Fluid geochemistry as useful tool for the recognition of the Lago Exsnia-Viscosa (Rome-Italy) as natural heritage

Procesi M.[1*], Cinti D.[1], Cabassi J.[2], Capecchiacci F.[3], Pizzino L.[1], Caracausi A.[1], Fazi S.[4], Casentini B.[4]

[1] Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Roma, Italy

[2] Institute of Geosciences and Earth Resources, National Research Council, CNR – IGG, Via La Pira 4, 50121 Firenze, Italy

[3] Università degli Studi di Firenze, Dipartimento Scienze della Terra, Via la Pira 4, 50121 Firenze

[4] IRSA-CNR, Via Salaria km 29.300, 00015 Monterotondo, Roma, Italy

EGU2020-3647

EGU General Assembly

How did lake form?

Lago Exsnia-Viscosa also known as Lago Bullicante, is a small artificial lake, 7.000 m² large with a maximum depth of 7 m, located within the urban area of the city of Rome. It has an anthropogenic origin due to excavation works that intercepted the underlying aquifer, giving rise to a water body (**Fig.1**). Due to the citizen protests, the works were immediately blocked and the whole area was expropriated and closed. The site, has remained closed, from '90s to today, favouring re-naturalization processes, new ecological systems and forbidding anthropogenic transformations. Currently, it represents a precious green area for the city, but is still in danger of being threatened by speculation.

Geologically speaking, the lake is located on the distal deposits of the Alban Hills Volcanic District (AHVD) in an area named "Acqua Bullicante" (i.e. Bubbling Water), where degassing phenomena were historically recorded (**Fig.2a-b**). The proximity of this volcanic district motivated the study on Lago Bullicante as potential open-air laboratory to trace possible degassing phenomena in a highly urbanized area. A preliminary geochemical sampling survey was carried out in winter 2018 and samples were collected along a vertical profile of the lake from the surface to the maximum depth (**Fig**.3a-**d**).

The results (**Fig.4-7**) are supporting the community and the local administration in order to make this green site a protected area and revealing an important step in the road map for the recognition as natural heritage to donate to their citizens.

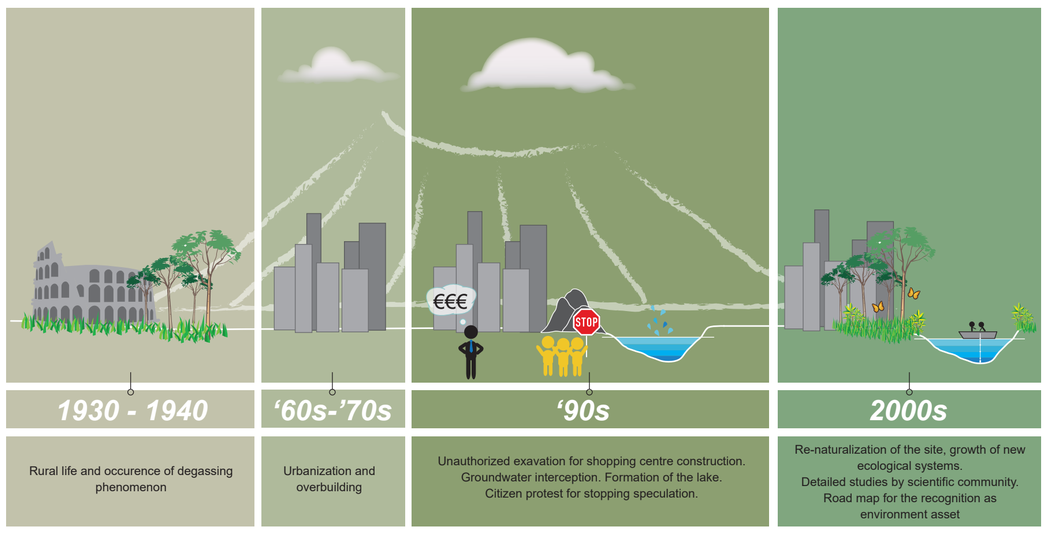

Fig.1: Timeline of the events that brought to the lake formation

Setting & Sampling

The AHVD is part of the Roman Comagmatic Province and developed along the Tyrrhenian Sea margin of central Italy. AHVD was interested by intense volcanic activity between 600 and 20 ka and, at present, it is considered at a quiescent state (*FUNICIELLO et alii, 2003; FREDA et alii, 2008*). The activity of the AHVD has been characterized by three main phases.

The Lake Bullicante is hosted on the deposits of the first phase of the volcano activity and in proximity of the Acqua Bullicante paleo-ditch (**Fig. 2a**), probably controlled by a fault in correspondence of which important degassing phenomena were in the past observed (*CAMPONESCHI & NOLASCO, 1982*).

Temperature (°C), Electrical Conductivity (EC in µS/cm), pH and dissolved O_2 (mg/L) were measured in winter 2018 along the lake vertical profile, from the lake surface to the bottom (7 m depth), and at interval of 1 m, by using dedicated electrodes. The measurements, along the entire profile, were also repeated in summer (June 2019) using a multi-parametric probe (**Fig.2b, Fig.3**).

Water and dissolved gas sampling for geochemical analyses was also carried out along lake vertical profile (**Fig.3c-d**)

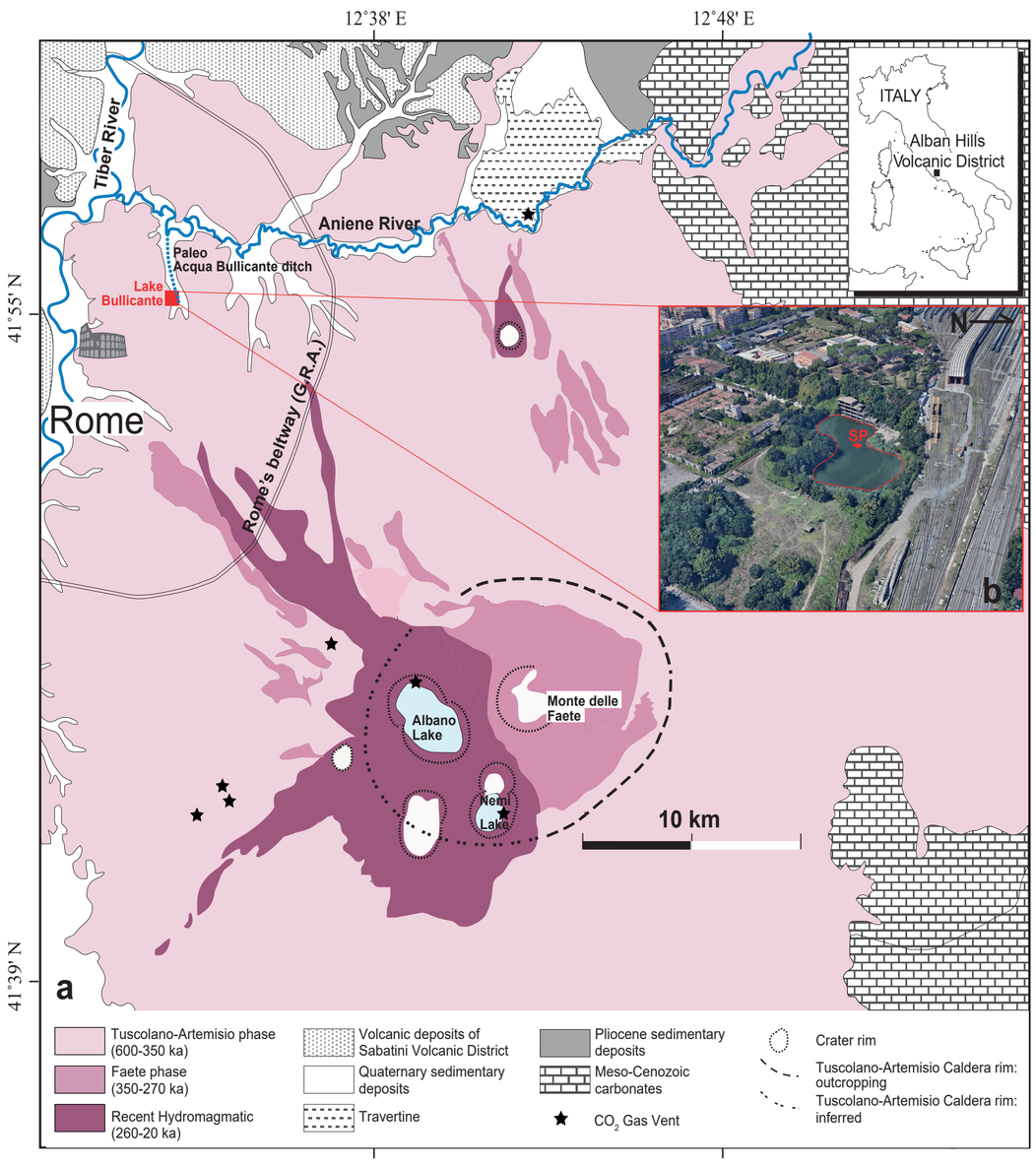

Fig.2: a) Simplified geological map of the AHVD (modified from *MARRA et alii, 2009*) and location of the Lake Bullicante. The three phases of volcanic activity are highlighted. b) Zoomed view on the lake, where the sampling point (SP) is also shown.

Fig.3: a) Panoramic view of the Lake Bullicante. b) Structure of the unlawful shopping centre. c) Researchers on INGV inflatable boat. d) Lake water sampling. (Photo credits: a) Maurizio Pastano; b) Monia Procesi; c) Daniele Cinti; d) Jacopo Cabassi).

Results & Discussions

The lake does not display during the winter, significant variation (T, pH, EC and dissolved O_2), on the contrary it is stratified during the summer (**Fig.4a-d**).

Lake water chemistry also does not show significant variations both for major and trace elements (**Fig.5a-e**). An exception is represented by the NO_3^- and NO_2^- concentrations (**Fig.5d**). In our case, the increase of NO_2^- and the simultaneous decrease of NO_3^- suggests the occurrence of denitrification processes. This hypothesis is supported by the relatively high concentration of dissolved CO_2 (~0.40 mmol/L) and by the values of $d^{13}C$-CO_2 (-21‰ V-PDB) that highlight an organic origin of the carbon dioxide (**Fig.5h**).

Moreover, the chemical and isotopic composition suggests that lake water has a meteoric origin (**Fig.5g**) and it is related to a Ca-HCO_3 shallow aquifer hosted into volcanic rocks (**Fig.6**), as confirmed by the $^{87}Sr/^{86}Sr$ ratio of lake, which falls in the range of values of Alban Hills volcanites, and the chemical-isotopic composition of neighbouring wells (**Fig.7**).

These results but in particular the evidence that the lake is fed by an aquifer hosted in the volcanic deposits and of consequence it is not a marsh, representes a key element in the recognizing process as an environmental asset.

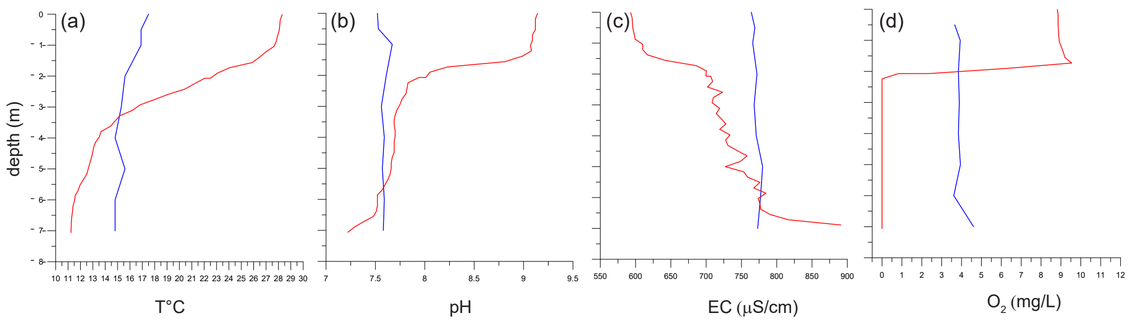

Fig.4: a) Winter (blue) and summer (red)vertical profiles along the Lake Bullicante water column of a) water temperature (°C); b) pH, c) electrical conductivity (EC, in µS/cm) and d) dissolved O_2 concentration (in mg/L).

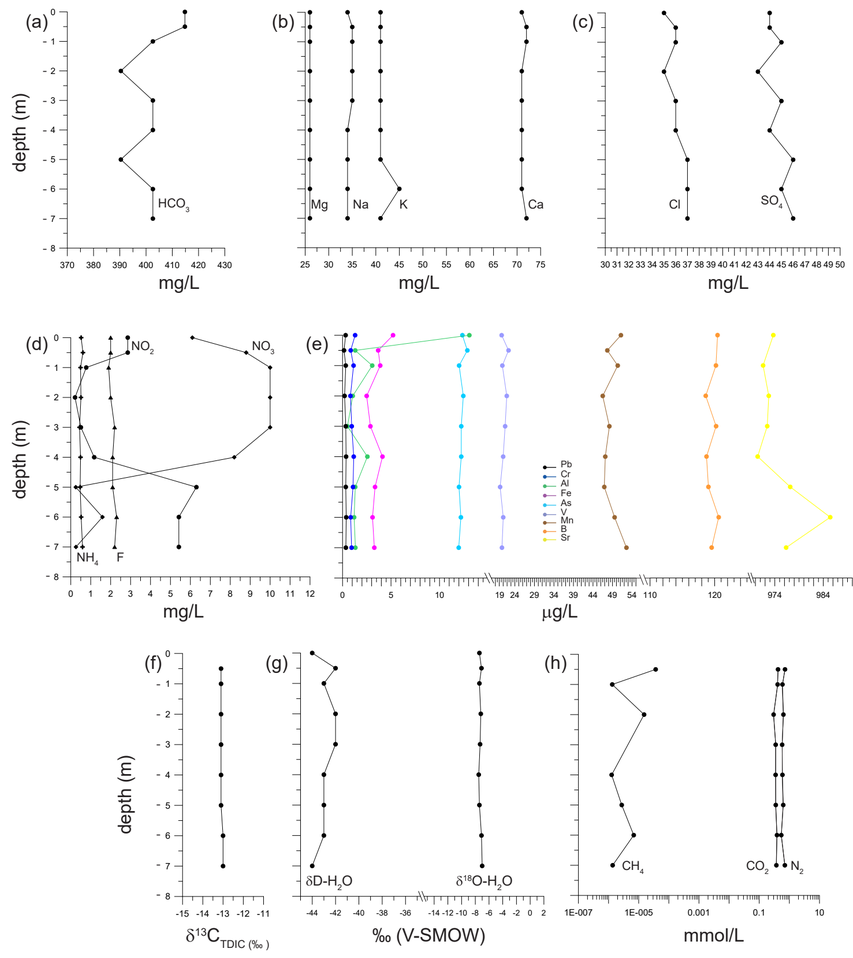

Fig.5: Vertical profile along the Lake Bullicante water column of a) HCO_3 concentration; b) Mg, Na, K and Ca concentrations; c) Cl and SO_4 concentrations; d) NO_3, NO_2, NH_4 and F concentrations; e) trace element (Pb, Cr, Al, Fe, As, V, Mn, B and Sr) concentrations; f) $\delta^{13}C$-CO_2 value (‰ vs. V-PDB), g) δD-H_2O and $\delta^{18}O$-H_2O values and h) dissolved CH_4, CO_2 and N_2 concentrations.

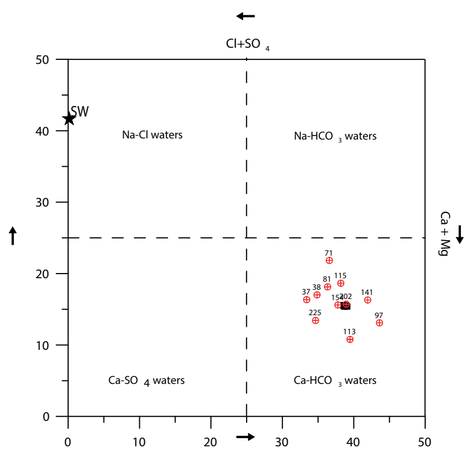

Fig.6: Langelier-Ludwig square diagram and comparison between the lake water (black squares) and the waters from wells (red circles) from *PIZZINO (2015)*.

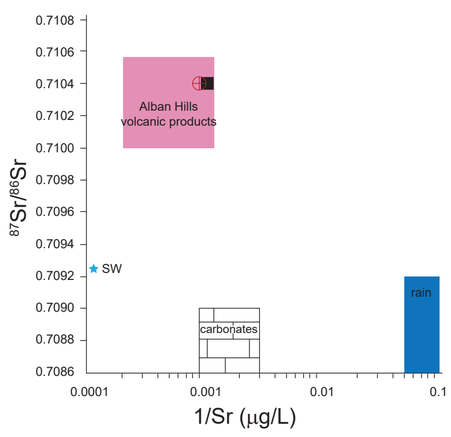

Fig.7: $^{87}Sr/^{86}Sr$ vs. 1/Sr of Lake Bullicante water sample and a water sample from a well taken as representative of the volcanic aquifer. For comparison, $^{87}Sr/^{86}Sr$ values/ranges of Alban Hills volcanic rocks, Apennine carbonate rocks , seawater (SW) and rainwater, are also shown. Symbols as in Fig. 6.

Many thanks are due to the INGV Laboratory of Palermo for the technical support in the dissolved gases, isotopic and trace elements analysis. This work was partially funded by, Davines SpA in the framework of the call "Ricerca il Futuro 2017" dedicated to the women researchers and by the INGV project "FISR Italia Centrale 2018".

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