125/259/320, 710/797 Calanchi and Dinelli, 2008); AD91-17 ("190-191/195-196, Marchini et al., 2014); MD90-917 (920-17, Zanchetta et al., 2008); MD90-918 (#210/223 Caron et al. 2012); PRAD1-2 (PRAD 1653, 2812, 3225, Bourne et al.,2010, 2015), Ionian Sea: MD25/4-12 (Y-3, Albert et al., 2015); RC9-191, 22M-60, V10 69 (Y-3, Y-5, X-6, Keller et al., 1978); KET-8222 (C-31, P-11, Paterne et al., 2008); KC01B (I-3, I-9, Insinga et al. 2014), Levantine Sea: RC9-183, RC9-181 (Y-5, Keller et al., 1978), Aegean Sea: V10-58 (Y-5, Keller et al., 1978); LC01 (4.925, 10.345, Satow et al., 2015), Tenaghi Philippon: (TP9.70, Albert et al., 2015; CI, Lowe et al., 2012), San Gregorio Magno Basin (Munno and Petrosino, 2007), Campo Felice basin (Giraudi et al., 2011, 2015), Sulmona basin (Giaccio et al. 2013b, Regattieri et al., 2015), Acerno basin (Petrosino et al., 2013b), Mercure basin (Giaccio et al., 2014).

6 References

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~~8 Figure and table captions~~

~~Figure 1: A: Location of Lake Ohrid in the Mediterranean region and of the Italian volcanoes. B: Geological map of the Lake Ohrid catchment modified after Lindhorst et al. (2015) and the core location from previous studies (Lz1120, Co1200/1201/1202/1262, and JO2004) and the ICDP main drill site DEEP.~~

~~Figure 2: (Litho-) Stratigraphy of the uppermost 247.8 mcd of the DEEP site sequence and the position of identified tephras. Thickness of tephra layers is not to scale, more detailed information about tephra thickness are provided in the text.~~

~~Figure 3: Total alkali-silica diagram (Bas et al., 1986) to classify and correlate the DEEP site tephra layers OH-DP-0027–OH-DP-2060 (a-j).~~ Discuss., 12, 16979-17007, 2015. ~~The full dataset of the DEEP site record is given in Table 1 and in the supplementary online material. For references of correlated tephras, see text.~~

~~Figure 4: Al_2O_3-FeO_{TOT} diagram for classification of comendites and pantellerites according to MacDonald (1974). Tephra OH-DP-0499 and most of the other P-11 equivalents show the typical bimodal chemical composition of P-11, except for the very distal equivalents LC21 10.345 and THP-TII5, which only have a pantelleritic part (see text for data references).~~

~~Figure 5: Age-depth plot for the selected DEEP site tephras. The ages of the tephras are based on recalculation of existing $^{40}Ar/^{39}Ar$ ages (Table 2) or according to published data for non $^{40}Ar/^{39}Ar$ ages. Chronological tie points were interpolated on a linear basis (blue line). The dotted lines in the insert indicate a suspicious change in the sedimentation rate for a different age of the Fall A tephra.~~

~~Table 1: Average major element glass composition (normalised to 100%) of investigated tephras OH-DP-0115 – OH-DP-2060 of the DEEP site sequence. All data were obtained using WDS, except for OH-DP-1817*, which is based on EDS measurements. The full dataset is given in the supplementary online material.~~

~~Table 2: Depths and ages of tephras in the DEEP site succession. $^{40}Ar/^{39}Ar$ ages (last column) are recalculated relative to ACs-2 at 1.193 Ma (Nomade et al., 2005) and the total decay constant of Steiger and Jäger (1977), with uncertainties given at 2σ. Tephra layers in italics are not considered for the age-depth modelling (Francke et al., 2015).~~

		SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total	Tot. Alkali	Alk. Ratio
OH-DP-0027	x̄	56.29	0.11	23.80	1.44	0.08	0.33	1.55	8.69	7.21	-	-	0.50	-	100.00	15.90	0.83
n=12	*s*	0.51	0.09	0.18	0.16	0.09	0.18	0.11	0.35	0.20	-	-	0.12	-	-	0.28	0.05
OT0702-3	x̄	59.10	0.17	21.58	1.95	0.17	0.16	1.76	7.56	7.02	-	-	0.52	-	100.00	14.58	0.93
n=9	*s*	0.51	0.08	0.12	0.11	0.06	0.09	0.13	0.53	0.26	-	-	0.03	-	-	0.66	0.07
Co1262-709		58.59	0.17	21.81	1.84	0.16	0.12	1.67	8.20	6.94	0.00	-	0.51	-	100	15.14	0.85
n=12		0.39	0.08	0.49	0.12	0.06	0.08	0.22	0.50	0.29	0.00	-	0.03	-	-	0.36	0.08
PT0915-2	x̄	58.34	0.18	21.59	1.92	0.15	0.24	1.97	7.93	6.85	0.09	-	0.73	-	100.00	14.79	0.87
n=10	*s*	0.30	0.05	0.38	0.12	0.06	0.10	0.42	0.24	0.18	0.18	-	0.06	-	-	0.33	0.03
TM-6a	*x̄*	*59.98*	*0.30*	*20.61*	*2.24*	*0.13*	*0.16*	*2.42*	*5.58*	*8.02*	*0.08*	*0.08*	*0.51*	-	*97.67*	*13.60*	*1.51*
n=13	*s*	*0.93*	*0.09*	*0.51*	*0.46*	*0.04*	*0.07*	*0.39*	*1.03*	*0.82*	*0.12*	*0.00*	*0.15*	-	*0.91*	*0.57*	*0.38*
TM-6b	x̄	58.71	0.16	21.10	1.99	0.19	0.15	2.11	8.14	6.82	0.13	0.10	0.49	-	98.21	14.96	0.88
n=12	*s*	1.53	0.09	0.83	1.00	0.07	0.26	1.19	1.11	0.88	0.20	0.09	0.18	-	1.27	0.97	0.31
MJ1/VJ1	x̄	58.76	0.21	21.03	1.85	0.19	0.12	2.41	7.38	7.12	-	0.30	0.57	0.06	98.12	14.51	0.96
n=27	*s*	1.42	0.11	0.81	0.81	0.08	0.21	1.24	0.73	0.85	-	0.18	0.21	0.04	0.88	1.51	0.07
KET8218 V1	x̄	60.04	0.10	21.49	1.74	0.00	0.00	1.82	7.72	7.05	-	-			99.96	14.77	0.91
n=n.a.	*s*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IN68-9 125cm	x̄	59.50	0.09	21.26	1.71	0.11	0.14	1.81	7.72	7.14	-	-	0.52	-	93.40	93.40	0.92
n=20	*s*	0.78	0.02	0.34	0.17	0.06	0.12	0.43	0.57	0.62	-	-	0.08	-	3.53	3.53	0.11
IN68-5 259cm	x̄	58.81	0.09	21.21	1.79	0.12	0.10	1.75	8.18	7.40	-	-	0.55	-	95.54	15.58	0.91
n=15	*s*	0.36	0.03	0.15	0.10	0.06	0.07	0.09	0.37	0.13	-	-	0.04	-	1.82	0.33	0.05
RF95-11 320cm	x̄	59.10	0.11	20.60	1.89	0.13	0.08	1.88	7.58	8.13	-	-	0.50	-	95.94	15.71	1.08
n=21	*s*	0.76	0.05	0.26	0.30	0.06	0.05	0.36	0.67	0.45	-	-	0.12	-	1.64	0.84	0.11
RF95-11 320cm	x̄	61.43	0.27	18.46	2.95	0.12	0.32	1.97	5.29	8.52	-	-	0.67	-	94.95	13.81	1.65
n=3	*s*	0.56	0.06	0.09	0.24	0.07	0.28	0.19	0.83	0.94	-	-	0.21	-	1.18	0.40	0.24
MD90-918 210cm	x̄	58.71	0.14	21.82	1.78	0.17	0.17	1.74	8.06	6.80	-	-	0.60	-	-	14.86	0.85
n=9	*s*	0.47	0.08	0.23	0.11	0.10	0.06	0.16	0.35	0.15	-	-	0.11	-	-	0.38	0.04
MD90-918 223cm	x̄	58.82	0.12	21.88	1.72	0.13	0.11	1.81	8.27	6.60	-	-	0.53	-	100.00	14.88	0.80
n=12	*s*	0.61	0.10	0.28	0.15	0.12	0.06	0.53	0.37	0.81	-	-	0.09	-	-	1.00	0.10
AD94-17 190-191 cm	x̄	58.69	0.14	21.97	1.70	0.14	0.26	1.72	8.17	6.73	-	-	0.49	-	100.00	14.90	0.82
n=14	*s*	0.74	0.11	0.21	0.16	0.09	0.09	0.34	0.43	0.47	-	-	0.09	-	-	0.79	0.05
AD94-17 195-196cm	x̄	58.51	0.13	22.13	1.73	0.15	0.43	1.68	8.13	6.65	-	-	0.51	-	100.00	14.78	0.83
n=10	*s*	0.31	0.07	0.32	0.15	0.09	0.09	0.21	0.79	0.45	-	-	0.06	-	-	0.38	0.15
OH-DP-0115	x̄	61.60	0.38	18.24	3.43	0.12	0.70	2.67	3.43	9.32	0.10	0.14	0.46	0.11	95.49	12.76	2.77
n=16	*s*	0.89	0.03	0.17	0.32	0.05	0.16	0.32	0.44	0.44	0.04	0.09	0.10	0.06	1.98	0.15	0.45
OT0702-4	x̄	61.27	0.39	18.70	3.11	0.11	0.67	2.35	3.73	9.22	-	-	0.46	-	100.00	12.96	2.52
n=12	*s*	0.61	0.05	0.12	0.20	0.06	0.17	0.24	0.44	0.46	-	-	0.10	-	-	0.11	0.42
OT0520-2	x̄	61.88	0.29	18.63	2.92	0.03	0.50	2.20	4.18	8.82	-	-	0.54	-	100.00	12.99	2.15
n=12	*s*	0.50	0.08	0.18	0.22	0.06	0.15	0.18	0.45	0.49	-	-	0.13	-	-	0.09	0.35
JO187	x̄	60.99	0.40	18.74	3.26	0.11	0.68	2.38	3.59	9.43	-	-	0.42	-	100.00	13.02	2.68
n=10	*s*	0.71	0.10	0.10	0.26	0.07	0.15	0.25	0.48	0.41	-	-	0.09	-	-	0.28	0.46
OT0700-1	x̄	61.60	0.38	18.74	3.03	0.10	0.67	2.30	3.74	8.94	-	-	0.50	-	100.00	12.68	2.44
n=12	*s*	0.75	0.10	0.15	0.34	0.09	0.16	0.30	0.44	0.43	-	-	0.13	-	-	0.24	0.39
PT0915-5	x̄	60.85	0.40	18.92	3.40	0.11	0.79	2.37	3.60	8.94	0.01	-	0.62	-	100.00	12.54	2.57
n=12	*s*	0.87	0.08	0.27	0.37	0.07	0.19	0.30	0.58	0.56	0.03	-	0.19	-	-	0.27	0.56

		SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total*	Tot. Alkali	Alk. Ratio
M25/4-12 Y-3	x̄	61.32	0.37	18.27	3.23	0.12	0.62	2.42	3.64	9.41	0.11	-	0.50	-	96.22	13.04	2.69
n=33	*s*	0.89	0.03	0.26	0.34	0.05	0.19	0.26	0.62	0.69	0.04	-	0.18	-	1.35	0.17	0.61
RC9 191 Y-3	x̄	62.76	0.36	18.21	2.98	0.17	0.25	2.07	4.44	8.75	-	-	-	-	-	-	-
n=n.a.	*s*	0.36	0.03	0.16	0.21	0.12	0.12	0.15	0.19	0.26	-	-	-	-	-	-	-
TM-15	x̄	62.22	0.38	18.36	3.27	0.13	0.61	2.19	3.85	8.36	0.12	-	0.52	-	96.32	12.21	2.21
n=20	*s*	0.76	0.03	0.20	0.29	0.04	0.14	0.22	0.43	0.54	0.06	-	0.10	-	0.46	0.21	0.36
TP-9.70	x̄	61.79	0.37	18.28	3.17	0.10	0.59	2.40	3.78	9.19	0.12	-	0.54	-	96.46	12.97	2.48
n=42	*s*	0.78	0.04	0.17	0.31	0.04	0.14	0.22	0.47	0.47	0.04	-	0.12	-	1.42	0.19	0.41
S-19	x̄	62.17	0.31	18.77	2.96	0.08	0.49	2.13	4.20	8.90	-	-	-	-	100.01	13.10	2.12
n=n.a.	*s*	1.15	0.07	0.14	0.47	0.04	0.26	0.29	0.38	0.50	-	-	-	-	-	-	-
C106 A2	x̄	62.63	0.34	18.24	3.15	0.15	0.47	2.12	4.15	8.75	-	-	-	-	100.00	12.90	2.11
n=12	*s*	0.20	0.06	0.12	0.12	0.08	0.08	0.10	0.19	0.14	-	-	-	-	-	-	-
C45 B2	x̄	62.41	0.33	18.30	3.17	0.15	0.50	2.13	4.30	8.71	-	-	-	-	100.00	13.01	2.03
n=11	*s*	0.32	0.10	0.29	0.10	0.08	0.09	0.10	0.15	0.08	-	-	-	-	-	-	-
MD90-917 920–17	x̄	61.41	0.37	18.72	3.17	0.08	0.70	2.44	3.52	9.14	-	-	0.44	-	100.00	12.66	2.60
n=n.a.	*s*	0.86	0.10	0.17	0.38	0.08	0.21	0.33	0.40	0.40	-	-	0.09	-	-	-	-
KET8004 C-7	x̄	63.12	0.25	18.53	3.03	0.00	0.14	2.17	3.86	8.86	-	-	-	-	99.96	12.72	2.30
n=n.a.	*s*	0.90	0.08	0.21	0.39	0.00	0.13	0.33	0.52	0.42	-	-	-	-	-	-	-
KET8011 C-7	x̄	61.90	0.33	19.14	2.95	0.00	0.49	2.75	3.62	8.79	-	-	-	-	99.97	12.41	2.43
n=n.a.	*s*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OH-DP-0169b	x̄	61.76	0.43	18.86	3.01	0.25	0.36	1.86	5.96	7.47	0.04	0.33	0.83	0.05	97.04	13.43	1.26
n=18	*s*	0.31	30.67	9.22	7.93	1.38	0.06	0.75	2.05	0.81	3.72	0.15	0.26	0.39	1.25	0.31	0.07
OH-DP-0169a	x̄	61.69	0.41	18.89	3.04	0.26	0.34	1.78	6.28	7.28	0.04	0.36	0.85	0.05	98.78	13.56	1.17
n=25	*s*	0.44	0.03	0.14	0.09	0.04	0.02	0.04	0.56	0.15	0.02	0.07	0.04	0.02	1.56	0.57	0.17
OT0700-2	x̄	60.84	0.39	19.21	2.98	0.20	0.42	1.77	6.06	7.45	-	-	0.68	-	100.00	13.51	1.29
n=17	*s*	0.38	0.09	0.18	0.19	0.07	0.12	0.25	0.82	0.72	-	-	0.11	-	-	0.33	0.50
OT05020-3	x̄	61.88	0.29	18.63	2.92	0.03	0.50	2.20	4.18	8.82	-	-	0.54	-	100.00	12.99	2.15
n=12	*s*	0.50	0.08	0.18	0.22	0.06	0.15	0.18	0.45	0.49	-	-	0.13	-	-	0.09	0.37
OT0702-6	x̄	60.83	0.40	19.13	2.93	0.18	0.48	1.77	6.31	7.34	-	-	0.65	-	100.00	13.65	1.17
n=11	*s*	0.30	0.10	0.11	0.13	0.09	0.08	0.20	0.44	0.25	-	-	0.10	-	-	0.31	0.13
JO-244	x̄	60.64	0.42	19.18	2.96	0.21	0.40	1.81	6.22	7.48	-	-	0.69	-	100.00	13.69	1.21
n=18	*s*	0.57	0.08	0.24	0.16	0.05	0.12	0.21	0.36	0.31	-	-	0.10	-	-	0.20	0.13
OT0701-1/5	x̄	60.92	0.41	19.15	3.02	0.20	0.44	1.80	5.87	7.57	-	-	0.64	-	100.00	13.44	1.37
n=41	*s*	0.64	0.07	0.69	0.18	0.07	0.14	0.30	1.12	0.97	-	-	0.14	-	-	0.38	0.69
PT0704-3	x̄	60.83	0.42	19.14	3.03	0.23	0.47	1.77	5.86	7.59	-	-	0.65	-	100.00	13.46	1.53
n=105	*s*	0.58	0.09	0.23	0.26	0.09	0.16	0.32	1.01	0.82	-	-	0.13	-	-	0.42	0.69
RC9 191 Y-5	x̄	61.56	0.44	18.90	3.59	0.17	0.59	1.97	5.55	7.26	-	-	-	-	96.48	12.80	1.31
V10 58 Y-5	*s*	62.46	0.36	18.43	2.11	0.16	0.40	2.16	6.33	7.59	-	-	-	-	93.52	13.92	1.20
C-13	x̄	62.20	0.35	19.30	2.94	0.08	1.75	5.92	7.41	-	-	-	-	-	99.95	13.33	1.25
C-13	*s*	61.50	0.31	19.15	3.13	0.33	2.50	3.54	9.50	-	-	-	-	-	99.96	13.04	2.68
PRAD 1653	x̄	61.00	0.43	19.71	2.93	0.24	0.28	1.68	6.72	7.01	-	-	-	-	95.89	13.73	1.04
n=14	*s*	0.49	0.04	0.11	0.29	0.04	0.03	0.07	0.20	0.12	-	-	-	-	0.87	0.27	0.03
I-3	x̄	61.45	0.41	18.40	3.12	0.19	0.54	2.16	4.88	7.84	0.09	0.26	0.65	-	97.01	12.84	1.72
n=14	*s*	1.14	0.05	0.43	0.43	0.06	0.24	0.56	0.94	0.97	0.06	0.11	0.21	-	2.48	0.47	0.63
Lc 21 4.925	x̄	61.93	0.46	18.03	3.20	0.21	0.44	2.05	6.20	7.46	-	-	-	-	95.35	13.66	1.25
n=32	*s*	0.74	0.10	0.25	0.47	0.08	0.36	0.70	0.94	0.48	-	-	-	-	1.33	0.93	0.30

		SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total*	Tot. Alkali	Alk. Ratio
TM18	x̄	61.60	0.43	18.92	2.93	0.24	0.35	1.75	5.78	7.04	0.05	0.33	0.79	-	98.64	12.82	1.24
n=61	*s*	0.46	0.03	0.36	0.11	0.03	0.07	0.16	0.75	0.53	0.02	0.04	0.08	-	1.71	0.83	0.25
ML2	x̄	61.01	0.48	18.18	3.02	0.21	0.44	2.12	5.64	8.05	-	0.07	0.71	-	96.51	13.70	1.57
n=105	*s*	0.42	0.04	0.19	0.21	0.06	0.15	0.32	1.20	1.02	-	0.04	0.20	-	1.46	0.32	0.69
S-17	x̄	61.67	0.33	19.18	2.90	0.22	0.27	1.60	6.42	7.38	-	-	-	-	100.00	13.80	1.15
n=n.a.	*s*	0.22	0.14	0.10	0.10	0.10	0.08	0.11	0.30	0.20	-	-	-	-	-	0.50	-
Tenaghi Phlippon CI	x̄	63.29	0.40	19.42	3.32	0.20	0.45	2.09	5.20	8.48	0.10	-	-	-	96.42	13.69	1.99
n=3	*s*	0.39	0.03	0.28	0.26	0.06	0.20	0.47	1.69	1.27	0.06	-	-	-	0.88	0.46	1.13
pre CI deposits	x̄	*58.94*	*0.40*	*19.75*	*3.45*	*0.25*	*0.34*	*2.04*	*6.46*	*7.58*	-	-	*0.79*	-	*97.76*	*14.04*	*1.19*
n=68	*s*	*0.38*	*0.02*	*0.16*	*0.14*	*0.03*	*0.04*	*0.10*	*0.51*	*0.30*	-	-	*0.04*	-	*1.32*	*0.26*	*0.14*
OH-DP-0404	x̄	57.49	0.54	19.05	5.10	0.17	1.30	4.33	4.06	7.72	0.24	0.18	0.50	0.09	97.08	11.78	1.93
n=20	*s*	1.00	0.11	0.45	0.67	0.04	0.24	0.65	0.54	0.62	0.07	0.08	0.09	0.05	1.33	0.93	0.25
OT0702-8	x̄	57.60	0.55	19.49	4.48	0.16	1.22	3.77	4.18	8.09	0.01	-	0.46	-	100.00	12.26	1.94
n=12	*s*	0.46	0.08	0.15	0.33	0.07	0.15	0.32	0.18	0.43	0.02	-	0.05	-	-	0.43	0.15
TM-24a	x̄	57.64	0.49	18.99	4.26	0.14	1.12	3.99	4.24	8.37	0.24	-	0.52	-	100.00	12.61	1.97
n=35	*s*	1.14	0.06	0.19	0.46	0.02	0.22	0.56	0.14	0.31	0.06	-	0.04	-	0.01	0.31	0.11
POP2	x̄	59.71	0.42	18.43	3.79	0.17	0.73	2.94	4.26	8.61	0.09	0.14	0.54	0.15	96.28	12.87	2.02
n=26	*s*	1.10	0.07	0.11	0.62	0.05	0.25	0.57	0.17	0.34	0.05	0.07	0.06	0.06	1.34	0.48	0.07
RF93-77 797cm	x̄	59.41	0.41	19.17	3.69	0.10	0.77	2.84	4.36	8.75	-	-	0.50	-	97.24	13.11	2.01
n=n.a	*s*	0.41	0.08	0.10	0.18	0.07	0.15	0.20	0.36	0.30	-	-	0.07	-	0.81	0.66	-
CM92-42 710cm	x̄	59.19	0.41	19.20	3.74	0.08	0.81	2.99	4.25	8.84	-	-	0.49	-	97.65	13.09	2.08
n=n.a	*s*	0.39	0.07	0.17	0.22	0.05	0.11	0.22	0.30	0.23	-	-	0.07	-	1.46	0.53	-
OH-DP-0435	x̄	61.06	0.45	18.53	3.09	0.30	0.36	1.78	6.12	6.98	0.05	0.37	0.86	0.05	96.82	13.10	1.16
n=22	*s*	0.34	0.04	0.17	0.12	0.10	0.09	0.10	0.52	0.55	0.03	0.13	0.14	0.03	1.60	0.26	0.20
OT0702-9	x̄	61.15	0.46	18.82	3.09	0.29	0.39	1.68	6.39	7.03	-	-	0.71	-	100.00	13.42	1.12
n=15	*s*	0.30	0.06	0.12	0.14	0.09	0.10	0.08	0.62	0.50	-	-	0.14	-	-	0.20	0.20
JO575	x̄	61.20	0.47	18.74	2.97	0.29	0.38	1.65	6.54	7.04	-	-	0.72	-	100.00	13.58	1.09
n=20	*s*	0.43	0.08	0.17	0.15	0.08	0.08	0.11	0.61	0.45	-	-	0.12	-	-	0.32	0.17
22M-60 X-6	x̄	61.45	0.49	18.52	3.80	0.22	0.59	2.06	6.20	6.66	-	-	-	-	94.53	12.86	1.08
n=n.a.	*s*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM27	x̄	61.43	0.46	18.57	2.85	0.23	0.40	1.84	6.32	7.25	0.06	-	0.71	-	97.86	13.57	1.17
n=22	*s*	0.40	0.02	0.09	0.13	0.06	0.08	0.11	0.66	0.50	0.04	-	0.14	-	1.40	0.24	0.19
POP4	x̄	61.49	0.45	18.26	3.08	0.25	0.38	1.77	5.84	7.36	0.04	0.28	0.75	0.05	97.05	13.20	1.28
n=31	*s*	0.42	0.03	0.11	0.11	0.07	0.06	0.08	0.52	0.43	0.02	0.10	0.14	0.03	1.31	0.28	0.17
S-10	x̄	62.38	0.40	18.86	2.81	0.24	0.29	1.61	6.02	7.39	-	-	-	-	-	13.41	1.23
n=n.a.	*s*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I-9	x̄	62.00	0.46	18.50	2.99	0.27	0.38	1.71	5.74	6.77	0.06	0.32	0.80	-	96.42	12.51	1.19
n=15	*s*	0.39	0.05	0.24	0.09	0.05	0.04	0.07	0.31	0.30	0.04	0.13	0.10	-	0.83	0.22	0.11
KET8004 DED8708 C-31	x̄	61.80	0.45	18.11	3.16	0.28	0.31	1.76	5.64	7.34	0.02	0.14	1.00	-	-	12.98	1.30
n=n.a.	*s*	0.50	0.09	0.19	0.17	0.11	0.16	0.21	0.54	0.60	0.03	0.08	0.25	-	-	1.14	-
KET8282 C-31	x̄	61.74	0.49	19.19	3.10	-	0.43	1.72	6.03	7.31	-	-	-	-	-	13.34	1.21
n=n.a.	*s*	0.34	0.08	0.11	0.18	-	0.08	0.14	0.71	0.68	-	-	-	-	-	1.39	-

		SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total*	Tot. Alkali	Alk. Ratio
KET8222 C-31	x̄	60.17	0.47	19.45	3.70	-	0.77	2.51	4.03	8.69	-	-	-	-	-	12.72	2.16
n=n.a.	*s*	0.12	0.04	0.04	0.20	-	0.06	0.25	0.55	0.62	-	-	-	-	-	1.17	-
PRAD2812	x̄	62.00	0.46	18.84	2.93	0.24	0.39	1.75	6.10	7.29	-	-	-	-	96.21	13.39	1.22
n=23	*s*	0.24	0.03	0.10	0.11	0.07	0.08	0.08	0.62	0.55	-	-	-	-	0.85	0.15	0.21
C1202 t1	x̄	60.16	0.45	18.36	3.30	0.32	0.31	1.77	7.34	6.60	0.17	0.30	0.91	-	96.82	13.94	1.05
n=20	*s*	0.28	0.12	0.25	0.22	0.11	0.08	0.11	0.21	0.21	0.12	0.18	0.06	-	1.81	0.26	0.03
CIL2	x̄	61.46	0.45	18.37	3.24	0.29	0.45	1.86	5.47	7.19	0.08	0.38	0.72	0.03	96.08	12.66	1.40
n=74	*s*	0.67	0.05	0.34	0.25	0.09	0.19	0.28	0.97	0.97	0.06	0.20	0.23	0.04	1.51	0.42	0.47
SM1	x̄	62.27	0.45	18.19	3.31	0.35	0.35	1.76	5.05	7.82	-	-	0.45	-	95.27	12.87	1.55
n=15	*s*	0.33	0.04	0.25	0.16	0.01	0.14	0.06	0.18	0.35	-	-	0.07	-	-	-	-
SM2	x̄	62.50	0.43	18.37	3.23	0.36	0.40	1.73	5.36	7.31	-	-	0.33	-	96.18	12.66	1.36
n=11	*s*	0.90	0.02	0.18	0.24	0.14	0.20	0.22	0.23	0.50	-	-	0.11	-	-	-	-
SA	x̄	62.21	0.41	18.50	3.34	0.22	0.42	1.80	4.77	7.94	-	-	0.39	-	96.36	12.71	1.66
n=16	*s*	0.24	0.07	0.17	0.09	0.10	0.07	0.09	0.21	0.16	-	-	0.10	-	-	-	-
OH-DP-0499	x̄	65.32	0.69	15.32	6.02	0.28	0.33	1.32	5.68	4.92	0.11	0.08	0.15	0.06	97.13	10.61	0.87
n=11 (trachyte)	*s*	1.06	0.08	0.88	0.31	0.04	0.09	0.25	0.36	0.09	0.04	0.05	0.05	0.02	1.70	0.41	0.05
OH-DP-0499	x̄	73.61	0.36	8.77	7.30	0.34	0.08	0.33	4.72	4.46	0.02	0.29	0.85	0.06	93.33	9.18	0.95
n=32 (pantellerite)	*s*	0.34	0.03	0.21	0.15	0.05	0.02	0.03	0.28	0.09	0.02	0.09	0.07	0.03	1.16	0.28	0.06
LC21 10.345	x̄	73.91	0.39	8.65	7.06	0.30	0.03	0.29	5.01	4.36	-	-	-	-	100.00	9.37	1.06
n=5	*s*	1.62	0.04	0.15	0.24	0.06	0.02	0.02	1.89	0.08	-	-	-	-	-	1.83	0.49
ODP3	x̄	65.05	0.75	15.61	5.66	0.29	0.41	1.43	5.85	4.78	0.15	0.07	0.10	-	96.81	10.64	0.95
n=14 (trachyte)	*s*	0.33	0.04	0.20	0.16	0.04	0.03	0.07	0.31	0.15	0.02	0.04	0.02	-	1.39	0.30	0.06
ODP3	x̄	73.58	0.39	9.40	6.63	0.32	0.10	0.31	4.83	4.43	0.02	0.24	0.68	-	94.78	9.25	1.40
n=4 (pantellerite)	*s*	0.98	0.02	1.21	0.83	0.02	0.05	0.01	0.61	0.11	0.01	0.08	0.17	-	2.21	0.64	0.10
TII5	x̄	75.46	0.38	8.99	7.28	0.22	0.06	0.30	6.24	4.59	-	-	-	-	95.94	10.82	0.74
n=15	*s*	0.57	0.04	0.14	0.28	0.09	0.02	0.03	0.30	0.26	-	-	-	-	0.69	0.31	0.85
ML5	x̄	66.22	0.75	14.33	6.05	0.30	0.27	1.16	5.59	4.99	-	-	-	-	95.86	10.58	0.90
n=6 (trachyte)	*s*	0.93	0.06	0.98	0.43	0.02	0.09	0.24	0.25	0.12	-	-	-	-	1.33	0.15	0.06
ML5	x̄	73.73	0.43	8.31	7.14	0.32	0.08	0.31	4.30	4.44					92.72	8.74	1.04
n=50 (pantellerite)	*s*	0.24	0.01	0.10	0.16	0.02	0.01	0.01	0.24	0.08					0.45	0.24	0.07
OT0702-10	x̄	66.18	0.43	16.23	5.96	0.23	0.20	0.84	5.85	5.79	-	0.13	-	-	100.00	11.64	0.99
n=3 (trachyte)	*s*	0.73	0.13	2.54	0.08	0.16	0.17	0.10	0.64	1.14	-	0.09	-	-	-	1.44	0.18
OT0702-10	x̄	72.52	0.41	9.34	6.70	0.31	0.12	0.34	5.06	4.50	-	0.71	-	-	100.00	9.55	0.91
n=6 (pantellerite)	*s*	0.72	0.08	1.12	0.36	0.05	0.06	0.06	0.64	0.28	-	0.07	-	-	-	0.56	0.17
JO941	x̄	72.28	0.37	8.54	6.79	0.29	0.10	0.29	6.33	4.39	-	0.69	-	-	100.00	10.71	0.69
n=13	*s*	0.26	0.11	0.09	0.10	0.09	0.21	0.05	0.18	0.09	-	0.05	-	-	-	0.14	0.48
KET8222 P-11	x̄	64.67	0.83	15.50	5.88	0.28	1.45	6.41	4.98	-	-	-	-	-	-	11.39	0.78
n=n.a. (trachyte)	*s*	0.68	0.10	0.71	0.19	0.14	0.20	0.27	0.19	-	-	-	-	-	-	0.46	-
KET8222 P-11	x̄	72.41	0.34	8.95	7.43	0.08	0.17	6.09	4.54	-	-	-	-	-	-	10.63	0.75
n=n.a. (pantellerite)	*s*	0.38	0.08	0.09	24.00	6.00	0.08	0.33	0.00	-	-	-	-	-	-	0.33	-
ODP2		*63.92*	*1.00*	*16.22*	*5.35*	*0.25*	*0.99*	*2.50*	*5.55*	*3.89*	*0.35*	*0.09*	*0.24*	-	*97.22*	*9.44*	*0.82*
n=18		*1.74*	*0.30*	*0.83*	*0.51*	*0.04*	*0.61*	*1.18*	*0.43*	*0.80*	*0.37*	*0.07*	*0.11*	-	*1.18*	*0.87*	*0.10*
ODP4		*65.10*	*0.72*	*15.89*	*5.72*	*0.30*	*0.38*	*1.41*	*5.62*	*4.72*	*0.14*	*0.05*	*0.15*		*96.33*	*10.35*	*0.90*
n=33 (trachyte)		*0.61*	*0.04*	*0.47*	*0.14*	*0.04*	*0.08*	*0.12*	*0.38*	*0.12*	*0.04*	*0.05*	*0.23*		*1.55*	*0.39*	*0.06*
ODP4		*74.58*	*0.40*	*8.70*	*6.98*	*0.36*	*0.07*	*0.29*	*4.25*	*4.33*	*0.03*	*0.30*	*0.73*		*93.45*	*8.55*	*1.35*
n=33 (pantellerite)		*0.18*	*0.02*	*0.00*	*0.04*	*0.06*	*0.01*	*0.01*	*0.26*	*0.09*	*0.02*	*0.01*	*0.04*		*0.39*	*0.22*	*0.05*

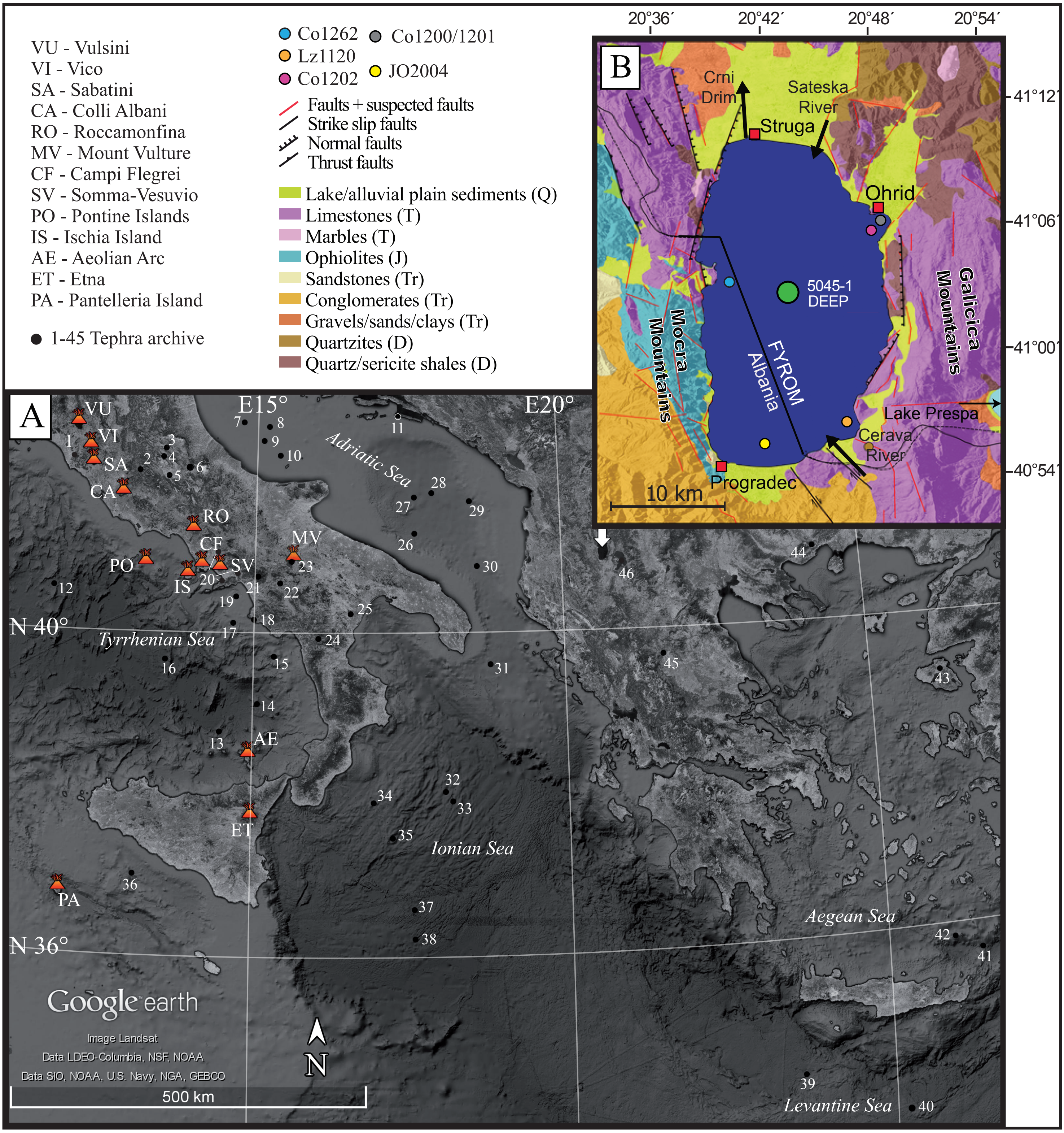
		SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total*	Tot. Alkali	Alk. Ratio
OH-DP-0617	x̄	60.15	0.43	19.77	2.75	0.15	0.42	2.38	5.04	8.85	0.05	0.49	0.24	0.12	94.36	13.89	1.76
n=13	*s*	0.33	0.02	0.28	0.09	0.04	0.02	0.06	0.16	0.26	0.02	0.10	0.02	0.04	1.62	0.16	0.10
CF5 V4	x̄	58.90	0.48	20.46	3.20	0.18	0.62	2.71	5.00	8.37	0.08	0.47	0.25	0.11	95.85	13.37	1.68
n=16	*s*	1.81	0.10	0.22	1.03	0.03	0.48	0.98	0.37	0.39	0.10	0.15	0.07	0.04	0.81	0.73	0.08
OT0701-6	x̄	59.58	0.44	20.04	2.76	0.13	0.51	2.31	5.24	8.80	-	-	0.18	-	100.00	14.04	1.68
n=15	*s*	0.22	0.07	0.12	0.14	0.09	0.08	0.09	0.15	0.16	-	-	0.04	-	-	0.10	0.08
Vico B	x̄	59.66	0.46	19.59	2.85	0.15	0.42	2.37	5.37	8.65	0.05	0.43	0.22	0.09	95.32	14.02	1.61
n=13	*s*	0.26	0.07	0.10	0.05	0.04	0.03	0.05	0.09	0.16	0.04	0.11	0.02	0.03	1.31	0.14	0.05
OH-DP-0624	x̄	51.40	1.02	18.17	8.00	0.19	3.09	8.36	3.20	5.88	0.68	0.19	0.34	0.37	97.77	9.08	1.84
n=19	*s*	3.60	0.22	0.62	2.13	0.03	1.17	2.48	0.68	1.45	0.28	0.06	0.08	0.17	1.29	2.08	0.18
OT0701-7	x̄	55.79	0.81	19.24	5.30	0.18	1.67	5.14	4.20	7.19	0.16	-	0.37	-	100.00	11.40	1.73
n=22	*s*	3.92	0.28	0.63	2.49	0.08	1.25	2.67	0.71	1.58	0.16	-	0.07	-	-	2.27	0.13
PRAD3225	x̄	57.82	0.68	19.12	4.15	0.19	1.05	4.05	4.88	8.08	-	-	-	-	97.21	12.95	1.65
n=11	*s*	2.77	0.16	0.39	1.73	0.01	0.90	2.00	0.60	1.10	-	-	-	-	1.19	1.68	0.06
CF5 V5	x̄	54.92	0.81	18.76	6.08	0.19	1.98	5.93	3.82	7.06	0.46	0.21	0.41	0.24	96.59	10.88	1.86
n=14	*s*	3.56	0.22	0.58	2.12	0.05	1.06	2.09	0.64	1.12	0.30	0.08	0.08	0.08	1.39	1.71	0.13
C-42	x̄	49.74	1.49	18.06	8.63	0.27	3.26	8.25	3.37	5.97	0.79	0.17	-	-	99.56	9.34	1.77
n=n.a.	*s*	1.08	0.30	0.26	0.61	0.17	0.21	0.56	0.13	0.24	0.19	0.05	-	-	-	0.37	-
Pittigliano tuff WDS	x̄	58.89	0.60	19.65	3.42	-	0.15	0.78	3.69	4.16	8.59	0.08	0.21	-	98.41	12.75	2.09
n=3	*s*	1.71	0.11	0.37	1.36	-	0.01	0.66	1.58	0.50	1.56	0.00	0.13	-	0.61	1.65	0.48
Pittigliano tuff XRF	x̄	58.69	0.57	19.43	1.74	1.96	0.15	0.71	3.25	4.03	9.28	0.12	0.00	0.00	96.51	13.32	2.38
n=3	*s*	1.33	0.05	0.19	0.36	0.39	0.00	0.30	0.87	0.59	1.04	0.09	0.00	0.00	0.61	0.80	0.56
OH-DP-1817	x̄	44.48	0.98	15.44	10.76	0.23	4.61	13.25	3.81	5.48	0.95	0.36	0.14	0.41	97.58	9.28	1.47
n=10	*s*	1.60	0.12	0.97	1.02	0.06	0.44	1.40	0.59	0.47	0.13	0.11	0.02	0.18	0.85	0.77	0.24
AH20-Pra	x̄	40.41	1.33	12.14	6.19	0.26	14.77	11.21	3.38	4.83	1.08	0.59	-	0.08	96.94	8.21	1.43
n=6	*s*	0.16	0.04	0.05	0.17	0.03	0.30	0.13	0.08	0.36	0.12	0.11	-	0.02	-	0.44	-
Sulmona Site 2	x̄	41.92	1.19	14.23	12.50	0.32	5.20	14.20	4.00	5.43	1.02	0.49	0.16	0.16	96.95	9.43	1.37
n=23	*s*	0.63	0.05	0.19	0.35	0.03	0.18	0.37	0.31	0.28	0.08	0.08	0.02	0.05	1.38	0.32	0.15
Sulmona Site 2a	x̄	43.01	1.17	14.77	11.53	0.28	4.75	13.59	3.83	6.07	1.00	0.45	0.14	0.14	97.61	9.90	1.64
n=30	*s*	1.40	0.15	0.94	1.16	0.06	1.01	1.57	0.41	1.46	0.13	0.12	0.02	0.07	1.12	1.21	0.60
Paganica site 5	x̄	43.47	1.10	15.34	10.87	0.29	4.78	13.15	3.75	6.42	0.82	0.45	0.14	0.27	96.70	10.17	1.80
n=18	*s*	1.86	0.16	1.76	1.20	0.07	1.19	2.17	0.98	1.32	0.17	0.16	0.05	0.12	1.22	1.70	0.54
Raiano site 3	x̄	43.68	1.06	14.49	10.62	0.27	5.24	13.69	3.53	6.53	0.88	0.44	0.13	0.21	97.79	10.06	1.85
n=22	*s*	1.04	0.21	1.42	0.76	0.05	1.06	1.55	0.31	1.20	0.13	0.11	0.02	0.14	0.66	1.30	0.34
PR basal fallout	x̄	42.83	1.41	12.65	11.60	0.22	6.51	16.30	2.96	4.42	1.10	0.48	-	0.03	97.96	7.38	1.49
n=10	*s*	0.17	0.11	0.11	0.09	0.04	0.10	0.29	0.06	0.11	0.06	0.14	-	0.03	0.86	0.14	0.04
CF7-V11	x̄	43.49	1.03	14.81	10.83	0.26	4.58	13.15	4.23	6.67	0.94	0.38	0.14	0.30	99.04	99.04	10.90
n=11	*s*	1.35	0.12	0.98	1.12	0.05	0.57	1.64	0.44	1.16	0.11	0.11	0.02	0.12	0.62	0.62	1.24

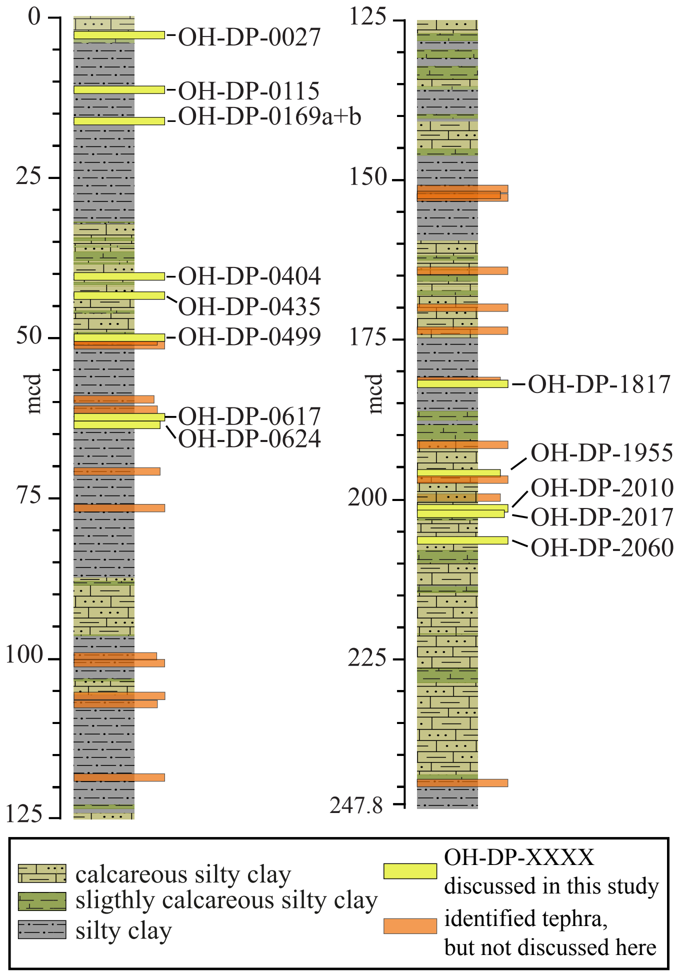
		SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total*	Tot. Alkali	Alk. Ratio
OH-DP-1955	x̄	57.53	0.57	20.51	4.03	0.18	0.56	4.55	4.78	6.97	0.09	0.31	0.23	0.21	96.70	11.75	1.47
n=18	*s*	1.49	0.10	0.47	0.34	0.04	0.07	0.52	0.72	1.55	0.02	0.11	0.05	0.05	1.83	1.90	0.33
SC5	x̄	58.42	0.48	21.16	3.01	0.20	0.36	4.41	4.84	6.63	0.14	0.33	0.24	0.18	94.64	11.47	1.38
n=17	*s*	1.37	0.09	0.98	0.74	0.08	0.16	0.52	0.52	0.69	0.10	0.18	0.10	0.14	1.55	0.91	0.20
Fall B	x̄	60.09	0.48	19.06	2.92	0.16	0.50	3.26	3.14	10.34	0.05	-	-	-	100.00	13.48	3.78
n=6	*s*	0.25	0.01	0.09	0.08	0.02	0.04	0.17	0.15	0.12	0.01	-	-	-	-	0.25	0.16
OH-DP-2010		54.03	0.76	18.14	6.33	0.15	1.77	6.23	3.08	8.66	0.35	0.32	0.08	0.49	97.59	11.73	2.87
n=22		3.62	0.17	0.72	1.75	0.03	0.81	1.81	0.49	0.89	0.19	0.11	0.03	0.16	1.77	1.10	0.43
Fall A		59.92	0.50	19.21	3.16	0.17	0.51	3.19	3.05	10.20	0.08	-	-	-	100.00	13.25	3.36
n=11		0.29	0.02	0.14	0.12	0.11	0.05	0.25	0.17	0.17	0.03	-	-	-	-	0.26	0.20
SC3		58.47	0.54	18.80	3.85	0.15	0.91	3.93	2.89	9.75	0.09	0.30	0.07	0.26	96.81	12.64	3.40
n=20		1.31	0.04	0.18	0.72	0.03	0.33	0.78	0.25	0.61	0.04	0.12	0.02	0.13	1.33	0.73	0.29
A9		58.87	0.55	19.13	3.60	0.12	0.59	3.57	3.65	9.81	0.11	0.28	0.14	-	97.10	13.46	2.73
n=16		1.13	0.24	0.37	0.73	0.10	0.22	0.69	0.38	0.60	0.11	0.14	0.07	-	1.25	0.38	0.41
Sulmona 5-1c		60.13	0.44	19.05	3.01	0.14	0.55	3.16	3.09	10.33	0.06	0.00	0.11	0.38	95.15	13.42	3.36
n=30		0.89	0.04	0.43	0.32	0.04	0.14	0.38	0.21	0.21	0.03	0.00	0.02	0.12	1.24	0.26	0.26
FIC-12.9		55.52	0.63	19.41	4.75	0.19	1.28	5.34	4.38	8.27	0.23	0.43	0.11	0.31	96.51	12.65	1.95
n=22		1.79	0.08	0.35	0.73	0.05	0.36	0.98	0.53	1.05	0.08	0.11	0.02	0.11	1.77	0.66	0.52
OH-DP-2017		64.43	0.44	18.27	2.59	0.18	0.29	1.06	5.65	6.32	0.05	0.24	0.36	0.11	94.22	11.97	0.29
n=21		0.20	0.08	0.12	0.08	0.03	0.02	0.05	0.26	0.14	0.03	0.07	0.02	0.03	0.60	1.12	0.06
A11		63.68	0.46	18.28	2.73	0.18	0.42	1.44	5.17	7.13	0.15	0.11	0.24	-	96.52	12.30	1.41
n=18		0.66	0.10	0.33	0.27	0.16	0.17	0.28	0.66	0.40	0.11	0.14	0.09	-	0.84	0.48	0.27
A12		64.18	0.51	17.85	2.56	0.23	0.30	1.09	6.09	6.57	0.12	0.11	0.39	-	96.37	12.66	1.08
n=17		0.53	0.12	0.23	0.23	0.16	0.09	0.20	0.33	0.20	0.12	0.13	0.08	-	0.92	0.31	0.08
SC2		66.20	0.35	16.97	3.01	0.26	0.32	0.98	5.27	5.71	0.02	0.02	0.50	0.40	95.38	10.98	1.09
n=16		0.58	0.03	0.17	0.21	0.03	0.13	0.26	0.27	0.12	0.02	0.01	0.04	0.10	1.21	0.32	0.05
OH-DP-2060		44.94	0.78	18.67	8.44	0.29	1.61	10.91	5.39	7.74	0.28	0.91	0.19	0.95	96.34	13.13	1.46
n=19		1.70	0.17	0.94	1.18	0.05	0.98	1.26	0.76	1.32	0.16	0.23	0.04	0.48	1.81	1.68	0.27
SUL 1-6		44.73	0.82	19.48	8.17	0.36	1.45	10.90	5.59	8.31	0.18	0.85	0.18	0.75	96.73	13.90	1.53
n=27		1.16	0.10	0.70	0.77	0.05	0.14	1.16	0.64	0.90	0.03	0.20	0.03	0.27	1.31	0.67	0.40
Oricola tuff		45.15	0.00	18.83	8.27	0.32	1.52	11.40	4.90	8.33	0.23	0.79	0.13	0.13	100.00	13.23	1.70
n=8		0.66	0.00	0.31	0.45	0.03	0.11	0.62	0.25	0.67	0.04	0.09	0.02	0.05	-	0.76	0.15
proximal TBA		45.74	0.76	19.16	7.80	0.30	1.40	10.20	5.49	8.93	0.21	0.86	-	0.85	98.02	14.42	1.63
n=7		0.79	0.11	0.14	0.19	0.03	0.06	0.46	0.27	0.29	0.03	0.14	-	0.10	0.70	0.27	0.12

WDS standard

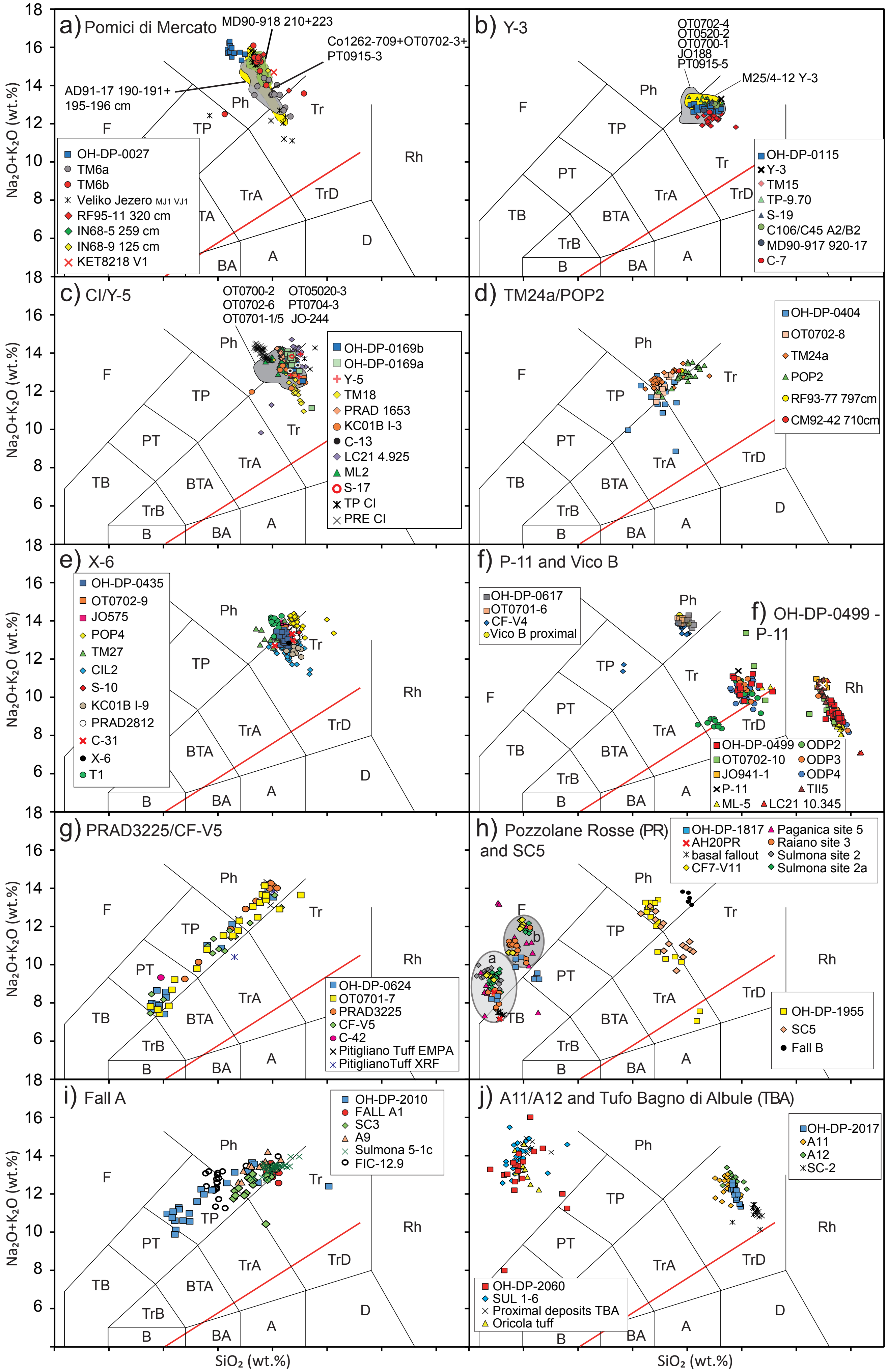
	SiO_2	TiO_2	Al_2O_3	FeO_{TOT}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	F	Cl	SO_3	Total
Standard 1 - USGS Rhyolite														
Measured mean	75.84	0.23	11.16	2.23	0.16	0.05	0.09	4.57	4.51	0.03	0.25	0.18	0.03	99.32
Recommended	76.00	0.19	11.50	2.02	0.16	0.08	0.10	4.75	4.47	-	-	-	0.03	99.30
Standard 2 - Kakanui Augite														
Measured mean	50.79	0.87	8.36	0.09	6.53	16.27	15.95	1.29	-	-	-	-	-	100.14
Recommended	50.46	0.84	8.28	0.13	6.51	16.28	16.00	1.30	-	-	-	-	-	99.80

Tephra DEEP site	Depth (mcd)	Eruption/ Tephra	Age (ka)	References	recalculated $^{40}Ar/^{39}Ar$ ages
OH-DP-0027	2.773	Mercato	8.43–8.63	Zanchetta et al., 2011	N.A.
OH-DP-0115	11.507	Y-3	28.68-29.42	Albert et al., 2015	N.A.
OH-DP-0169	16.933	Campanian Ignimbrite/Y-5	39.28±0.1	De Vivo et al., 2001	39.6±0.1
OH-DP-0404	40.486	POP2	102±2.4	Regattieri et al., 2015	N.A.
OH-DP-0435	43.513	X-6	109±2	Iori et al., 2014	109±2
OH-DP-0499	49.947	P-11	133.5±2	Satow et al., 2015	N.A.
OH-DP-0617	61.726	Vico "Ignimbrite B"	157±3	Laurenzi and Villa, 1987	162±6
OH-DP-0624	**62.413**	**Pitigliano Tuff**	**158±22**	**Turbeville, 1992a**	**163±22**
OH-DP-1817	181.769	Pozzolane Rosse	457±4	Karner et al., 2001	457±4
			457±2	Giaccio et al., 2013	457±2
OH-DP-1955	195.566	SC5	493.1±10.9	Giaccio et al., 2014	493.1±10.9
OH-DP-2010	**201.049**	**Sabatini Fall A**	**499±3**	**Marra et al., 2014**	**496±3**
OH-DP-2017	201.782	Acerno A11-12	514±6	Petrosino et al., 2014	511±6
OH-DP-2060	206.080	Tufo di Bagni Albule	527±2	Marra et al., 2009	527±2

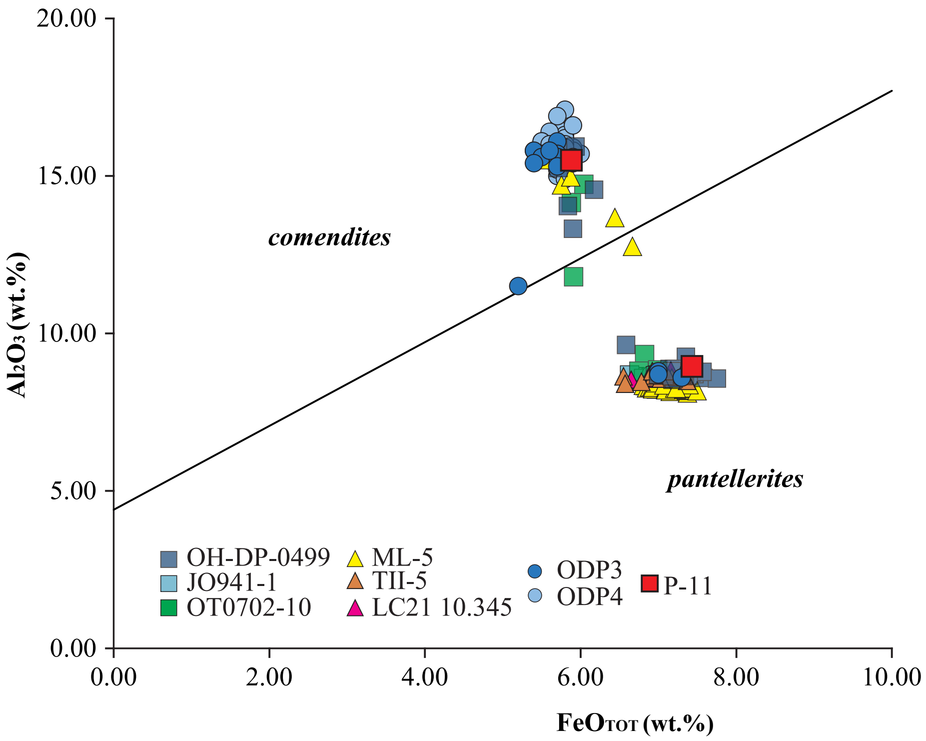

VU - Vulsini
VI - Vico
SA - Sabatini
CA - Colli Albani
RO - Roccamonfina
MV - Mount Vulture
CF - Campi Flegrei
SV - Somma-Vesuvio
PO - Pontine Islands
IS - Ischia Island
AE - Aeolian Arc
ET - Etna
PA - Pantelleria Island
1-45 Tephra archive
Co1262
Co1200/1201
Lz1120
Co1202
JO2004
Faults + suspected faults
Strike slip faults
Normal faults
Thrust faults
Lake/alluvial plain sediments (Q)
Limestones (T)
Marbles (T)
Ophiolites (J)
Sandstones (Tr)
Conglomerates (Tr)
Gravels/sands/clays (Tr)
Quartzites (D)
Quartz/sericite shales (D)
A
E15°
E20°
Adriatic Sea
Tyrrhenian Sea
Ionian Sea
Aegean Sea
Levantine Sea
N 40°
N 36°
Google earth
Image Landsat
Data LDEO-Columbia, NSF, NOAA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
500 km
N
B
20°36′
20°42′
20°48′
20°54′
41°12′
41°06′
41°00′
40°54′
Crni Drim
Sateska River
Struga
Ohrid
5045-1 DEEP
FYROM
Albania
Mocra Mountains
Galicica Mountains
Lake Prespa
Cerava River
Pogradec
10 km



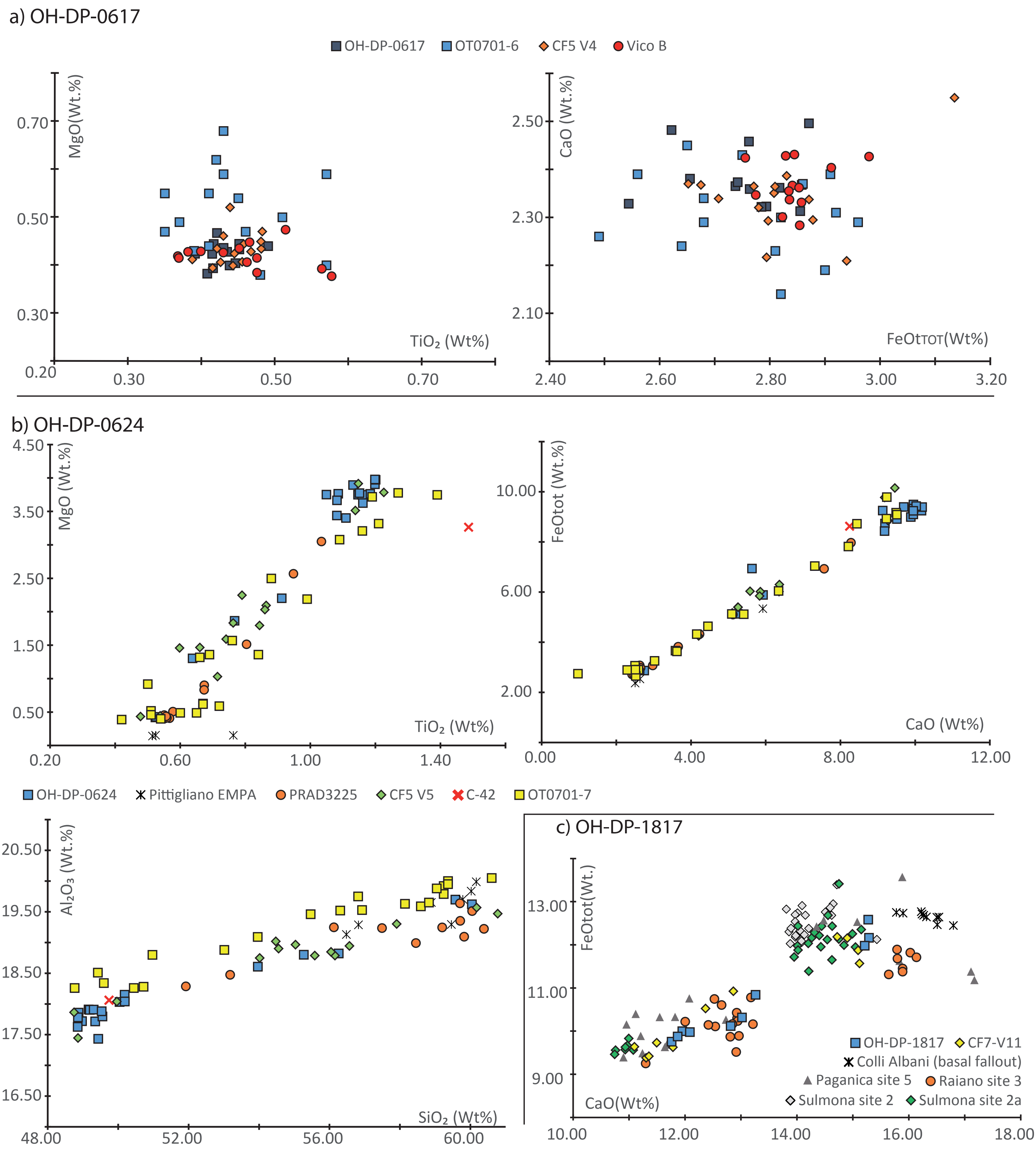
0
25
50
75
100
125
mcd
OH-DP-0027
OH-DP-0115
OH-DP-0169a+b
OH-DP-0404
OH-DP-0435
OH-DP-0499
OH-DP-0617
OH-DP-0624
125
150
175
200
225
247.8
mcd
OH-DP-1817
OH-DP-1955
OH-DP-2010
OH-DP-2017
OH-DP-2060
calcareous silty clay
sligthly calcareous silty clay
silty clay
OH-DP-XXXX
discussed in this study
identified tephra,
but not discussed here



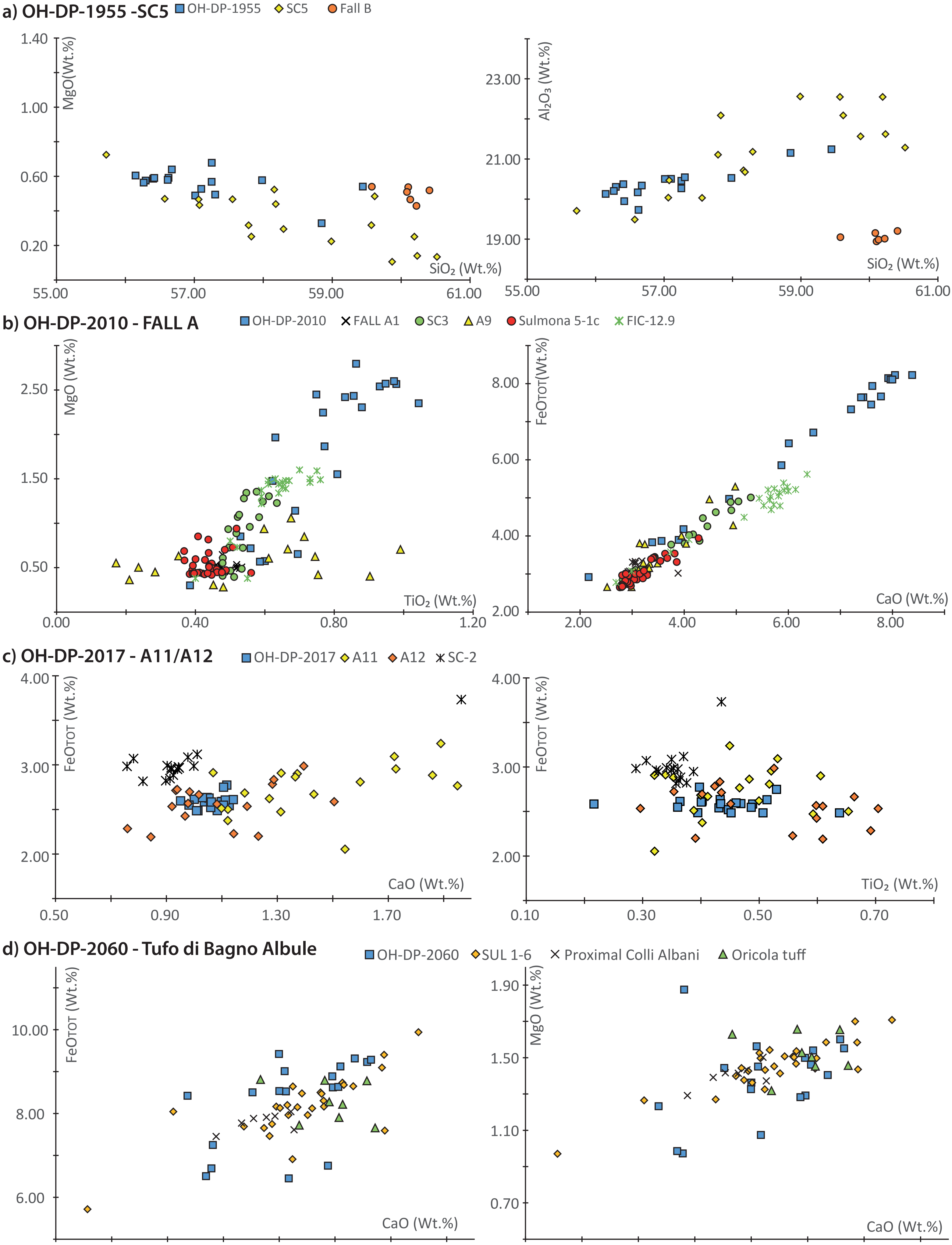
a) Pomici di Mercato
MD90-918 210+223
Co1262-709+OT0702-3+
PT0915-3
AD91-17 190-191+
195-196 cm
OH-DP-0027
TM6a
TM6b
Veliko Jezero MJ1 VJ1
RF95-11 320 cm
IN68-5 259 cm
IN68-9 125 cm
KET8218 V1
b) Y-3
OT0702-4
OT0520-2
OT0700-1
JO188
PT0915-5
M25/4-12 Y-3
OH-DP-0115
Y-3
TM15
TP-9.70
S-19
C106/C45 A2/B2
MD90-917 920-17
C-7
c) CI/Y-5
OT0700-2
OT0702-6
OT0701-1/5
OT05020-3
PT0704-3
JO-244
OH-DP-0169b
OH-DP-0169a
Y-5
TM18
PRAD 1653
KC01B I-3
C-13
LC21 4.925
ML2
S-17
TP CI
PRE CI
d) TM24a/POP2
OH-DP-0404
OT0702-8
TM24a
POP2
RF93-77 797cm
CM92-42 710cm
e) X-6
OH-DP-0435
OT0702-9
JO575
POP4
TM27
CIL2
S-10
KC01B I-9
PRAD2812
C-31
X-6
T1
f) P-11 and Vico B
OH-DP-0617
OT0701-6
CF-V4
Vico B proximal
f) OH-DP-0499 - P-11
OH-DP-0499
OT0702-10
JO941-1
P-11
ML-5
ODP2
ODP3
ODP4
TII5
LC21 10.345
g) PRAD3225/CF-V5
OH-DP-0624
OT0701-7
PRAD3225
CF-V5
C-42
Pitigliano Tuff EMPA
PitiglianoTuff XRF
h) Pozzolane Rosse (PR) and SC5
OH-DP-1817
AH20PR
basal fallout
CF7-V11
Paganica site 5
Raiano site 3
Sulmona site 2
Sulmona site 2a
OH-DP-1955
SC5
Fall B
i) Fall A
OH-DP-2010
FALL A1
SC3
A9
Sulmona 5-1c
FIC-12.9
j) A11/A12 and Tufo Bagno di Albule (TBA)
OH-DP-2017
A11
A12
SC-2
OH-DP-2060
SUL 1-6
Proximal deposits TBA
Oricola tuff
F
Ph
TP
PT
TB
TrB
B
BTA
BA
TrA
A
Tr
TrD
D
Rh
Na_2O+K_2O (wt.%)
SiO_2 (wt.%)



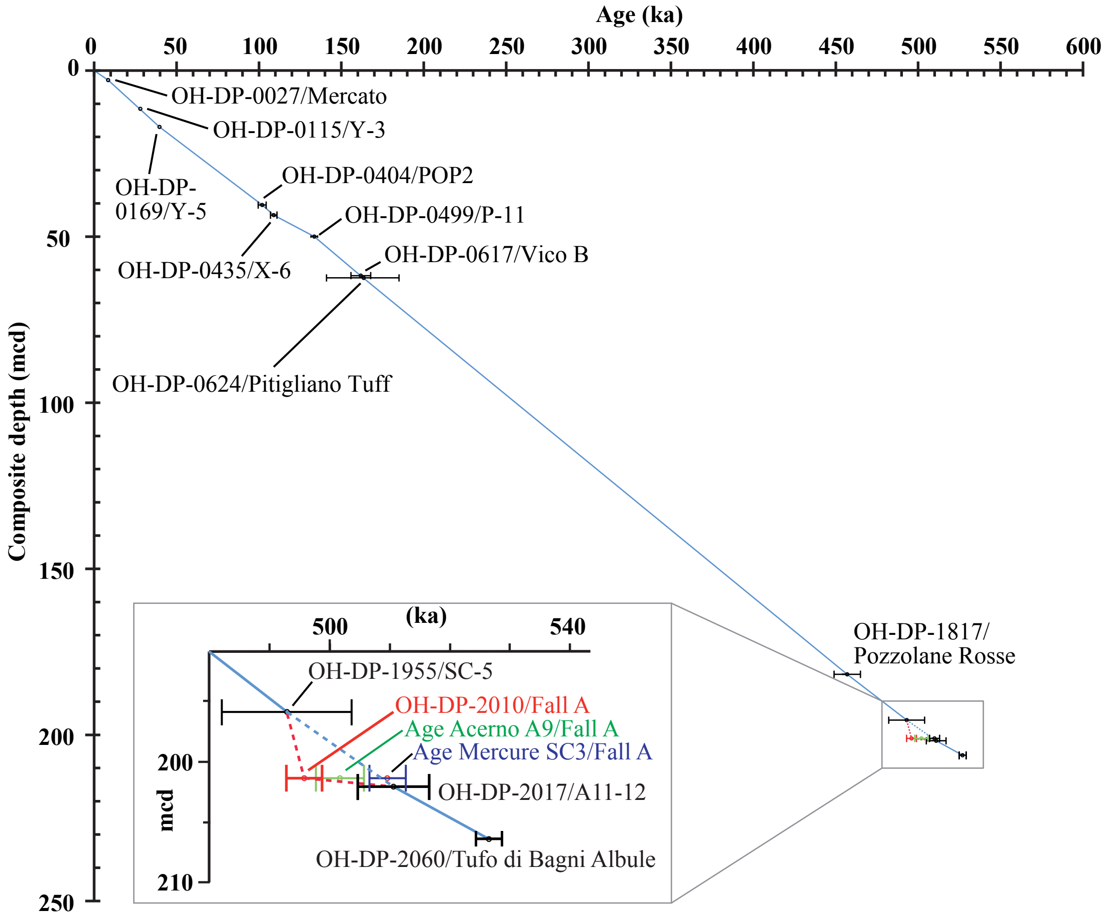
20.00
15.00
10.00
5.00
0.00
0.00
2.00
4.00
6.00
8.00
10.00
Al2O3 (wt.%)
FeOTOT (wt.%)
comendites
pantellerites
OH-DP-0499
JO941-1
OT0702-10
ML-5
TII-5
LC21 10.345
ODP3
ODP4
P-11



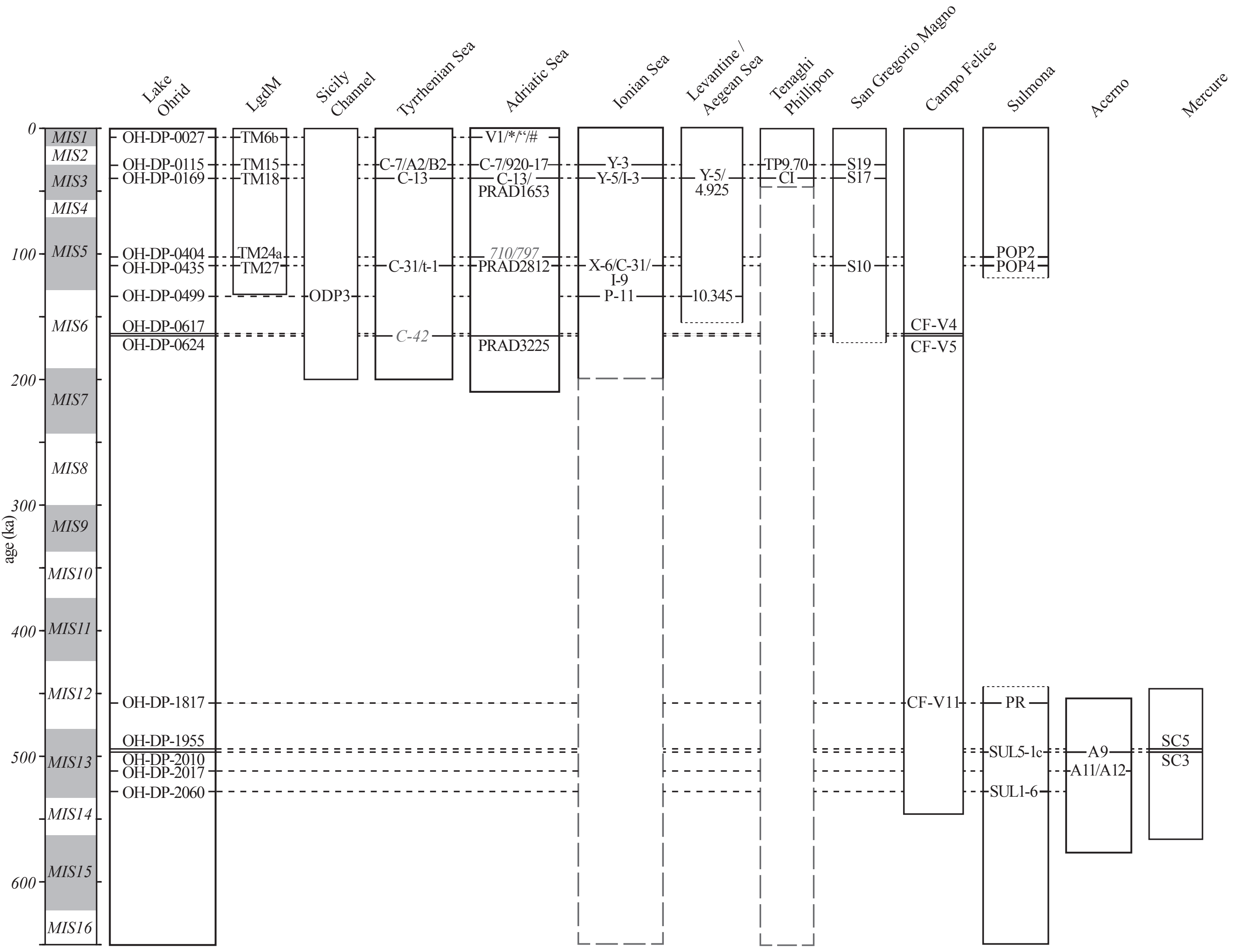
a) OH-DP-0617
OH-DP-0617
OT0701-6
CF5 V4
Vico B
MgO(Wt.%)
0.70
0.50
0.30
0.20
0.30
0.50
0.70
TiO_2 (Wt%)
CaO (Wt.%)
2.50
2.30
2.10
2.40
2.60
2.80
3.00
3.20
FeOtTOT(Wt%)
b) OH-DP-0624
MgO (Wt.%)
4.50
3.50
2.50
1.50
0.50
0.20
0.60
1.00
1.40
TiO_2 (Wt%)
FeOtot (Wt.%)
10.00
6.00
2.00
0.00
4.00
8.00
12.00
CaO (Wt%)
OH-DP-0624
Pittigliano EMPA
PRAD3225
CF5 V5
C-42
OT0701-7
Al_2O_3 (Wt.%)
20.50
19.50
18.50
17.50
16.50
48.00
52.00
56.00
60.00
SiO_2 (Wt%)
c) OH-DP-1817
FeOtot(Wt.)
13.00
11.00
9.00
CaO(Wt%)
10.00
12.00
14.00
16.00
18.00
OH-DP-1817
CF7-V11
Colli Albani (basal fallout)
Paganica site 5
Raiano site 3
Sulmona site 2
Sulmona site 2a



a) OH-DP-1955 -SC5
OH-DP-1955
SC5
Fall B
MgO(Wt.%)
1.40
1.00
0.60
0.20
SiO2 (Wt.%)
55.00
57.00
59.00
61.00
Al2O3 (Wt.%)
23.00
21.00
19.00
SiO2 (Wt.%)
55.00
57.00
59.00
61.00
b) OH-DP-2010 - FALL A
OH-DP-2010
FALL A1
SC3
A9
Sulmona 5-1c
FIC-12.9
MgO (Wt.%)
2.50
1.50
0.50
TiO2 (Wt.%)
0.00
0.40
0.80
1.20
FeOTOT(Wt.%)
8.00
6.00
4.00
2.00
CaO (Wt.%)
2.00
4.00
6.00
8.00
c) OH-DP-2017 - A11/A12
OH-DP-2017
A11
A12
SC-2
FeOTOT (Wt.%)
4.00
3.00
2.00
CaO (Wt.%)
0.50
0.90
1.30
1.70
FeOTOT (Wt.%)
4.00
3.00
2.00
TiO2 (Wt.%)
0.10
0.30
0.50
0.70
d) OH-DP-2060 - Tufo di Bagno Albule
OH-DP-2060
SUL 1-6
Proximal Colli Albani
Oricola tuff
FeOTOT (Wt.%)
10.00
8.00
6.00
CaO (Wt.%)
6.50
8.50
10.50
12.50
MgO (Wt.%)
1.90
1.50
1.10
0.70
CaO (Wt.%)
6.50
8.50
10.50
12.50



Age (ka)
0
50
100
150
200
250
300
350
400
450
500
550
600
Composite depth (mcd)
0
50
100
150
200
250
OH-DP-0027/Mercato
OH-DP-0115/Y-3
OH-DP-0169/Y-5
OH-DP-0404/POP2
OH-DP-0499/P-11
OH-DP-0435/X-6
OH-DP-0617/Vico B
OH-DP-0624/Pitigliano Tuff
OH-DP-1817/
Pozzolane Rosse
(ka)
500
540
200
210
mcd
OH-DP-1955/SC-5
OH-DP-2010/Fall A
Age Acerno A9/Fall A
Age Mercure SC3/Fall A
OH-DP-2017/A11-12
OH-DP-2060/Tufo di Bagni Albule



Lake Ohrid
LgdM
Sicily Channel
Tyrrhenian Sea
Adriatic Sea
Ionian Sea
Levantine / Aegean Sea
Tenaghi Phillipon
San Gregorio Magno
Campo Felice
Sulmona
Acerno
Mercure
age (ka)
0
100
200
300
400
500
600
MIS1
MIS2
MIS3
MIS4
MIS5
MIS6
MIS7
MIS8
MIS9
MIS10
MIS11
MIS12
MIS13
MIS14
MIS15
MIS16
OH-DP-0027
OH-DP-0115
OH-DP-0169
OH-DP-0404
OH-DP-0435
OH-DP-0499
OH-DP-0617
OH-DP-0624
OH-DP-1817
OH-DP-1955
OH-DP-2010
OH-DP-2017
OH-DP-2060
TM6b
TM15
TM18
TM24a
TM27
ODP3
C-7/A2/B2
C-13
C-31/t-1
C-42
V1/*/°/#
C-7/920-17
C-13/ PRAD1653
710/797
PRAD2812
PRAD3225
Y-3
Y-5/I-3
X-6/C-31/ I-9
P-11
Y-5/ 4.925
10.345
TP9.70
CI
S19
S17
S10
CF-V4
CF-V5
CF-V11
POP2
POP4
PR
SUL5-1c
SUL1-6
A9
A11/A12
SC5
SC3