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FUCINO PALAEO-LAKE: TOWARDS THE PALAEOENVIRONMENTAL HISTORY OF THE LAST 430 KA

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ABSTRACT: The sedimentary succession deposited in Fucino palaeo-lake potentially records the environmental history of the Central Mediterranean Region continuously since the early Pleistocene and up to recent historical times. Fucino palaeo-lake sediments are interbedded with numerous volcanic ash layers which allow the reconstruction a robust and independent chronological framework of past environment changes. This framework is a fundamental tool to synchronise different archives at a regional and extra-regional scale and to better understand the spatio-temporal climate variability in the Quaternary at the orbital and millennial-scales. Here we present new preliminary data for the last five glacial to interglacial cycles.

KEYWORDS: Fucino palaeo-lake, drilling, core catcher, Quaternary, volcanic ash

1. INTRODUCTION

In June 2015 drilling operations in Fucino Basin resulted in the recovery of a 82 m long pilot core (cores F1-F3 in Fig. 1) documenting the interval from early marine isotope stage (MIS) 6 to late Holocene. Investigations on cores F1-F3 (Giaccio et al., 2015a; 2017) documented the potential for this natural archive to produce a regionally representative and independently dated record of climatic variability. From a chronological point of view, the site is particularly relevant because of its proximity to Quaternary peri-Tyrrhenian volcanic centres. (Fig. 2). These volcanic centres had an intense explosive activity which resulted in the deposition of a number of tephra in the basin. These tephra layers can be used today as important chronological and stratigraphic marker beds (e.g. Giaccio et al., 2012, 2015b; Regattieri et al., 2017). This is a crucial requirement for comparing intra- and inter-regional palaeoclimatic records based on different dating methods. In particular, the rich tephrostratigraphic content poses the basis for a better understanding of the temporal relationship between them and with respect to the main climatic forcing (e.g. orbital). Furthermore it allows to evaluate differences in magnitude and expression of Quaternary palaeoclimatic change across regions.

With the purpose to extend back in time the record, a new drilling campaign (cores F4-F5) was set in Fucino Basin in June 2017. The preliminary analyses so far performed on the lacustrine marls and the chronological assistance provided by the tephro-stratigraphic framework, indicate that the recovered succession continuously spans the last five glacial to interglacial cycles, i.e. from MIS 12/MIS 11 up to the Holocene.

2. GEOLOGICAL SETTING

The Fucino Basin, located in the Central Apennine Chain, Abruzzo (Fig. 1a), is the largest intermountain basin in the Central Apennines. This basin is an active tectonic basin and its evolution was controlled by two antithetic fault systems (NE-SW and NW-SE; Galadini & Galli, 2000). The opening of the basin, possibly concurrent with the onset of lacustrine sedimentation, commenced in the early Pleistocene in response to an extensional phase along the Apennine Chain (e.g. D'Agostino et al., 2001). Unlike other basins in this region, Fucino Lake has continuously existed since the early Pleistocene and till 1875 AD, when the lake was artificially drained.

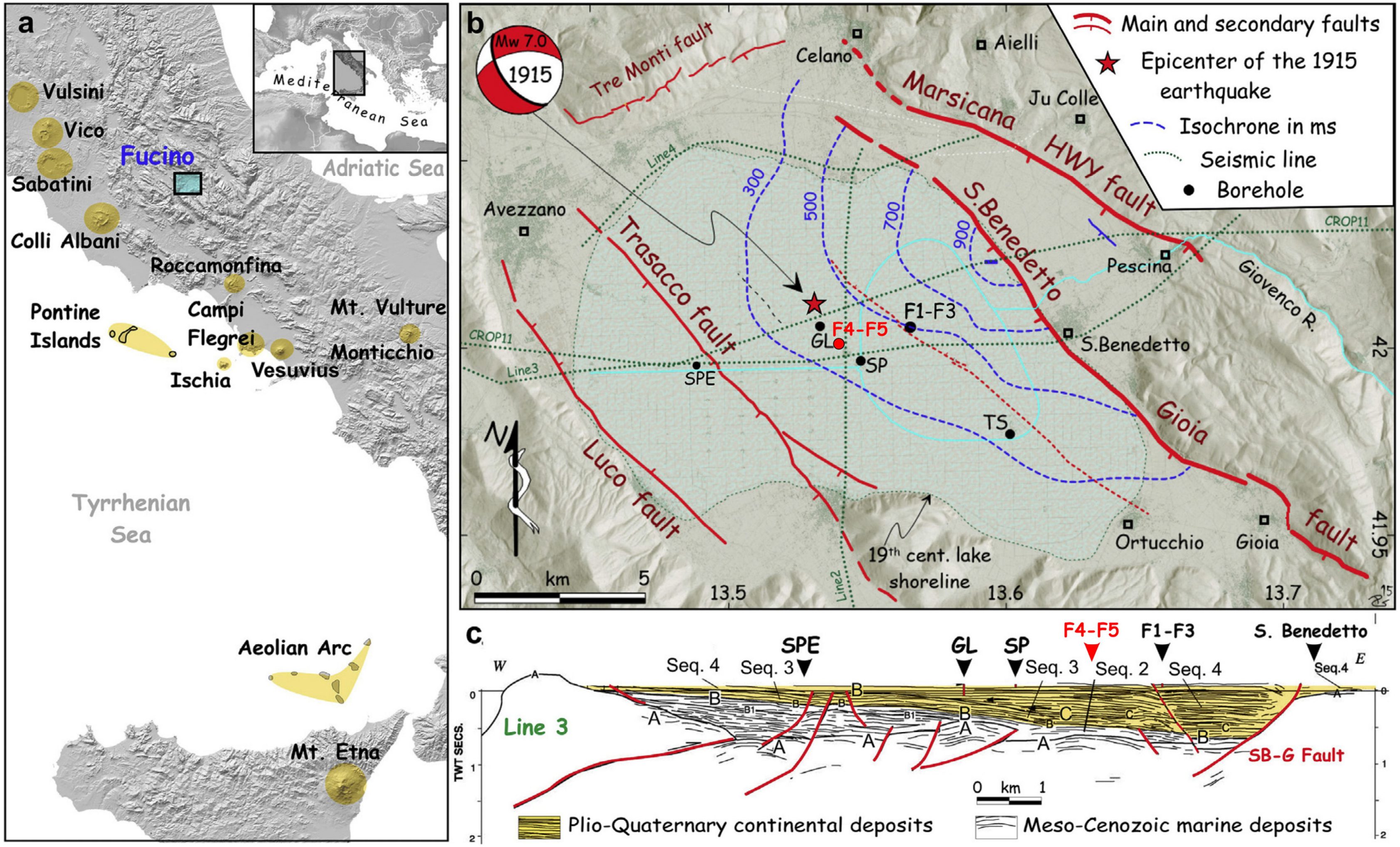

Fig.1 - Reference map of the Fucino Basin (a) Location of Fucino Basin with respect to the main eruptive centers active during the last 1.8 Ma. (b) Shaded relief of the Fucino Plain showing the location of the GeoLazio (GL), Telespazio (TS), Strada Provinciale 20 (SP), Fucino 1 and 3 (Giaccio et al., 2015; 2017) and 4 and 5 (this study) boreholes. Dashed blue lines are the isochrones (in ms) of the Plio-Quaternary infilling with respect to the Quaternary master faults (bold red lines= responsible for the asymmetrical (half-graben) basin geometry. Dotted green lines are the traces of the available seismic lines. (c) Seismic line 3 (see trace in panel b) showing the internal architecture of the Plio-Quaternary continental deposits of the Fucino Basin along a W-E oriented profile. The projected location of the GL, SP, F1-F3 and F4-F5 boreholes is also shown. A, B, C: main unconformities; Seq. 2 Messinian foredeep sediments; Seq. 3: Pliocene fluvial and alluvial deposites; Seq. 4: Quaternary lacustrine and fluvial deposits. Figure modified after Giaccio et al. (2015a).

3. MATERIAL AND METHODS

3.1 Drilling operations

The drilling site (Fig 1 b, c) was selected by evaluating the sedimentation rate obtained from the combined interpretation of tephro-chronological information collected from pre-existing cores (see Fig. 1 caption) and the general sedimentary-tectonic architecture of the basin (Fig. 1 b, c). Compared to the previous drilling site (F1-F3), the F4-F5 site provided us the opportunity of recovering a less expanded sedimentary succession. At the selected site (42.00 °N, 13.54 °E), two parallel holes down to ca. 86 m below ground level (b.g.l.). Cores were recovered with identical 1.5 m long coring devices operating with an offset of 75 cm to ensure overlap between the F4 and F5 series. Core catchers were subsampled directly in the field, whereas cores were carefully packed and stored for further analyses. The F4 hole was logged immediately after drilling and down to a depth of 80 m b.g.l. The logging equipment consisted of a multi-sensor (gamma ray, resistivity and magnetic susceptibility) probe operating in accord to the internal protocols of the Leibniz Institute for Applied Geophysics (LIAG).

3.2. Preliminary core analysis

Core opening and core description was carried out at the University of Cologne, Germany. Macroscopic tephra layers were directly sampled for further analyses in specialised laboratories, while for suspect cryptotephra smearslides were taken for optical-microscope analysis. Cores underwent non-destructive analysis, (i.e. X-ray fluorescence scanning and magnetic susceptibility).

Further analyses were conducted at the palaeomagnetic laboratory in Grubenhagen (Einbeck, Germany) of the LIAG. Here the stable components of natural remanent magnetization (NRM) where characterised. After preliminary studies, a raw core composite was elaborated by taking into account drilling depths and clear stratigraphic markers, such as tephra layers, to match the F4 and F5 cores. This preliminary composite profile served the purposes of core sub-sampling for further analyses. Subsampling was carried at a variable resolution (from 1 cm every 2nd cm to every 8th cm) and resulted in a set of more 2000 samples which are currently being processed.

3.3 Geochemical analyses on core catcher material

Total carbon (TC), total inorganic carbon (TIC), total nitrogen (TN), total sulfur (TS), and stable oxygen isotope compositions were measured on discrete samples from the top of each core catcher. Samples were dried in an oven at 50 °C. After disaggregation and sieving, the fraction below 100 µm was powdered and homogenised for geochemical analyses. TN and TS were determined with a vario Micro cube combustion CNS elemental analyser (Elementar, Germany) after combustion at 1150 °C, whilst TC and TIC were measured with a DIMATOC 200 (DIMATEC, Germany) at the University of Cologne, Germany. TOC was calculated by subtracting TIC from TC.

3.4. Preliminary tephra analyses

Major and minor oxide element compositions were determined on micro-pumice fragments and/or glass shards, from some selected tephra from cores F4-F5. The analyses were carried out at the IGAG-CNR in Rome, Italy, using a Cameca SX50 electron microprobe equipped with a five-wavelength dispersive spectrometer analytical.

4. RESULTS AND DISCUSSION

The analyses run in the core samples so far allowed us to recognise more than 130 macroscopic tephra layers. Preliminary tephrostratigraphic surveys evidenced the presence of 16 tephra in common with the F1-F3 drilling site in the first 35 m. This confirmed that the uppermost 35 m in F4-F5 replicate the F1-F3 record (i.e. the last ca. 190 ka). Preliminary analyses on some of the major tephra layers from the lower part of the recovered succession (i.e. below 35 m) allowed us to identify the correlatives of other important regional tephrostratigraphic markers. Among these, the most relevant are listed in the table below:

F4-F5 drilling depth (m b.g.l.)	Tephra correlative	Approximative age (ka BP)
72	Villa Senni	367
83	Pozzolane Nere	405
85	Vico β	413
85.5	Vico α	422

The Vico α tephra, together with a sharp and clear change in the lithological properties of the sediment, constrains the lowermost part of our succession to the MIS 11-12 boundary.

Results from biogeochemical analyses on the core catcher material show that the different proxies are involved in a significant variability, with major trends consistent between the different proxies (Fig. 2). Changes in TIC are assumed to be mainly related to authigenic (i.e. biomediated) precipitation of calcite, according to the results from F1-F4 core (Giaccio et al., 2015). This process could be favoured by enhanced lake primary productivity as well as by increased Ca input from the catchment (e.g. Gierlowsky-Kordesh, 2010; Vogel et al., 2010). As for TOC, similarly to TIC, its variation is generally controlled by the rate of organic matter production in the lake and in catchment vegetation (Leng et al., 2013) and by the preservation of OM. Therefore higher values of both TIC and TOC could be linked to warmer and wetter periods (i.e. interglacials/interstadials), where ions and nutrient are flushed from the well-developed soils into the lake. The TOC/TN ratio is usually related to the source of OM (aquatic/terrestrial), with higher (lower) values indicating prevailing terrestrial (lacustrine) input (Meyers & Ishiwatari, 1995).

The general variability expressed by the proxy series depicts changes of the palaeoenvironmental context, which can be interpreted in the frame of the climate

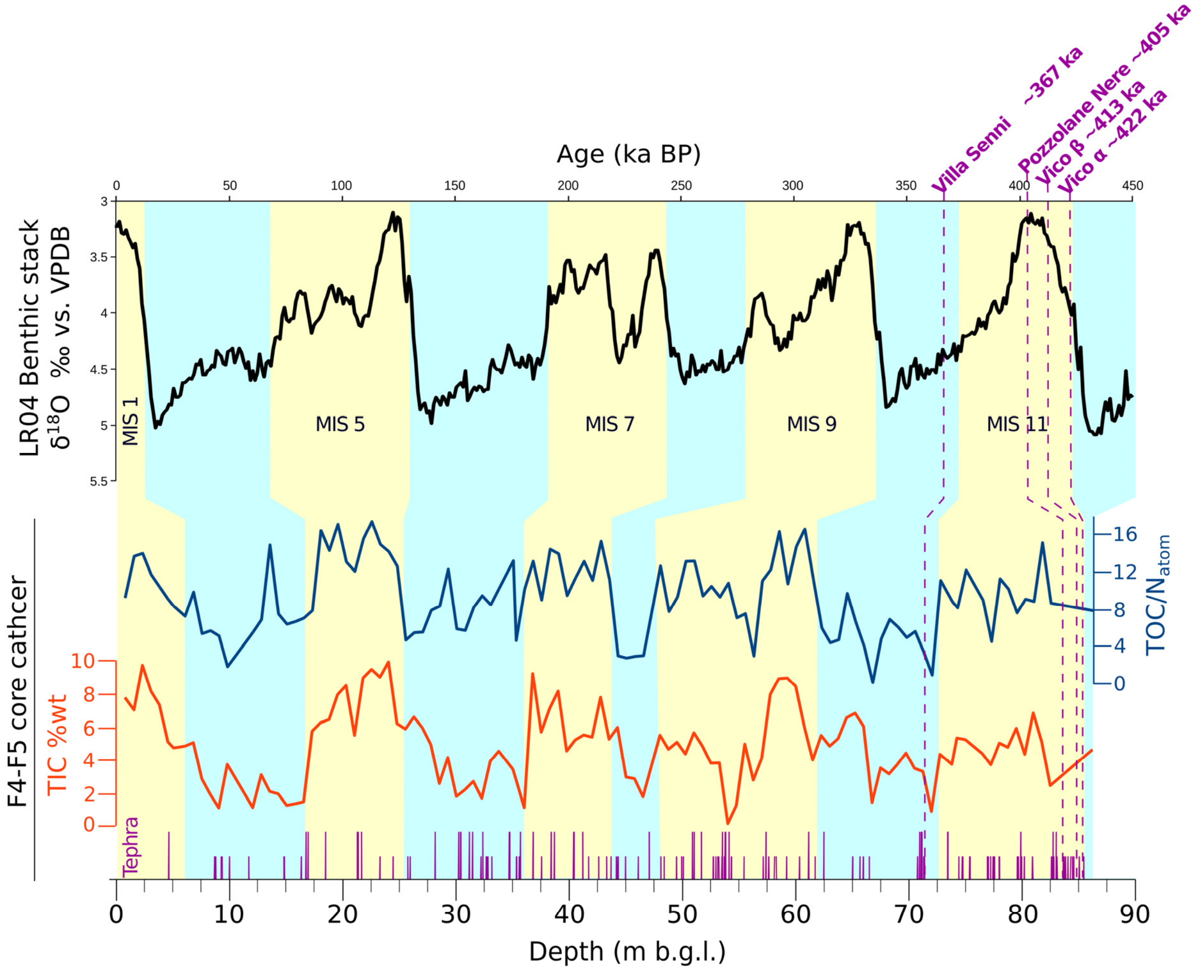

Fig. 2 - Preliminary data from Fucino F4-F5 drilling plotted against drilling depths compared to the LR04 benthic stack (Lisiecki & Raymo, 2005). Yellow and blue shadings indicate odd and even numbered Marine Isotope Stages, respectively.

variability of the last 5 glacial-interglacial cycles. This is demonstrated by the good correlation potential of the TIC and TOC curves from Fucino Lake with the LR04 benthic stack (Fig. 2). During the MIS 10, 8, 6 and 4-2 glacial intervals, reduced lake productivity and contraction of terrestrial vegetation with respect to the lacustrine one determined, respectively, lower TIC and TOC as well as lower TOC/TN ratio. Interestingly, despite the relatively low time resolution obtained from the core catcher material, our record shows some of the main features of the Middle-Late Pleistocene climate variability. This is characterised by relatively abrupt glacial terminations and the progressive enhancement of the 100-ka power (e.g. Tzedakis et al., 2017).

5. CONCLUSIONS

Ongoing and future investigations, including detailed petrographic and geochemical analyses and radiometric dating of tephra layers, together with high-resolution biogeochemical, stable isotope and palaeomagnetic analyses, will make it possible to fully explore the potential of the Fucino lacustrine succession as a long climatic archive.

We are currently preparing a composite profile anchored to the sedimentary succession by borehole logging data. This represents a fundamental step to establish a reliable age-depth model. The rich tephrostratigraphic documentation appears very promising thanks to several macroscopic tephra layers and numerous cryptotephra. Most of these tephra originate from the nearby peri-Tyrrhenian volcanic centres, which were characterised by a peculiar eruptive history. This makes Fucino tephra layers particularly suitable for both indirect (geochemical fingerprinting) and direct (^{40}Ar/^{39}Ar) dating. This will make it possible to elaborate a robust and completely independent chronology for the observed variations in biogeochemical and magnetic parameters over the interval between Termination V and the Holocene. Such a multi-proxy and high resolution approach will allow to address in detail climatically driven environmental changes at both orbital and millennial scales and to evaluate their duration and magnitude on a broad geographic scale.

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