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Geothermal Exploration of the Suio Area, Central Italy

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ABSTRACT

The Suio area is part of the peri-Tyrrhenian sector of central Italy, a thermally anomalous area where CO_2-pressurized hydrothermal reservoirs develop in a complex geodynamic setting. Thermalism is commonly attributed to the post-orogenic magmatic activity, which occurred from Pliocene to Quaternary in response to an extensional regime.

The Suio area shows thermo-mineral springs located in a boundary zone between the NW side of the Roccamonfina Volcanic Complex (RVC) and the Aurunci carbonatic range. The chemical composition of these springs reflects the unique lithology of the aquifer where they are flowing. The relationship between volcanic and carbonate complexes suggests that mineralization is strongly enhanced by acid gas emissions (CO_2, H_2S) and high temperatures.

As a final product, the intense water–rock interaction brings highly mineralized waters that could be divided in two sub-groups according to the amount of solubilized $CaCO_3$ or to the degree of interaction with carbonatic rocks. All Suio thermal waters have a very similar Mg/(Na+K) and Na/K ratio (0.65 and 3, respectively) confirming their circulation into the carbonatic complex, with an enrichment of fluids deriving from RVC. Common geothermometers used in order to evaluate the reservoir equilibrium temperature indicate values ranging from 125° to 150°C.

The present acquired data suggest that the area could be a suitable location for direct applications of the geothermal resource. Starting from the hydro-geologic model, the authors are performing numerical simulations, verifying the conceptual-model and comparing simulated results with recollected data.

1. INTRODUCTION

Thermal emissions and mineral springs, as well as areas characterized by an anomalously high CO_2 diffuse degassing from the soil, are spatially controlled by fractures and faults related to an extensional tectonic regime (Minissale, 2004). Karst systems usually host a thermal basin, especially when in contact with volcanic masses.

This study is focused on Terme di Suio situated on the Garigliano River, 20 km SSE of Cassino and straddling Campania and Lazio. The site consists of 12 thermal springs aligned along two faults trending approximately NW and NE. The faults separate a thick series of Mesozoic limestones and dolomites to the west from the leucite and alkali-trachyte lavas of Roccamonfina Volcano. Roccamonfina caldera is about 20 km in diameter, and was active 630-53 ka (Caprano et al., 1992).

For hydro-geological purposes, the main goal lies in understanding circulation paths and defining water fluxes. On the other hand, it is important to define the heat transfer, in order to exploit the geothermal potential of a site. To permit subsequent thermodynamic considerations, a preliminary study on the Suio spring site has been led, focusing on the hydro-geological features of the area. Taking into account geologic, structural, geomorphologic, geochemical and hydrological data, this work intends to give support to a first numerical-modeling of Suio spring.

2. GEOLOGICAL SETTING

The Suio thermal basin is located in the Southern Lazio, between the Roccamonfina volcanic unit (hereinafter referred to as RU) and the final sector of the Lepini-Ausoni-Aurunci unit (hereinafter LAAU), along the right side of the Garigliano river (Fig. 1A, 1B).The important Ortona-Roccamonfina structural line passes in correspondence to the volcanic area, to the East of the investigated area.

From a stratigraphical point of view, LAUU belongs to the Lazio-Abruzzi platform series: more than 2000 m of meso-cenozoic dolostone and limestone, followed by terrigenous deposits, related to the orogenetic processes. LAUU is characterized by a main thrust that is shown along the NE boundary.

Roccamonfina quaternary volcanism takes its origin from the opening of the back-arc basin, with lava-banks followed by pyroclastic deposits. In this area, quaternary volcanism clutches the Garigliano river between the LAAU and the Roccamonfina edifice. In the gorge, the Garigliano river is structurally controlled with a sharp change of direction from Apennine to counter-Apennine trend, moving from North towards South (Fig. 1B).

Structural data collected by the authors in the mesozoic unit confirm the dominance of an Apennine-trend system on the E-W and N-S. An opening phase generates a Horst & Graben geometry: graben sectors host the RU.

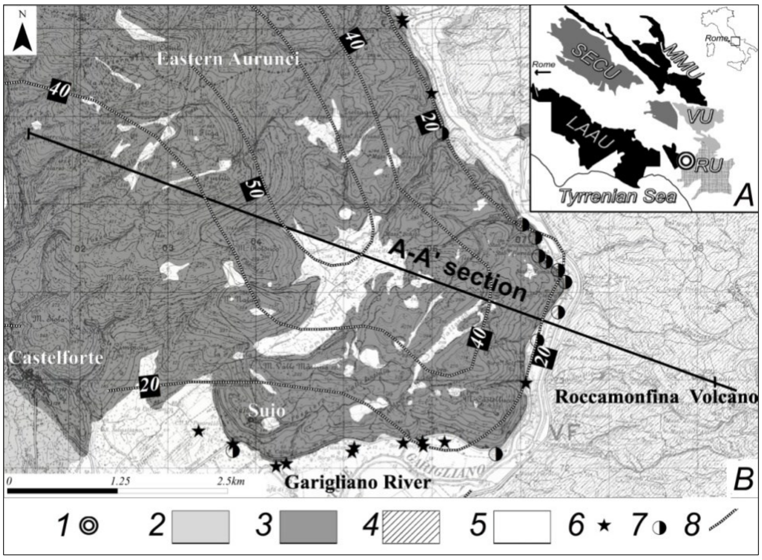

Figure 1: A) Hydro-geologic sketch of Southern Lazio hydro-structures. Legend: LAAU - Lepini-Ausoni-Aurunci unit; RU - Roccamonfina unit; VU - Venafro unit; SECU, Simbruini-Ernici-Cairo unit; MMU - Meta-Marsica unit. B) Hydro-geologic map of Suio springs. Legend: 1- Area shown in Fig.1B;2 - Carbonatic complex;3 Terrigenous complex; 4 - Volcanic complex; 5 Alluvial-residual soil complex; 6 - Cold spring (T<25 °C); 7 - Hot springs (T>25 °C); 8 - Piezometric line.A-A' Section is shown in Fig.2.

Proofs are represented by deep boreholes, made at nearby Gallo village (Watts, 1987): here sin/post-orogenetic deposits (i.e. piggy-back sequence) are hidden under a thick blanket of volcanic material (about 800 m). Eastern Ausoni is the end sector of the LAAU and it can be considered an isolated hydro-structure, separated by way of two important lateral ramps at West and North-East.

3. HYDROGEOLOGICAL SETTING

The connection between the RVC volcanic sequence and the sedimentary basement allows transmission of groundwaters from a limited spatial extent through the low and impermeable multilayer aquifer system (Allocca et al. 2007). The hydrogeological system was first described by Capelli et al. (1999), while the groundwater flow path dynamics were characterized by several authors (Allocca et al. 2007: Capelli et al. 1999: Celico 1983).

Lava flows and domes are highly permeable because of extensive permeability along cooling generated fractures. Likewise, breccias are highly permeable and in direct contact with the sedimentary basement (Watts 1987).

Groundwater recharge into the system occurs along dip-slip faults through the lava domes (Capelli et al. 1999). Conversely, pyroclastic formations act as barriers to groundwater flow because of their welded texture. Pyroclastic formations result in variable extent and thickness for permeable layers and confine the zones where the aquifer is recharged.

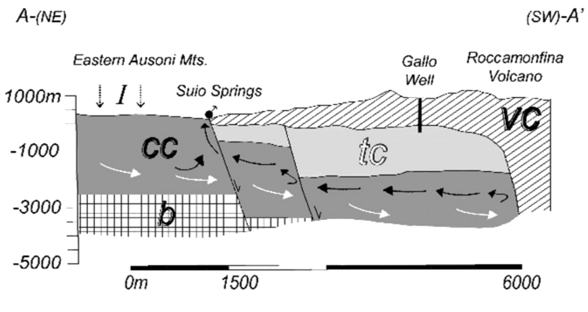

Figure 2: Schematic hydro-geologicalsection A-A'. Legend: b - inferred basement;cc - calcareous complex; tc - terrigenous complex; vc - volcanic complex;I – Infiltration waters.Heat source establishes a convective loop that allows rising of thermo-mineral water (black arrows), in correspondenceto Suio springs, starting from cold -karst water (white arrows).

A carbonate regional aquifer recharged from the lateral Apennine chain reservoir is the basement of the RVC. The carbonate aquifer is highly permeable because of long-term chemical weathering and karstification. Groundwater transport within the carbonate regional aquifer is discontinuous because of localized impermeable clay/marl complexes interposed between the carbonatic basement and the lavas of Roccamonfina’s first eruptive period. Moving away from the volcanic edifice, the carbonate sedimentary basement is overlain by pyroclastic deposits and highly permeable, unconfined detrital material, which leads to variations in groundwater transport (Allocca et al. 2007).

Suio springs are one of the biggest delivery mechanisms for Eastern-Aurunci underground-waters, with linear springs evaluated between 1 m^3/s and 5 m^3/s (Baldoni et al. 2012). Along the Garigliano river, linear springs are dominant and only a small amount of water comes out by punctual springs, with quotes ranging from 20 to 10 m (Fig. 1B). Nevertheless during the study activity, census of punctual springs has been very important, in order to understand physical and chemical features and their spatial distribution.

3. DISCUSSION AND CONCLUSIONS

The Suio thermal waters are highly mineralized and contain large quantities of dissolved CO_2 associated with minor H_2S and CH_4. This type of manifestation is commonly found in the west coastal sector of central-northern Italy associated with both thermal and cold springs (Panichi and Tongiorgi, 1976). Their origin, at least in the northern Apennines, is related to metamorphism of carbonate layers embedded in the Paleozoic crystalline metamorphic basement beneath the Mesozoic carbonate series (Duchi and Minissale, 1994).

Suio thermal waters can be divided in two groups according to the amount of solubilized $CaCO_3$ or, similarly, to the degree of interaction with carbonatic rocks. All Suio thermal waters have a very similar Mg/(Na ? K) and Na/K ratio (0.65 and 3, respectively) confirming their circulation into the same type of volcanic deposits of the western flank of the volcanic edifice. However, a portion of this thermal basin shows also evidence of interactions with carbonatic rock of the Aurunci range

Temperature differences of mineral waters could be related to structural features. Cold-mineral water arises from E-W tectonic elements that are older than the Apennine and counter-Apennine trend, accountable for thermo-mineral water.

Common geothermometers used in order to evaluate the reservoir equilibrium temperature indicate values ranging from 125 to 150°C (D’Amore et al., 1995).

The present acquired data suggest that the area could be a suitable location for direct applications of the geothermal resource. However, other more specific geological-geochemical studies (e.g. isotopic analysis) are in progress in order to improve the understanding of the geothermal potential of the Suio area.

For thermo-mineral water, we propose a conceptual model in which carbonatic-karst complex is directly in contact with volcanic conduit, through a hydro-geologic section (Fig. 2). Following Nunziata and Gerecitano (2011), the magmatic chamber has been included, estimated with a depth ranging from 4 to 5 km. The hydro-geologic section shows a water-circulation path inside the carbonatic complex: in Fig. 2, with an average temperature of 200°C,the heat source establishes a convective loop that allows the rising of thermo-mineral water (black arrows), starting from cold-karst water (white arrows).

Starting from the hydro-geologic section of Fig. 2, numerical simulations have been performed, in order to verify the conceptual model and to compare the simulation results with the measured spring-data (well-temperature gradient).

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